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Long-term operation of an Electro-Stimulated Anaerobic Reactor (ELSAR®) on Brewery Wastewater

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INTRODUCTION & OBJECTIVES

Coupling anaerobic digestion with electrochemistry have shown promising results and opens a wide spectrum of possibilities in the wastewater sector due, among others, to the extra methane production that takes place thanks to bioelectrochemical electron transfer pathways on electrodes and to its robustness [3].

The use of a microbial electrochemical fluidized bed reactor (pat. EP 2927196 A1, co-developed with U. of Alcalá de Henares) registered as Electro-Stimulated Anaerobic Reactor (ELSAR®) has been reported as a suitable solution where electron transfer by electroactive bacteria allows to stimulate the degradation of organic matter [4].

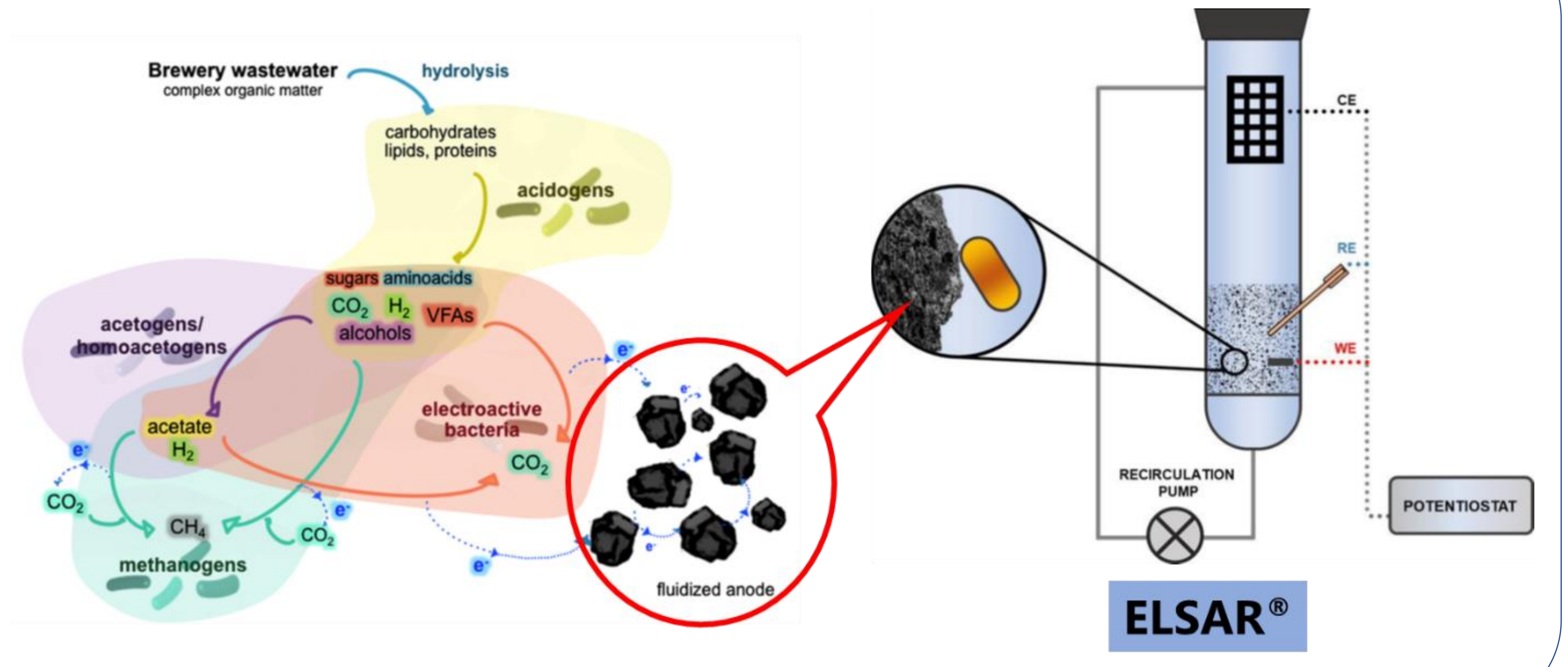
Previous lab and pre-pilot tests of ELSAR® technology applied to the treatment of brewery wastewater not only allowed a deep understanding about the process, but showed significant improvements compared to conventional anaerobic fluidized bed reactor (AFBR), in concordance with what has been widely reported in several references in other anaerobic bioelectrochemical systems [3]. Some of the most relevant findings were:

