EPSRC
Engineering and Physical Sciences Research Council

Newcastle University

Getting ~~The Most~~ Out Of Sludge

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nufeb

The largest single arch railway bridge:1725

Roman design: unchanged since 179 BC

Causey Arch, Built 1725

Largest Railway Bridge 1882

- Designed in the 1880s
- Design grounded in sound structural theory of Maxwell and Rankine

Sludge and Thermodynamics

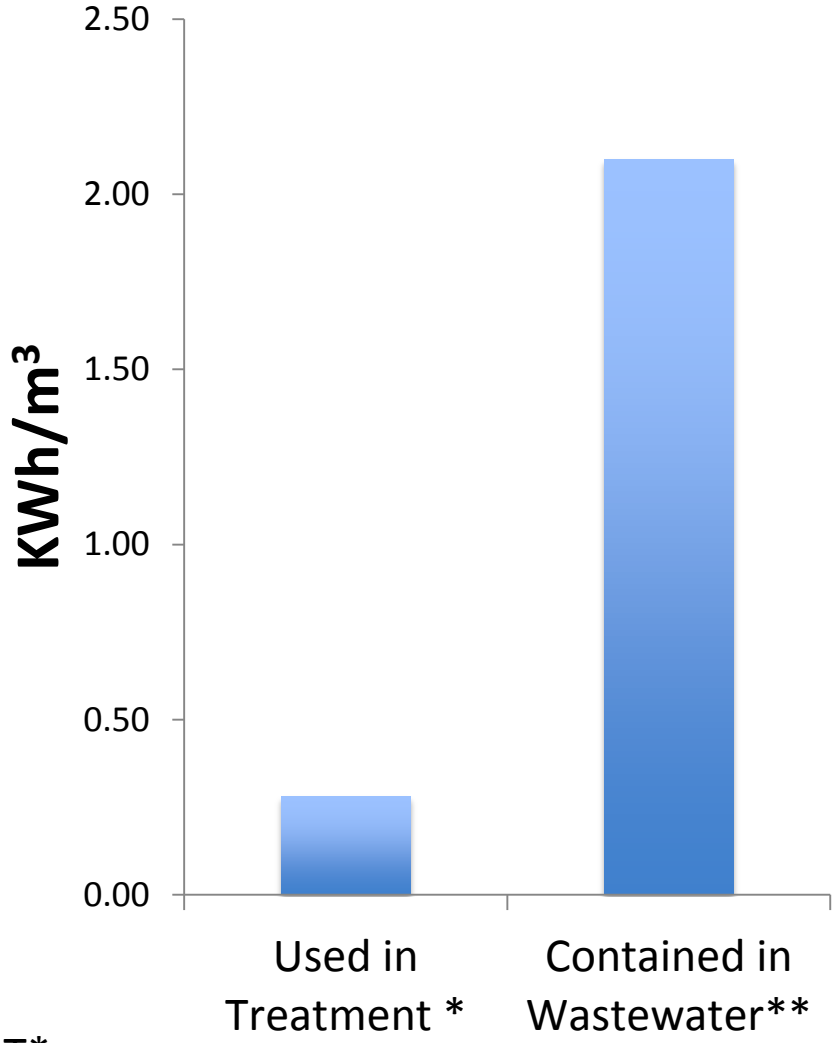
$$\frac{-\Delta G_{Cat}}{\Delta G_{Ana} + \Delta G_{dis}}$$

$-\Delta G^{01}_{cat}$ Aerobic Heterotrophs = 2942 (kJ/moleDonor)

$-\Delta G^{01}_{cat}$ Anaerobic Fermenters= 136 (kJ/moleDonor)

Sludge is an inevitable consequence of using oxygen as a terminal electron acceptor

