Open-pond Cultivation of Microalgal Polycultures on Landfill Leachate

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Abstract

Utilizing waste effluent for the production of renewable fuel sources not only reduces our dependence on fossil fuels but also provides an opportunity for environmental bioremediation. Liquid that permeates through layers of municipal waste in landfills (landfill leachate) is a waste effluent that requires collection and costly treatment. Landfill leachate (LL) has sufficient nutrients for microalgae cultivation, making it a viable growth medium for algae used in biofuel production. Total ammonia nitrogen (TAN) is typically very high in LL, which hinders algal growth, prompting cultivation in diluted LL or determining other favorable conditions for growth. The research objective was to grow indigenous microalgae outdoors in a 100-L raceway pond in non-diluted LL. Mature leachate was collected from a closed landfill and characterized for pH, conductivity, alkalinity, solids concentrations and chemical oxygen demand. The leachate was inoculated with a microalgal polyculture and monitored daily for pH, growth (optical density) and TAN. Carbon dioxide was added continuously to the pond through a diffuser for pH control. Microscopy was used to evaluate the biodiversity of the microalgal polyculture before and after the trial. Results showed that algal biomass increased in 100% LL over the 11-day period. CO_2 was an effective means of maintaining a neutral pH, which favored the presence of ionized ammonia (NH_4^+) rather than unionized, free ammonia (NH_3) that can disrupt algal cellular metabolism. Certain algae strains were more tolerant than others. The overall reduction of TAN from 825 to 4 ppm demonstrates the potential of microalgae for bioremediation of landfill leachate.

Introduction

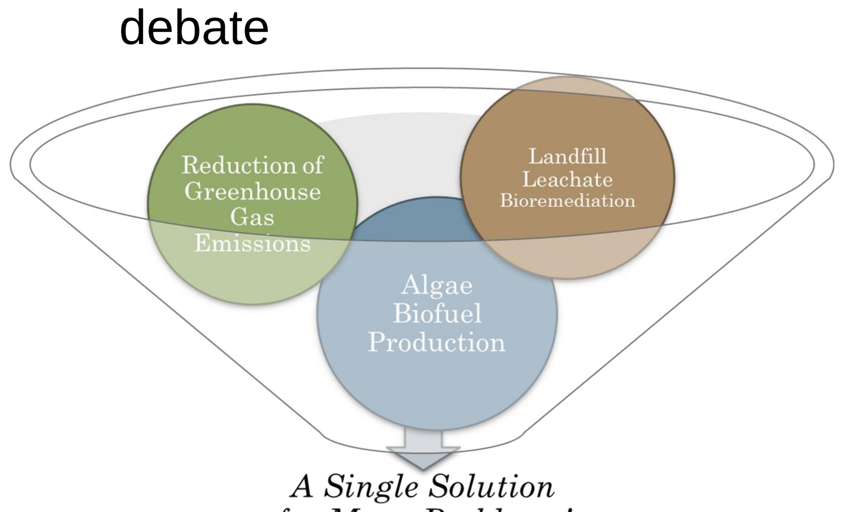
Microalgae can produce carbohydrates, lipids, and proteins. These products can be used as possible sources of biofuel[1]:

- ***Biodiesel*** from algae lipids
- ***Bioethanol*** from algae press cake remaining after lipid extraction
- ***Biogas*** from anaerobically digesting algae biomass

Leachate collected from Alachua County Southwest Landfill (ACSWL), Archer, FL

Using microalgae as a renewable source of fuel provides many advantages:

- High biomass production
- Cultivation on non-arable land
- Elimination of food versus fuel debate



Landfill leachate (LL) is liquid that permeates through landfills

- Must be managed to prevent contamination to the environment[2]
- Widely available
- LL from different landfills demonstrate different properties
- Nutrients present in LL allows for algae growth[3]

Objective

Evaluate the growth and remediation potential of microalgae in 100% landfill leachate using outdoor 100-L open raceway ponds

