Comparison of Air Emissions
from a **Negatively Aerated CASP** and **Turned Windrow**
During Composting of a Food Waste and Green Waste Mix

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Summary

In the Summer of 2009, ECS arranged for side by side composting trials of a mixture of food and green waste to compare air emissions from a traditional turned windrow and a negatively aerated fabric Covered Aerated Static Pile (CASP) system. The trials were conducted by California State University, Fresno (CSUF) research dairy personnel as part of a USDA funded Phase II SBIR grant. An identical feedstock mixture of 25% food waste and 75% green waste, by weight, was used for both trials which were started on the same day at the same location. Emissions samples were collected from the surface of the windrow both before and after turning, and from the exhaust duct of the Negative CASP pile. The samples were analyzed in real-time using a photo-acoustic gas analyzer (LumaSense). The Negative CASP system was shown to emit significantly lower quantities of VOCs and ammonia than the open windrow method, and the Negative CASP system demonstrated higher bio-oxidation rates during the first weeks indicating more efficient composting.

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Negative CASP

As the requirement to air control emissions has steadily grown, ECS has developed and tested a number of different technologies to address this need. The Negative CASP (Figure 6) is designed to generate a negative pressure gradient across the fabric cover to affect a uniquely high capture efficiency of all gaseous emissions from the compost pile. All of the air drawn through the cover and into the pile is exhausted to a biofilter for scrubbing. Inherent in the design, and unique among other compost emission control fabrics, is the ability to provide continuous high aeration rates sufficient to maintain Best Management Levels of oxygen and temperatures during high rate composting. The Negative CASP has five major components:

- Impermeable Aeration Cover (AC) with one-way inlet orifices
- Pipe-on-grade aeration floor
- Negative (suction) aeration system
- Automated aeration control and temperature monitoring
- Biofilter

The cover is made of an impermeable fabric that is of medium weight, highly UV resistant, and readily repaired in the field. Air is continuously drawn into the pile through single-direction air ports in the cover. The aeration rate is automatically controlled per operator set-points. The result is an enclosed compost pile with near zero fugitive emissions from the surface, and relatively small volume of process exhaust air that can be effectively scrubbed. Air emissions tests of the covered pile surfaces have shown no significant emissions through the cover material or the ports. Therefore, all emissions produced are contained within the aeration system and exhausted through the biofilter. In Phase I of this grant, testing at CSUF demonstrated biofilter efficiencies of 96-99% for the target gas species.

Test Methods

The Negative CASP trial used a simple pilot system to supply the aeration and control (Photos 1 & 2). The pile was built to a height of 8 feet, with a footprint of 15ft x 65ft. The exhaust air from this pile was scrubbed in a free-standing biofilter. The Negative CASP pile was broken down once during the trial period on Day 22 and rebuilt. Measurements of emissions from the exhaust duct were taken five times during the trial period. During Phase I of this study measurements of VOCs above the fabric cover indicated they were at background levels; emissions did not escape through the impermeable and negatively pressurized cover. Unfortunately, tests were not conducted during this study to test the air emissions from the negatively aerated pile surfaces without covers in-place.

The windrow trial was built to a 4 foot height with an approximate 8 foot width at the base (Photo 3). This small cross-section provided a best-case scenario, due to the high surface to mass ratio, for passive cooling and supply of oxygen. The windrow was turned six times during the 35 day trial period. In each case, surface emissions measurements using flux chambers were taken before the windrow was turned and for a period of one hour after the turning. The values shown below are the averages of these before and after measurements.

Feedstock and final material samples were also taken for both trials, to determine final stability of the material in each trial.

Results

Prior to commencing the side by side trials, the Negative CASP Biofilter efficiency was tested on a mix that contained 87% green waste and 13% food waste. The results of the three gasses analyzed are shown in Table 1.

Gas species	Exhaust duct (grams/minute)	Biofilter surface	Control efficiency
Total VOCs	189	1.2	99.4%
Methane	829	4.0	99.5%
Nitrous oxide	17.8	0.1	99.2%

Table 1

Large scale commercial biofilters regularly exceed 90% control efficiency. But we attribute the high scrubbing efficiencies measured with the nature of the VOC's (mostly low molecular weight alcohols per Kumar et. al.), the relatively low chemical loading rates on the media, and the consistently cool temperatures in the media which enhances both gas solubility in the film layer and promotes mesophilic bacteria.

