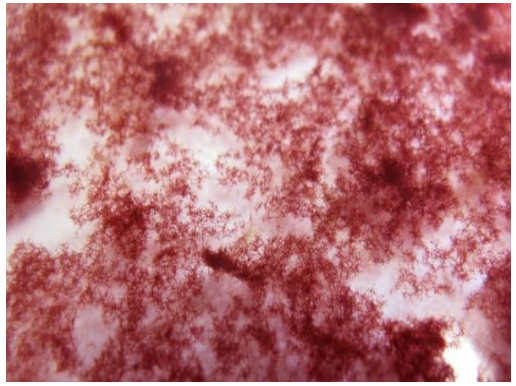
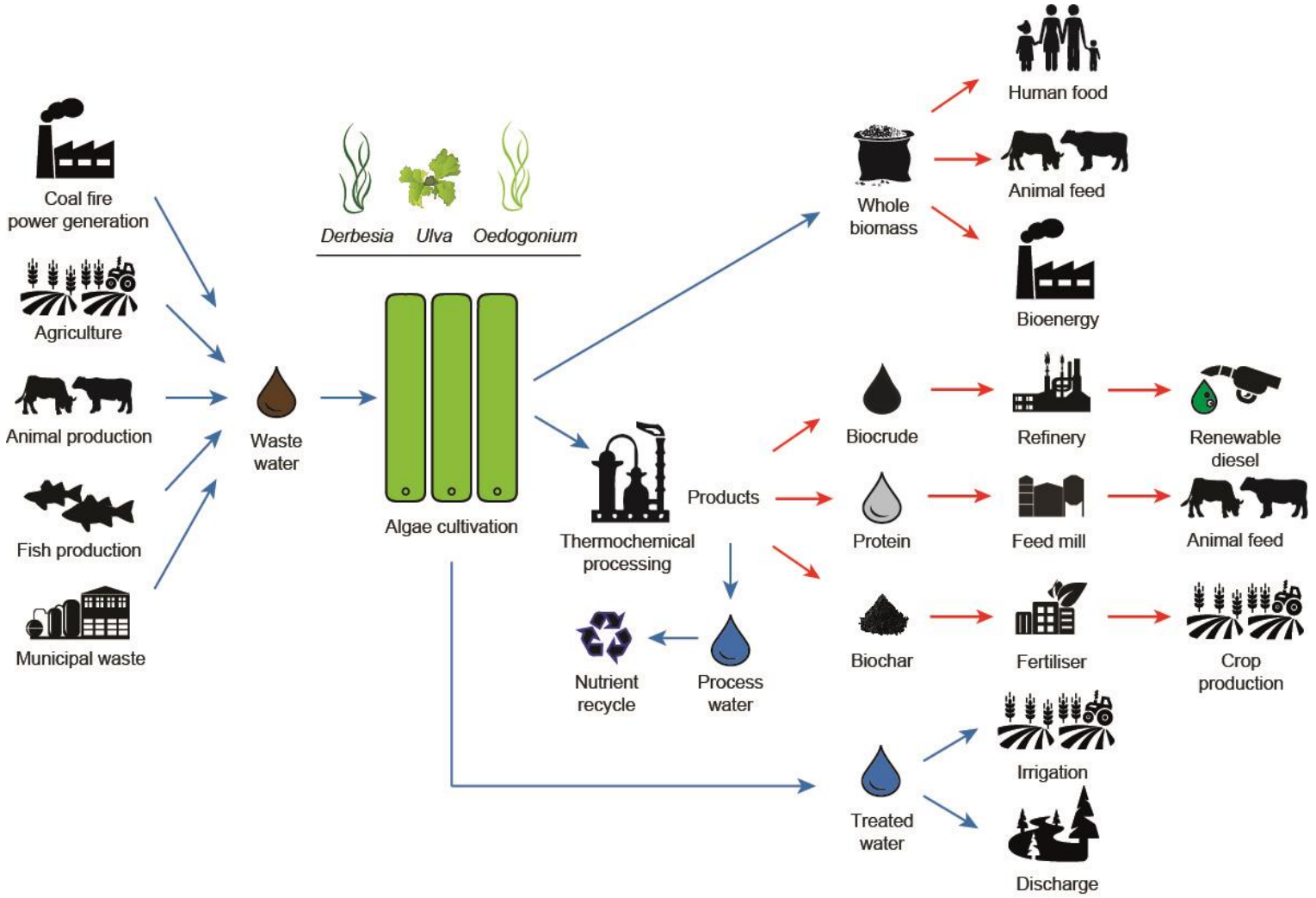
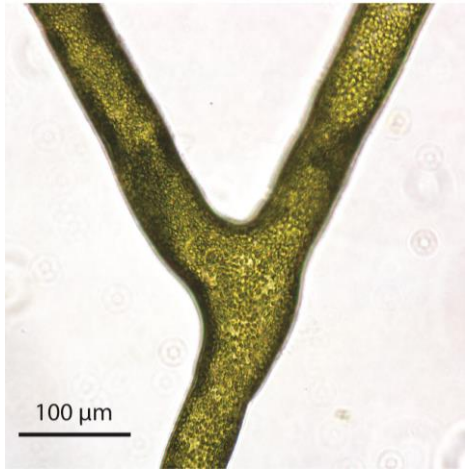
Bioremediation of wastewater using freshwater macroalgae

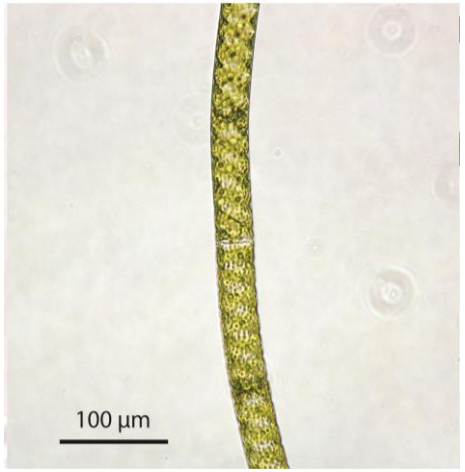


The integrated production of macroalgae in wastewater : land-based



Bioremediation 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

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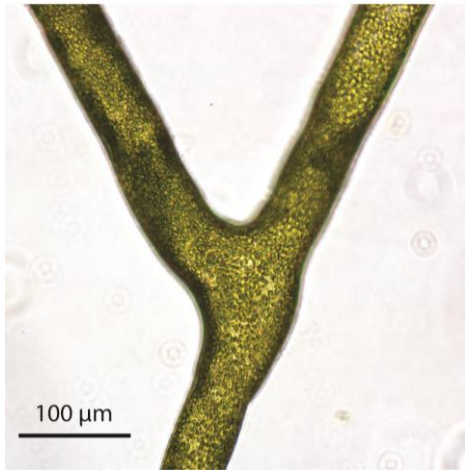
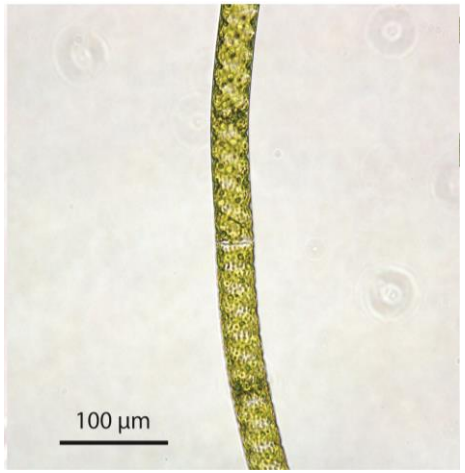
- Residual nitrogen and phosphorous is an ideal resource for freshwater macroalgae
- The cultivation of freshwater macroalgae is effective for the capture and reuse of nutrients

