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Water Sensitive Cities

4th water sensitive cities conference

Australian Government
Department of Industry and Science

Business
Cooperative Research
Centres Programme

Purple Phototrophic Bacteria: a silver bullet for effective resource recovery from wastewater?

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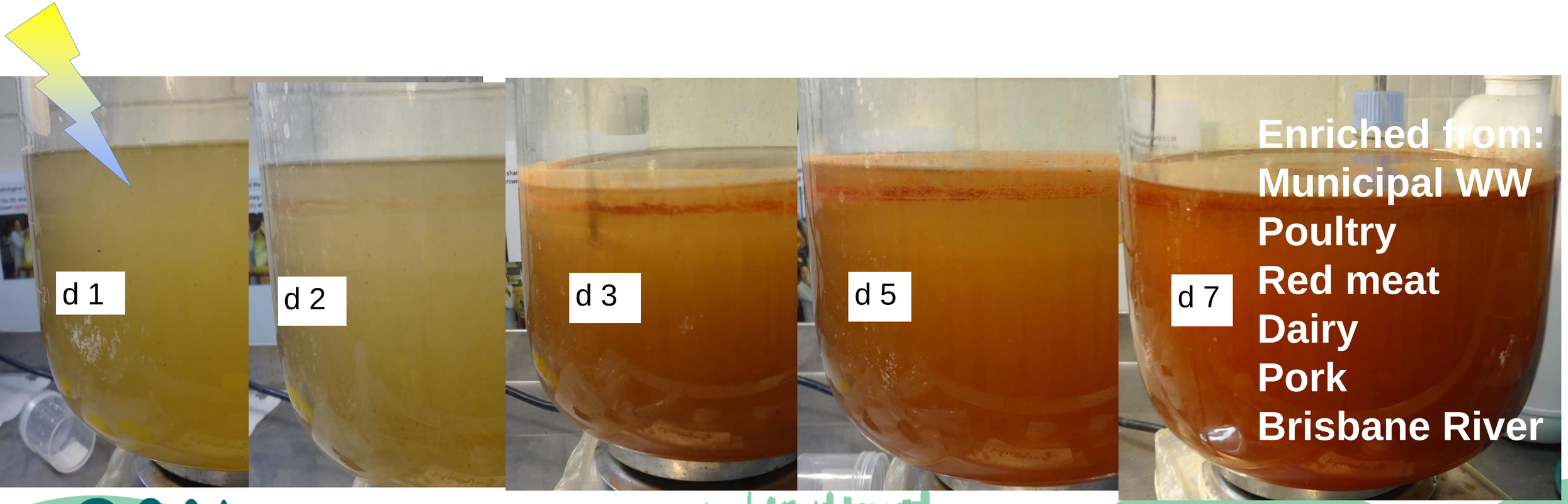
THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CREATE CHANGE

Purple phototrophic bacteria for resource recovery – Why?

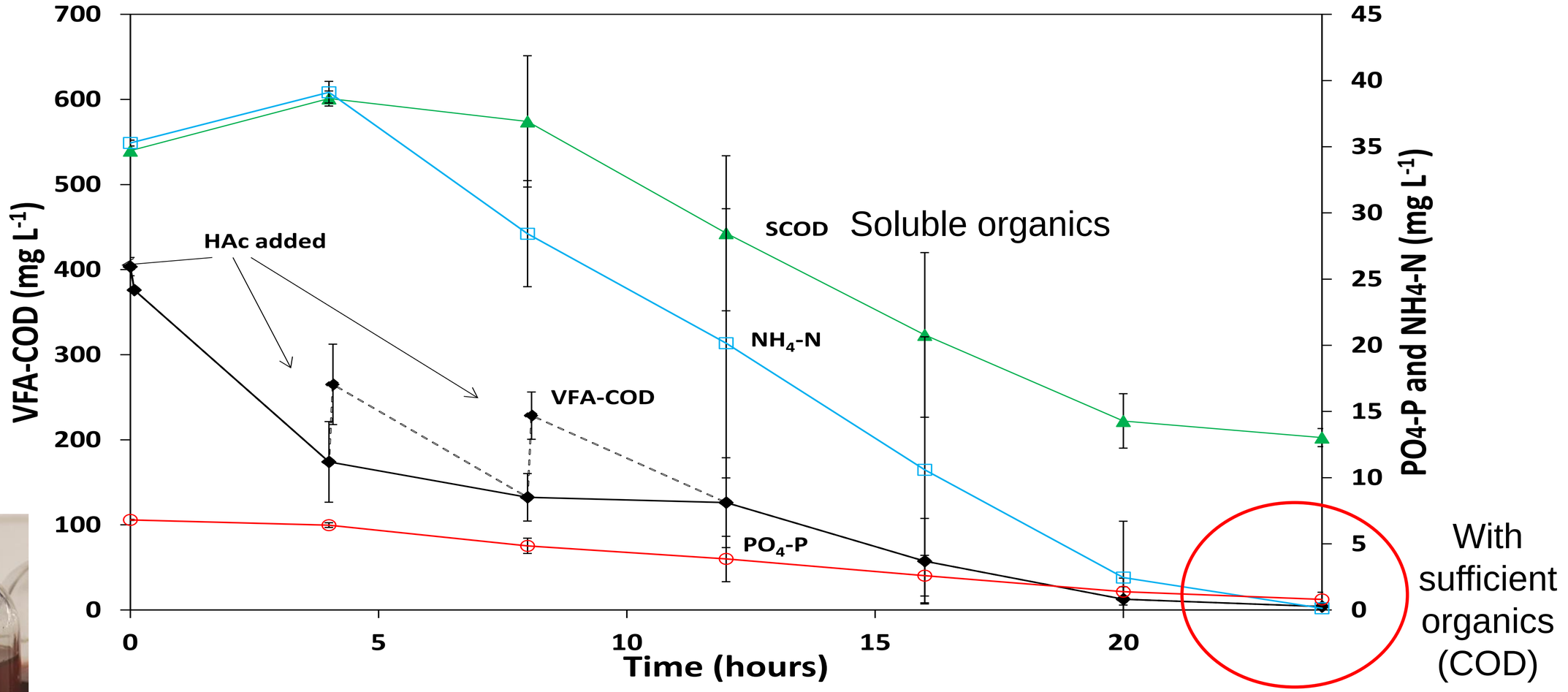
- Ubiquitous – enrichment without inoculum in ~7 days from almost every source
- Anaerobically selected by IR light via Bacteriochlorophyll A, B (>800 nm)



Purple phototrophic bacteria for resource recovery – Why?

