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EMBG Exeter Microbial Biofuels Group

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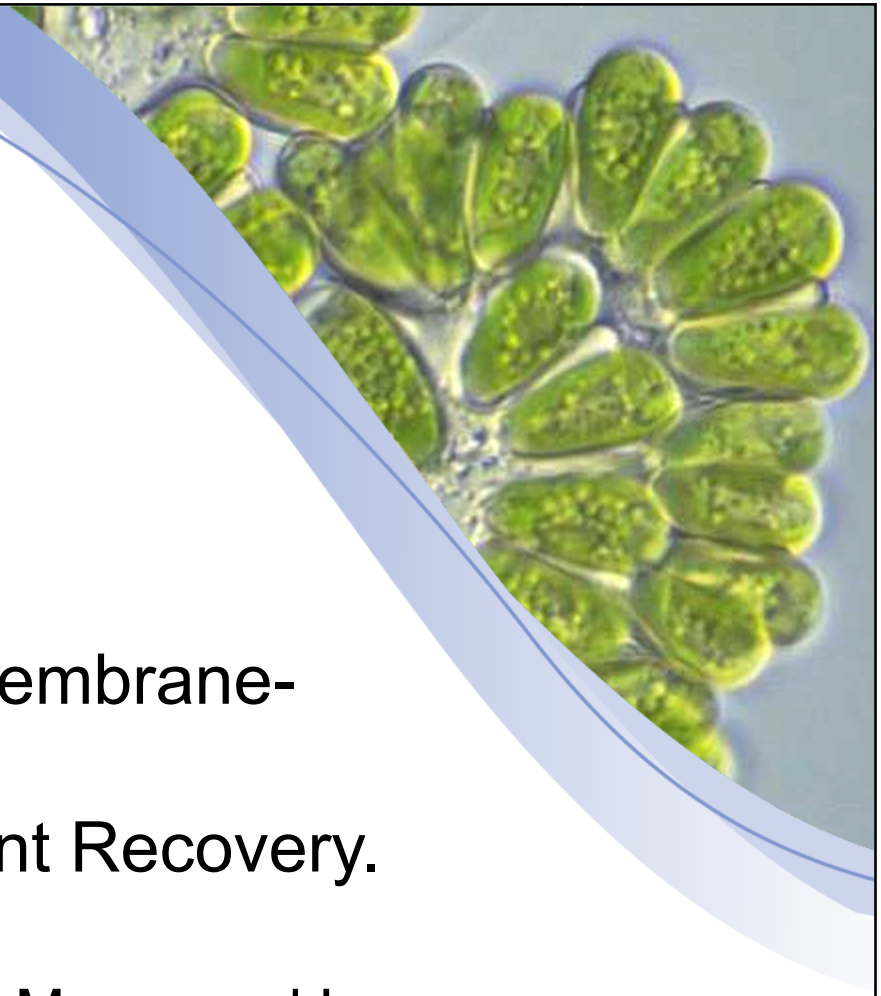

Cultivation of Microalgae with Membrane-Filtered Waste Water; Implications for Energy & Nutrient Recovery.

Pickett, Ozcan, Jean, Quiñones, Yeh, Moore and Love

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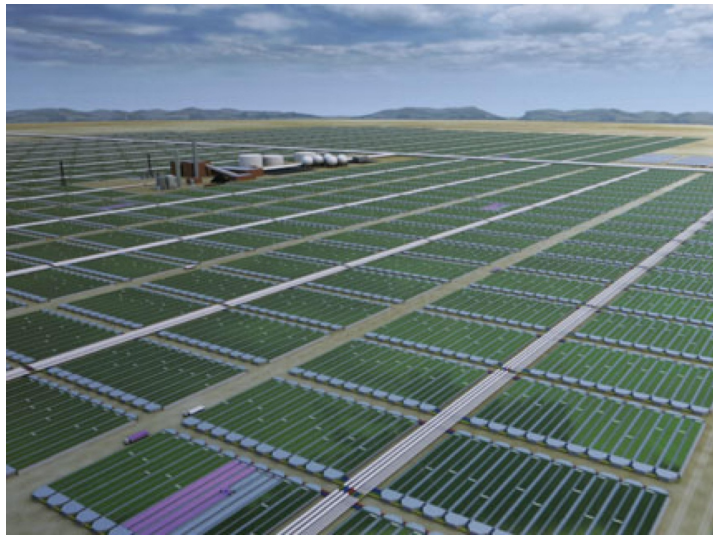
Advanced Biofuels from Algae

- Cultured on non-agricultural areas, marginal lands or in the sea.
- Highly productive compared to land plants.
- Less water use than for crops.
- Potential to recycle mineral nutrients from waste water.
- Fix CO_2.