[1] 1 km^3 = 1000 GL

Freshwater macroalgae

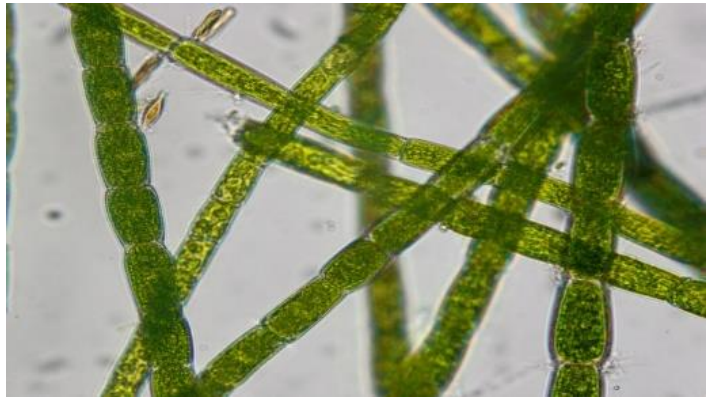




Rhizoclonium, *Cladophora*, *Hydrodictyon*, *Stigeoclonium*, *Oedogonium*

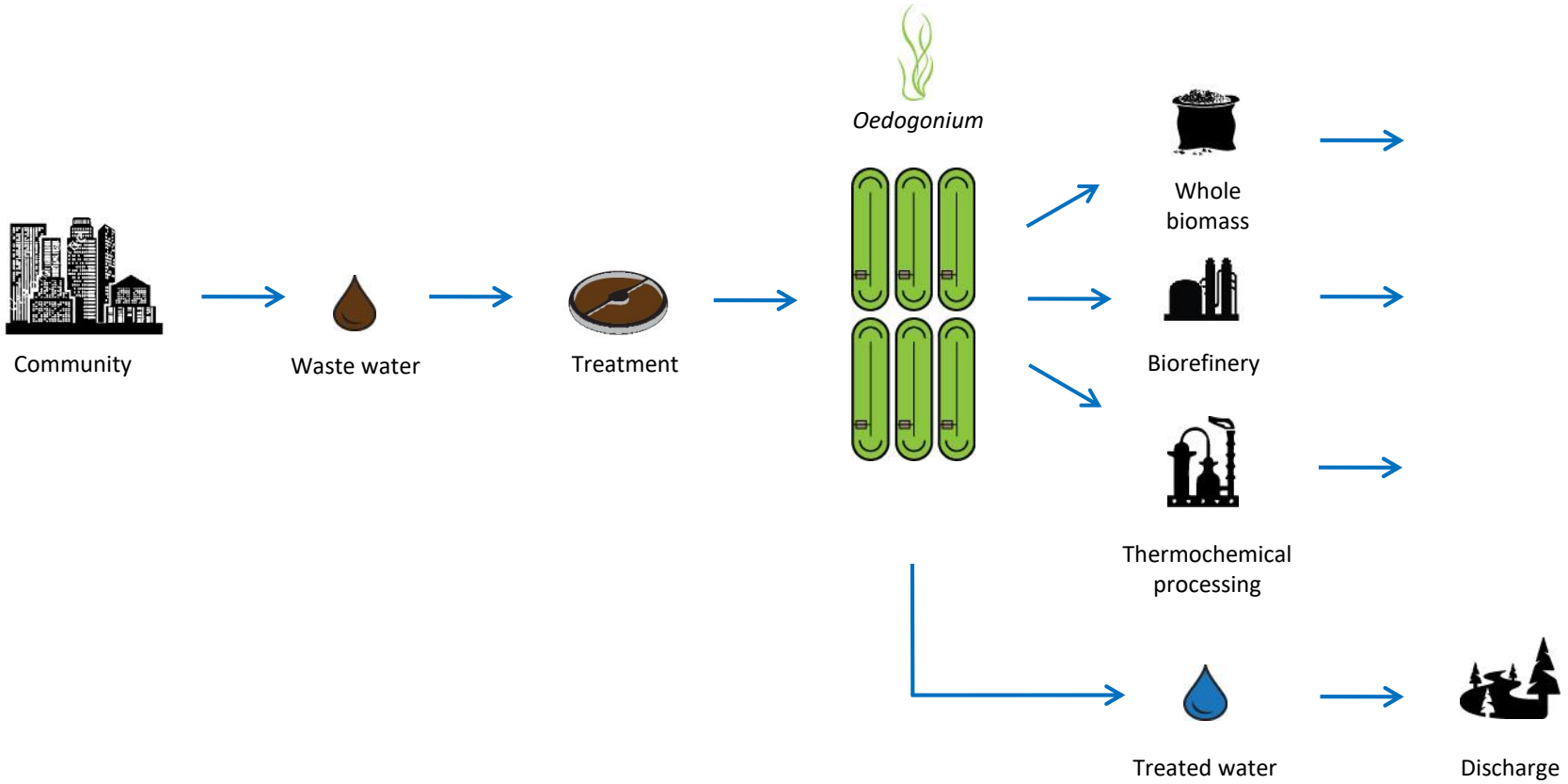
Freshwater macroalgae - *Oedogonium*

- Cosmopolitan
- Diverse
- Robust[1]
- Highly competitive[1]
- Dominant[1]
- High protein content[2]
- High energy content[2]

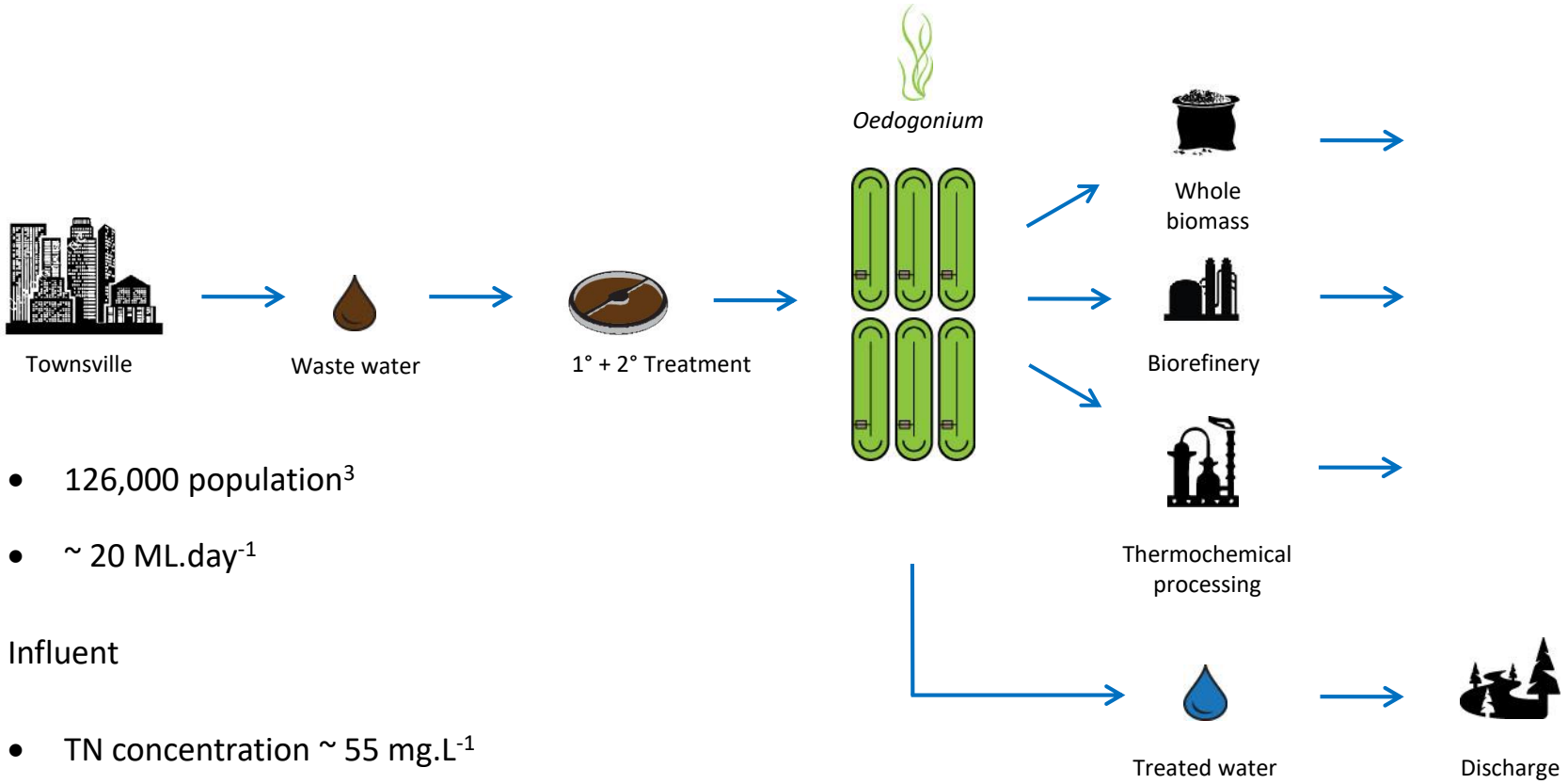


[1]Lawton et al. PLoS ONE 9 (2014) e90223, [2]Cole et al. Algal Research 7 (2015) 58-65

