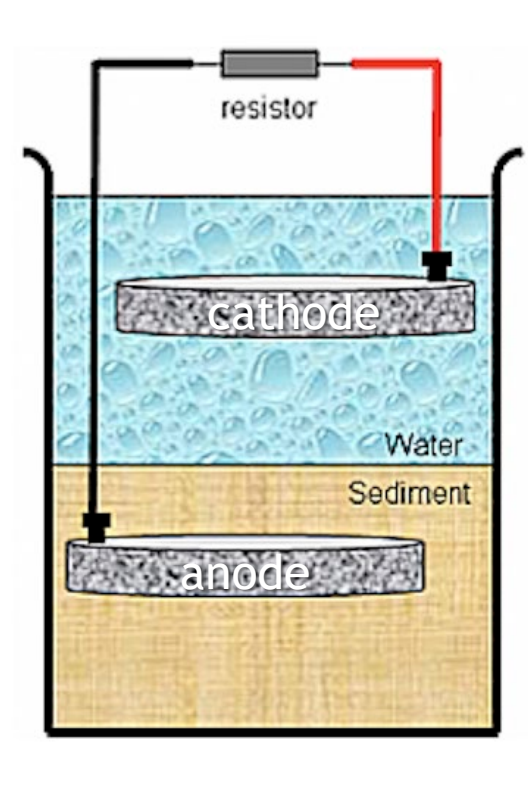
Enhanced Marine SMFCs for the Biodegradation of a Mixture of Low and High Molecular Weight PAHs

Hamdan Z. Hamdan; Darine A. Salam

Department of Civil and Environmental Engineering,
Faculty of Engineering and Architecture,
American University of Beirut,
Beirut, Lebanon

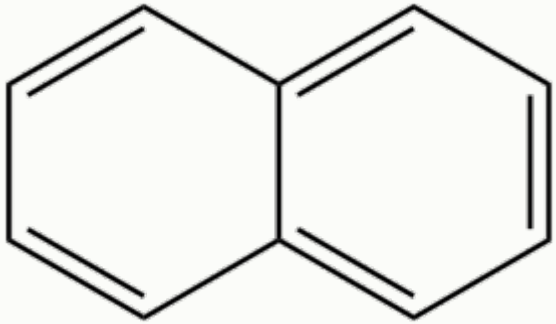
Definition

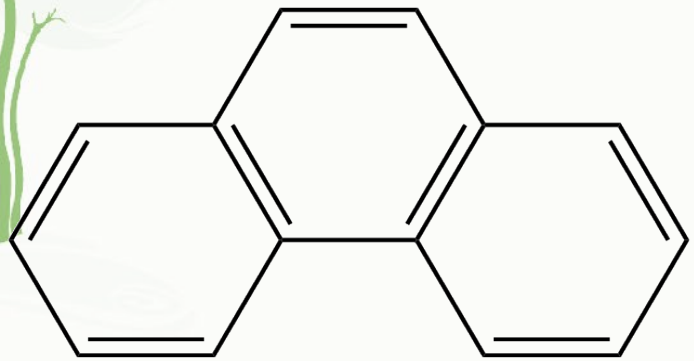
- Sediment microbial fuel cell (SMFC)
  - Microbial electron transfer
  - External terminal electron acceptor (TEA)
  - Exoelectrogens
- Anode
  - Anaerobic sediments
  - TEA
  - Enhanced organic compounds degradation
- Cathode
  - Oxygen rich water
  - Electrical current
- Oxygen
  - Ultimate TEA
  - Thermodynamic favorability

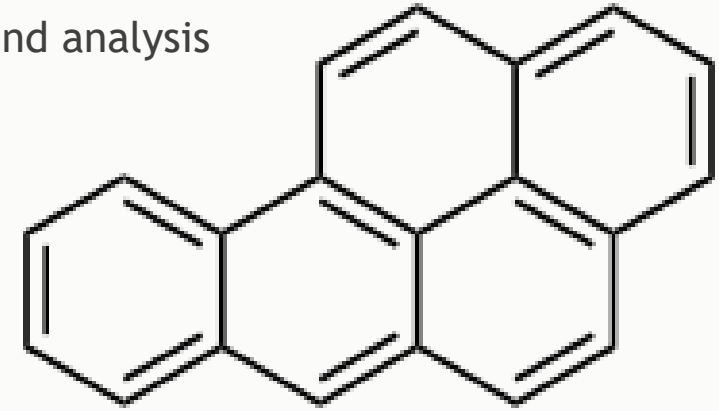


Background Information: PAHs Pollution

- EPA priority pollutant list
  - PAHs
- Reluctance to biodegradation
  - Limitations
- Marine environment
  - Limited literature
  - High sulfate concentrations
  - Low iron concentration
  - Microbial community characterization and analysis

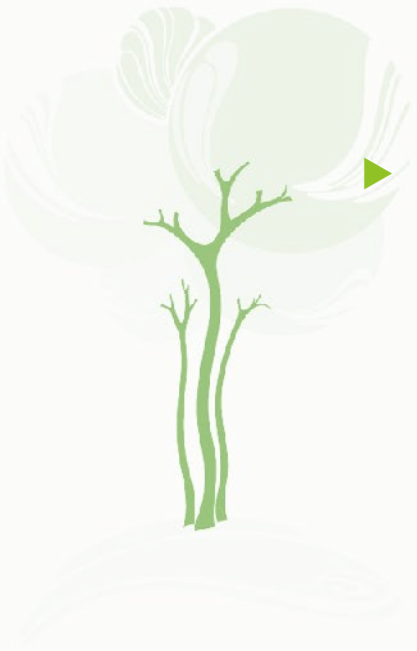






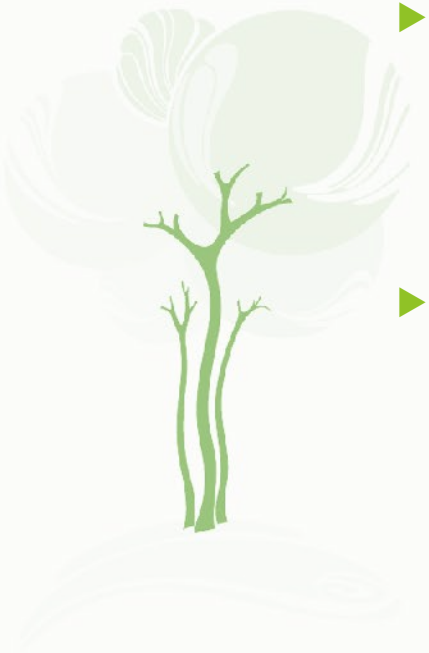
Marine SMFCs Biofilm Characteristics

- Anode biofilm
  - Critical factor in understanding and optimizing bioelectrochemical processes
  - Anode reduction in the case of SMFCs
  - Careful analysis and understanding of the associated microbes
- Microbial reduction transition
  - FeRB not able to outcompete existing microbial populations
  - Limited abundance
  - Stable SRB
- complexity of the sediment microbial structure
  - Direct impact on success and failure of an anode biofilm
  - Limited success of SMFC



