SIXTH FRAMEWORK PROGRAMME

Neptune FP6 Project

Bio-electrochemical systems [BES]
From power to value added chemicals production from wastewater

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The University Of Queensland AUSTRALIA

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LabMET

Universiteit Gent

Neptune workshop: Technical Solutions for Nutrient and Micropollutants Removal in WWTPs

Université Laval, Québec, March 25-26, 2010

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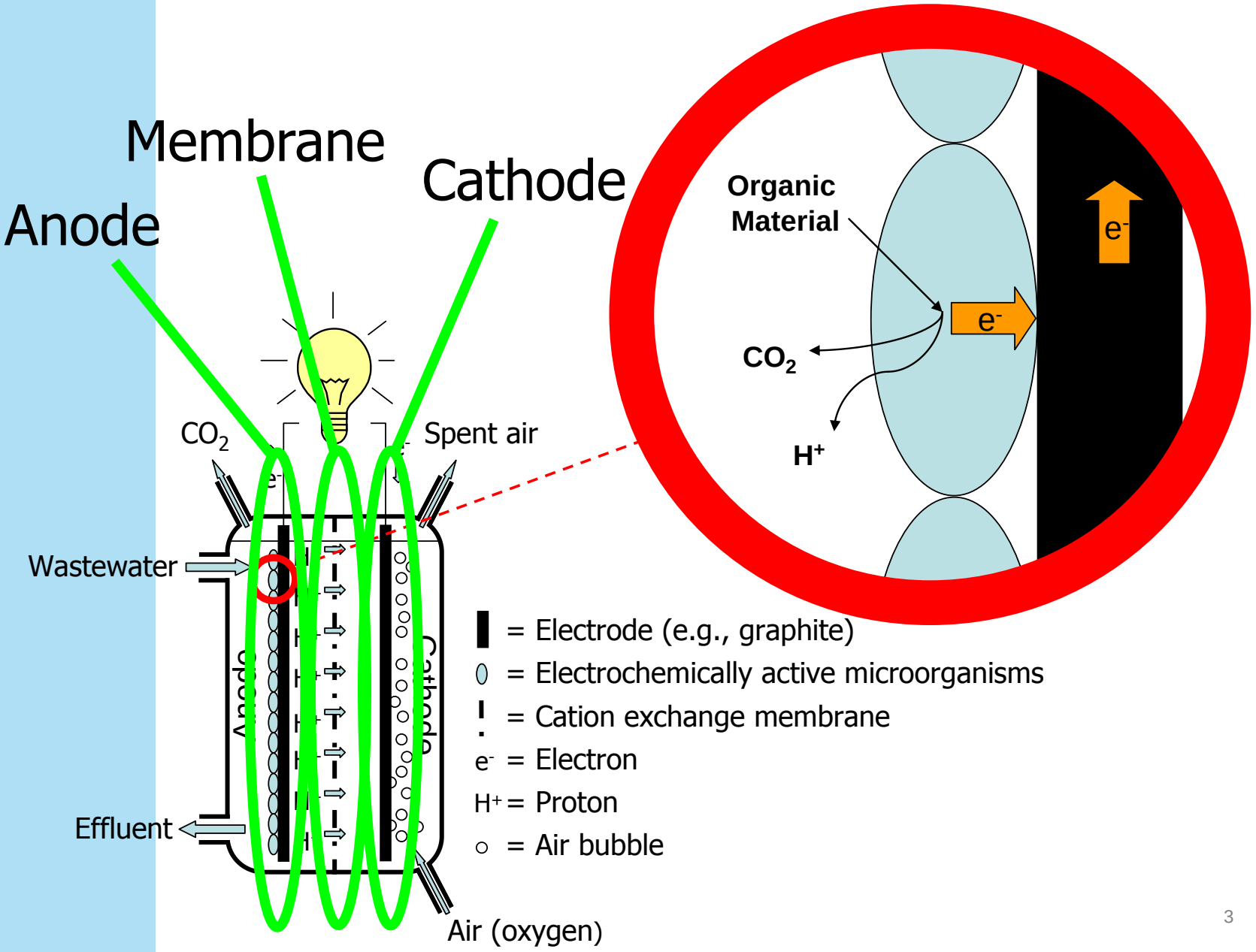
Outline

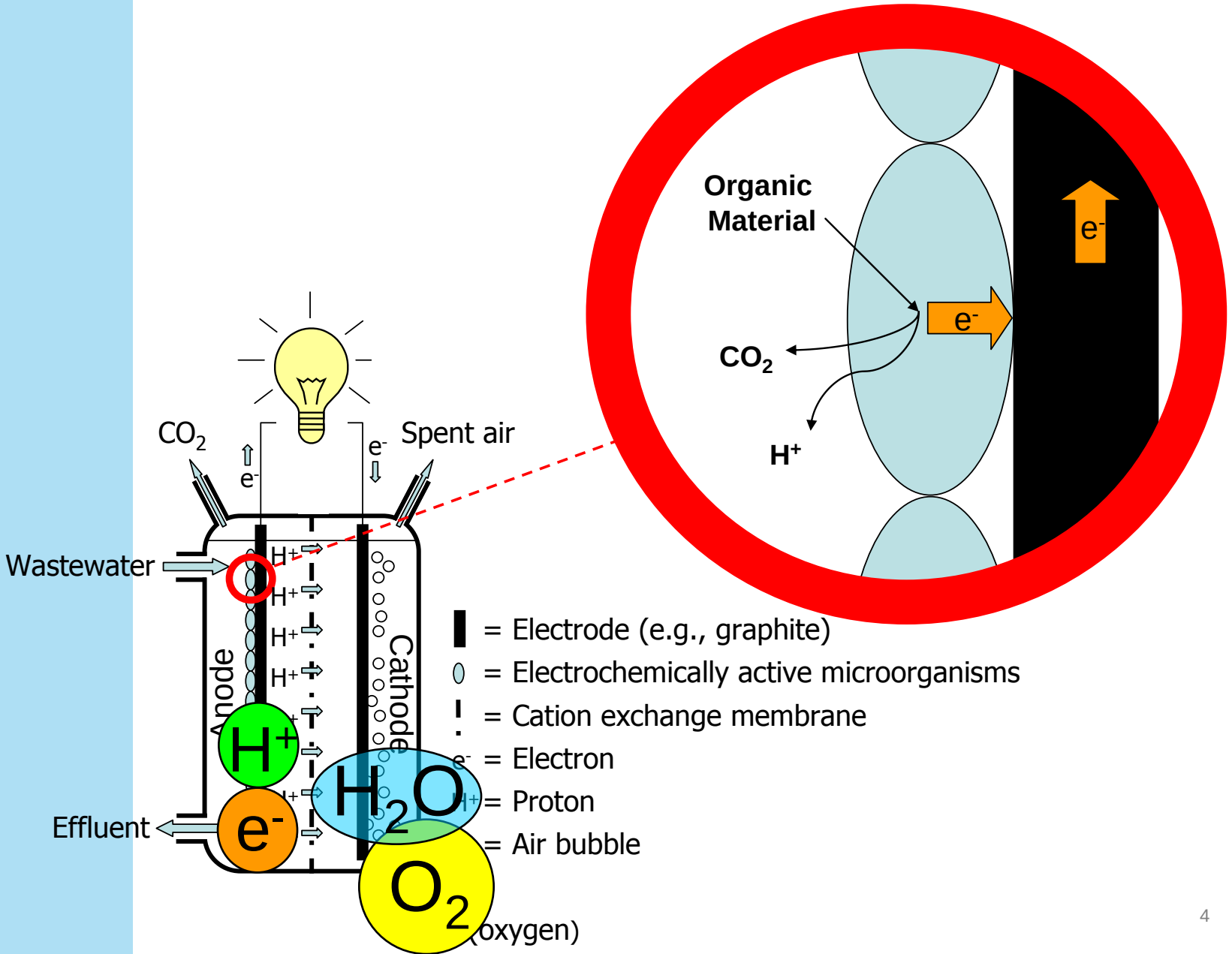
MFC general

Bio-Electrochemical Systmes

The MFC component of the Neptune project

How does an MFC work?




Organic Material
e-
e-
CO2
H+
CO2
e-
e-
Spent air
Wastewater
H+
H+
H+
H+
H+
Anode
Cathode
H+
H2O
e-
O2
Effluent
= Electrode (e.g., graphite)
= Electrochemically active microorganisms
= Cation exchange membrane
e- = Electron
H+ = Proton
= Air bubble
(oxygen)

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MFC/BES – Novel?

Electrical Effects accompanying the Decomposition of Organic Compounds.

