Anaerobic digestion of algae harvested from an algal turf scrubber at the Port of Baltimore

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Introduction

Algal Turf Scrubber (ATS) and Bioremediation

- ATS is a bioremediation technology that removes nutrients from eutrophic surface water by pumping pulses of eutrophic water down a flow-way.
- Algae in the water forms a mat ("turf") on the textured surface of the flow-way to creates a diverse biofilm, producing a contained algal bloom (Fig. 1).
- The biofilm of an ATS removes dissolved nutrients and adds oxygen to the water that flows down the flow-way, as the algae metabolizes the nutrients and incorporates them into its biomass through photosynthesis.
- The ATS is approved from non-point source nutrient treatment in Maryland's Water Quality Trading program, which provides financial incentives to parties that install advanced stormwater management technologies on their property.

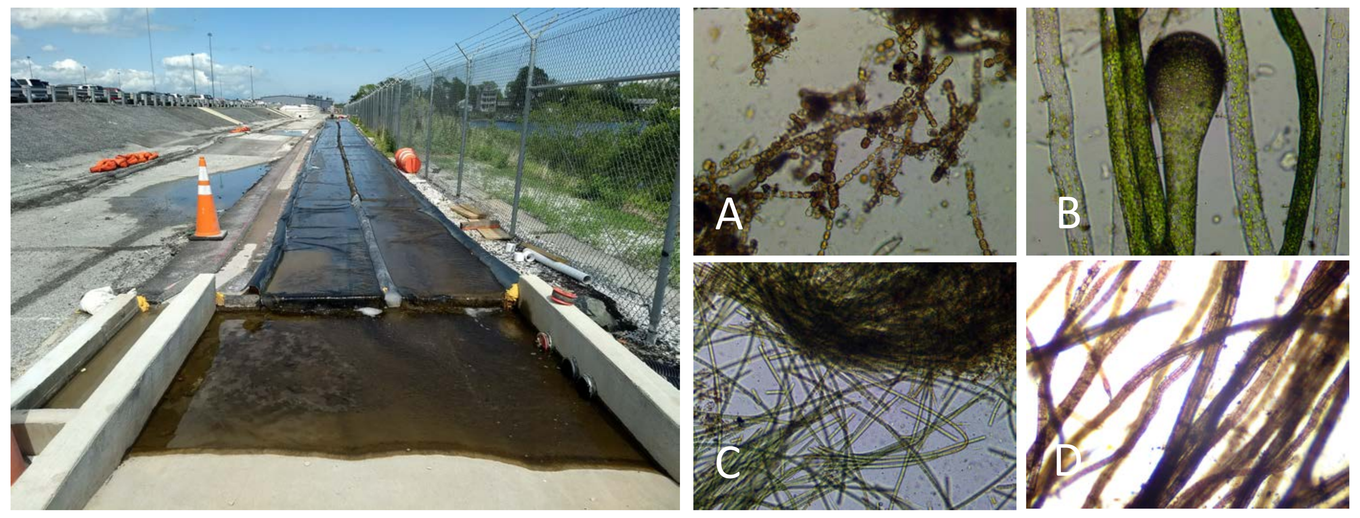

Figure 1: An ATS flow-way system installed at the Port of Baltimore and some common algae observed in its biofilm; (A) *Melosira* sp., (B) *Enteromorpha* sp., (C) *Oscillatoria* sp., (D) *Rhodocorton* sp.

Anaerobic Digestion (AD) and Bioenergy

- Decomposition process that naturally occurs in the absence of oxygen; utilized in wastewater treatment plants and farms to process organic wastes into methane (CH_4)-rich biogas, which may be utilized similarly to natural gas for heating or electricity generation (Fig. 2).
- Liquid digester effluent contains processed nutrients, especially high levels of ammonium (NH_4^+), and may be used as-is as a fertilizer or the solids can be separated and used for animal bedding on farms.

