INVESTIGATION OF HEAVY METAL REMOVAL FROM SYNTHETIC DESALTER EFFLUENT USING ULTRAFILTRATION AND MICROBIAL FUEL CELL

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- Objectives
- Materials and Methodology
- Micellar Enhanced Ultrafiltration
- Microbial Fuel Cell
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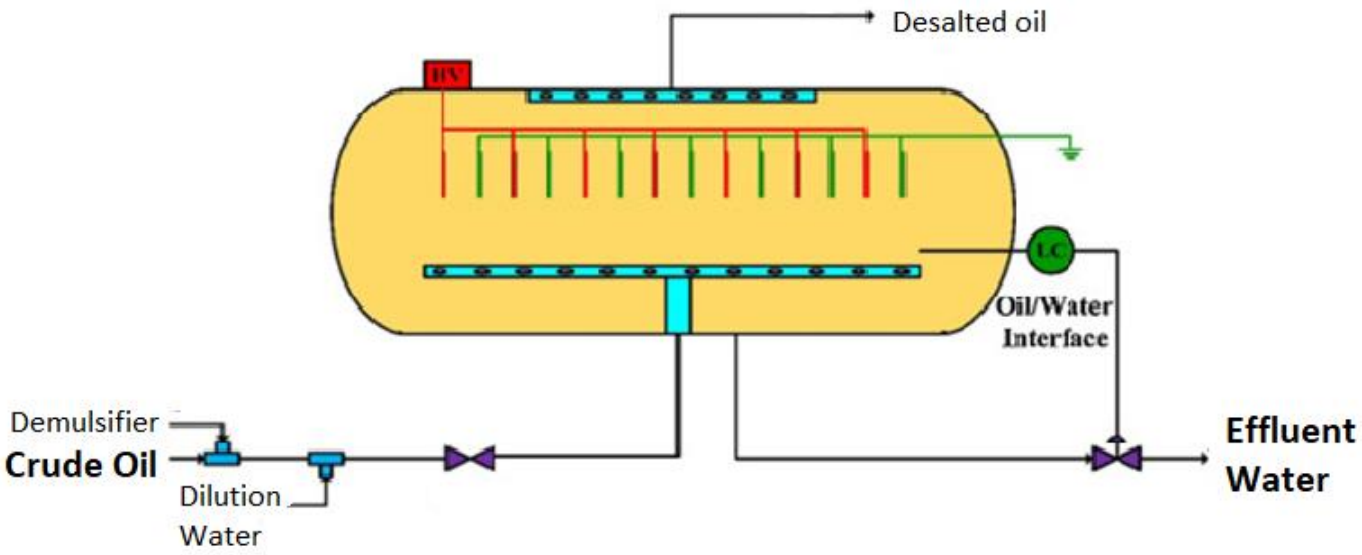
Desalter Effluent



3200 bbl/day of desalter effluent per **1000 bbl/day** of crude oil treated

Removal of undesirable components from crude oil by emulsification and electrostatic fields, washing with water.

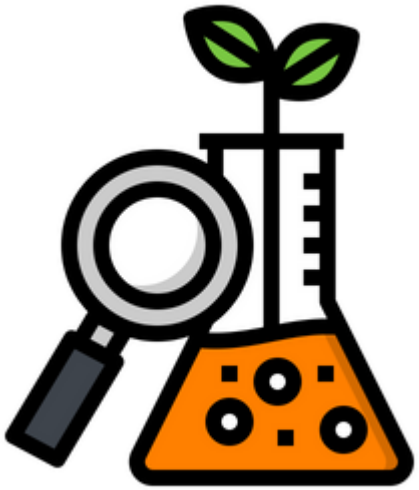
https://doi.org/10.1016/j.cep.2015.06.011