Experimental Design

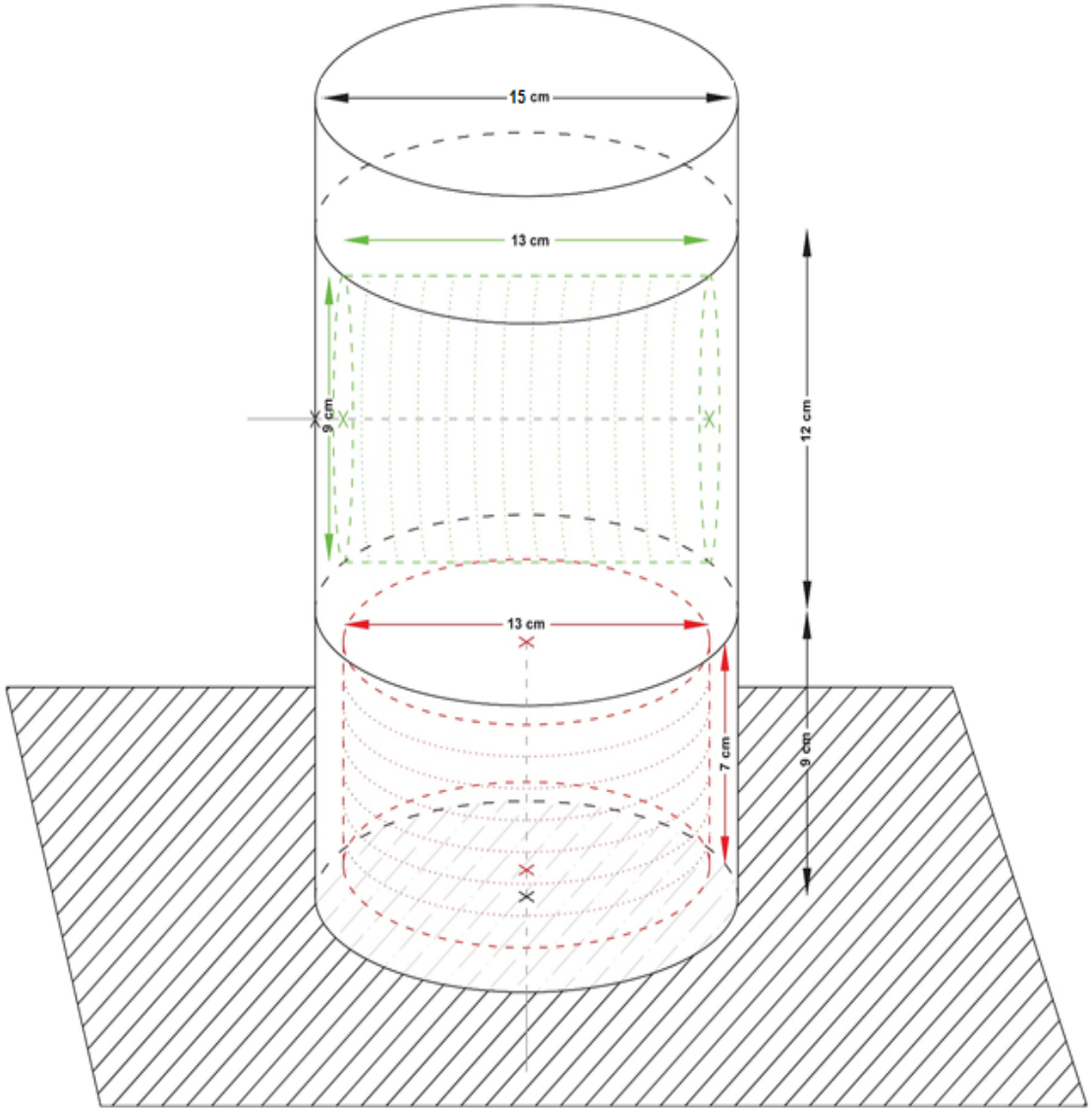
- FeRB enrichment in marine SMFCs
  - Deficient in FeRB
- Bioremediation of a range PAHs
  - High molecular weight PAHs is very limited
  - 2-, 3-, 4-, and 5-ringed PAHs
  - Naphthalene, fluorene, pyrene and BAP
  - Simulate a complex mixture of PAHs
- SMFCs operation
  - Anode reducing conditions
  - Bacterial sulfate reduction inhibition
  - Ferric iron stimulation
- Evolution of microbial populations



Methodology: Sediment and Seawater

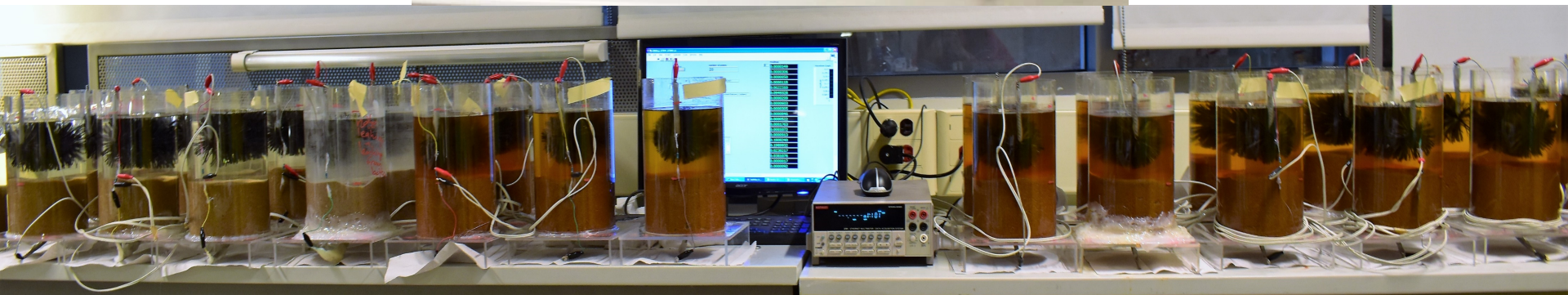
- Marine sediments
  - Jiyeh, Lebanon, near the Jiyeh powerplant
  - 2006 oil spill
    - 15000 tons of heavy fuel oil
  - Daily oil contamination
    - Shipping
    - Loading/unloading
- Grab sediment samples
  - 5-6 meters below the surface
  - 30 cm below the sediment/water interface
- Preparation of sediment
  - PAHs spiking
  - Iron amendment