By M. C. POTTER, Sc.D., M.A., Professor of Botany in the University of Durham.

(Communicated by Dr. A. D. Waller, F.R.S. Received July 14, 1911.)

18. The Bacterial Culture as an Electrical Half-Cell. BARNETT COHEN, Department of Physiological Chemistry, Johns Hopkins Medical School, Baltimore, Md.

It is well known that bacterial growth is accompanied by a chemical reduction of the culture medium together with a loss of heat and the liberation of oxidation products such as H_2O and CO_2, etc. The measurement of the over-all intensity of the reduction can be made potentiometrically; and it can be shown that, when the neutralizing effects of atmospheric oxygen are eliminated, the reduction potential mounts appreciably.

Proc. R. Soc. London Ser. B ***1911,*** *84,* 260-276.

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Yatala Pilot Plant

World's first MFC pilot plant (a collaboration between the (AWMC) our Neptune partner LabMet, Ghent University (Belgium)).

1m^3 plant, which was started up in Sept 2007.

Results thus far:

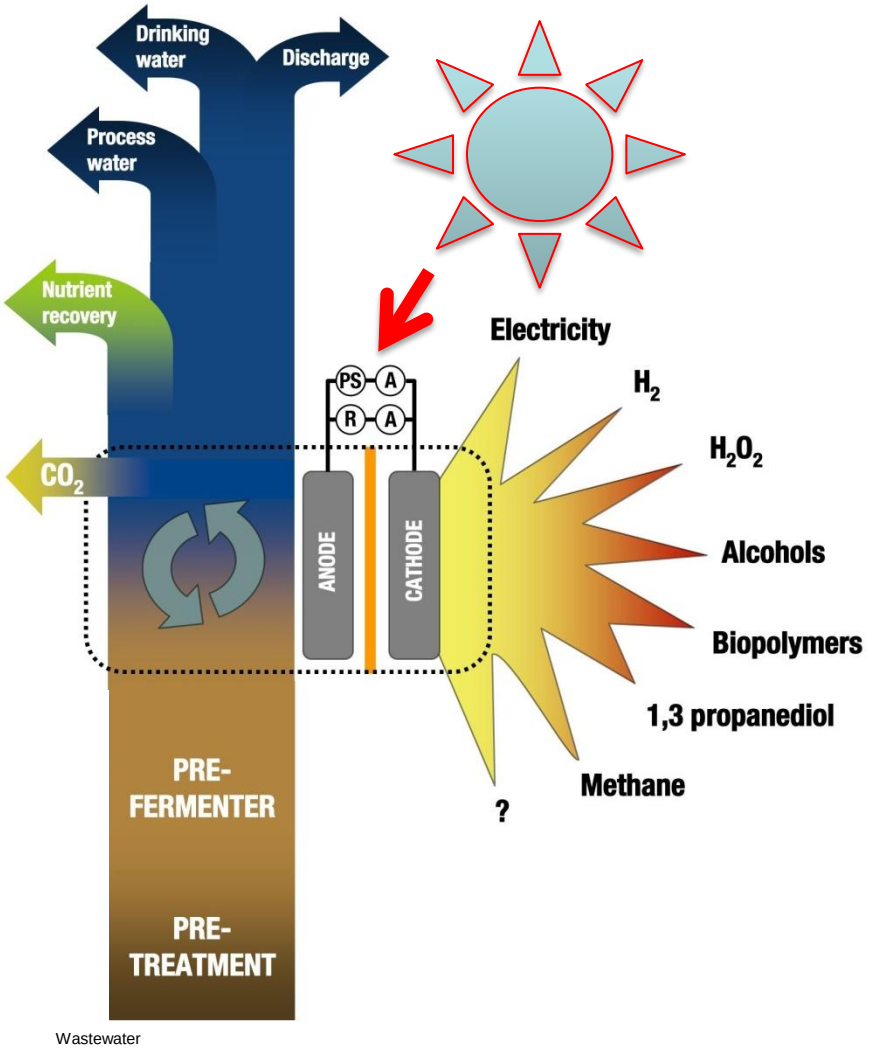
* Cell current of 2A (400mV set point voltage)
* COD removal of 0.2 $kgCODm^3d^{-1}$ as current
* Power densities of 0.5 Wm^{-2} (membrane area) and 8.5 Wm^{-3} (reactor volume).

Product value per m^3 (@ 1000 A/m^3)

- Electricity: ~$1/day
- Methane: ~$1/day

Bio-Electrochemical Systems

"Sustainable value from wastewater"



Product value per m^3 (@ 1000 A/m^3)

- Electricity: ~$1/day
- Methane: ~$1/day
- Hydrogen: ~$5/day
- Hydrogen peroxide: ~$20/day
- Sodium hydroxide: ~$30/day
- Mix $NaOH/H_2O_2$ ~$50/day
- 1,3 Propanediol ~$40/day

Excluding electricity costs ($1-3/day)!

Economic Implications

Standard Module

Size ~ 1 m^3

Module price

$25,000

Wastewater

1-100m^3/day

Wastewater

(with reduced organic content)

