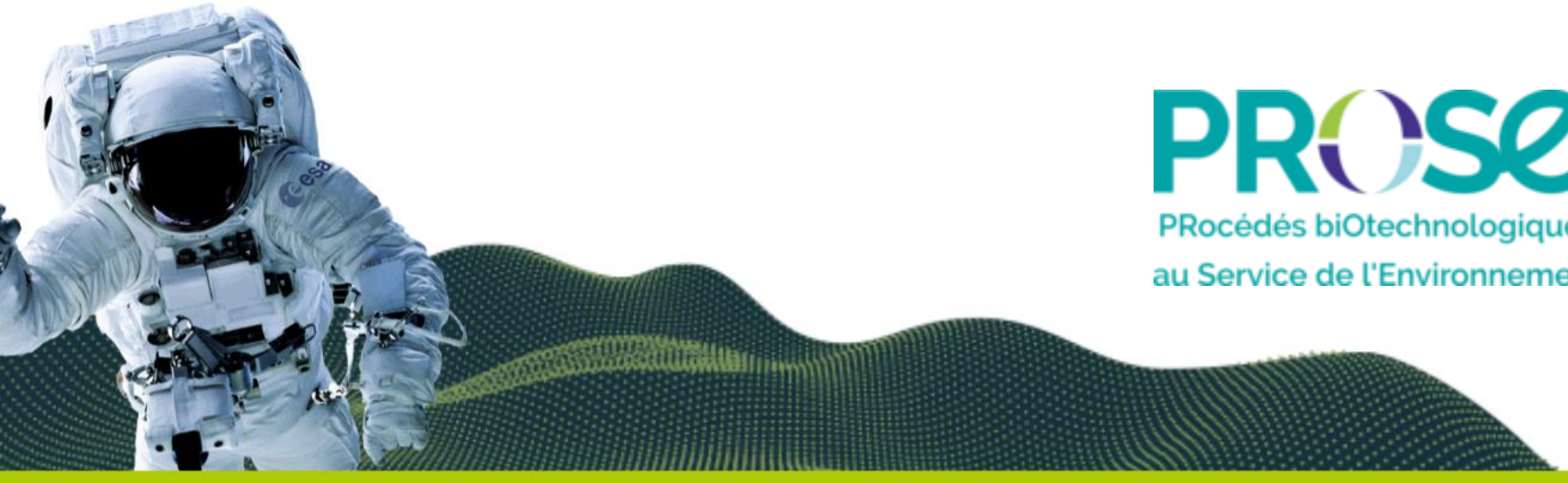
MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

Electroactive biofilm development under controlled hydrodynamic in a Couette-Taylor electrochemical reactor

Florent Bouchon, Ahlem Filali, Chrystelle Bureau, Alain Bergel, Théodore Bouchez, Yannick Fayolle