Air emissions data collected from the side by side composting trials are summarized below in a series of graphs. The primary pollutants of interest here are VOCs and ammonia. A graph and of CO_2 emissions is also included as an indication of relatively level composting activity in each trial.

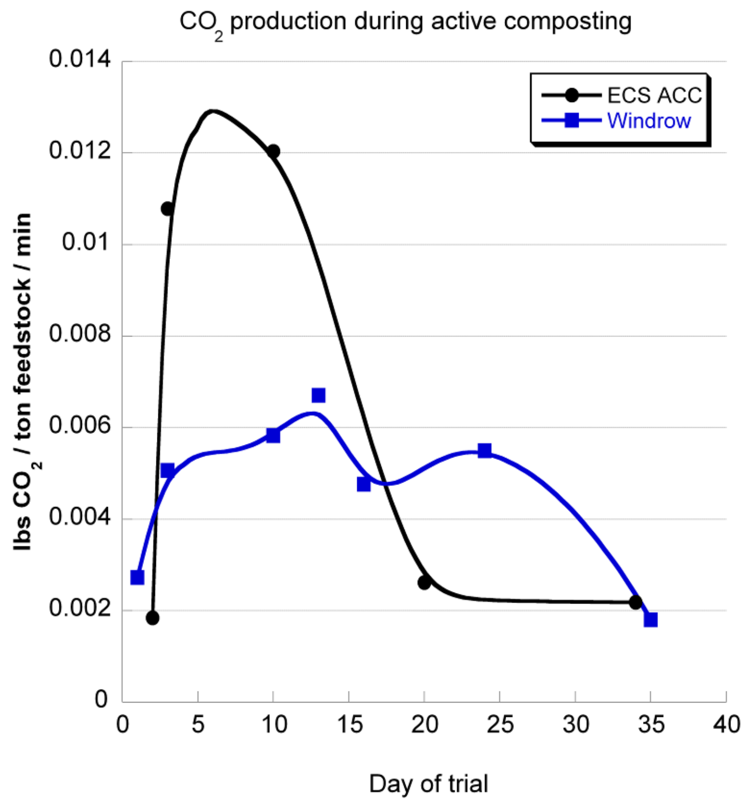

Figure 1 (note ECS ACC = Negative CASP)

Figure 1 shows production of CO_2 during composting with each of the two methods. The actively aerated Negative CASP system produces significantly more CO_2 during the first half of the trial, indicating a higher rate of decomposition. The rate of decomposition in the windrow stays relatively steady until nearly day 30. The cumulative measured emissions of CO2 are 278 lb/ton for the Negative CASP and 235 lb/ton for the windrow. Samples taken after day 35 produced stability measurements of 1.7 mg CO2-C/g total solids/day for the Negative CASP and 2.3 for the windrow. However, a sample taken from the Negative CASP pile at Day 20 measured 2.2 mg CO2-C/g total solids/day. This further indicates that most composting in the Negative CASP pile occurred in the first 10-15 days, and further decomposition was likely limited by the stability of the remaining material.