Treatment model



Cleveland Bay MWWTP



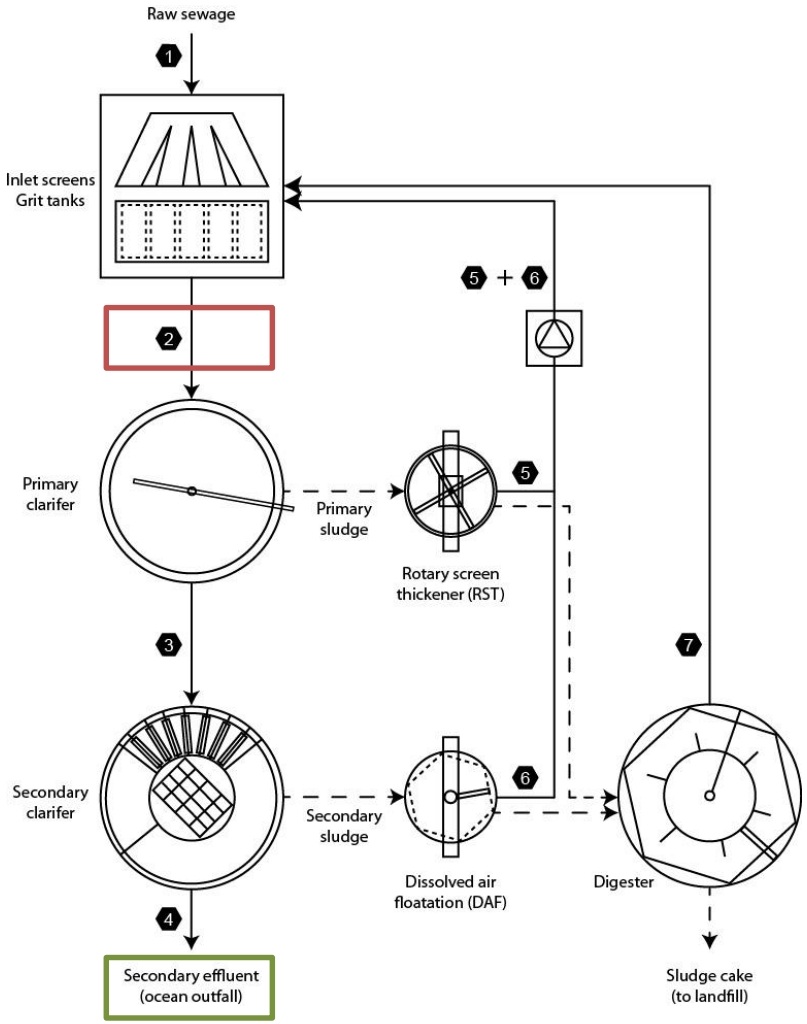
- 126,000 population[3]
- ~ 20 ML.day^{-1}

Influent

- TN concentration ~ 55 mg.L^{-1}
- TP concentration ~ 8.3 mg.L^{-1}

[3]Cole et al. Algal Research 20 (2016) 100-109

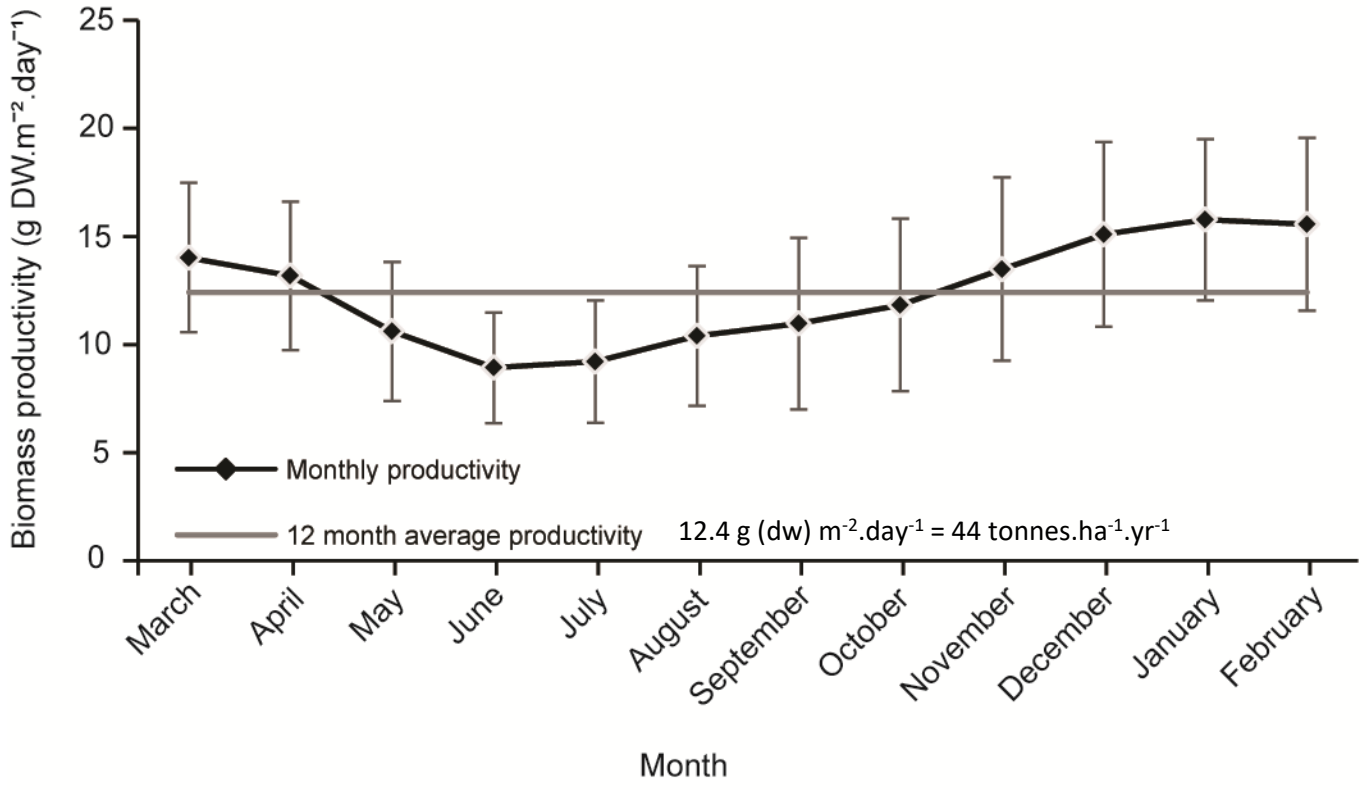
Cleveland Bay MWWTP



	1	2	3	4	5	6	7
Effluent	Raw sewage	Raw sewage + returns	Primary effluent	Secondary effluent	RST return	DAF return	Centrate return
Flow (ML/d)	29.0	29.8	29.6	29.0	0.2	0.4	0.2
Mass (kg/d)							
TN	1450	1632	1437	116	10	6	166
TP	232	247	215	23	2	3	10
Concentration (mg/L)							
TN	50	55	49	4	57	15	817
TP	8.0	8.3	7.3	0.8	9.5	7.8	52
TN:TP	6:1	7:1	7:1	5:1	6:1	2:1	16:1
Mass balance (%)							
Flow	100	103	102	100	1	1	1
TN	100	113	99	8	1	0	11
TP	100	106	93	10	1	1	4