PROSE
PRocédés biOtechnologiques au Service de l'Environnement

RÉPUBLIQUE FRANÇAISE
Liberté Égalité Fraternité

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AU SERVICE DE LA SCIENCE

ANR-17-CE06-0015-01, 2018-2023

Wastewater energetic impact : greywater

Tank oxygenation

75% for the plant

France : 3%

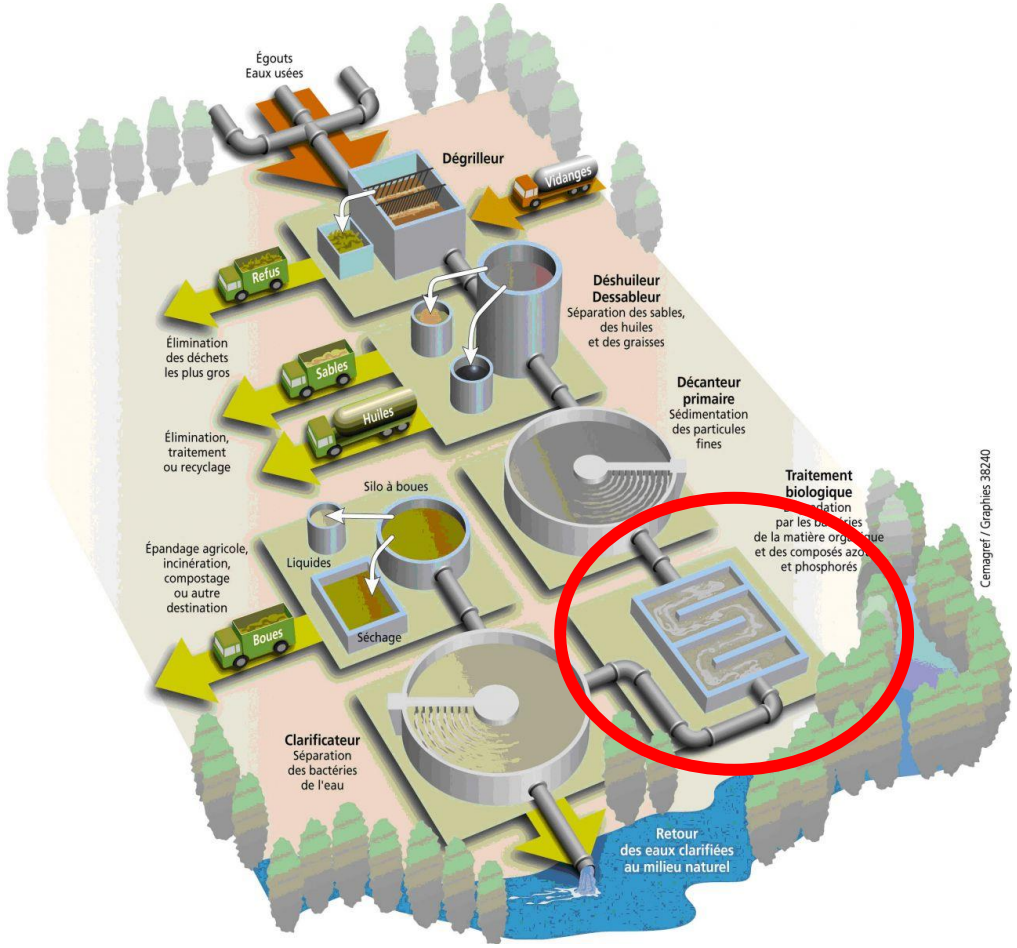

Figure 1 : Wastewater treatment process

Wastewater energetic impact : greywater

Tank oxygenation

75% for the plant

France : 3%

Need of a way to decrease this consumption

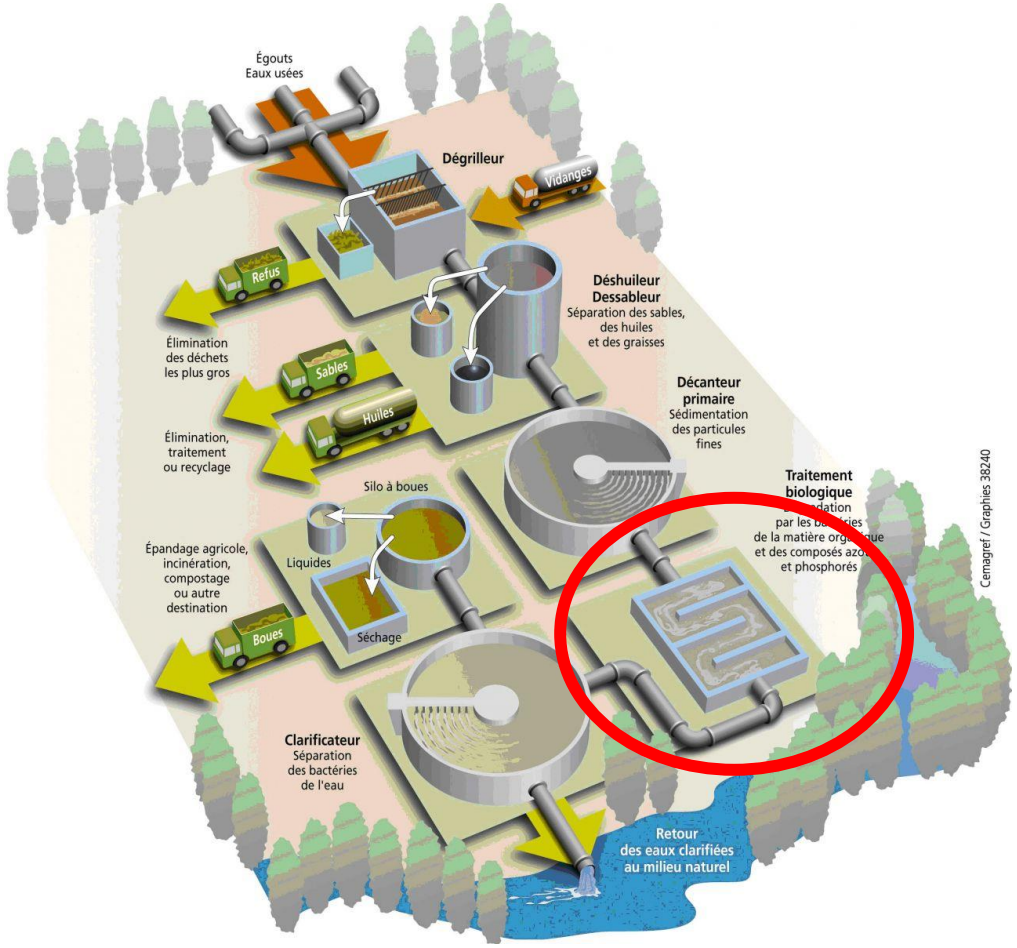

Figure 1 : Wastewater treatment process

Bio-Electrochemical Systems to separate the redox process in 2 compartments

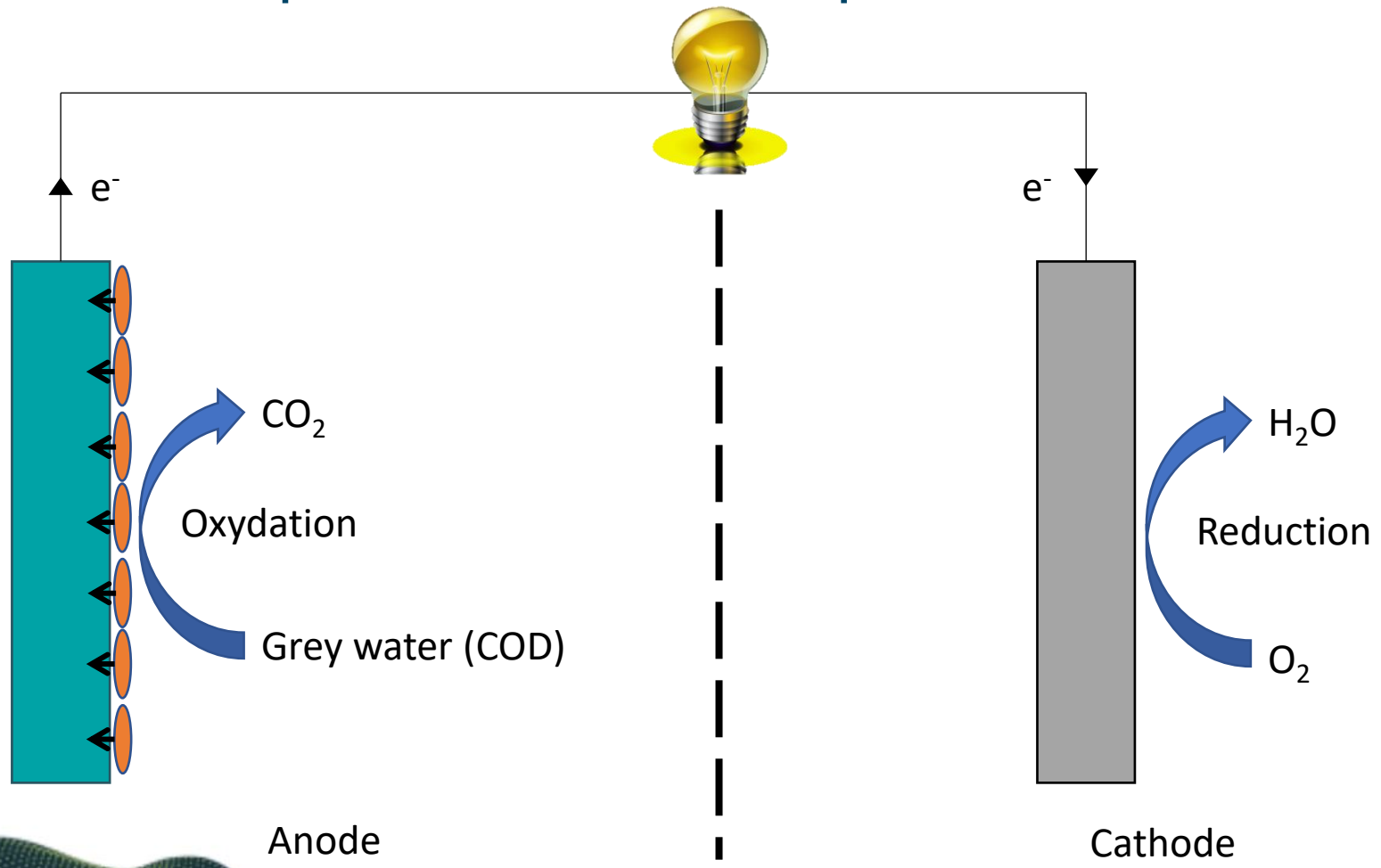

Figure 2 : The MFC principle

A bio-electrochemical snorkel : BIOTUBA

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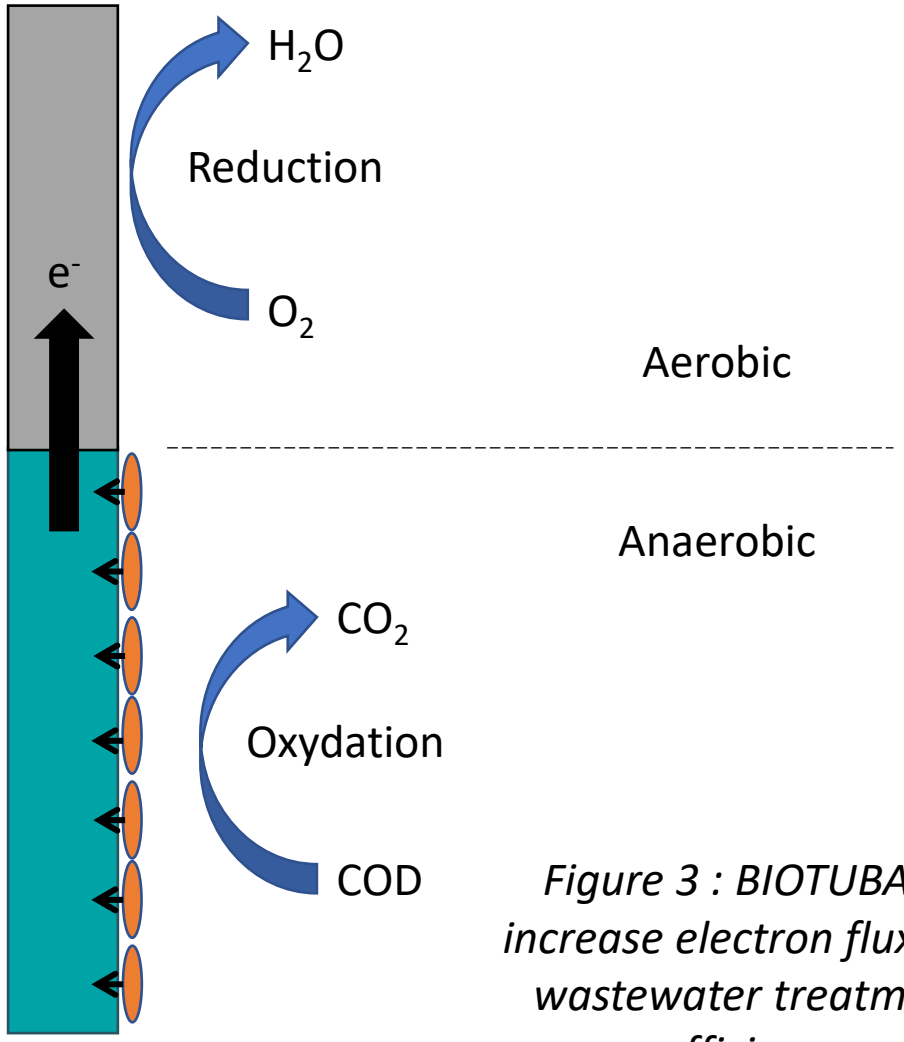
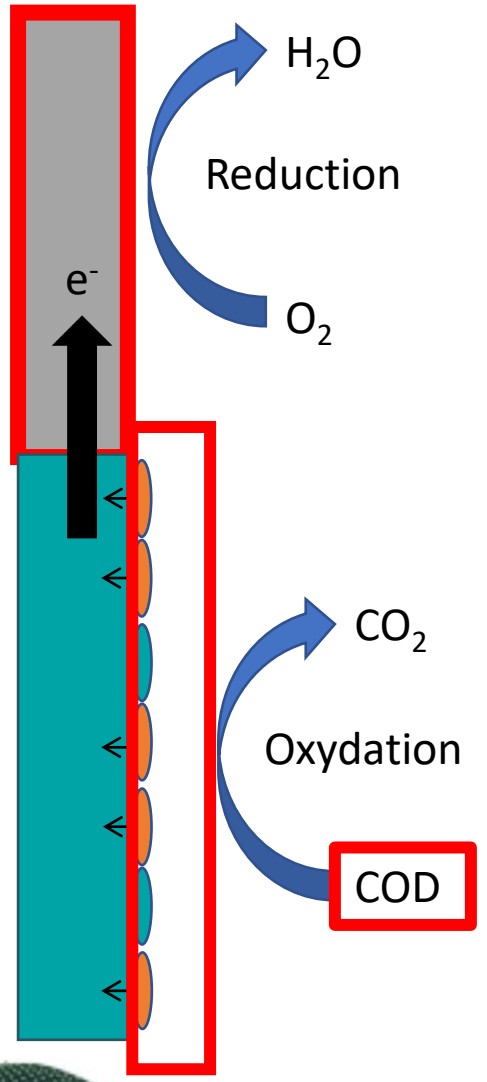


Figure 3 : BIOTUBA to increase electron flux and wastewater treatment efficiency

Erable *et al.*, 2011

A bio-electrochemical snorkel : BIOTUBA

Limiting parameters



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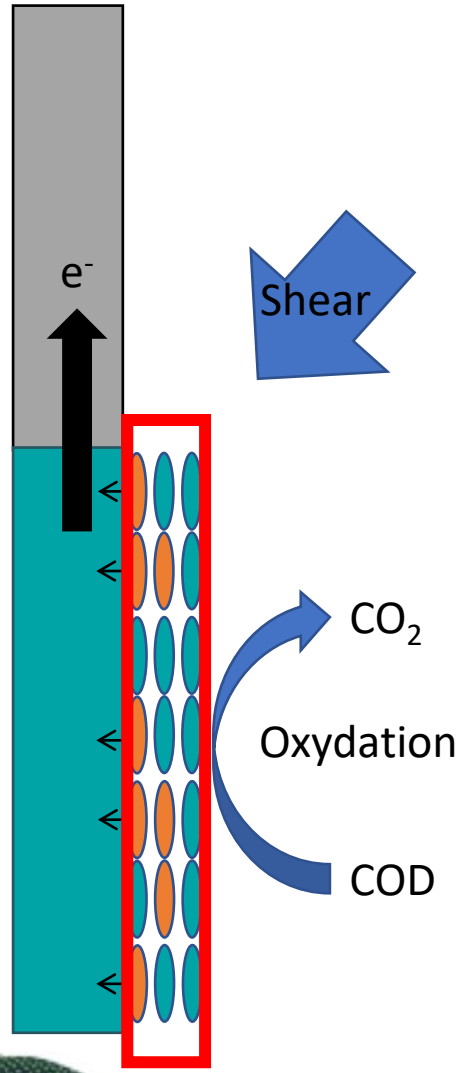
Biofilm aging :
↘ Catalytic activity

➡ A way to boost the decreasing activity of aged biofilm?