Energy in Wastewater: 8Kj/litre

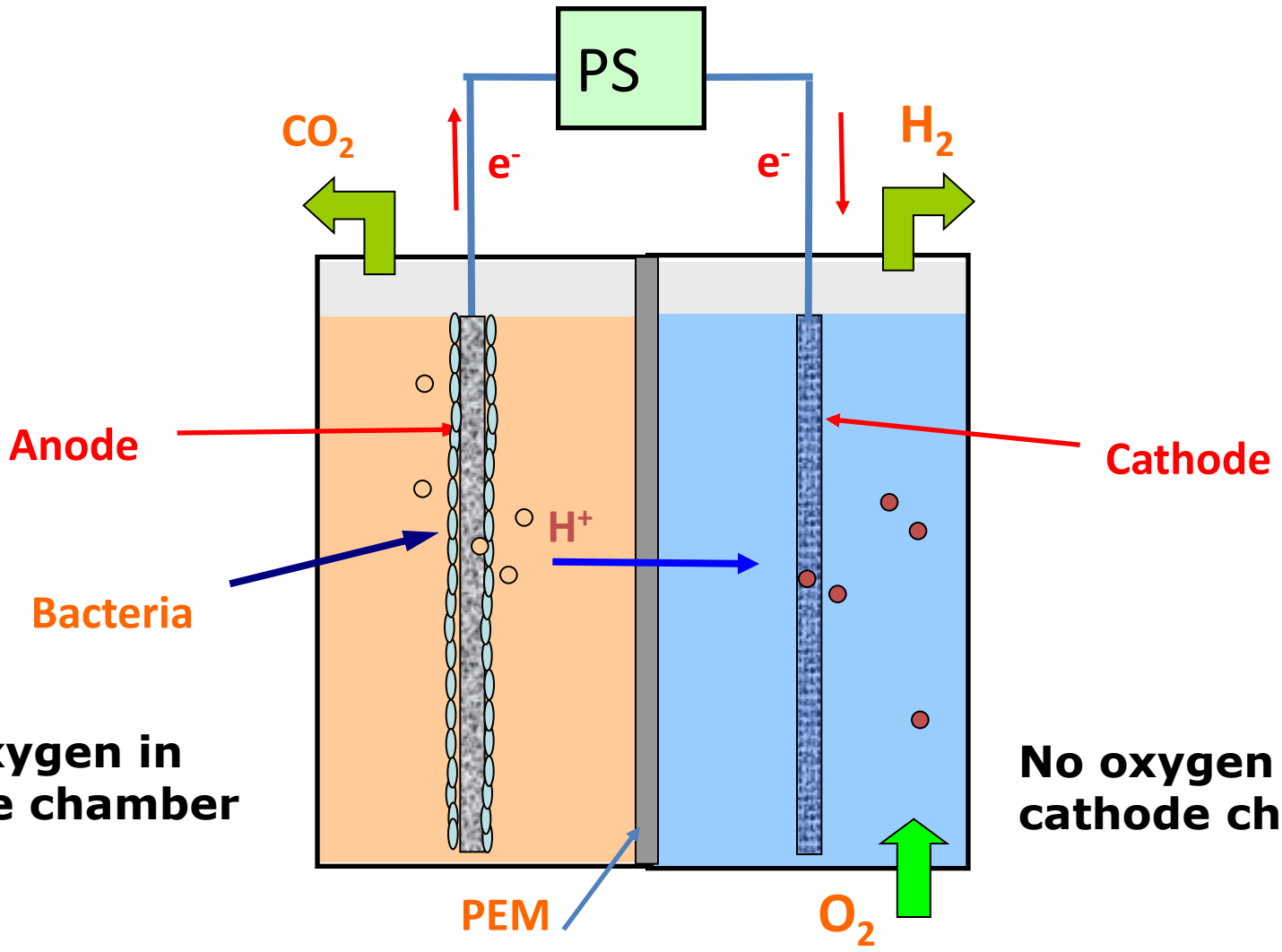


Heidrich et al., 2011, ES&T*
Northumbrian Water 2013*

Change Your Electron Acceptor