[3]Cole et al. Algal Research 20 (2016) 100-109

Cleveland Bay MWWTP



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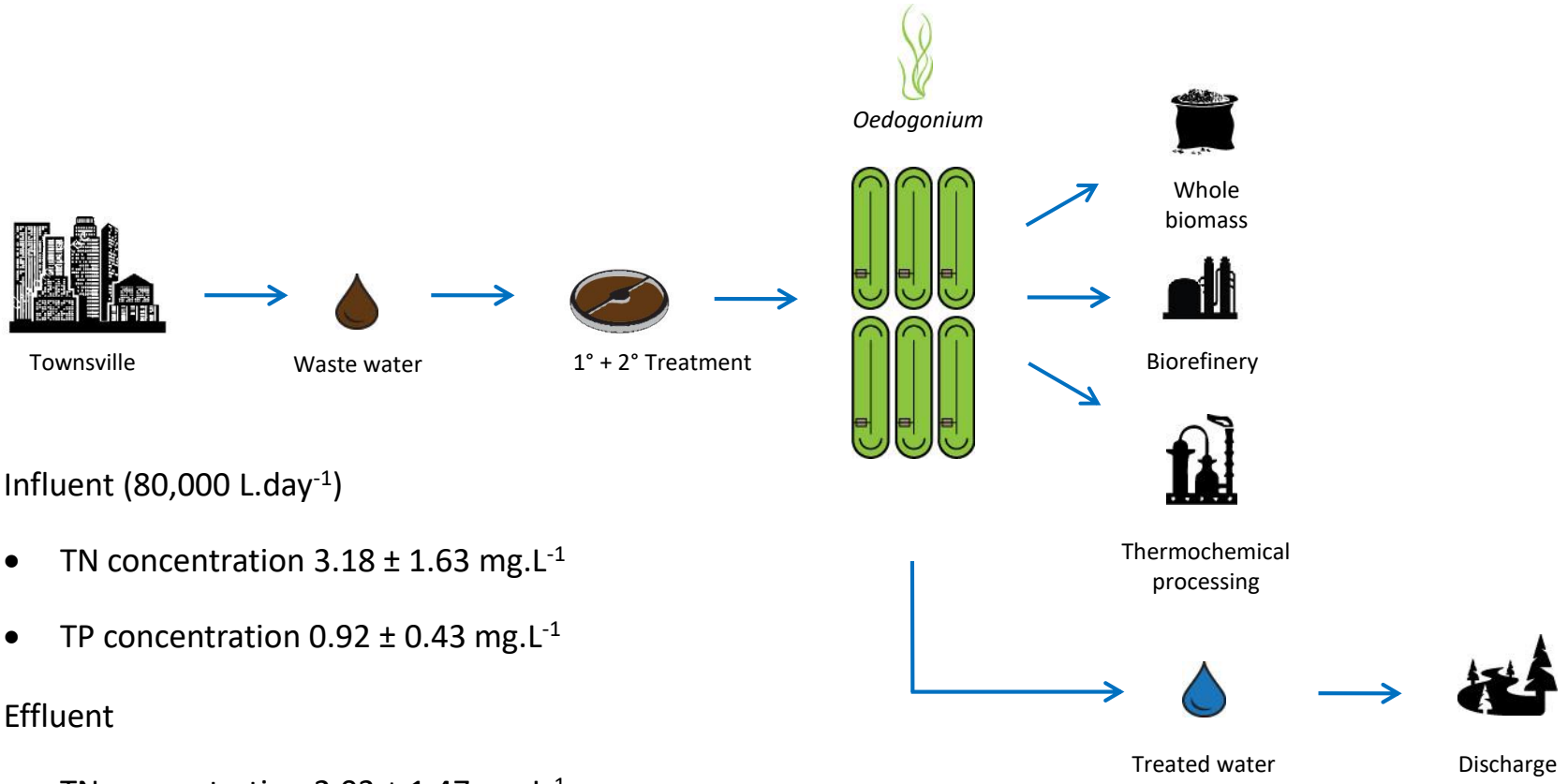


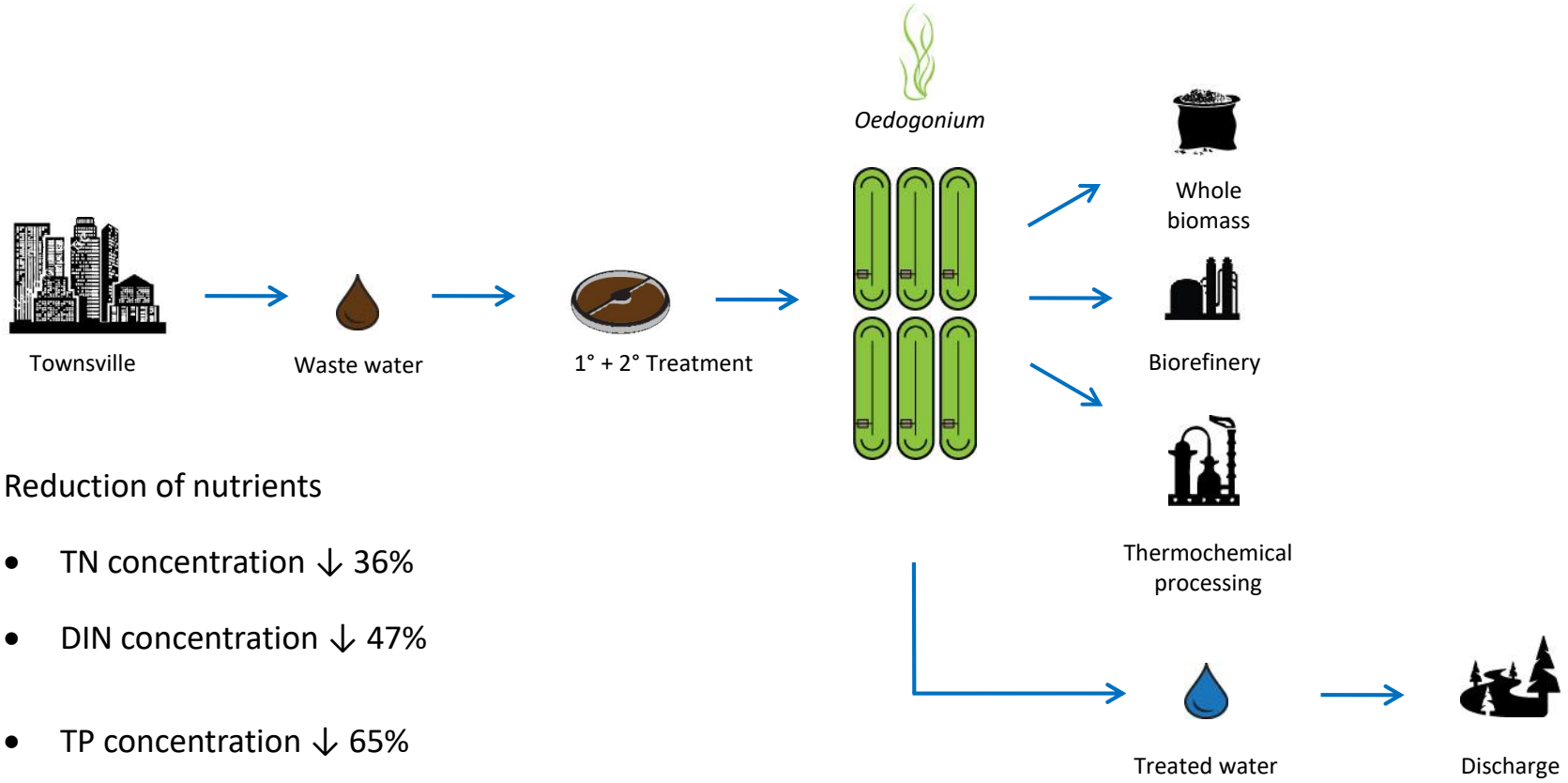
Influent (80,000 $L.day^{-1}$)