Methods

- Inoculate 100-L open raceway pond with indigenous algae – 20% (v/v)
- Use light microscopy to evaluate biodiversity of microalgal cultures
- On-demand diffusion of carbon dioxide (CO_2) into pond at a pressure of 10 psi to maintain culture at pH=7
- Leachate characterization including pH, conductivity, alkalinity, chemical oxygen demand (COD), solids concentrations, total ammonia nitrogen (TAN), and optical density (OD)
- Daily monitoring of pond including pH, OD (spectroscopy at 750 nm) and TAN
- Conduct analyses in triplicate and in accordance with Standard Methods[4]

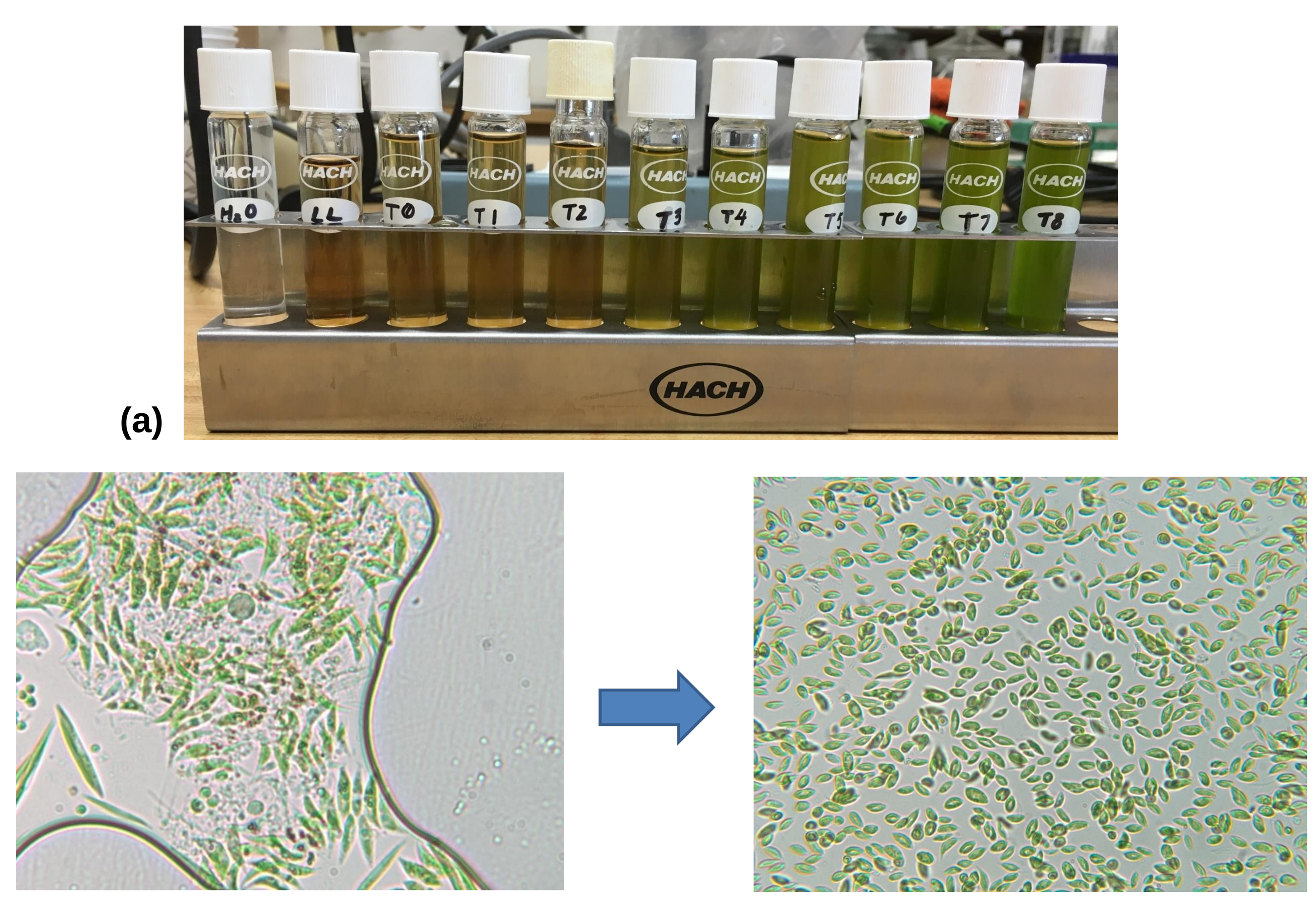
100-L Raceway Pond

Inoculating pond with indigenous algae

Results

Table 1. Physico-chemical Composition of ACSWL Leachate

