Wastewater Reclamation and Biofuel Production Using Algae

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Cal Poly Algae Technology Group

Recent Major Projects

• 2014 US DOE Algae Biomass Yield Project
• 2013 US DOE Water & Nutrient Recycling Project
• 2013 US DOE ATP\(^3\) Testbed Site (Prime: ASU)
• 2011 CEC Algae Biofuels & Wastewater Reclamation

• Investigators from:
  – Engineering
  – Chemistry
  – Microbiology
  – Animal nutrition
  – Natural Resources
  – Food science
Cal Poly is an ATP³ testbed site in ASU network.

ATP³ has been a very fruitful project: Harmonization of production, lab standardization, and great collaboration.
Site of DOE Project with Cal Poly & MicroBio

Algae Wastewater Treatment Plant → Biofuel Plant

Two 14,000 m² paddle wheel mixed raceways

←Paddle wheels
Wastewaters (WW) contain hazards but also resources...
Beyond protecting environmental water quality, the goals of wastewater treatment are to ...

- Recycle water
- Recover nutrients
- Produce biofuels
RNEW® Technology

Recycle

Nutrients

Energy

Water

• CO₂ addition to allow complete nutrient removal
• Harvesting by bioflocculation
• Low cost
• Low energy intensity vs. conventional treatment
• Biofuel via digestion or hydrothermal liquefaction
Full-scale raceway systems in California, Israel, S. Africa, New Zealand (but not designed for nutrient removal).
Typical Electro-Mechanical Treatment Plant

- Sludge Settling Tanks
- Aeration Basins with Air Blowers
Algae wastewater treatment is low cost and energy efficient. Algae nutrient removal is seasonal.

Save 50% total cost. Save 67% electricity (w/out biogas)
Algae wastewater treatment plant becomes a dedicated algae biofuel plant
Wastewater recycling supports much larger cultivation area than just treatment.
“Pressure cooking” (hydrothermal liquefaction) converts algae to biocrude oil.

Pacific Northwest National Lab & Cal Poly
What does it take to reach 2500 gal/ac-yr?

Two main unknowns are to be determined in field studies:

Biofuel Intermediate Goal:
2500 gal/ac-yr = 6.4 mL/m²-d = 6 g oil/m²-d

HTL Conversion:
?? g oil / g biomass

Productivity:
?? g biomass / m²-day

What kind of productivity?
With wastewater, we have gross, net, and autotrophic.
What does it take to reach 2500 gal/ac-yr?

Two main unknowns are to be determined in field studies.

Biofuel Intermediate Goal:

2500 gal/ac-yr = 6.4 mL/m²-d = 6 g oil/m²-d

HTL Conversion:

0.35 g oil / g biomass (preliminary result)

Productivity Need:

17 g biomass / m²-day

If harvesting - dewatering efficiency is 85%:

20 g biomass / m²-day needed
Add CO₂ to balance C:N:P ratio and achieve completed nutrient assimilation.

**CO₂ Enhanced**
- 600 mg/L Algae
- <1 mg/L NH₄⁺-N
- <0.3 mg/L PO₄³⁻-P

**Air Sparged**
- 130 mg/L Algae
- 25 mg/L NH₄⁺-N
- 3 mg/L PO₄³⁻-P

Lundquist et al., Cal Poly
Algae Field Station for wastewater treatment & biofuels at San Luis Obispo, California
2-day vs. 3-day hydraulic residence times tested.

Compared productivity & treatment.
Ponds-in-series test for treatment & water reuse

For biofuels, water reuse builds-up inhibitory compounds.

Objectives:
1. Total N ≤ 10 mg/L throughout winter.
2. Compare productivity.

CO₂ Addition:
ON at pH 8.6
OFF at pH 8.5
Great productivity with wastewater raceways!

But what is “algae productivity” in media with organic matter? What is the autotrophic portion? Why care?
Good ammonia nitrogen removal except mid-"winter" when mechanical aeration needed.
Nitrification occurs, but not ammonia volatilization at pH 8.5 in 33-m² raceways.

Mass Balance

March 06, 2013 - August 29, 2013
3 day HRT

Total Nitrogen (kg)

TKN
NO2
NO3

Influent
Pond 4
Pond 5
Pond 6

Triplicate Ponds

Algae to be removed in clarifier
Phosphorus removal would need 3-4 rounds of growth in places needing <0.5 mg/L P.

R&D on “luxury uptake” of excess P needed.

Algae to be removed in clarifier
Site of DOE Project with Cal Poly & MicroBio

Algae Wastewater Treatment Plant → Biofuel Plant

Facultative Ponds

Settling Ponds

Paddle wheels

Two 3.5-acre raceways
At full-scale, algae are coagulated, settled, and solar dried.

~100,000 gallons of 3% solids algae in decanted settling basin

Concrete drying pad

Solar dried algae
We run three conditions in triplicate.
Goal: maximize productivity and treatment.
Edge effects in pilot units throw off scale-up projections.

Edge effects from shading are minimized with transparent paddles and dividers.
Remote control and data logging capabilities

Feed rates, CO₂ dosing, paddle speeds, etc. can be changed on timer basis or remotely.
Primary Clarifier
2-hour residence time

Pilot-Scale Raceways
2-5 day HRT

Algae Settlers
(2-3 hours)

Treated Wastewater

Algae Drying Beds & Screens

Algae Thickener

Supernatant Tank
Are large raceway facilities practical?

A 1,000-acre algae biofuel facility takes in 12 million gallons per day of wastewater (120,000 population)
Wastewater pipelines out of town are common.

Lancaster, California
157,000 population

Effluent used for alfalfa irrigation.

Water and nutrients are recycled at low running cost, but pipeline investment needed.

Converted to activated sludge due to N limit. Now N fertilizer is purchased.
Stockton, California
292,000 population

Land was reserved early. Now city has grown to the edge of the ponds.

Used by Audubon Society for bird watching.

City owns real estate under the ponds that is now valuable.
Napa, California
77,000 population

Treated pond effluent is discharged to a river during winter and used to irrigate pasture and soon grape vineyard during summer.
Modesto, California
485,000 population

During winter, treated effluent is partly stored in reservoirs and partly discharged to a river.

During summer, City-owned cattle pasture is irrigated.
In US, 5 billion gallons per year (BGY) of algae biofuel is feasible with wastewater use, but 21 BGY may outstrip supply of municipal and animal wastewaters. [Preliminary, 2014 Venteris et al.]

21 BGY is US aviation kerosene use. [ ]

5 BGY in 2900 farms

21 BGY in 14,000 farms

2014 Venteris, Skaggs, Wigmosta, Coleman
Algae + wastewater + biofuel: Why do it?

WW-supported biofuel is small compared to need but...

- 5-20 billion gallons is still a lot and we need to make use of every feedstock.
- WWT is needed regardless.
- WWT is expensive, but algae cuts the cost.
- Algae WWT saves electricity.
- Algae WWT captures nutrients for reuse.
  - But with increased handling and trucking costs
- Treat WW: Get your feedstock for free.
- High fuel:co-product ratio with reclaimed water.
- Build algae production expertise and capacity.
Global Interest: Current proposals for algae WWT, biofuel, and aquaculture projects

1,500 acres (600 ha) site-specific algae production facility rendering.
Biofuel project under construction currently.
Aquaculture pilot plant with flue gas CO$_2$
High value product proposal
Conclusion

Algae Love Wastewater
Acknowledgments


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Thank you for your attention

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