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A bio-electrochemical snorkel : BIOTUBA

Limiting parameters

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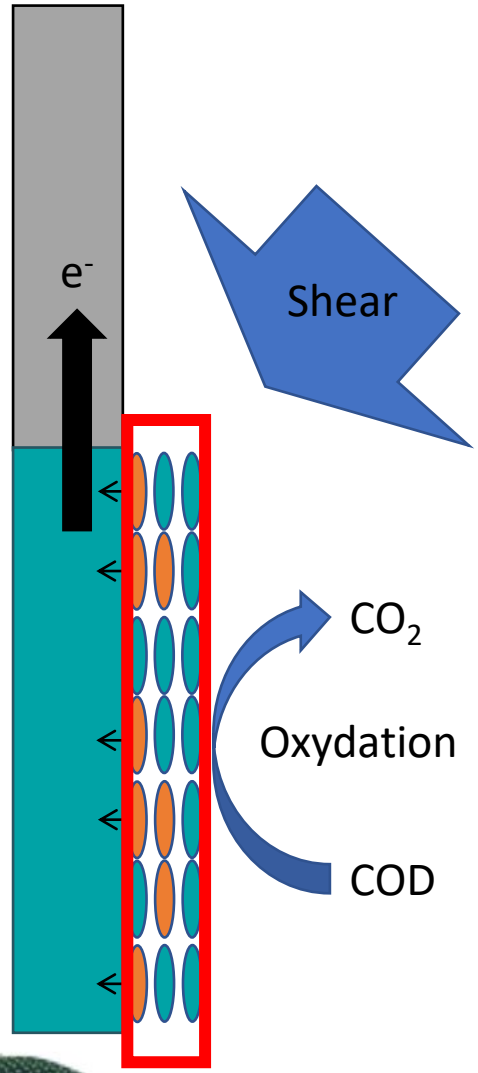
?

Detachment of non-electroactive bacteria on the biofilm surface



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The first eCTR to characterize precisely the shear stress effect on electroactive biofilms

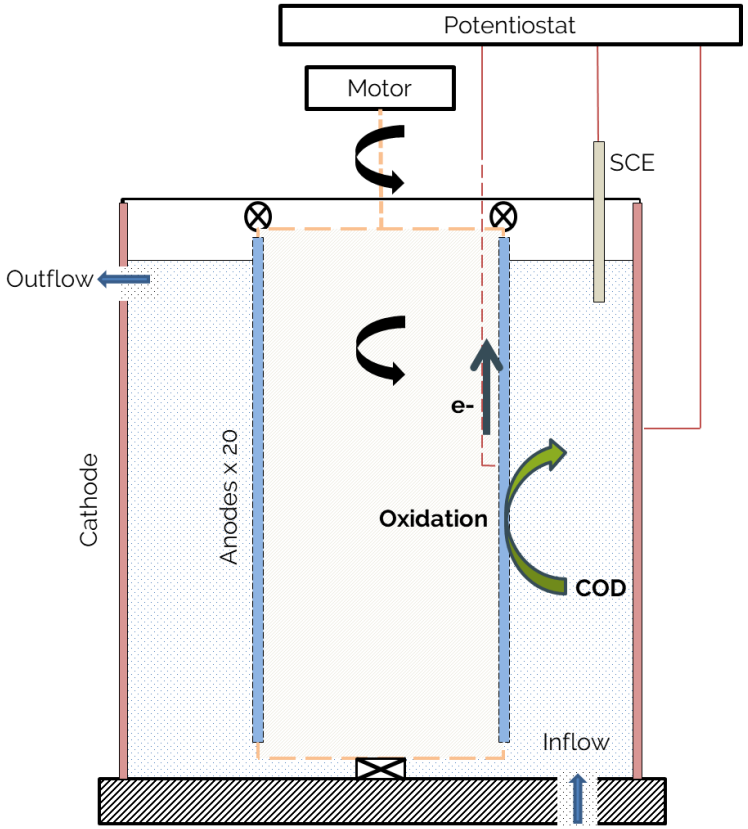

Figure 4 : Taylor-Couette reactor adapted to electroactive biofilm analysis

Advantages :

- **Decoupling** shear stress and other parameters (input flow rate or imposed voltage)

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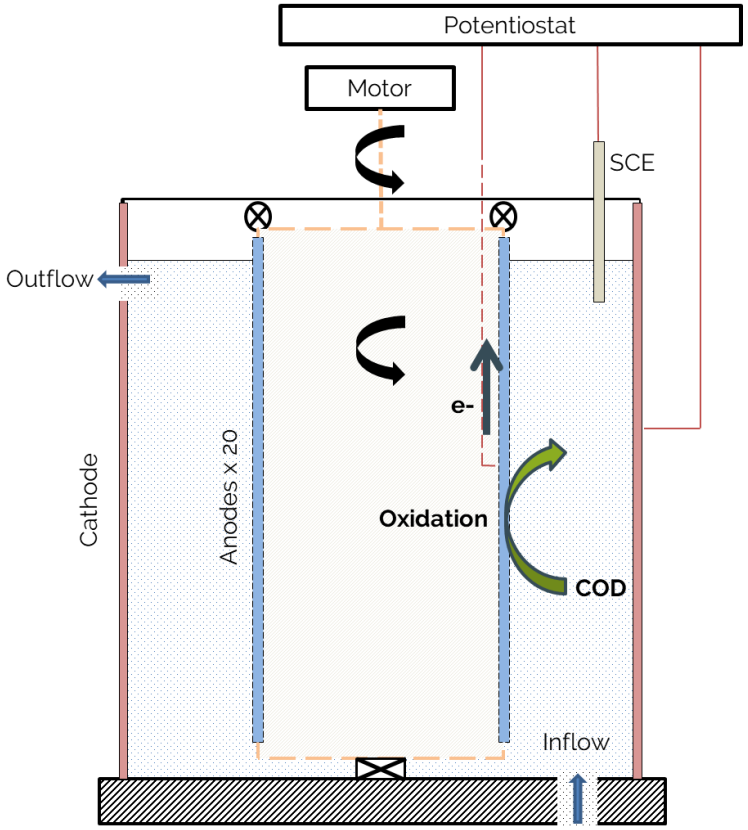

Figure 4 : Taylor-Couette reactor adapted to electroactive biofilm analysis

Advantages :

- **Decoupling** shear stress and other parameters (input flow rate or imposed voltage)
- Big size electrodes (20 cm²)
- Hydrodynamics **perfectly identical** for the 20 electrodes

Initiating the development of an electroactive biofilm under controlled low hydrodynamic

Reminder of the limiting parameters:

- ❑ Cathode size
- ❑ Substrate concentration
- ❑ Biofilm catalysis

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- ✓ Real greywater supplemented with acetate
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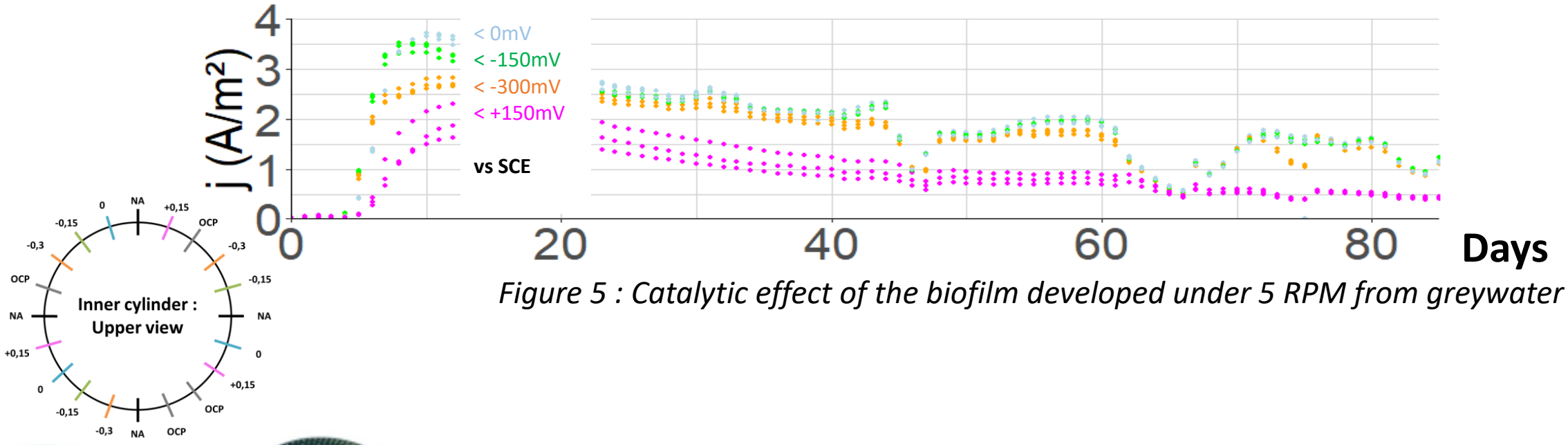

