Report Topic

An Investigation of the Potential for Ground-Level Ozone Formation Resulting from Compost Facility Emissions

California Department of Resources Recycling and Recovery

December 2010

Contractor's Report
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Publication # DRRR-2011-006

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Prepared as part of contract number IWM 09012 for $33,000.

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Acknowledgments

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Special Thanks

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- Alameda County Waste Management Authority
- All Valley Environmental/Kochergen Farms
- Isabel Faria, Ph.D., UC Davis Dept. of Civil & Environmental Engineering
- Grover Landscaping, Inc.
- Walter Ham, Ph.D., UC Davis Dept. of Civil & Environmental Engineering
- Prof. Mike Kleeman, UC Davis Dept. of Civil & Environmental Engineering
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Executive Summary

Ground-level ozone is a serious problem in many of California's inland valleys, where mountain ranges trap polluted air.

The federal Clean Air Act directs regional air quality control districts to reduce ozone levels below federal thresholds, under penalty of lost federal transportation funds. These districts generally attempt to lower ozone levels by controlling the precursors, VOC and NO_x. Air district officials in two of California's most challenged air basins, covering the San Joaquin Valley and the greater Los Angeles area, have identified composting facilities and their raw materials as a source of precursors, and propose regulations to reduce VOC emissions from the composting feedstocks.

The steady stream of raw materials flowing to composting facilities is a direct result of California's Integrated Waste Management Act, which requires municipal governments to divert half of all wastes away from landfill disposal. Composting can be a cost-effective means to convert large volumes of urban green wastes into valuable products for agriculture. However, landfilling costs are very competitive with composting, and new regulations which increase composting costs can be expected to drive organic materials back to the landfill, decreasing solid waste diversion rates and depriving agriculture of a low-cost organic soil amendment.

Earlier research initiated by CalRecycle and sponsored by several composters and public agencies found that composting emissions are more than 80 percent light alcohols, low-reactivity compounds which are not expected to produce large amounts of ozone when mixed into the larger atmosphere. The ozone-formation potential of the total composting VOC mix is low, and it is similar to the potential from other agricultural sources.

This report concerns the second phase of the project, funded by CalRecycle. This research confirmed the previous findings and found that a pseudo biofilter cap made out of oversized materials screened from finished compost is an effective ozone mitigation measure. The cap reduced average measured ozone formation by 27 percent in five-day-old piles and by 36 percent in 21-day-old piles.

These research conclusions are significant findings in understanding air quality issues and how to mediate ozone impacts. This study suggests that reducing emissions during the latter phase of the active emissions period—around week three—will yield clean air benefits. Moreover, because of the low overall ozone formation potential of the VOC emissions profile from composting piles, reducing composting pile emissions is unlikely to have a detectable impact on regional tropospheric ozone levels.

Study Design

In this project, the study team evaluated additional samples, and tested the efficacy of one potential mitigation measure, known as the pseudo-biofilter compost cap (compost cap or cap). This mitigation measure uses a layer of previously composted materials, 4-6 inches deep, which is spread atop an actively composting pile. The finished materials host a large number of micro-organisms that use carbon compounds such as VOCs for food. As emissions filter up through the compost cap, pulled by the convective forces within the actively composting pile, they are consumed by the micro-organisms in the cap.

Previous studies had used finished product for the cap; for this study, the research used a compost cap made of oversized materials screened from finished compost, known as "overs." Overs are a common byproduct at compost facilities and can be burdensome to manage. The team first tested the overs to ensure they were not a source of ozone-forming emissions. Once it was determined that the ozone formation potential of overs was negligible, the study team set out to determine whether overs might replace the use of finished product for the cap. The overs were effective for this purpose.

As in the earlier work, sampling focused on identifying the greatest possible range of VOCs emanating from composting piles, including highly reactive compounds which may not be captured using typical mass-VOC measurement techniques. Samples were taken using a wind tunnel device, and routed into stainless steel canisters and sorbent tubes for holding and transport to a lab, where they were analyzed on a gas chromatograph/mass spectrometer. Once the individual compounds and concentrations were measured, the emissions mix was run through a computer model to predict how much ozone will be formed in the atmosphere based on the addition of the source emissions.

The test protocol employed a mobile ozone formation chamber (known as the MOChA), which was towed to the composting sites behind a pickup truck. The study team measured actual ozone formation from the composting emissions within the chamber in real time. The next step was to compare MOChA chamber measurements with the ozone formation calculated by the model based on the identified VOCs within the emissions sample. If the model and the measured emissions were relatively close (within around 20 ppb), then it is highly likely that all of the reactive, ozone-forming compounds within the source emissions had been properly identified.

Two composting facilities were selected for this research project and hosted the study team for one week at each facility. One facility is located in

Modesto, in the northern San Joaquin Valley, and the other facility is located near Tulare, in the southern San Joaquin Valley.

Results and Conclusions

There are three key overall conclusions from both phases of this work:

1. A pseudo biofilter cap made out of oversized materials screened from finished compost is an effective ozone mitigation measure. The cap reduced average ozone formation measured in the MOChA chamber by 27 percent in five-day-old piles, and by 36 percent in 21-day-old piles. Use of the model increased the performance of the cap to an ozone formation potential reduction of more than half.

2. VOCs from green waste composting are a diverse mixture, but are comprised of 80-95 percent low-reactivity alcohols. The ozone formation potential of the total composting VOC mix is considered low, and is similar to other agricultural sources.

3. Emissions from three-week-old composting piles appeared to form slightly more ozone than those from piles composting for only a few days, even though the younger piles had a higher overall emissions rate.

The specific results from Phase 2 of the study can be summarized as follows:

- VOC emissions coming from a six-week-old windrow and from large piles of oversized material (screened from finished compost) that were either one day or five days old, all had low ozone formation potential.

- A side-by-side comparison of two sets of active windrows (each set constructed with identical material), one set from materials composting for about five days, and another set from materials which had been composting for about three weeks, was conducted. Each set of windrows was comprised of one windrow topped with a pseudo biofilter cap of oversized, previously composted material, and an identical windrow without the cap. In both cases, the cap was effective in reducing both the VOC mass emissions and the ozone formation from the windrow.

The study team identified all VOCs which were greater than 0.05 ppb by volume in any sample. More than 50 VOCs were identified in some samples, while some of the piles of oversized, previously composted materials had fewer than 20 detected constituents. The three main alcohols—ethanol, wood alcohol (methanol) and isopropyl—comprised greater than 90 percent of the total emissions by volume in all samples. Acetone, which is exempt from Clean Air Act regulations because of its very low ozone formation potential, was generally the fourth most prevalent compound. Formaldehyde and acetaldehyde were top 10 compounds in many samples; these are highly reactive ozone-forming compounds but are mostly found in the range of 1-2 ppb by volume. Naturally occurring terpenes like alpha-pinene and limonene were not found in all samples, but are moderately reactive compounds and occasionally were found in the 1 ppb range. Other compounds generally were found in fractions of a part per billion.