$1/day

Electricity Input

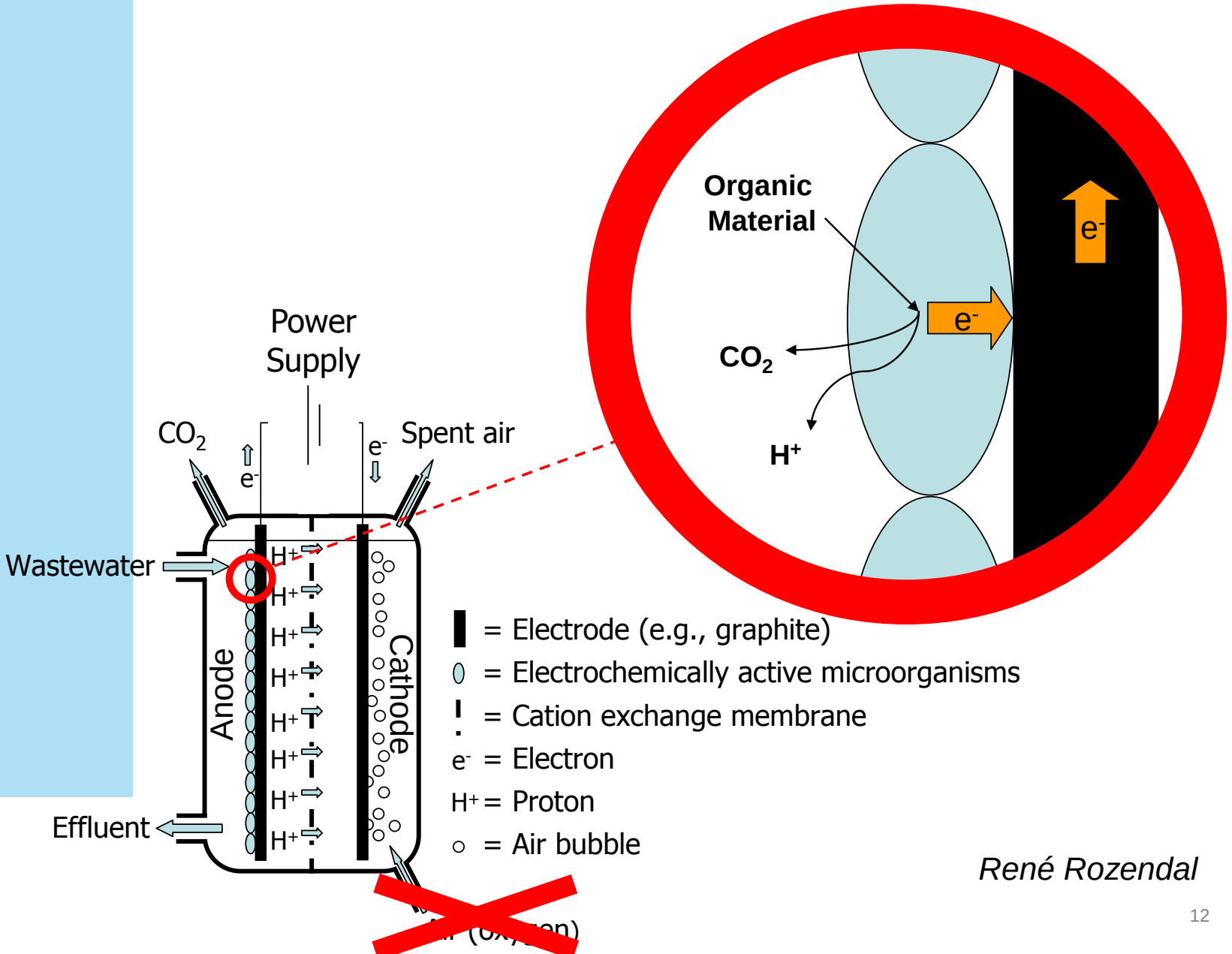
Caustic soda / Hydrogen peroxide

$7000-24,000/year

Bilexys

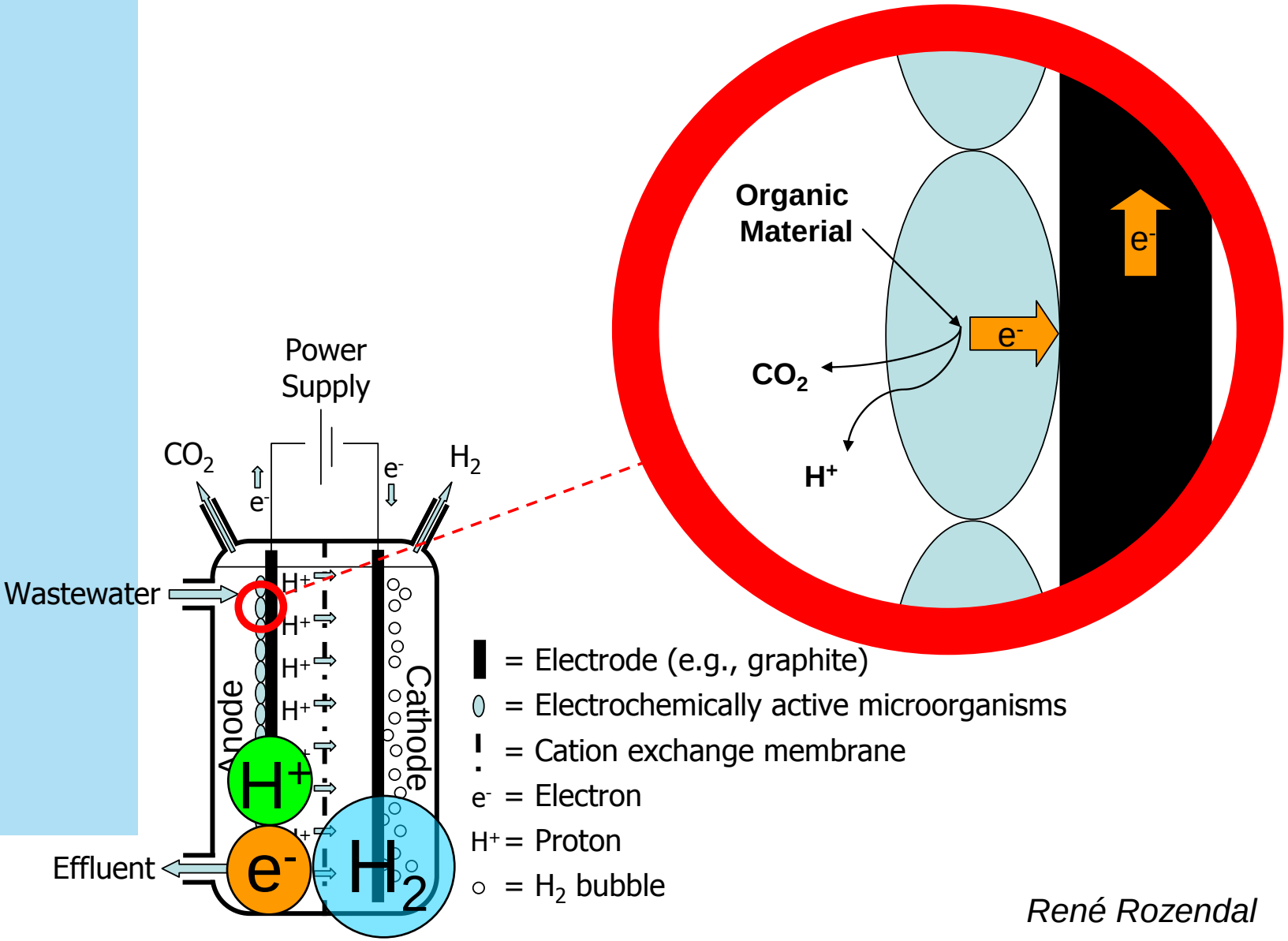
Korneel Rabaey, René Rozendal

Microbial electrolysis cell



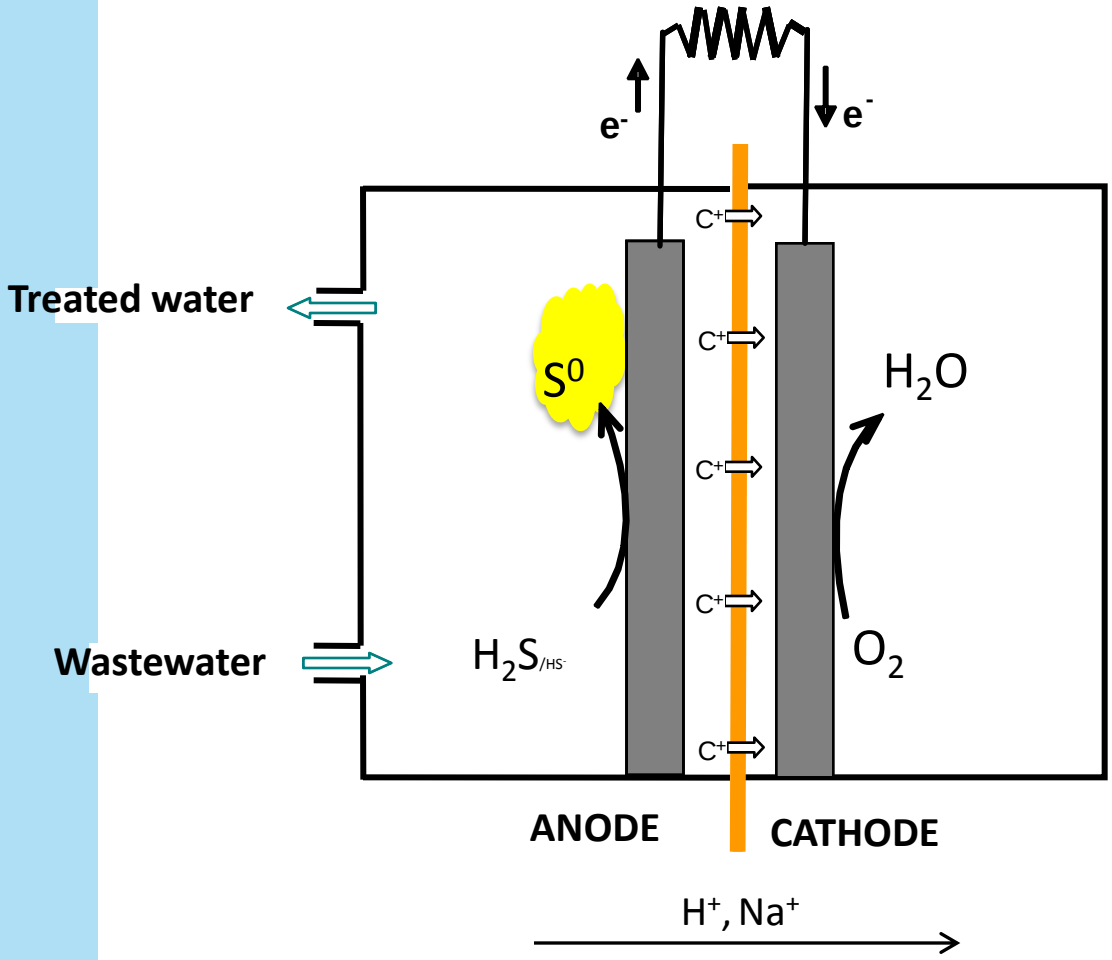
René Rozendal

Microbial electrolysis cell



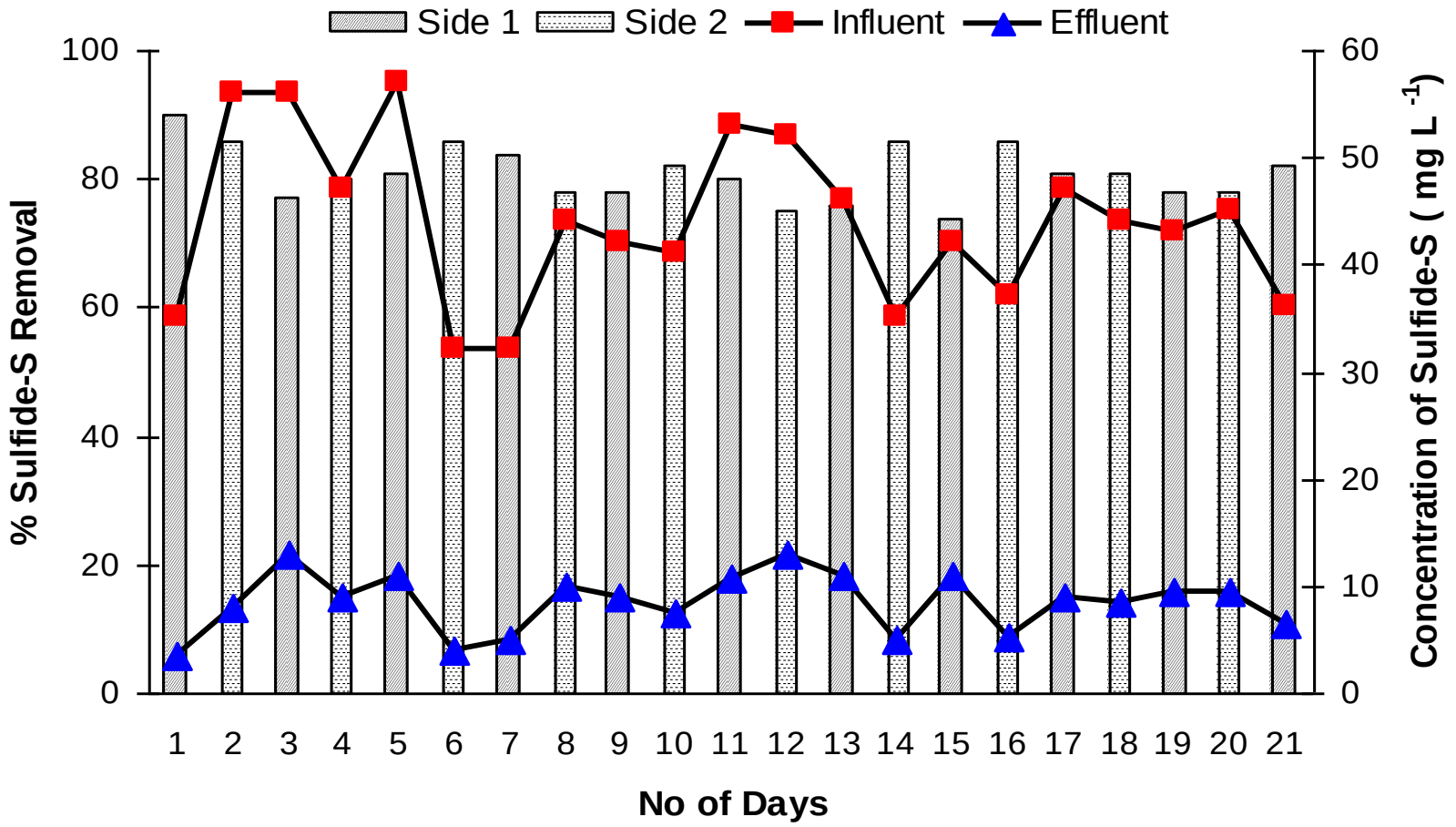