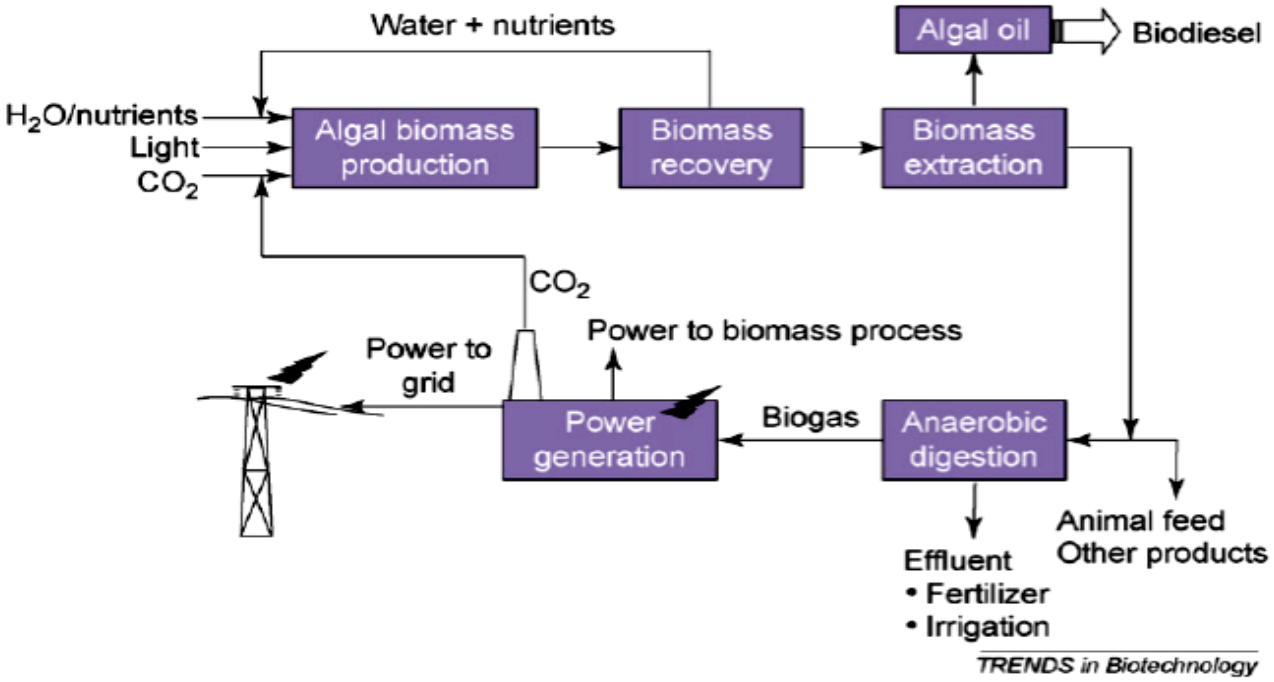
The Economic Barrier

- Algal products (biomass or oils) are too expensive compared to other biofuels to be profitable (land, CAPEX, culture type, predation, water pumping, harvesting, processing *etc*.

