Using Produced Water to Grow Microalgae

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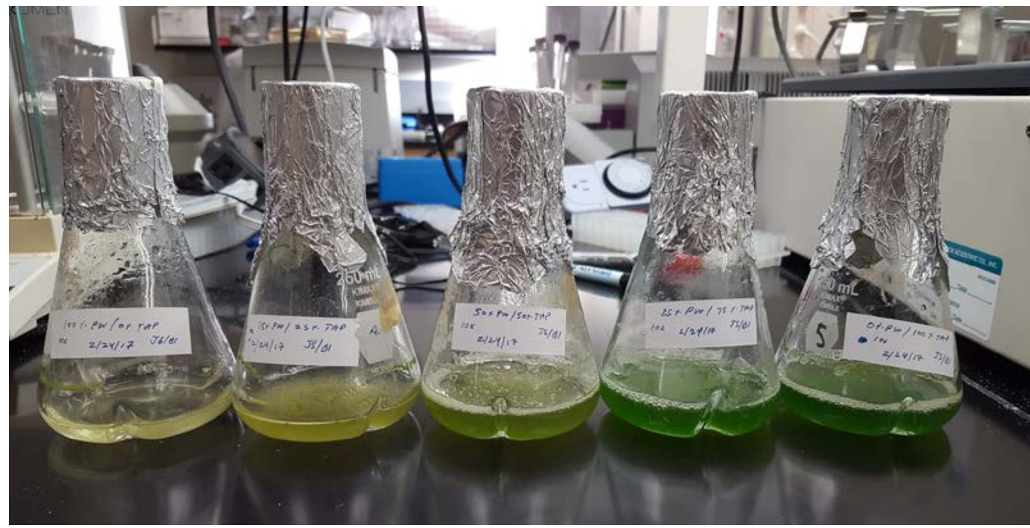

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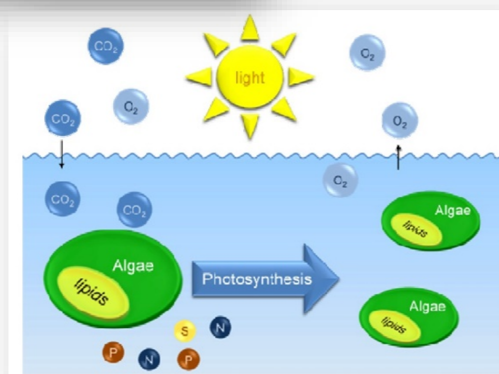
This presentation focuses on challenges in treating produced water and evaluating its use as a medium to grow microalgae

