

Department of Chemical Engineering

Does my Research Need more Math??? The Wonders of Bioelectrochemistry

Dr Mirella Di Lorenzo

M.Di.Lorenzo@bath.ac.uk

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Today's talk



- 1. An introduction to Biological Fuel Cells
 Discovering 'electrical' bacteria!
- 2. Energy from wastewaters
 The pee power!
- 3. Sensors for water

 If bugs don't like it, you better don't drink it!
- 4. Where is the MATH?

I have a vision...

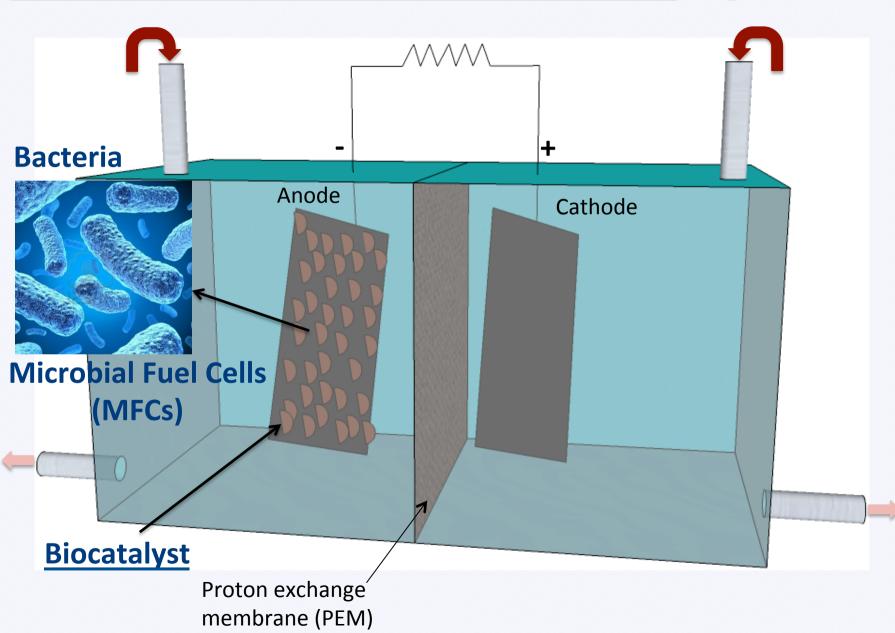


To develop:

- 1. Effective bioelectrochemical devices for the *renewable* and *carbon-neutral* generation of electricity from wastewaters.
- 2. Compact, handy and cost-effective biosensors for quick on-site and real-time assessment of water quality.

