Sequential microbial fuel cell-vermifiler system for treatment of winery wastewater

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Introduction

Finding means to recycle wastewater for other uses is necessary due the limited access of freshwater. The most energy-intensive portion of the treatment process is aerating the wastewater to facilitate microbial oxidation of compounds. Since 2015, we have partnered with D'Argenzio Winery in Santa Rosa, to test a system for onsite treatment of wine wastewater that does not require aeration. Wastewater (WW) from a pH neutralization tank is pumped into two tubular microbial fuel cells (MFCs), one of which flows through an earthworm-containing filter to irrigate landscaping, while other recycles back to the tank (Figure 1). Here we report on the capacity of natural bed media filters, with and without earthworms, to remove organic compounds from the winery MFC effluent.

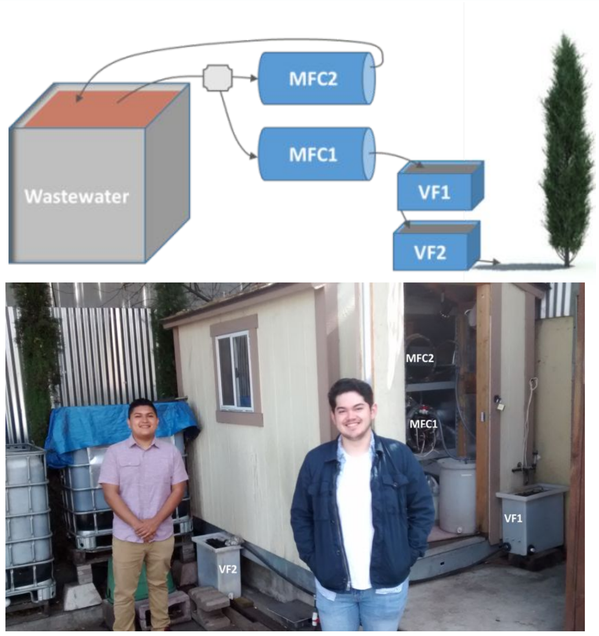

Fig. 1. *Top:* A flow schematic of the treatment system. *Bottom:* The field site located at Vintners Square in Santa Rosa, CA.

Fig 2. Plant growth assays demonstrated that vermifiltration removes growth-inhibitory components from the treated wastewater (data not shown), potentially due to the observed removal of phenolic compounds. Pictured are Baby Romaine Lettuce plants irrigated with tap water or water from VF1; arranged randomly.

Study aims

- ❑ Testing of organic filtration beds as a final polishing step for MFC-treated winery wastewater.
- ❑ Measure the removal of soluble organics from wastewater through soluble chemical oxygen demand (sCOD) and phenolics
- ❑ Determine the impact of red earthworms (*Eisenia fetida*) on the removal activities of the filter beds.

Polishing of MFC-treated winery wastewater

- ❑ Levels of soluble organics substantially decreased in wastewater that was introduced (input) to MFC 1 and showed only a slight decrease by subsequent passage through a vermifilter (Fig 2).
- ❑ A refined version of vermifilter and WW distributor was created to allow effective COD removal all throughout new vermifilter at a constant rate. (Figs 3 & 4).
- ❑ Initial filters were made with peat:cedar-rice bran bed medium which supported the growth of earthworms (Fig. 3) Additional filters were made from cedar-rice bran "enzyme bath" bed medium then stacked above the previous filter allowing migration of earthworms. (Fig 4).