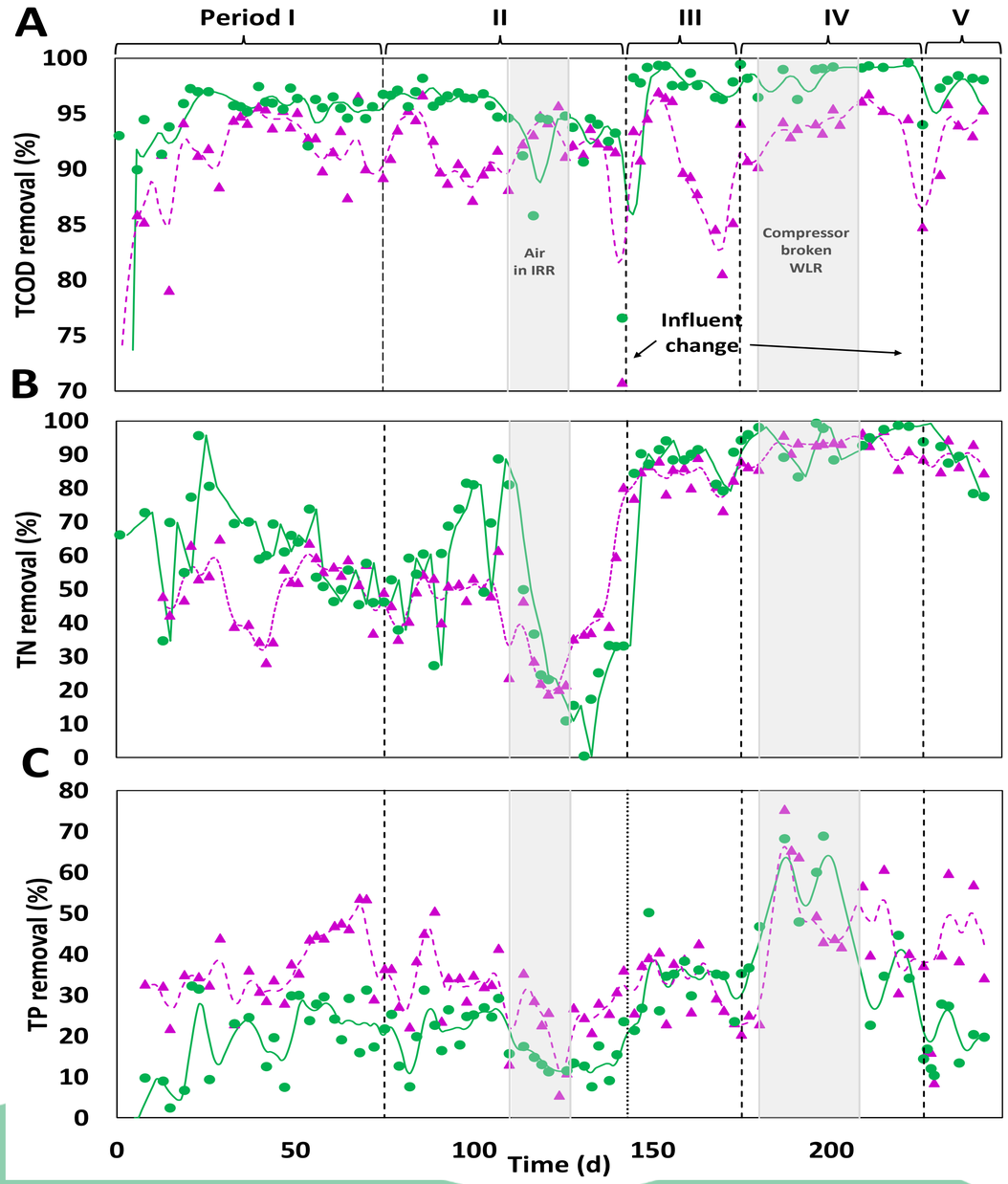
- Purple phototrophic bacteria are anoxygenic phototrophic organisms and generate ATP from light (infrared) while growing preferably photoheterotrophically
- Organics (mainly VFAs) can be assimilated into biomass, resulting in yields close to 1
- N and P are assimilated/accumulated (**up to 60% Crude Protein Content**)

Domestic wastewater treatment with PPB



Simultaneous organics, nitrogen and phosphorous uptake.
For every 100 g of organics (COD) ~9 g of N and 1.5 g of P – Anaerobic!

Agri-industrial wastewater-continuous (poultry processing wastewater)



- 9.0 kWh $m^{-3}_{treated}$
- Illumination: 7.0 MWh $tonne^{-1}$ PPB or ~\$1400 $tonne^{-1}$ @20cent kWh^{-1}

+ Harvesting costs (up concentration)
+ Drying/sterilization costs

Total costs >\$2000 $tonne^{-1}$

What is the value of the produced PPB biomass?