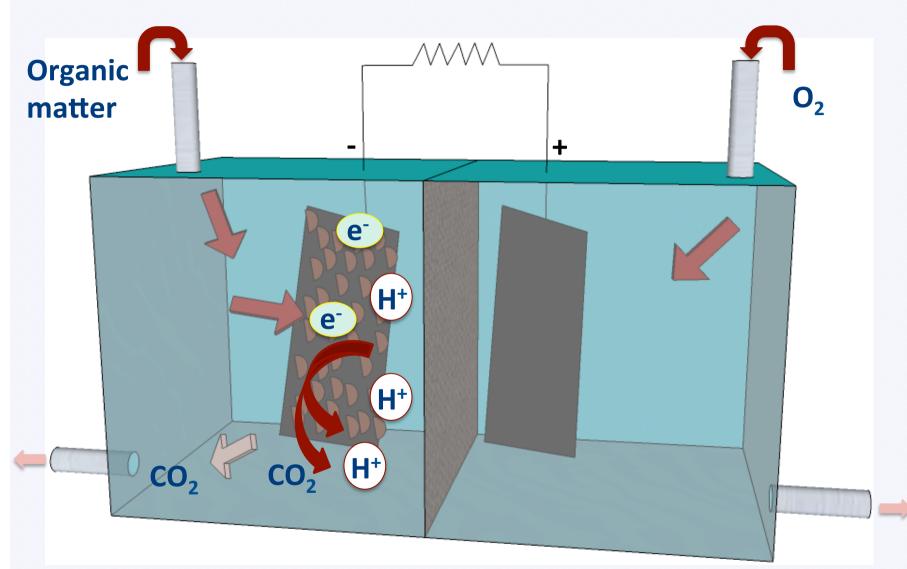
BFCs: Principles of operation





BFCs: Principles of operation

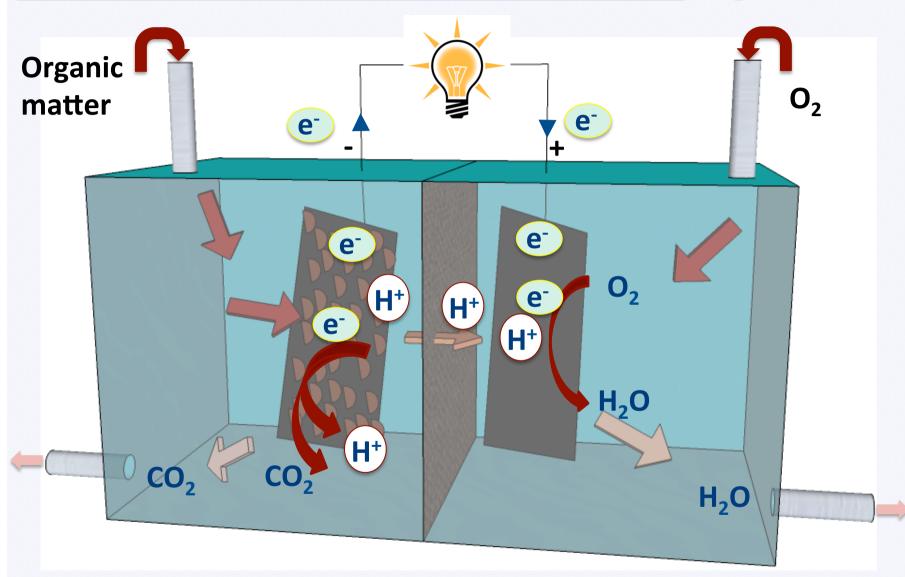




Organic matter \rightarrow e⁻ + H⁺ + CO₂

BFCs: Principles of operation



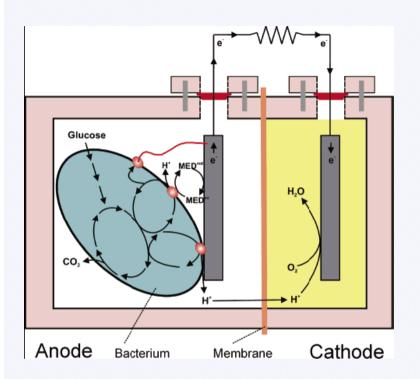


Organic matter
$$\rightarrow e^- + H^+ + CO_2$$

$$O_2 + e^- + H^+ \longrightarrow H_2O$$

How can bacteria generate electricity?



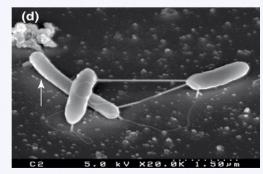


Mediated electron transfer (MET):

- By means of low molecular weight electron shuttles
- **Electron shuttling proteins**

Direct electron transfer (DET):

- From cell surface of redox active proteins
- Via electron conductive "nano-wires" produced by the bacteria (wired community)
- By other yet undiscovered pathways



Trends in Microbiology, Vol 14, No.12

BFCs harvest energy from waste







Agriculture





Farms



Domestic

Waste as a resource





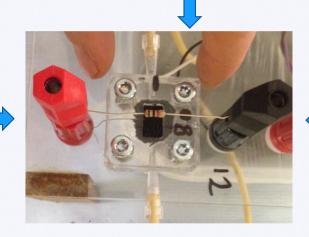
- 2.4 billion people worldwide have no sanitation
- In UK over 10 bn litres of sewage produced every day
- Almost 2% of the average daily electricity consumption in UK is used to treat sewage
- Wastewaters contain more chemical energy than this!
- Giving value to these wastes would alter economics in favour of deploying treatment, and would improve social conditions, environmental emissions and energy conservation and security

Areas of research



1 Innovative designs

Optimising the operational conditions



Cost-effective materials

Enhancing power generation

WEE could be used to generate electricity, claim researchers.

They have developed mirrobial had cells that use the natural biological processes of bacteria. They reset as organic matter said as string

matter took as trine-passes through the inch-iquers device, which rom-only El to El each. The cells more resisted by sequent at the Univer-city of Rath, Ourse, Mary

University of London and Bristol Biosmergy Cantra.