Change Your Thermodynamics

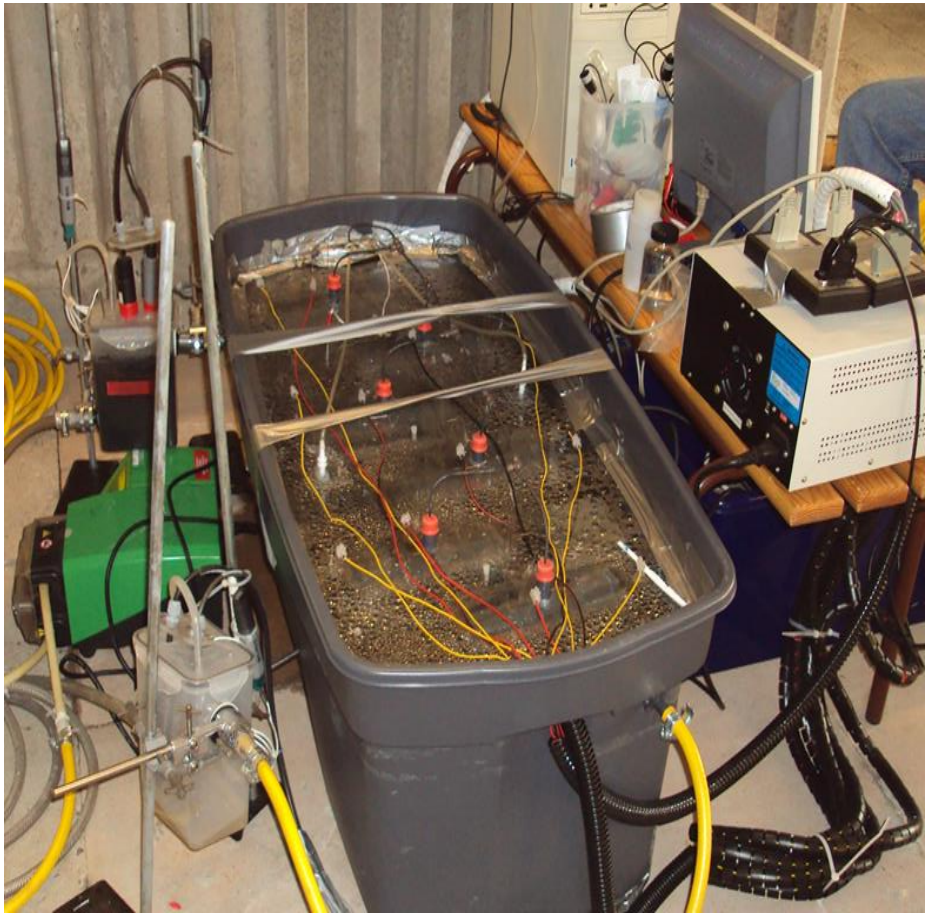
- 1. An Electrode
  - Microbial Electrolysis Cell
- 2. CO_2
  - Anaerobic Wastewater Treatment

