Development of a hybrid anaerobic digestion-microbial fuel cell system for treating winery wastewater

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Introduction

Wastewater treatment is an expensive proposition for many businesses, often the most cost effective solution is to ship all waste offsite for treatment. The most energy-intensive portion of the treatment process is aerating the wastewater to facilitate microbial oxidation of organic compounds. Microbial Fuel Cells have been immerging in recent years as an energy-saving substitute for wastewater aeration. We have partnered with a local winery in Santa Rosa and have deployed a pilot system that combines anaerobic digestion (AD) with microbial fuel cell (MFC) technology for the treatment of wine waste onsite. Results gathered from the testing and optimization of this system will inform the development of full-scale AD-MFC-based systems to treat winery wastewater to a level suitable for irrigation while producing energy.

Methods

AD-MFC (Anaerobic Digester Microbial Fuel Cell)**:** A 50-liter custom acrylic cylinder was used as our digester. The cylinder contained a rubber spiral in order to create a channel the waste must follow to ensure maximum retention time. The waste was fed into the cylinder by a peristaltic pump at 8.8 ml/min. This produced a retention time of around 5 days. The electrodes were made of carbon fiber for its corrosion resistant and conductive properties. The anodes were placed one in each quadrant horizontally across the entire cylinder. The anodes were constructed like a bristle brush in order to achieve maximum surface area. There was also a hollow chamber horizontally through the entire cylinder which had walls made of impermeable carbon fiber which was used as a cathode.

Waste: We used wine waste from a local winery to feed the MFC. The waste was stored in a 350 gal "pH stabilization tank" from which our pump could draw feed directly. Due to the acidic nature of the waste (around 3.5pH) we would dilute the waste at a ratio of 1L of waste to 5L of water. If the pH in the feed tank dropped below 6.8, potassium carbonate was added to neutralize the acid and buffer the solution.

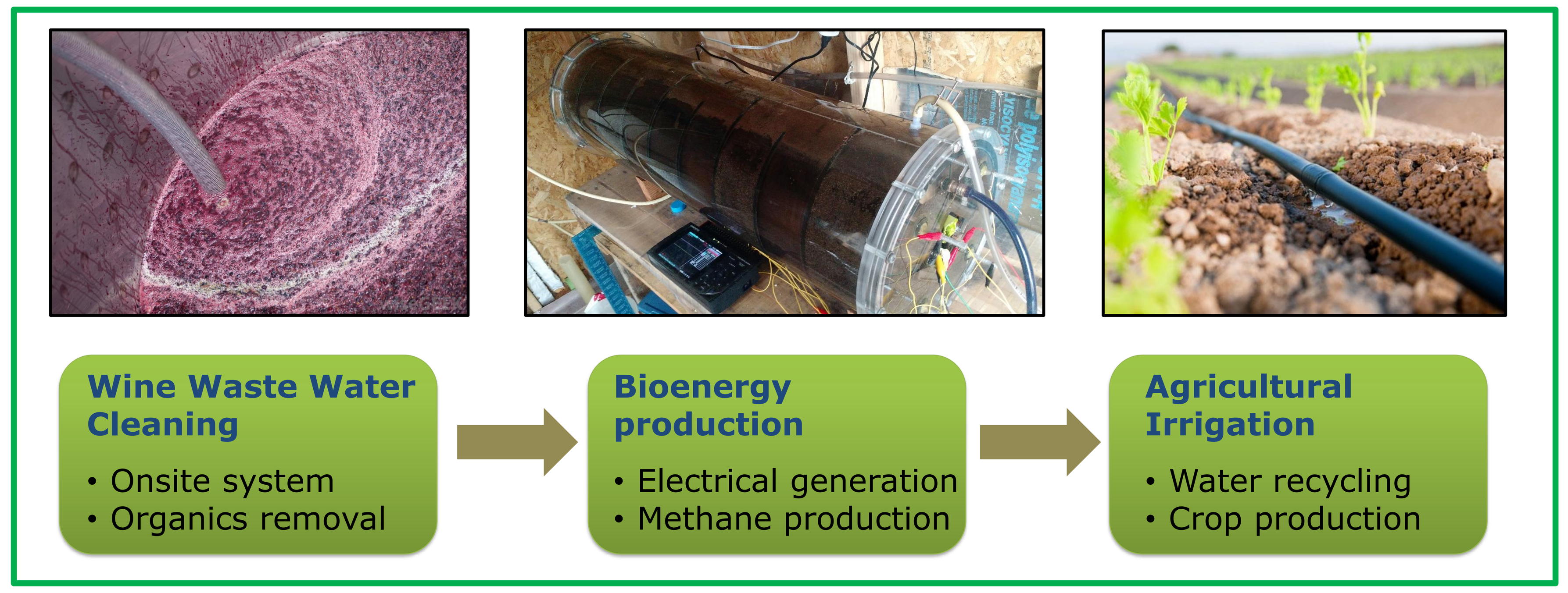
Data collection: Voltage was tracked using an off the shelf voltage logger. The logger collected an instantaneous voltage reading each hour. We had a unique device that would open the circuit and allow voltage potential to build up.