René Rozendal

Sulfide Removal in Electrochemical Cell



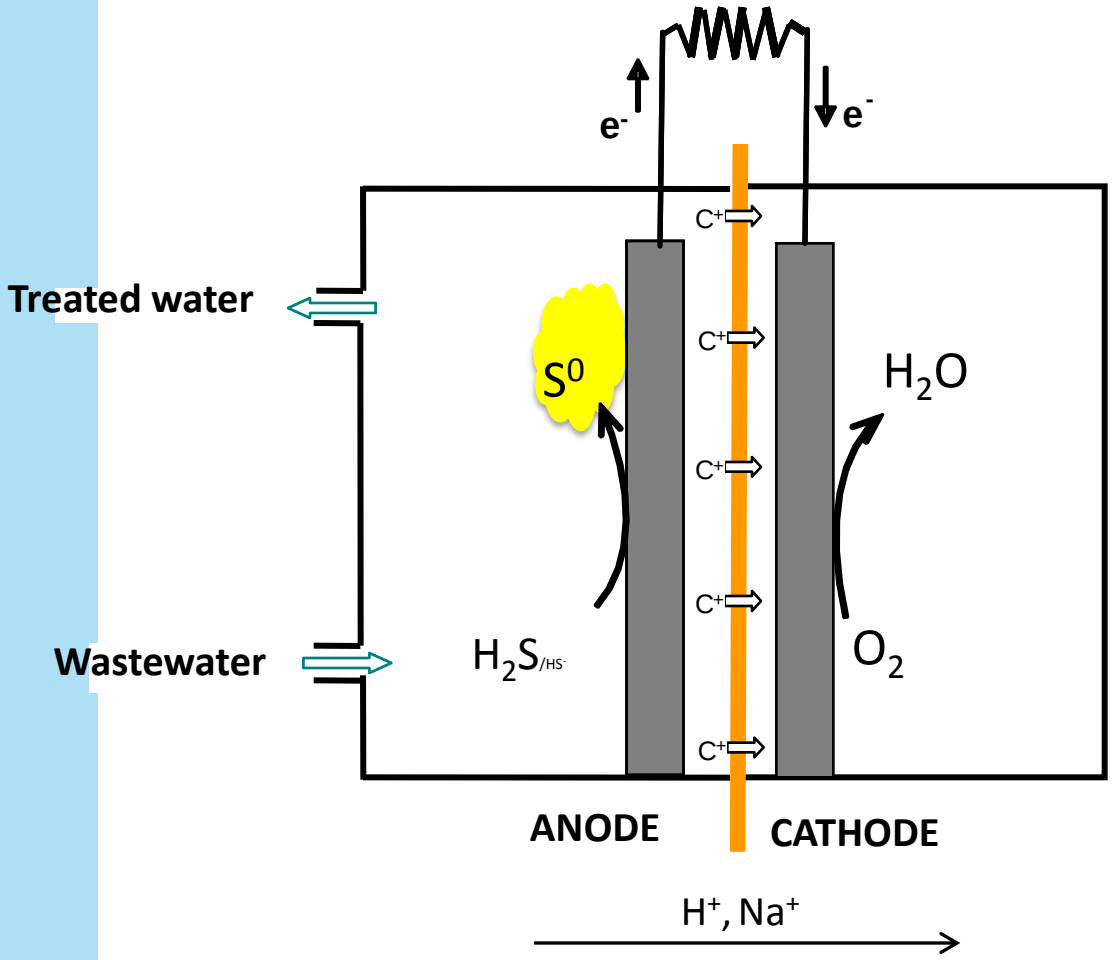
Paritam Dutta

Continuous sulfide removal from paper mill wastewater



Paritam Dutta

Sulfide Removal in Electrochemical Cell



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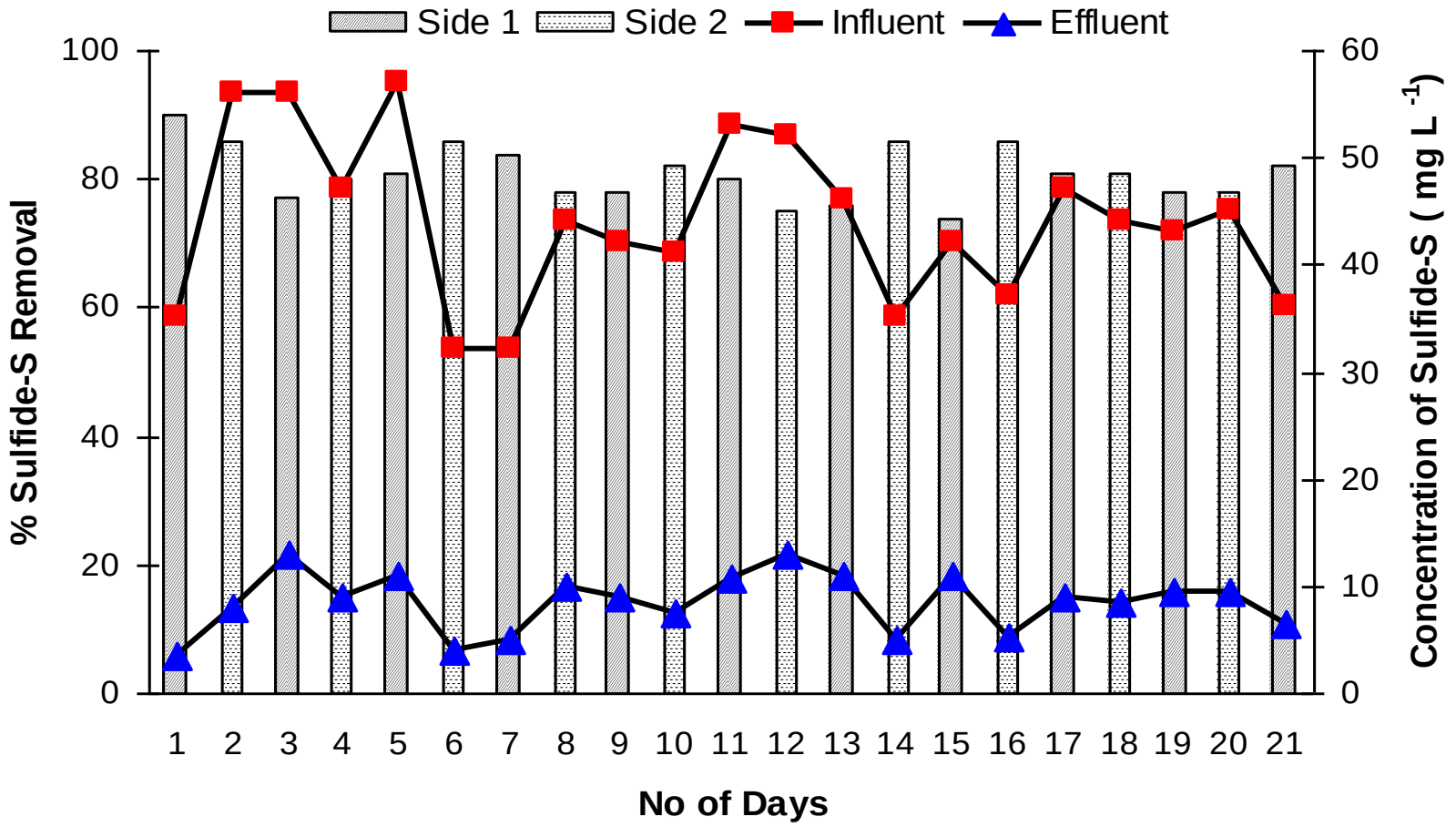