Chemical engineer De Mirella Di Lorence soid "If we can harmon the potential power of this leaman warts, we could revolutionies how slee-tricity is generated."

Battery that has a wee bit more power

A RATTERY powered by a count become an environ-tally friendly source of power

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McBoatface is top name

BOATY McRoatface has won a poil for the name of a new polar research sixts.

It received 134,109 votes beating Poppy-Mai-named after a 16-month old curver victim - on 34.371

The Natural Environment Research Council, which set the online poll, said: "Will now review the names."

Arience Minister to Johnson will make the decision on the 6200 million ship.

Urine mobile power for £1

SCEINTISTS have developed retetature fuel rells that use urine to generate electricity to power mebbs phones.

The inch square device. which costs about £1, was developed by a group including Bath University.

Dr Mirella Di Lerenzo, from Bath, said: "If we can harness the outential owner. of this human waste, we could revolutionies how electricity is generated."

Tiny fuell cell uses urine to generate electricity

 Miniature device. costs as little as £1

 New design is small and powerful

Do No AMERICAN PARKET

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Microbial had cells use may bud sells

"check to" backwise to have into electricity.

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This can be assessing used Researchers have directored to directly power electrical a constance fast officenting devices. Researchers are this new kind of microbial had cell icomodet more sewerful and chosper than other similar

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and much cheaper alternathe to planteum, which is one month used to other may rebind ural biological processes of ... Dr Mireila di Lovenno, les-



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Mini fuel cell spark of hope from urine

RESEARCHERS have developed a miniature fuel cell costing as little as \$1 which our generate electricity from tirine. The device, a microbial finel reil, rould be used to create a renewable and carbon-neutral way of generating power to remote areas of very little cost.

Rash of the fael cells, developed by researchers at the University of Both, Queen Mary University of London and the Bristol Biosnergy Centre, costs il to il. Microbial feet cells use natural triclogical



6 STATE Monday, April 16, 2916.

Generating electrici-pee

RESEARCHERS have developed a miniature fuel cell that can turn peeinta mestricity.

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Fuel cell is re-volt-ing

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Tiny fuel cell uses urine to make electricity RESEARCHERS have developed a London and the Bristol Blumergy ministrare-had cold counting on little: Control, courts 61 to 62.

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could be used to create a renewable and carbon touthal way of generating power to remote

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Researchers say this new bind of microbial had call in smaller. more powerful and charger than aliter similar devices.

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WE ARE always backing for green ways to generate power - and this one younds, er, every pee-so. A mire fuel call which costs () could make electricity from unine. but compressed transfers. British researchers say it may

neutral way of getting power to serente areas al very little cost. Or Mirelia Di Lorenzo, of Bath versity, said: 1f we can harness the potential power of this human waste, we could revolutionise how electricity is generated.

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BY GAME BAYMEN

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Created builds.

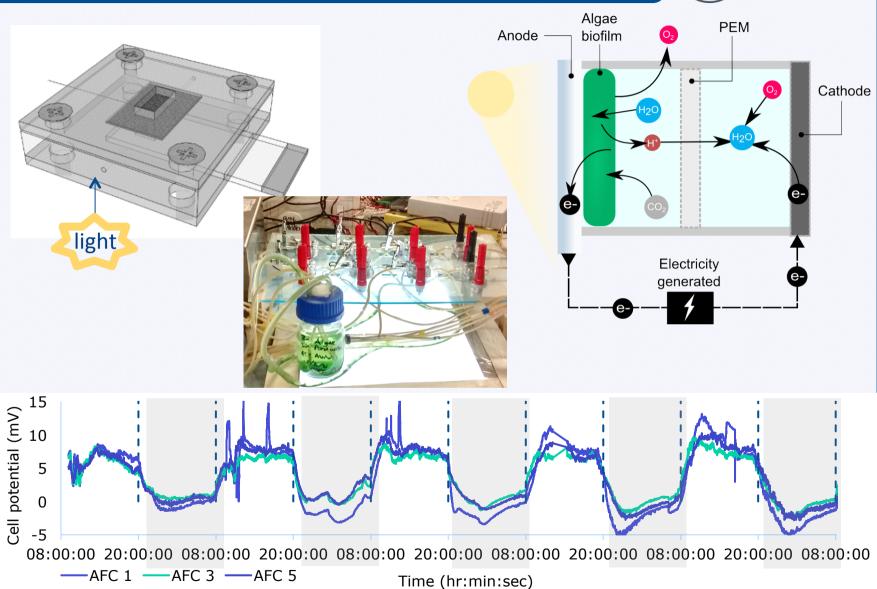
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course, which include The researchers worked on the self's design to maximize the power that, rould be gen-

