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Anaerobic Co-Digestion of Algae from a Bioremediation System with Manure and Food Wastes

Overview

The algal turf scrubber (ATS) is a type of bioremediation system that uses a "turf" of algae to clean nutrient pollution from bodies of water. Excess algae must be harvested periodically from an ATS to maintain its health, but management and disposal of the algal waste creates a logistical challenge that operators must account for prior to installation. In agricultural areas, established anaerobic digestion infrastructure could be effective at disposing the algal waste. This document will provide an introduction to algal turf scrubbers, their installation and maintenance requirements, and algal waste management via anaerobic digestion in the context of an agricultural setting. Data from a recent study at the University of Maryland College Park will be used to support this

Algal Turf Scrubbers (ATS)

The basic structure of an ATS is a long, contained channel lined with a textured material, for example rope or plastic mesh, over which water is pumped up from a stream or river. Algae naturally present in the water readily attaches to this lining and forms a turf. As additional water is pumped across the turf, the growing algae metabolize dissolved nutrients and carbon and incorporate it into their tissues. The water is delivered in pulses, rather than continuously; pulsed water mimics wave action in the algae's natural habitat, and slows the flow of water over the turf to give the it more time to clean it. The rate of the pulses should be controlled to maintain a minimum water depth of 3-5" over the turf at all times, to prevent it from drying out (Figure 1).

Figure 1: An example of an algal turf scubber, or ATS, installed on the Anacostia River at a park in Bladensburg, Maryland.

Siting and Installation of an ATS

An appropriate site for an ATS is near to the body of water to be treated, but flooding patters at a potential site should be considered when planning an installation. If regular flooding is expected, the system should be anchored to prevent damage during storms.

The chosen site's slope may also need to be adjusted prior to installation. A near-level surface is recommended to maintain the minimum water depth inside the ATS. Unused parking lots, docks, and stream bank reinforcements have been used to site ATS systems in urban areas for this reason, as they are typically already sufficiently flat for an ATS to be installed (Figure 2).

Figure 2: The size of an algal turf scrubber can be customized according to the space available at a site, from small dockside units (top) to large commercial systems (bottom). Nutrient uptake and the volume of algae grown increase with surface area.

Sunlight to the site is the final factor that needs to be considered when planning to install an ATS. Algae rely on sunlight for photosynthesis just like land plants and shading for any length of time can disrupt its growth. This will in turn reduce nutrient and carbon uptake on the turf, which can negatively impact the system's ability to meet its remediation targets. The chosen site should have minimal trees or buildings nearby to prevent significant shading at any time of the day.

Harvesting Algae

Over time, the turf can grow so thickly that its weight overcomes the algae's ability to attach itself to the lining and may detach in a process called "sloughing." If this happens, the algae containing the trapped pollution can wash away, effectively negating the effects of the remediation treatment. To prevent this, the excess algae needs to be harvested periodically – a weekly harvest schedule is typical. Harvest should be done as early in the day as possible, as research has found the afternoon heat and sun can damage the delicate foundation of the turf and limit its regeneration.

The harvesting process is as follows:

1. Turn off all water pumps ~60 minutes before the scheduled harvest time.
2. Allow remaining water to drain off the turf.
3. Sample the water and algae on the ATS, if needed for permitting requirements.
4. Harvest the algae. Vacuums may be used to suction it directly from the turf for small-scale units, but for larger-scale systems it is recommended to first "push" it into a holding area with rubber scrapers and then vacuum up the accumulated liquid.

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The time that an ATS will be operational in a given year is determined by the local climate. The growth of algae slows when temperatures fall, which in turn slows their rate of pollutant uptake. This is not a significant issue in tropical or subtropical climates, where seasonal temperatures are largely consistent year-round, but in temperate regions such as the Chesapeake Bay Watershed, ATS will not be as effective to use in colder months. It is estimated that ATS in Maryland may typically be used effectively from April-November each year, though the operational schedule may be adjusted to a given year's conditions. Operators should plan their harvest schedule accordingly.

