

Role of the gaseous inlet flow rate in a tubular pilot scale MEC for biogas upgrading

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Biogas, the main product of the anaerobic digestion (AD) process, is a gas mixture mainly composed by carbon dioxide and methane. To obtain biomethane, with a high percentage of methane (>95%), is necessary a purification step to remove the impurities such as NH₃, H₂S, and an upgrade step to increase CH₄ percentage by removing the CO₂. These last steps are economically expensive and usually the biogas is utilized for the cogeneration of electricity and heat, however, an innovative strategy for biogas upgrading consist in the utilization of a microbial electrolysis cell (MEC) in which the reduction of carbon dioxide to methane is performed by a biocathode. The bioelectromethanogenesis reaction is made by electroactive microorganisms who convert CO₂ into CH₄ (Villano et al., 2010). Here, a fully biological tubular Microbial Electrolysis Cell (MEC) has been developed for the upgrading of biogas through the bioelectromethanogenesis reaction coupled with the COD oxidation, i.e., the reduction reaction occurred in a cathodic chamber converting the CO₂ into CH₄ while the oxidation of the organic matter by an anodic biofilm partially sustained the energy demand of the process. Furthermore, an additional CO₂ removal mechanism consists in the CO₂ sorption as HCO₃⁻, due to alkalinity generation in the catholyte. In the tubular MEC, the electroactive microorganism's selection was obtained by polarizing the cathode at -1.3 V vs. SHE. Once the best gaseous flow rate was selected at 9.75 L/ L d (between 4.88, 9.75 and 13.81 L/L d), the cathodic potential was changed from -1.3 to -1.8 and 2.3 V vs SHE. As reported in a previous experiment (Cristiani, 2021), the increase of the cathodic potential did change the electrochemical reaction inside the anodic chamber. Moreover, during the three different runs conducted with the cathodic potential controlled at - 1.3 V; - 1.8 V; - 2.3 V vs. SHE the performances (in terms of the CH₄ production and CO₂ abatement) were evaluated in order to enhance the process.