wastewaters from **Energy**

Photo-BFCs

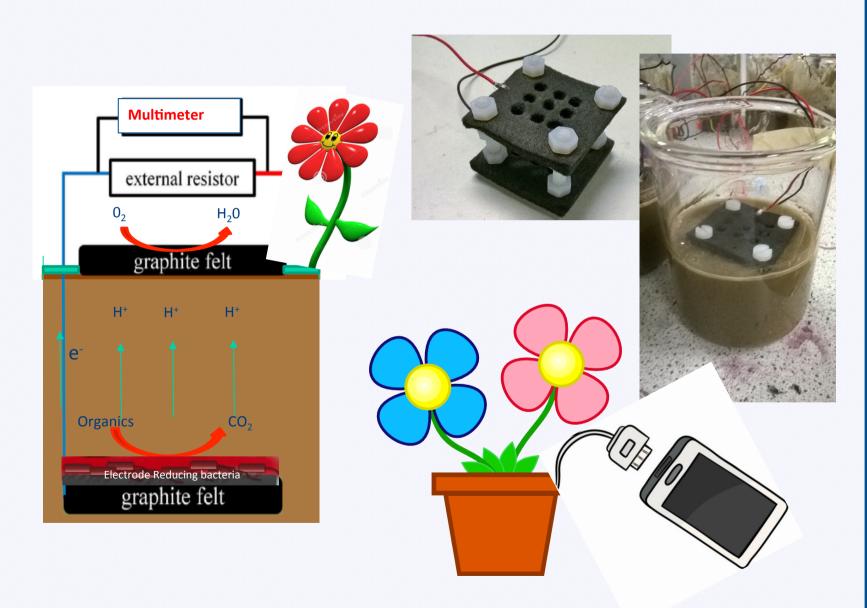




5. New materials

Power from the pot!





Why water quality monitoring





The heavy use of chemicals (agricultural, industrial and domestic) has increased the risk of freshwater contamination.

The detection at very low concentration (*micropollutants*: picograms per litre to nanograms per litre) via traditional analytic tools can be difficult.

Real time on site monitoring is important to:

- Undertake immediate action;
- Map the distribution of micropollutants in surface water;
- Assess and monitor the efficacy of the wastewater treatment.

MFC sensors



Microbial fuel cells as sensors for water quality:

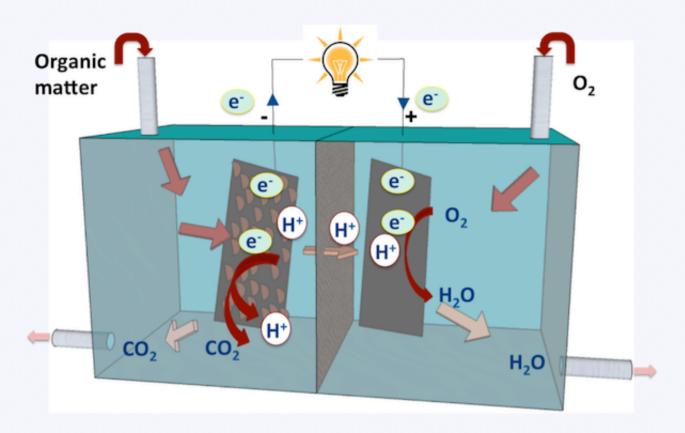
Bioactivity investigations
Online monitoring
On site operation
Cost-effective and simple
Self-powered operation



3. Sensors for Water

How BFC can be used as biosensors?