Microbial Electrolysis Cell: Make Hydrogen from Sewage



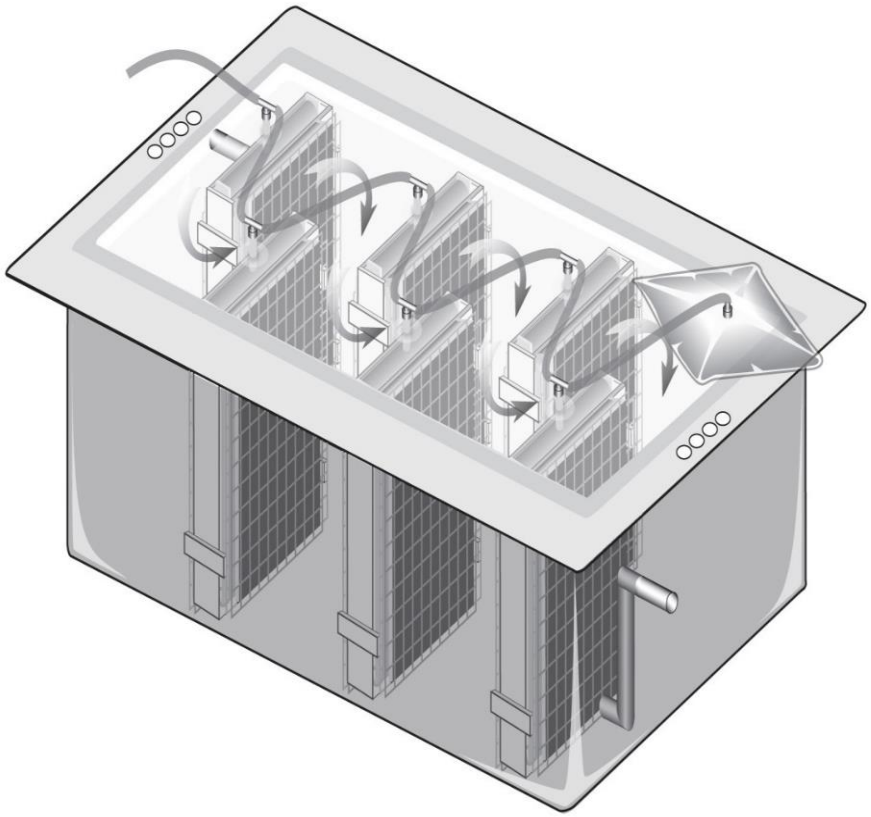
Simple Designs

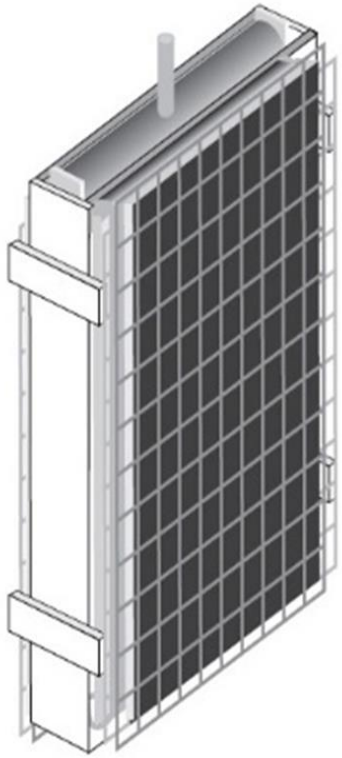
- Low load
- Low temperatures
- Cheap materials



But we understood the principles

- Rare electrogenic microbes + low temp = long start up
- Membrane needed (microbes eat H_2)
- Design – simple, low cost, retrofittable, scalable – (now $1m^2$)





And so - it works

- 0.6 L/day of 99% pure hydrogen for 12 months
- Gas production continuous
- Average 50% of the electrical energy input was recovered
- Average COD removal 44%
- Volumetric loading rate was 0.14 kgCOD/m^3/day,

Heidrich et al. 2013, 2014.

But it does not pay (yet)

- Longer Reactors for COD removal
- More efficient 3D Anodes
- Improved H_2 recovery
- Break even vs Activated Sludge ~ 5 years

Full Scale Domestic Wastewater Treatment in UASB (PE ~1000,000)