Significance of this Research

High cost and chemicals disposal

Environmental concerns due to toxicity of heavy metals

High-value by-products and energy production



Objectives

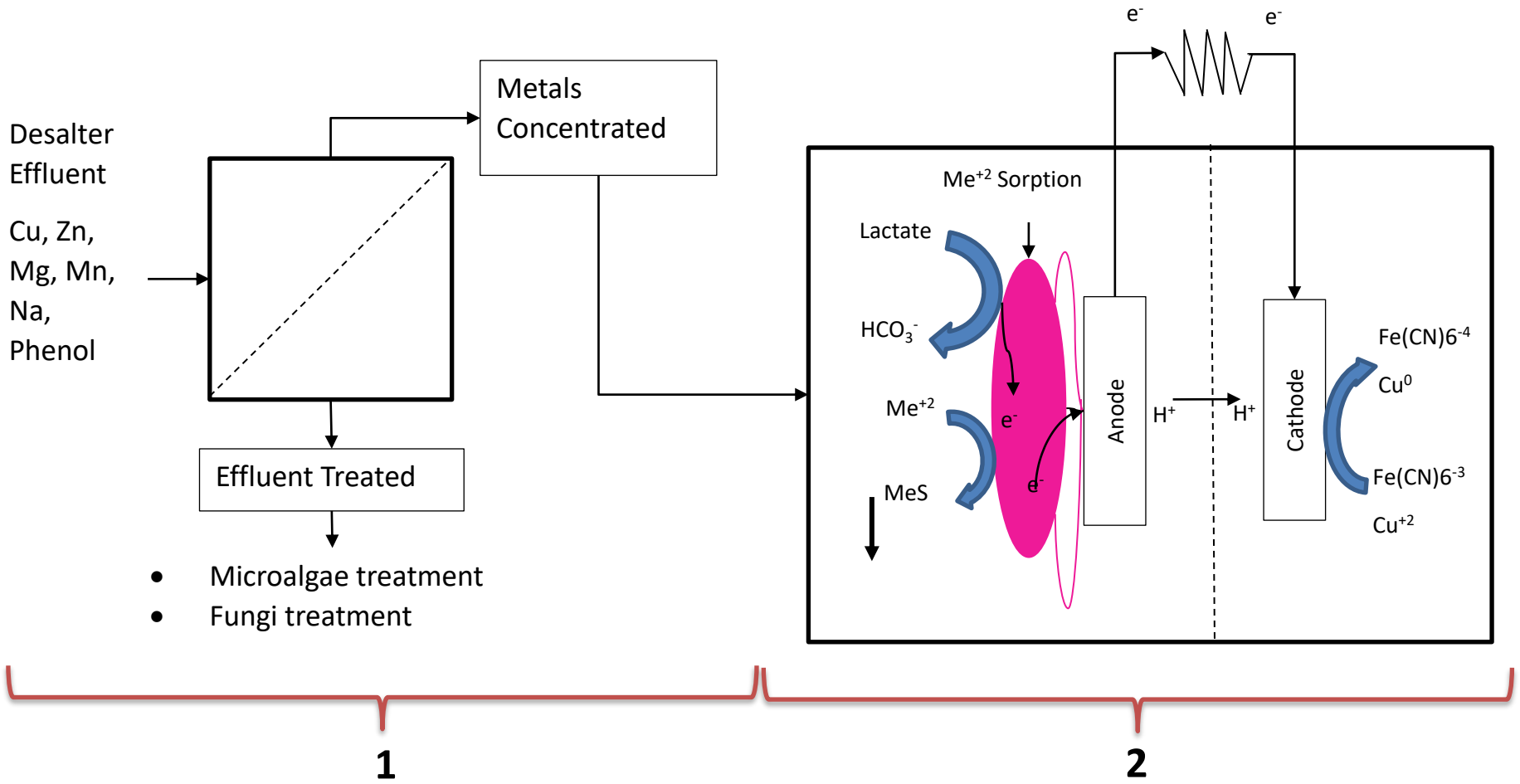
Investigate heavy metal removal from desalter effluent using two steps approach.

1. Micellar Enhanced Ultrafiltration (MEUF) to capture metals.
2. Remove of heavy metals using Microbial Fuel Cell (MFC) for power generation.

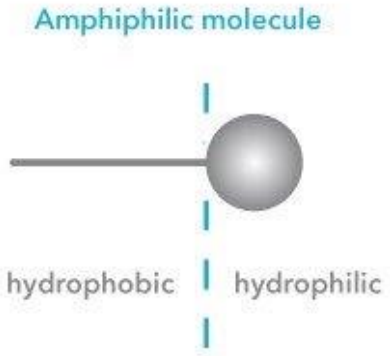
Materials

- Desalter effluent / Synthetic solution
- *Shewanella oneidensis MR-1*
- Ultrafiltration membrane 3000 MWCO PES
  - Active membrane area 200 cm^2
  - 200 to 400 mL/min
  - Maximum pressure of 4 bar
  - Maximum temperature of 60 °C
- Rhamnolipid (RHL) from *Pseudomonas aeruginosa,* MW 584 g/gmol, Nonionic at low pH and anionic at higher pH.
- Dual MFC
- Cation exchange membrane
- Carbon felt electrodes

Research Methodology



Surfactants and Biosurfactants



- Anionic
- Cationic
- Nonanionic

Decrease the surface and interfacial tension

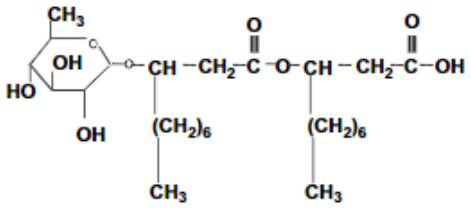
https://blog.biolinscientific.com/what-are-surfactants-and-how-do-they-work