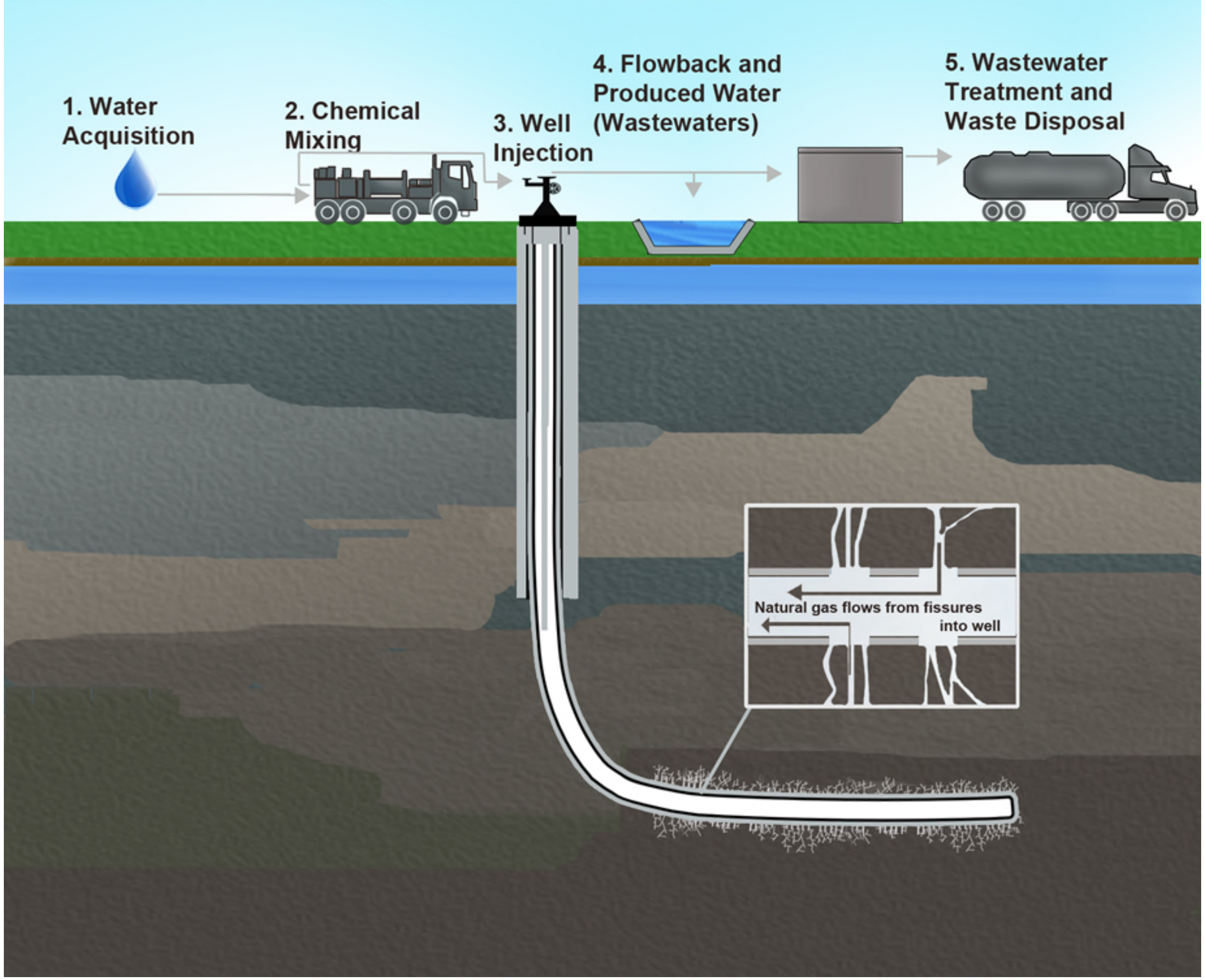
Produced Water - Challenges



Results of Algae Growth

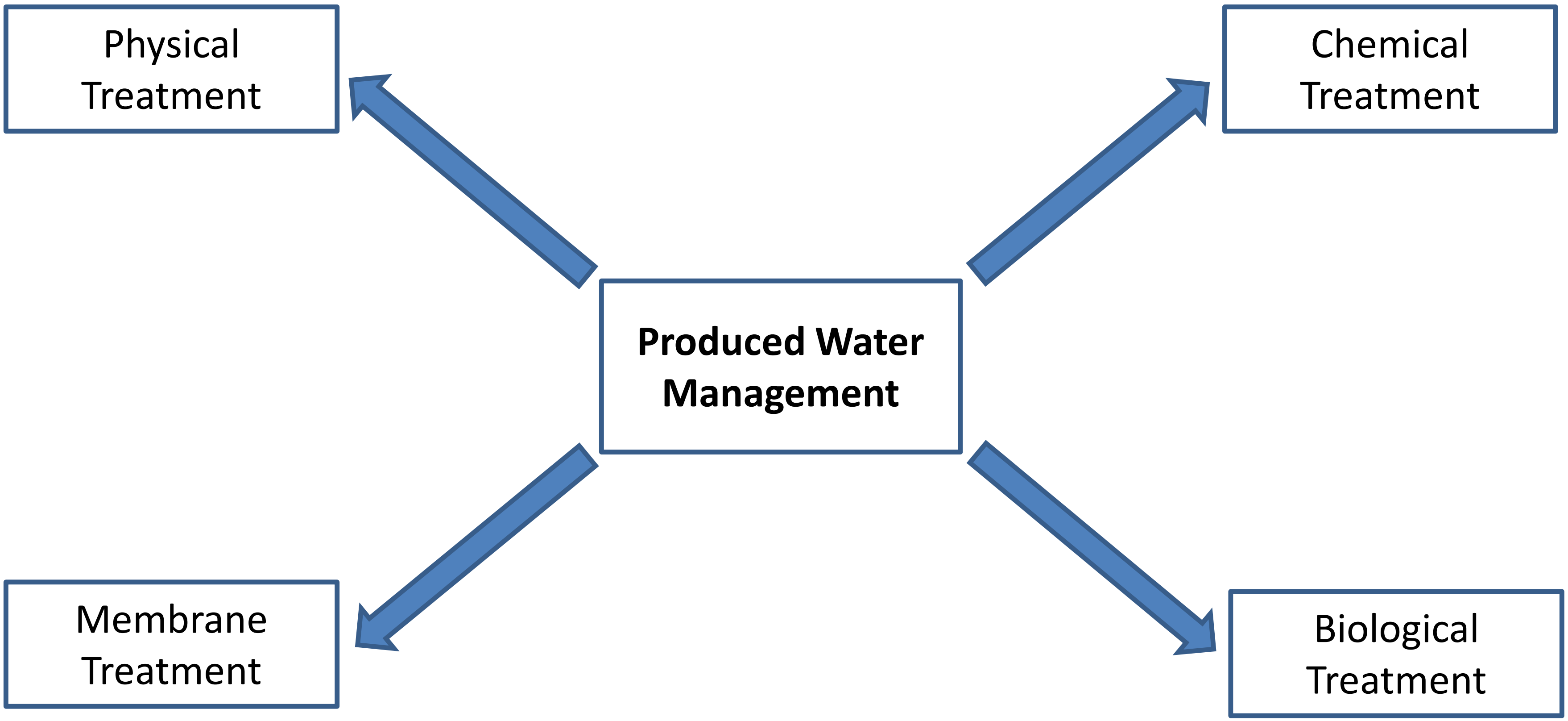
Potential Applications

Oil E&P results in large volumes of produced water(PW) - unsafe for disposal and further treatment is necessary



Source: U.S. Environmental Protection Agency

Treatment of produced water is an effective way and has the potential to be a harmless product than being a waste



Biosorption using microalgae is ecologically-safer, efficient and the produced biomass can be utilized to generate biofuels

Table 1 A summary of the processes and their features used in produced water treatment[6,7]

Treatment	Hydrocarbons removal	Suspended solids removal	Metal removal	Softening and SAR adjustment	Soluble organic removal	Pre/post treatment	Desalination	PW recovery (%)	Toxics removal[a]	Environmental/ economical sustainability	Feed quality
Hydrocyclone		✓				✓		High		Long lifetime, low energy input	All TDS
Gas flotation	✓	✓				Coagulation		~100		Coagulant, pumping costs	High TOC and oil
Ultra-filtration	✓	✓				Straining, desalination		85–100		Polymeric/ceramic membranes cost	All TDS
Sand filtration		✓				Coagulation		~100		Optional coagulant	All TDS
Aeration & sedimentation		✓	✓			✓		Low		No energy and chemical use	No restrictions
Chemical precipitation		✓	✓	✓				95	✓	Good in combined processes	High TDS
Oxidation			✓		✓	✓		100		High cost chemical	All TDS
Ion exchange			✓	✓		Mineral removal, remineralization		~100	✓	Resin regeneration, pumping costs	$0.5 < TDS < 7\ g\ L^{-1}$
Adsorption	✓		✓	✓	✓	✓		~100	✓	Pumps, plumbing and chemical needed	All TDS
Membrane separation				✓		Extensive pre and post treatment	✓	30–60		Chemical cleaning and high-pressure pumps needed	$0.5 < TDS < 50\ g\ L^{-1}$
Freeze/thaw evaporation	✓	✓	✓	✓	✓	Deoiling	✓	50 (in winter)		Limited by land availability and climate conditions	$TDS > 40\ g\ L^{-1}$ with no methanol
Evaporation and distillation					✓	Less rigorous pretreatment	✓	20–70		High energy demand	High TDS range
Electrodialysis				✓	✓	Filtration, pH adjustment	✓	70–90		Complicated operation, chemical cleaning use	$TDS < 8\ g\ L^{-1}$
Biological activities	✓			✓	✓	Sedimentation	✓	100	✓	Low cost, no chemical use	$Cl^{-} < 6600$ and oil $< 60\ mg\ L^{-1}$

[a] Special constituents of concern, such as boron and BTEX compounds (sum of benzene, toluene, ethylbenzene, and xylenes).