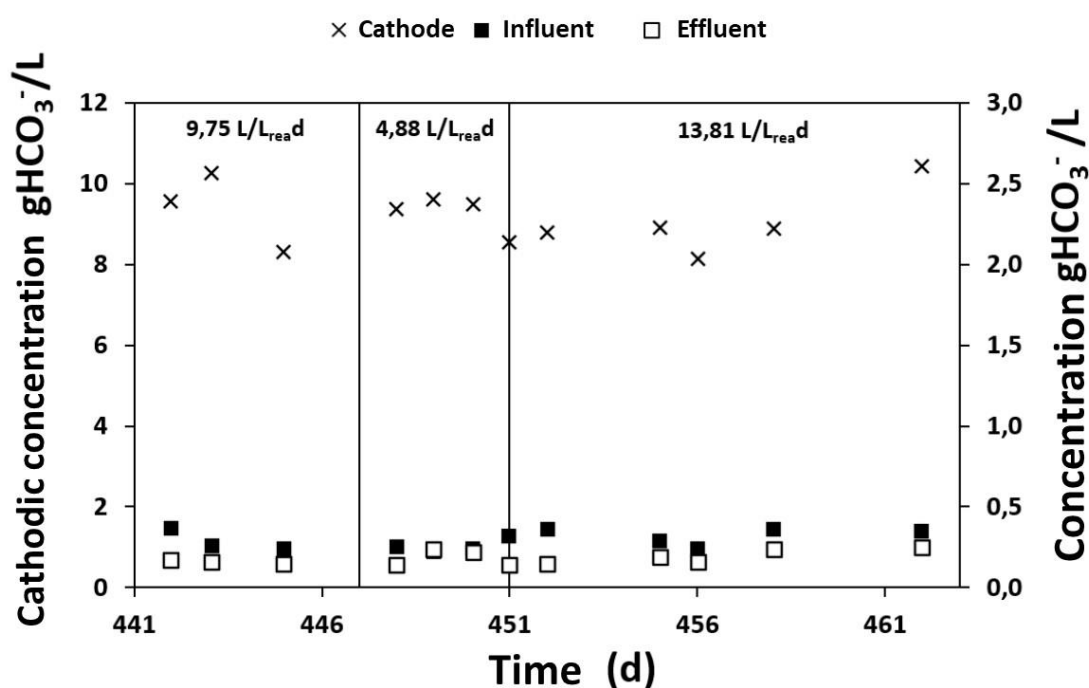


Figure 1. Bicarbonate concentration inside the liquid phases.

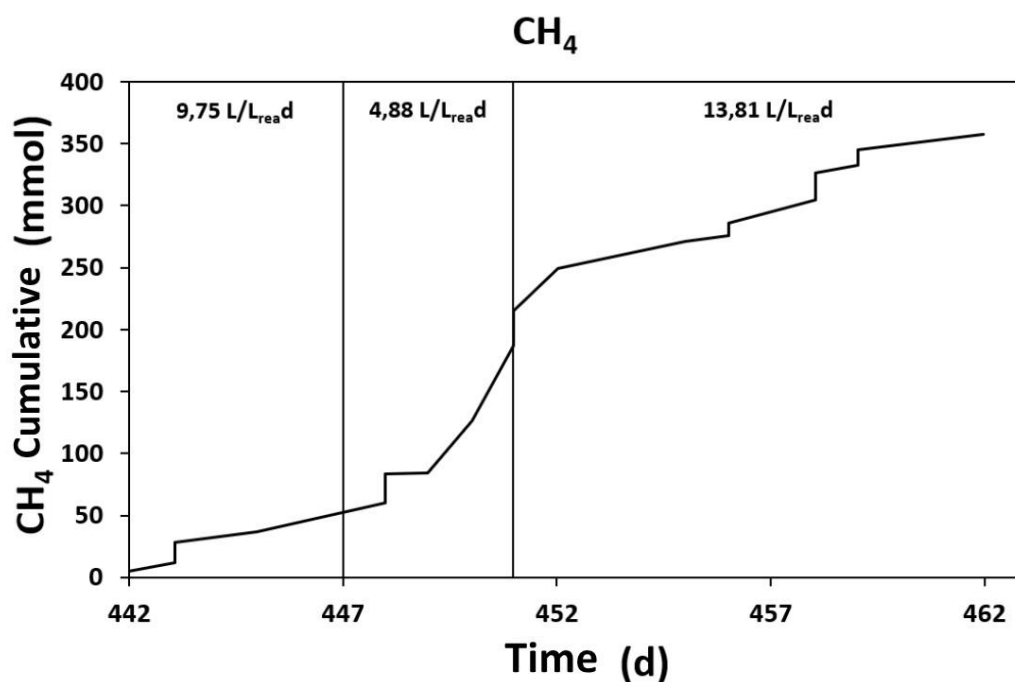


Figure 2. Cumulative methane produced by the biocathode.

As shown in the figures modifying the gaseous inlet flow rate did not significantly change the bicarbonate concentration inside the catholyte, whereas the CH₄ production did change. Table 1 summarizes the performance of the pilot scale MEC using three different gaseous flow rates.

Table 1. Performance comparison between the streams.

Flow rate (L/Ld)	4.88	9.75	13.81
CO ₂ removal (mmol/d)	254 ± 51	657 ± 123	409 ± 53
HCO ₃ ⁻ spilled (mmol/d)	193 ± 1	470 ± 24	216 ± 13
CH ₄ production (mmol/d)	26 ± 4	10 ± 3	12 ± 3

The highest CO₂ removal was obtained with a gaseous flow rate of 9.75 L/Ld whereas the measured methane production was significantly lower than the one obtained with other flow rates. It is interesting to note that the bicarbonate concentration inside the catholyte did not significantly change whereas the daily amount of spilled bicarbonate did.

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