Biofuel

Breaking the Economic Barrier

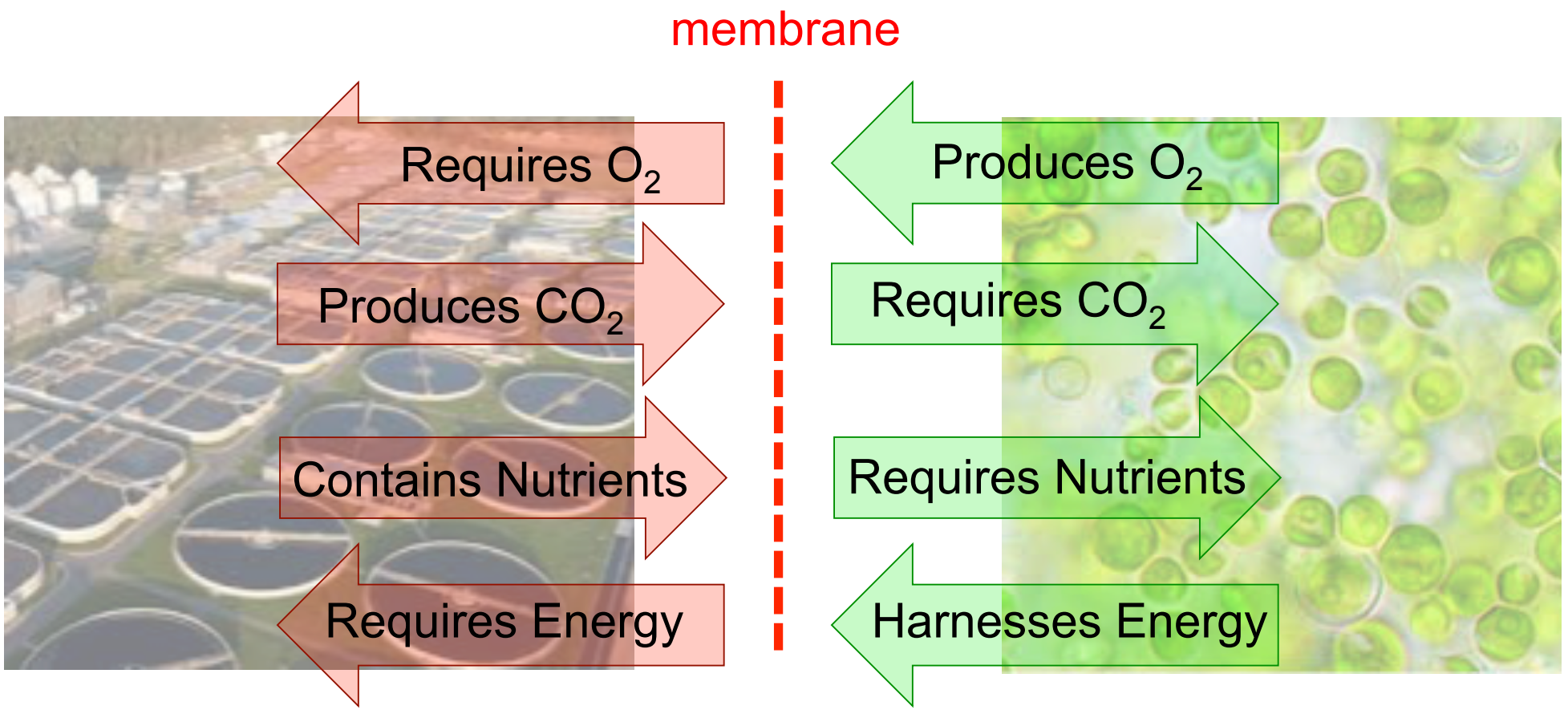
- Options are to piggy-back on other processes to develop the technology; alternative foods, protein, HVCs, cosmetics *etc.*
- The **Integrated Bio-Refinery** concept – Easy to say; Hard to do.



Research Incentive

- **Water and Energy Savings**
  - Treatment plants expend energy to remove nutrients before discharge.
  - Coupling algal cultivation with wastewater treatment – “Free” nutrient removal, a high value product and “how-to” knowledge.
- BUT, problems:
  - Competition / predation from existing wastewater biota.
  - Turbidity due to light penetration.
- Possible to separate algal culture from the wastewater (?)

Research Incentive



Is (urban) wastewater a suitable medium for algal cultivation?