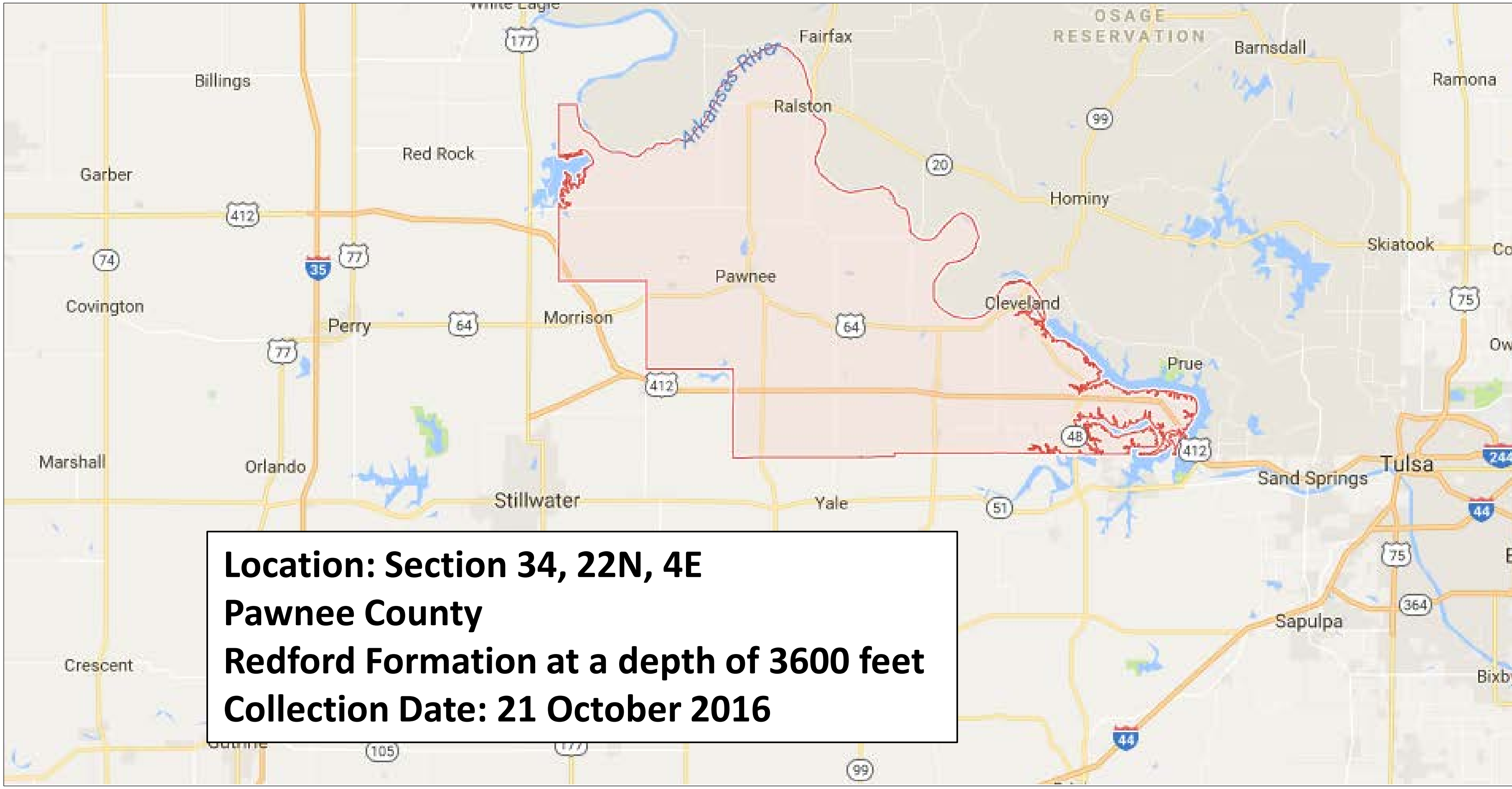
Source : L. L. Landkamer and G. Thyne, Final Report: Produced Water Management and Beneficial Use, United States Department of Energy, National Energy Technology Laboratory, 2009

Produced water has high levels of salinity and also has nutrients such as nitrogen and potassium that can sustain algae growth

Parameter	Minimum value	Maximum value	Heavy metal	Minimum value (mg/l)	Maximum value (mg/l)
Density (kg/m^3)	1014	1140	Calcium	13	25 800
Conductivity (µS/cm)	4200	58 600	Sodium	132	97 000
Surface tension (dyn/cm)	43	78	Potassium	24	4300
pH	4.3	10	Magnesium	8	6000
TOC (mg/l)	0	1500	Iron	<0.1	100
TSS (mg/l)	1.2	1000	Aluminium	310	410
Total oil (IR; mg/l)	2	565	Boron	5	95
Volatile (BTX; mg/l)	0.39	35	Barium	1.3	650
Base/neutrals (mg/l)	—	<140	Cadmium	<0.005	0.2
Chloride (mg/l)	80	200 000	Copper	<0.02	1.5
Bicarbonate (mg/l)	77	3990	Chromium	0.02	1.1
Sulphate (mg/l)	<2	1650	Lithium	3	50
Ammoniacal nitrogen (mg/l)	10	300	Manganese	<0.004	175
Sulphite (mg/l)	—	10	Lead	0.002	8.8
Total polar (mg/L)	9.7	600	Strontium	0.02	1000
Higher acids (mg/l)	<1	63	Titanium	<0.01	0.7
Phenol (mg/l)	0.009	23	Zinc	0.01	35
Volatile fatty acids (mg/l)	2	4900	Arsenic	<0.005	0.3
			Mercury	<0.005	0.3
			Silver	<0.001	0.15
			Beryllium	<0.001	0.004

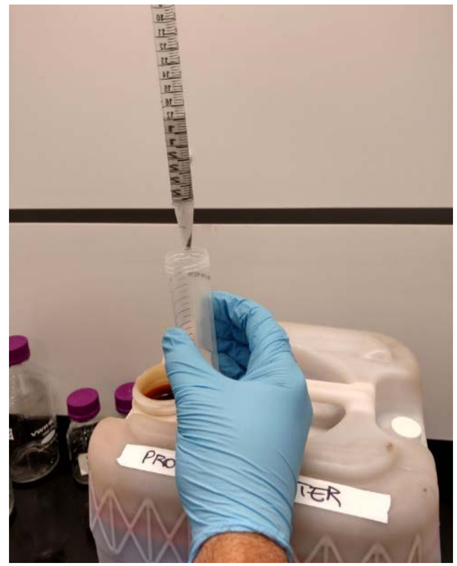
Source: P.J.C. Tibbetts, I.T. Buchanan, L.J. Gawel, R. Large, A comprehensive determination of produced water composition, in: J.P. Ray, F.R. Engelhardt (Eds.), Produced Water: Technological/Environmental Issues and Solutions, Plenum Publishing Corp., New York, 1992, pp. 97–113

Produced Water used for this study was collected from the Pawnee County in Oklahoma



Pre-treatment of PW involved centrifugation and vacuum filtration to remove the solids. The final, clear PW had a salinity of ~ 147,000 ppm

Stored at ambient conditions



Sampling from a well-mixed can

Vacuum Filtration (Size ~ 2 micron)

