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# Microbial bioelectro-refining of effluents and wastewater streams for the production of hydrogen and platform molecules

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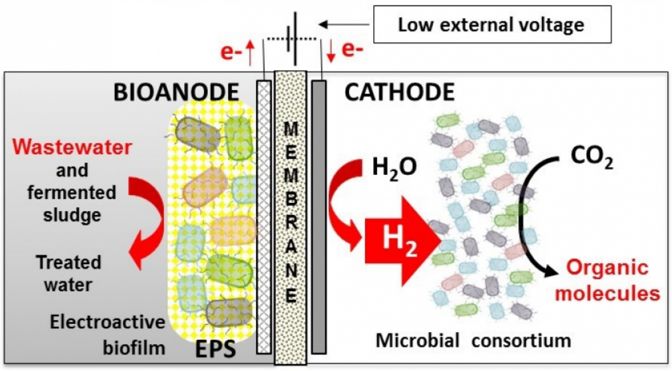
## PURPOSE OF THE ABSTRACT

Within the framework of the energy transition and France's bioeconomy strategy, effluents are now considered as real resources to be recycled in order to produce clean water, bioenergy (biogas, biohydrogen), biosourced materials (fertilisers, biomaterials, bioplastics), as well as platform molecules that interest the chemical and pharmaceutical industries. In such a scheme of ecological, energetic and economic mutation, the wastewater treatment plant of the future has the ambition to become a recycling plant, or rather a real environmental biorefinery plant, by relying on resources available in large quantities and universally. In this context, bioelectrochemical processes are strategic technological building blocks to achieve this ambition of a biorefinery for wastewater effluents and products. The adjective "bioelectrochemical" is appropriate here as it is the electrode-microorganism interfaces, i.e. electroactive biofilms [1], that catalyse the material and/or energy transformation steps. Microbial electrosynthesis [2] is an emerging bioelectrochemical process, originating in the USA in 2010, in which electricity (preferably decarbonised) is used to (1) recover fatal energy from effluents at the bioanode and (2) drive microbial biosynthetic processes from $CO_2$ at the cathode. This therefore virtuously allows both the treatment of effluents, the direct capture of $CO_2$, and the so-called "green" production of biofuels (alcohols) or organic synthons such as short-chain organic acids (acetate, propionate, butyrate...).
In 10 years, the scientific advances have been very rapid. The LGC in Toulouse has positioned itself as a leader in the field and has demonstrated, within the framework of the PIA Biorare project (2011-2017), that hydrogen plays a central role in the mechanism of the microbial reduction of $CO_2$ to organic molecules on cathodes [3]. It is easy to imagine that the rate of production of organic molecules in this case is closely linked to the concentration of bioavailable hydrogen in solution ($V=V_{max} [H_2]/(K_m+[H_2])$) and to the electrochemical kinetics of generation of this electron donor on the cathode.
The challenge of our work was therefore to boost the generation of the $H_2$ intermediate at the cathode of bioelectrochemical reactors by physically separating the $H_2$ production process from that of microbial $CO_2$ hydrogenation. Modelling work has enabled us to dimension optimal designs of continuous bioelectrochemical reactors, as well as to create a 3D electrode whose architecture is optimised to recover as many electrons as possible from the effluents, not to affect the resistance to charge transfer in solution, to allow a homogeneous flow of the effluents in the electrode and to avoid clogging by the consequent development of the microbial biofilm.
An extensive modelling study using Comsol Multiphysics® was carried out. The model consists of the simultaneous calculation of the potential and current distribution, velocity and pressure drop for the fluid flow (continuous wastewater supply) as well as the mass transfer of organic matter. Different reactor geometries were considered. The 3D electrode design was scaled up taking into account the impact of the geometry on fluid flow, mass transfer and potential/current distribution. The strategic positioning of the 3D electrode can avoid the formation of a preferential path for the fluid flow, and thus allow for optimal consumption of organic material and optimal electron recovery. The use of the 3D electrode instead of the conventional 2D plates potentially increases the generation of the $H_2$ intermediate by more than 50% for a 10L pilot operating at constant electrolysis voltage. Pilot-scale experimental operations were also conducted to validate the model data.

[1] Erable et al., 2010 https://doi.org/10.1080/08927010903161281

[2] Bian et al., 2020 https://doi.org/10.1016/j.biortech.2020.122863
[3] Blanchet et al., 2015 https://doi.org/10.1039/C5EE03088A

## FIGURES




## FIGURE 1

Principle of the microbial electrosynthesis process

oxidation of effluents and wastewater on the one hand and microbial hydrogenation of CO2 on the other

## FIGURE 2


## KEYWORDS

wastewater | bioelectrochemical systems | hydrogen | platform molecules


## BIBLIOGRAPHY