Purple phototrophic bacteria as microbial protein

Feed component	Fishmeal	Rendered Meat Meal	Poultry by-product meal	Blood meal	Soybean meal	PPB
Total Protein (wt%)	**64.5**	**55.6**	**59.7**	**89.2**	**50**	**63.7**
Amino acids (wt%)						
Leucine	4.48	2.85	4.11	10.82	3.63	3.4
Valine	2.77	2.52	2.86	7.48	2.55	2.5
Arginine	3.82	3.6	4.06	3.75	3.67	2.3
Phenylalanine	4.35	4.35	2.99	3.97	4.2	2.2
Threonine	2.31	1.64	0.94	3.76	1.89	2.1
Lysine	4.72	2.93	3.06	7.45	3.08	2
Isoleucine	2.66	1.64	2.3	0.97	2.14	1.9
Methionine	2.31	1.25	1.94	2.32	1.43	1
Histidine	1.45	0.89	1.09	5.14	1.22	1
Trypthophan	0.57	0.34	0.46	1.04	0.69	
Price AUD ton^{-1} (dry)	**1860- 2280**	**400-600**	**400-600**	**870-1160**	**390-440**	**330 – 2250**
Protein price in $ kg^{-1}	**2.9 – 3.5**	**0.7-1.1**	**0.7-1.0**	**1.0-1.3**	**0.7-0.9**	**0.7 – 3.5**

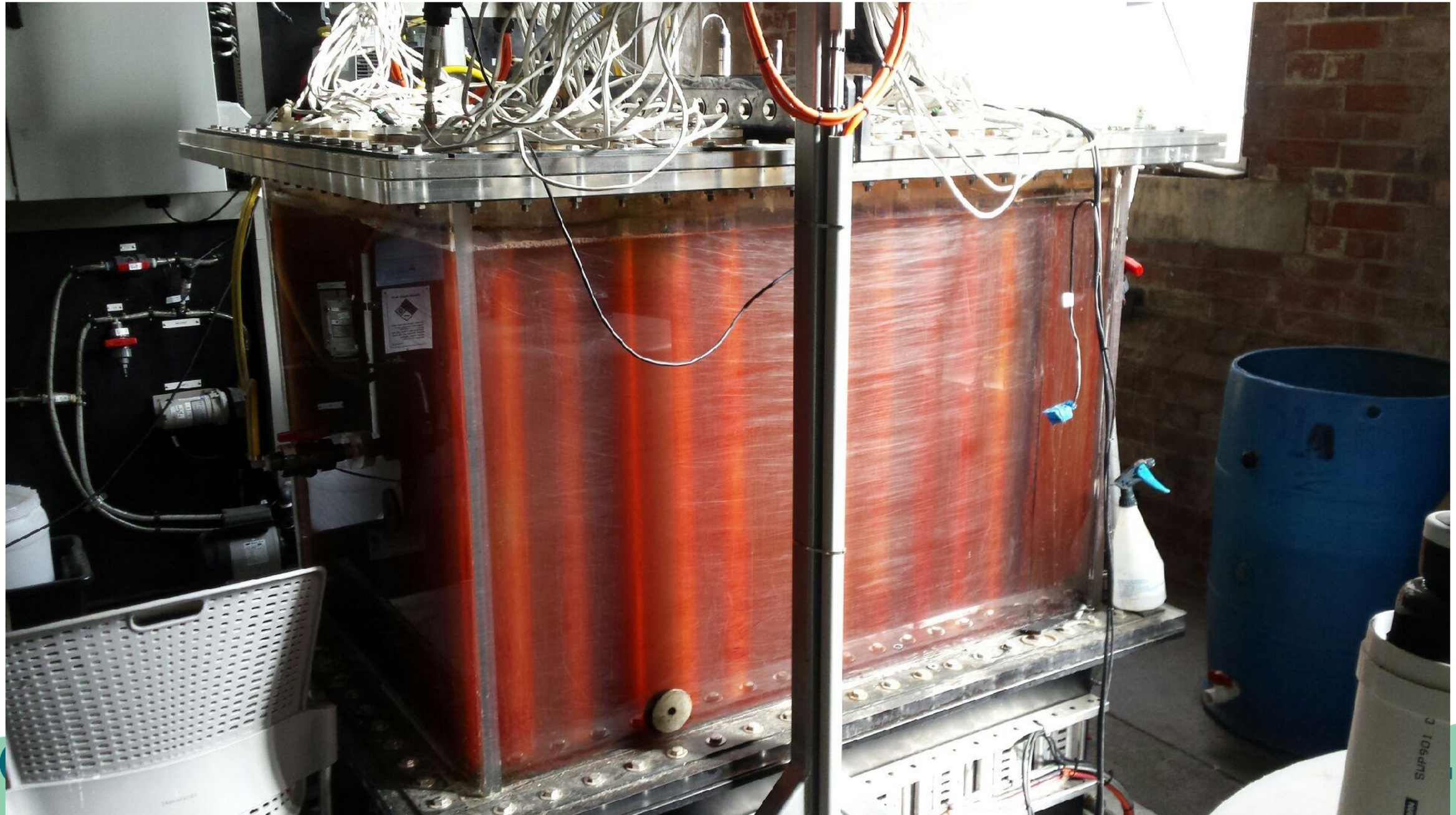
Wastewater as substrate for microbial protein production

- Resource recovery, zero substrate costs
- Savings of COD, N, P discharge costs
- Revenue from product