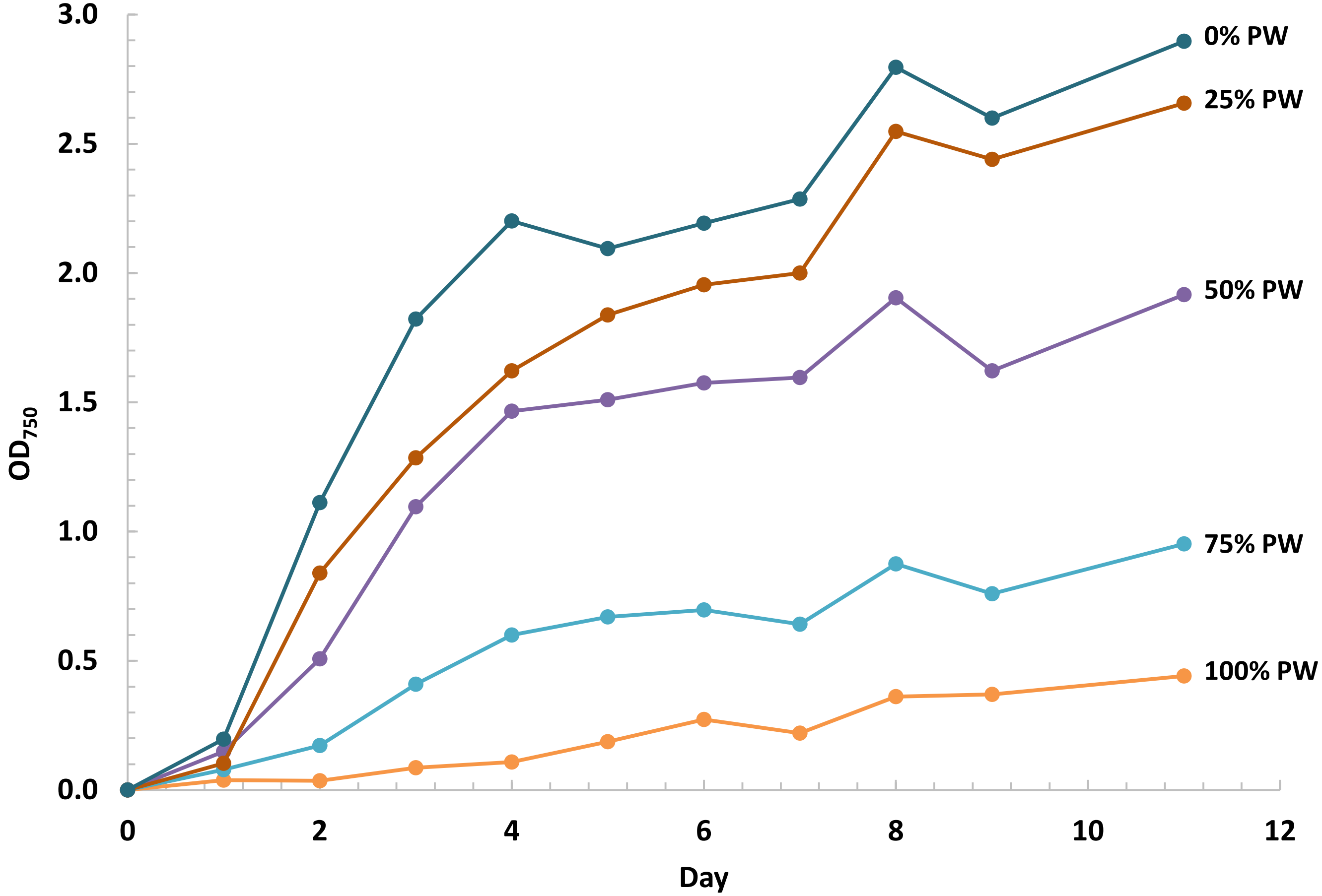
Chlamydomonas reinhardtii, **is a well known model strain for algae growth studies, due to its ease of culturing**

Algae were grown in varying proportions of the standard media and diluted produced water

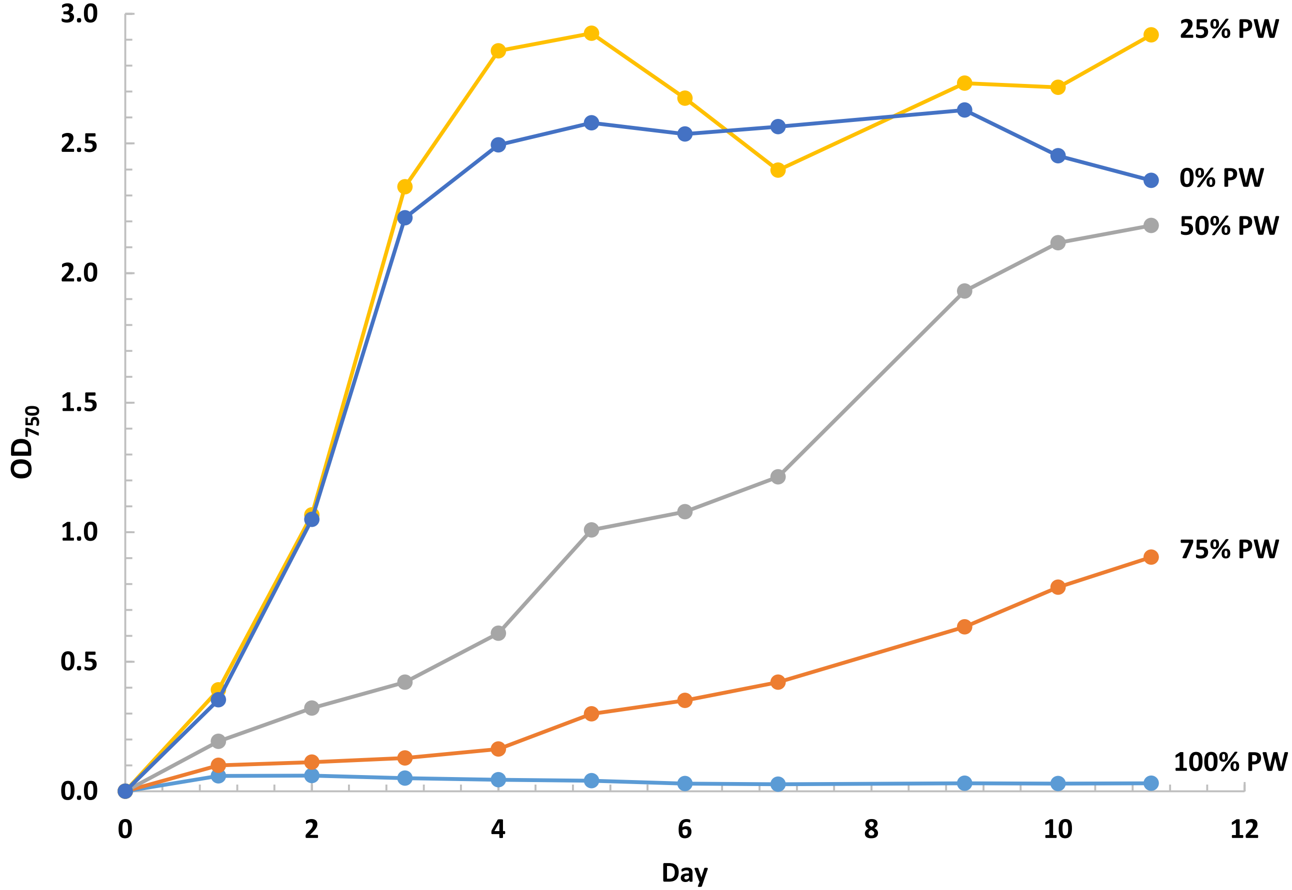
PW (%)	TAP (%)
0	100
20	80
40	60
60	40
80	20
100	0