Biosurfactant → Renewable resources →

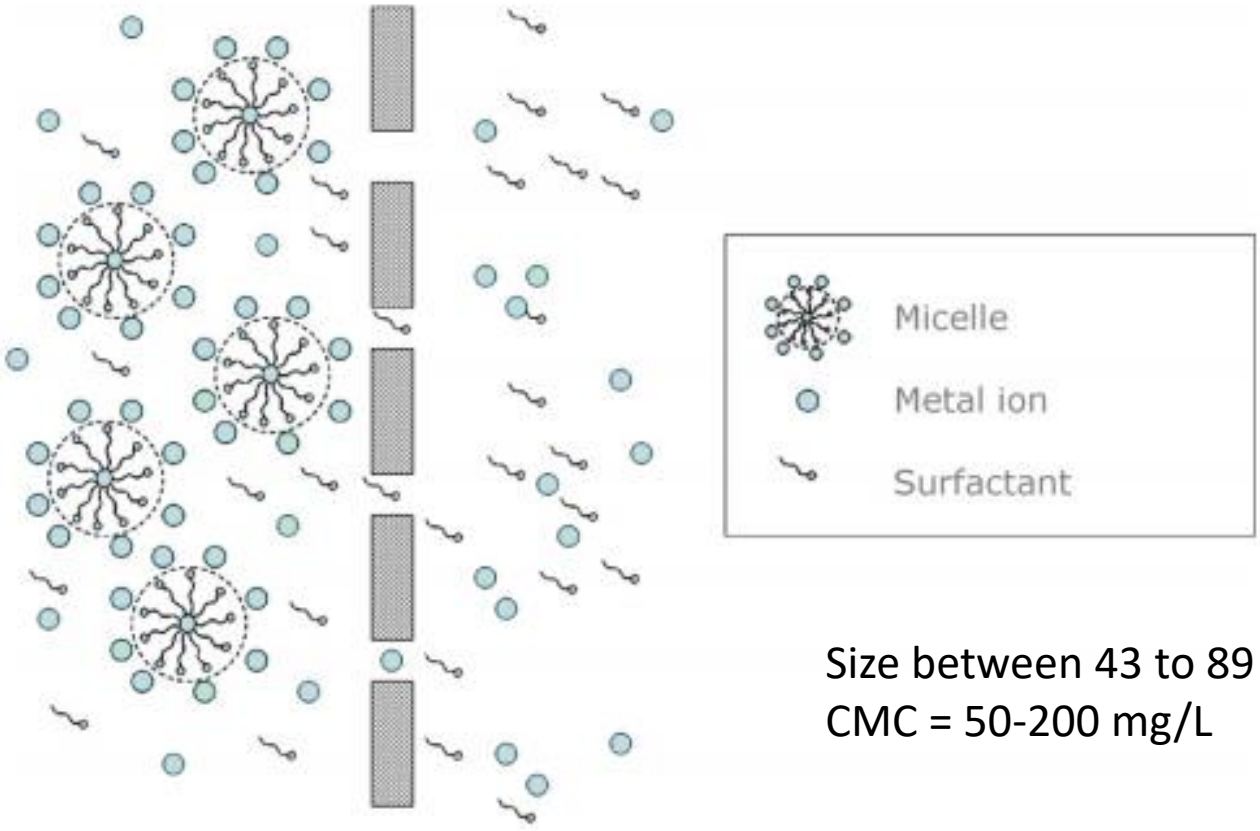
- Water soluble carbon sources
- Water immiscible substrates
- Microorganism

- Glycolipids
- Phospholipids
- Lipopeptides
- Hydroxylated fatty acids

Rhamnolipid



Micellar Enhanced Ultrafiltration

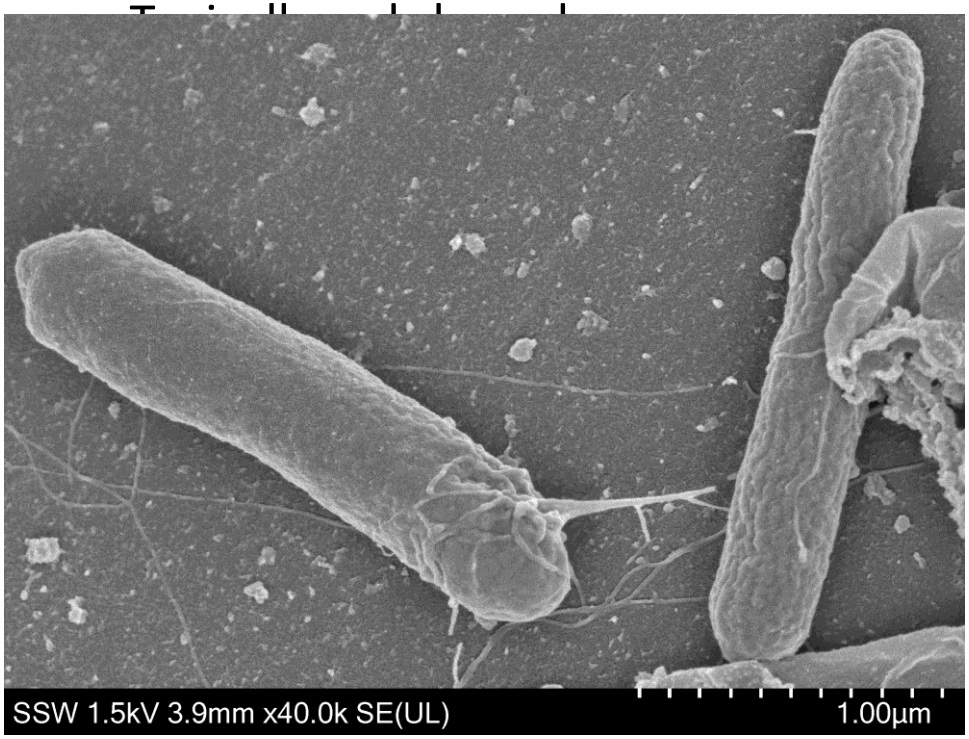


Size between 43 to 89 nm
CMC = 50-200 mg/L

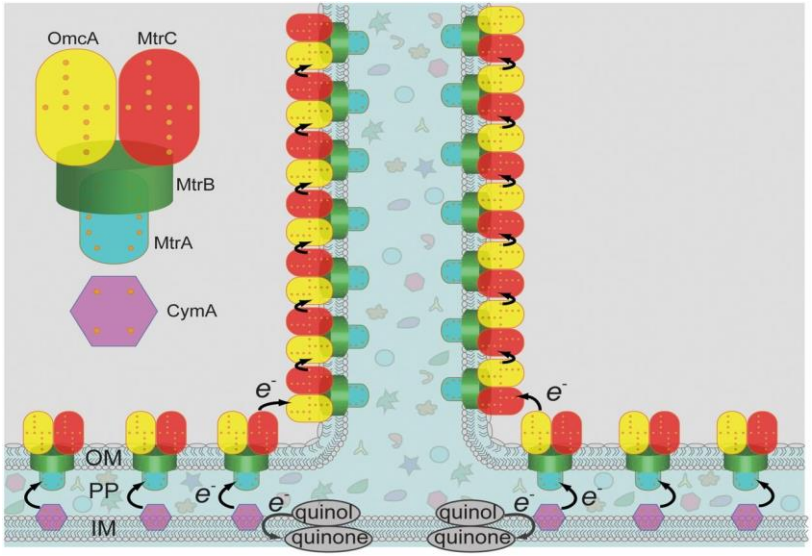
https://doi.org/10.1016/j.seppur.2008.11.013