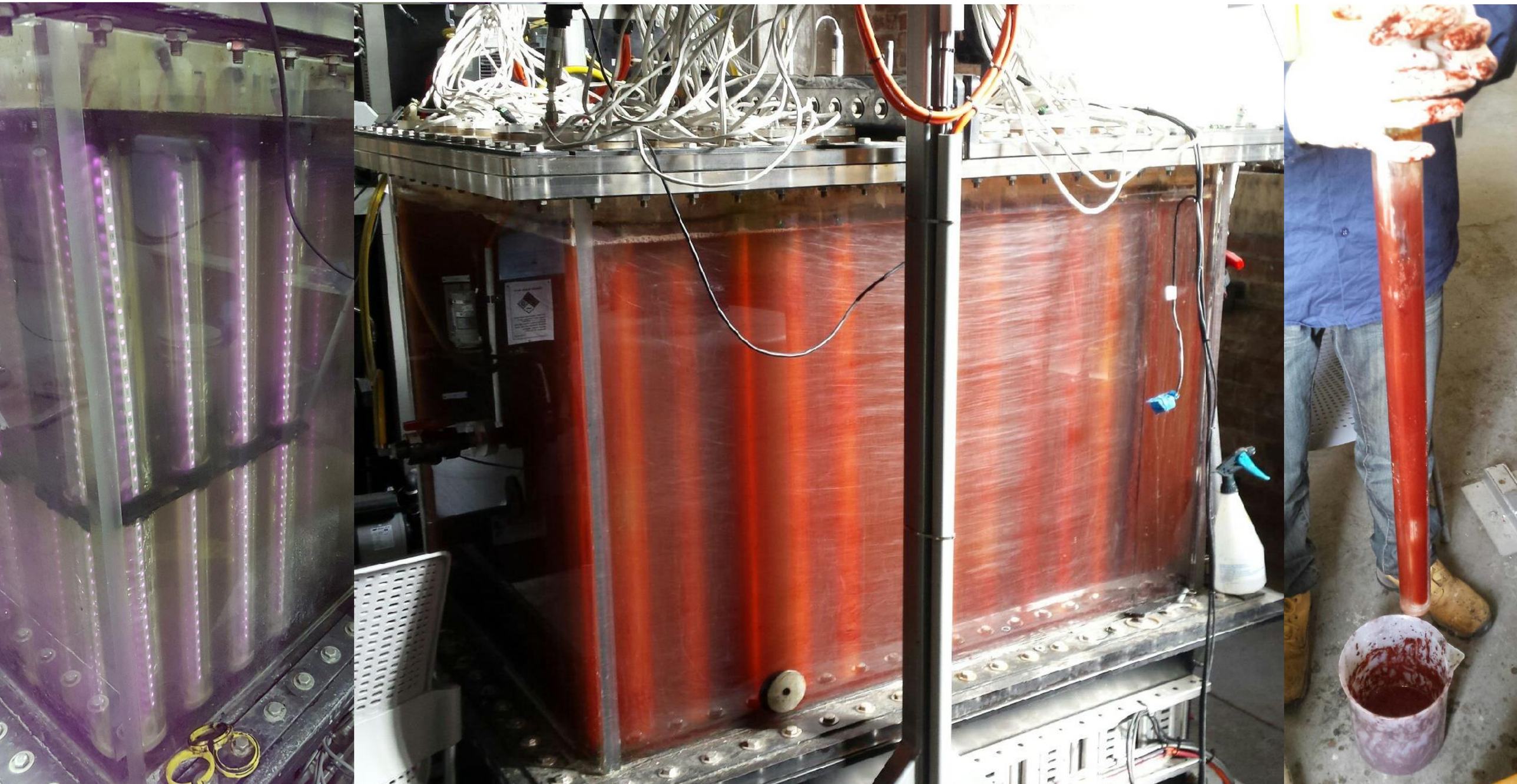
- Mixed cultures problems, grazers, variable product quality, consistency, toxic constituents, pollution

- **<u>Country specific legislation – not straightforward</u>**

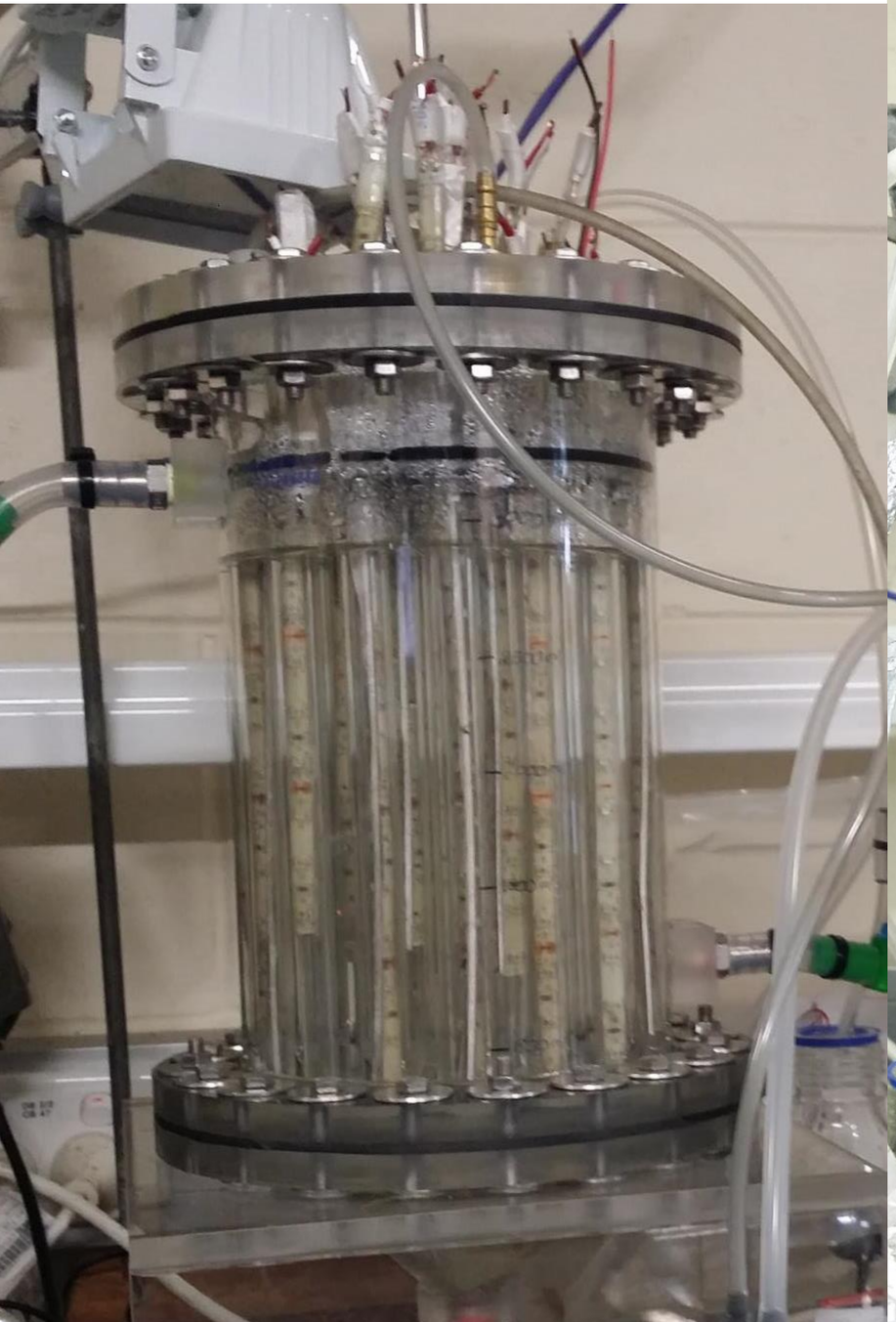
Attached growth (biofilm) PPB systems for microbial protein production