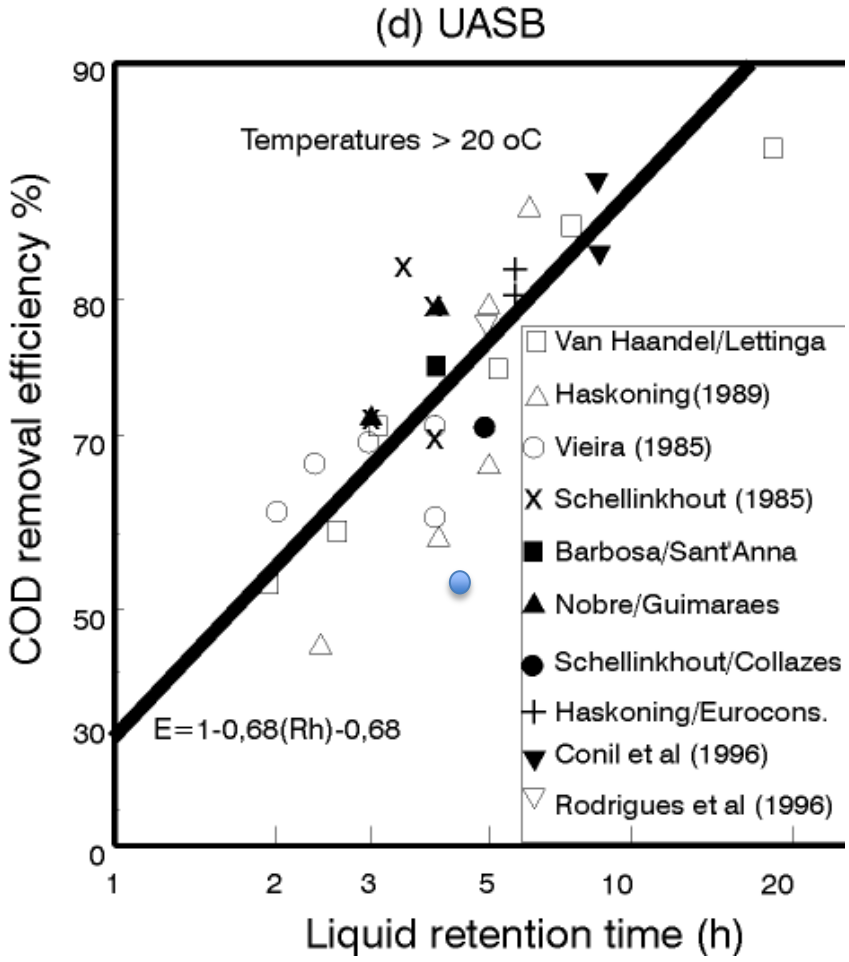
Minas Gerais, Brazil

UASB in The UK

- Great work in Cranfield
  - UASB
  - Membrane Reactors
    - Energy negative
- Struggle at <10^{o}C

Thank you: Bruce Jefferson and Ana Soares

UASB Key Details: reactor size

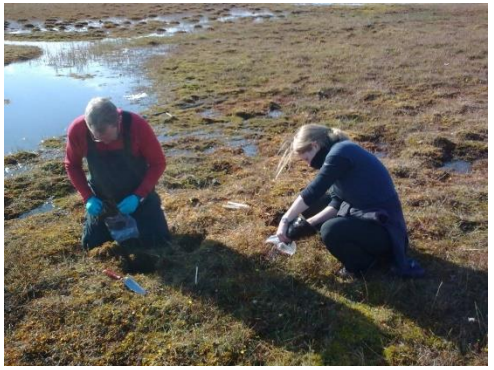


Van Haandel in preparation

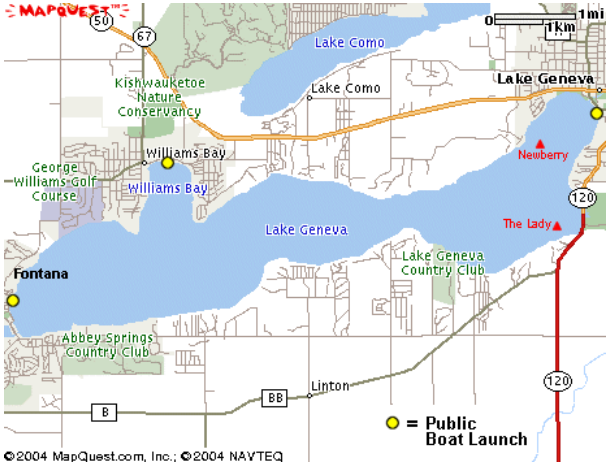
- Design by HRT
- Design Guidelines all at > 20 ^{o}C.