Shewanella oneidensis

- Gram negative and facultative



Reduction of metal ions through extracellular membrane



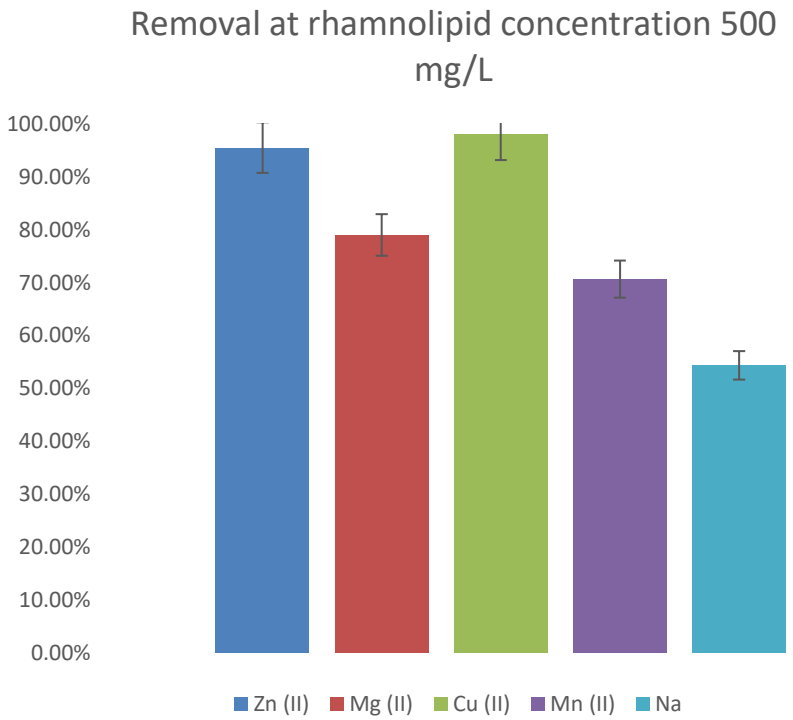
https://doi.org/10.1099/mic.0.000382

Electrical conductivities comparable to inorganic semiconductors. Mechanical strength similar to polymers.

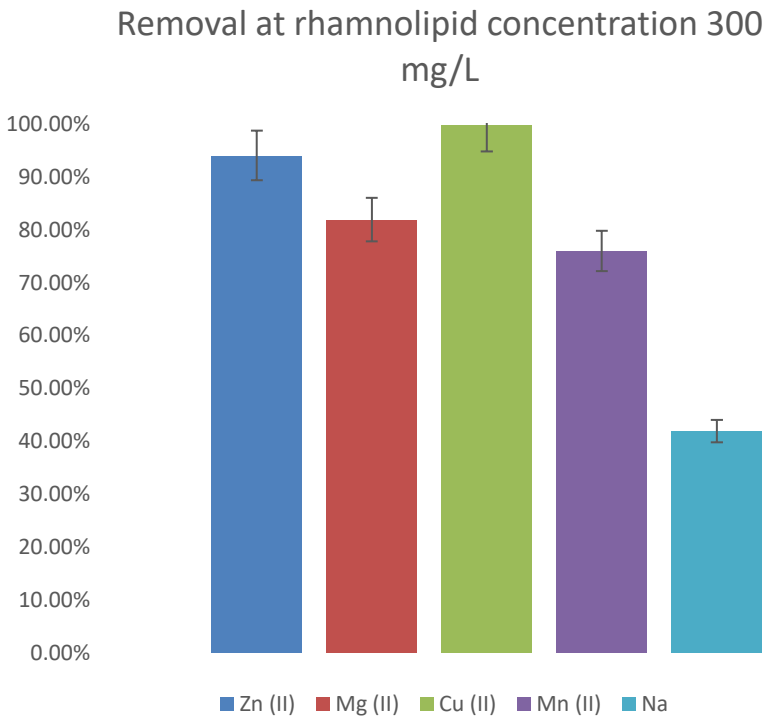
Metals Concentration

Compound	Concentration 1	Concentration 2	Concentration 3	Concentration 4
Zn	13.5 mg/L	27.0 mg/L	40.5 mg/L	500 mg/L
Mn	7.5 mg/L	15.0 mg/L	22.5 mg/L	500 mg/L
Mg	415.0 mg/L	830.0 mg/L	1245.0 mg/L	500 mg/L
Cu	10.5 mg/L	21.0 mg/L	31.5 mg/L	500 mg/L
Na	2410.0 mg/L	2410.0 mg/L	2410.0 mg/L	500 mg/L
C_6H_5OH	354 mM	354 mM	354 mM	NA