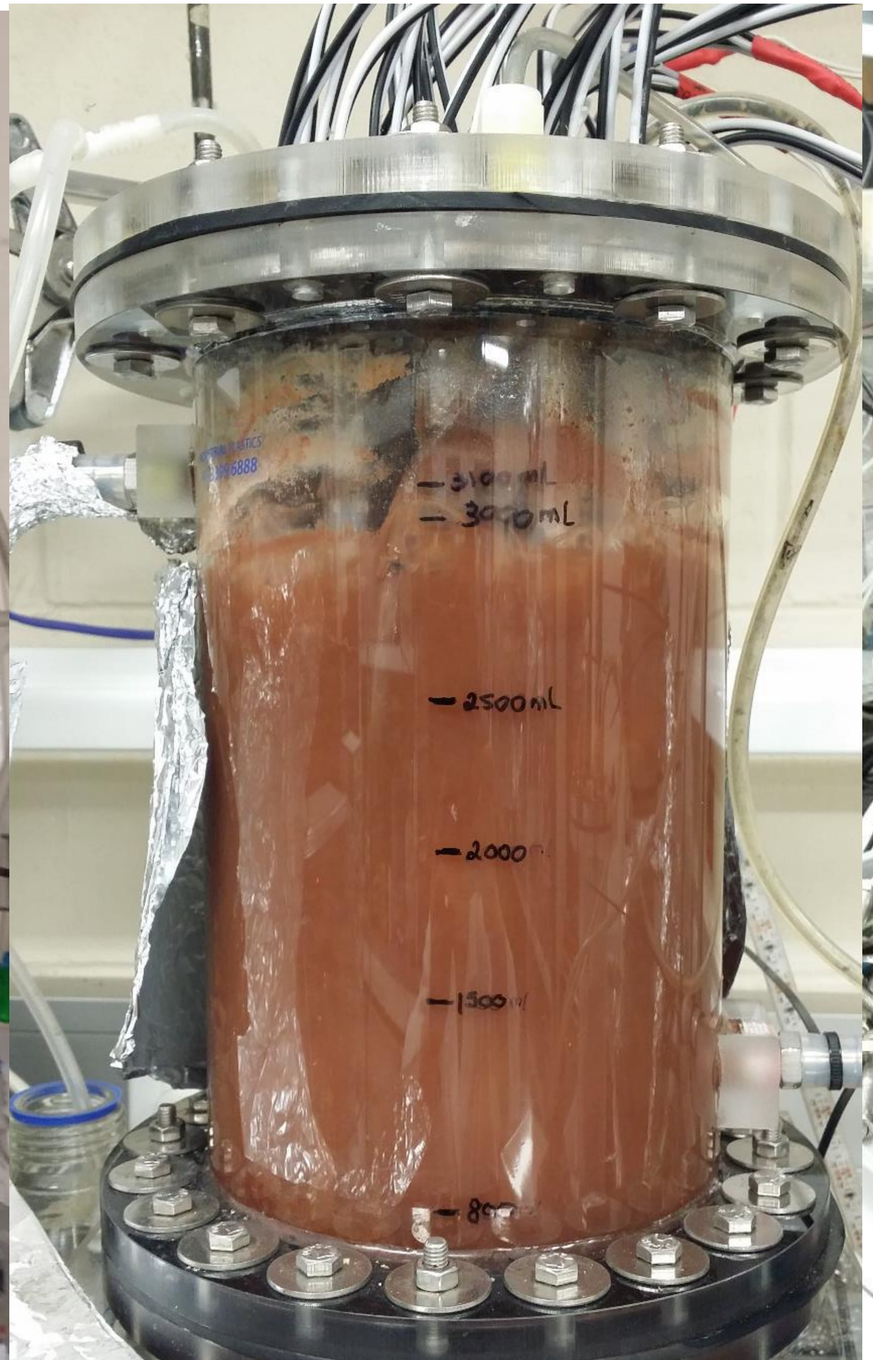


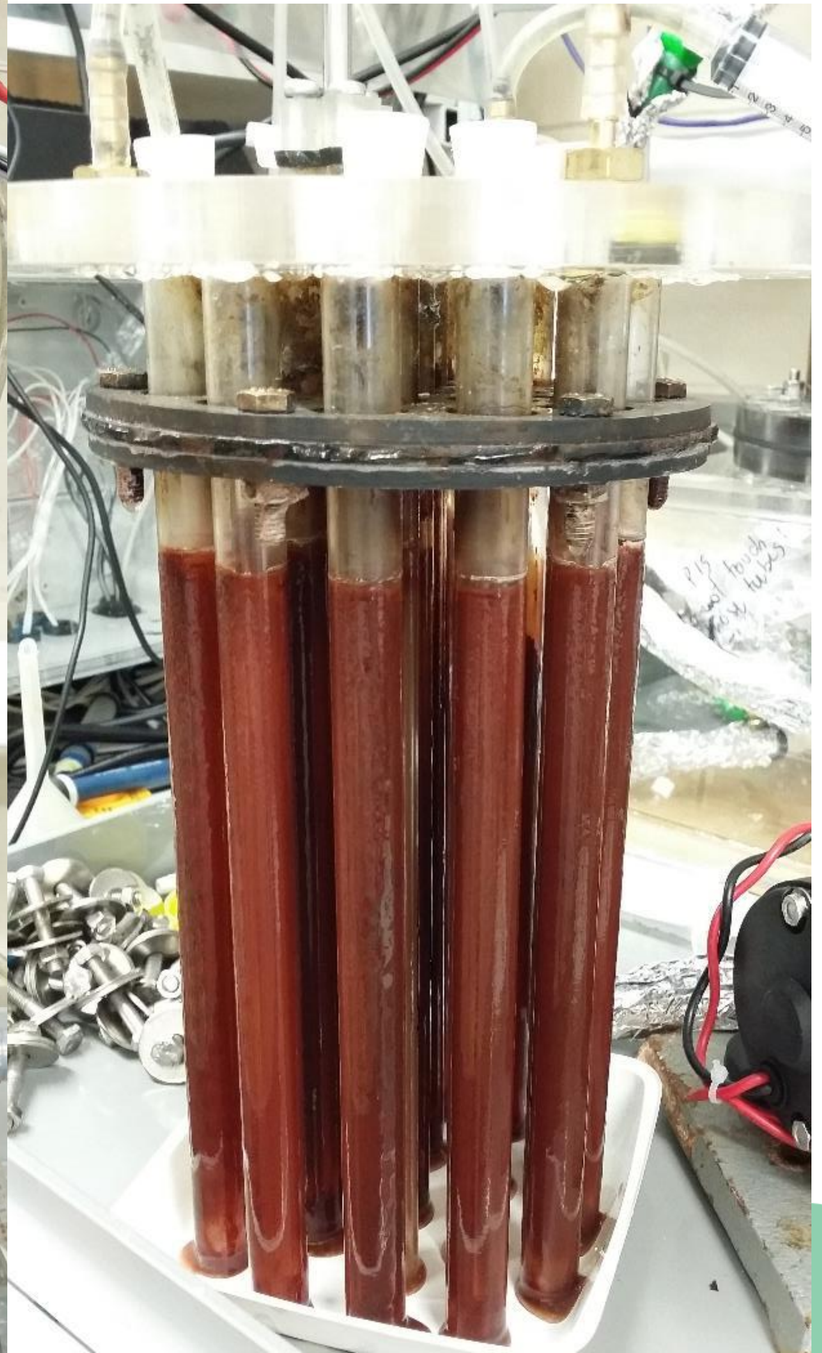
Attached growth (biofilm) PPB systems for microbial protein production