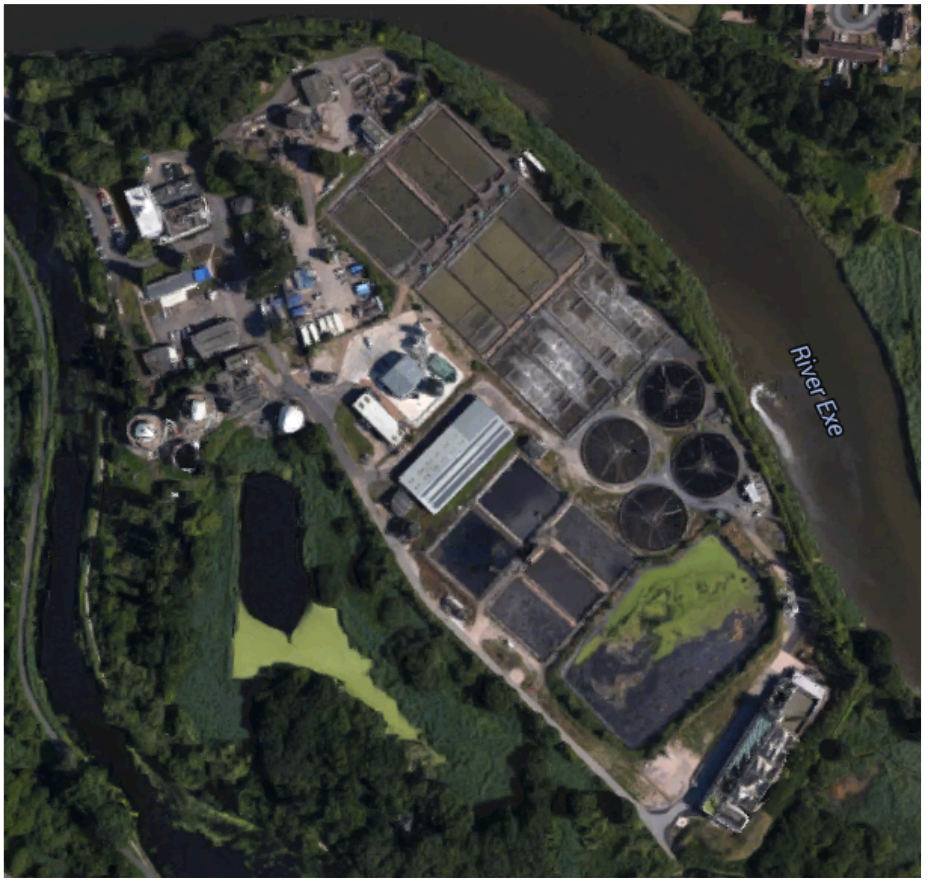
Research Objectives

- Determine the effect of **membrane pore size** for waste water filtration on algal (*Chlorella sorokiniana*) growth and nutrient removal.

- Determine the effect of monoculture algal cultivation on the autochthonous microbial consortium in waste water using metagenomic analysis.

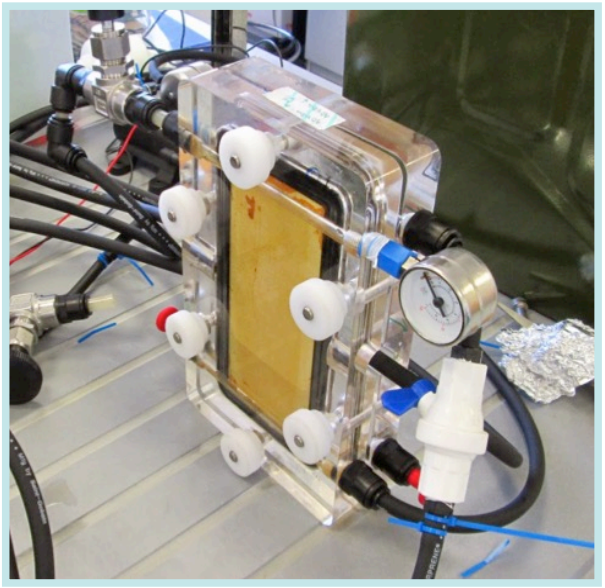
Countess Wear Treatment Plant

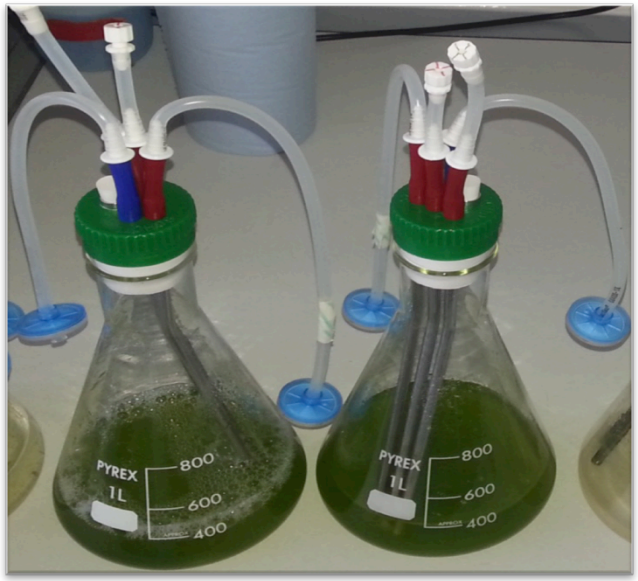
- Required to nitrify waste water to meet ammonia discharge limit, but no nitrate limits.
- In EU / UK, discharge standards are increasingly stringent.
- Algae may be used to remove nutrients to meet these limits.