Methodology: SMFC Design



Methodology: SMFC Operation

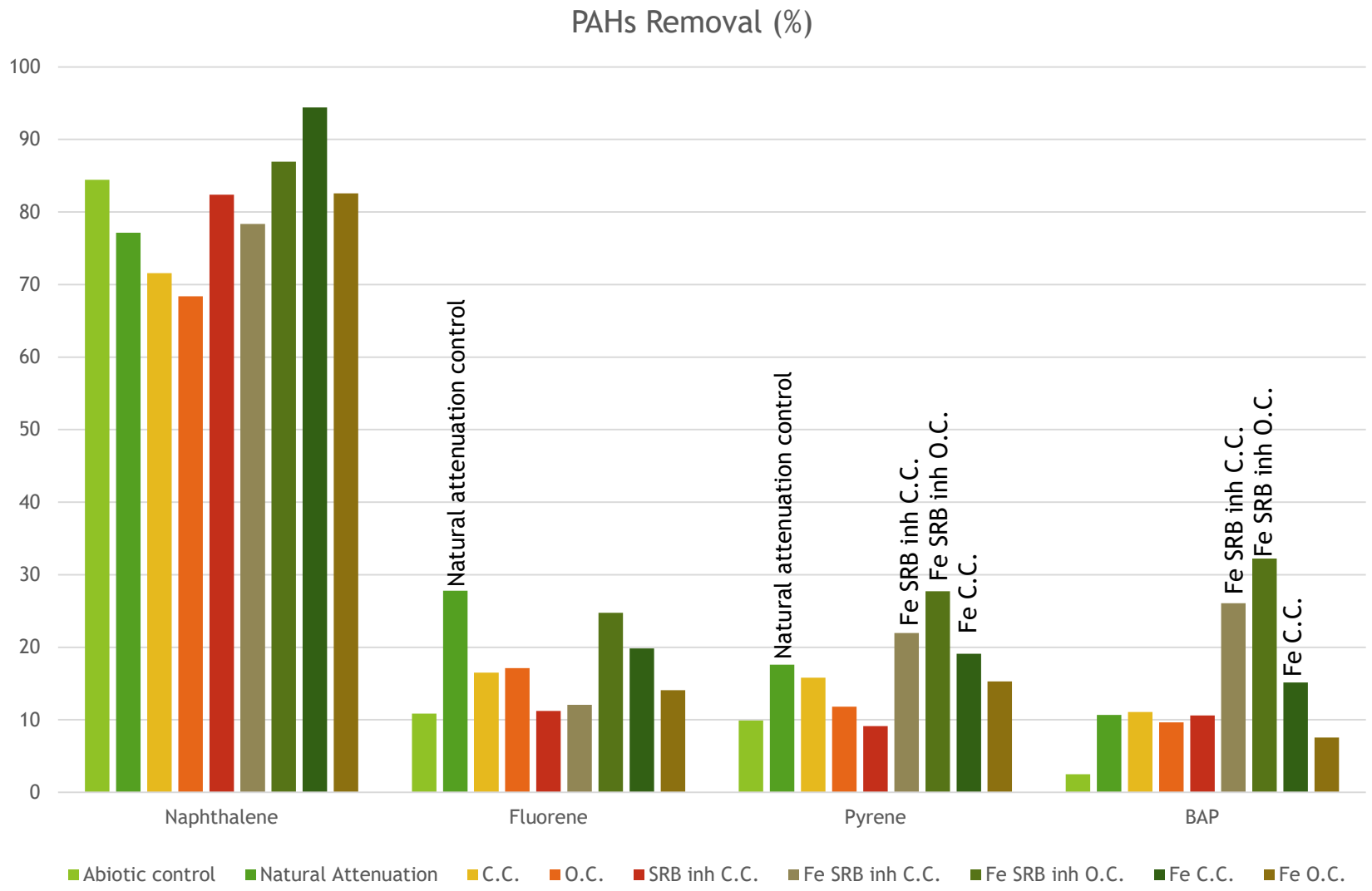
Operating condition	Closed/ Open circuit	Iron enrichment	SRB inhibition	Abbreviation	Description
1	Closed	-	-	C.C.	Conventional SMFCs
2	Closed	-	+	SRB inh C.C.	SMFCs operated under closed circuit condition with molybdate addition to inhibit sulfate-reducing bacteria (SRB)
3	Closed	-	-	Abiotic control	Autoclaved plus sodium azide addition
4	Open	-	-	O.C.	Control open circuit
5	Closed	+	-	Fe C.C.	SMFCs operated under closed circuit condition with iron enrichment
6	Closed	+	+	Fe SRB inh CC	SMFCs operated under closed circuit condition with molybdate addition to inhibit sulfate-reducing bacteria (SRB) and iron addition
7	Open	+	-	Fe O.C.	Control SMFCs operated under open circuit conditions with iron enrichment
8	Open	+	+	Fe SRB inh O.C.	Control SMFCs operated under open circuit conditions with iron enrichment and SRB inhibition
9	NA	-	-	Natural attenuation	Natural attenuation control with no brushes