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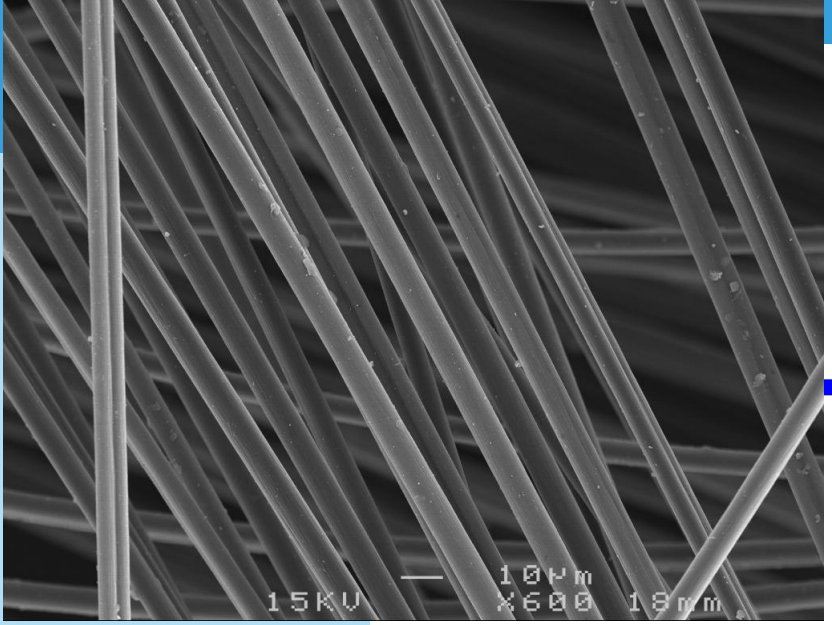
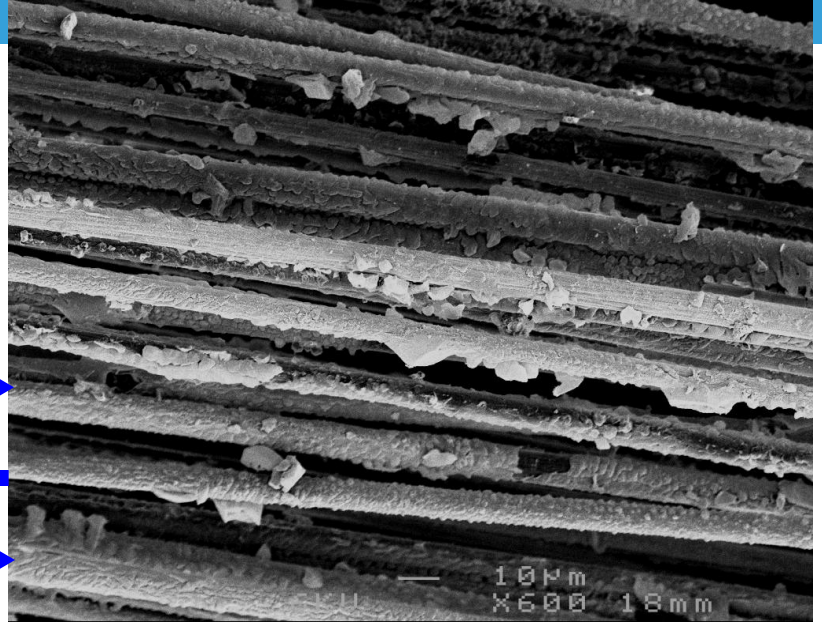
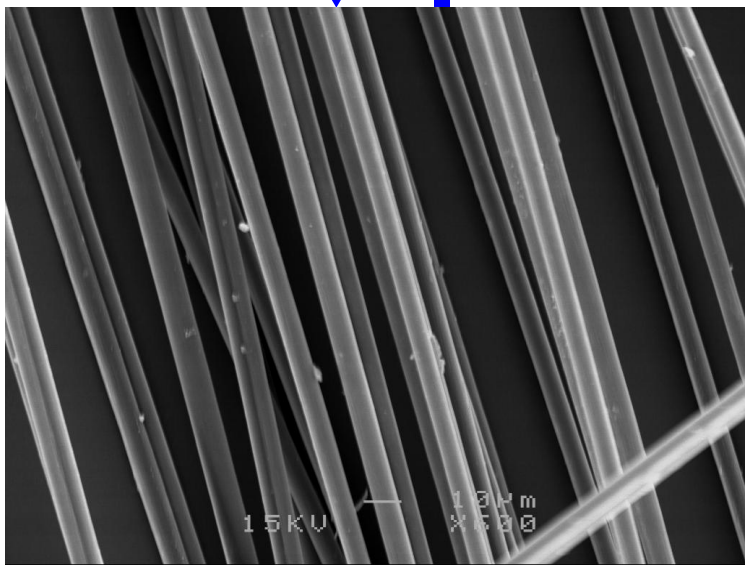