Component	Average ± std. dev. (*n* = 3)
pH	7.95 ± 0.05
Alkalinity (mg $CaCO_3$/L)	5453 ± 46
Total COD (mg/L)	1763 ± 137
Conductivity (mS/cm)	12.7 ± 0.0
Total solids (% wet weight)	0.66 ± 0.01
Volatile solids (% total solids)	12.8 ± 1.3
TAN (mg/L)	887 ± 10
Optical density (Absorbance)	0.014 ± 0.002



(b) Day 0 - 100X Magnification

(c) Day 11 - 100X Magnification *Schroederia* and *Chlorogonium*

Figure 1. Pond samples in daily progression (a) and microscopic images showing transition of microalgae from a polyculture on Day 0 (b) to a biculture on Day 11 (c)

Results

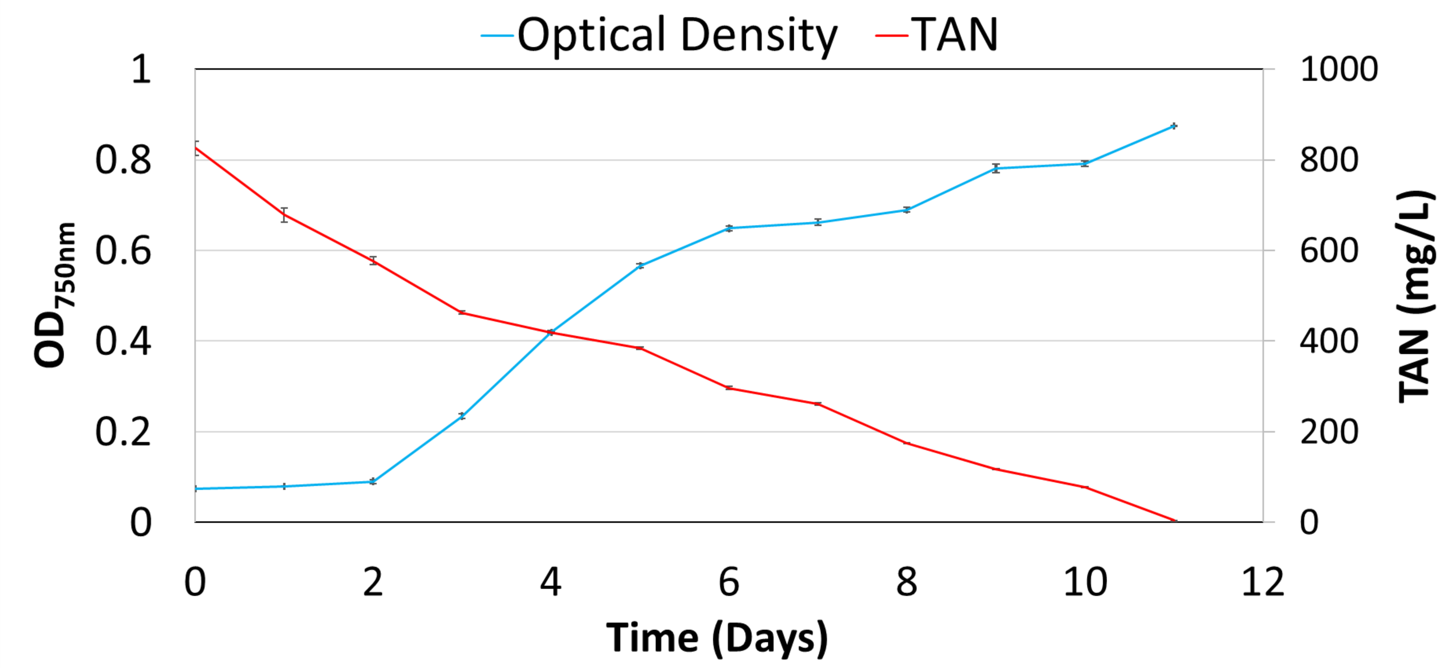


Figure 2. Optical Density and TAN Concentrations of Pond
(Error bars represent standard deviation, n = 3)