COD Removal (Chemical Oxygen Demand) was tracked using mail order kits. Samples were collected directly from the effluent and influent lines. The difference in the COD readings determines the COD removal. Samples were analyzed in a spectrometer for absorbance at 600 nm and compared to known standards. Both soluble and total COD removal were calculated. Total COD removal was determined using unmodified samples. Soluble COD was determined by centrifuging both influent and effluent samples for 5 min at 2000 *g*.

Daily data pH and temperature data were collected via a Mettler-Toledo GmbH handheld probe.

The gas sample was analyzed by a local lab (Analytical Science in Petaluma, CA.) via gas chromatography. The gas was gathered by feeding our gas escape line directly into a gas sample collection bag.

Image 2 The field site located at Vintners Square in Santa Rosa, CA. No significant data was gathered from the Aquatic Scrubber



Results

- Passage of wastewater through the AD-MFC resulted in a significant COD removal. The percent removal increased as the system matured. This trend continued until the system crashed and COD removal stopped. The system also produced a voltage potential.
- The voltage increased with the COD removal until simultaneous freeze-related clogging of the biogas and liquid effluent resulted in system collapse and the COD removal stopped. The voltage also dropped, but then recovered while the COD removal did not.
- Because the voltage was not linked to the COD removal, electrogenic bacteria MFCs may not be the true source of COD removal; the system may be acting primarily as a AD digester.
- While running normally, pH was raised drastically.

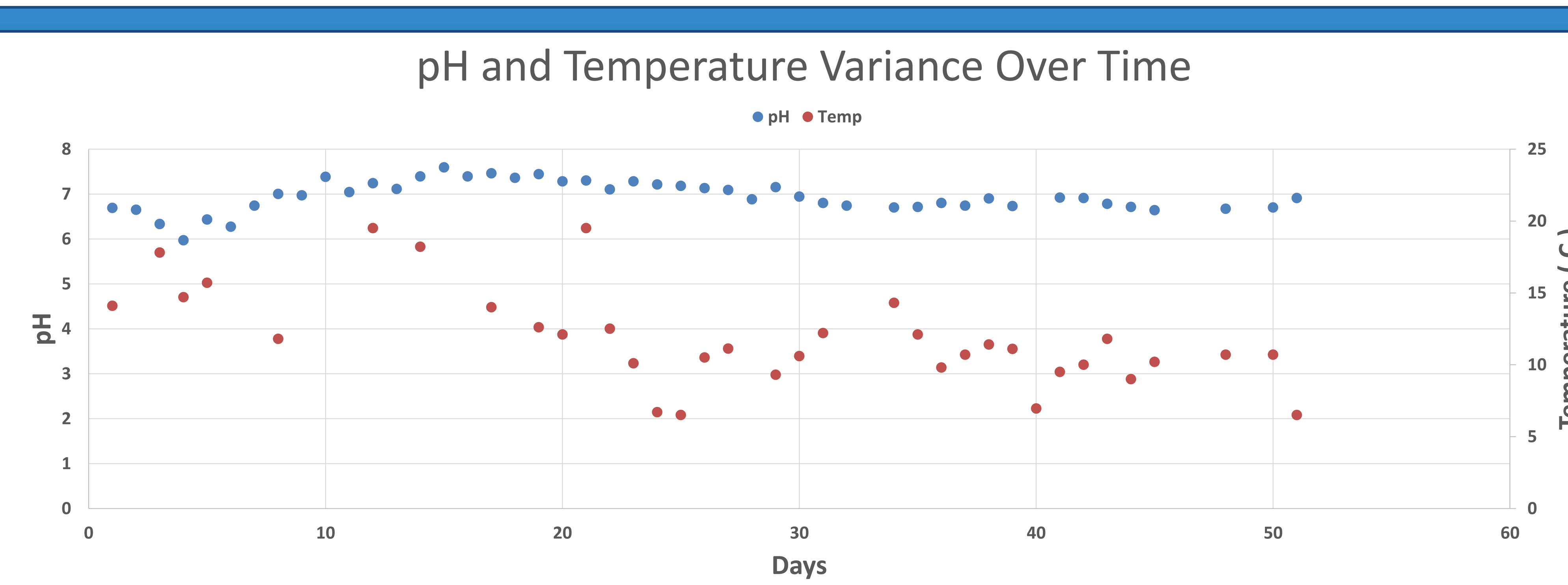


Fig. 1 The system handled the changing temperature well. Even during low temperatures approaching 6ºC the system removed over 90% of the COD. The pH of the effluent also remained stable.