The Maximum Incremental Reactivity (MIR) scale is the most common scale used to compare the ozone formation potential of various compounds. Any compound or mixture with an MIR of less than 2 is considered to have low reactivity. The average MIR of all samples taken in Modesto was .95. The average MIR of all samples taken in Tulare was 1.13. The MIR of a typical urban VOC mixture is about 3.6.

A unique aspect to the MOChA approach to studying the formation of ozone from VOC sources is the ability to compare observed (measured) ozone formation in the MOChA chamber with the ozone predicted from the detailed VOC mixture measurements. Past projects have generally shown a difference between the model and MOChA of about 10-20 ppb. For a highly variable source whose VOCs are both low in concentration and low in reactivity, such as composting pile emissions, this comparison can be more difficult.

Figure ES-1 shows an overview of the Modesto dataset (see Appendix E for complete details). At Modesto, the ozone formation measured inside the MOChA from the piles of previously composted, oversized materials (one- and five-days-old) was not detectable, because it was within 5-10 ppb of the ozone expected to be formed by the defined background gas mixture (mini-surrogate). Ozone formation from the six-week-old piles was in the range of 15 ppb, which is extremely low. For the six-week-old pile, the model and the ozone observed within the chamber were within 2 ppb agreement, which is excellent.

Figure ES-1: Modeled, observed (measured in the MOChA chamber) and average ozone formation from the Modesto dataset in parts per billion (negative values converted to zero). The mini-surrogate refers to the background air mixture containing NOx and other VOCs which is added to the ozone formation chamber to simulate conditions in the San Joaquin Valley on a typical summer day. Two replicates were completed for each sample type; each replicate is graphed separately.

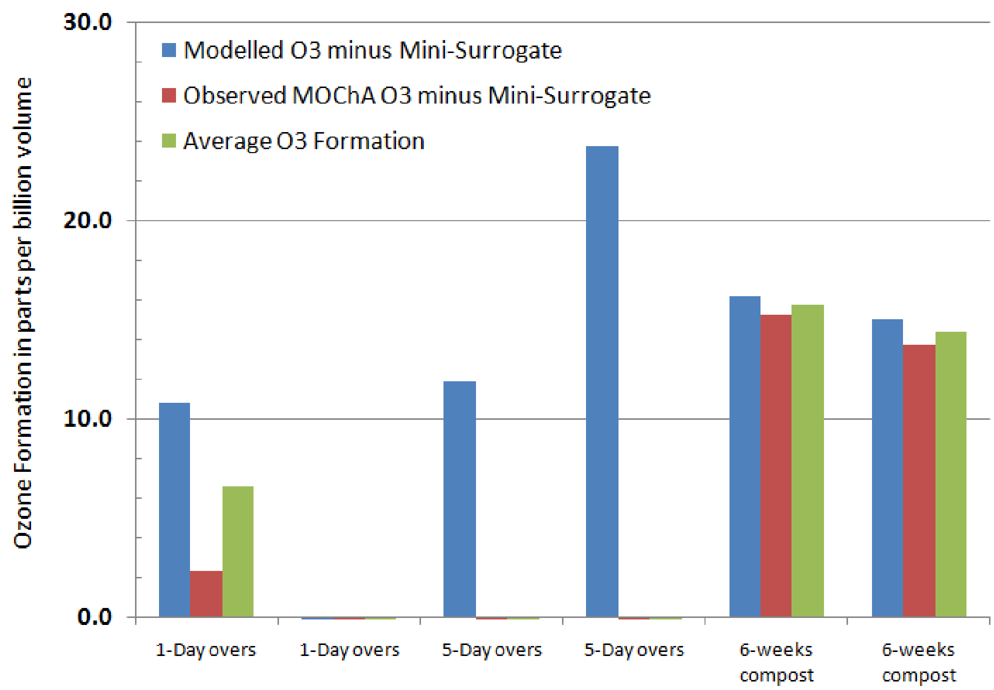
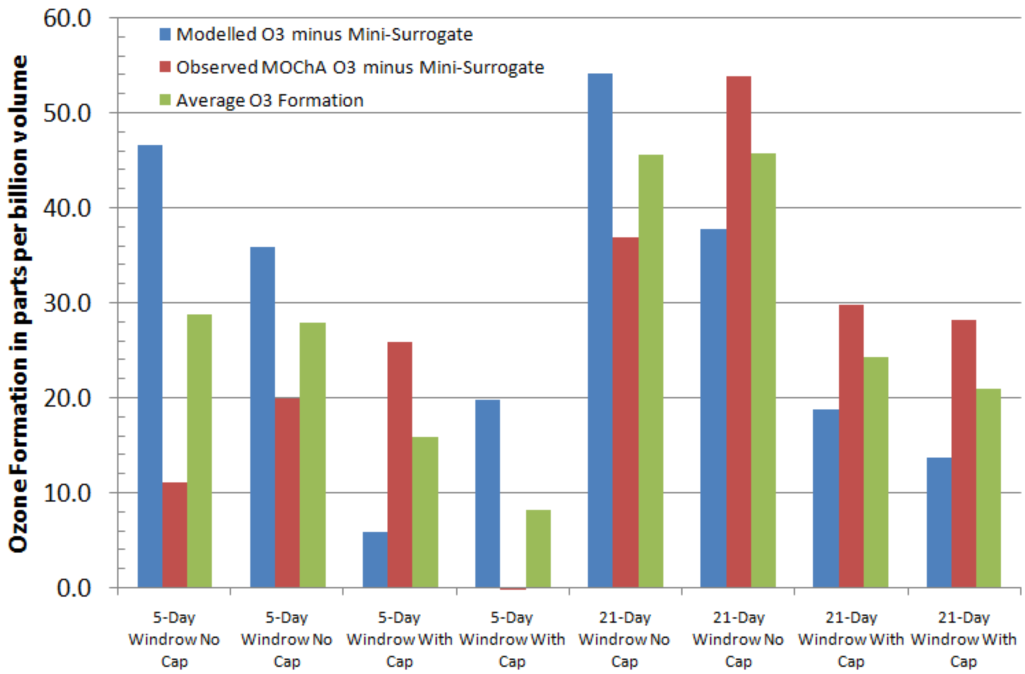


Figure ES-2 shows an overview of the Tulare dataset (see Appendix E for complete details). All but one of the samples in Tulare resulted in measureable ozone formation from the source. Ozone formation measured in the MOChA chamber ranged from a high of 53 ppb in a 21-day-old, uncapped pile, to zero in a five-day-old, capped pile. Piles with the pseudo-biofilter cap emitted fewer total VOCs—and generally formed less ozone—than their uncapped twins. The difference was most pronounced in the 21-day-old piles. There were two instances where the difference between the model and the MOChA chamber was greater than 20 ppb, both occurring with the samples from the five-day-old piles.