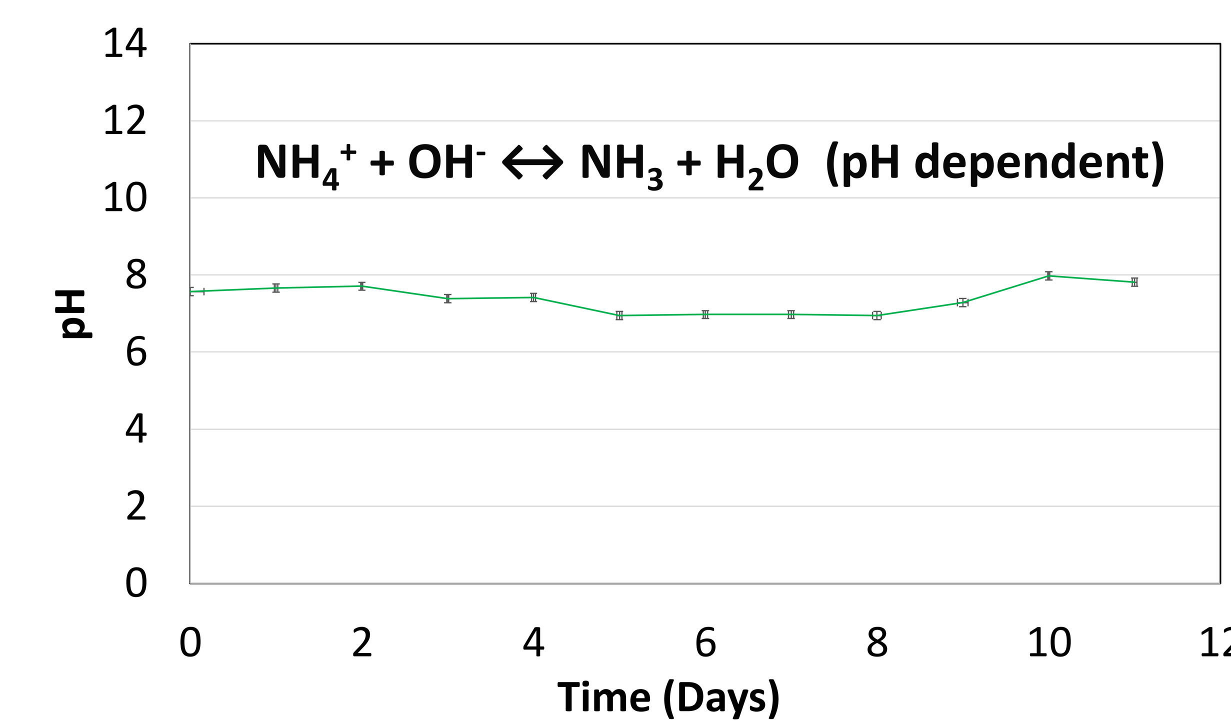


Figure 3. pH of Pond
(Error bars represent standard deviation, n = 3)

The ammonia concentrations in the LL did not inhibit algal growth as CO_2 was an effective means of controlling pH. TAN can be partitioned into an ionized form (NH_4^+) or an unionized gaseous form (NH_3) known as free ammonia depending on pH and temperature. At high pH, the equation shifts toward free ammonia, which is more toxic and can disrupt algal cellular metabolism. In this study, a neutral pH was maintained and TAN concentrations (primarily in the form of ammonium) decreased from 825 to 4 ppm as the nutrients were effectively utilized by the algal biomass.

Conclusions

- Algal growth was evident in 100% landfill leachate
- The microalgal polyculture evolved into a predominant biculture of *Schroederia* sp. and *Chlorogonium capillatum,* suggesting that these algae are more tolerant of high-ammonia wastewaters
- CO_2 was effective at maintaining a neutral pH, which promoted nutrient uptake by the algae and prevented inhibition from free ammonia

References

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Acknowledgements

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