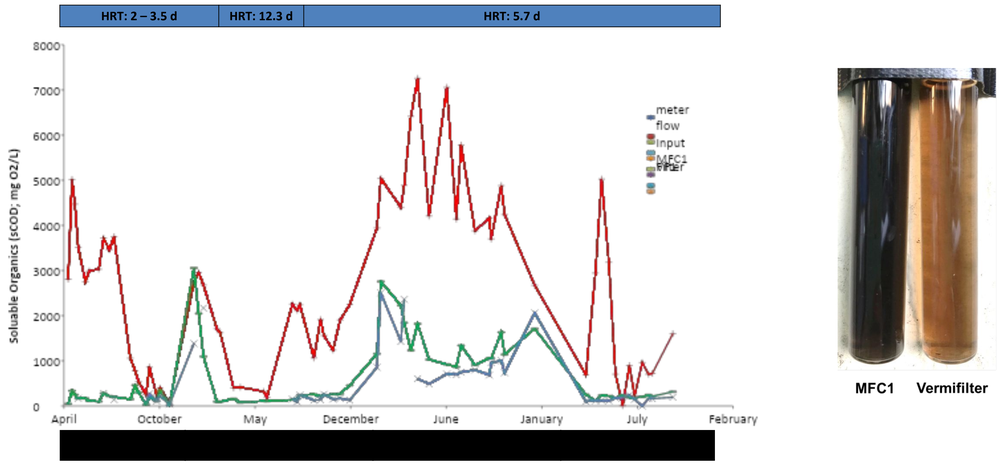

Fig. 3. Concentrations of soluble organics (sCOD) in water flowing through the Vintners Square treatment system. *Left:* Progressive decreasing trend of sCOD traces found in WW *Right:* Relative clarity of MFC1 effluent compared to effluent from the vermifilter.

Fig. 4. *Left:* Filters containing a peat:cedar-rice bran bed medium with sand distributor of winery wastewater. Stackable cedar-rice bran "enzyme bath" bath medium placed on top previous vermifilter to promote worm migration (*Right*) *Photo inset:* Red earthworm (*Eisenia fetida).*

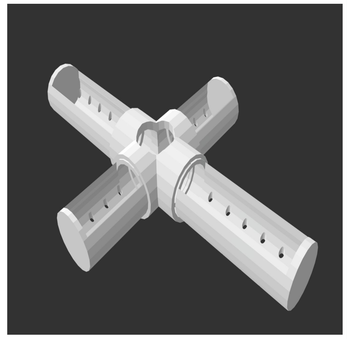

Fig. 5. New design concept created from computer-aided design (CAD) for distribution of wastewater all throughout the new vermifilter system. Entire component is created from a corn-based poly lactic acid (PLA) filament.

Removal of phenolics in winery wastewater

- ❑ Traces of phenolic compound shows significant decrease from different stages of wastewater treatment process. (Fig 6).

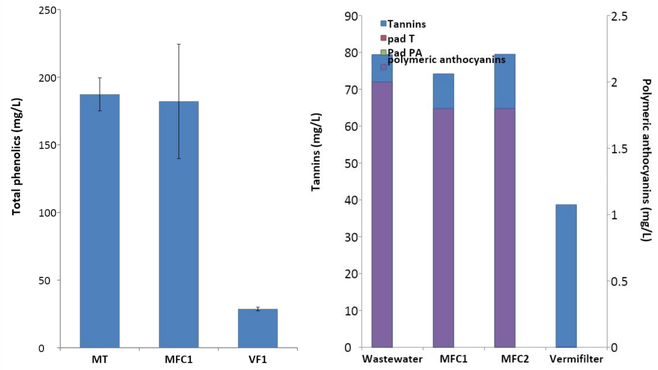

Fig. 6. *Left:* Concentrations of total phenolics measured by the Folin-Ciocalteu method at different stages of the WW treatment process. *Right:* Traces of the polyphenols tannins and polymeric anthocyanins throughout the WW treatment process.

Conclusions and future work:

- ❑ Passage through MFC1 removes the majority of organics from the wastewater but does not appreciably remove phenolics.
- ❑ The system exhibited lowest removal activity in the winter.
- ❑ The VF1 vermifilter at Vintners Square dramatically lowered the levels of phenolics in MFC-treated wastewater.
- ❑ Both the reduced coloration and improvement of the water for irrigation quality conferred by vermifiltration may be due to the removal of phenolics from the water.
- ❑ Phenolic-degrading microbes will be investigated for potential use in inoculating bed media to further increase the removal rate of phenolics by the filters.
- ❑ Worm migration of new vermifilter layers will be observed for more efficient ways to determine worm density as well as wastewater effluent sampling.

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