Figure ES-2: *Modeled, observed (measured in the MOChA chamber) and average ozone formation from the Tulare dataset in parts per billion (negative values converted to zero). The mini-surrogate refers to the background air mixture containing NOx and other VOCs which is added to the ozone formation chamber to simulate conditions in the San Joaquin Valley on a typical summer day. Two replicates were completed for each sample type; each replicate is graphed separately. Average = model + MOChA /2.*

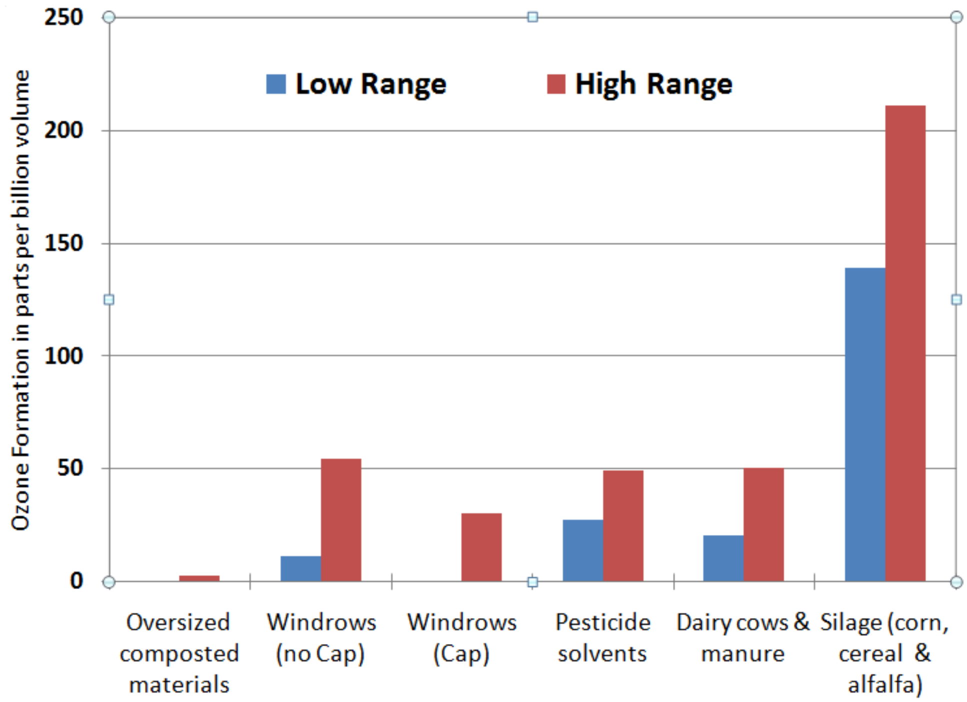


In the case of three-week-old windrows covered with a cap of oversized material, the average ozone formed in the mobile chamber for both replicates was 36 percent less than its uncapped twin. Average measured ozone formation in the five-day-old capped windrow was reduced by 27 percent over its uncapped mate. When the observed ozone formation in the MOChA chamber for the two replicates is averaged with the modeled ozone formation based on the individual constituents, the pseudo-biofilter cap gives an emissions reduction of greater than 50 percent for both sets.

Earlier research on VOC emissions has shown that three-week-old windrows have lower total VOC emissions flux—or flow of emissions from the pile—than windrows only a few days old. This research project, along with the associated previous field experiments, evaluated the spectrum and relative proportions of reactive compounds in the total composting VOC emissions mix. It is noteworthy that, while three-week-old windrows have lower total VOC emissions than few-day-old windrows, this research shows that three-week-old windrows have a higher ozone formation potential than windrows only a few days old. Phase I results from this project came to the same conclusion.

Figure ES-3 shows measured ozone formation in the MOChA chamber for all sources tested to date. Overall, greenwaste composting feedstocks formed ozone in the range of 0-53 ppb in the MOChA chamber. The most reactive agricultural ozone source tested in the MOChA chamber so far, the silage used to feed dairy cows, ranged from 139 to 211 ppb.

Figure ES-3: Observed ozone formation in the MOChA chamber in ppbv for various tested agricultural sources.



Although previous studies have focused ozone mitigation efforts on the first two weeks of composting, this study suggests that reducing emission during the latter phase of the active emissions period—around week three—will yield clean air benefits. Focusing mitigations when pile management is less intensive—after the mandatory pathogen reduction process which requires five turns in 15 days—allows the cap to be left in place for a longer period of time, and reduces the time and diesel power needed to re-apply the cap. Furthermore, when the oversized materials from the cap are mixed into the composting pile, they provide pile structure which reduces bulk density and improves air flow within the pile, a reasonable strategy for reducing odors and emissions.

Introduction

Background

Volatile Organic Compounds (VOCs) are a class of more than 1,000 gaseous compounds which vary tremendously in terms of their odor, toxicity, and reactivity with other atmospheric constituents. Many VOCs react with oxides of nitrogen (NO_x) in the presence of sunlight to form ground-level or tropospheric ozone, a Clean Air Act criteria pollutant with significant negative impacts on human health and on plants, including agricultural crops.

The reactivity of any given VOC influences its ozone formation potential. Researchers have classified most common VOCs using a reactivity index, and the U.S. Environmental Protection Agency has exempted certain very low reactivity compounds from Clean Air Act regulations.

Composters have come under scrutiny from air quality officials because of the emission of VOCs during the natural decay processes of composting piles of feedstocks. In areas with severe ozone non-attainment issues, such as the San Joaquin Valley and the Los Angeles basin, regulators are drafting regulations that will restrict the operations of composting facilities and could require some composters to undertake expensive upgrades such as enclosure or forced aeration. Because the composting business model is based on low profit margin, high volume, and efficient production, strict air quality requirements could force some operators out of business. Losing organics processing facilities would undermine 20 years of work by CalRecycle and its predecessor agency to increase diversion of organic materials away from landfills and into more productive uses. Such a development would deprive farmers of affordable sources of compost, an important product for building soil health and ensuring food security. Compost is fundamental to organic crop production, and organic production is growing in terms of both acreage and total dollar value.