Figure 5 : Catalytic effect of the biofilm developed under 5 RPM from greywater

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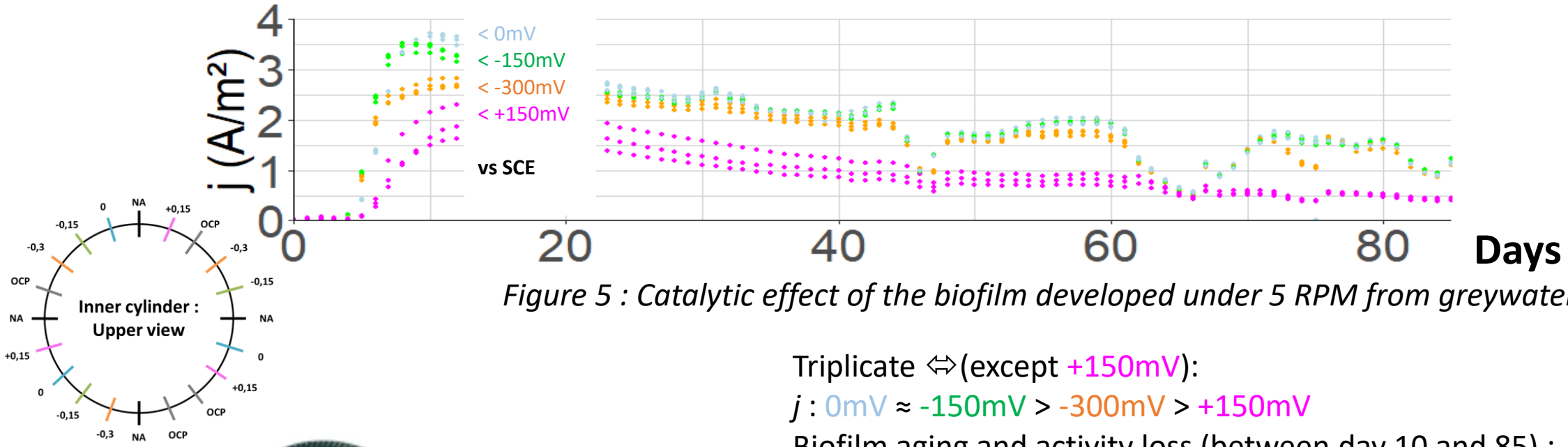


Figure 5 : Catalytic effect of the biofilm developed under 5 RPM from greywater

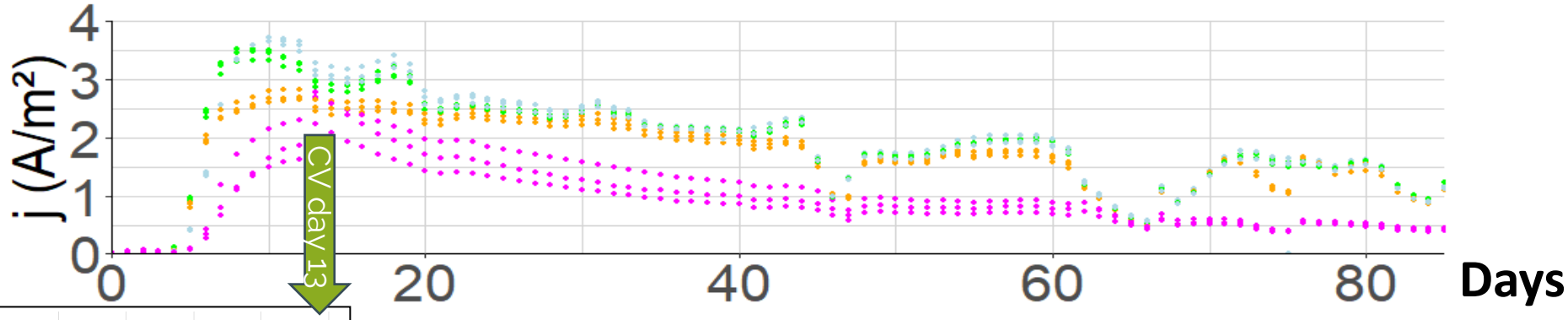
Triplicate ⇔(except +150mV):

j : 0mV ≈ -150mV > -300mV > +150mV

Biofilm aging and activity loss (between day 10 and 85) :

j_{loss} : 55% < 60% < 65% < 80%

Characterizing electro-microbial anodic activity: Cyclic Voltammetry (CV)



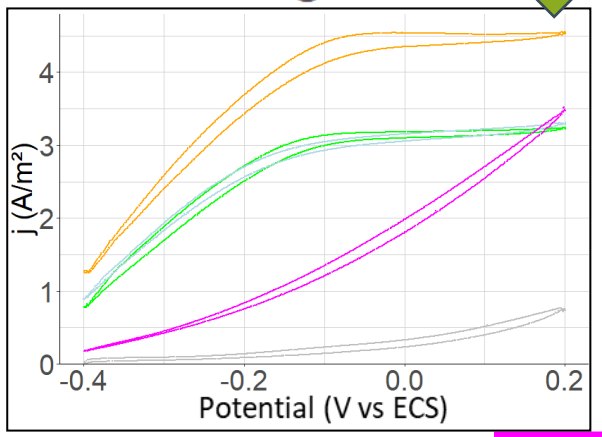


Figure 7 : CV obtained at the end of the biofilm growth phase

-300mV > -150mV = 0mV > +150mV

Lower catalysis effect

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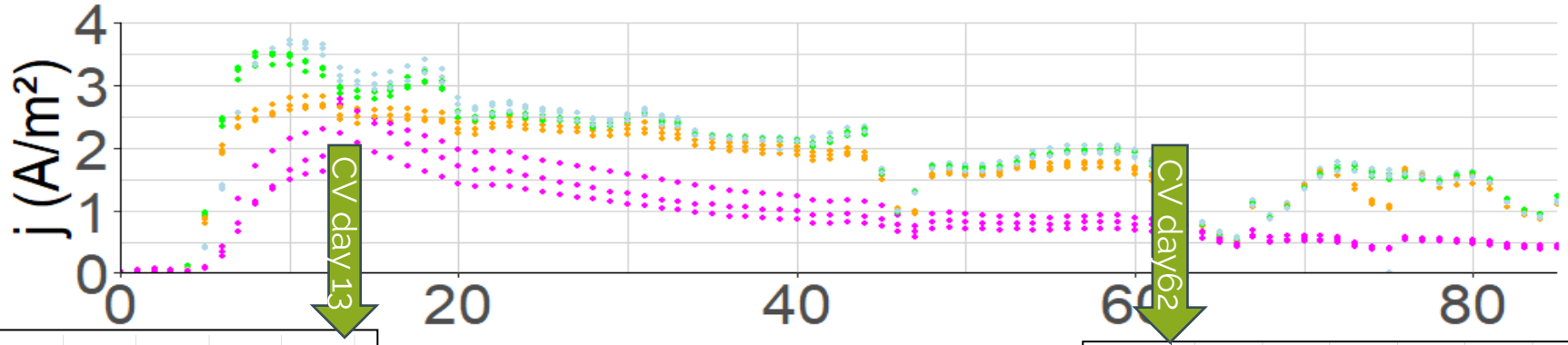

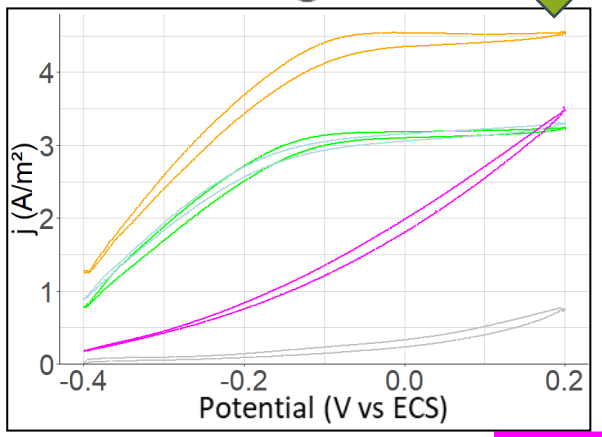

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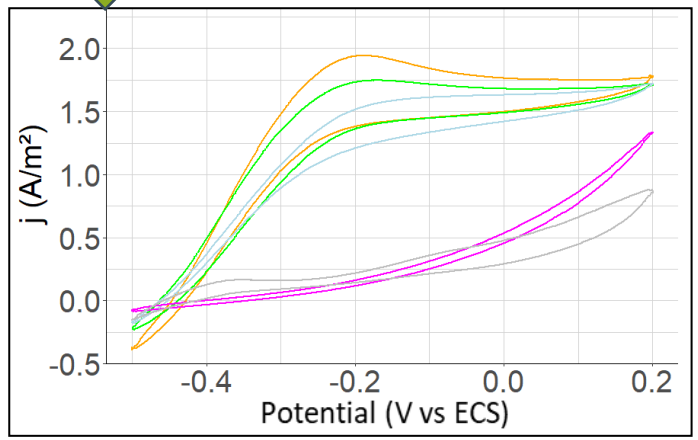

Figure 8 : CV for the activity plateau of the biofilm

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Converge ≈0

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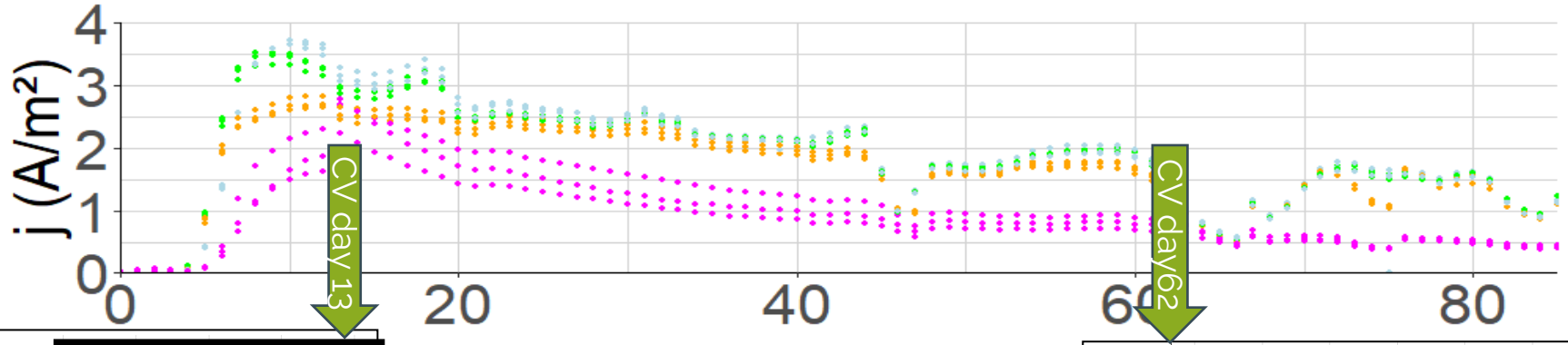