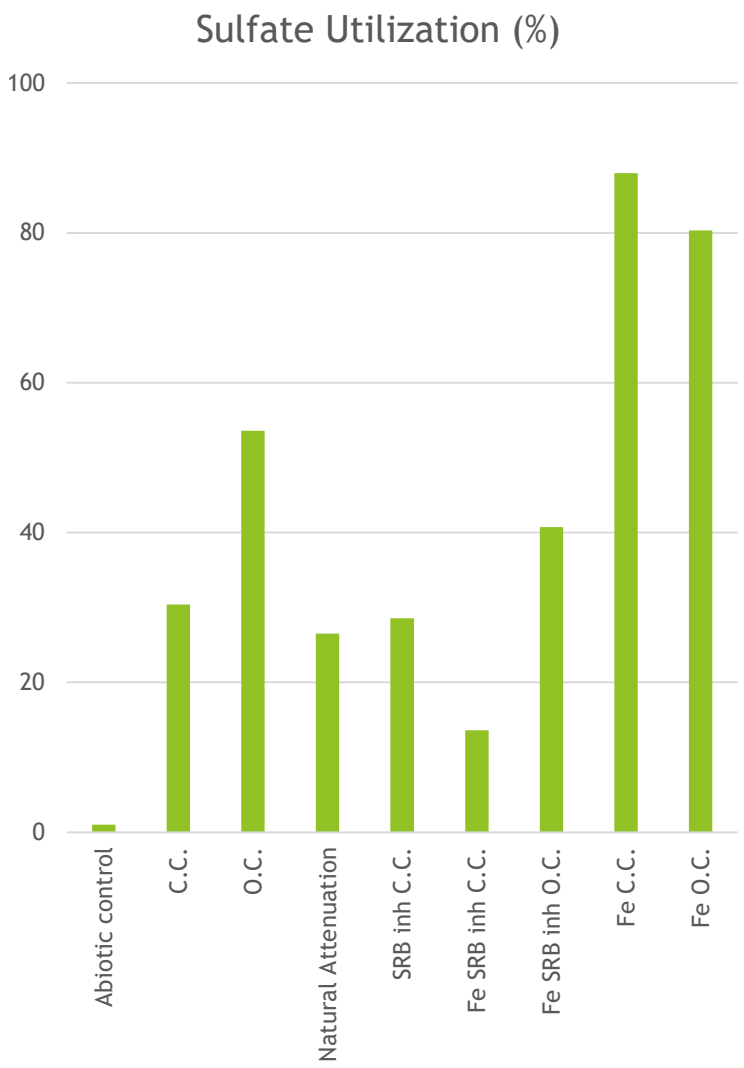
Methodology: Monitoring

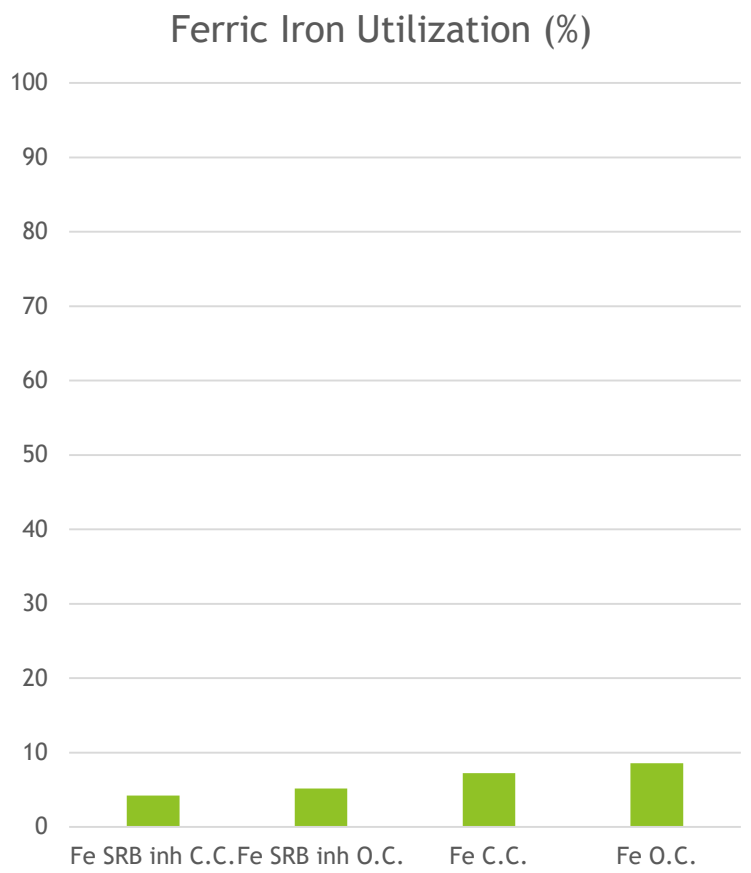
- Sets of quadruplicates
  - 1 SMFC per condition sacrificed periodically over 26 weeks
    - Weeks: 1, 7, 18 and 26
  - Disassembly process
  - PAHs → Soxhlet →HPLC
  - Microbial Analysis → extraction → sequencing (MRDNA)
  - Sulfates and iron → standard methods
  - Voltage recording → data acquisition system