- 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 $mg.L^{-1}$

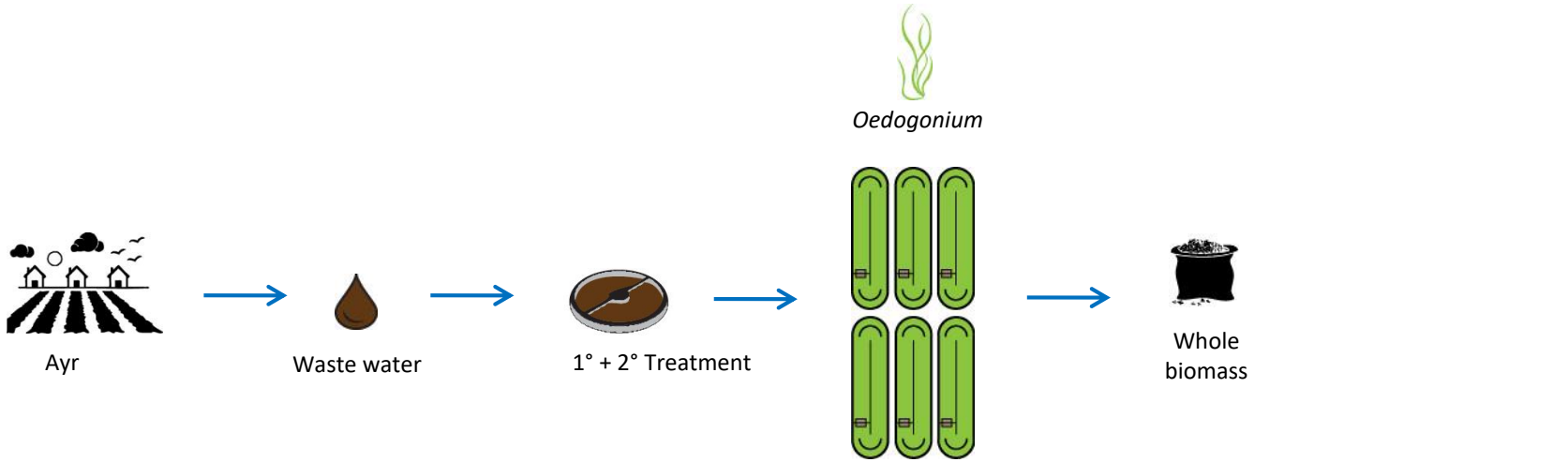
Cleveland Bay MWWTP



Reduction of nutrients

- TN concentration ↓ 36%
- DIN concentration ↓ 47%
- TP concentration ↓ 65%
- FRP concentration ↓ 69%

Burdekin Shire MWWTP



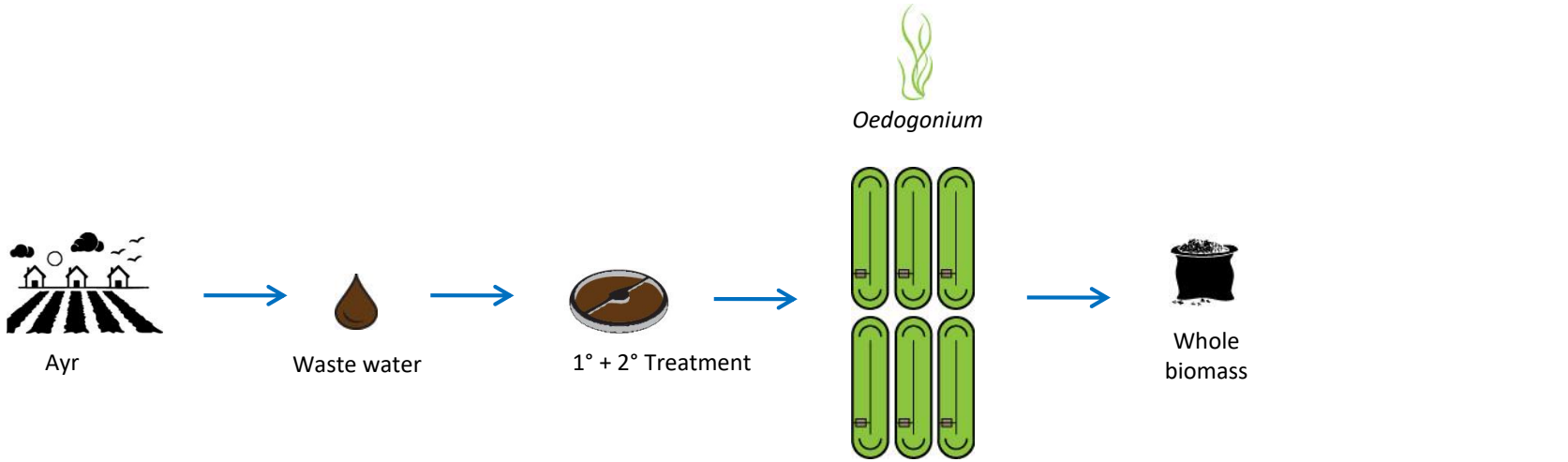
Influent (experimental = 7 day cycle x 5 weeks)

- TN concentration 9.7 ± 0.9 $mg.L^{-1}$
- TP concentration 8.2 ± 0.6 $mg.L^{-1}$

Effluent

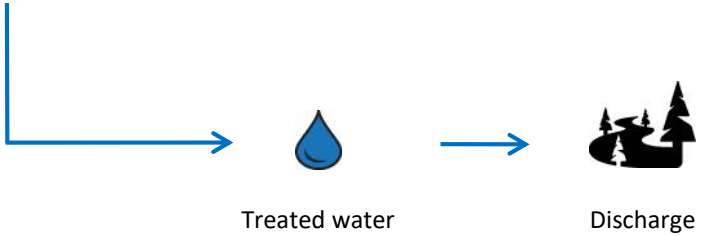
- TN concentration 1.53 ± 0.37 $mg.L^{-1}$
- TP concentration 0.32 ± 0.16 $mg.L^{-1}$

Burdekin Shire MWWTP



Reduction of nutrients

- TN concentration ↓ 74%
- DIN concentration ↓ 99.8%
- TP concentration ↓ 77%
- FRP concentration ↓ 69.5%



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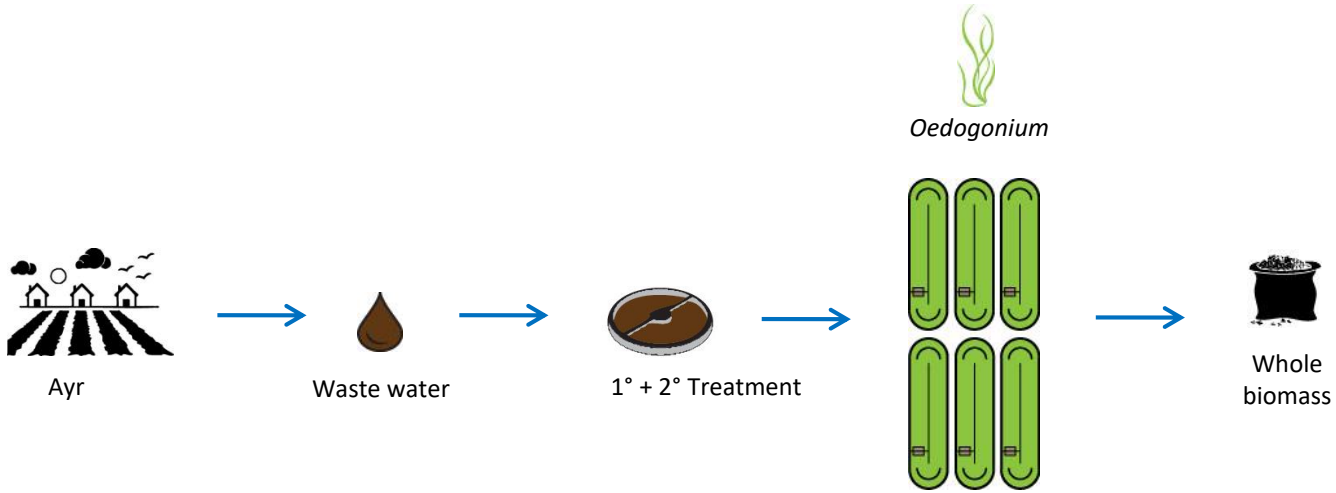
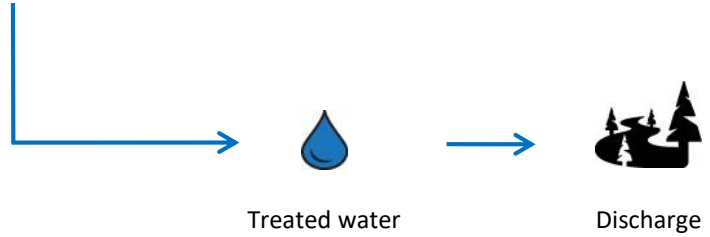
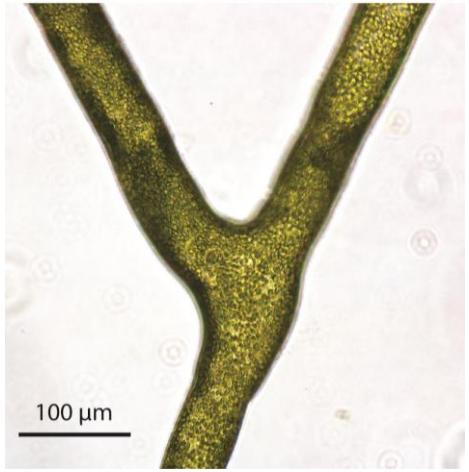


