Algal Wastewater Remediation

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WATER RESOURCES

- **1.4 billion km^3 water available on earth**
- **Nearly 97% is salt water in the oceans**
- **World freshwater reserves are estimated at around 35 million km^3 (mostly locked up in glaciers and permanent snow cover, or in deep groundwater, inaccessible to humans)**
- ***By the year 2025, 2/3 of the world population will face drinking water scarcity***

Wastewater from Oil and Gas Production Operations

- 2.0 trillion cubic feet of natural gas produced in 2013
- Oklahoma: 4th largest natural gas producing state in the country
- 12,000 private and commercial injection and disposal wells in the USA, 414 in OK
- Billions of gallons of wastewater produced each year

Animal Production Industry in Oklahoma

- Oklahoma is the 5th in beef and the 8th largest swine production state in the US
- Over 2.5 million cattle and 2.4 million pigs and about 56,000 cattle and 2700 Hog & Pig operations.
- The animal production industry is estimated to be the largest agricultural contributor to water pollution.
- Animal wastes are stored and treated in lagoons ranging from 2-4 acres and 6-8 feet deep.

Objectives

To develop and optimize an integrated biological wastewater treatment system that will clean up wastewater generated during hydraulic fracturing for oil and gas production and animal production.

Microalgae

- **Microorganism / plants**
- **Photosynthesis**

$$6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$$

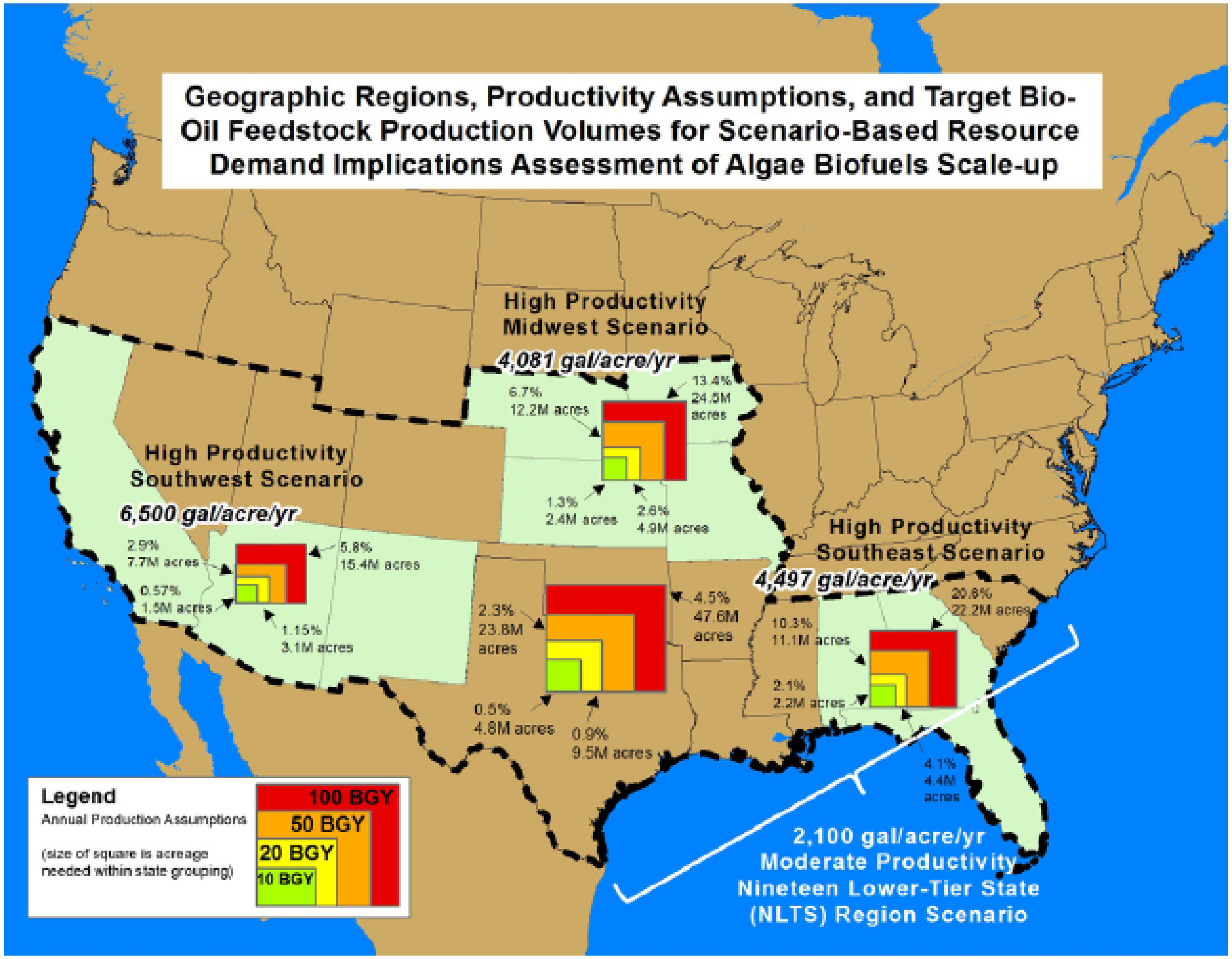
Why Microalgae ?