Metal Removal

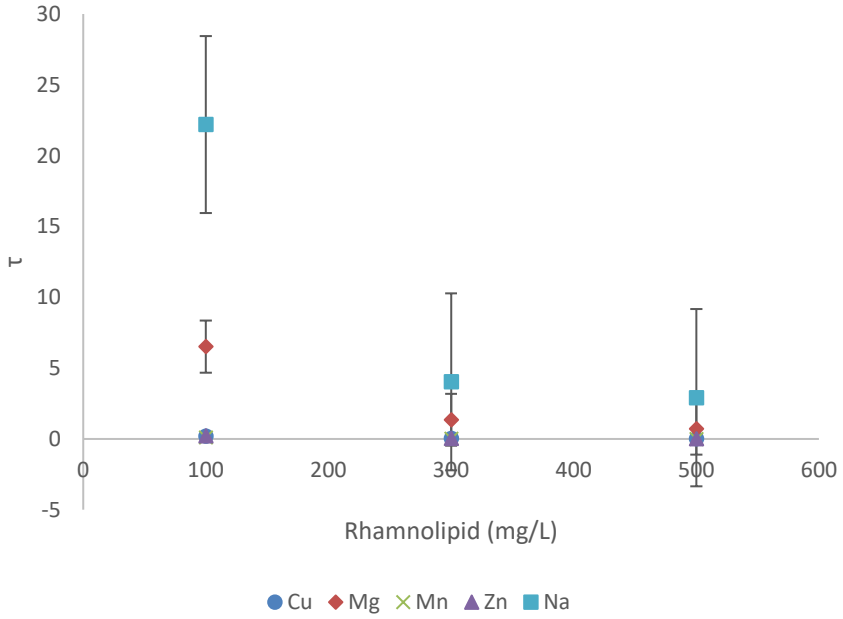


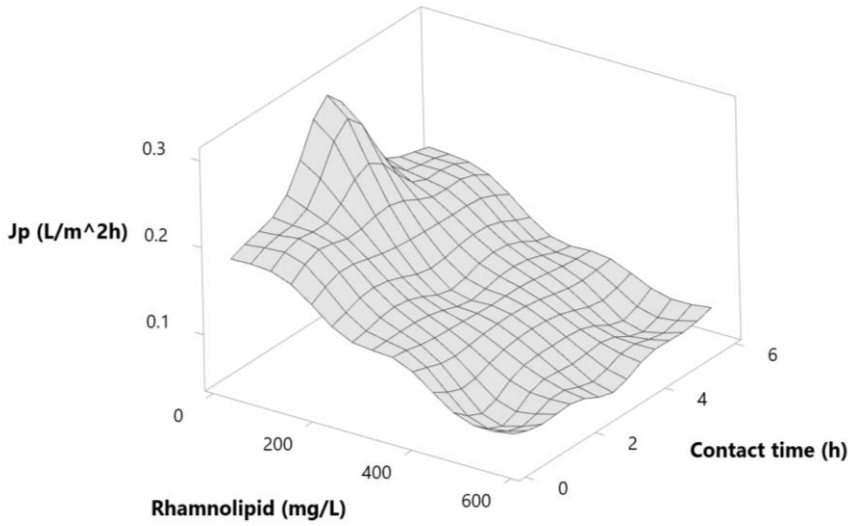
Maximum = 98.10 % Cu
Minimum = 54.36% Na
Average = 79.54%