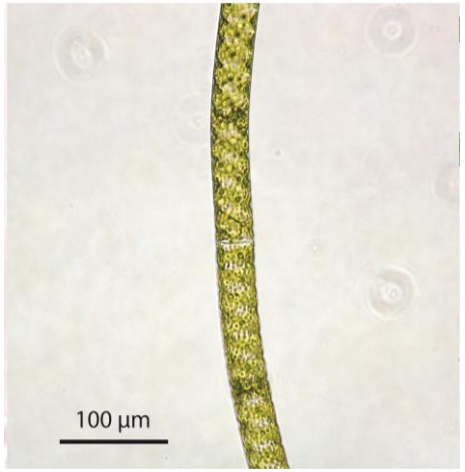
Whole of facility model

- 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}

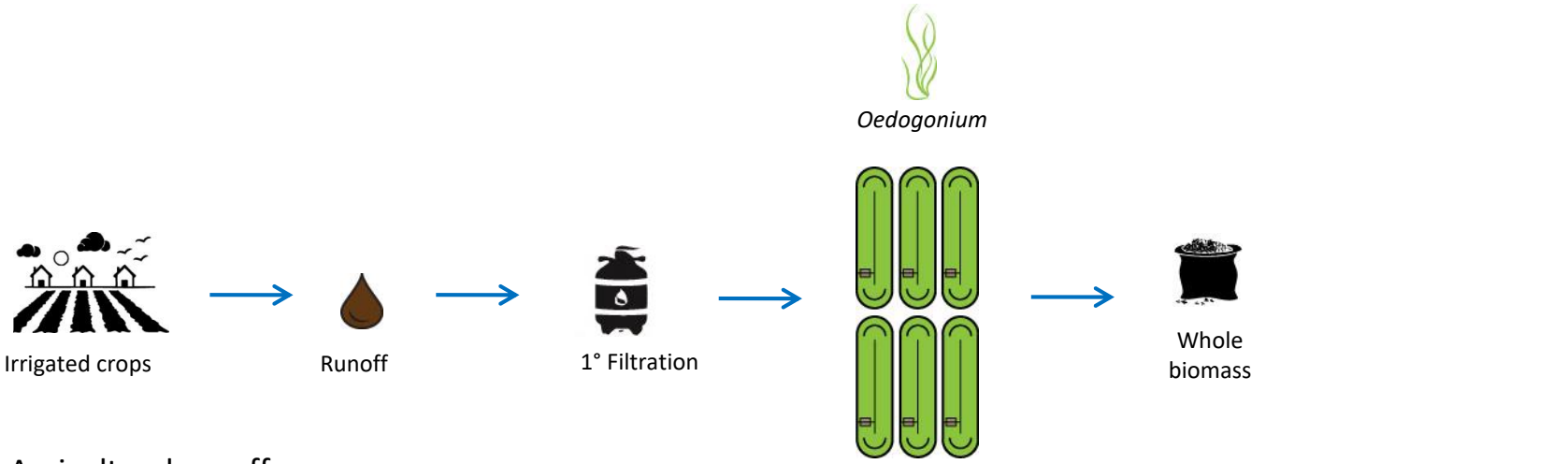


Broadening the model to treat agricultural runoff using freshwater macroalgae



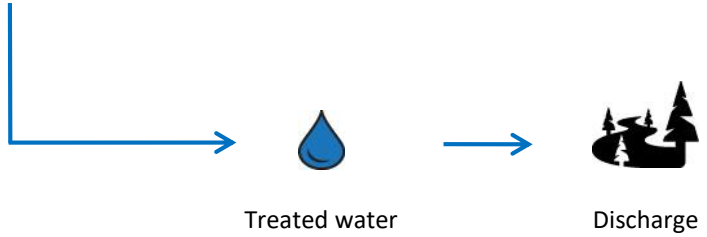


Agricultural runoff

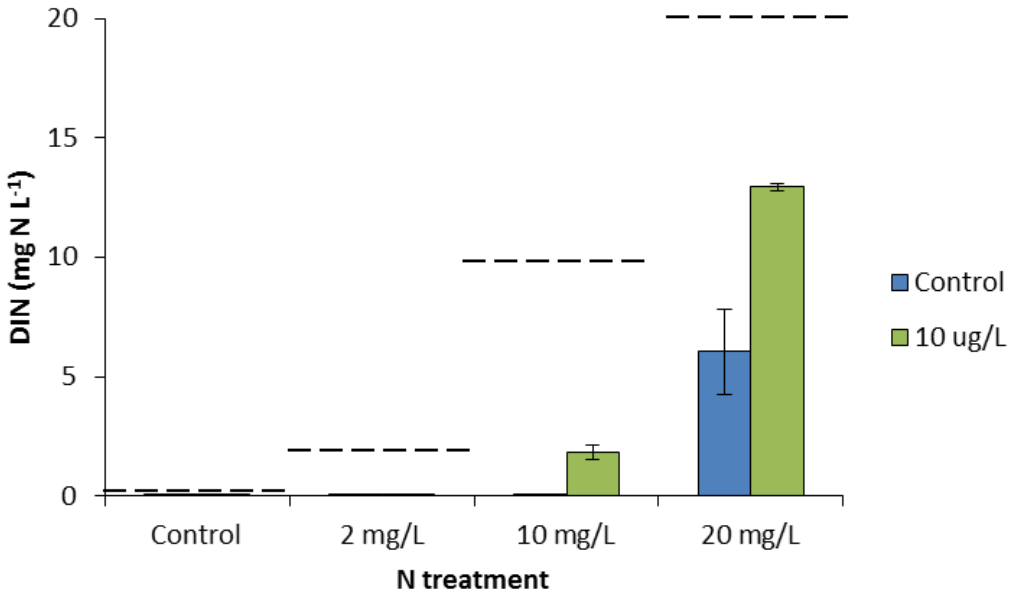


Agricultural runoff

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



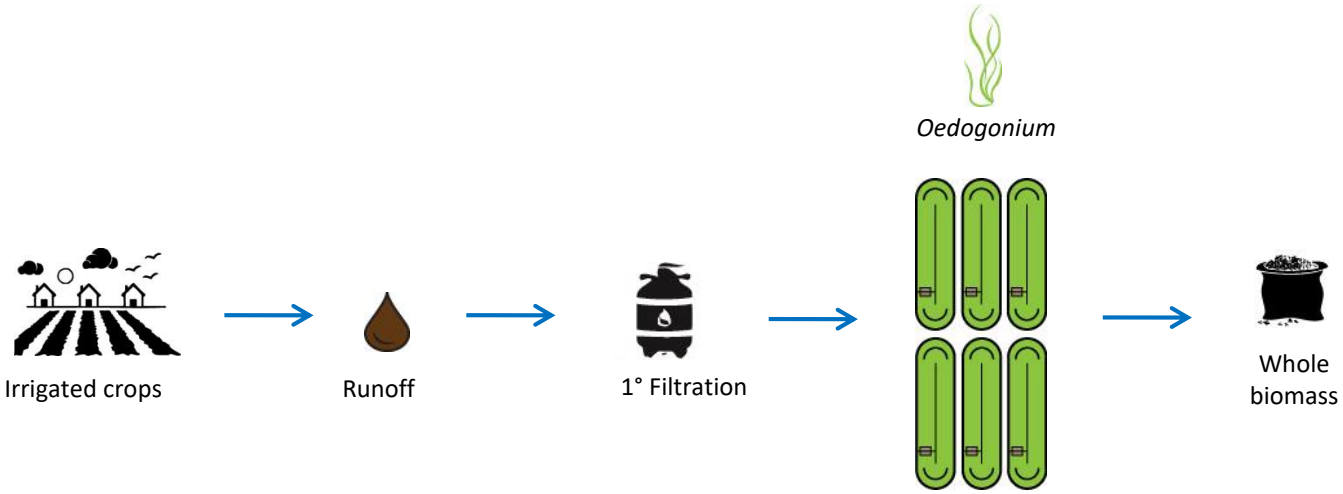
Agricultural runoff



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

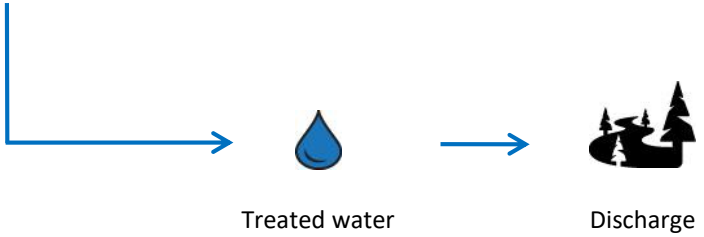
Agricultural runoff - initial concentrations of DIN from 0 – 20 mg.L^{-1} with diuron at 10 µg.L^{-1}