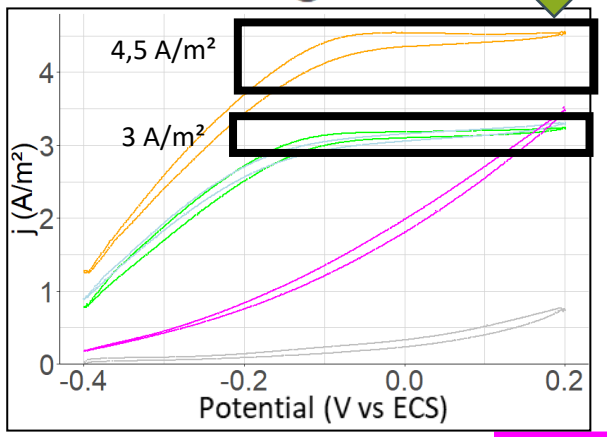
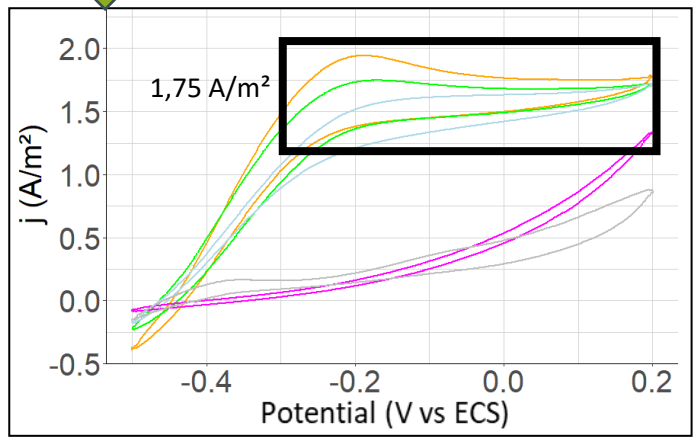


Figure 7 : CV obtained at the end of the biofilm growth phase

←Growth vs mature→

↘ j_{max} :

-60% / -50% / -50% / -65%



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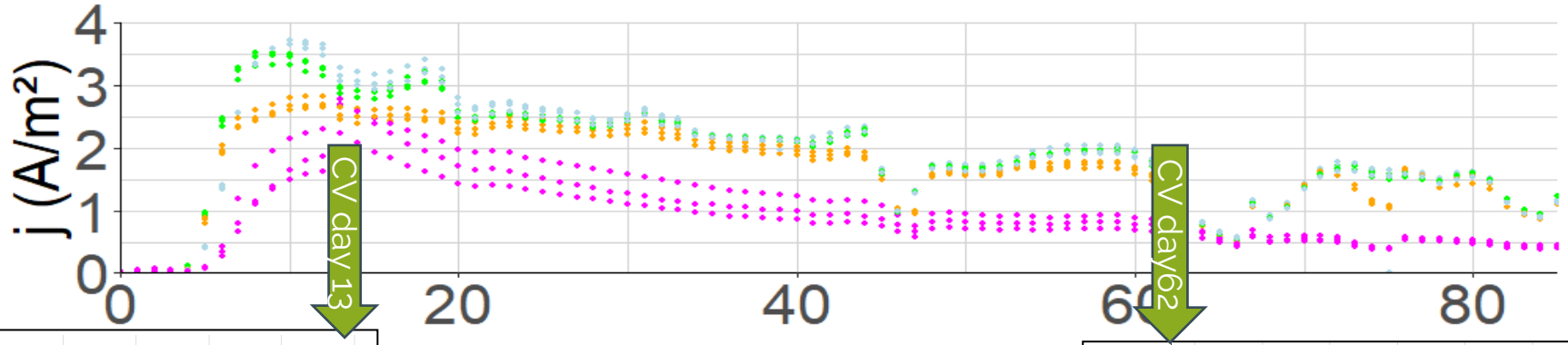

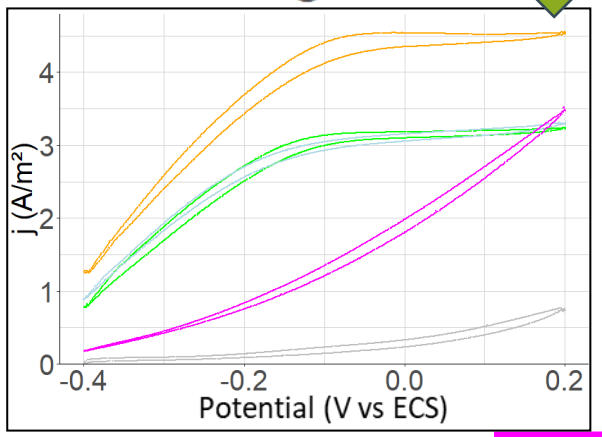

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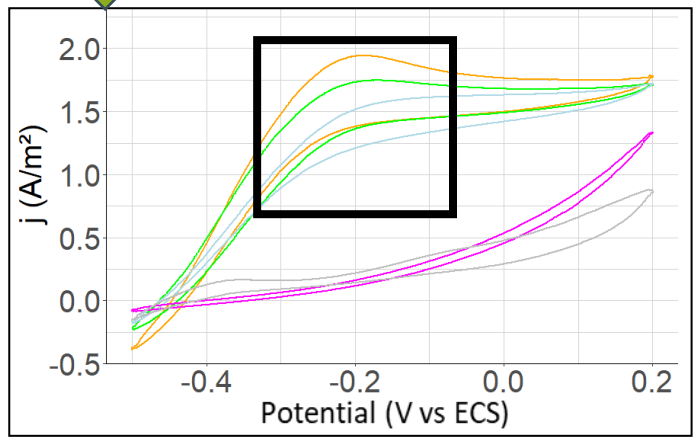
↗ Diffusion limitation phenomena

-300mV / -150mV



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Electrochemical analysis summary

Bio-electrochemical COD removal (Chronoamperometry):

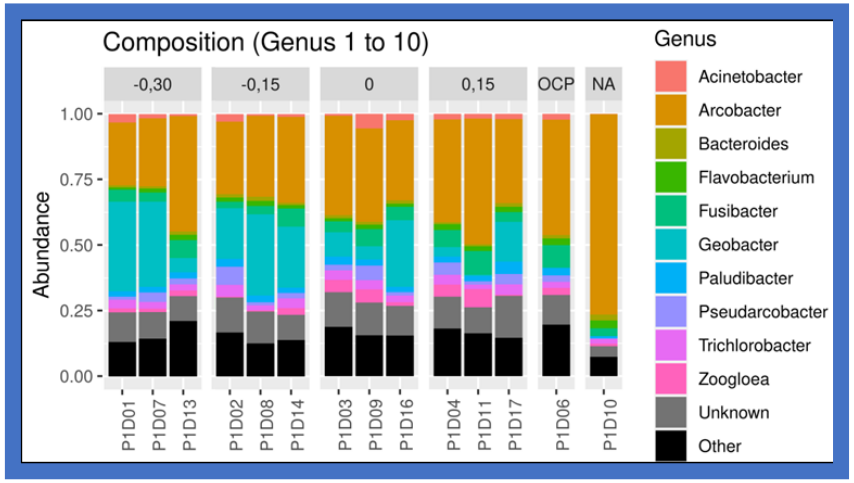
Biological catalysis (Cyclic Voltammetry):