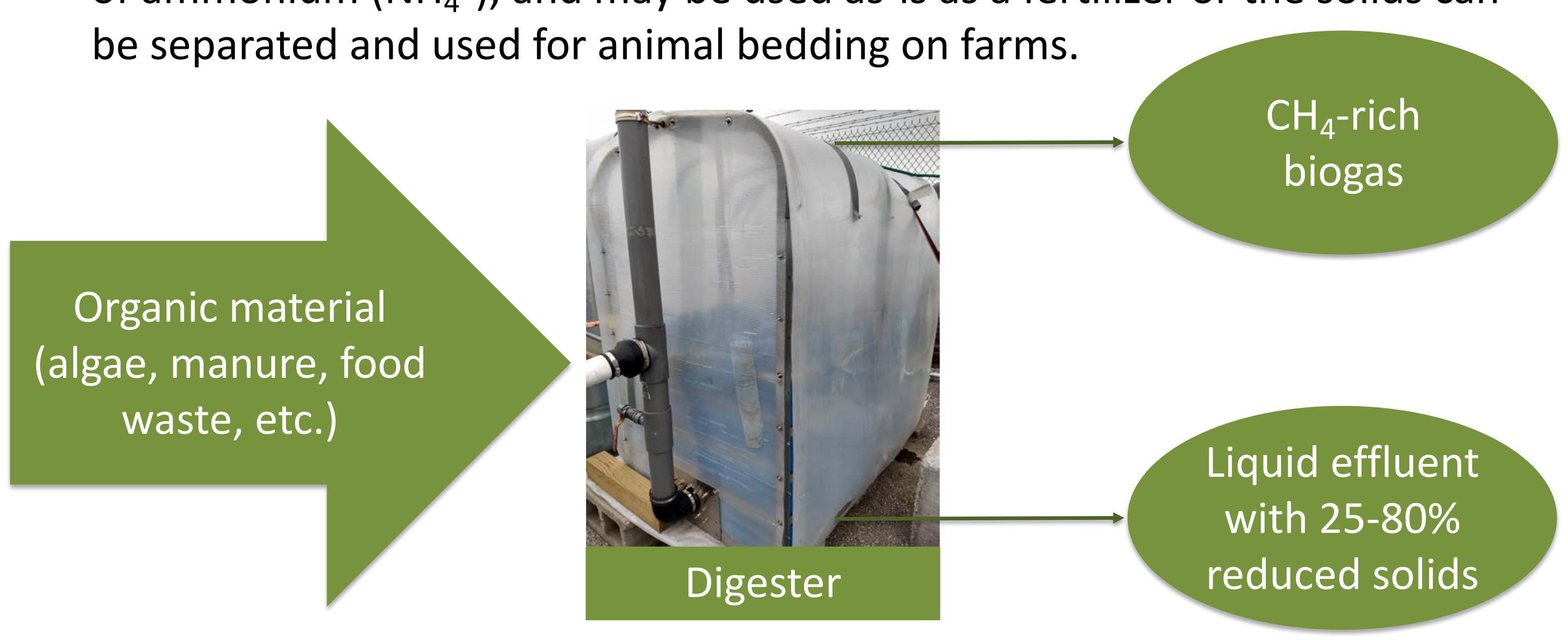

Figure 2: The process of anaerobic digestion.

Objectives

- Utilize a 61x2 m ATS to produce an algal feedstock for AD at the Port of Baltimore's Dundalk Terminal, combining bioremediation with bioenergy production at-scale over two growing seasons (July 2018-October 2019).
- Determine how an ATS algae feedstock impacts the volume and quality of biogas produced from AD and create a viable bioenergy feedstock.

Methods

- For the 2018 growing season, three digesters (D1, D2, and D3) were used to process the algae harvest; D1 and D2 were replicates operated in parallel, while D3 was connected in series with D2 (Fig. 3).
- The system was further improved for the 2019 growing season by incorporating recirculation heating systems into D1 and D2 to reduce temperature variability and improve the homogeneity of the liquid digestate; the operational fluid volume of D1 and D2 were increased from 1700 to 2000 L to accommodate this (Table 1).
- Algae was harvested weekly every Thursday fed to the digesters incrementally on a Monday-Wednesday-Friday feeding schedule.

Table 1: Experimental design parameters of the Port of Baltimore ATS-AD research, 2018-2019.

Parameter	2018	2019
Operational Period	July 22 – Oct 20	June 21 - Oct 24
Operational Time (weeks)	13	18
Digester Fluid Volume (L)	D1,D2 = 1700 D3 = 500	D1,D2 = 2000 D3 = 500
HRT (days)	D1 = 50 ± 14 D2+D3 = 65 ± 18	D1 = 52 ± 9 D2+D3 = 65 ± 12
Total algae fed (m^3 per growing season)	3.5	6.2
Algae loading rate (L/week per system)	271	327
Total solids (TS) of algae feedstock (%)	3.91 ± 1.09	3.81 ± 0.41

