Urine-tricity Project

Irene Merino Jimenez

Bristol BioEnergy Centre
University of the West of England
Microbial Fuel Cells

- By definition, it is a system, which *converts microbial (bio-chemical) energy directly into electricity*
- In other words, it is a *bio-battery* that never runs out, as long as the microbes are kept fed
- The feedstock (fuel) can be any organic matter, even waste
- This renders the MFC technology competitive for waste utilisation *via* energy recovery
Fuel Cell with bacteria
How do they work?

Inoculation phase
Activated sludge to the Anode chamber

Organic matter
Urine

CO₂

Anode Electrode
Semipermeable Membrane
Cathode Electrode

H⁺
e⁻

O₂ from the air
Oxygen reduction reaction

Catholyte accumulation
MFCs treating urine

Optimizing MFCs materials at an affordable cost

- **Ceramic** material outperformed commercially available cation exchange **membrane** (CEM)
- Composition, porosity and thickness of the ceramic affect the MFC power output

**Comparison Individual FFC vs. Terracotta**
Fuel Cell with bacteria
How do they work?

- Cylindrical design.
- Anode outside – Around the cylinder.
- Cathode inside the cylinder.
- Cathode chamber initially empty.
- Easy catholyte accumulation
- Ceramic properties affect the catholyte quality and quantity.
MFCs treating urine
Catholyte generation

• Catholyte quality varies with:
  – Porosity/composition/properties of the ceramic membrane
  – Ceramic thickness

• Catholyte pH increases with:
  – *Electricity generation* from the MFC
  – Accumulation time

• Pathogen killing agent
MFCs treating urine
Catholyte generation

• Catholyte quality varies with:
  – Porosity/composition/properties of the ceramic membrane
  – Ceramic thickness

• Catholyte pH increases with:
  – Electricity generation from the MFC
  – Accumulation time

• Pathogen killing agent
MFCs treating urine
Catholyte generation

- Catholyte quality varies with:
  - Porosity/composition/properties of the ceramic membrane
  - Ceramic thickness

- Catholyte pH increases with:
  - Electricity generation from the MFC
  - Accumulation time

- **Pathogen killing agent:**

![Graphs showing pH and catholyte accumulated over time for different pathogen controls and conditions.]
The MFC technology can kill pathogens during operation in a cascade of 9 MFCs:

- Bioluminescence and viable counts showed killing of pathogens inside the anode of MFCs generating electricity (ca. 4 log-fold).
- Further decrease could potentially be achieved with a longer cascade.

Urine with E. Coli + S. enteritidis
MFCs treating urine

Nutrient recovery: Struvite

- Struvite precipitation by addition of Mg sources (i.e. SeaSalts)
- Mg added to the urine before fed into the MFCs
- Increased MFC power output by 10 %
- 94 % of the solids precipitated was struvite

MFCs in a Stack
Electricity generation

- Miniaturization of MFCs increases the efficiency

- Scaling up multiple MFCs into modules, modules connected fluidically and electrically, but maintaining isolation
Field Trials

PEE POWER™ Urinal on-campus, U.W.E., Bristol, U.K.

- 8 Modules: 288 units (50 mW average power production)
- Direct powering of 4 LED lights (1.2 W)
- Low flow rate (5-10 users/day ~ 2.5-5 L/day)
- Up to 90 % COD reduction and max. 50 % Total Nitrogen reduction

Field Trials
PEE POWER™ Urinal, Glastonbury Festival 2015, U.K.

- 12 Modules: 432 units (1 mW/MFC = ca.400mW) for direct powering of 6 LED lights (2.5W)
- High flow rate (825 users/day).
- Urinal processed more than 2,500 litres of urine during the festival (~ 300L/day)
- Up to 70 % COD reduction (average 30%) and 15%- 79% Total Nitrogen reduction

Field Trials

PEE POWER™ Urinal, Glastonbury Festival 2016, U.K.

- 12 smaller modules (steady state reached after 5-6 days: 424 mW) for direct powering of 6 LED strips packaged as tubes (2.86W)
- Optimum feeding regime ~ 155 L/day (590 mW)
- Performance decreased with excessively high flow rate ~ 560 L/day
- Average 48 % COD reduction and 13 % Total Nitrogen reduction

![Graph showing current, power, and voltage over time](image)

**Field trial**

- COD (g/L)
  - Inlet: 6.0 ± 0.2
  - Outlet: 3.0 ± 0.2
  - Reduction: 48%
- N-concentration (g/L)
  - Total Nitrogen: 3.0 ± 0.2
  - NH₄: 8.0 ± 0.2
  - Reduction: 13%, 84%

![LED lights powered by the MFC stack](image)

![MFC Modules](image)
Commercialization
Approaches and challenges

• Aim to spin-out a company in 2017

• Manufacturing to achieve economies of scale for electrodes, ceramics and MFCs modules for stack development is a big challenge

• Currently in discussions with 10 commercial partners

• Need access to raw materials (ceramic, metals, carbon, semi-conductors) and their fabrication for MFC and electrode development

• Imminent calibration trial with 100 modules in the UK

• Calibration trial of 1000 modules outside the UK coming up
MFCs as a component to larger-scale blackwater/solid-waste treatment technologies

- Example: Collaboration with Caltech
MFC technology is able to:

- Electricity generation
- Catholyte production
- Pathogen killing
- COD reduction
- Nutrients Recovery

Remote power
- Remote lighting
- Mobile phone charging

Water Re-use
- Fertilizer

Dischargeable effluent
- Fertilizer
- New biomass

Raw materials for manufacturing, for fertilizer
- Nutrients for further growth
- Struvite, P, K, NH$_4^+$

Challenges:

- Pure solid treatment is a challenge due to fluid dynamics; however can be treated if mixed
- Mass manufacture of electrodes, ceramics and modules
THANK YOU!!

- Electricity
- Catholyte
- Pathogen killing
- COD reduction
- Nutrients Recovery