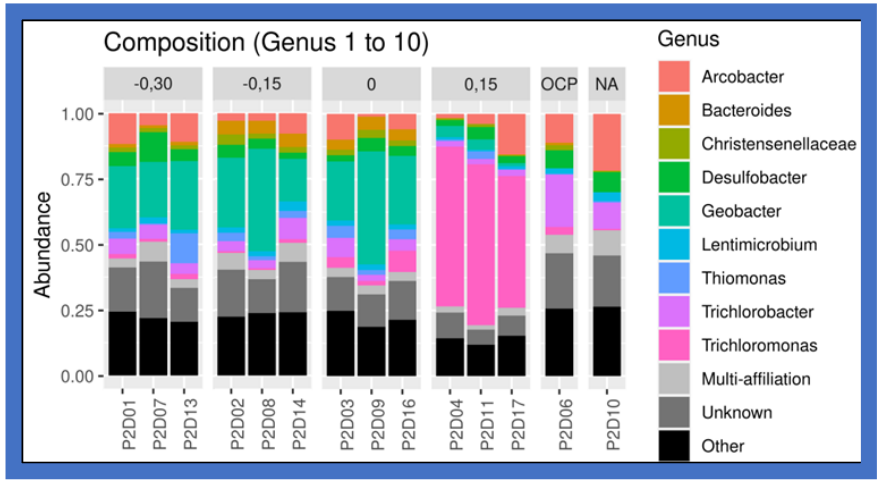
Microbial communities in the biofilm

Day13

Day62

gDNA





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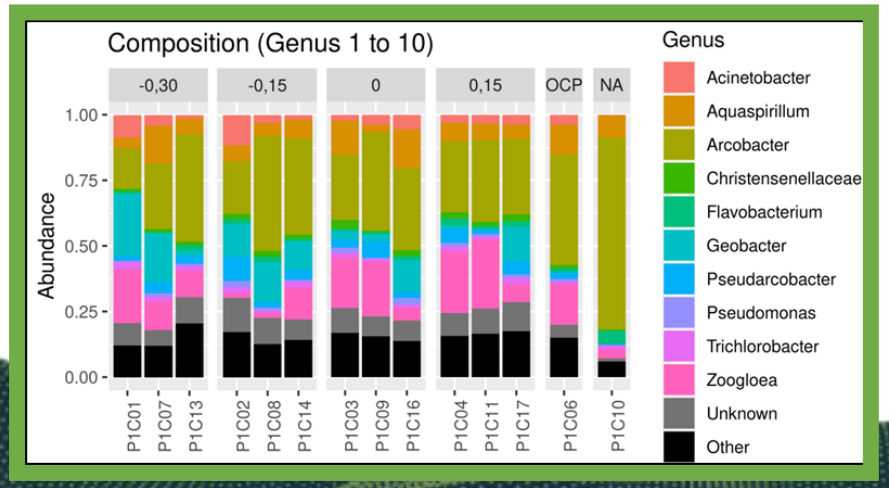
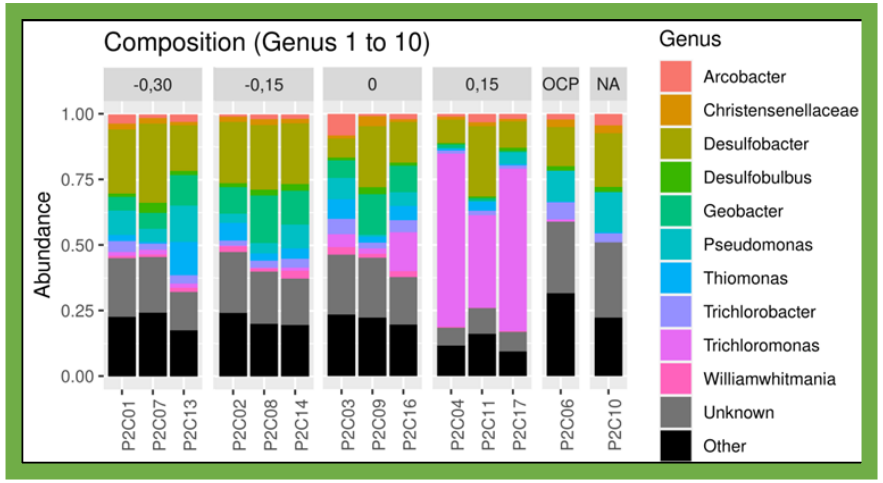
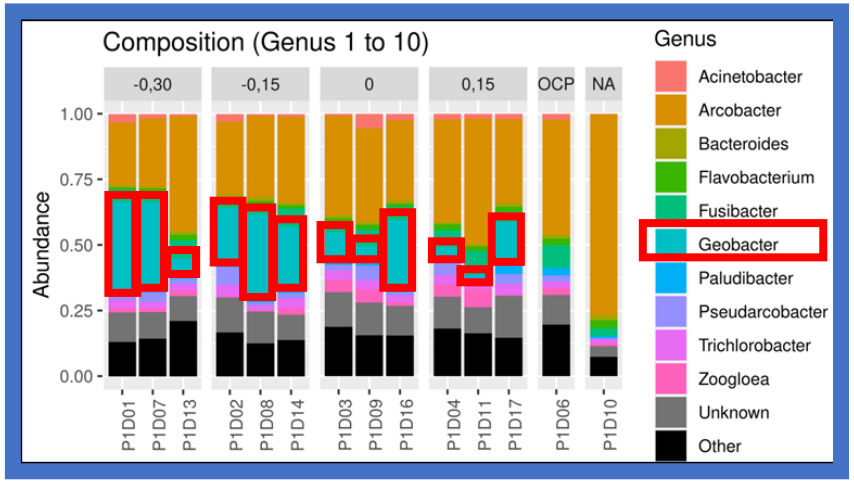




Geobacter, the electroactive bacterium

gDNA

Day13

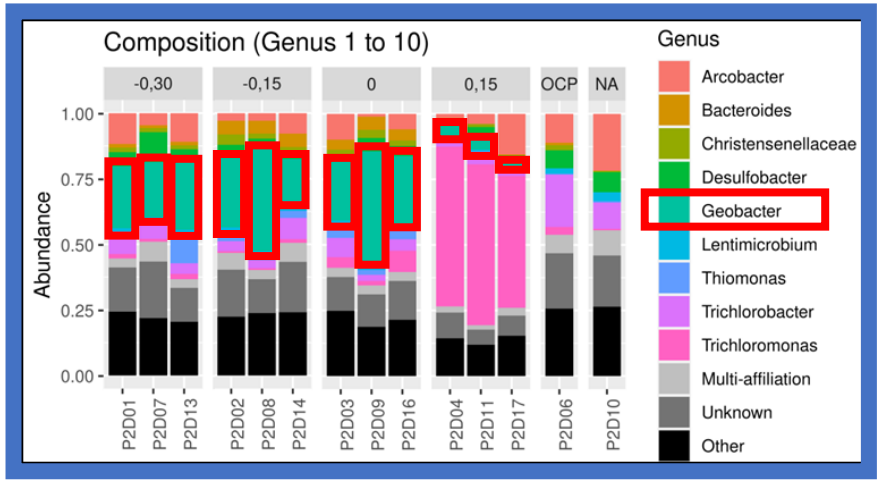


In the most electroactive conditions:

-300mV / -150mV / 0mV

(↗: 20 -> 25%)

Day62



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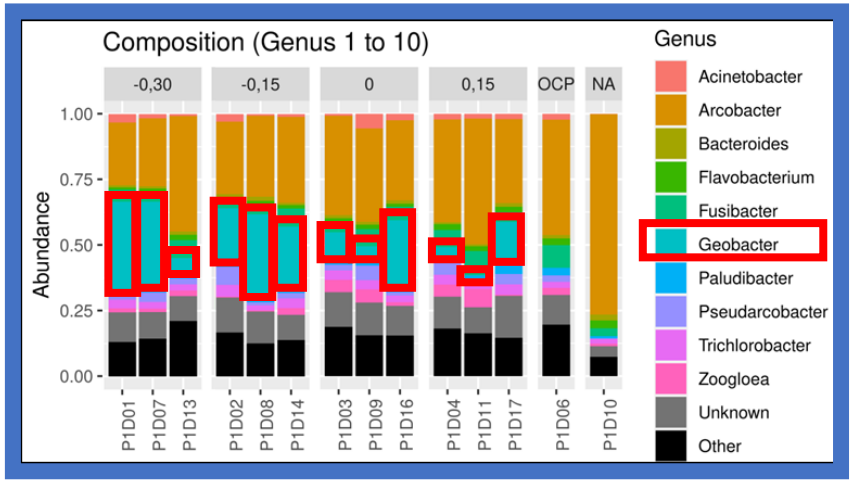

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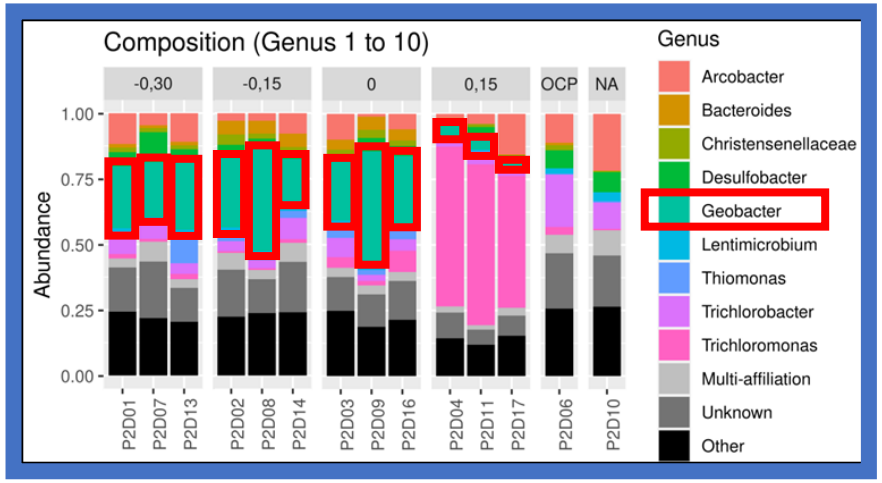
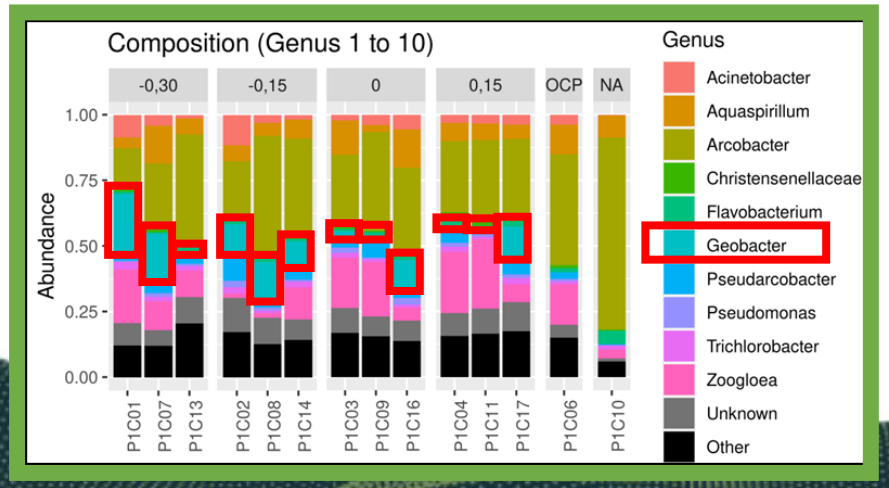
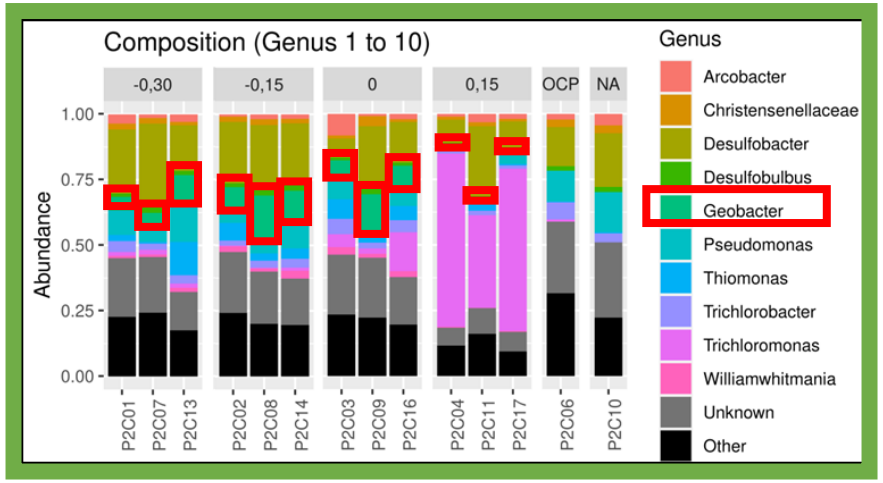