Before deposition of sulfur

after deposition of sulfur

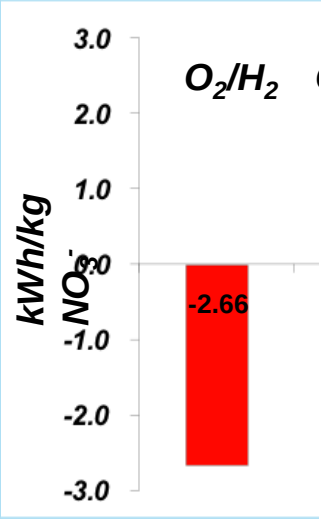
$_{after}$regeneration

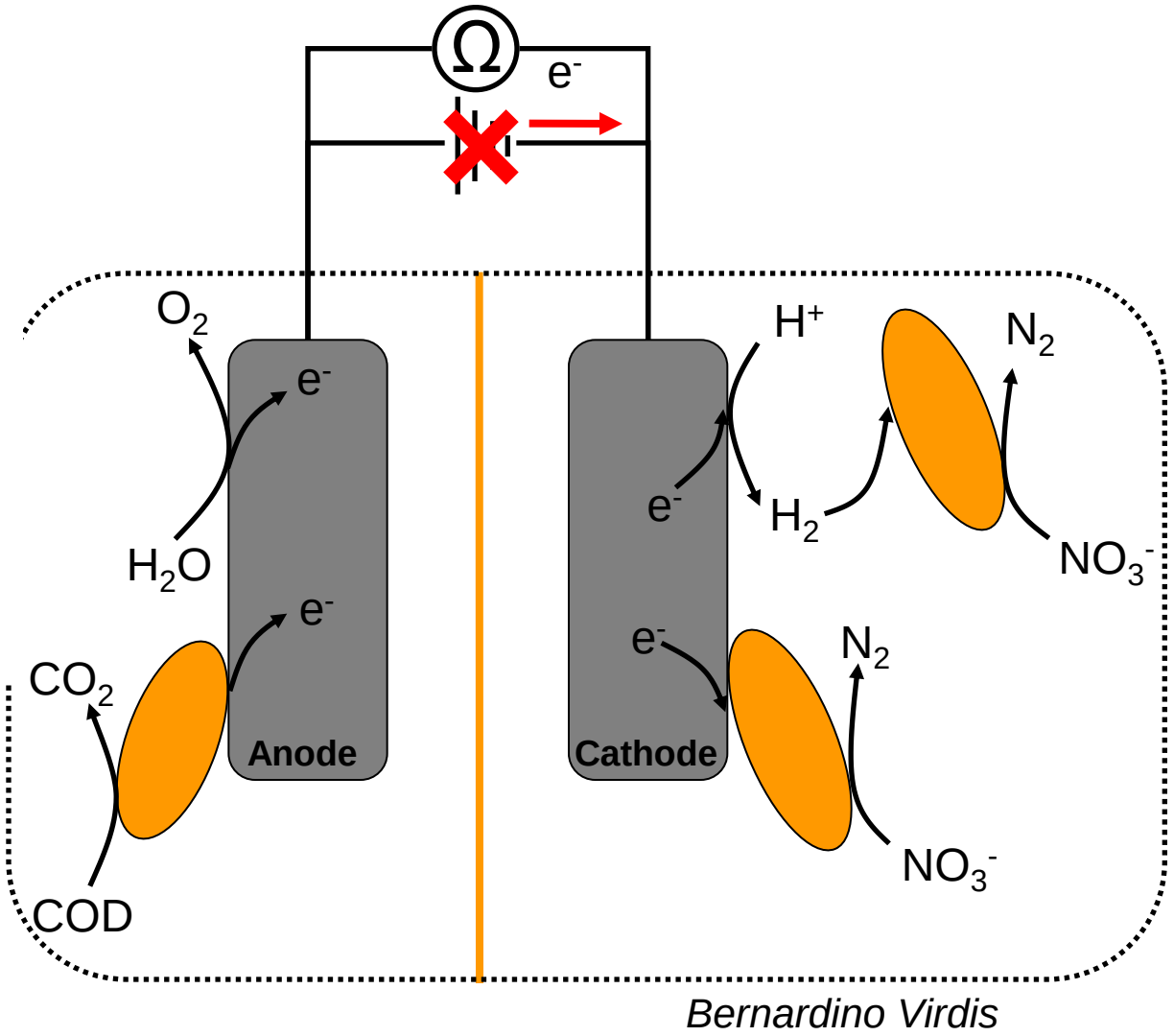


Sulfide / Poly-sulfide

Paritam Dutta

Nitrate Reduction in Bioelectrochemical System

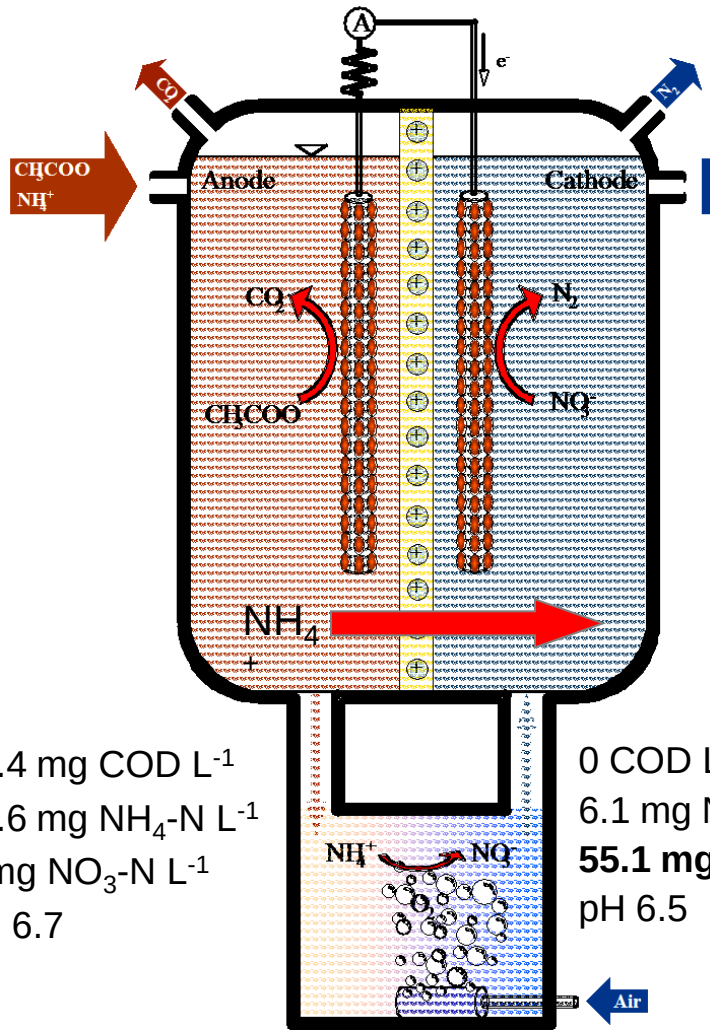




Bernardino Virdis

Loop MFC system with external nitrification

256.4 mg COD L^{-1}
88.0 mg NH_4-N L^{-1}
0 mg NO_3-N L^{-1}
pH 7



0 COD L^{-1}
26.9 mg NH_4-N L^{-1}
1.6 mg NO_3-N L^{-1}
pH 7

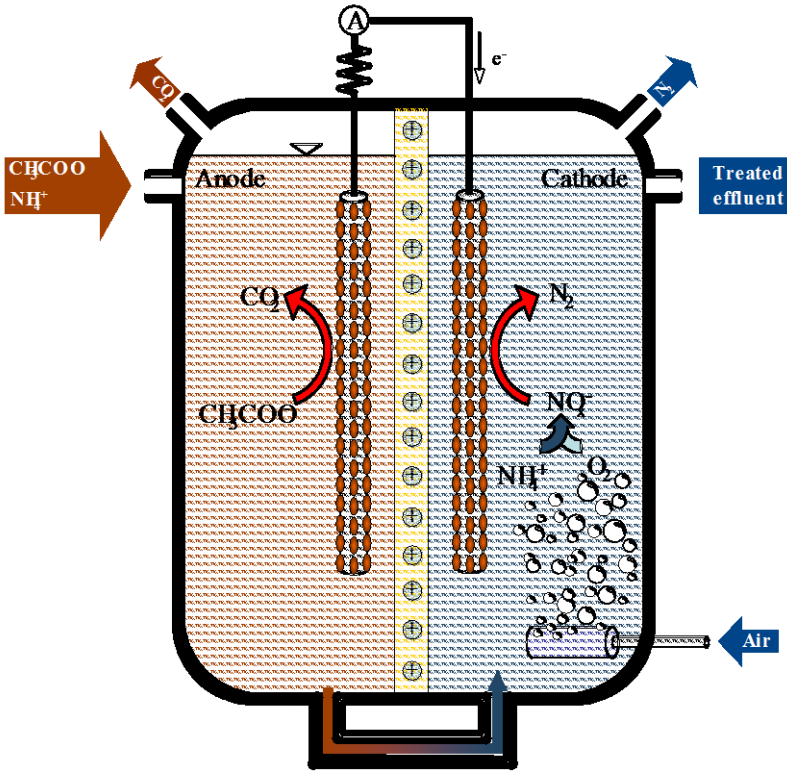
16.4 mg COD L^{-1}
65.6 mg NH_4-N L^{-1}
0 mg NO_3-N L^{-1}
pH 6.7

0 COD L^{-1}
6.1 mg NH_4-N L^{-1}
55.1 mg NO_3-N L^{-1}
pH 6.5

Power output W m^{-3}	C removal %	N removal %	COD/N g g^{-1}
4.4	100	**67.4**	4.1

Loop MFC system with *in-situ* nitrification

239.2 mg COD L^{-1}
53.3 mg NH_4-N L^{-1}
0 mg NO_3-N L^{-1}
pH 7.1



0 COD L^{-1}
2.13 mg NH_4-N L^{-1}
1.0 mg NO_3-N L^{-1}
pH 7.1

3.7 mg COD L^{-1}
24.8 mg NH_4-N L^{-1}
0 mg NO_3-N L^{-1}
pH 6.6

Power output W m^{-3}	C removal %	N removal %	COD/N g g^{-1}
1.3	100	**94.1 ± 0.9**	4.5

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Neptune FP6 Project

Project Neptune

Focus is on the opportunity to use biosolids as an energy source…
so capture electrons that result from the oxidisation of sludge-COD at the anode of a BES

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Neptune FP6 Project

Biosolids: solid byproducts produced by sewage treatment processes.