- *Grow in water with high salt concentration*
- *Absorb minerals, heavy metals and excess nutrients from waste water and degrade some chemicals*
- Capture (1.6 – 2.0 grams of CO_2 / gram algal biomass produced)
- Produce oxygen
- They accumulate high value compounds in the cells: oil, protein and other very high value compounds
- Fast growth (some strains can double their biomass within a few hours during the exponential growth phase)

Why is this study important?
Strain Selection

- 72,500 species existing; 32,260 species described; <20 species are being researched for biofuel production
- Intrinsic properties of algal strains are critical for their commercial cultivation
- Site specific adaptation

US Regions Suitable for Microalgae Cultivation

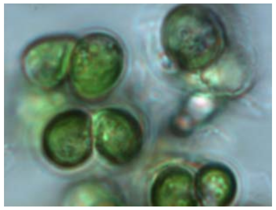


- Year around solar radiation
- Mild temperatures
- Availability of suitable land
- Water availability

Pate et al. 2011. Resource Demand Implications for US Algae Biofuels Production Scale-up. Applied Energy, 88:3377-3388

Why Oklahoma Native Algae Strains?

- ***Unicellular algae strains were isolated from the Salt Plains National Wildlife Refuge in Oklahoma, USA in 1998.***
- **Native strains well suited for growth in regional environmental conditions;**
- **Isolated from the Great Salt Plains in Oklahoma.**
  - **The Great Salt Plains a shallow, hypersaline aquatic habitat subject to large fluctuations in temperature and salinity; an extreme environment;**
  - **Algae strains expected to better withstand the fluctuations in outdoor production ponds.**



METHODS

1) Determine types and concentrations of the contaminants present in animal wastewater and frac water collected from wells operating in OK,
2) Screen Oklahoma native microalgae strains for their ability to grow in wastewater,
3) Select the most productive strain and examine its capacity for removing contaminants from wastewater,
4) Evaluate potential of the algal biomass grown in wastewater for biofuel production.

Chemical Composition of Wastewater

	Flow back	Produced	Animal Waste
Cations (mg L^{-1})			
Na	5111	8596	110
Ca	8	101	24
Mg	50	37	24
K	48	179	313
Anions (mg L^{-1})			
NO_3-N	39	0.2	42
Cl^-	7065	13492	189
SO_4^{2-}	21	18	108
B	30	114	0.6
HCO_3^-	1396	868	678
CO_3^{2-}	341	77	54
Trace elements (mg L^{-1})			
Zn	0.06	-	-
Cu	0.03	-	0.05
Mn	0	0	-
Fe	0.2	-	0.05
NH_4^+	-	86	-
ICAP_P	-	0.01	21
TDS	16104	25014	1624
pH	9	8.5	8.6

Biomass Productivity (g/L) of Algae Strains

	Standard Medium	*Animal Wastewater*
Picochlorum oklahomensis	*2.1*	*2.5*
SP23-*Aphanocapsa*	*1.7*	*1.1*