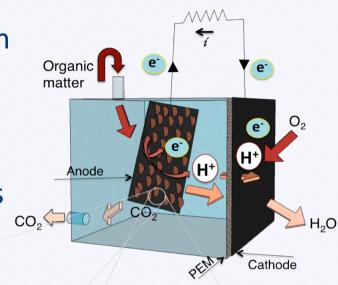
The current generated by the BFC is an indicator of the metabolic activity of the electroactive bacteria at the anode

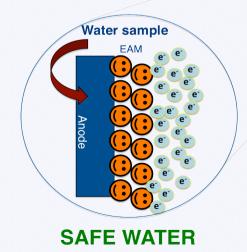
3. Sensors for Water

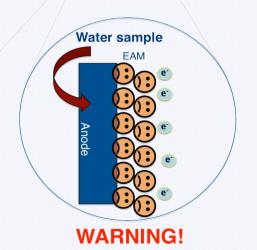
Detection of toxicants



If the BFC works at *saturated* fuel concentration, and other parameters such as pH, salinity, temperature and anode potential are fixed, then unexpected variations in the current output can be associated with the presence of toxicants in the feeding stream

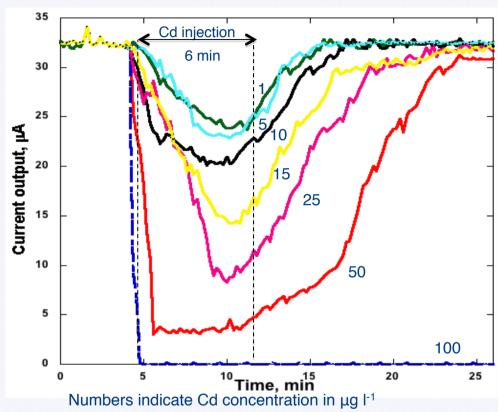




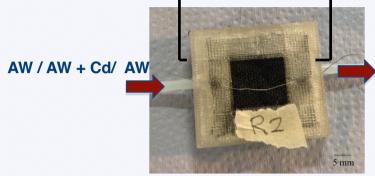


EAM: electroactive microbes

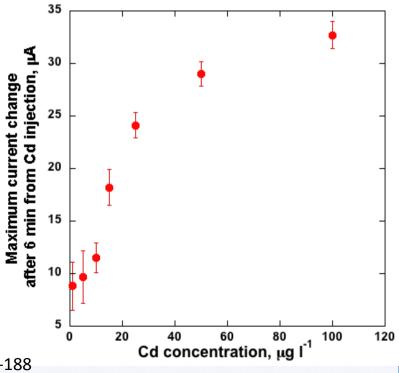
Response to cadmium (as Cd²⁺SO₄²⁻)



- Dynamic range: **1 25 μg I**-1
- Lower detection limit: 1 μg I⁻¹
- Sensitivity (with respect to anode surface area):
 0.2 μA μM⁻¹ cm⁻²



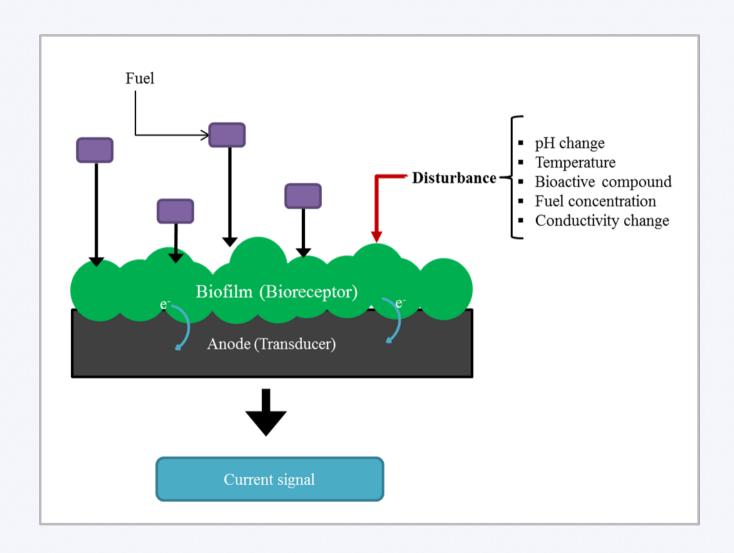
AW: Artificial wastewater containing 3 mM of acetate as fuel



Di Lorenzo M, et al. 2014 Biosensors and Bioelectronics, 62:182-188

Does my research need more math?





Does my research need more math?



- Need for:
- A consistent method to interpret the output signals of the BFC sensor and filter out all the noise and disturbances to prevent false positives or false negatives;
- A way to 'display' complex data in a userfriendly way that also non-experts can easily understand;
- A way to support effective device designs with mathematical models