Results: PAHs biodegradation

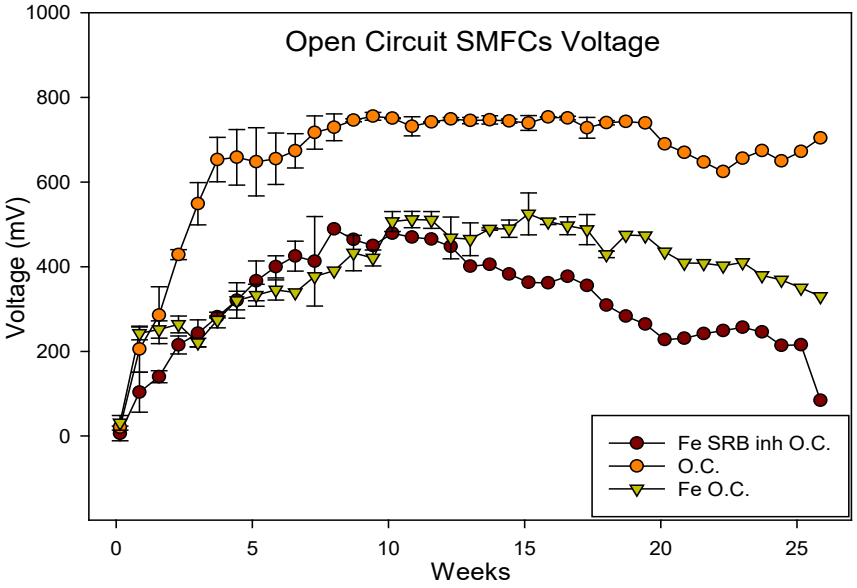


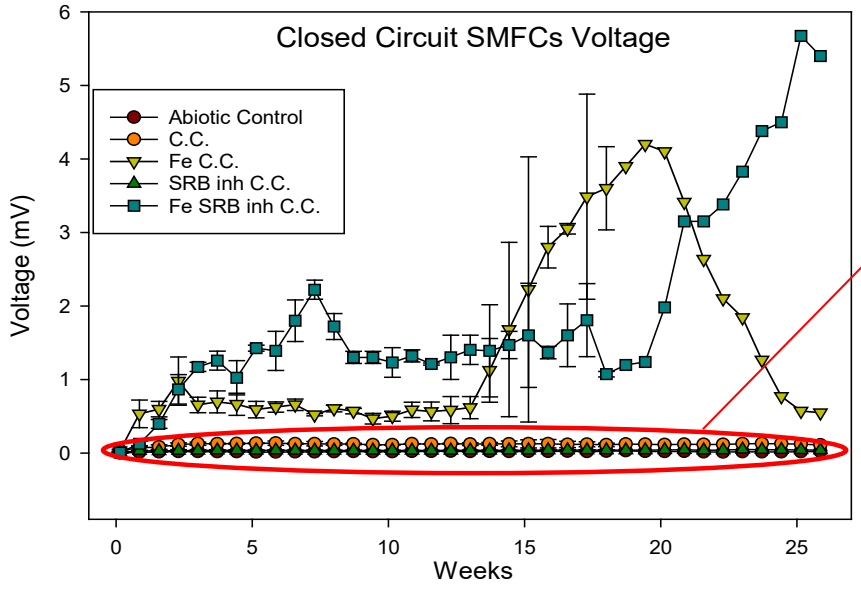
Results: TEA Utilization

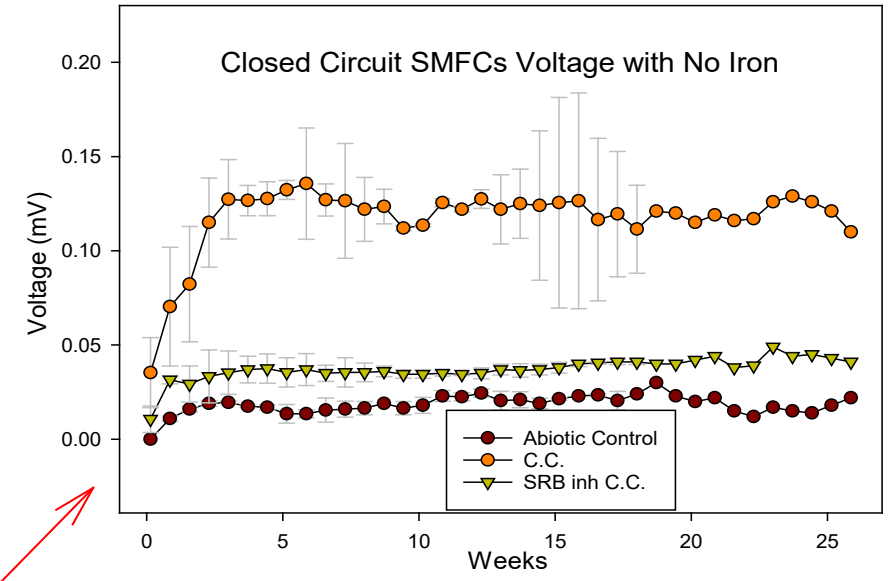




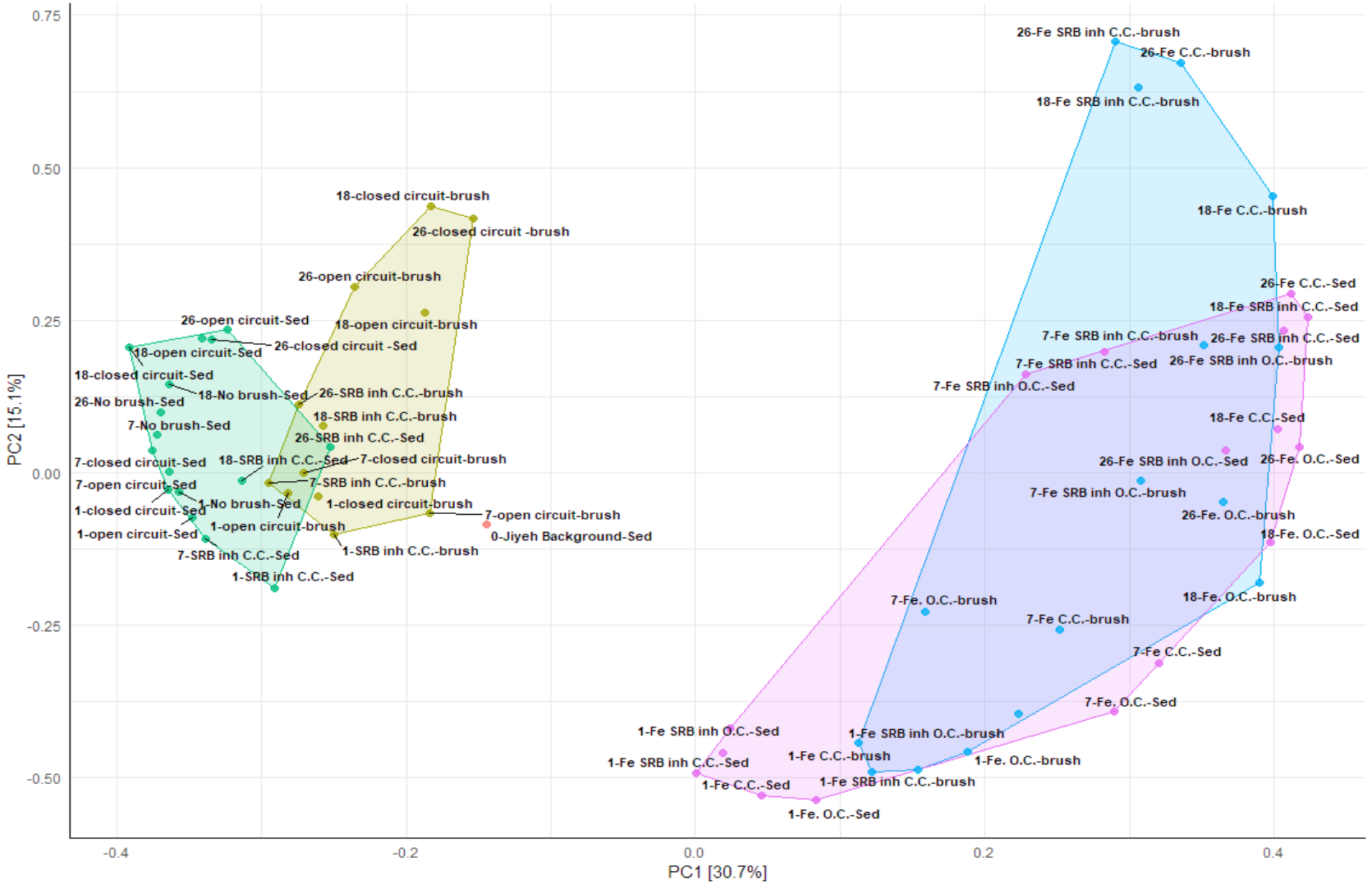
Results: Voltage







Results: Microbial Community Analysis Principal Component Analysis (PCA)