- ELSAR® exhibited to be more resilient and robust than anaerobic fluidized bed reactor (AFBR) under several stress conditions [1]
- The increase in the generation of hydrogen increases the calorific power of the biogas produced, hence improving the energetic efficiency of the system
- Energy consumption of ELSAR® in all cases was < 0.4 kWh·kg^{-1} removed COD [2]

In order to (a) validate a start-up procedure and to (b) continue in the upscaling and maturity of the solution, an ELSAR® prototype fed with brewery wastewater has been operated during 1 year at mesophilic range.

ELSAR® = fluidized reactor + bioelectrochemical system

Adapted from [2] and [4]



GAC = granular activated carbon. WE = Working Electrode. RE = Reference Electrode. CE = Counter Electrode.

Electroactive bacteria grow in fluidized bed of GAC → Bacteria transfer electrons from the oxidation of the Organic Matter present in wastewater to GAC → The capacitive granules are discharged at a current collector (poised at a higher potential than granules) → Power is produced

GAC acts as an electro-conductive material that stores electrons

METHODS

A 450 L-capacity cylindrical reactor was inoculated with anaerobic granular sludge from a near AFBR. The ELSAR® was fed with primary-settled wastewater coming from a brewery in Alovera, Spain (Table 1) as described in Table 2.

The reactor was operated in mesophilic conditions ranging the organic loading rate (OLR), between 0,95 ± 0,17 and 10,74 ± 0,47 kgCOD/(m^3·d) (Table 2). Wastewater and biogas were analyzed 5 days/week. A power supply was connected to electrodes operated under potentiostatic conditions, with the anode fixed at 1,0V (vs. Ag/AgCl). Granular activated carbon was used as fluidized anode. Two reference electrodes (Ag/AgCl 3M) allowed to also monitor the cathode and cell potentials during operation. Graphite and stainless steel were used as anodic collector and as electrode, respectively.

Table 1. Wastewater composition

PARAMETER	UNITS	INLET
pH	-log[H$^+$]	7,68 ± 0,26
EC	mS/cm	3,36 ± 0,24
COD	mg/L	2751 ± 391
SO_4^{2-}	mg/L	140 ± 27
TN	mg/L	23 ± 4
TP	mg/L	8 ± 2
VFA	mg/L	563 ± 327

Table 2. Feeding regime

	DAYS RANGE	LENGTH [days]	OLR [kg COD/(m^3·d)]	ΔOLR*
I	1 - 53	53	0,95 ± 0,17	-
II	54 - 107	54	3,18 ± 0,31	+234%
III	108 - 156	49	5,85 ± 1,02	+84%
IV	157 - 225	69	9,39 ± 0,20	+61%
V	226 - 378	153	10,74 ± 0,47	+14%

