Self-cleansing peroxide mechanism to improve resilience and energy efficiency in microbial electrolysis cells (MECs)

Sam Settle[1], Richard Law[1], Andrew Moore[2], Elizabeth Heidrich[1]
[1]Newcastle University, [2]Northumbrian Water Ltd

WATER INFRASTRUCTURE AND RESILIENCE WIRe

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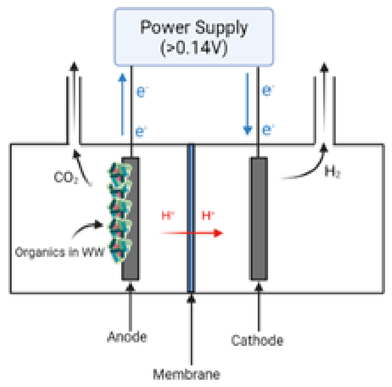
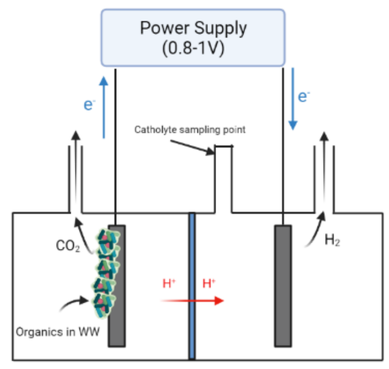
Context (1)

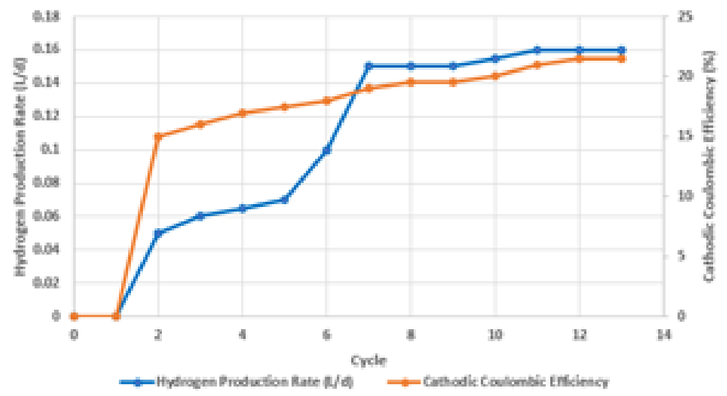
- Water and sewerage sector consumes 2-3% of the UK's electricity supply and produces around 4.35 million tonnes CO_2 equivalent of greenhouse gas emissions. The UK water sector aims to achieve net-zero carbon emissions before 2030.
- MECs are a promising biotechnology that can convert organic pollutants in wastewater (WW) into H_2 gas using an electroactive biofilm and a voltage input (> 0.14V)
- None of the MEC pilot-reactors operating with real WW have achieved an energy neutral or positive energy state due to low H_2 recoveries. A major H_2 sink is believed to be through H_2 scavenging microbes at the catholyte.
- This section of the research project aims to develop a sterilisation technique based on in-situ electrochemical H_2O_2 generation to eliminate the H_2 scavenging microbes to improve overall system resilience and energy efficiency.

Simple schematic of a microbial electrolysis cell

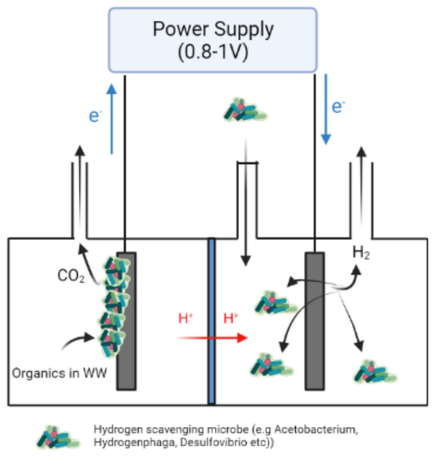


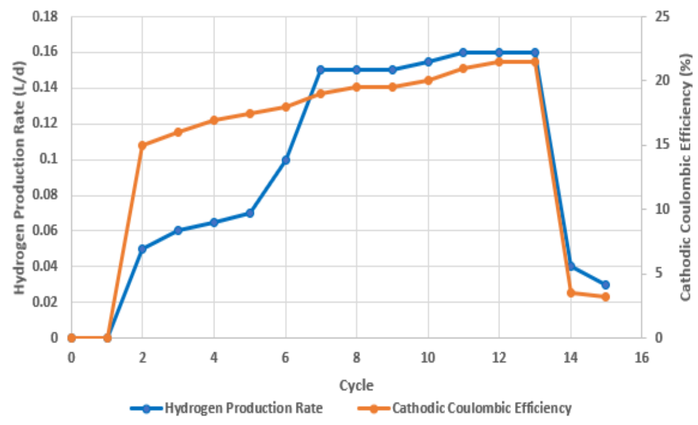
Concept (2)



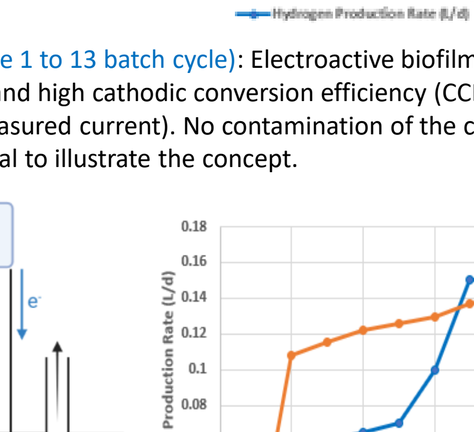


STABLE SYSTEM (Batch cycle 1 to 13 batch cycle): Electroactive biofilm acclimatised to anode surface. Stable H_2 production rate and high cathodic conversion efficiency (CCE) (moles of H_2 recovered divided by theoretical moles in measured current). No contamination of the catholyte by H_2 scavenging microbes. Data is theoretical to illustrate the concept.