Media

- Chu13 Media (**Chu**).
- Post-nitrification clarifier effluent stream (**CE-Raw**) .
- CE filtered using rayflow cross-flow filtration modules (Orelis Environment) fitted with 0.1 µm (**CE-MF**) or 40 kDa (**CE-UF**)PVDF membranes.

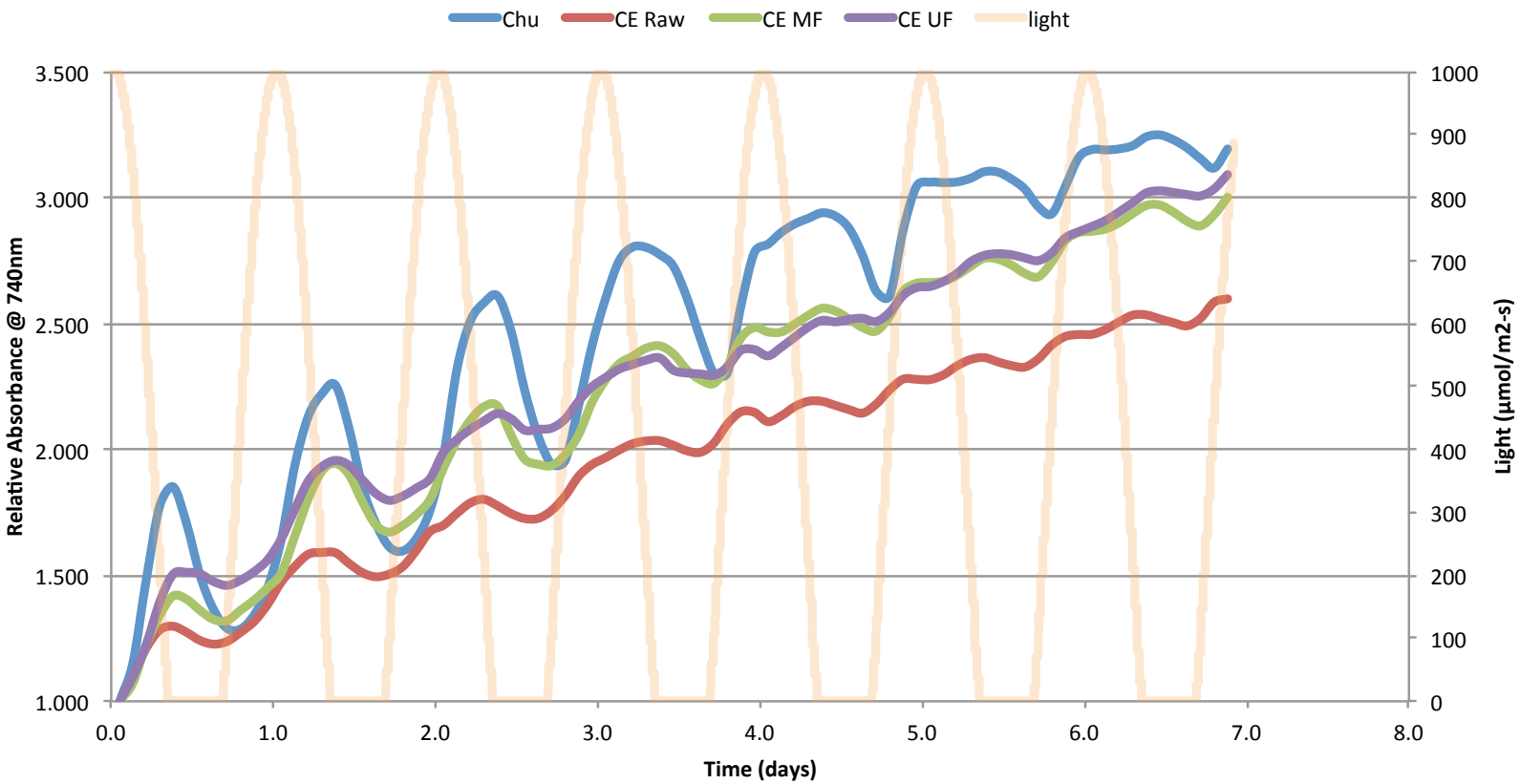




Culture Conditions