Tris-Acetate-Phosphate (TAP) medium, is the standard medium for C. reinhardtii

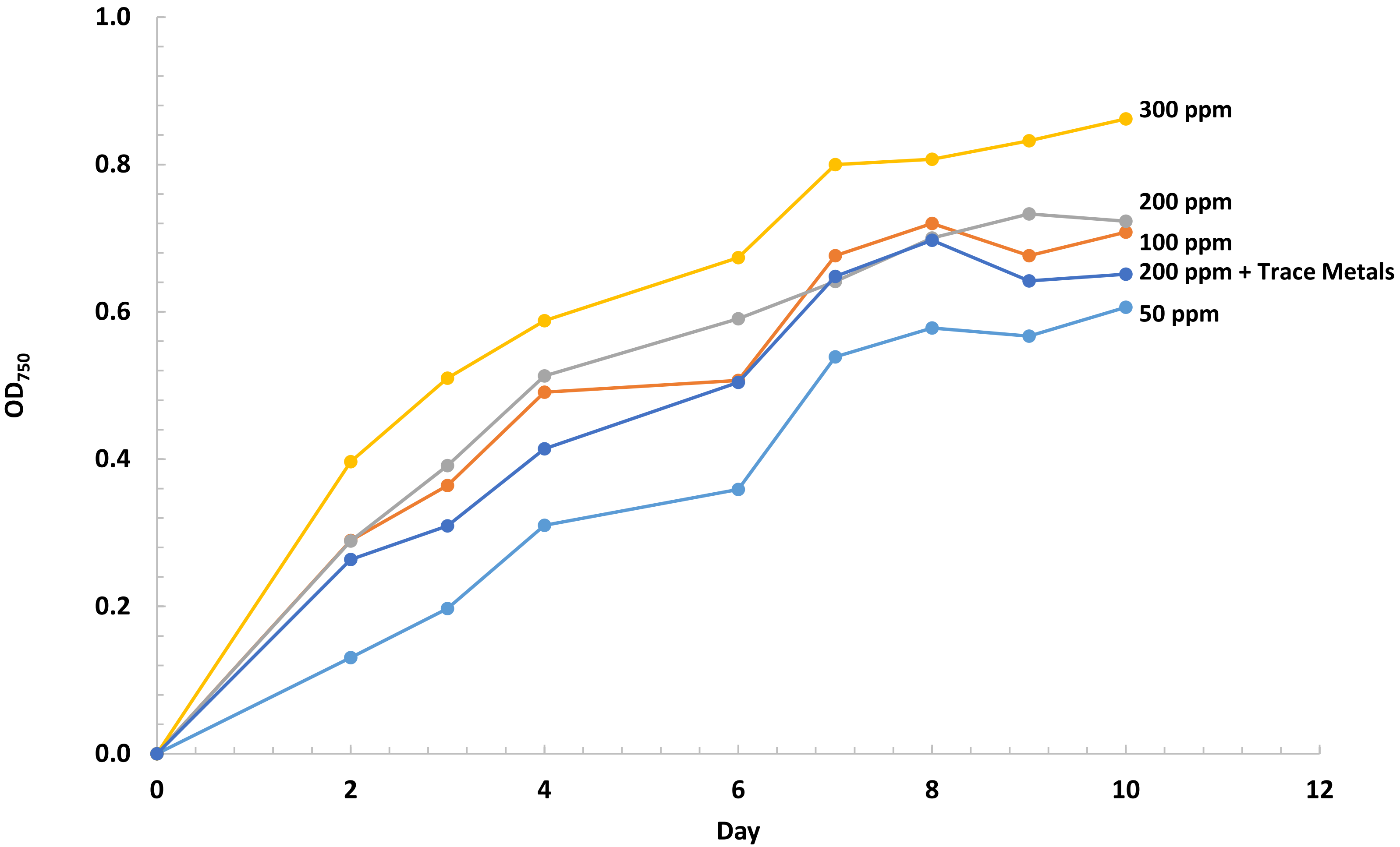
C. reinhardtii grows even in just the diluted produced water (20x) i.e., at low salinity and the growth rates get better when grown along with TAP medium



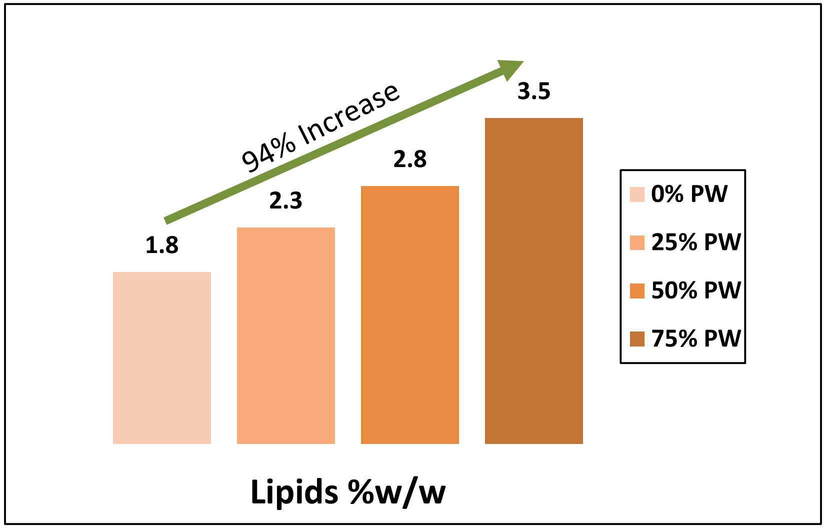
C. reinhardtii does not grow well in the higher saline produced water (~10x). The growth rates get better when grown along with TAP medium

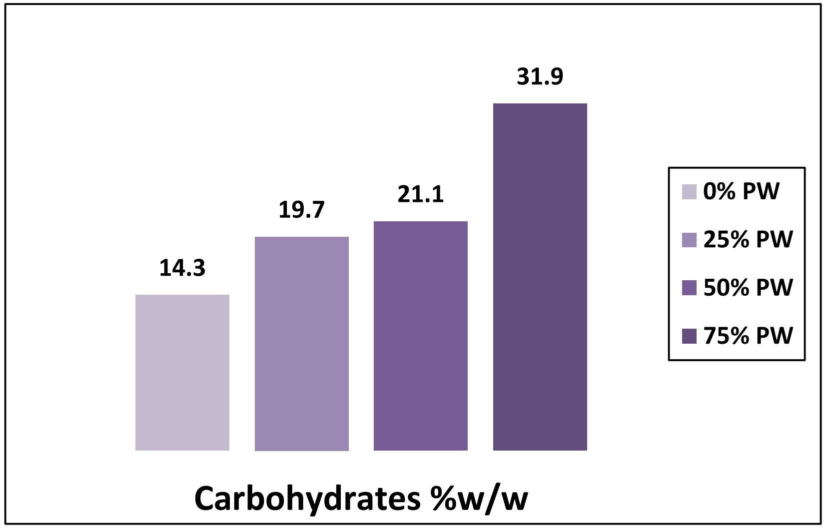


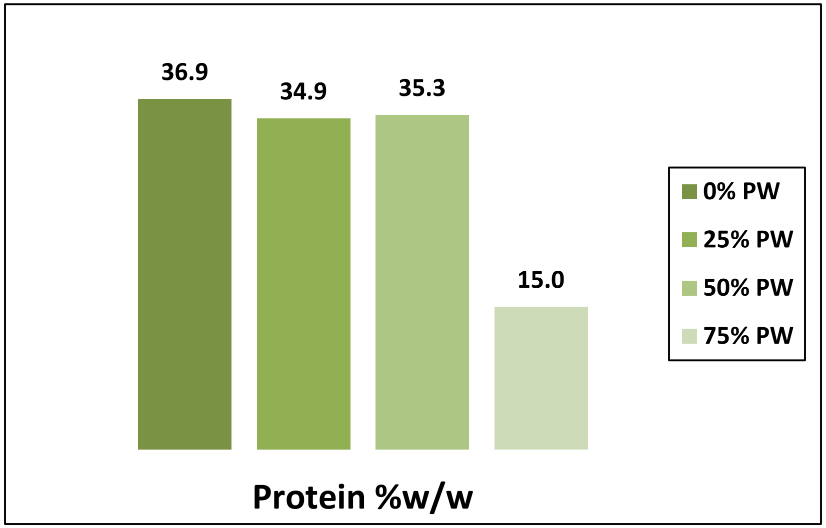
C. reinhardtii does grow in the media wherein Sodium nitrate, Potassium phosphate and trace metals were used as supplements