Looking For Low Temperature Anaerobes

Svalbard, in the high Arctic ''N78º, E11, 15,16º'' (average temperature -16 – 6 ºC)

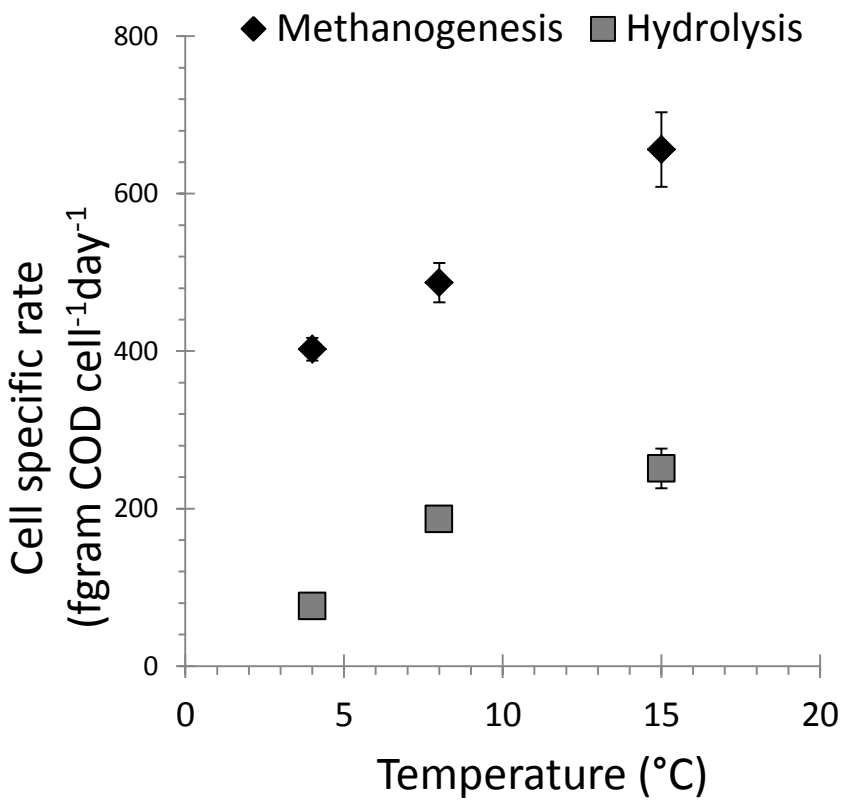


Lake Geneva ''N 46º23'04'', E 6º25'07'' (average temperature -11 – 17 ºC)