Up until 2009, there had been no study with the specific intent of analyzing emissions from composting piles to capture and identify every VOC being emitted, and to determine whether these compounds were likely to react with NO_x to form ozone. Therefore, the contribution of composting facilities to regional ozone problems was not proven.

An earlier segment of this project, conducted in fall 2009 and funded by two municipal agencies and four composters, isolated the full range of VOCs emanating from composting piles, including the highly reactive ones which are not distinguished using total mass VOC measurement techniques. To accomplish this, VOCs were captured using sampling instruments such as a flux chambers and wind tunnels, and routed to stainless steel canisters where the gases were held until they could be taken to a laboratory for analysis with a gas chromatograph and mass spectrometer (GC/MS). Other containment methods for captured gases, such as sorbent tubes, are better suited for highly reactive gases such as aldehydes, and are used in addition to the steel canisters. The fall 2009 sampling indicated that a wind tunnel was a preferred method for sampling emissions, because the emissions captured by the flux chamber, even when routed through an ice trap to reduce water, were still too wet to be properly measured in the mobile ozone formation chamber (MOChA).

Like the contractor's previous efforts with dairies and field spraying in orchards, this approach includes the use of the MOChA to make real-time field measurements of ozone formation from composting emissions. The MOChA is a rectangular wood box approximately 4-by-8-feet in dimensions mounted on a 12-foot metal trailer and pulled behind a pickup truck to research sites. The box is described in greater detail in another section of this report.

Gas species and proportions eluted from the GC/MS, based on the samples from the canisters and sorbent tubes, were run through the state-of-the-art photochemical model for atmospheric simulations of both ozone formation and aerosols. The model, known as SAPRC (Statewide Air Pollution Research Center), was developed and documented from 1990 through 2010 by Dr. William Carter at the University of California, Riverside. Briefly, SAPRC accounts for all the major and minor gases—both organic and non-organic (e.g. NO_x, H_2O)—in a sample of gas mixture (as in the atmosphere), and includes temperature and sun angle as parameters. With a progression of time steps, it calculates how much ozone is formed, as well as how VOCs are converted progressively to CO_2. One can then compare with the MOChA measurement of actual ozone formation in the field—with a small correction for chamber wall losses.

The values obtained from the MOChA were compared to the modeled ozone concentrations that would be expected to be formed based on the identified VOC species and their indexed reactivity. If the amount of ozone formed in the MOChA matched the modeled ozone amounts, within reasonable parameters, then that confirmed all of the VOCs being emitted had been measured and identified.

Project Goals and Objectives

The primary goals of this project were to further investigate a finding generated by the results of the fall 2009 sampling, and to validate a variation on an emissions mitigation measure which has been suggested by past research and appears to be operationally feasible for commercial composters. This variation would reduce the cost of implementing the emissions reduction measure, while assisting composters in managing a by-product of the composting process. The variation also may help composters increase or maintain natural airflow through the composting pile.

An unexpected result observed during the fall 2009 sampling was that while bulk composting emissions are known to peak early in the process—within the first 7-10 days—the emissions profile of a 14-21-day-old composting pile contained a higher proportion of reactive compounds. The percentage of highly reactive compounds in the five-day-old piles tested in the fall sampling was around one percent, while nearly three percent of the emissions from the 21-day-old piles were considered strongly reactive. A goal of the study was to whether that condition persists by testing piles that were six weeks old.

One of the most promising and operationally feasible composting VOC mitigation measures studied to date is the application of a layer of finished compost 4-6 inches deep on top of active composting piles. This mitigation, known as a pseudo-biofilter compost cap, was shown in a previous study funded by CalRecycle's predecessor agency to reduce the total mass of VOC emissions by up to 75 percent over the first two weeks of composting. A subsequent study funded by the San Joaquin Valley Unified Air Pollution Control District showed a 53 percent emissions reduction over the first three weeks of the composting process.

The cap breaks down VOCs by acting as a biofilter. Microbes living within the biofilter layer consume carbon-containing compounds for food. As the emissions are drawn up through the composting pile, pulled by the convective forces created by heating within the pile core, they are consumed in the biofilter layer.

Many biofilters are comprised of moistened wood chips, a filter medium similar to compost "overs," the large particles which do not break down during a composting cycle and are screened out of the finished product at the end, before it is sold. This research project tested whether compost overs are effective when applied as a pseudo-biofilter cap. As a precursor to that, it was necessary to determine whether the overs themselves are a source of reactive VOC emissions. In order to do that, the study team tested two overs piles of differing ages.

Overs are produced at every composting facility, and management of overs can be problematic. Depending on the contamination levels and the situation of the operator, overs may be sold as mulch or sent to a biomass facility for power production. Composting facilities co-located with a landfill have the easy option to send overs for either disposal or use as alternative landfill cover.

Some composting facility operators incorporate overs into their new windrows. This provides two clear benefits. First, the large particle size of overs decreases the bulk density of the new composting pile, allowing better air infiltration throughout the pile. The second advantage is that microbes living within the overs can "inoculate" the newly formed pile of composting feedstocks, effectively jump-starting the composting process. A composting cap applied to the surface of a new pile, and then mixed into the pile at the first turn, would ostensibly provide both benefits in addition any emissions reductions attributable to the cap. Because composting piles tend to increase in density as the composting process continues, an overs cap at the three-week mark would provide many of the same benefits, though inoculation would not be as critical at this stage.

To test whether the pseudo-biofilter compost cap made of overs was effective required the creation of pairs of composting piles of identical feedstocks of the same age. One composting pile in each pair was covered with a pseudo-biofilter cap made of overs. The compost facility operator built two pairs of matching composting piles for this experiment. One pair was made of materials which had been composting for five days, and the other pair was made of materials which had been composting for three weeks.

Sampling Strategy

This research contract funded two field projects of one week duration each at the two facilities, and followed an earlier study which also comprised two, one-week field projects. Sites were chosen for both projects based on (1) willingness to host, (2) being sizable and therefore inherently representative of this diverse industry, (3) being successful and therefore inherently 'good practitioners' in the current industry, and (4) located in California's San Joaquin Valley. All four sites for these two studies met all four criteria.

The two facilities selected were:

- City of Modesto Compost Facility, located approximately 12 miles southwest of Modesto. This city-run facility accepts approximately 70,000 tons per year of curbside and landscape-generated greenwaste collected from Modesto and surrounding communities. The facility is permitted to process biosolids collected from its sewage treatment plant, but these materials were not tested. This site was selected for a previous emissions research project conducted by the California Integrated Waste Management Board in 2004.
- Tulare County Compost & Biomass, Inc., located east of Tulare (TCCBI). This privately owned and operated facility accepts approximately 60,000 tons per year of curbside and landscaper-generated greenwaste collected in and around the cities of Visalia, Tulare, Porterville, and Exeter. This site does not accept manure or biosolids. This facility was the site of an emissions study conducted in 2009 by the San Joaquin Valley Unified Air Pollution Control District.