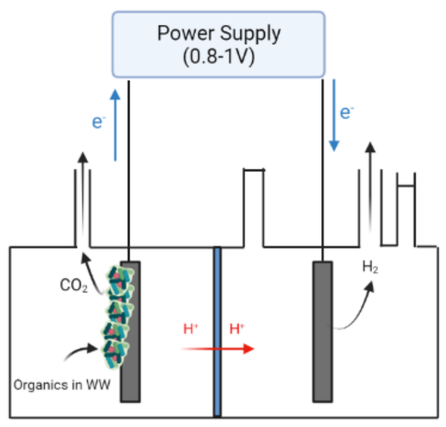


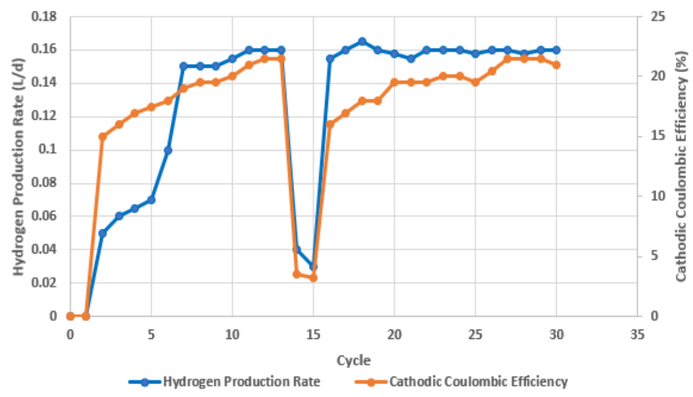


SCAVENGING SYSTEM (Batch cycle 14 to 15): H_2 scavengers contaminate the catholyte. H_2 production rates decrease with cathodic coulombic efficiency as the end-product is diverted elsewhere.



PEROXIDE STERILISATION: Voltage is ramped down to 0.5V and aeration is applied to electrochemically generate H_2O_2 at the cathode. H_2 scavengers are eliminated.

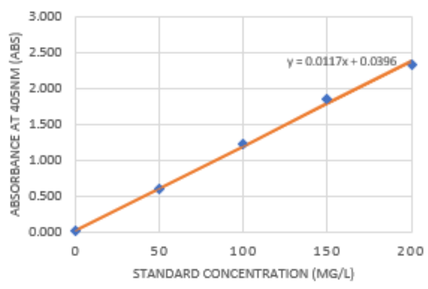




STABLE SYSTEM (Batch cycle 16 onwards): Catholyte is sterilised. Input voltage ramps up to 0.8-1V to stimulate H_2 production. The resilience provided by the H_2O_2 mechanism is assessed in terms recovery time and the ability for the system to generate the same level or more H_2 and CCE compared to the pre-shock (contamination) state.

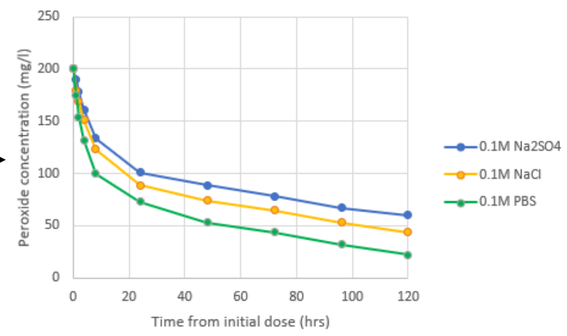
Proposed methodology (3)

H_2O_2 concentration calibration curves



Calibration curve of 0.1M PBS using UV-vis of orange [TiO_2^{2+}] complex.

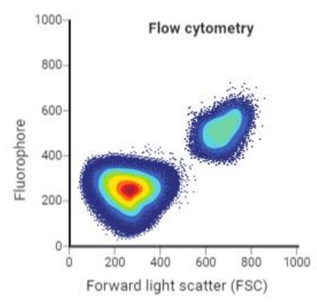
H_2O_2 stability tests for catholytes over neutral to alkaline pH range



Catholyte optimization tests (data is theoretical)

Determine required H_2O_2 concentration for sterilization. WW injected into cathode chamber in H_2 mode and dosed at set H_2O_2 concentrations

Sterilization efficiency with flow cytometry



Assess dominant O_2 reduction reaction for stainless steel mesh cathode using electrochemical techniques.

$O_2 + 4e^- + 4H^+ \longrightarrow 2H_2O$
$O_2 + 2e^- + 2H^+ \longrightarrow H_2O_2$?

Test if in-situ H_2O_2 mechanism provides resilience. Assess in terms of recovery time, CCE and H_2 production rate.

6 MECs in H_2 mode with induced contamination:

Group 1—Control (no H_2O_2, 0.8-1V)

Group 2— Aeration, no voltage drop

Group 3—In-situ H_2O_2

If mechanism provides resilience, test during a pilot trial under real-world conditions

Likely Outputs (4)

- A proof-of-concept study which examines the functionality of periodic sterilisation of the cathode chamber with electrochemically generated H_2O_2 to facilitate resilience against H_2-scavenging microbes and improve energy recovery.
- The study will provide greater insight into H_2 sinks within pilot-scale MEC modules and provide direction into addressing these.

For further information:
s.settle2@newcastle.ac.uk
Postal address: School of Engineering, Cassie Building, Newcastle-upon-Tyne, NE1 7RU

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Newcastle University

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