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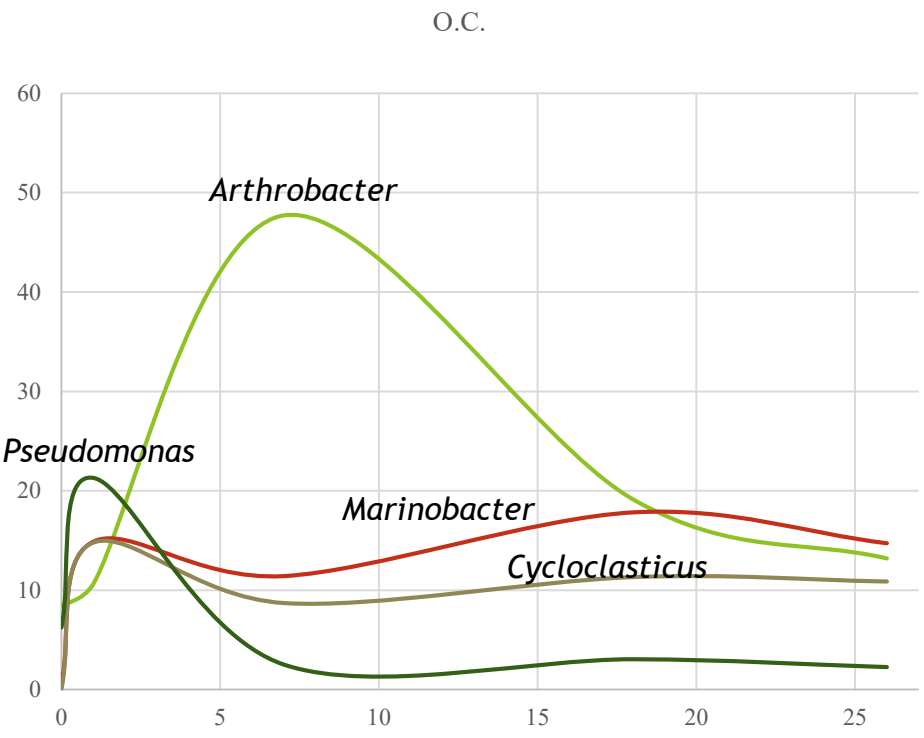