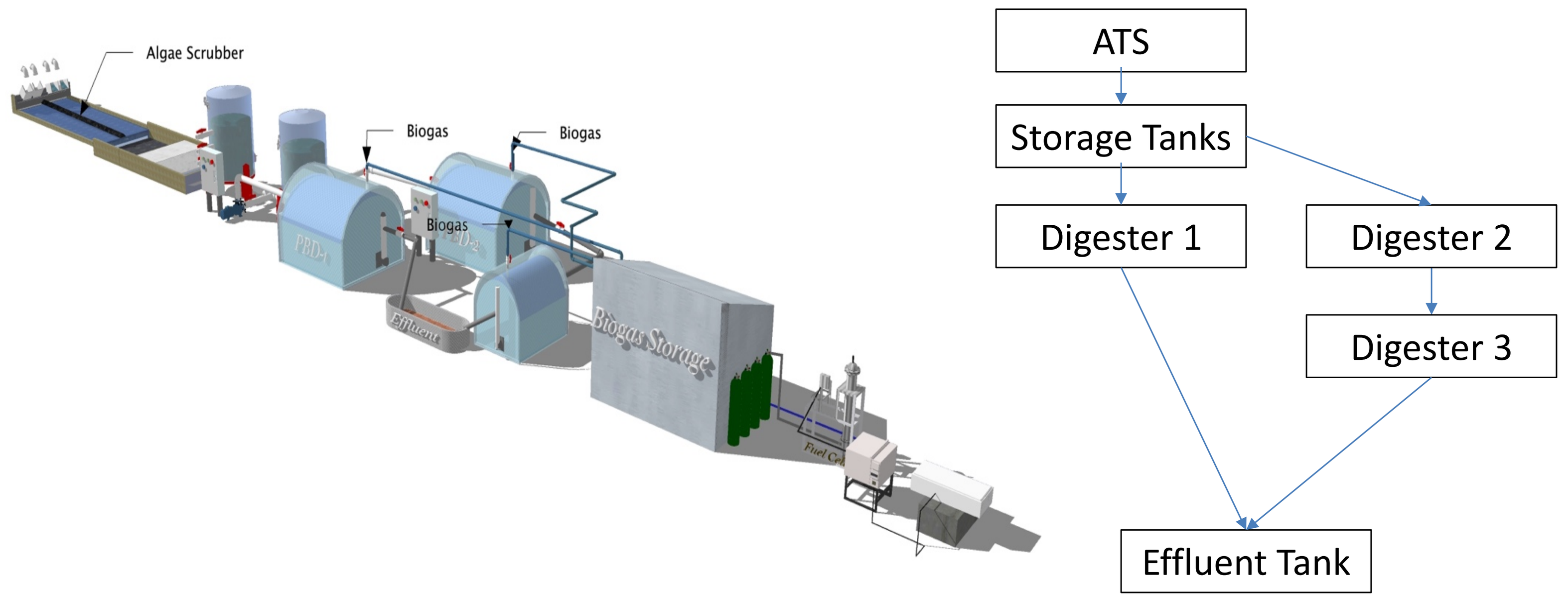

Figure 3: Schematic and design of ATS-AD system at the Port of Baltimore's Dundalk Terminal, 2018-2019.

Results

- The three AD units produced 246 and 484 L CH_4/week with an efficiency of 115 and 198 L CH_4/kg volatile solids (VS) fed in 2018 and 2019, respectively.
- The higher HRT of the D2+D3 system resulted in higher CH_4 production than D1 alone in both 2018 and 2019; leaks in D1 during 2019 further reduced performance compared to D2+D3 (Fig. 4, Table 2).
- The concentration of the corrosive trace gas hydrogen sulfide (H_2S) in the biogas was extremely low during 2018. While H_2S rose in all digesters in 2019, it remained low compared to biogas from traditional AD feedstocks such as manure, which may produce >8000 ppm H_2S without treatment.[1]