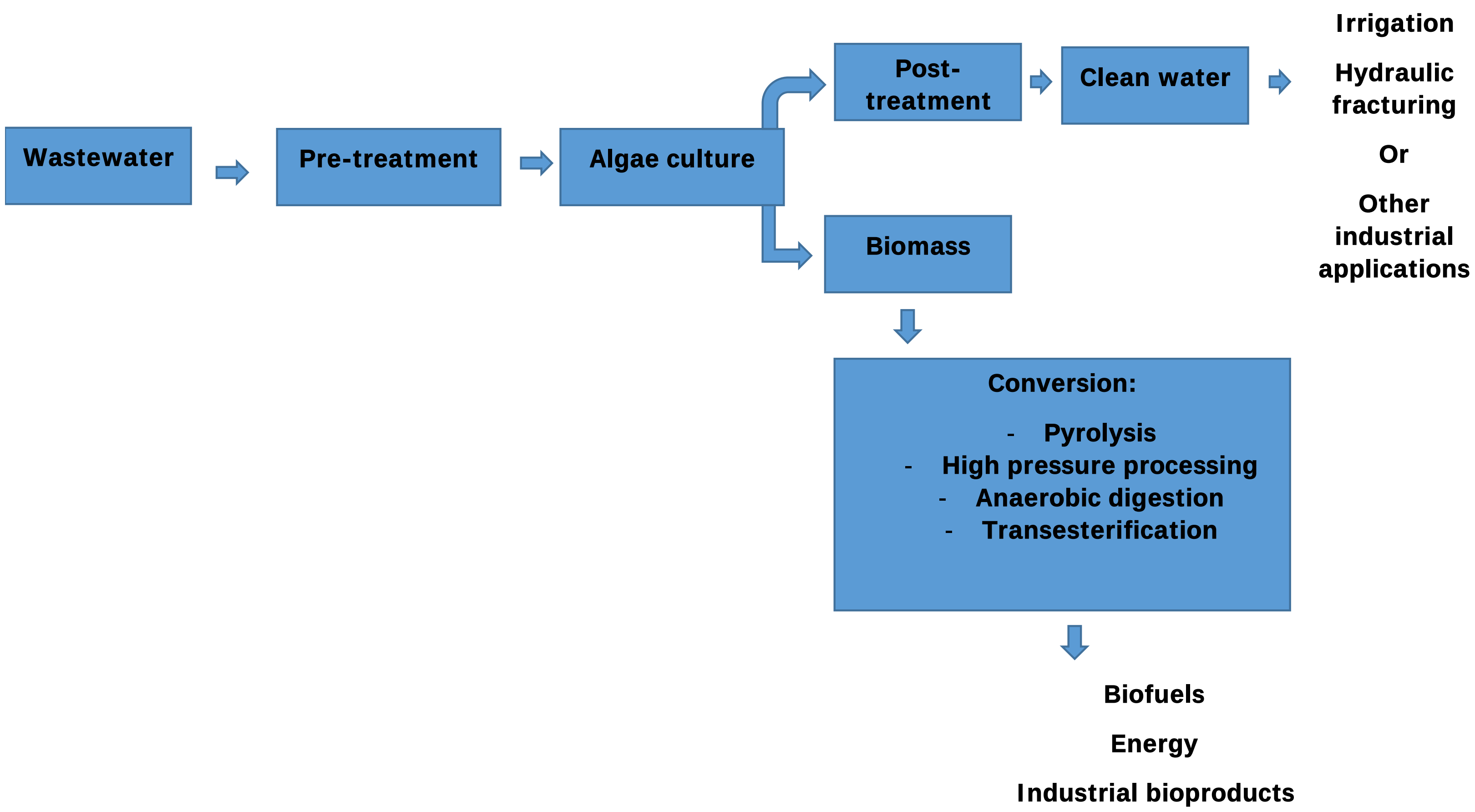
Biomass Productivity (g/L) of Algae Strains

	Standard Medium	*Frac Water*	*Frac Water +Fertilizer*
SP23	*1.7*	*0.97*	*3.4*
SP22	*0.4*	*0.4*	*7.7*

Reduction (%) in Chemical Content of Wastewater after Algal Treatment

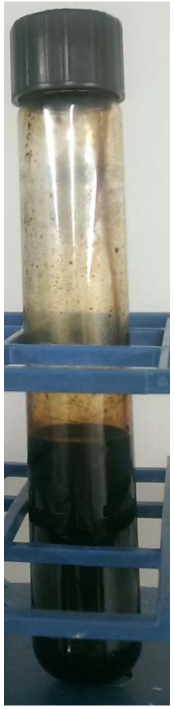
	Flow back	*Produced*	
Na	60	74	
Ca	-	40	
Mg	47	10	
K	83	60	
NO_3-N	0	2	
Cl^-	-	64	
SO_4^{2-}	-	-	
B	98	65	
HCO_3^-	90	53	
NH_4^+	-	96	-
TDS	70	60	

Algal Biorefinery



Potential Products from Algal Biomass

Algal biomass



Bio-oil

Bio-char

Conclusions

- Several algae strains grows in frac and animal wastewater
- Algal treatment of wastewater effectively removes some of the undesirable chemical from water
- Algal biomass can be used to produce bio-oil, biogas and bio-char and potentially improve the economic feasibility of wastewater treatment

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