Maximum = 99.81% Cu
Minimum = 41.91% Na
Average = 78.74%

Rhamnolipid Loading Capacity and Permeate Flux

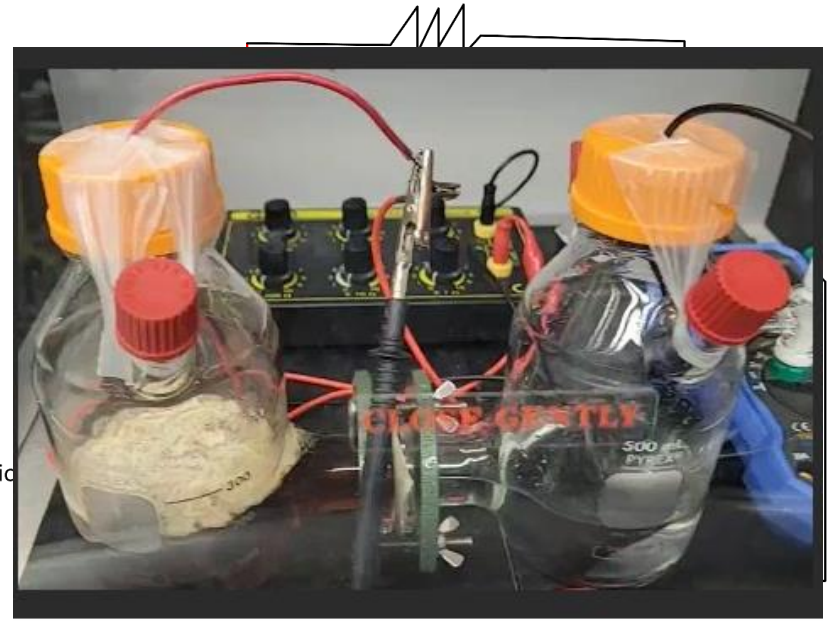


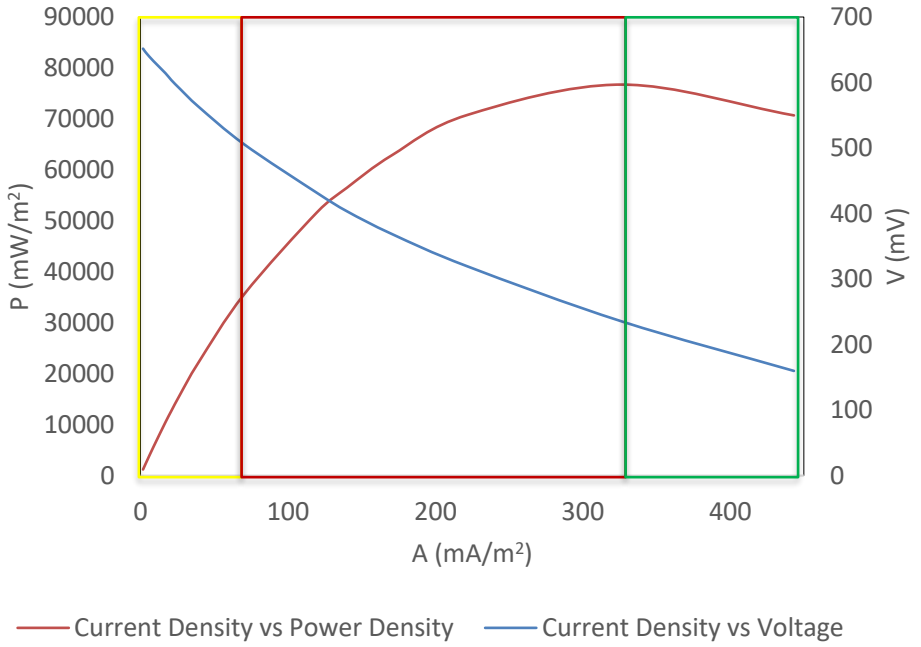


- Phenol does not affect significantly τ
- Na has the high loading capacity on rhamnolipid

- Jp is inversely proportional to rhamnolipid concentration
- Higher and low contact times reduce Jp