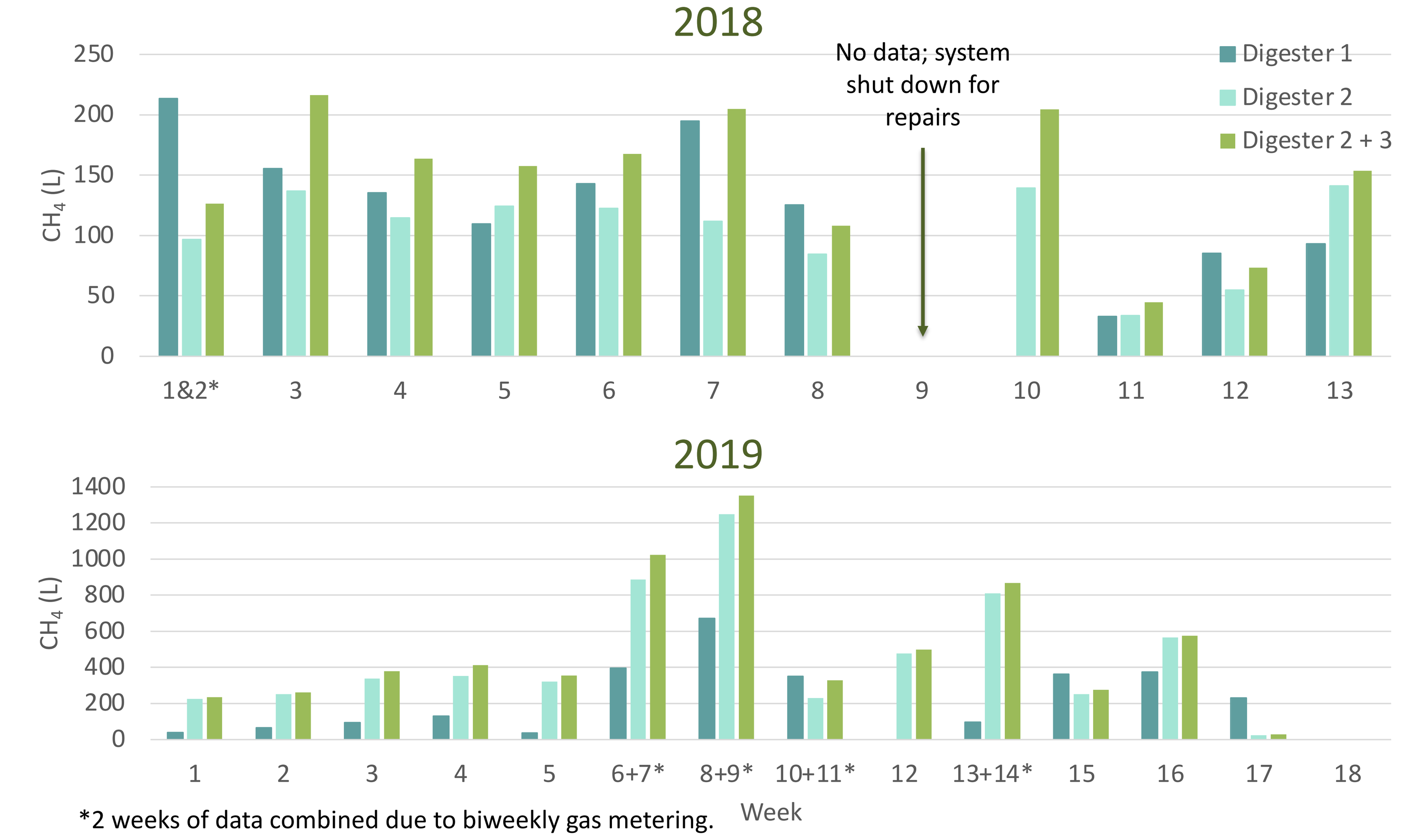

Figure 4: Methane production from the Port of Baltimore ATS-AD, 2018-2019.

Table 2: Summary of biogas production from AD of ATS algae at the Port of Baltimore, 2018-2019.

	2018		2019	
	D1	D2+D3	D1	D2+D3
CH_4 (L/week)	117	129	117	367
L CH_4/kg VS fed	51.5	63.5	40.5	157
Total biogas (m^3)	1.8	2.5	2.8	8.8
% CH_4	72.0 ± 1.8	67.4 ± 3.9	71.9 ± 1.3	68.6 ± 2.5
% CO_2	16.8 ± 0.5	16.8 ± 0.5	18.1 ± 1.2	14.9 ± 1.1
% O_2	0.25 ± 0.05	0.37 ± 0.18	1.22 ± 0.73	0.38 ± 0.21
% N_2	11.0 ± 2.0	15.4 ± 4.2	10.3 ± 1.7	16.9 ± 3.0
H_2S (ppm)	2.00 ± 0.25	1.85 ± 0.23	868 ± 254	250 ± 109

Conclusions

- Algae produced from an ATS can be successfully utilized for biomethane production via AD to produce 51.5-157 L of CH_4/kg VS in the feedstock, depending on the system's HRT and the rate of algal growth from the ATS.
- Biogas produced from ATS algae appears to be very high quality, with a high concentration of CH_4 (68-72%) and low H_2S (2-868 ppm) in the biogas. This is consistent with results from the literature that suggest ATS algae may reduce H_2S in AD biogas due to its high iron content.[2]

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