In the first week at Modesto, emissions samples were collected from windrows in the six-week-old range. During this week, emissions from two large piles of overs were also tested. One of the piles was one day old, and the other pile had been in place for five days. Two replicates were taken on each of the three pile types samples. An effort to collect an additional replicate for very young windrows was rained out, as the MOChA and instruments cannot be exposed to significant rain.

Four test windrows (elongated piles of composting feedstocks) were created for the second week of testing at TCCBI. Two windrows were made of brand new feedstocks on the Friday prior to the arrival of the test team, making the piles four days old when testing began. One of those windrows was covered with a cap of six inches of overs. Two additional windrows were formed out of feedstocks which were 21 days old. Again, one of the windrows was covered with a six-inch-deep cap of overs. Two replicates were taken on each of the four windrows to determine the impact of the overs on the types and amounts of VOCs being emitted by the two different aged materials. The morning and afternoon efforts alternated between the mitigation windrows and the control windrow in order to achieve representative comparison.

Sampling Protocols

The sampling team used a wind tunnel to pull samples off the composting windrow. The wind tunnel is a rectangular stainless steel enclosure with half of the bottom open to receive the source emissions. The model in use has a 0.32 m^2 area and a volume of 0.08 m^3. The wind tunnel is placed 0.5" into the selected composting pile location to fix the tunnel surface. The wind tunnel is equipped with a chemisorbant-and-activated-carbon filter at the intake to clean the air being pulled into the chamber. That filter is replaced each week.

The use of the wind tunnel instead of the flux chamber provides a larger surface area, a defined flow direction, and air exchange rates or air speed in the tunnel which may be more representative of natural conditions. Moreover, higher air flow provides dilution of emissions that helps to counter the high humidity interference with the photo-acoustic measuring device used in tandem with the ozone chamber, as well as water aerosol (fog) formation in the ozone chamber—which precludes ozone formation.

The first sampling port in the wind tunnel allows the sampling of inlet air. The second port allows the sampling of post-filter air and the third port is used for source sampling at the tunnel outlet. A perforated stainless steel tube in the tunnel is connected to each sampling port. This perforated sampling tube ensures mixing so that representative samples are collected. The outlet baffle of the tunnel helps avoid back pressure which might be caused by ambient wind during sampling. A fan was used to push the filtered air through the tunnel. The fan mixed the inlet air with the emissions and drew them toward the tunnel outlet. The bulk speed in the wind tunnel, which is measured using a pressure gauge installed on the tunnel, can be adjusted between 0.13 and 0.47 meters per second, with the resulting air exchanges of 10 to 35 per minute respectively. The velocity profile in the tunnel was fairly uniform and consistent (Schmidt and Bicudo, 2002). After each experiment, the tunnel was wiped and cleaned with dry paper towels and flushed on a clean surface with zero air. All the Teflon tubes were purged with zero air after every experiment.

Samples from the outlet port of the wind tunnel were pulled into a sampling train using Teflon tubing. Flow in each sampling medium was regulated either with a flow regulator (canister) or low flow pumps (sorbent tubes) and excess flow was passed aside to avoid any back pressure.

The study team used six-liter passivated stainless canisters to collect VOC samples for laboratory analysis using U.S. EPA method TO-15. Charcoal sorbent tubes containing 400 mg and 200 mg of activated carbon in two successive sections were used to collect less volatile/semi volatile organic compounds. Carbonyl compounds (aldehydes and acetone), which may either be present in the sample or may be an oxidation product, were captured using sorbent tubes comprising 300 and 150 mg silica gel impregnated with 2,4-

dinitrophenylhydrazine (DNPH) in the front and backup section of the tube (U.S. EPA TO-11A, 1999, ASTM D 5197).

Sampled tubes and field blanks were capped, labeled and placed in polypropylene bags immediately after collection and stored in an ice chest with ice packs. After delivery to the laboratory at the Department of Civil and Environmental Engineering at UC Davis, they were refrigerated until analysis.

In view of the complex nature of composting emissions, multiple sampling techniques were applied to collect the widest possible range of VOCs. Six-liter passivated stainless canisters were used to collect VOC samples to be analyzed in the laboratory using U.S. EPA method TO-15. The charcoal sorbent tubes containing 400 mg and 200 mg of activated carbon in two successive sections were used to collect less volatile/semi volatile organic compounds at the sampling rate of 1.5 L/min for 2-3 hours. Charcoal tubes supplemented canister samples to ensure that a full range of hydrocarbons were measured in the sample, but they are not typically analyzed unless there is a large disagreement between the model and the MOChA chamber results. Carbonyl compounds (aldehydes and acetone), which may either be present in the sample or may be an oxidation product, were captured using sorbent tubes comprising 300 and 150 mg silica gel impregnated with 2,4-dinitrophenylhydrazine (DNPH) in the front and backup section of the tube (U.S. EPA TO-11A, 1999, ASTM D 5197). Samples were collected at the sampling flow rate of 200-500 mL per min^{-1} for 2-3 hours. Backup sorbent sections of charcoal and DNPH silica tubes were analyzed to determine the breakthrough of sample collection.

All the sorbent tube samples were collected in duplicate, while more than half of the canisters also were collected in duplicate depending on the availability of canisters and experimental set up. Sampled tubes and field blanks were capped, labeled, and placed in polypropylene bags immediately after collection and stored in an ice chest with ice packs as per protocol. Once delivered to the laboratory at the Department of Civil and Environmental Engineering at UC Davis, they were refrigerated until analysis. Canisters were capped and stored at ambient temperature with their filled chain-of-custody form. One-month storage time is the maximum recommended for canister samples (U.S. EPA TO-15). All the experimental details, including location and sample collection information, were maintained in the data sheet. All the samples (sorbent tubes, canisters) were planned to be analyzed within 2-3 weeks after sampling.

The study team measured alcohols, which constitute a major fraction of composting emissions, using an INNOVA photo-acoustic multi-gas monitor. This INNOVA is configured for methanol, ethanol, 2-propanol, and water vapor through the use of respective optical filters, and is calibrated by the instrument manufacturer. This analyzer is capable of monitoring these compounds at one-minute intervals.

Physico-chemical properties of the sampled composting pile were studied along with the VOC measurements. Internal pile temperature was measured at 1-foot and 4-foot depths below the wind tunnel using commercial-style compost temperature probe. Additional properties of the compost being tested were measured on site using the following protocols:

- Porosity (volumetric addition of water);
- Density (gravimetric and volumetric measurements);
- Moisture saturation (qualitative, with a soil moisture meter); and
- pH (by addition of water to make a paste; USDA Agricultural Handbook 60).

