Bioresidiation of wastewater using freshwater macroalgae
The integrated production of macroalgae in wastewater: land-based.
Bioresmediation of treated municipal wastewater using freshwater macroalgae
Municipal Waste Water as a Resource

- Globally > 181 km$^3$ (181 million ML) of municipal waste water is treated annually$^1$
- < 13% is reused with > 87% discharged to the environment
- Australia ~ 256 L per person per day > 2000 GL (2 million ML)
- Residual concentration of nitrogen > 3 mg L$^{-1}$ and phosphorous > 0.5 mg L$^{-1}$
- Residual is expensive to treat on a per unit basis compared to bulk sewage

------------------------------------------------------------------------------------------------------

- Residual nitrogen and phosphorous is an ideal resource for freshwater macroalgae
- The cultivation of freshwater macroalgae is effective for the capture and reuse of nutrients

$^1$ 1 km$^3$ = 1000 GL
Freshwater macroalgae

Rhizoclonium, Cladophora, Hydrodictyon, Stigeoclonium, Oedogonium
Freshwater macroalgae - *Oedogonium*

- Cosmopolitan
- Diverse
- Robust
- Highly competitive
- Dominant
- High protein content
- High energy content

Treatment model

- Community
- Waste water
- Treatment
- Oedogonium
- Whole biomass
- Biorefinery
- Thermochemical processing
- Treated water
- Discharge
Cleveland Bay MWWTP

- 126,000 population
- ~20 ML.day⁻¹

Influent
- TN concentration ~ 55 mg.L⁻¹
- TP concentration ~ 8.3 mg.L⁻¹

Cleveland Bay MWWTP

Biomass productivity (g DW m⁻² day⁻¹)

- Monthly productivity
- 12 month average productivity

12.4 g (dw) m⁻² day⁻¹ = 44 tonnes ha⁻¹ yr⁻¹

March | April | May | June | July | August | September | October | November | December | January | February

Cleveland Bay MWWTP

Influent (80,000 L.day⁻¹)
- TN concentration 3.18 ± 1.63 mg.L⁻¹
- TP concentration 0.92 ± 0.43 mg.L⁻¹

Effluent
- TN concentration 2.03 ± 1.47 mg.L⁻¹
- TP concentration 0.32 ± 0.16 mg.L⁻¹
Cleveland Bay MWWTP

Reduction of nutrients

- TN concentration ↓ 36%
- DIN concentration ↓ 47%
- TP concentration ↓ 65%
- FRP concentration ↓ 69%
**Influent (experimental = 7 day cycle x 5 weeks)**

- TN concentration 9.7 ± 0.9 mg.L⁻¹
- TP concentration 8.2 ± 0.6 mg.L⁻¹

**Effluent**

- TN concentration 1.53 ± 0.37 mg.L⁻¹
- TP concentration 0.32 ± 0.16 mg.L⁻¹
Reduction of nutrients

- TN concentration ↓ 74%
- DIN concentration ↓ 99.8%
- TP concentration ↓ 77%
- FRP concentration ↓ 69.5%
Whole of facility model

- 3 Ha site with a flow of 1.6 ML.day$^{-1}$ (5.6 day RT)
- Removal of ~95% DIN and 75% TP
- Productivity 18.8 g (dw) m$^{-2}$.day$^{-1}$
- Equivalent of 66 tonne (dw) Ha$^{-1}$.yr$^{-1}$

Oedogonium

Discharge

Treated water
Broadening the model to treat agricultural runoff using freshwater macroalgae
Agricultural runoff

- 1° filtration to remove suspended solids
- Bioremediation to remove N and P
- Compliance with net zero discharge
- Discharge / reuse of waste water
Agricultural runoff

Mean (± S.E.) concentration of dissolved inorganic nitrogen (DIN) in water samples

Agricultural runoff - initial concentrations of DIN from 0 – 20 mg.L\(^{-1}\) with diuron at 10 µg.L\(^{-1}\)
Agricultural runoff

Reduction of nutrients

- DIN concentration (10 mg.L\(^{-1}\)) ↓ 99.6%
- DIN concentration (10 mg.L\(^{-1}\)) ↓ 81.8% (+ diuron)
- FRP concentration ↓ 73.7%
Agricultural runoff

- Year-round treatment of water after it leaves the farm
- Provide primary treatment of dissolved inorganic nutrients
- Complements wetlands
  - Pre or post wetland treatment
Agricultural runoff

- Year-round treatment of water after it leaves the farm
- Provide primary treatment of dissolved inorganic nutrients
- Complements wetlands
  - Pre or post wetland treatment
• Year-round treatment of water after it leaves the farm
• Provide primary treatment of dissolved inorganic nutrients
• Complements wetlands
  – Pre or post wetland treatment
Deriving value from biomass

Irrigated crops

Oedogonium

Whole biomass

Biorefinery

Thermochemical processing

Treated water

Discharge

Human food
Animal feed
Animal feed
Bioenergy
Fertiliser

Nutraceuticals

Biocrude
Protein
Biochar
Biochemical profile - *Oedogonium*

- Protein 23.1 % (sum of total amino acids)
- Essential amino acids 10.0 % (total EEA)
- Lipid 10.4 % (total lipid)
- Total fatty acids 6.4 %
- PUFA 4.6%
- Dietary fibre 34.5 % (insoluble + soluble)
- Ash 10.1 %

- Carbon 42.9 %
- Hydrogen 6.4 %
- Oxygen 36.7 %
- Nitrogen 5.1 %
- Sulphur 0.27 %
- Phosphorous 1.07 %

- HHV 19 MJ.kg$^{-1}$

3Cole et al. Algal Research 20 (2016) 100-109
Animal feeds and feed supplements (quality and quantity of amino acids = lupins)
Summary

- Scalable technology
- Broad application
- Transparent accounting of nutrients and carbon
- Delivers biomass as a product
- Value-adding options diversify with scale of production