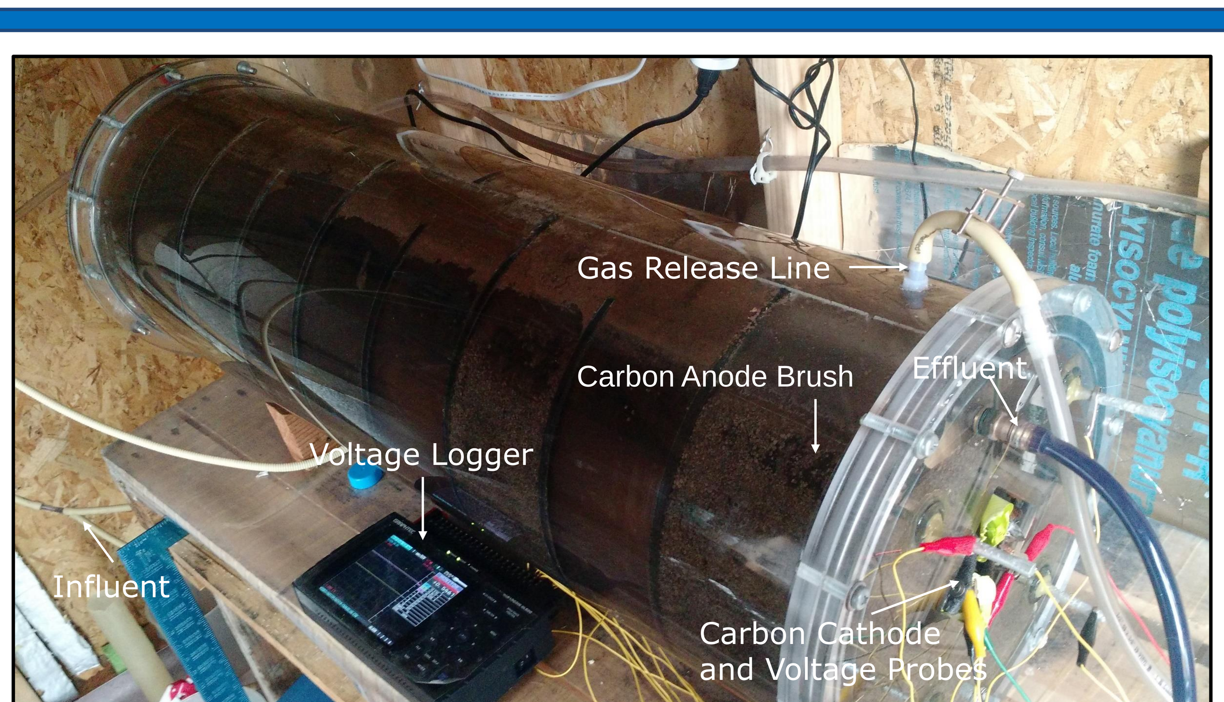


Image 1 The AD-MFC system is a unique 50 liter acrylic. Acrylic was chosen for the ability to view the internal section of the AD-MFC during field tests.