Samples were taken of the composting pile below the wind tunnel and delivered those to the UC Davis laboratory for analysis of:

- Water content (drying at 105 degrees C to constant mass); and
- C:N ratio—using Carlo-Erba combustion test, performed at the Division of Agriculture and Natural Resources analytical lab (http://anlab.ucdavis.edu/ on the UC Davis campus.

Mobile Ozone Chamber

Mobile Ozone Chamber Assays (MOChA) were used for direct on-site measurement of ozone formation from composting emissions. MOChA chambers were characterized and used successfully in the research team's previous studies, which have been published in peer-reviewed journals (Howard, et al., 2008, Kumar et al., 2008, Howard et al., 2010, in press).

The MOChA chamber is a rectangular wood box approximately 4-by-8-feet in dimension, which is mounted on a 12-foot metal trailer and pulled behind a pickup truck to research sites. The box is equipped on the inside with 26, 4-foot-long UV lights installed on one inner side of the chamber, capable of generating 50 $W\ m^{-2}$ of UV radiation. This particular type of light bulb was selected because the bulbs give off light in the near-ultraviolet portion of the light spectrum, the one which tends to form ozone in the atmosphere. The MOChA is equipped with two 12-inch fans to prevent heating of the box above normal summer (ozone season) temperatures.

A 1,000-liter Teflon bag inside the MOChA chamber was filled with the air sample drawn from the sampling port of the wind tunnel using Teflon-coated diaphragm pumps at a flow rate of approximately 50 $L\ min^{-1}$ until the bag is full, which takes approximately 20 minutes. A Teflon membrane filter was used at the sampling inlet point of bag to remove particulate matter from the sample.

Nitrogen oxide (NO_x) in the concentration range of 45-55 ppb was introduced into the bag using a gas cylinder (10.1± 0.5 ppm as NO_2 in air) to simulate the typical NO_x level of rural/ agricultural areas of the San Joaquin Valley during summer ozone episodes. The background reactive organic gases (or minisurrogate) consists of a 55 ± 1 ethylene, 33 ± 1 percent hexane, and 12 ± 1 percent xylene mixture by volume, and also were introduced in the bag. The purpose of the minisurrogate was to take the source emissions and mix them with a representative, well-defined atmosphere acting as the receiving air with which emissions from any source will mix. The study team then assessed how much more ozone is formed than would be formed by the receiving air itself. Six-liter "grab" canister samples of VOC concentration also were collected from the bag at the start of each MOChA experiment, in order to verify that the VOC mixture reaching the bag (through tubing and pump) is identical to that measured directly at the source.

Once the Teflon bag was full with the combined sample and the introduced gas mixtures, the lights were turned on, exposing the bag within the MOChA chamber to 50 W m^{-2} of UV radiation for 180 minutes. Probes measured temperature and relative humidity, while dedicated instruments measured concentrations of oxides of nitrogen (as NO, NO_2 & NO_x) and ozone from samples removed from the Teflon bag at 0-5, 20-30, 55-65, 85-90, 115-120, 145-150, and 175-180 minutes. Ambient air was measured in between bag measurements so that the ozone and NO_x instruments remained active and flowing. The intermittent sampling schedule allowed 180-minute experiments to be conducted while ensuring that the final Teflon bag sample volume did not drop below 60-70 percent of initial bag sample volume—at which point the effects of increased surface-to-volume ratio would begin to bias the measurements. After each experiment the Teflon bag was emptied and flushed (re-filled and emptied again) with clean air produced by a Zero-Air generator. A new Teflon bag was used for each week in the field. Moreover, each bag was checked for contamination at regular intervals and was replaced with the spare bag whenever required.

Sample Analysis Protocols

Besides the Ozone Chamber measurement, VOC measurements were conducted using three techniques:

1. - Photo-acoustic infrared absorption monitored the small alcohols and major non-VOCs: H_2O, CO_2 and NH_3. This occurred at the start of the field experiment while the source sample was being filled into the ozone chamber.

2. - Canister sampling was followed by cryo-focused GC-MS (gas chromatography-mass spectrometer) analysis (for highly volatile and non-polar or semi-polar VOCs) using the established EPA TO-15 protocol.

3. - DNPH-impregnated sorbent tubes followed by HPLC (high-performance liquid chromatograph), for highly reactive aldehydes and ketones, using the established EPA TO-11 protocol.

A fourth method, charcoal sorbent tube-sampling followed by solvent elution and GC-MS, aimed to quantify a broader range of moderately volatile VOCs. This method is used for worker safety through NIOSH (method 1500 for hydrocarbons, method 1501 for aromatic hydrocarbons, and method 1552 for terpenes) and has been described and validated in various publications. These samples have not yet been needed in any study to find ozone-forming VOCs which are not otherwise accounted for. Since they are easy to sample and stable during storage, they were collected "just in case" there was a mismatch of 50 or 100 ppb in the ozone formation predicted by model versus what was observed in the MOChA.

Data Analysis

Hundreds of compounds fall under the definition of volatile organic compounds. Some of these compounds contribute significantly to ozone formation in the atmosphere, and others do not. There is no single approach to measure the full range of compounds. The study team employed multiple techniques in order to obtain the widest possible profile of VOC emissions from the composting source. They combined compounds analyzed by several techniques to make a complete emission profile from the source samples. Results from canister samples gave a wide range of compounds and were supplemented with the carbonyls trapped in the DNPH silica tubes. Alcohols (methanol, ethanol, 2-propanol) were measured with the INNOVA analyzer.

Quality control processes included using field blanks on greater than 10 percent of all samples, field duplicates, laboratory calibration standards, and laboratory blanks. These processes ensured that canisters and sorbent materials are being kept clean through transport to and from the field, and that field samples are reproducible.