Attached PPB treating red meat processing wastewater



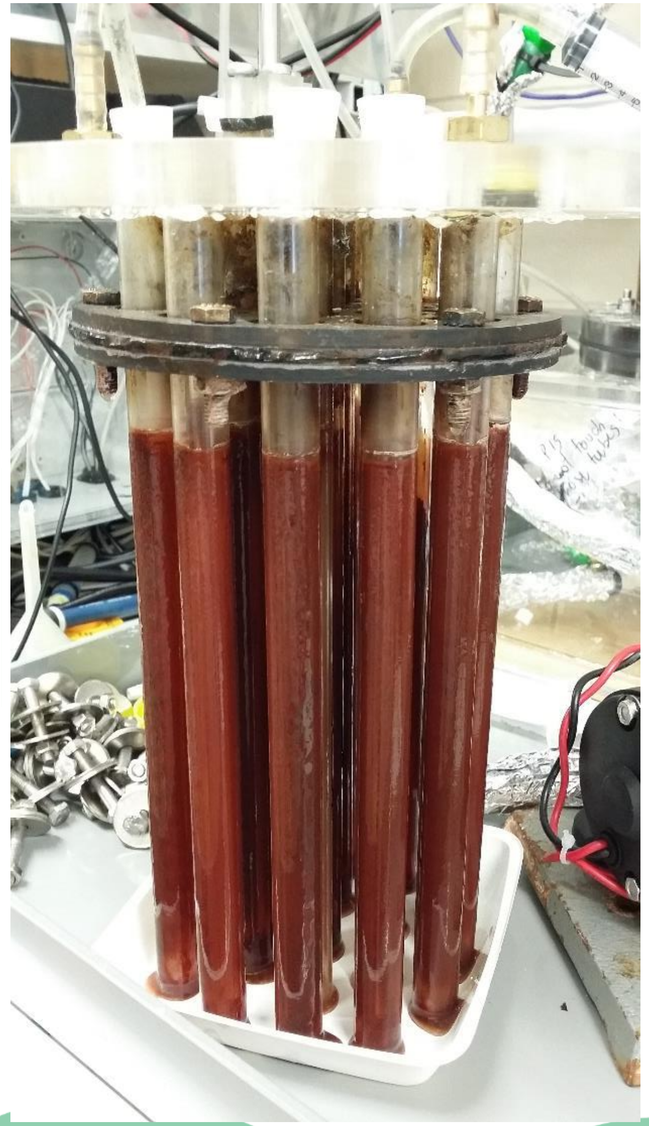




Attached PPB biomass characteristics

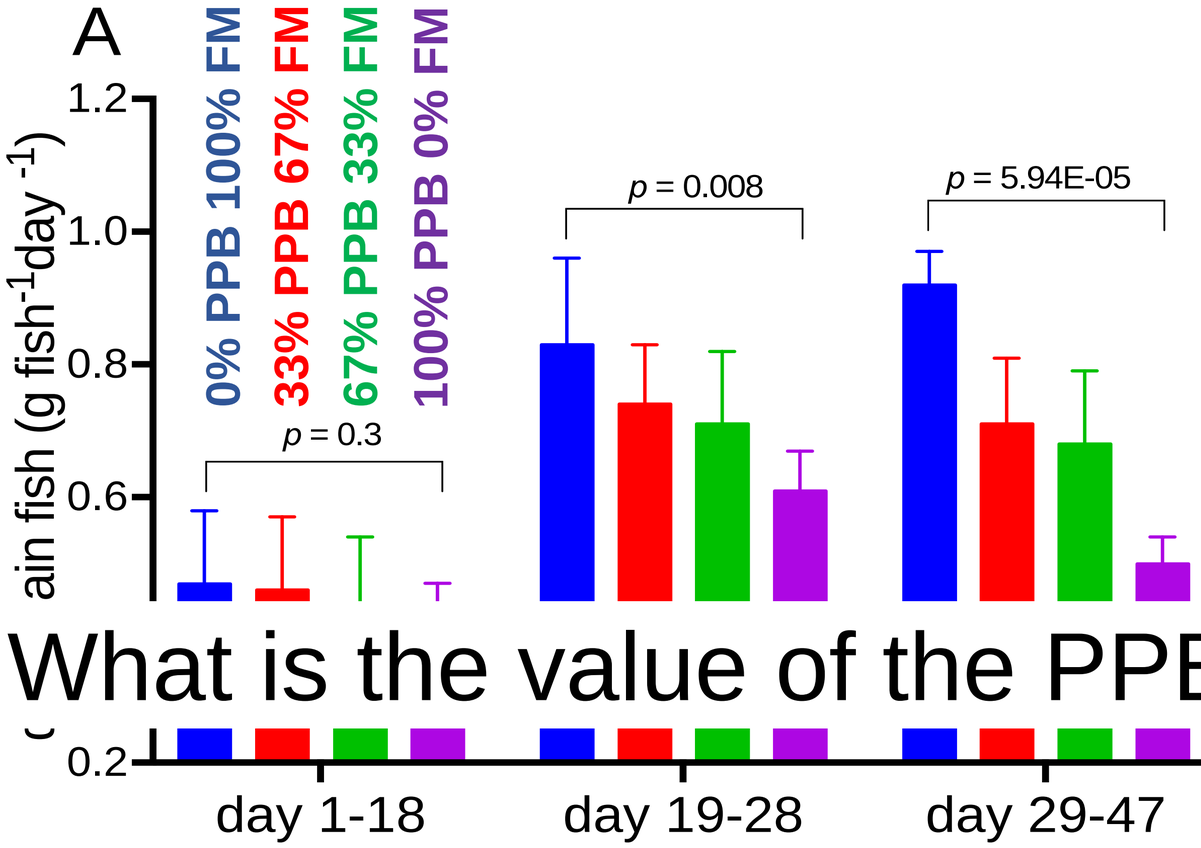
n=36

	Unit	B1-3	B4-6	B7-12
TCOD/VS ratio	(-)	1.8±0.06	1.8±0.15	1.7±0.05
Crude protein	g gVS^{-1}	0.6 ±0.03	0.6±0.05	0.6±0.02
Nitrogen	mgN gVS^{-1}	103±0.004	102±0.01	104±0.004
Phosphorus	mgTP gVS^{-1}	14±0.001	13±0.001	13±0.001
Volatile solids	g L^{-1}	61±15	99±16	158±31
Organic fraction	% VS of TS	96±3.5	96±2.7	94±1.3
Bacterio chlorophyll	mgBChl gVS^{-1}	-	22±7.4	24±5.1
Total carotenoids	mgCarot gVS^{-1}	-	10±4.0	11±2.8