cDNA



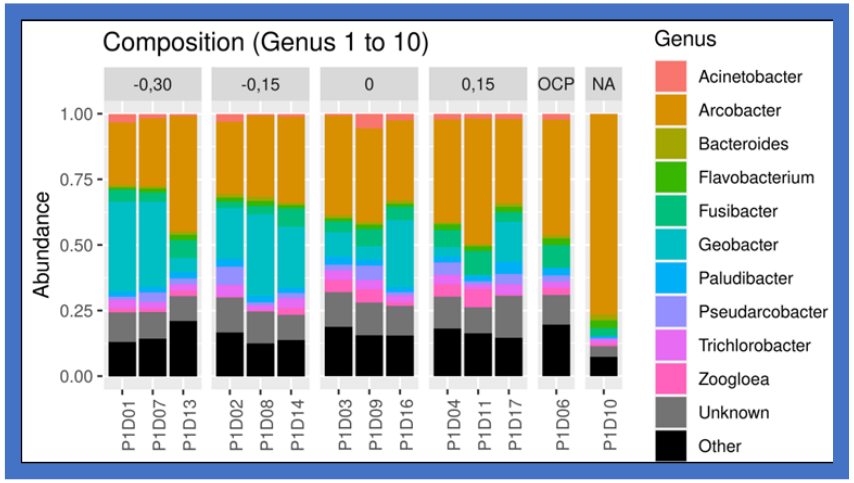
- ❑ Presence ++
- ❑ Activity – (10% -> 9%)



Hypothesis for *Trichloromonas*

gDNA

Day13



Mainly represented in mature biofilms +150mV

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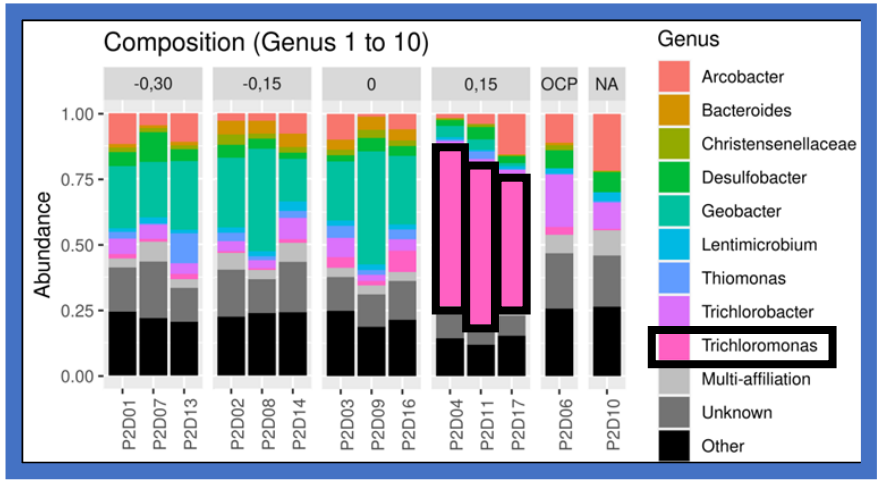
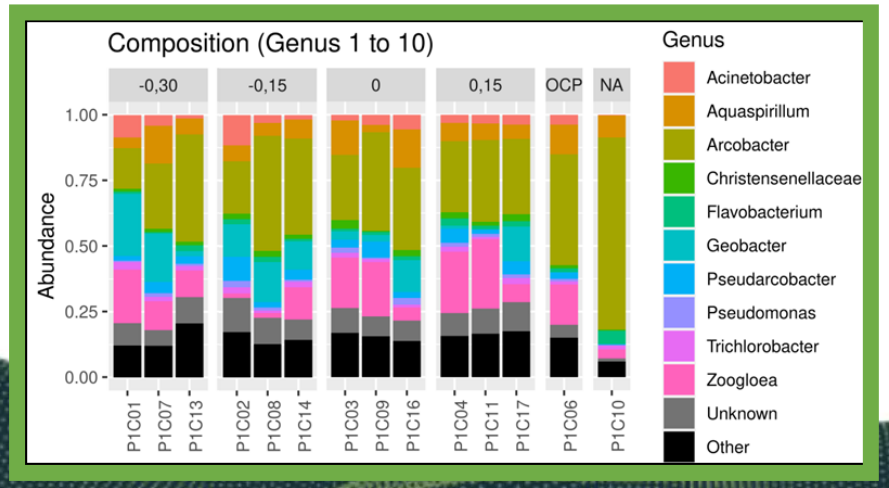


cDNA



- Electrochemical activity

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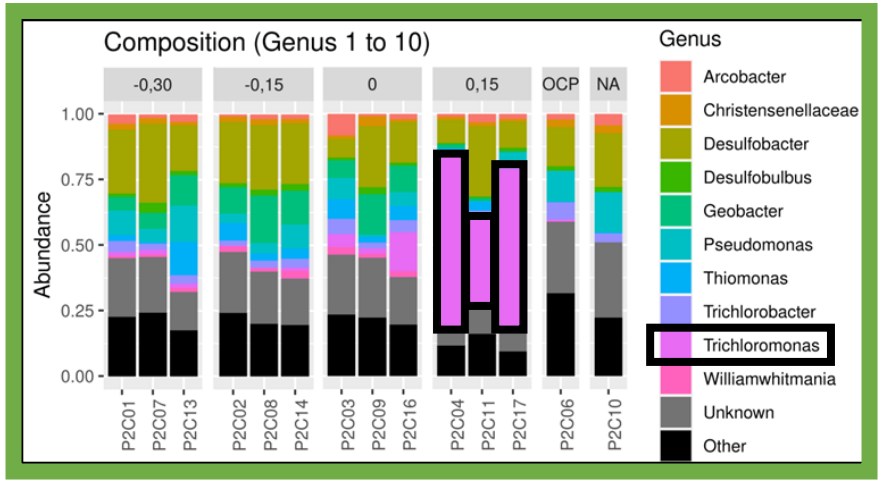
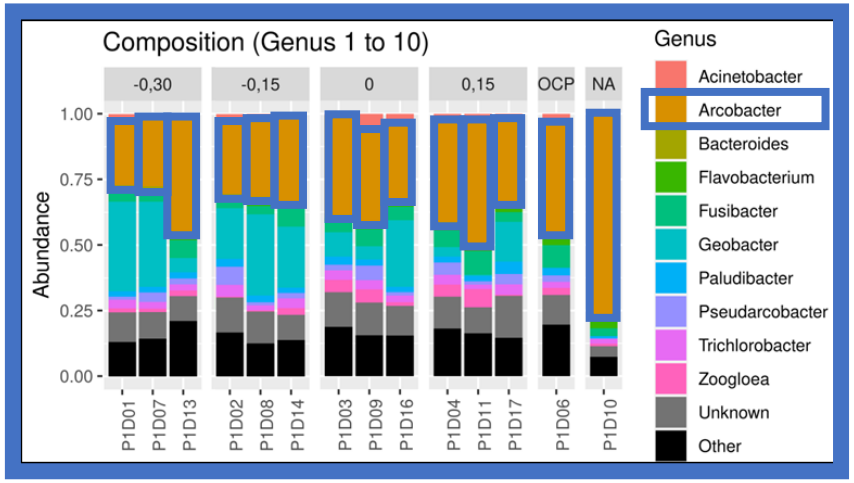
- N_2 fixation / cooperation ?



Hypothesis for *Arcobacter*

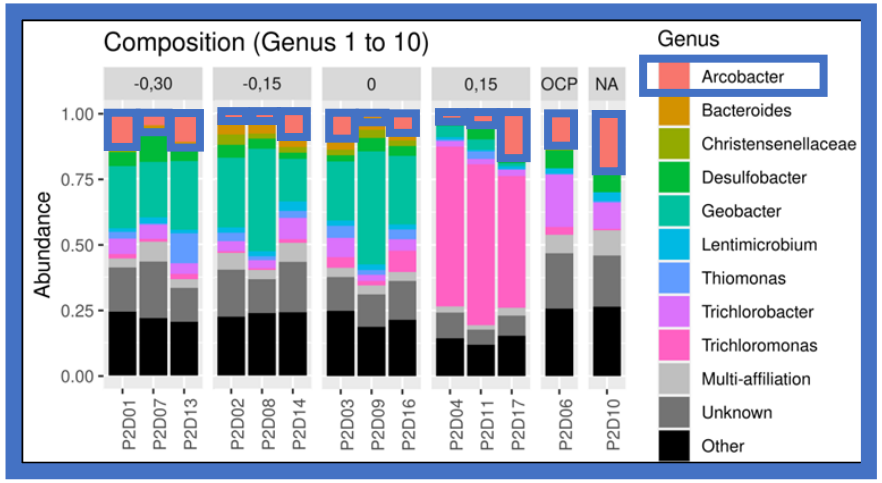
gDNA

Day13



- Mainly represented during growth phase
- Then tends to be negligible
- Within all the biofilms