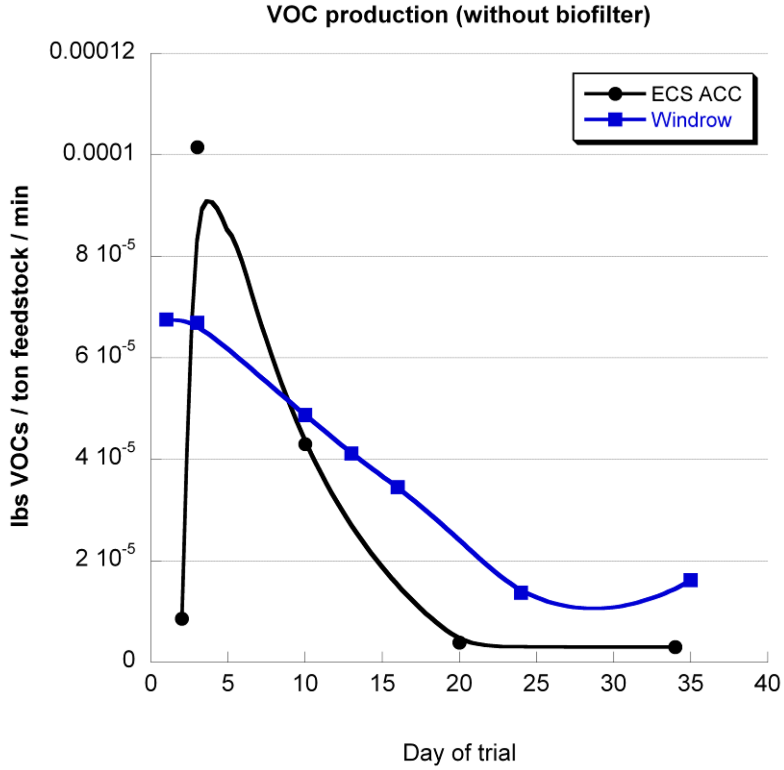

Figure 2 (note ECS ACC = Negative CASP)

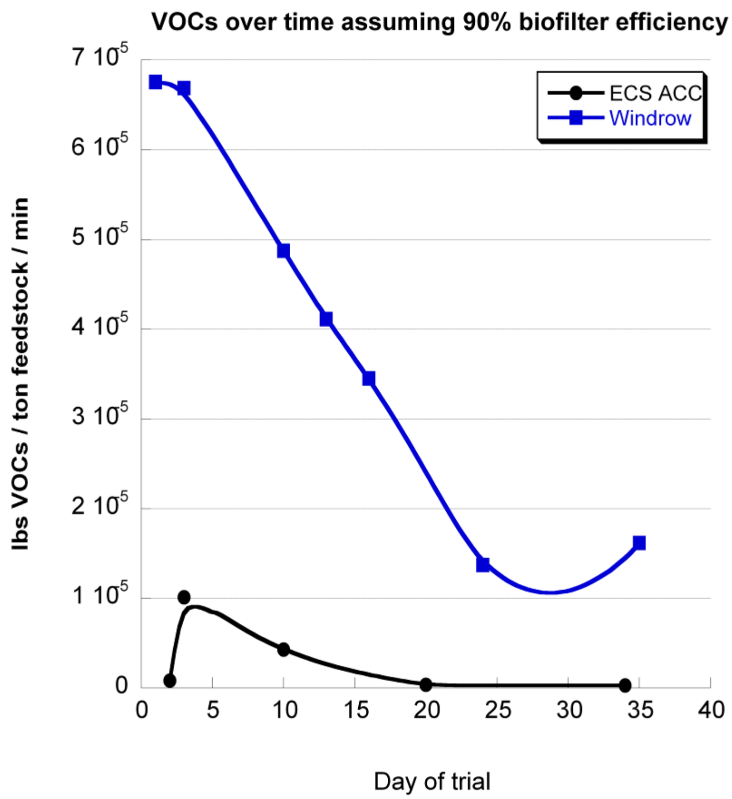

Figure 3 (note ECS ACC = Negative CASP)

Figures 2 and 3 show measured emissions of non-methane volatile organic compounds (VOCs) from both the Negative CASP and windrow trials. Figure 2 shows total emissions, while in Figure 3, the Negative CASP emission rates are corrected to account for a 90% control rate by the biofilter. (Earlier in this same study the engineers at CSUF measured a the scrubbing efficiency of over 97% by a biofilter with the same design and the same pilot ASP system).