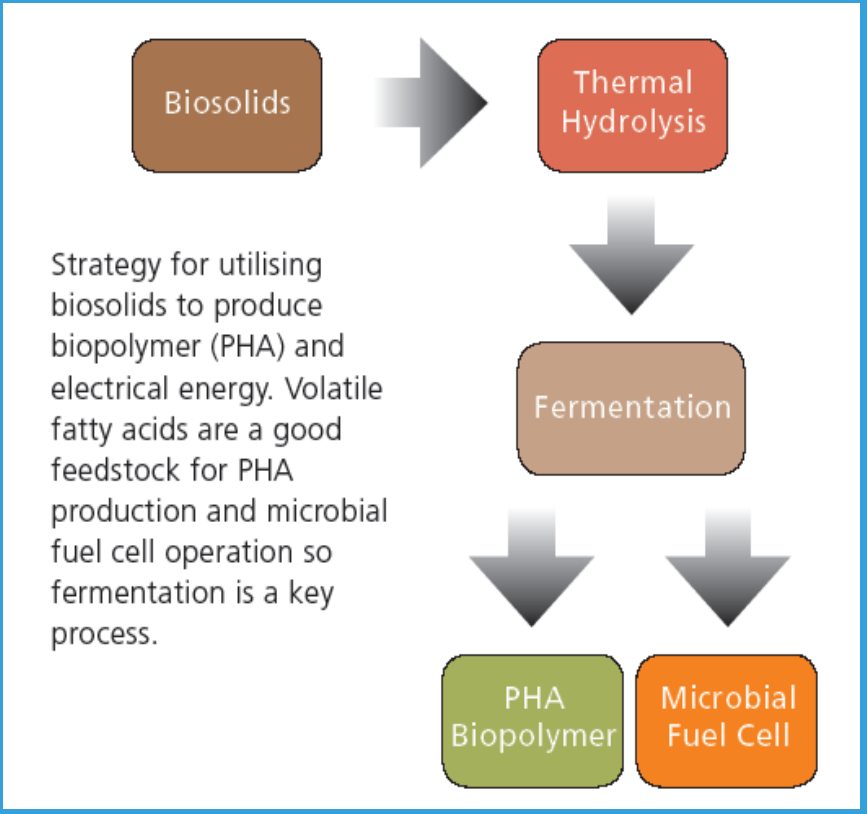
A burden for WWTPs: handling and disposing of biosolids is a cost and causes long term GHG emissions if disposed of in landfills.

We see biosolids as a high volume, renewable carbon and energy source.

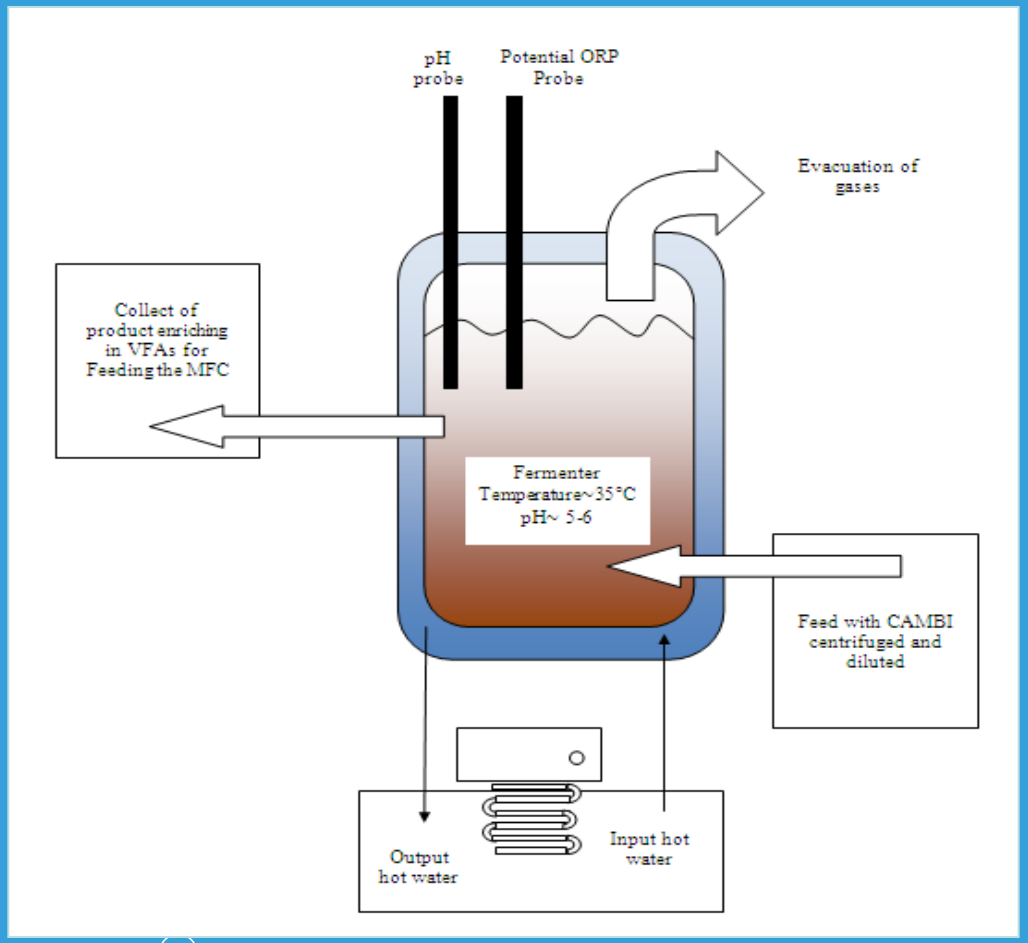
Objectives:

1: Quantify energy (electricity) generation when running an MFC on hydrolysed biosolids.

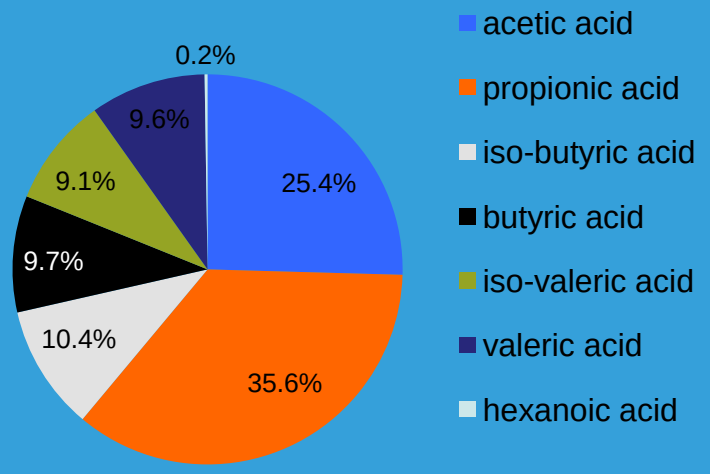
2: Identify factors limiting efficiencies.



Strategy for utilising biosolids to produce biopolymer (PHA) and electrical energy. Volatile fatty acids are a good feedstock for PHA production and microbial fuel cell operation so fermentation is a key process.



Fermenter effluent



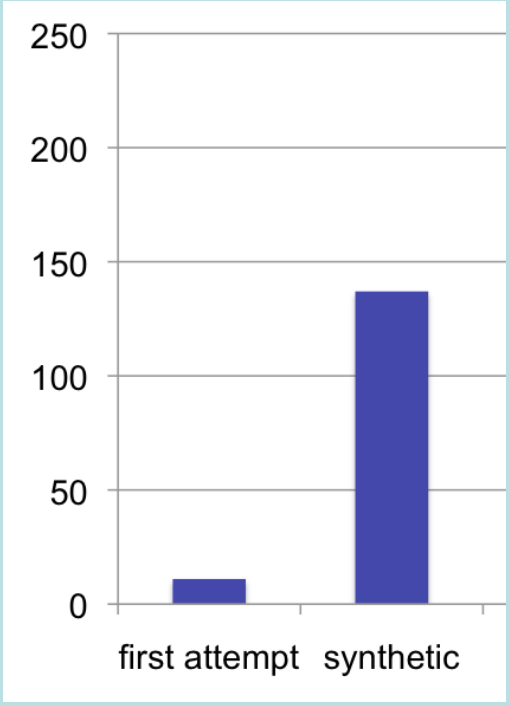
	VFA [mg/L]	pH	K [mS]
Infl.	289	5.52	1.781
Effl.	1072	6.07	1.047

Optimal: one day HRT and control pH [solids contribution minimal]