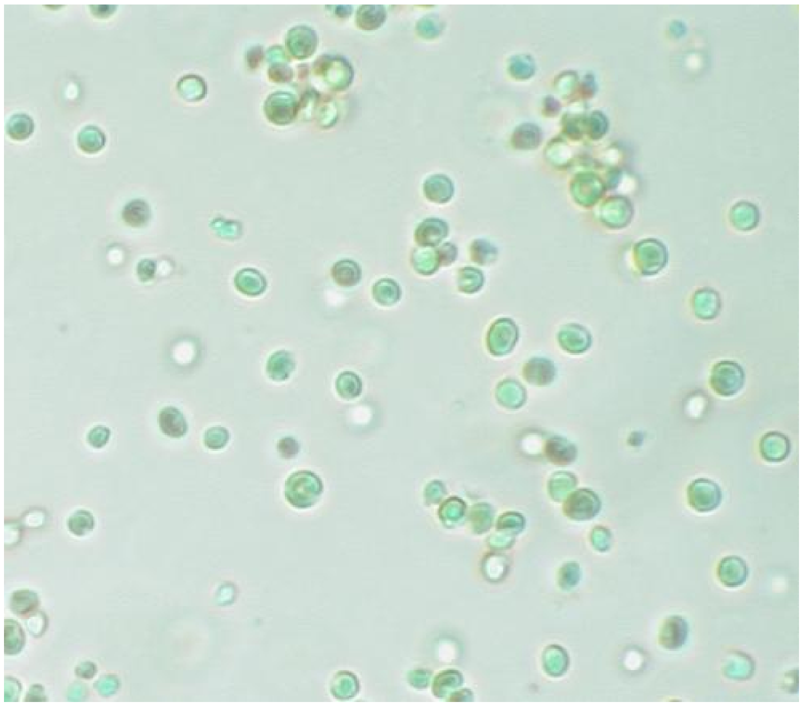
C. reinhardtii grown in PW has more lipid and carbohydrates on weight basis. However, it has lower protein content