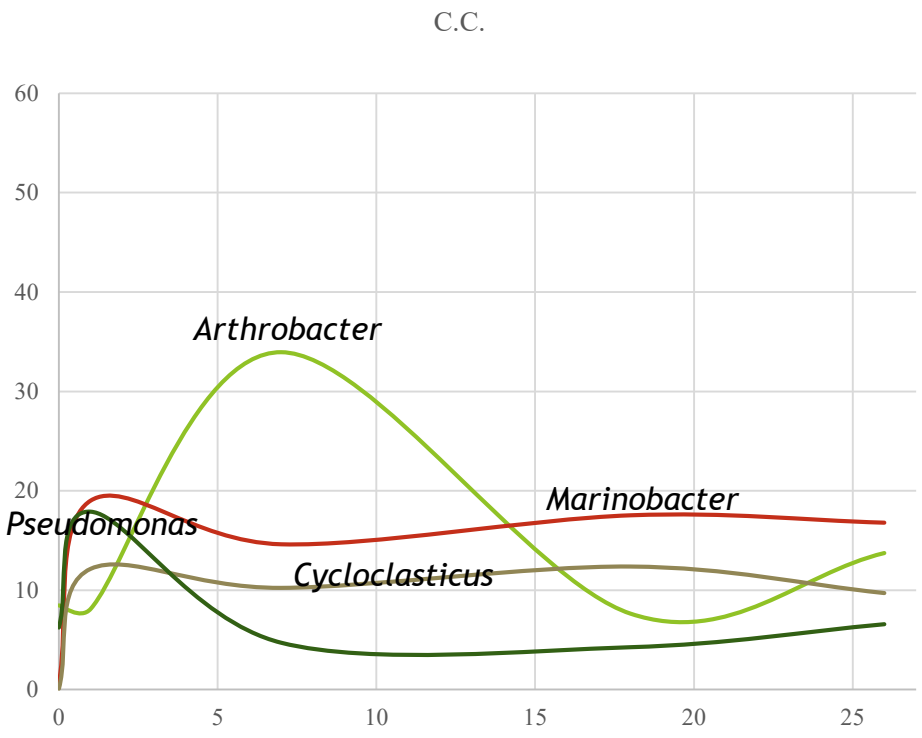

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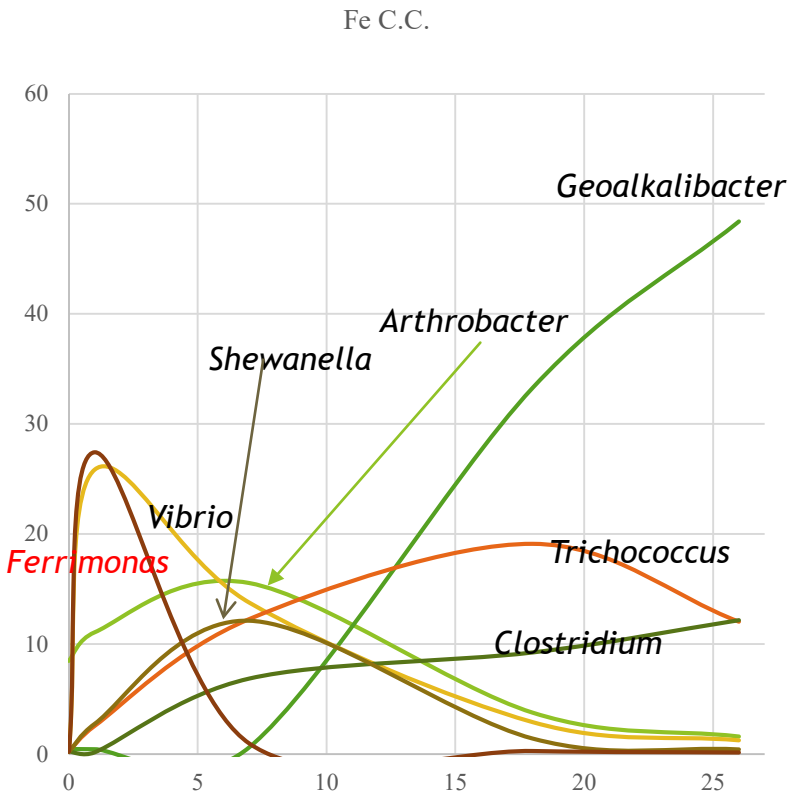

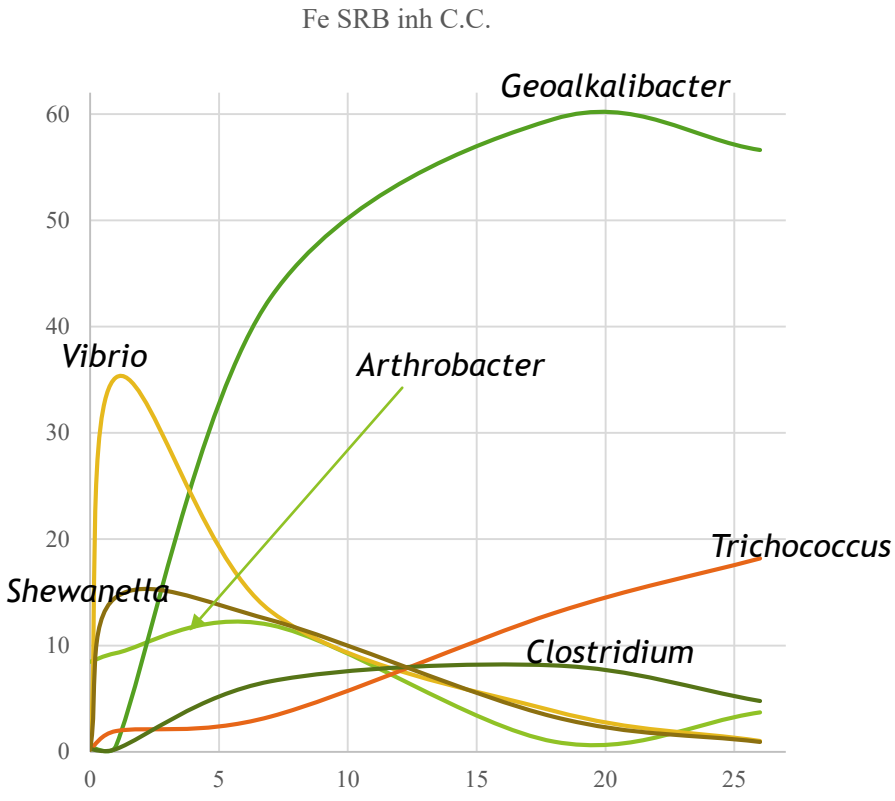

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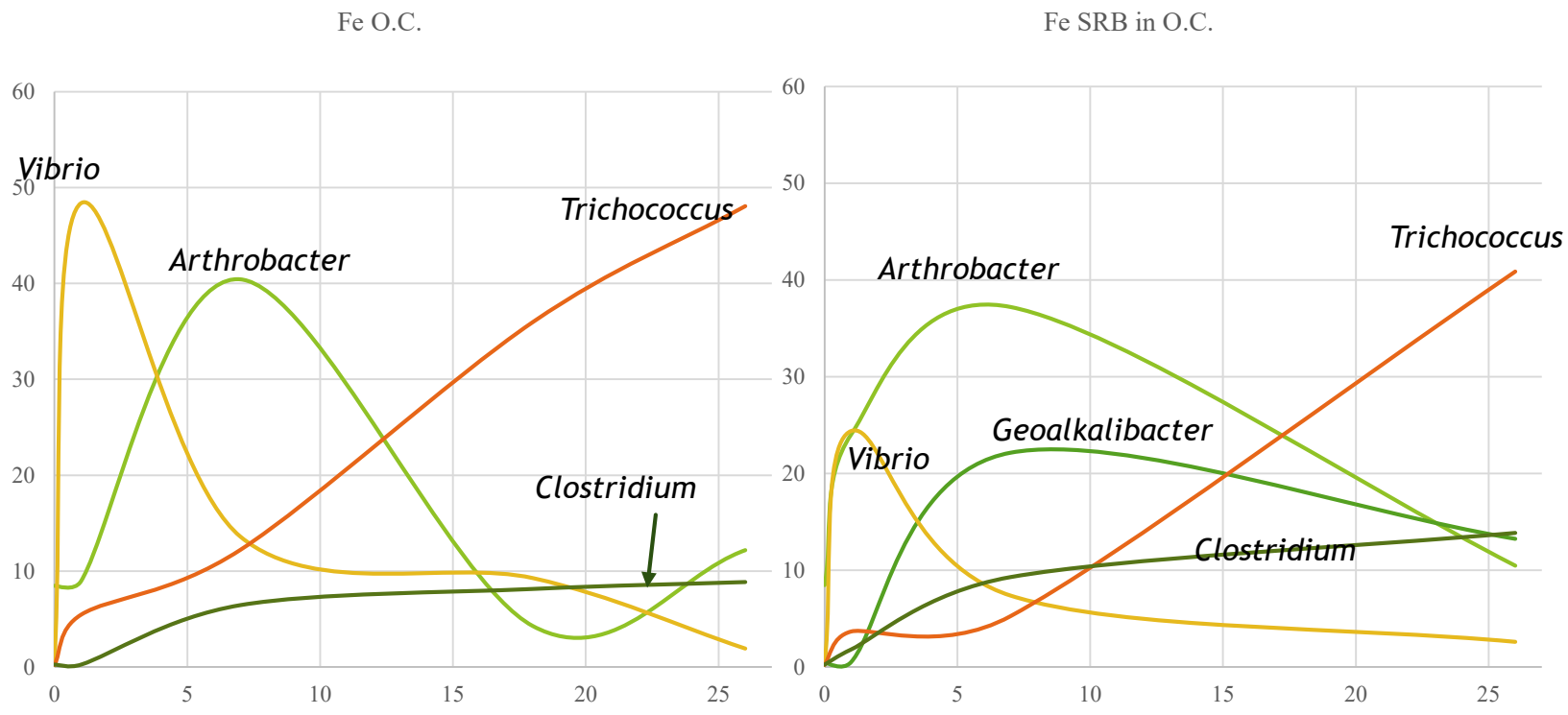