Operating a MFC with real fermented hydrolysed biosolids… **FINDINGS**

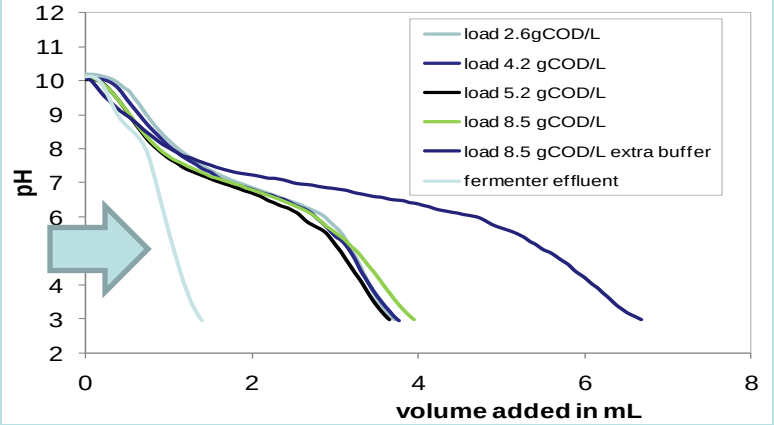
Load ~ 350mg VFA/L = 2.6gCOD-VFA/L.d

-300mV vs Ag/AgCl



NOT GREAT PERFORMANCE COMPARED TO OPERATION WITH SYNTHETIC SUBSTRATE!

WHY?



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Operating a MFC with real fermented hydrolysed biosolids… **FINDINGS**

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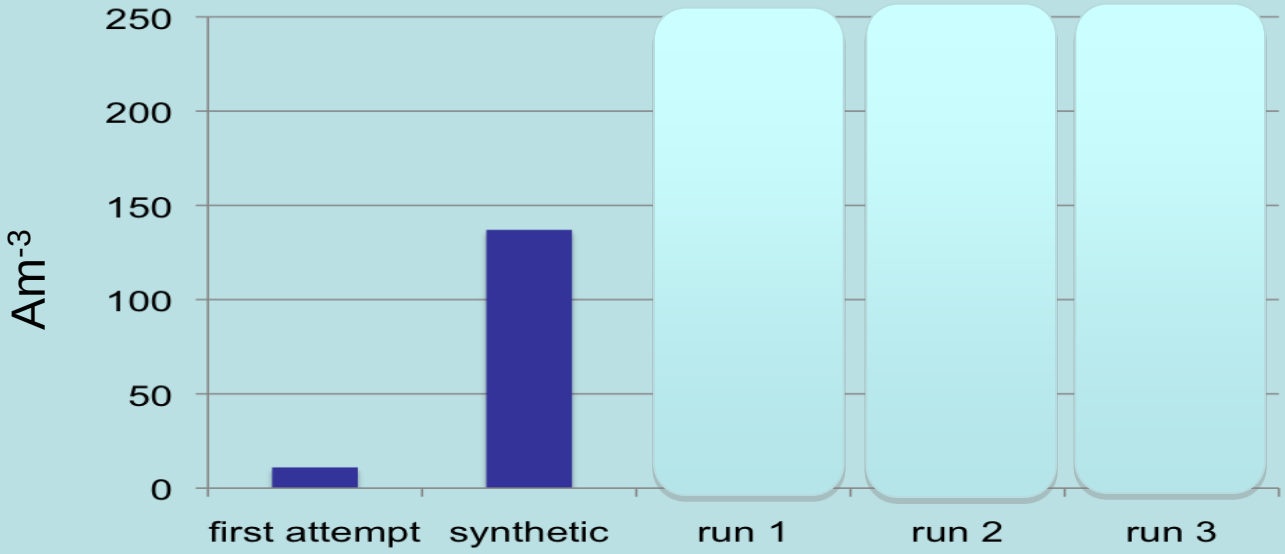
-300mV vs Ag/AgCl



run 1 = 1/3 ferm.eff + 2/3 MQ

run 2 = 1/3 ferm.eff + 2/3 MQ + phosphate buffer

run 3 = 1/3 ferm.eff + 2/3 MQ + NaCl/KCl mix

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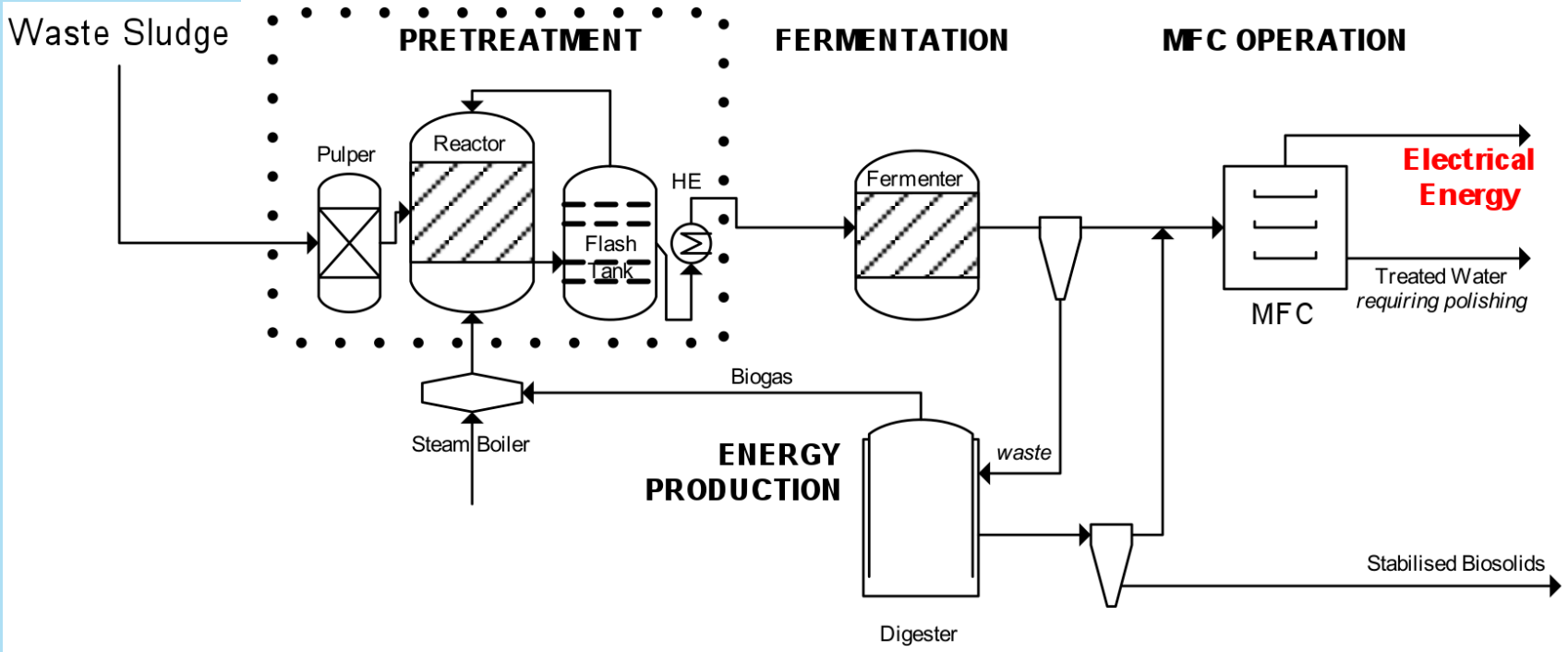
Operating a MFC with real fermented hydrolysed biosolids… **FINDINGS**

Run	*Set-point potential of -300mV vs Ag/AgCl*	VFA [mg/L]	MFC effluent pH	Current density [Am^{-3}]	Coulombic Efficiency {COD-VFA} [%]
Syn	**Synthetic sample**	360	6.77	137	50
4	1/3 ferm.eff + 2/3 **syn buffer**	398	7.1	155	85
5	1/3 ferm.eff + 2/3 AD effluent	390	7.7	191	84
6	1/2 ferm.eff + 1/2 AD effluent	656	7.6	216	82
7	3/4 ferm.eff + 1/4 AD effluent	800	7.2	215	96

Integrating concept into WWTP



Next step is to figure out what to do at the cathode – energy or value-added products?

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Australian project work was funded through International Science Linkages scheme of DIISR

Australian Government
Department of Innovation Industry, Science and Research

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Project teams at AWMC, UQ and LabMet, UGent

6th International Conference on Sewer Processes and Networks

7-10 November 2010

Surfers Paradise, Gold Coast, Australia

http://www.spn6.net

FULL PAPER OR EXTENDED ABSTRACTS DUE 3 MAY 2010