Algal Waste and Anaerobic Digestion

The amount of algal waste that the operator will have to manage is determined by the size of the system – larger surface area will correspond to higher algal yield over time. The harvest size and characteristics may also vary weekly and seasonally at a given site, according to the local climate.

In urban areas the algal waste is typically trucked away to wastewater management facilities, though anaerobic digestion is emerging as an alternative disposal method. Anaerobic digesters are an increasingly common infrastructure in agricultural areas for disposal of manure and food waste. Digesters are reactor systems containing a "soup" of bacteria, which break down wastes. Carbon is converted into carbon dioxide and methane (CH_4), which is also the primary component of natural gas. This CH_4-rich biogas may be sold to provide the farm with a value-added product or used by the operator on-site to support the farm's operations. The process also liberates nutrients trapped in the wastes, returning them to a dissolved state in the liquid effluent from the digester. This liquid may this be used as a fertilizer for the farm as well.

Co-digestion of Algae and Farm Wastes

A recent study at the University of Maryland assessed how algae from an ATS can be co-digested with three common wastes used in digesters in Maryland: dairy manure, poultry litter, and food waste. There are some differences between algae from an ATS and more conventional wastes used in anaerobic digestion, including a relatively higher moisture content and lower concentration of organic materials, or volatile solids (VS) (Table 1).

Table 1: Characteristics of algal turf scrubber (ATS) algae compared to three common anaerobic digestion wastes. DM = dairy manure, PL = poultry litter, FW = food waste.

	Total Solids (%)	**Volatile Solids* (%)**	**Total N (g/L)**	**Total P (g/L)**
Algae	4.82±0.02	0.61±0.00	1.22±0.02	0.6±0.04
DM	15.4±0.0	13.3±0.1	4.14±0.35	2.53±0.22
FW	45.3±0.3	43.6±0.2	3.04±0.49	2.07±0.4
PL	71.0±0.1	50.0±0.3	3.08±0.41	1.94±0.21

*An approximation of the organic material in the waste that can be converted into CO_2 and CH_4.

The algae-only reactors generated the smallest amount of CH_4 with 109 L CH_4/kg VS. Each of the other three single-waste reactors generated 2.7-3.5 times more: dairy manure = 299 L CH_4/kg VS; food waste = 384 L CH_4/kg VS; and poultry litter = 302 L CH_4/kg VS. A decline in CH_4 generation was observed with increasing loading of algae, likely due to the high moisture content diluting the reactor effluent. However, the decline was determined to be insignificant when algae and any of the three and wastes were co-digested at ratios of 1:10 or 1:5 based on their respective organic contents. This indicates that algae from ATS systems can be incorporated into these digesters without significantly reducing CH_4 yield, provided the algae is added at lower loading rate than the conventional wastes. The digester operator should carefully consider that most (~95%) of the algae waste will consist of water, and adjust the loading rate of their digester accordingly.

A follow up study also used the effluent from these reactors as experimental fertilizers for buttercrunch lettuce plants in a greenhouse setting. The lettuce fertilized by reactor effluents generated ~20-40% less biomass when compared to a commercial fertilizer used as a control, but no symptoms of acute toxicity were observed for any of the effluent fertilizers, regardless of algae loading ratio.

Conclusions

The ATS is a bioremediation technology that has been used in cities but could also be used on farms that make up much of the Chesapeake Bay Watershed if the logistical questions of algal disposal can be addressed. The waste can be successfully co-digested with dairy manure, poultry litter, and food waste. However, the relatively high moisture content of the algae must be accounted for when planning co-digestion loading rate. The dilution effect could be beneficial for digestion of low-moisture wastes such as poultry litter, by replacing fresh water usually needed in these reactors to commence a digestion reaction. The addition of algae into the reactors does not appear to affect the safety of their effluent to plants when used as a fertilizer, however more research is still needed to follow up on these findings before these effluents are applied to food crops.

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