Microbial Fuel Cell





External Resistance = 1 kΩ

Maximum Power Density = 76766.7 mW/m^2

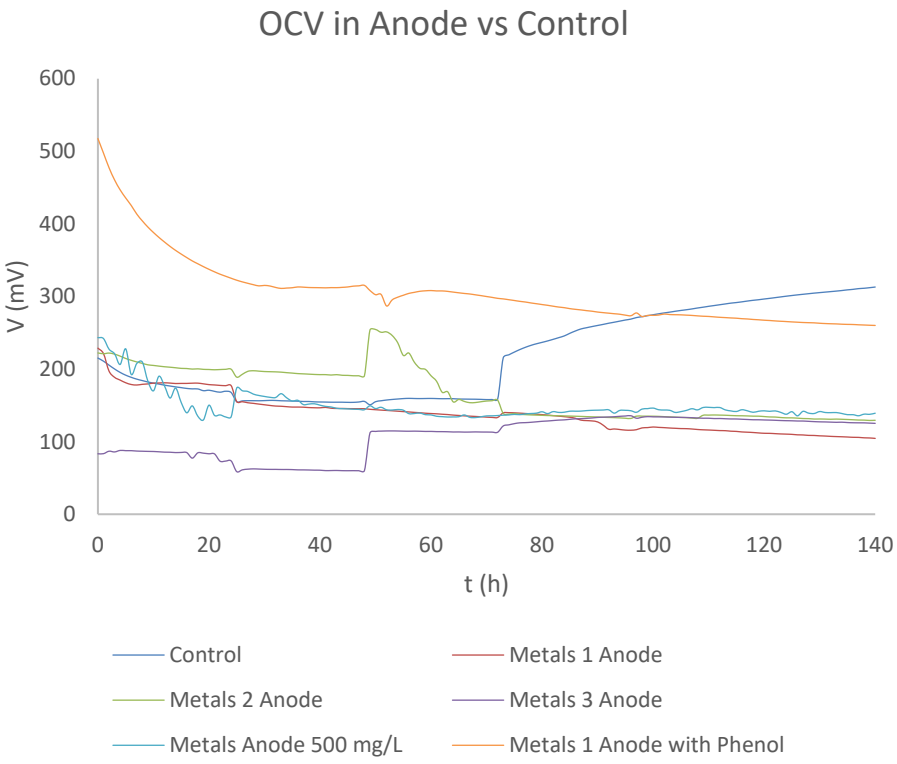
Current Density = 326.5 mA/m^2

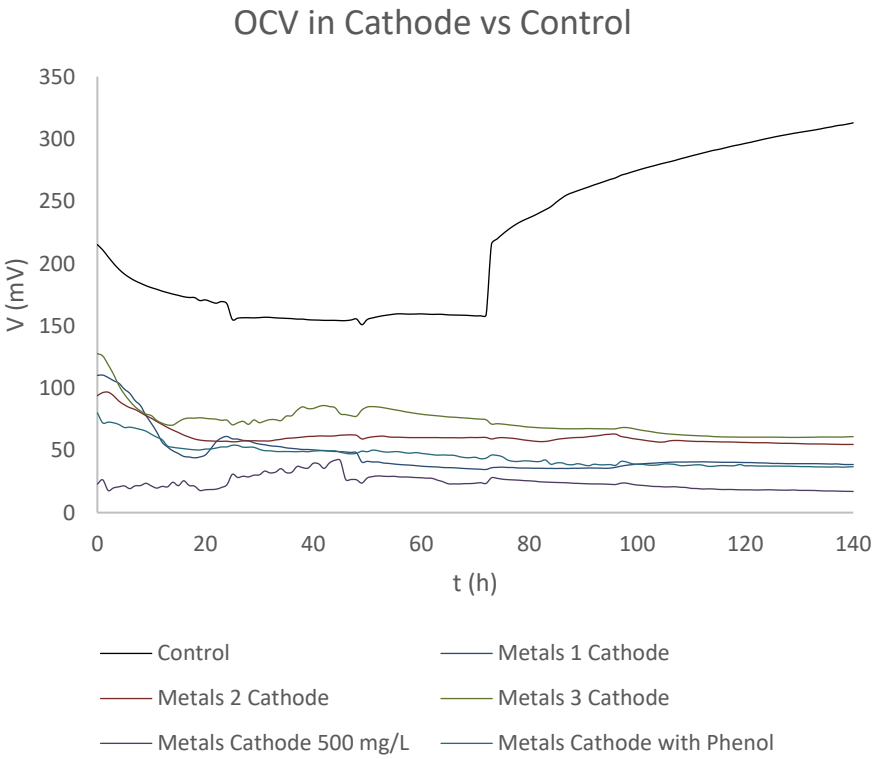
--- Activation losses

--- Ohmic losses

--- Concentration losses

Output Current Voltage

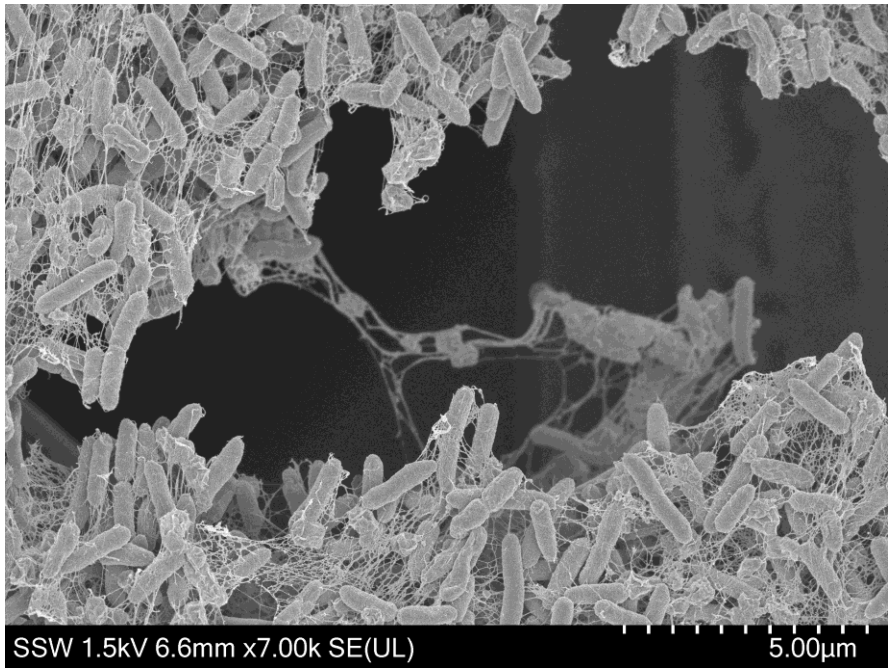


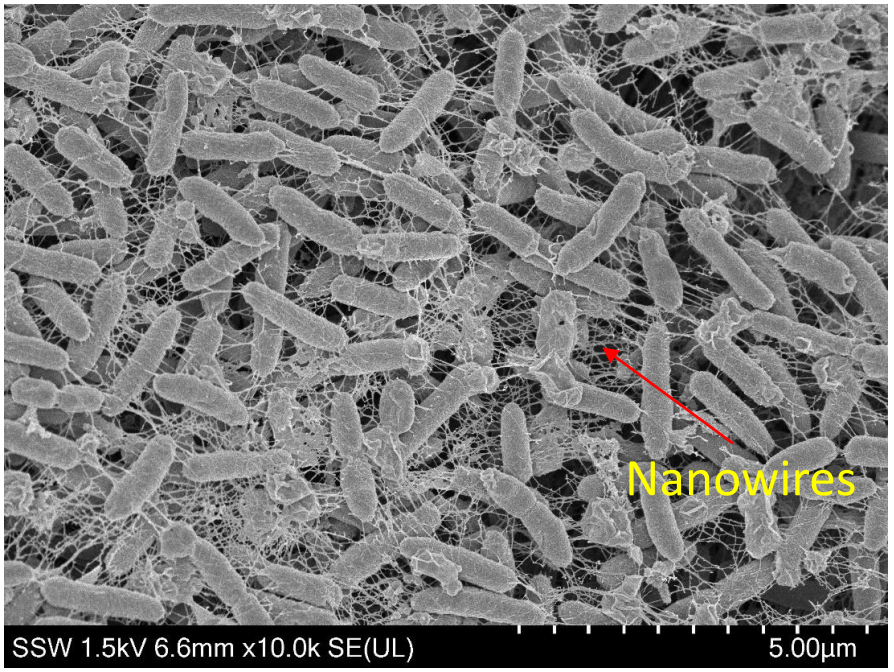


Maximum = 517.55 mV in Conc. 1 + Phenol
Minimum = 135.75 mV in Conc. 3
Average (mV): Conc. 1 = 138.76; Conc. 2 = 167.24; Conc. 3 = 107.28; Conc. 4 = 149.60; Conc. 1+Phenol = 306.07