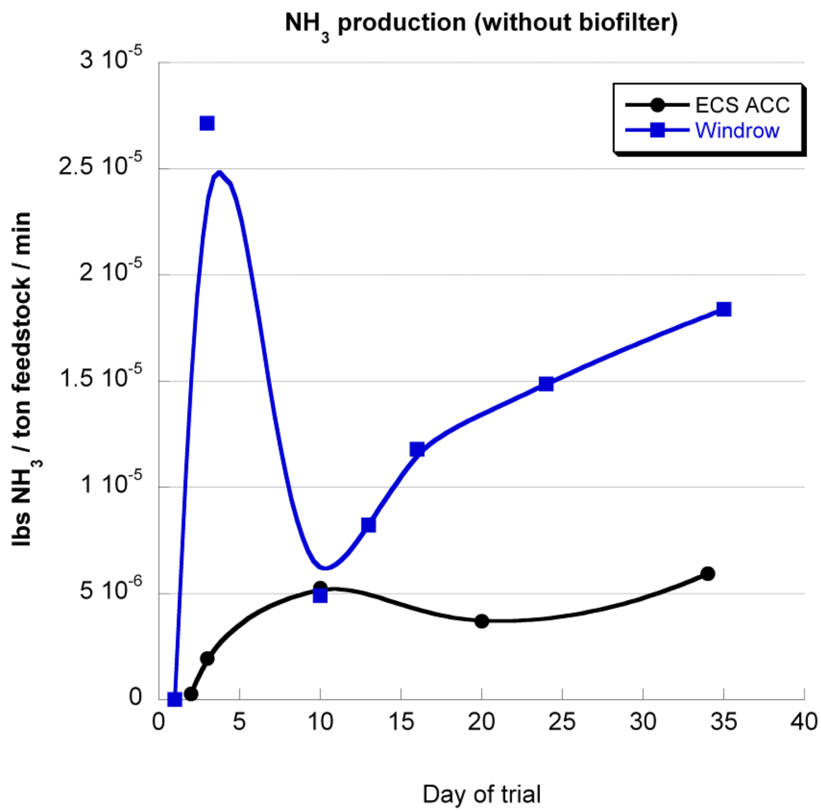

Figure 4 (note ECS ACC = Negative CASP)

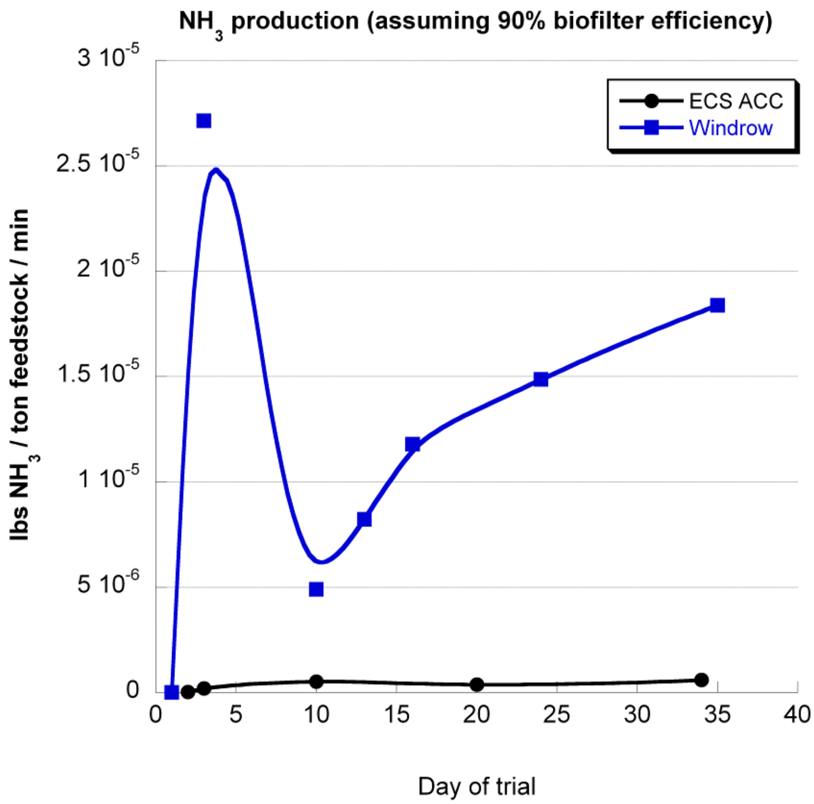

Figure 5

Figures 4 and 5 show emissions of ammonia from each of the two trials. Figure 4 shows raw emissions and Figure 5 shows corrected emissions from the biofilter in the Negative CASP system assuming a capture rate of 90%. In Figure 4, the amount of ammonia produced by the Negative CASP is lower than what is produced by the windrow, even without considering the control effect of the Negative CASP biofilter. This indicates more aerobic conditions in the actively aerated Negative CASP than in the passively aerated windrow.

Table 2 below shows cumulative measured emissions for each trial over the whole period. Due to control from the biofilter, total emissions of VOCs and ammonia are much lower in the Negative CASP system that in a turned windrow even though composting activity is similar in each case.