Flux rates (mass/time/area) for any compound were calculated using the air flow rate in the wind tunnel, the concentration of the compound in the outlet sample, and the surface area covered by the tunnel. The formula is as follows:

$$\text{Flux Rate } (mg/m^2/min) = \frac{\text{Target concentration } (mg/m^3) \text{ x Flow rate in the tunnel } (m3/min)}{\text{Exposed surface area } (m^2)}$$

Net ozone formation from MOChA is calculated using the following equation (Carter et al., 1995) because an increase in NO represents a net production of ozone from NO_2 photolysis – independent of VOC reaction:

$$\text{Net } O_3 \text{ formation } (\Delta O_3) = (O_3^{\text{ final}} - O_3^{\text{initial}}) - (NO^{\text{final}} - NO^{\text{initial}}) \qquad (1)$$

The study team calculated the net ozone formation from the VOCs in the source by subtracting the expected ozone formation from the defined background gas mixture (known as the mini-surrogate) that is added to each MOChA experiment. In some earlier studies, the amount of ozone formed from the source VOCs was so high that a small variation in mini-surrogate VOC concentration was insignificant. In this study; however, the amount of ozone formed from the source VOCs was relatively small, so greater precision regarding the mini-surrogate contribution to ozone formation in the chamber was needed. To increase the precision of the ozone modeling from the mini-surrogate, the team collected canister samples from the Teflon bag at the start of each MOChA experiment. In this way, the team knew the actual concentrations of the mini-surrogate gases in the chamber for each MOChA run.

The team measured ozone concentrations inside the MOChA chamber using an ozone analyzer (Model 450, Advanced Pollution Instrumentation, Inc., San Diego, CA). This device uses the ultraviolet absorption method and is accurate to 1 ppb. Concentrations of NOx (NO and NO2) were measured inside the ozone chamber using a chemiluminescence analyzer (Model #ML9841A, Teledyne Monitor Labs, Englewood, CO). Any production of nitric oxide (NO) was subtracted because production of NO represents ozone which was formed by the light itself and without the contribution of VOCs.

The study team ran photo-chemical model calculations for the VOCs obtained from the combined laboratory analysis of the composting emissions to calculate modeled ozone formation. They validated the model in two previously published papers (Howard et al., *Atmospheric Environment* 42 (2008) 5267–5277 and Kumar et al, *Journal of ASTM International*, Vol. 5, No. 7). When modeled values of ozone formation match the on-site MOChA values for measured ozone, this confirms the capture of the complete ozone precursor VOC profile.

Interpretation & Discussion

This research study immediately followed a project using similar methods to report the full range of VOCs emitting from green waste composting, as well as the ozone formation potential for those emissions. Testing was initially conducted at the early and intermediate-early stages of the composting process, because emissions are known to be most prolific then.

Since the earlier project was the team's first effort to conduct complete VOC speciation from composting windrow emissions, different sampling approaches—a flux chamber at the first site and a wind tunnel at the second—were used before adequate overall success was achieved with real-time ozone monitoring in the MOChA chamber. The results from the predecessor study was written up as a manuscript for a peer-reviewed journal, where it has been submitted, reviewed, minor revisions completed, and resubmitted to await final acceptance.

In the prior study, VOCs from three types of sources were studied: fresh tipped piles of unprocessed green waste, three-to-six-day-old windrows of processed green waste, and two-to-three-week-old windrows of processed green waste. Multiple sampling and analytical approaches were applied to ensure the detection of the greatest possible range of the gaseous organic components emitted. More than 100 VOCs were detected and quantified in this study, including aliphatic alkanes, alkenes, aromatic hydrocarbons, biogenic organics, aldehydes, ketones, alcohols, furans, acids, esters, ether, halogenated hydrocarbons and dimethyl disulfide (DMDS). Alcohols were found to be the dominating VOCs in the emissions from a composting pile regardless of age, making up from 80-95 percent of the total emissions in every age pile.

Ozone formation was instigated using the MOChA chamber, measured using an ultra-violet absorption device, compared with photochemical model calculations, and determined to be low. The VOCs making up the great majority of the composting source were considered to be low reactivity; that is, they had a maximum incremental reactivity (MIR) of less than two, and the overall reactivity of the mix was also very low. The reactivity of a typical urban VOC mix is moderate, with an average MIR of around 3.6 (http://www.engr.ucr.edu/~carter/SAPRC). Common plant-based biogenic VOCs--such as pinene and limonene—have an MIR around 4.5. This study found that two-to-three-week-old piles had a slightly more reactive emissions profile than the younger piles, but are still a weak source.

In the current study, the team assessed the VOCs and OFP from older windrows (six weeks), from freshly produced (<1-day-old) oversized materials, known as "overs," and from five-day-old overs. Confirming that overs are not a significant source of ozone-forming VOCs, the study team conducted a side-by-side study using two pairs of identically prepared windrows. One set of windrows was made of materials which had been composting for five days, which previous studies had determined are at or near the peak of total emissions. The other set was from materials that had been composting for 21 days, which the team's previous work had shown produced a slightly more reactive emissions mix. One windrow out of each pair was covered with a 6-inch-deep layer of oversized materials. The layer of materials is thickest on the top of the pile, and tends to thin out as the layer cascades down the angled sides of the windrow. The layer of materials is known as a pseudo-biofilter cap, because it acts like a biofilter.

This study confirms the emissions profile first clarified during the previous efforts. Wood alcohol, isopropyl alcohol, and ethanol comprised more than 90 percent by volume of the emissions from all but one of the piles tested in this project. The only other compounds making up more than 1 percent of the emissions mix of any of the piles in this study were acetone, alpha pinene, and limonene. Acetone is exempt from Clean Air Act regulations, because of its very low reactivity. Overall, the minor compounds found in composting emissions are highly variable, as are the feedstocks themselves. Not all of the compounds found in this study were found in the previous efforts, and some found in the earlier study were not found this time. One would expect to find common biogenic VOCs such as pinene isomers, limonene and camphor in composting emissions. These compounds tend to be moderately reactive. The study team found them in both studies. In most cases, however, these compounds were measured in the range of a few tenths of one percent of the total emissions.

A variety of aldehydes were also found in this study. Aldehydes can be highly reactive, but again the study team found these compounds in very low concentrations, in most cases less than one half of one percent of the total emissions for any individual compound.

A hypothesis tested in this experiment was whether the pseudo-biofilter compost cap would reduce the overall reactivity of the emissions mix. This was plausible because a regular biofilter operates in much the same manner as the cap, and engineers regularly use biofilters to scrub VOCs out of emissions streams. In this experiment, the pseudo-biofilter compost cap did reduce the overall ozone formed from the pile, but that appeared to be due to the cap's overall impact to lower total emissions. The impact of the cap on the overall emissions profile of the younger windrow was negligible. However, for the three-week-old pile, the MIR of the mix increased slightly, and a few higher reactivity compounds were detected which were either absent or found at lower levels in the uncapped windrow.

Even though the two windrows in each set were made from the same batch of material, composting feedstocks are highly variable, and it is plausible that the modeled increase in the reactivity of the mix was the result of variations in the feedstock mix rather than the action of the compost cap. Limonene and alpha pinene, for example, were present in the five-day-old windrow but completely absent from its capped twin. In the case of the three-week-old windrow, limonene and alpha pinene levels were higher in the capped windrow than in its uncapped twin. It seems unlikely that the cap would operate differently based on the age of the underlying materials.