Maximum = 127.7 mV in Conc. 3
Minimum = 41.95 mV in Conc. 4
Average (mV): Conc. 1 = 46.35; Conc. 2 = 61.21; Conc. 3 = 73.02; Conc. 4 = 24.14; Conc. 1+Phenol = 45.75

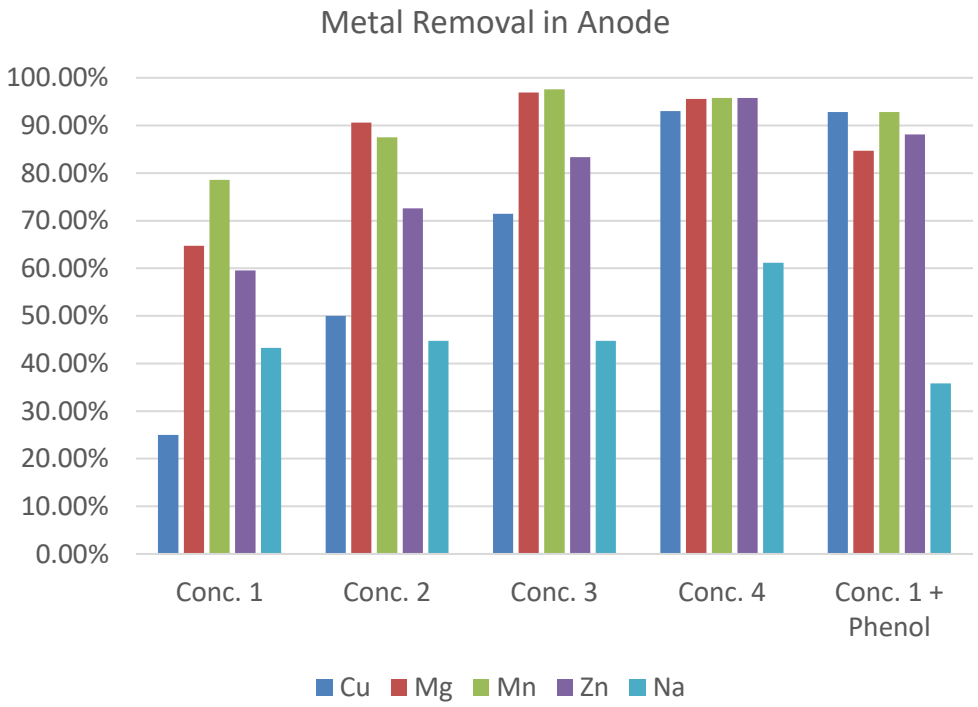
Biofilm Formation

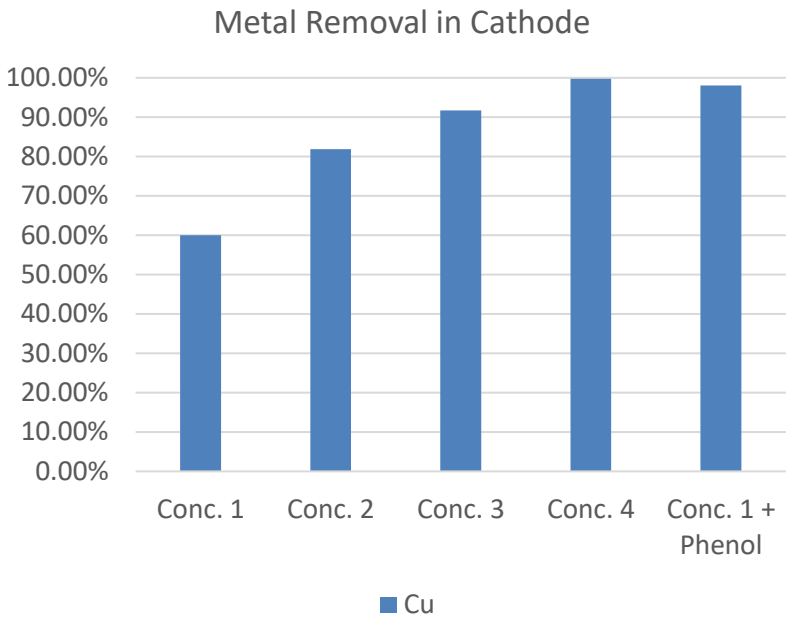




- Bacterial nanowires are a periplasmic extension of the extracellular membrane
- Nanowires are a response of oxygen limitation conditions
- Microbial nanowires increase the resistance to metal toxicity

Metal Removal by MFC





Maximum = 97.62% Mn in Conc. 3
Minimum = 25.00% Cu in Conc. 1

Maximum = 99.78% Cu in Conc. 4
Minimum = 60.00% Cu in Conc. 1
Average = 86.31%

Future and Ongoing Work

- Analysis of bacterial growth under different metal and phenol concentrations.
- Investigation of metals deposition on the cathode electrode surface.
- Investigation of complex rhamnolipid-metals in anode and cathode chambers of MFC.
- Investigation of bacterial growth in rhamnolipid solutions.

Conclusions

- The results indicated that at rhamnolipid concentrations above CMC (50 mg/L), the removal rates are highly efficient which is above 41.91%.
- Maximum power density and OCV were reached at concentration 1 with phenol in the mixture due to the less toxicity of metals and viability of phenol as carbon source for the bacteria.
- The highest removal of all metals by MFC including sodium were at concentration 4 without phenol, however, phenol affected Na removal significantly reducing it from 61.19% to 35.82%.

Acknowledgements