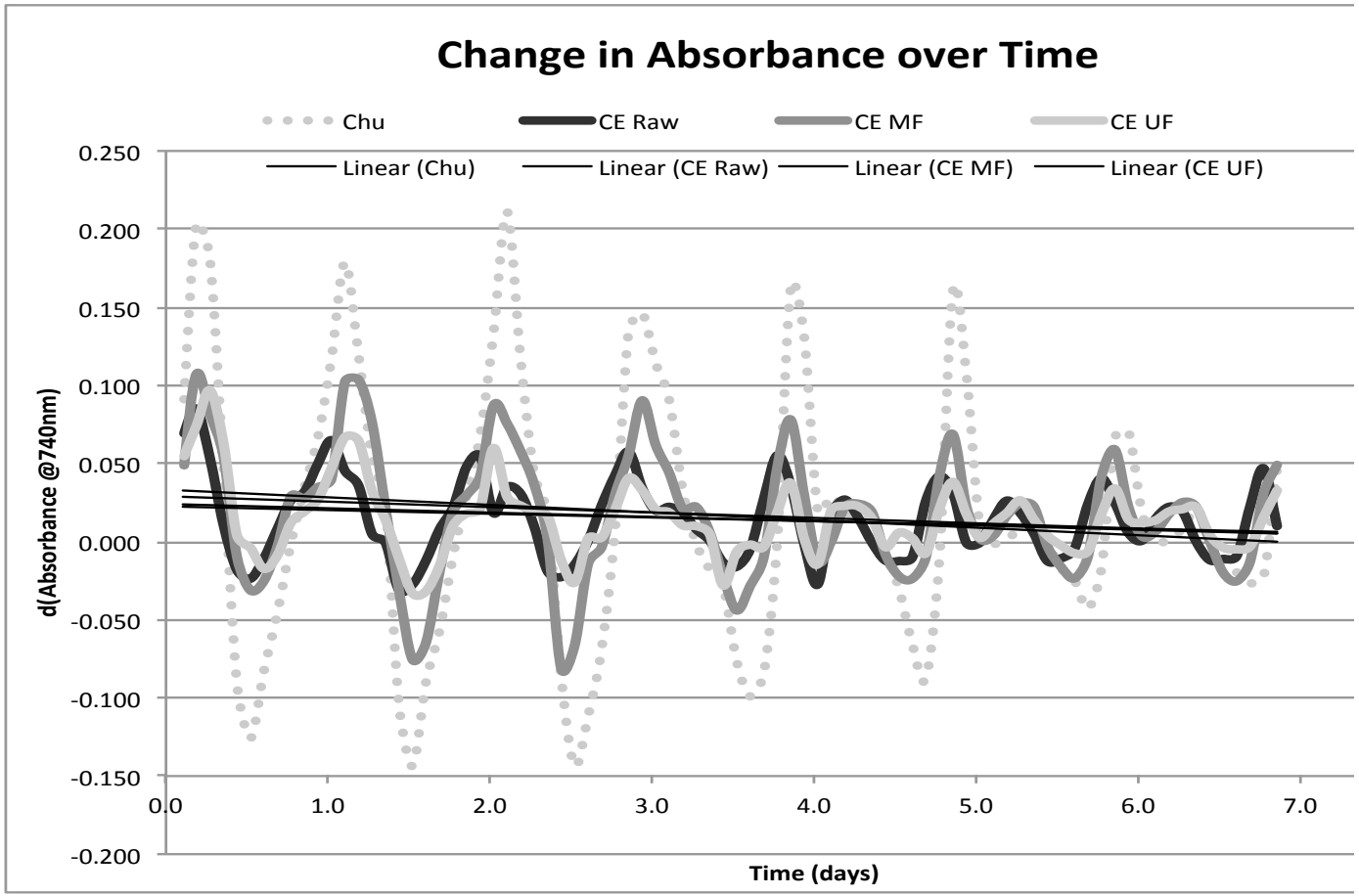
- Algem Photobioreactors (Algenuity).
- Clarified effluent harvested in June from Countess Wear WWTP.
- Light and temperature profiles correspond to June in Exeter.
- OD_{740} (algal growth) monitored at 2 h intervals for 7 days.
- 4 independent replicates per treatment.
- Randomised design.