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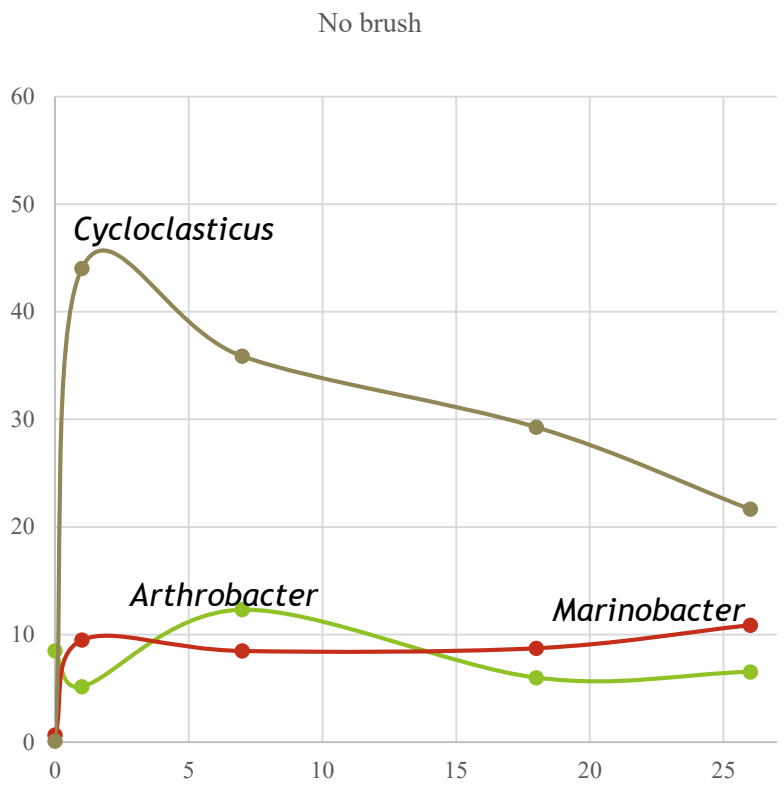

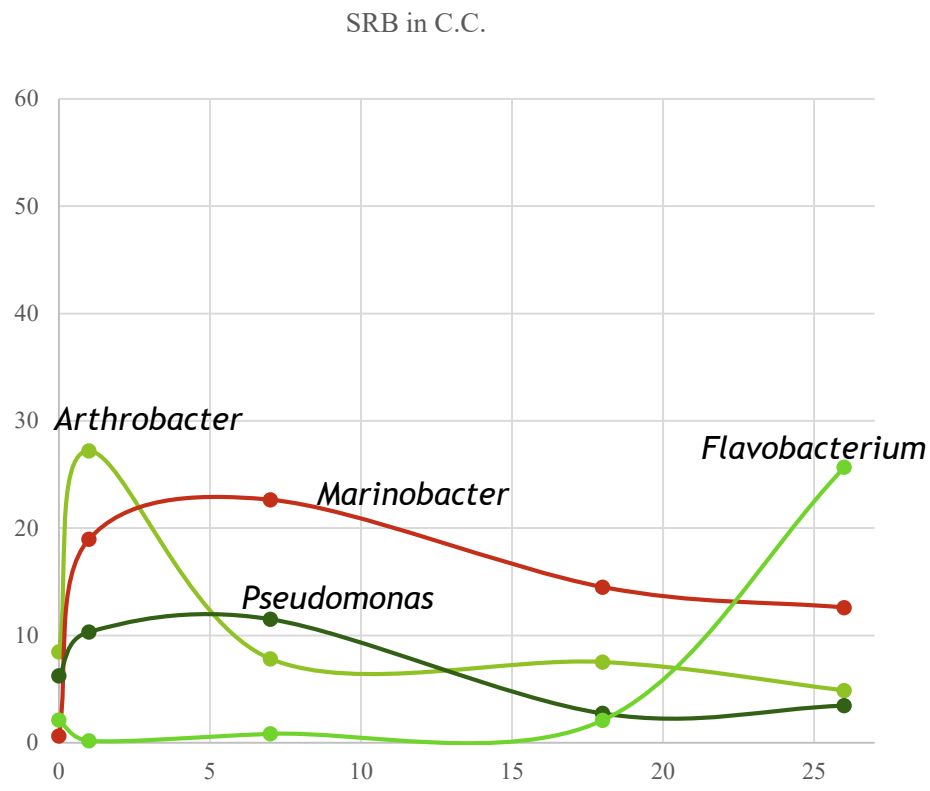

Conclusions

- Ferric iron stimulation in marine
  - Successful in terms of enriching for electrochemically active microbial populations
    - Not possible under conventional SMFC
- Microbial enrichment
  - Heavily dependent on the sediment characteristics
  - Type of contamination
  - Low abundance of iron reducers in marine sediments
- SRB inhibition
  - Limited the dominance of sulfate reducers
  - Better potential for evolving exoelectrogens
  - 92.5% *Geoalkalibacter* in anodic biofilm of Fe SRB inh C.C.
- However!!!
  - PAHs bioremediation potential of marine SMFCs
  - More correlated to parameters different from simple employment of anode as a TEA
    - Highest removal was observed in the absence of anode as a TEA, and in the presence of ferric iron stimulation, when SRB communities were inhibited (32% removal)
- Variation in the microbial community structure
  - Heavily driven by the operating conditions
  - Directly related to the observed variation in the performance of the SMFCs
  - Heavily linked with the removal of PAHs and the generated voltage
- Results
  - Better understanding of the ferric iron enrichment in marine settings is needed

Thank you for listening

Questions are welcome

- *For Contact*
  - *Darine Salam: ds40@aub.edu.lb*
  - *Hamdan Hamdan: hzh05@mail.aub.edu*