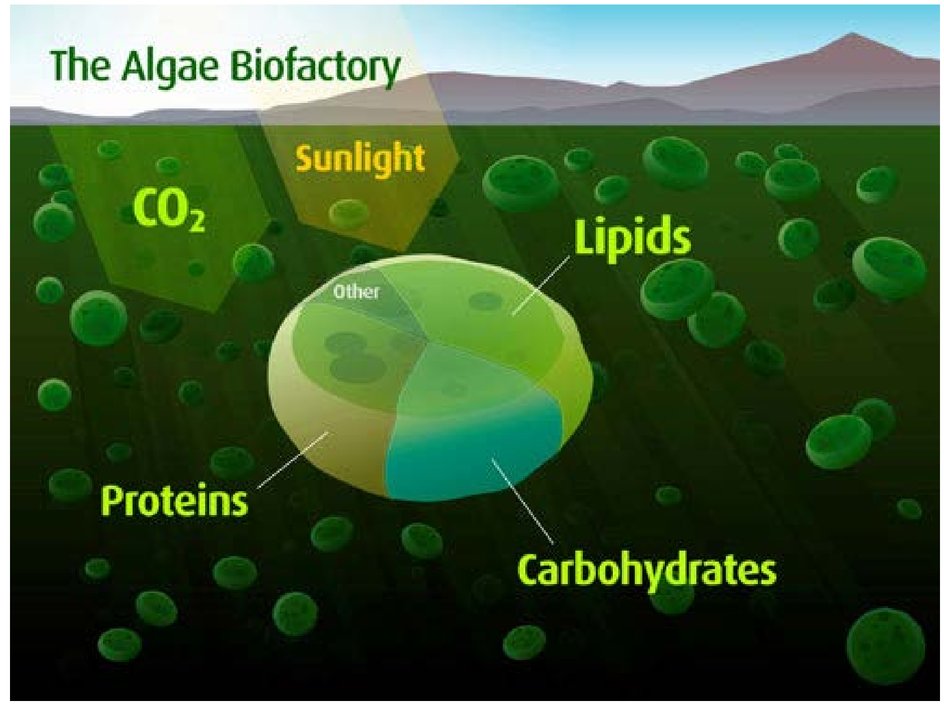




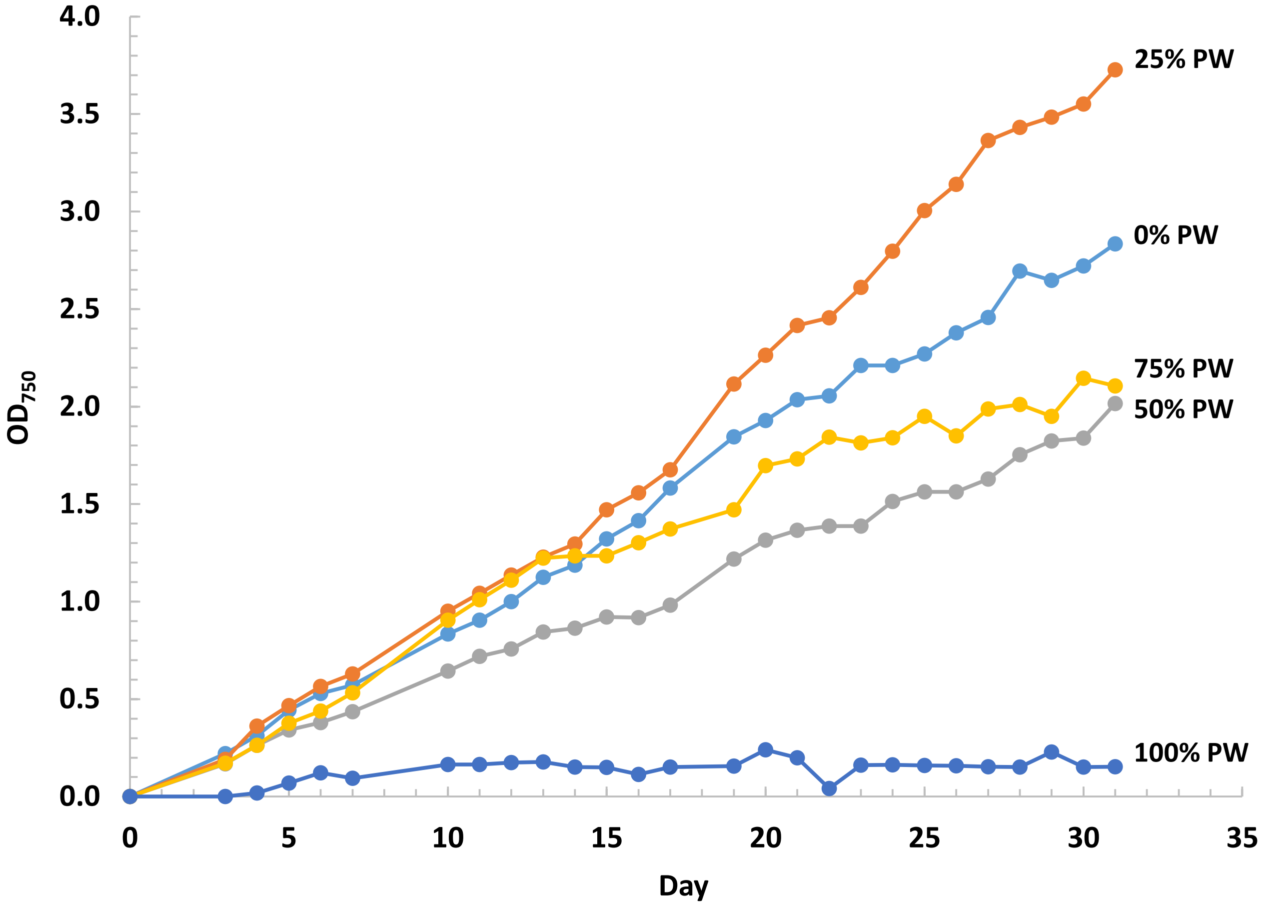


Marine microalgae species such as *Nannochloropsis sp.* show higher tolerance to salinity with better production rates

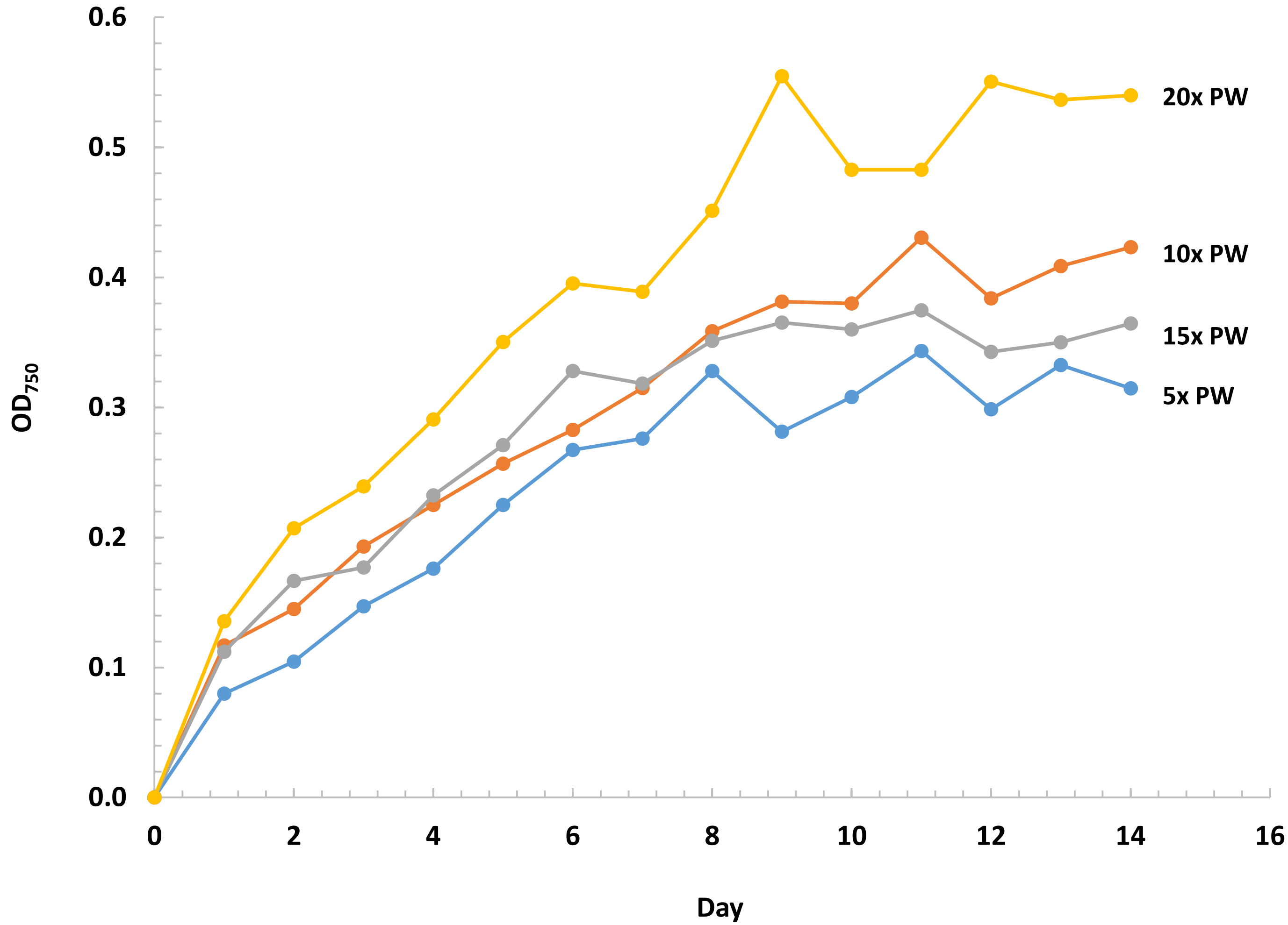




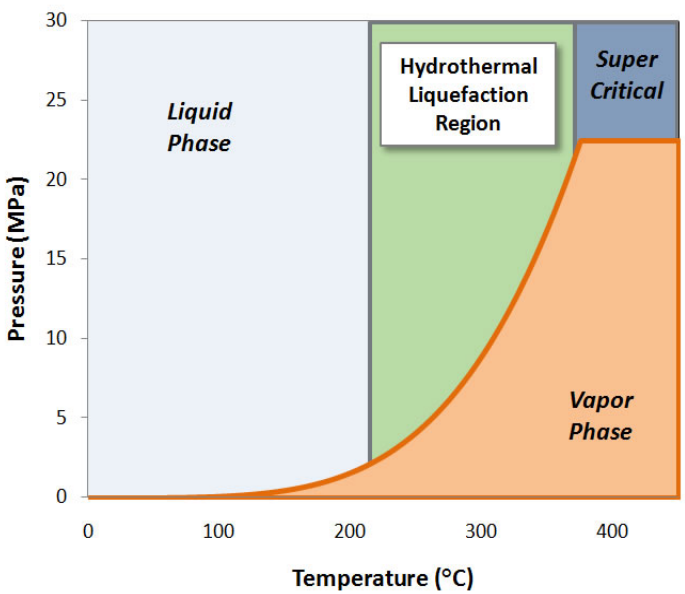
Nannochloropsis sp. grows in the diluted PW(20X) and has higher growth rates when combined with the Alga Grow seawater medium