Activity Down to 4°C

- Totally Different Bacteria
- COD Removal < 100 mg/l at 4°C
- Methane at 4°C

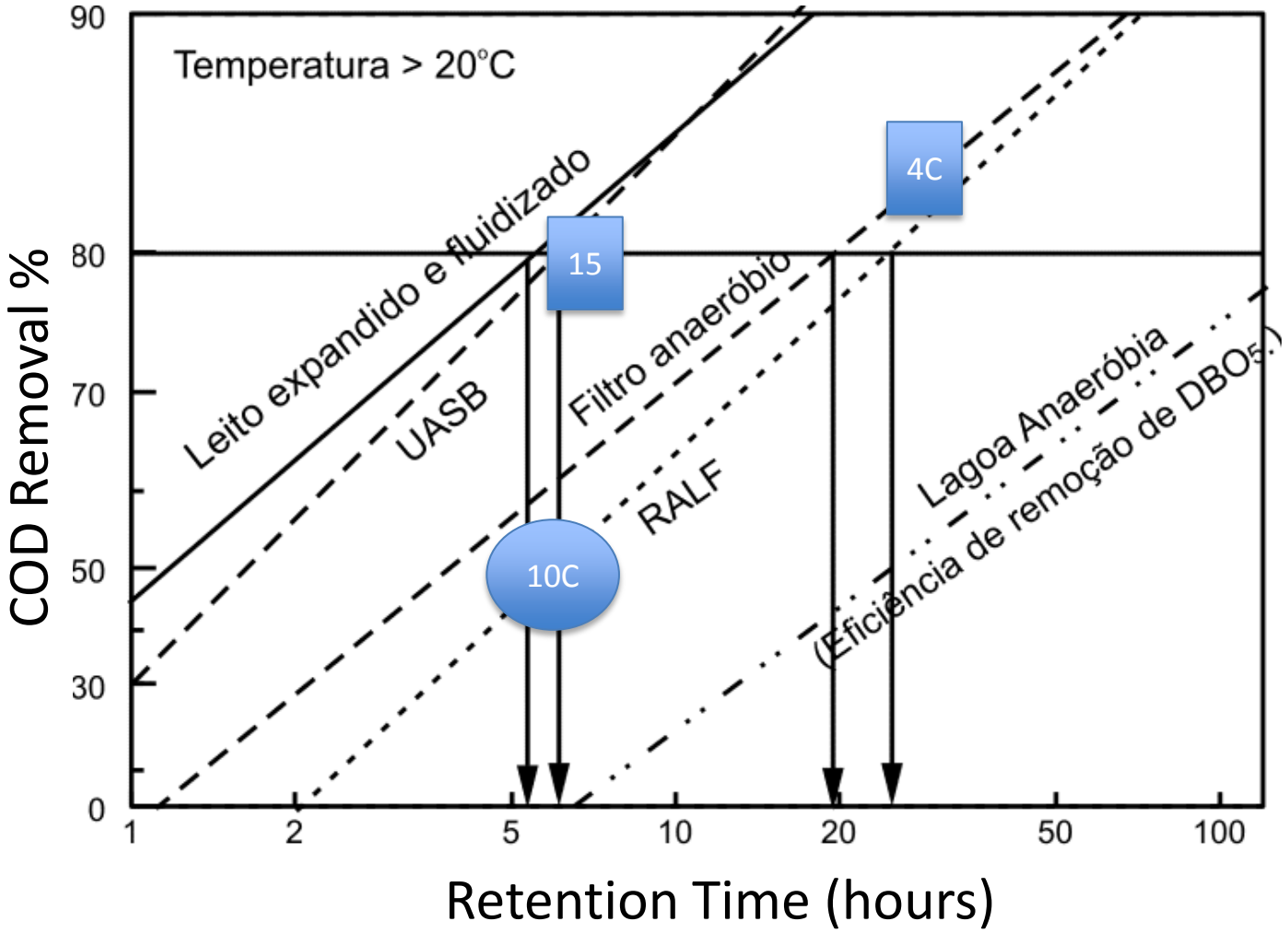


Sizing a reactor

Temperature °C	COD Turnover (fg/cell/day)	No. of Cells for Hydrolysis 100g COD	Reactor (m^3/person)
4	76	1.32×10^{15}	0.132
8	186	5.38×10^{14}	0.0538
15	250	4.00×10^{14}	0.04

Temperature °C	CH_4 Turnover (fg/cell/day)	No. of Cells for Methanogenesis of 100g COD	Reactor (m^3/person)
4	6.3	1.32×10^{15}	0.254
8	7.6	5.38×10^{14}	0.211
15	10.25	4.00×10^{14}	0.156

Are we there yet?



Van Haandel 2014

Get out of sludge!

- If you have O_2 you have sludge
  - "Yen canna break the laws of physics"
- Microbial Electrolysis Cells
  - "Works" at low temp
  - Not yet economic
- Anaerobic Domestic Wastewater
  - Can be done
  - Temperature problem close to solution

Anaerobic Domestic Wastewater Treatment

Thank You

My Colleagues in Newcastle