Optimisation of Scale-Up of Microbial Fuel Cells for Sustainable Wastewater Treatment for Positive Net Energy Generation

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Research drivers

Sustainable sources of energy:

Global energy crisis along with the unsustainable supply of fossil fuels.

Water demand, resources, sanitation and wastewater treatment:

Low energy input contrary to technologies with high capital cost and intense energy consumption.

Food and drinks industry:

8-15lt of liquid by-product produced per litre of whisky contributing to pollution unless treated.

Comparative advantages of MFC technology

Apart from a broad variety of applications both in the W&WWT field (e.g. desalination) and in other fields (e.g. sensors, robotics and production of chemicals), MFCs provide a variety of advantage points in the wastewater treatment sector:

- Operation in a wide range of temperatures (microbial community robustness for industrial applications)
- Minimum energy input therefore highly sustainable and eco-friendly
- Microorganisms being the catalyst for substrate oxidation, create a self-replicating, self-sustaining system
- Electricity generation which can be particularly useful in remote access areas

Microbial fuel cell principles

Utilising metabolic reactions of electrochemically active microorganisms Microbial Fuel Cells break down organic compounds in wastewater converting the chemical energy into electrical.

Electrons are collected by the anode electrode in the anaerobic compartment and are transferred through external wiring to the cathode which in this particular case is exposed to ambient air.

(Source: Logan et al., 2006, Logan 2008, Choi, 2015)

Microbial fuel cell designs

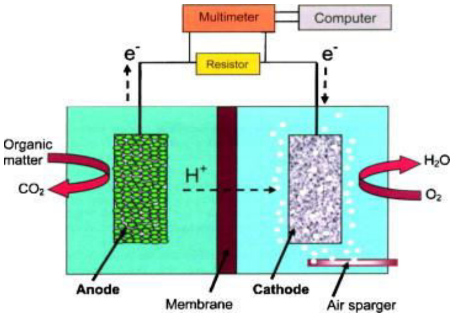

Figure 1: H-shape MFC

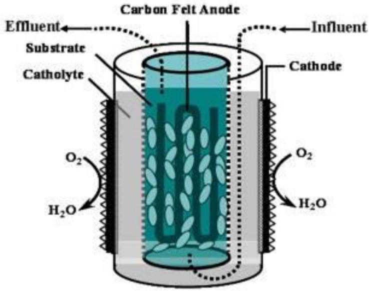

Figure 2: Tubular (vertical) MFC

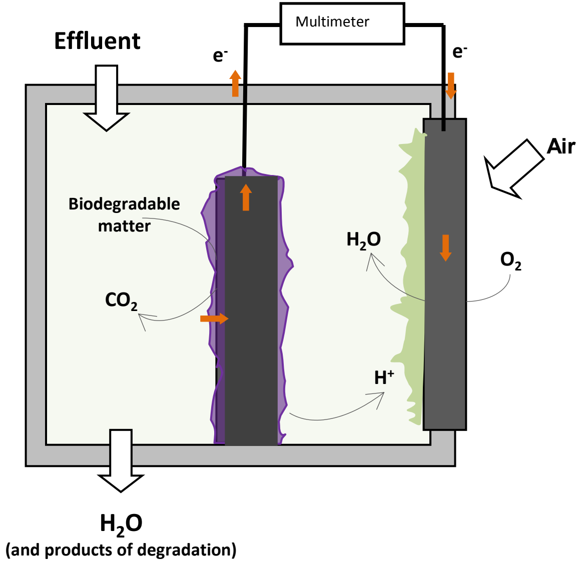

Figure 3: Single chamber open air cathode MFC

Source: Logan 2008

Materials and construction

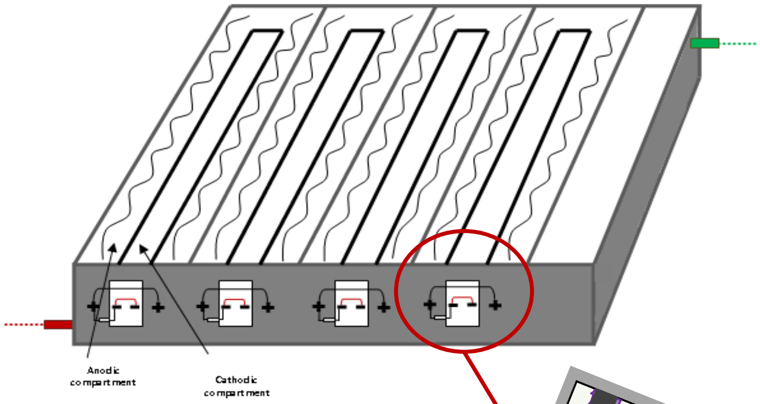

Figure 4: Schematic approach of 100lt MFC unit

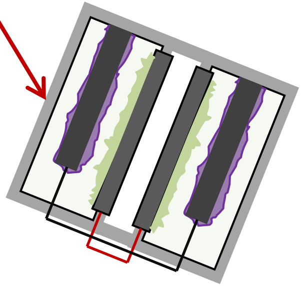

Figure 5: Section of top plan

Table 1: Materials typically used in MFCs (Source: Du et al., 2007)