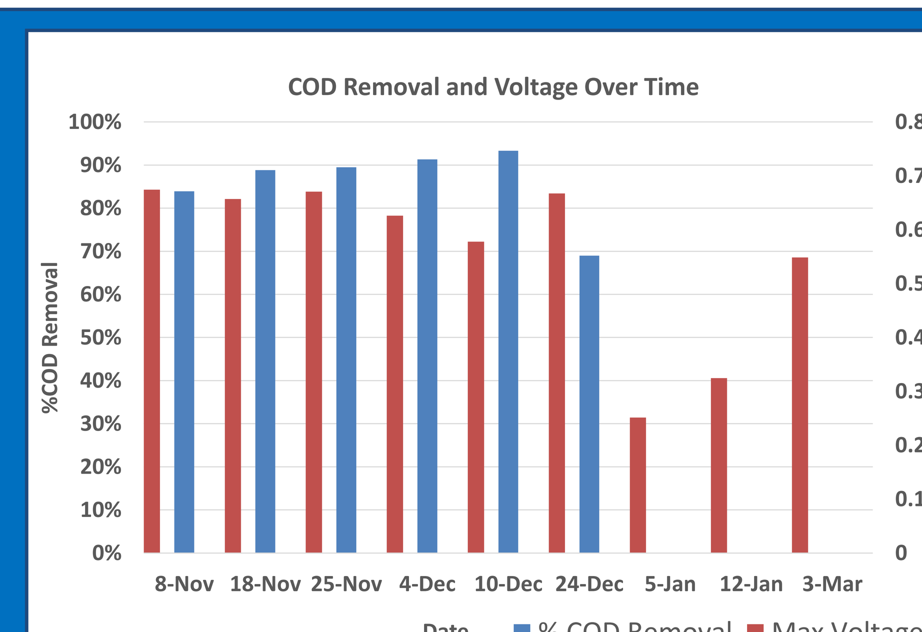


Fig. 2 COD removal gradually increased with time until the system exhibited massive COD removal reduction on the 23rd of Dec. Voltage is not related to our COD removal.

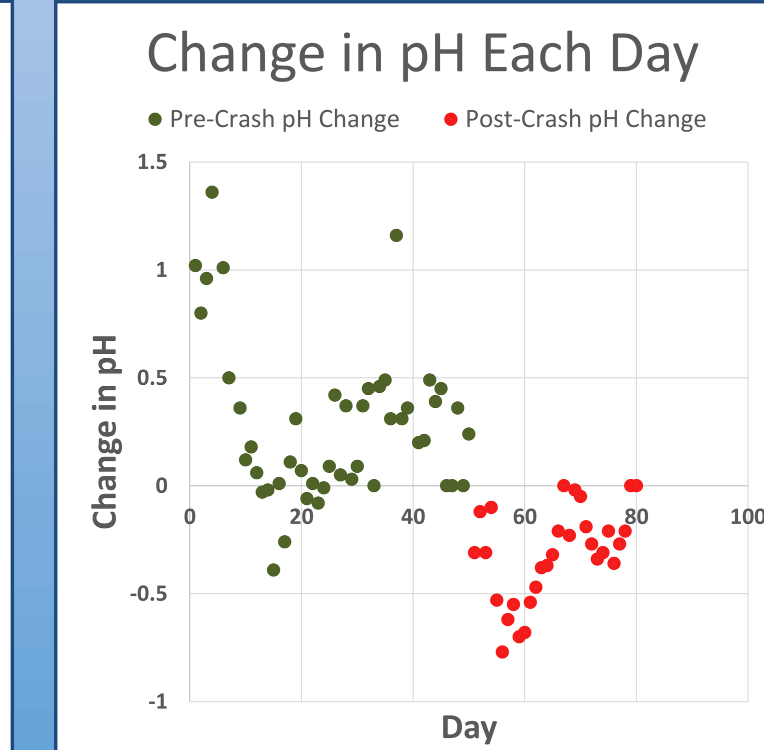


Fig. 3. The AD-MFC increased the pH of the effluent relative to the influent pH during nominal functioning. After the crash the pH was decreased by the AD-MFC. Potentially whatever is removing the COD is also increasing pH.

Amount [mole%]	Name
-	Helium
0.00330	Hydrogen
2.48103	Oxygen
9.14150	Nitrogen
57.55491	Methane
-	Carbon Monoxide
10.42170	Carbon Dioxide

Table 1. The gas produced by the MFC was mostly methane with significant levels of carbon dioxide. This is consistent with current waste water anaerobic digesters. About 20% of the sample was unaccounted for, possibly because the gas was not detectable by our gas chromatographer. The oxygen and nitrogen is probably due to atmospheric contamination as the ratios are the same as ambient ratios.

Conclusions and Future Prospects

- The system displayed COD removal efficiency close to that of full-scale high-efficiency anaerobic digesters. However, our system ran at ambient temperatures with the only energy input being that of the pump.
- Gas production is similar to that of anaerobic digesters. The tubular shape of the enclosed system allows for easy harvesting of the biogas.
- The AD-MFC technology may only utilize the AD process for COD removal. Further trials will be needed to compare similar systems while controlling for electrode presence.
- The system should be able to run with minimal supervision in a field application.
- Biogas is produced with methane concentrations similar to standard AD systems.

Acknowledgements

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WATERS Collaborative

SANTA ROSA ★ VINTNERS SQUARE