Day62



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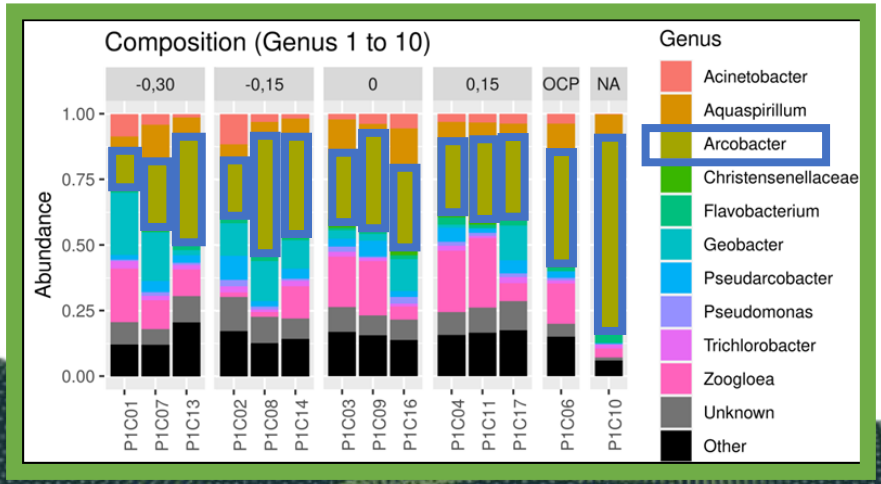
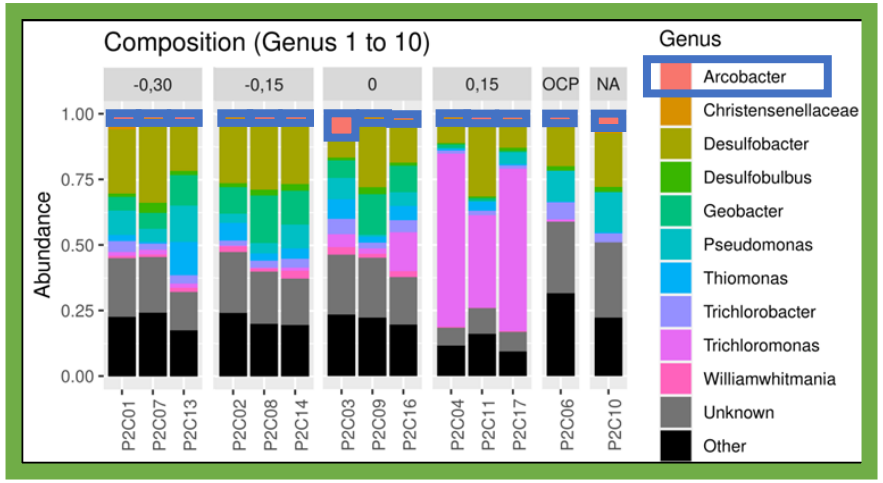


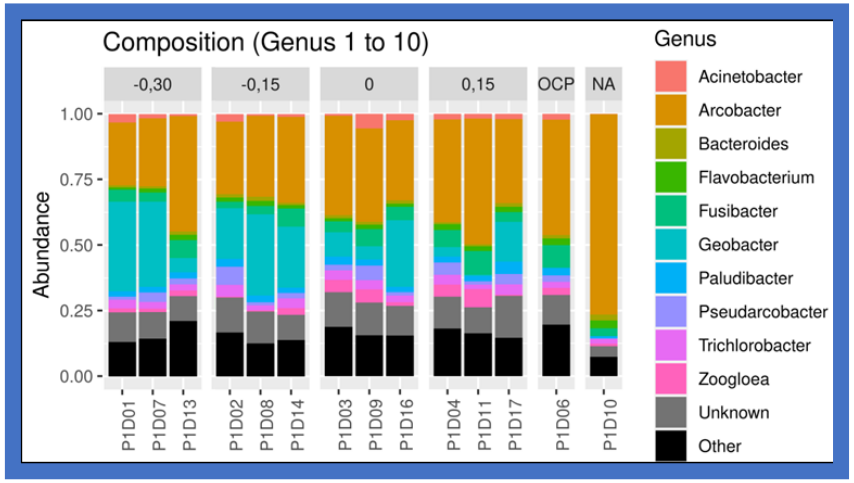
- Most important proportion
- Initial role in the biofilm adhesion?



Hypothesis for *Desulfobacter*

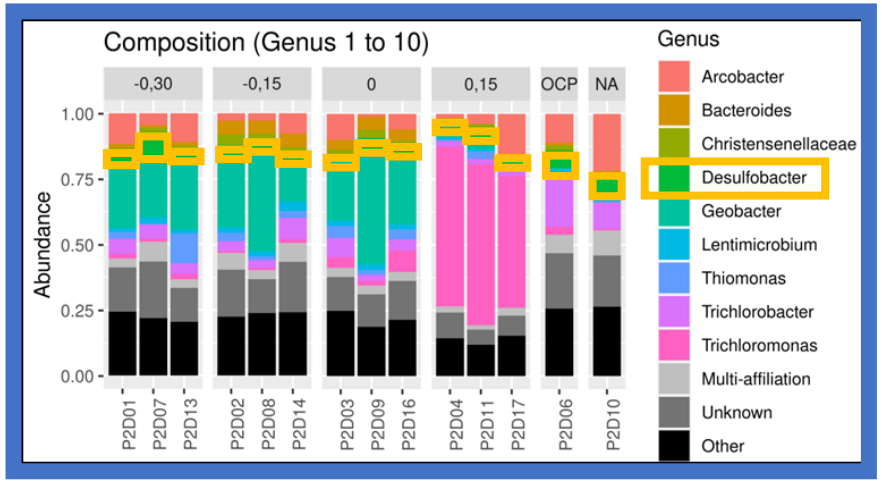
gDNA

Day13



- Only present in mature biofilm
- For all imposed voltage

Day62



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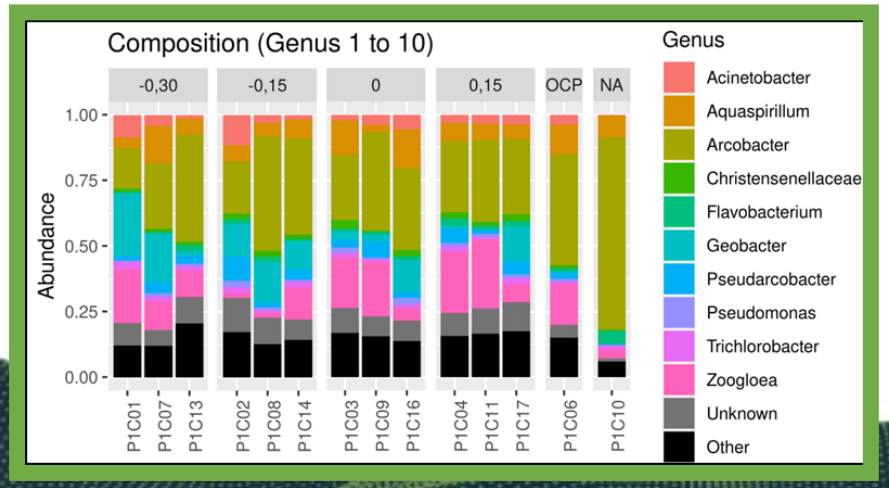
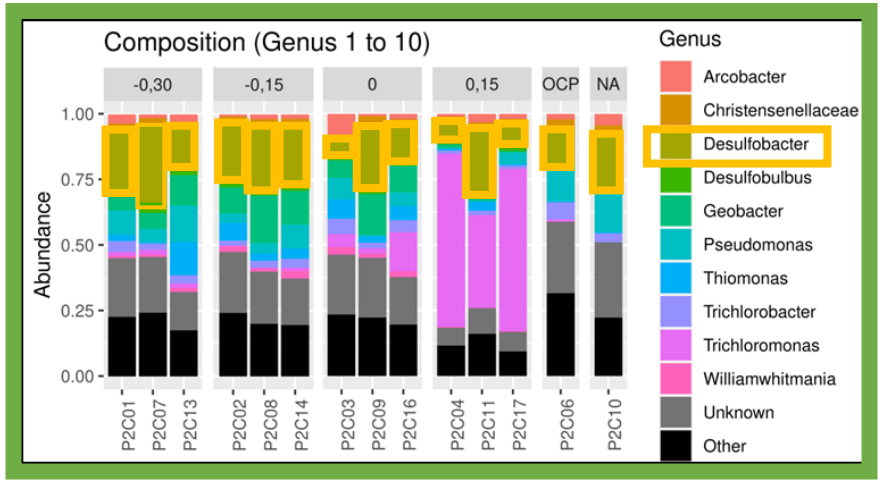
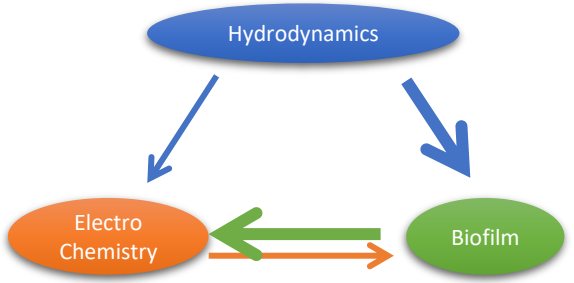


- Activity +++ in comparison to small presence
- Competition with *Geobacter* / Indicator for biofilm aging?



Take home message

- ✓ Development of a Taylor Couette electrochemical reactor validated for electro-active biofilm studies
- ✓ 3 fist months of operation showing biofilm aging
- ✓ Allow to characterize electrochemically and biologically the aging



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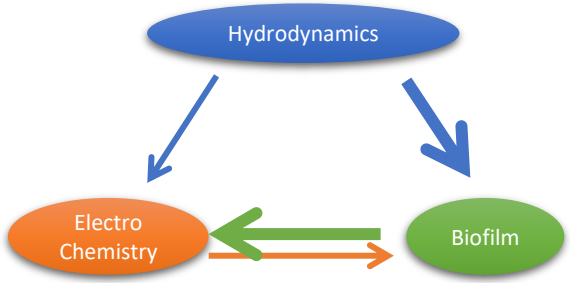

Perspectives

- **Using the reactor to increase the shear stress:**
  - ❑ Best accessibility to substrate?
  - ❑ Detachment of Desulfobacter?
  - ❑ More long term effect to investigate

→ **Control Tool**

- **Other shear rates for biofilm growth:**
  - ❑ Changes in microbial communities?
  - ❑ Best efficiency or best resilience?

→ **Development Parameter**

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THANK YOU.

Florent Bouchon
Unité PROSE, INRAe Antony
florent.bouchon@inrae.fr

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