Attached growth (biofilm) PPB systems for value add products

Barramundi feed trials: Substitute 33, 66 and 100 % of fishmeal in commercial feed with PPB



What is the value of the PPB biomass?? 2000$/tonne??

What are the PPB biomass production costs

Artificial illumination + up concentration + drying/sterilization >$2000 per tonne

Natural illumination:

- Illumination costs are zero (-$1400)

Attached (biofilm) growth:

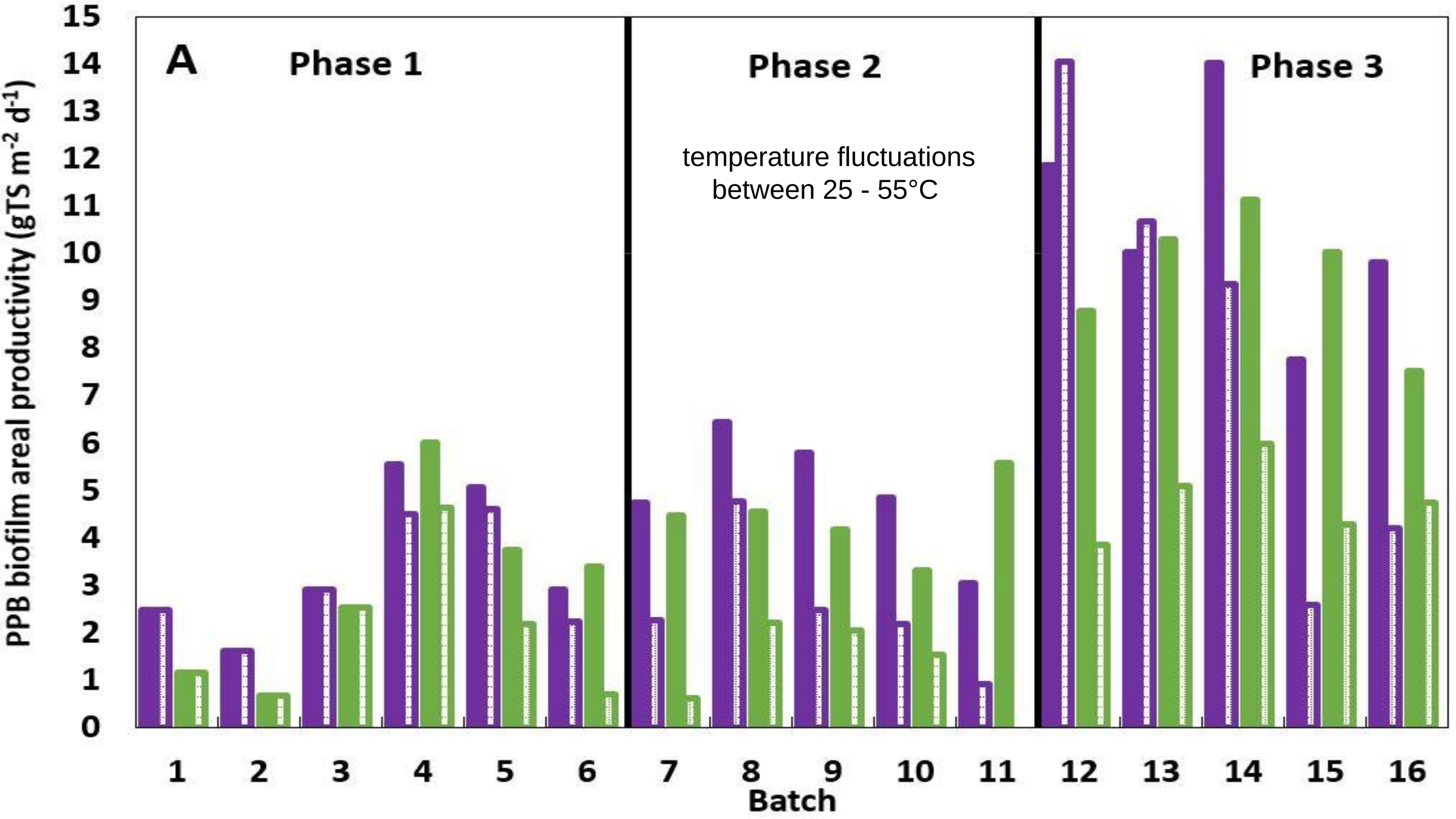
- Substantially reduces harvesting costs as biomass can be harvested ~16% dry -no centrifuges, flocculants etc…