Algal Growth



- Chu, CE-MF and CE-UF support similar levels of algal growth.
- Growth marginally reduced in CE (predation / competition).

Algal Growth



- Growth rate of all cultures reduces over time.

Nutrient Removal

- Samples filtered through 0.1 µm Whatman filter at 0 and 7 days
- Total Nitrogen, Ammonia, Nitrate and Phosphorus determined.

	Total Nitrogen			Total Ammonia			Total Nitrate			Total Phosphorus		
	Initial	Final	%Δ	Initial	Final	%Δ	Initial	Final	%Δ	Initial	Final	%Δ
Chu	46.0	31.2	31%	0.0	0.2	N/A	45.9	15.9	65%	63.4	1.6	97%
CE Raw	46.6	21.4	54%	4.8	0.1	99%	34.1	17.2	48%	15.5	0.0	100%
CE MF	44.0	21.3	52%	6.0	0.1	99%	37.6	17.7	53%	12.5	0.0	100%
CE UF	43.7	22.6	48%	5.8	0.0	100%	36.0	18.8	48%	9.5	0.0	100%

- **Complete removal** of Ammonia and Phosphorus.
- Approximately 50% of Nitrate removed.

Implications of Nutrient Removal

- Nutrient limitation may be reason for the observed slow down in culture growth rates.

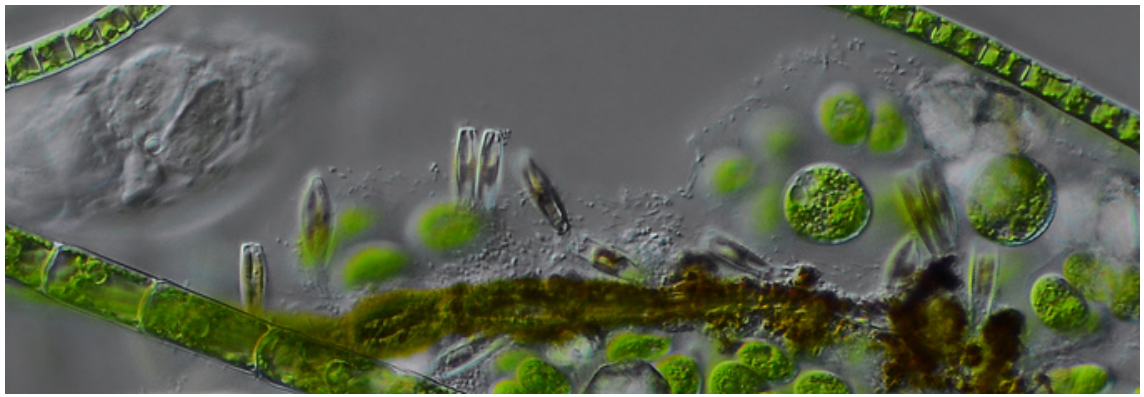
- Closed systems, such as this batch study, may require additional nutrients to sustain maximal growth rates; Fed Batch.
- Open systems, such as a waste water treatment plant with continuously flowing waste water, should not require any supplements for growth – However, what is the optimum retention time (flow rate) in the culture?

Conclusions

- Clarified (urban) waste water effluent is a suitable medium for algal growth, though may result in competitive stress on cultured algae.
- Pore size of post-clarification filter had no effect on nutrient removal.
- Pore size of post-clarification filter little effect on overall algal growth.

Conclusions

- Wastewater Treatment Plants may gain some energy savings by coupling algal cultivation with normal treatment in the form of nutrient removal… further research is required to quantify.
- Necessity to balance algal growth and water flow with nutrient removal.
- A barrier may be required to protect an algal culture from predatory or competitor species endemic in wastewater.



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