Cumulative Gas Emissions (lbs/ton feedstock)			
Gas Species	Negative CASP Total	Negative CASP w/Biofilter 90% Control	Windrow Total
VOC	1.2	0.12	1.6
NH_3	0.2	0.02	0.7
CO_2	278	--	235

Table 2

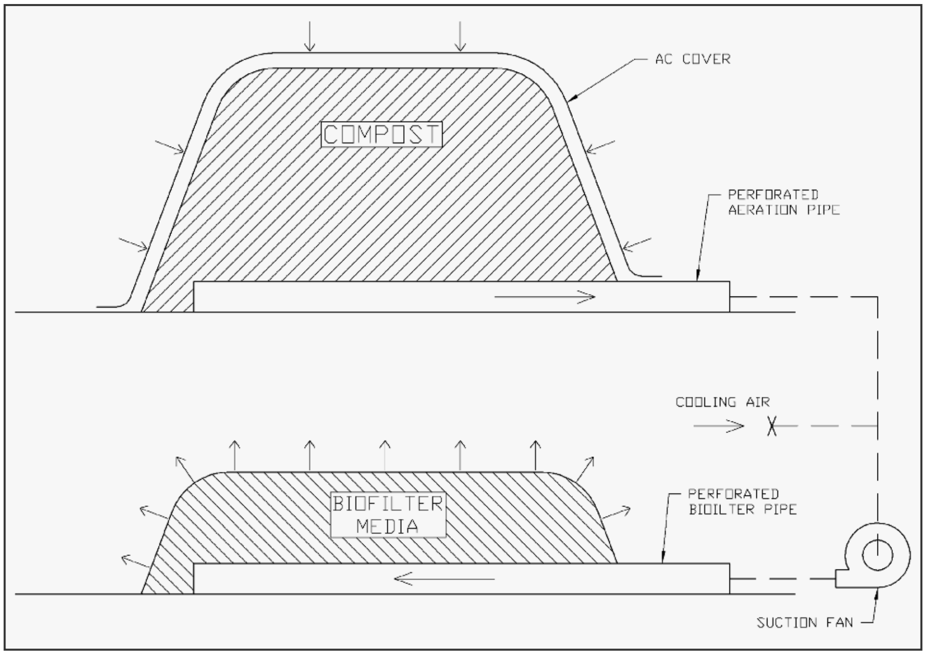

Figure 6 – Negative CASP Diagram

Photo 1- Negative CASP Pilot at CSUF Dairy

Photo 2- Negative CASP Pilot Biofilter Emissions Testing

Photo 3 – Test windrow during turning

Conclusions

Overall, VOC production (not emissions) was reduced by 25% in the Negative CASP compared to the windrow. However, even granting only a 90% biofilter scrubbing efficiency, the emissions to the atmosphere by the Negative CASP system are reduced by 92.5% compared to the small windrow. We would expect this difference to be even more pronounced in a larger commercial-scale windrow with smaller surface area to mass ratio.

The period in which vast majority of the VOC's were produced by the Negative CASP was during the first 10-15 days. It is also noteworthy that much more CO_2 was produced during this period in the Negative CASP compared to the windrow. Per the finding of other researchers (Sundberg, Keener, etc.), this enhanced bio-oxidation is indicative of the effects of high oxygen and modest temperatures to support high bio-oxidation rates. The combination of these effects demonstrates the utility of an initial intensive composting period to 'burn-off' and control most of the emissions and quickly achieve a semi-stabilized compost.

It should also be noted that one of the characteristics of a Negative CASP is that the exhaust air leaving the pile is at maximum of the thermocline through the pile (cool at the top, hot at the floor). Thus, there is little to no absorption of the VOCs generated in the pile near the aeration floor due to Henry's law (temperature effects on gas solubility). A Positive bio-layer CASP on the other hand has a much cooler exterior layer due to ambient effects. This cool layer condenses moisture from the warm saturated air rising through the pile, absorbs VOCs, and supports the mesophilic bacteria that are most effect at bio-oxidizing VOCs to provide a significant scrubbing effect. This effect was not measured in this study, but researchers such as Card and Schmidt (BioCycle 2012) and Horowitz and Noble (BioCycle 2013) others have reported bio-layers providing 95% control efficiency in Positive CASP's.