Components	Materials
Anode	Graphite, graphite felt, carbon paper, carbon-cloth, Pt, Pt black, reticulated vitreous carbon (RVC)
Cathode	Graphite, graphite felt, carbon paper, carbon-cloth, Pt, Pt black, RVC
Anodic chamber	Glass, polycarbonate, Plexiglas, PVC
Cathodic chamber	Glass, polycarbonate, Plexiglas, PVC
Proton exchange system	Proton exchange membrane: Nafion, Ultrex, polyethylene.poly (styrene-co-divinylbenzene); salt bridge, porcelain septum, or solely electrolyte
Electrode catalyst	Pt, Pt black, MnO_2, Fe^{3+}, polyaniline, electron mediator immobilised on anode

Results and discussion

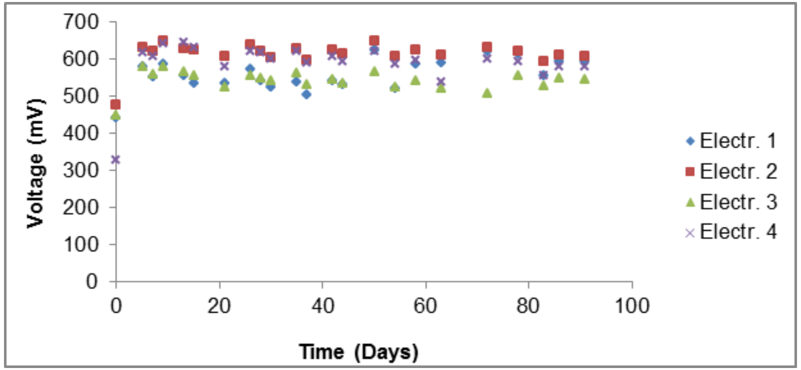

Figure 6: Open circuit voltage (OCV) generation from four electrode pairs in 100lt MFC

Open circuit voltage represents the maximum voltage that can be measured across each pair of electrode in the absence of external load

	OCV (mV)	SC (mA)	P_{max} (mW)
1st electr.	558±42	124±23	70±15
2nd electr.	614±33	133±23	82±16
3rd electr.	542±28	126±17	69±11
4th electr.	589±62	132±20	79±16

Table 2: Average electrical characteristics of MFC in open circuit mode

Results and discussion

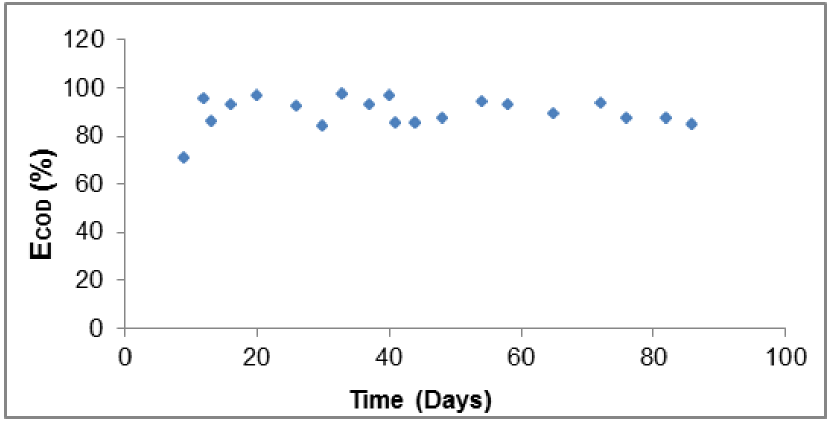

Figure 7: E_{COD}(%) from final MFC exit point

- Started at 71% and immediately increased to approximately 96%.
- Over the 90 days monitoring period, E_{COD} only slightly fluctuated and stabilised at 90±6%.
- Maximum removal efficiency of 97% was monitored.

Future work

- Scientific understanding of the characteristics of cells in order to optimise power output and coulombic efficiency
- Optimum stacked configurations and choice of operational parameters
- Scientific understanding of modelling and CFD application
- Enhanced development of MFC units for scale-up

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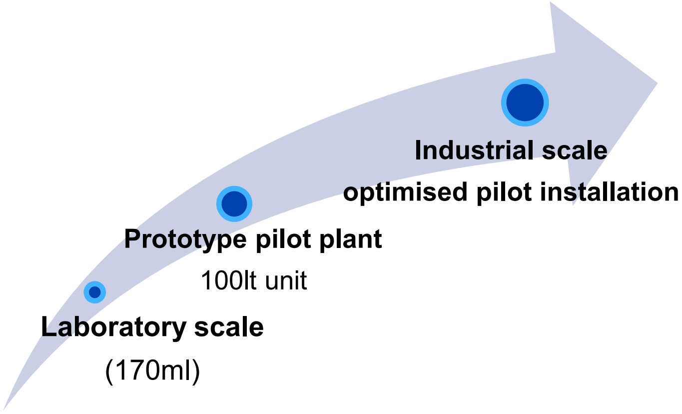
Implementation outcome



<u>The prototype pilot plant installation</u>:

- demonstrated the ability to treat fundamental characteristics of wastewater

Therefore

- can also be applied in wastewater generally deriving from the food and drinks industry with similar properties
- research and development stage that will lead to development of industrial volume sizes
- Demonstrated sustainable electricity generation

Ongoing development on effluents of the whisky distillation by-products treatment process will lead to an enhanced design that will be able to work competitively and/or complimentary to existing WWT technologies

Thank you very much

for your attention