* *vs.* previous period

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ACKNOWLEDGEMENTS

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RESULTS AND CONCLUSIONS

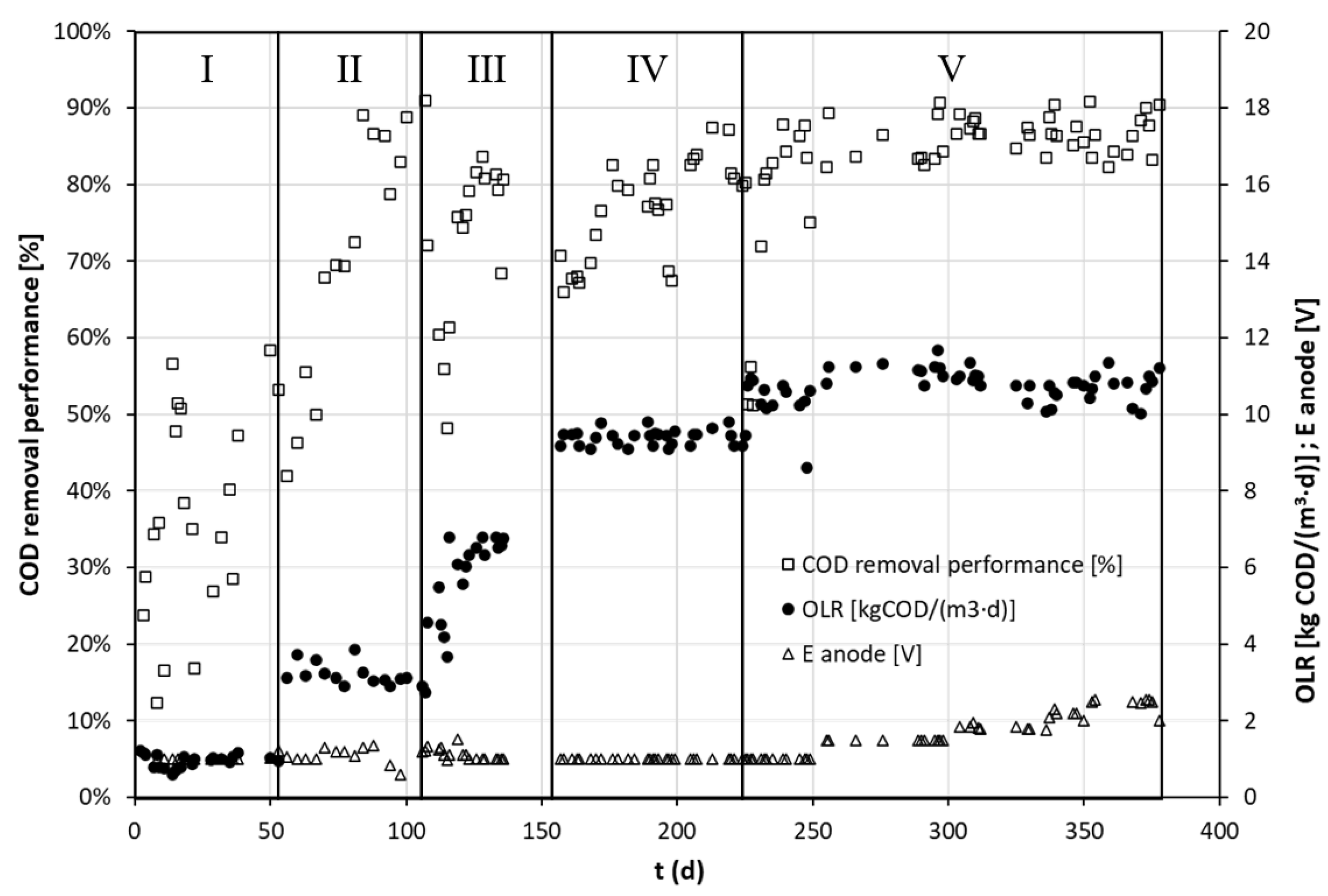

***Figure 1.** Evolution of COD removal performance, Organic loading rate (OLR) and anode potential*

- The commissioning strategy based on duplicating the organic loading rate every 40 to 60 days was found as feasible, showing no instability between periods.
- Biogas composition, considered a good indicator of the microbiological balance inside the reactor, showed constant and relatively high content of CH_4 (80,3 ± 3,8% v:v on a dry basis) from the start, indicating fast adaptation of the methanogenic community. H_2 content in biogas above 2000 ppmv (the threshold limit of the sensor in this experience) was repeatedly detected in periods *IV* and *V*.
- This high H_2 content in biogas (usually negligible in AFBR) can be explained as a consequence of water reduction reaction taking place in the cathode [1]. Thus, the amount of produced H_2 is proportional to the amount of cathode surface. Thanks to this the calorific power of the obtained biogas increases (>1,2%), improving the energetic efficiency of the system.

Promising results encouraged Aqualia to build a pre-commercial proof of ELSAR® for industrial contexts

Design guidelines

1. Prioritize low A/V ratio (electrode area : reactor volume) and affordable electrode materials → low CAPEX
2. Minimize distance between anodic and cathodic collector → minimum ohmic resistance
3. Minimize fluidification velocity difference between biomass and GAC → possible coexistence of anode and biomass

Pre-commercial ELSAR®

Reactor features
- Flow 20 m^3·h^{-1}
- Loading Rate 2000 kg COD·d^{-1}
- Mesophilic range

Expected results
- 90% COD removal
- 31 Nm^3 biogas·h^{-1}
- Start-up April 2024

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