Agricultural runoff



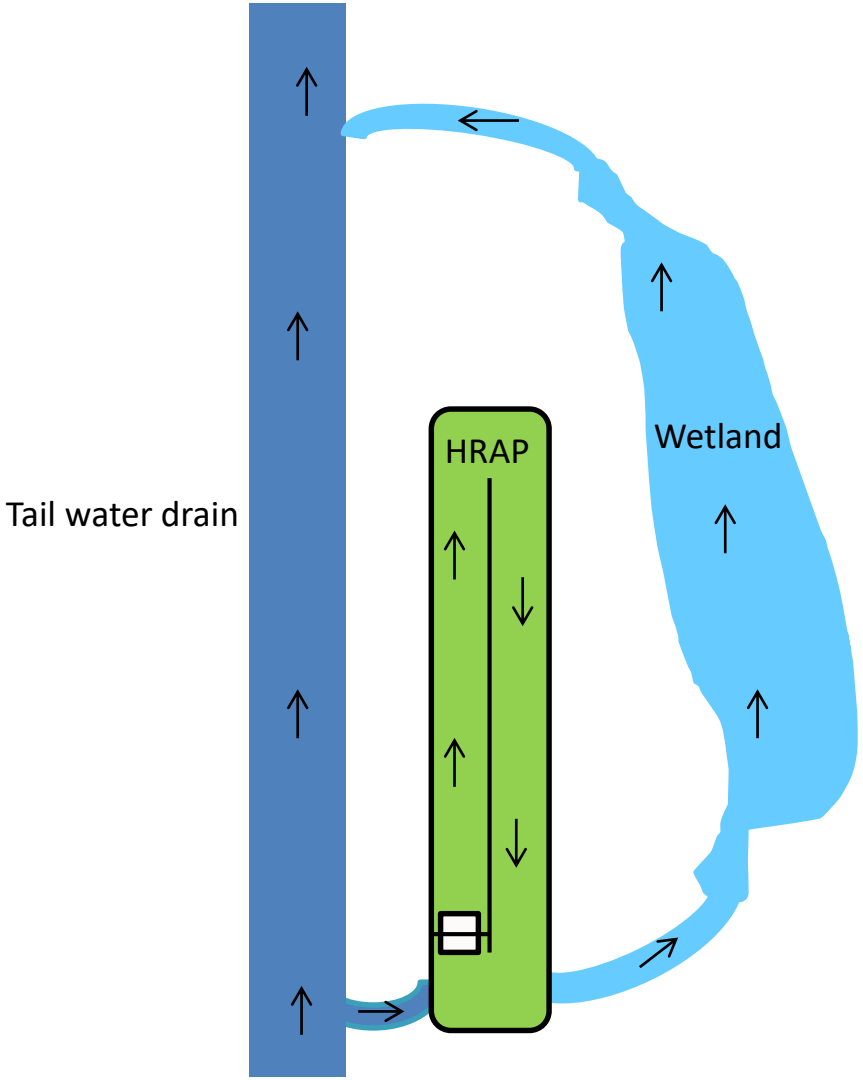
Reduction of nutrients

- 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



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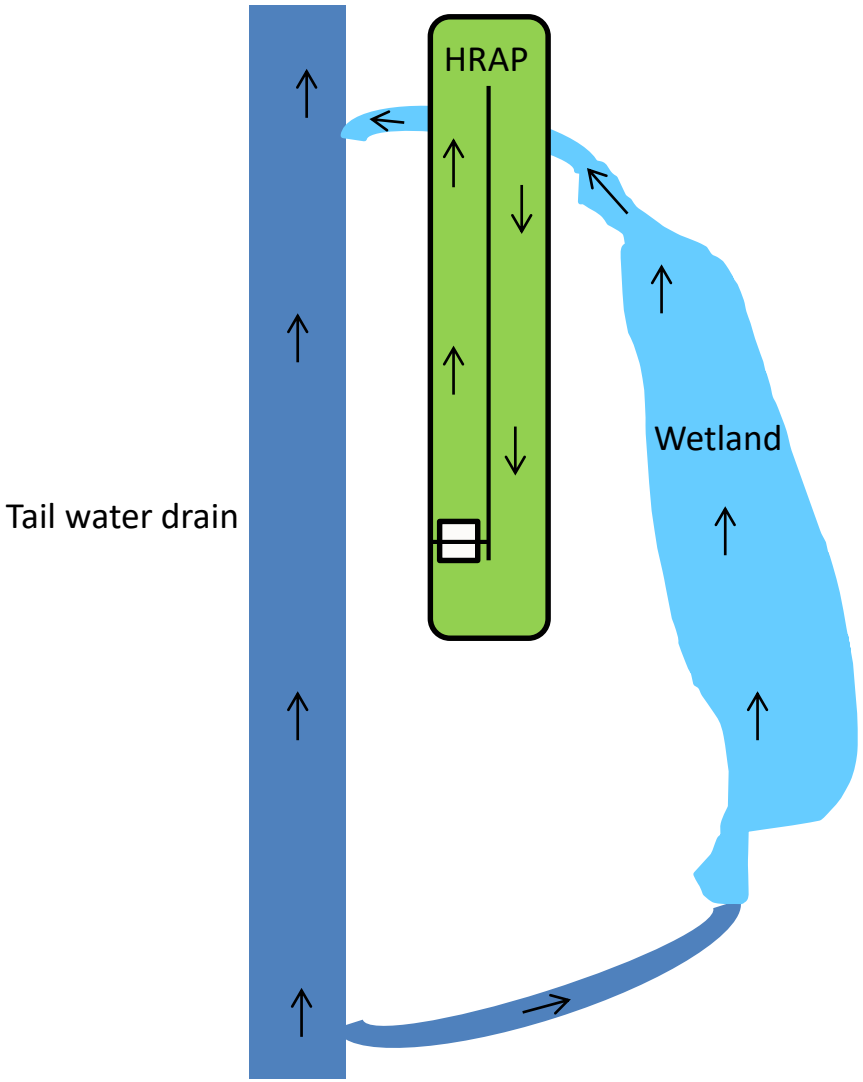