Dewatering :

- Dewatering costs will be the same.

Sterilization

- Sterilization costs remain, it is grown on wastewater!!


A
Phase 1
Phase 2
Phase 3
temperature fluctuations
between 25 - 55°C
PPB biofilm areal productivity (gTS m-2 d-1)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
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2
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12
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14
15
16
Batch

The potential of PPB technology as silver bullet application?

Potential advantages

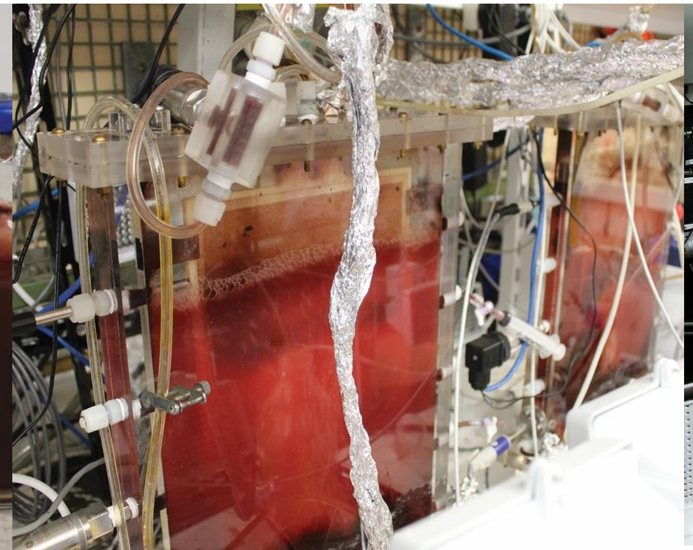
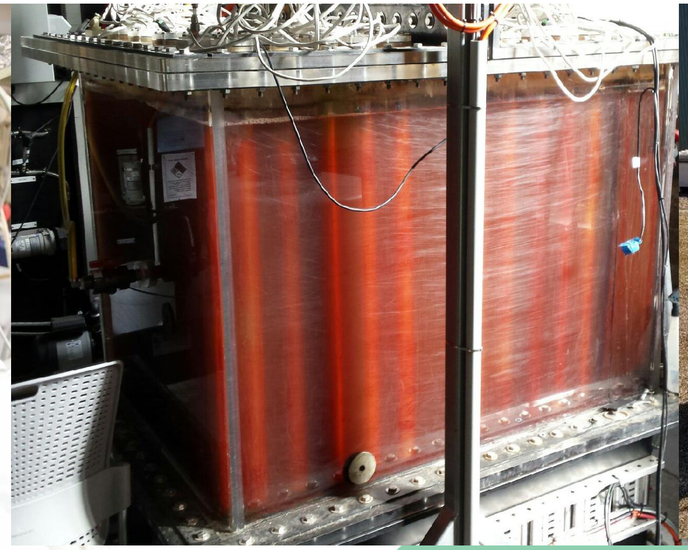
- Primary treatment on a vast range of wastewaters (no niche technology)
- Simultaneous removal of COD, N and P
- High biomass yields and consistently high protein content (>60%)
- Attached growth eliminates dewatering equipment, flocculants and allows for a consistent quality product – almost independently from the source
- Bulk substitution of fishmeal seems feasible ($/tonne??)

- No product inhibition e.g. from oxygen
- No sensors or controls used
- Heat(cold) resistant – no cooling required
- Zero substrate costs
- Anaerobic- no aeration required – reduces mixing energy!

The potential of PPB technology as silver bullet application?

Potential disadvantages

- Non-sterile source and legislative hurdles
- Reduced volumetric productivities due to biofilm
- Batch wise harvesting and associated downtime
- Incomplete wastewater treatment, residual COD, N and P in the effluent
- Harvesting needs to be optimized.


We are currently working on a demonstration plant as part of an Advanced Queensland Industry Fellowship with

GHD, Aquatec Maxcon, Ridley, Ingham, The Queensland Government as project partners

Acknowledgments

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