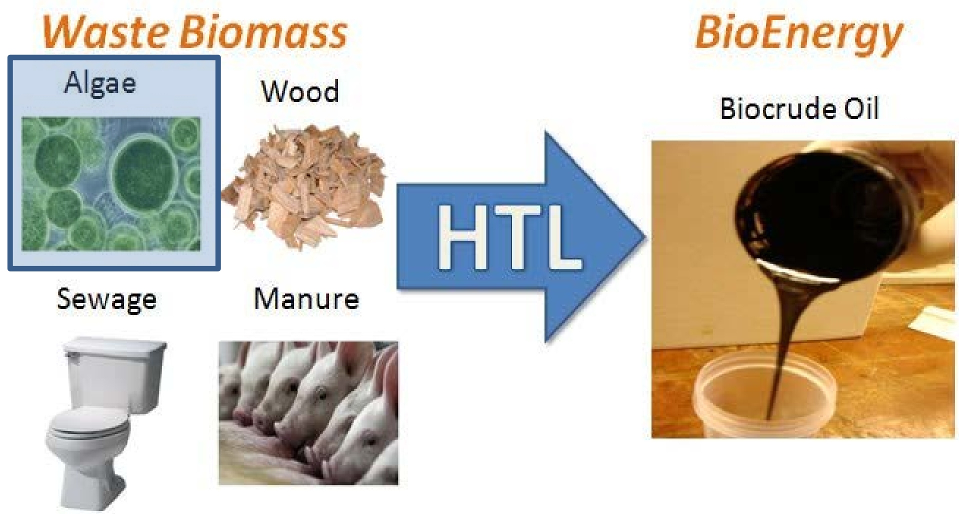


Nannochloropsis sp. grown in varying factors of diluted PW. Salinity stunts the growth of the algae



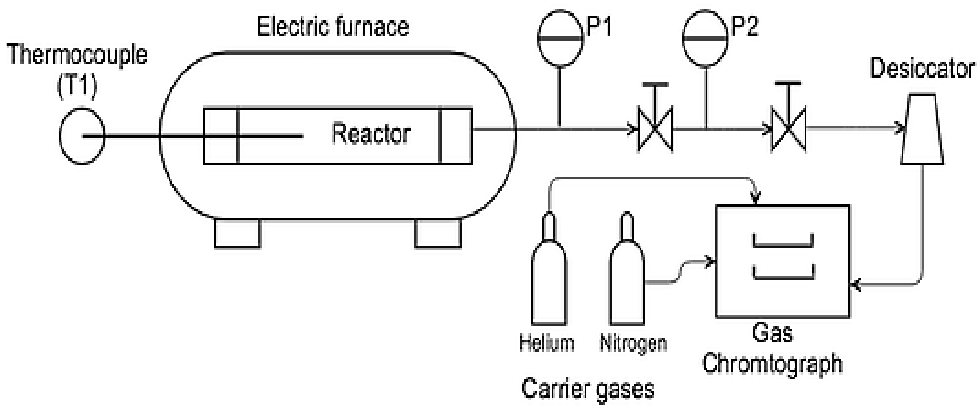
Algae biomass could be converted to bio crude by Hydrothermal Liquefaction (HTL) that mimics fossil fuel generation

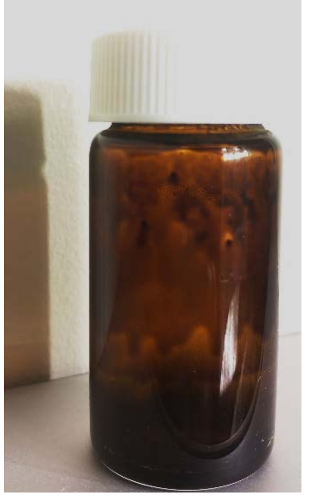




- Lipids are a source for triglycerides which are useful in biofuels production
- *Dunaliella* sp. and *Nannochloropsis* are both known to have higher lipid levels than *C. reinhardtii*

C. Reinhardtii was used as the source of biomass in HTL and the yield of bio-crude was 20% on weight basis of the algae



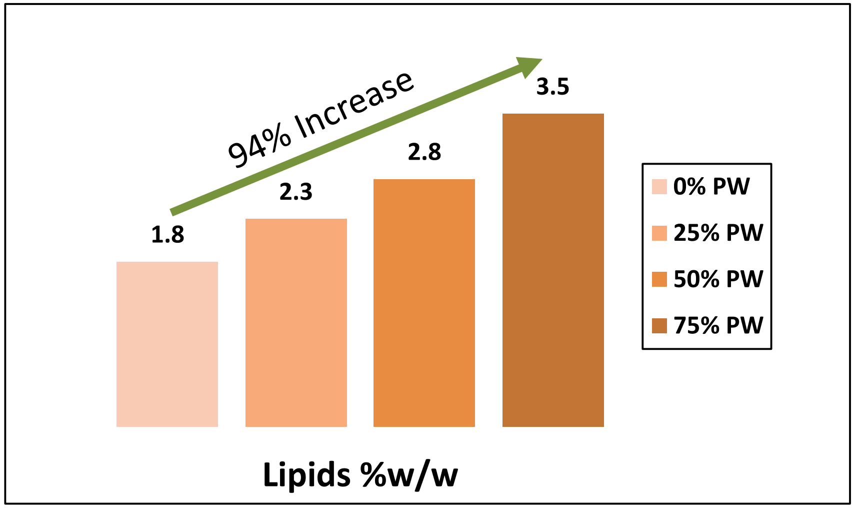


Yield of bio-crude : 20-40%

Process Temperature : 300°C

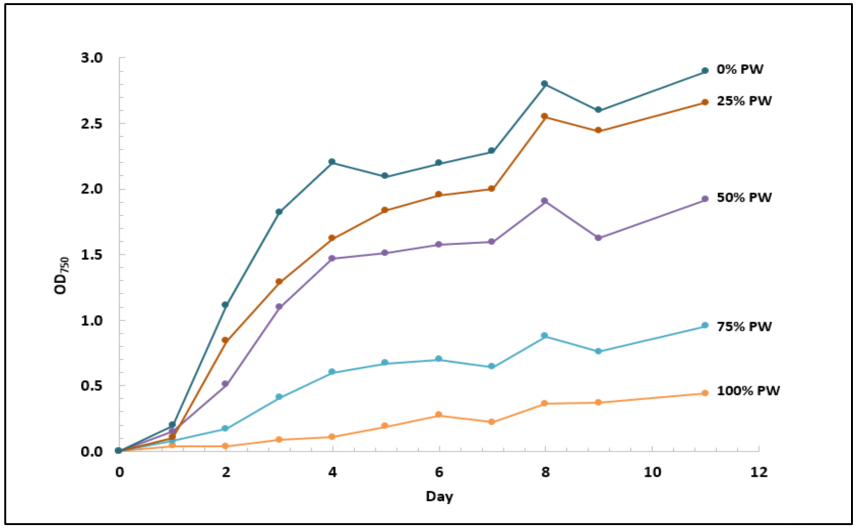
Process Time : 60 minutes

In summary, produced water can be potentially used to grow microalgae either standalone or by mixing with other media



Algae grown in PW is higher in lipids

The biomass can be used to produce bio-crude via hydrothermal liquefaction



Questions?

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