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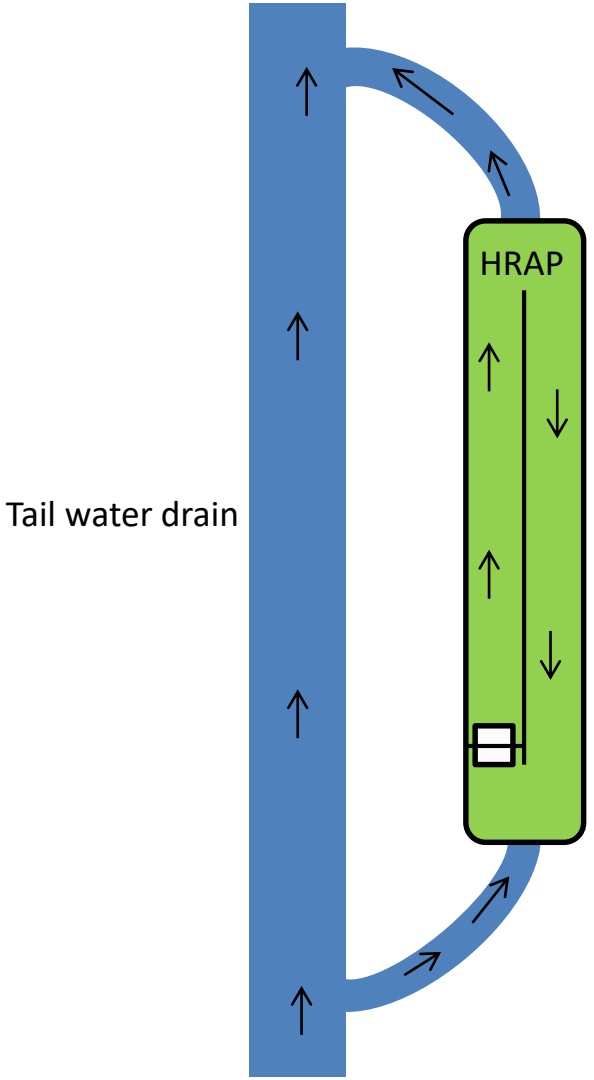
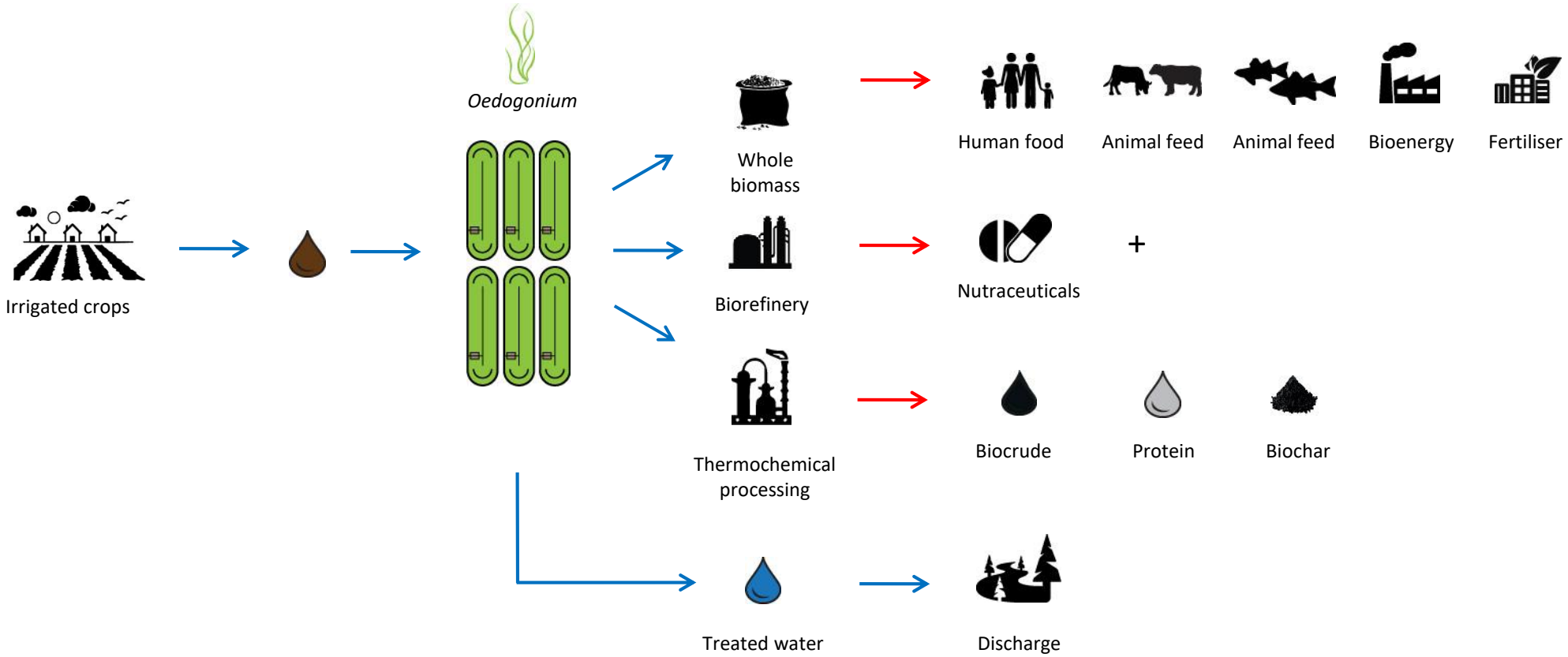


Deriving value from biomass



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 %

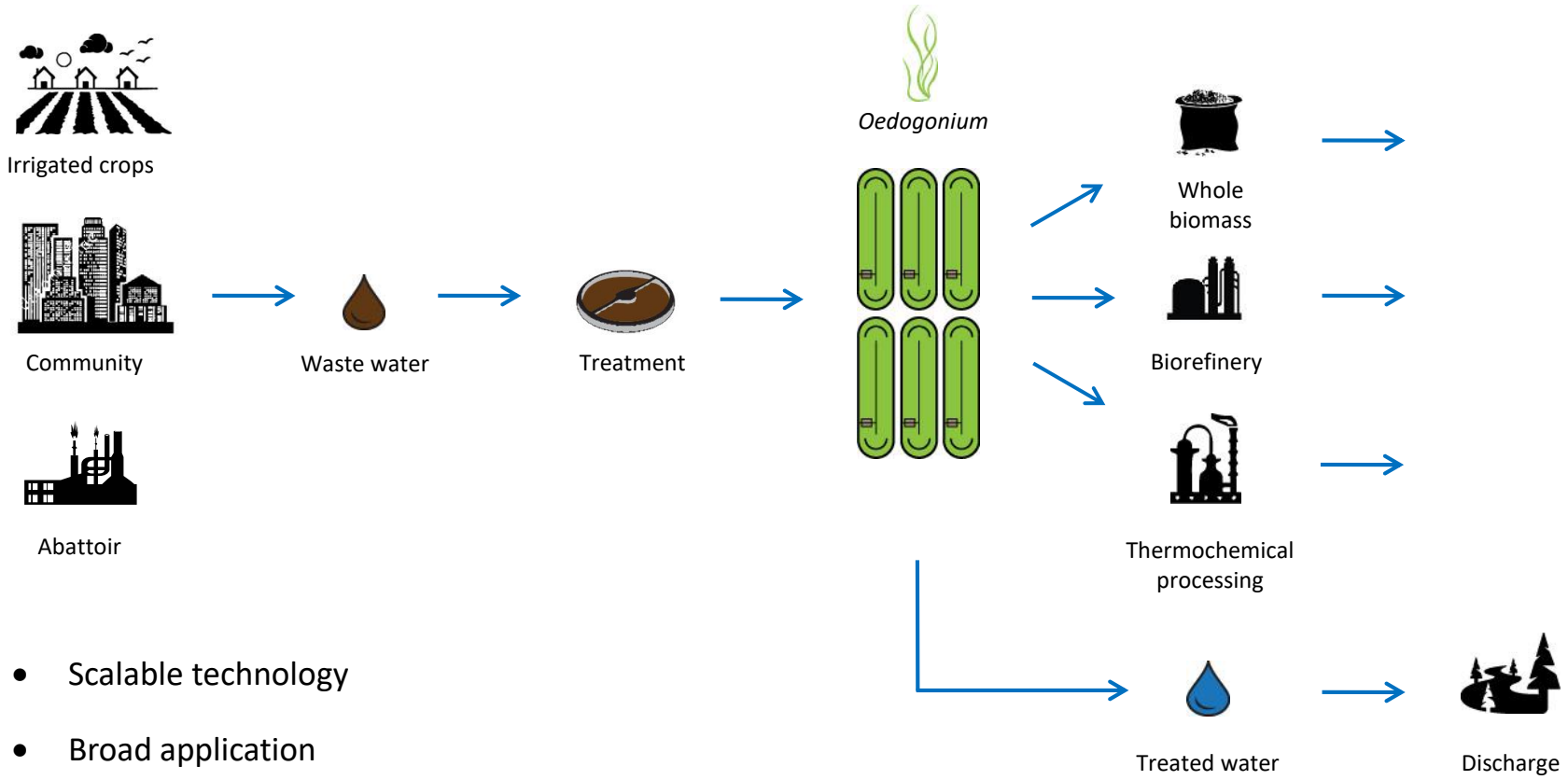
- Carbon 42.9 %
- Hydrogen 6.4 %
- Oxygen 36.7 %
- Nitrogen 5.1 %
- Sulphur 0.27 %
- Phosphorous 1.07 %

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

[3]Cole 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