This study does not appear to support the theory that the compost cap might target larger and more complex molecules. More study would be needed to confirm whether the cap consistently alters the overall composition of composting emissions. However, it was clear that the cap's action of reducing the total amount of emissions also reduced ozone formation, and that capping of both very young and slightly older composting windrows accrues a significant emissions benefit. This is important because regulators may assume the benefit of the cap to be limited to the very early stages of decomposition, but this study confirms the finding from the previous study that the middle stages of decomposition produce a highly variable and slightly more potent emissions mix.

This study tested overs as the material for the compost cap. Previous studies tested finished screened or unscreened compost as the cap materials. Overs are the large pieces screened out from the finished product, and some finished product remains stuck to the large particles. Overs as a cap have two advantages over finished product, one economic and one operational. Economically, overs are a waste product. Their only potential economic value is to be sold as mulch or as biomass fuel, but that is not possible if they contain more than a trace of contaminants, which they often do. Composting facilities associated with a landfill may dispose the overs, use them as alternative cover for disposed solid waste, or use them for erosion control. From an operational standpoint, it is beneficial to incorporate overs into a new pile, as the large particles provide pore spaces and structure which helps keep the piles aerobic. Because of the attached finished product and associated microbes, overs also act as an inoculant which can jump start the composting process. Therefore, it would seem to be both economically and operationally beneficial to use overs as a cap material instead of finished product. This study confirmed that such a practice will reduce the ozone formation potential of the pile.

This study compared ozone measured in the MOChA chamber with ozone which would be expected to be seen in the chamber based on the gas concentrations captured in the canisters and tubes and analyzed on the GC-MS. Variations can be explained by several factors, including the limitations of the real-time measurement equipment, the inherent high variability of composting feedstocks, and the inherent variations in microbially driven composting process. But variations must also taken into the context of a very weak ozone-forming source. Because the net ozone formation numbers are low, small variations look larger. However, the overall picture remains is of a VOC source dominated by low-reactivity alcohols and unlikely to play a major role in regional trophospheric ozone formation.

For this entire set of 14 experiments (two were missed – one due to rain, the other due instrument malfunction), the model over-predicted ozone by an average of 8.7 ppb. However, the variance of mismatch (between model and experiment) was larger, at 20 ppb, so there is not a statistically significant bias. The typical match for many experiments of this sort is about 10-20 ppb, so the performance during this study was typical. For example, mini-surrogate-only studies in the lab, under controlled conditions, the reproducibility is about plus or minus 4 ppb; under field conditions, variance of 6-8 ppb for a simple mixture would be expected. For complex mixtures, larger variance is reasonable.

Conclusions

The study team characterized the VOC emissions coming from a six-week-old windrow and from large piles of oversized material (screened from finished compost) that were either one day or five days old, and found that all are weak sources of reactive VOCs. The team made side-by-side comparisons of two sets of active windrows (each set constructed with identical material), one set from materials which had been composting for five days, and another set from materials which had been composting for three weeks. Each set of windrows was comprised of one windrow topped with a pseudo biofilter cap of 6 inches of oversized composted material, and an identical windrow without the cap. The team characterized the emissions from each of the piles, and again found that their overall reactivity was low.

Three lightweight, low reactivity alcohols—ethanol, methanol and isopropyl—made up more than 90 percent of the emissions from all sources tested in this experiment. This is consistent with earlier experiments on this emissions source. Acetone was usually the fourth most prevalent compound. A wide variety of other compounds were found, including biogenic terpenes and aldehydes, but other compounds almost never comprise more than 1 percent of the total emissions mix, and most often comprise fractions of a percent.

Using the Maximum Incremental Reactivity (MIR) Scale, the most commonly used method of comparing the relative reactivity of compounds, the range of total mass weighted reactivity of all piles was 0.8-1.48, with six-week-old compost and five-day-old oversized materials having the lowest overall reactivity, and 21-day-old windrows having the highest overall reactivity. On the Equal Benefit Incremental Reactivity (EBIR) scale, which may be more appropriate for the San Joaquin Valley because of its relatively high levels of natural and man-made VOCs, the range of reactivity was 0.3-1.06.

Ozone formation in the mobile chamber from the oversized materials was indistinguishable from the ozone formed by the background atmospheric mix (known as the mini-surrogate). The ozone formed by the six-week-old compost pile was in the range of 15 ppb. Ozone formation from the five-day-old uncapped windrows was 15 +- 4.4 ppb, and was reduced by the use of the pseudo-biofilter compost cap by an average of 4 ppb, though the variability was higher than for the uncapped windrows. Consistent with prior experiments, ozone formation from uncapped 21-day-old windrows was higher than other windrows, 45+-8.4 ppb on average. Ozone formation for 21-day-old windrows was reduced to 29 +-.9 ppb by the use of the pseudo-biofilter compost cap.

When averaged with the ozone amounts predicted by the model using measured VOC results from canister samples, sorbent tube and INNOVA experiments, ozone formation above the amount expected from the mini-surrogate background gas remained low, with the 21-day-old windrow forming the most ozone. In the case of five-day-old oversized material, average ozone production—based on the model and the MOChA—was -2.2 +-3.1 ppb, indistinguishable from zero. For newly sieved oversized material, average ozone production was 1.4+- 7.4 ppb—also indistinguishable from zero. For six-week-old windrows, average ozone was detected at 15.0 +- 0.9 ppb. For five-day-old windrows without a cap, the average ozone production was 28.4 +- 0.6 ppb, but an identical windrow with the cap had an ozone formation potential of 12.1 +- 5.4 ppb—nearly a 60 percent reduction. For a 21-day-old windrow, ozone formation was 45.8 +- 0.2 ppb, but with a cap, this was lowered to 22.7 +- 2.4 ppb—approximately a 50 percent reduction. See Appendix E for detailed ozone measurements.

In both cases, the cap was effective in reducing both the VOC mass emissions and ozone formation from the emissions, even though the average reactivity of the canister/sorbent tube/INNOVA emissions samples from the capped windrow was either the same as its uncapped twin, or slightly elevated.

Tables 1 and 2 show average mass VOC emissions and ozone formation from the sources, as well as the impact of the cap.

Table 1: Average total emissions in canister and tube sample in parts per billion of volume, two replicates.

Material	Uncapped windrow or pile	Capped windrow	% Reduction
0-1-Day Overs*	267.6		
5-Day Overs	352.7		
6-Week Windrow	484.7		
5-Day Windrow	704.8	306.8	56%
21-Day Windrow	475.6	329.9	31%

*Three replicates

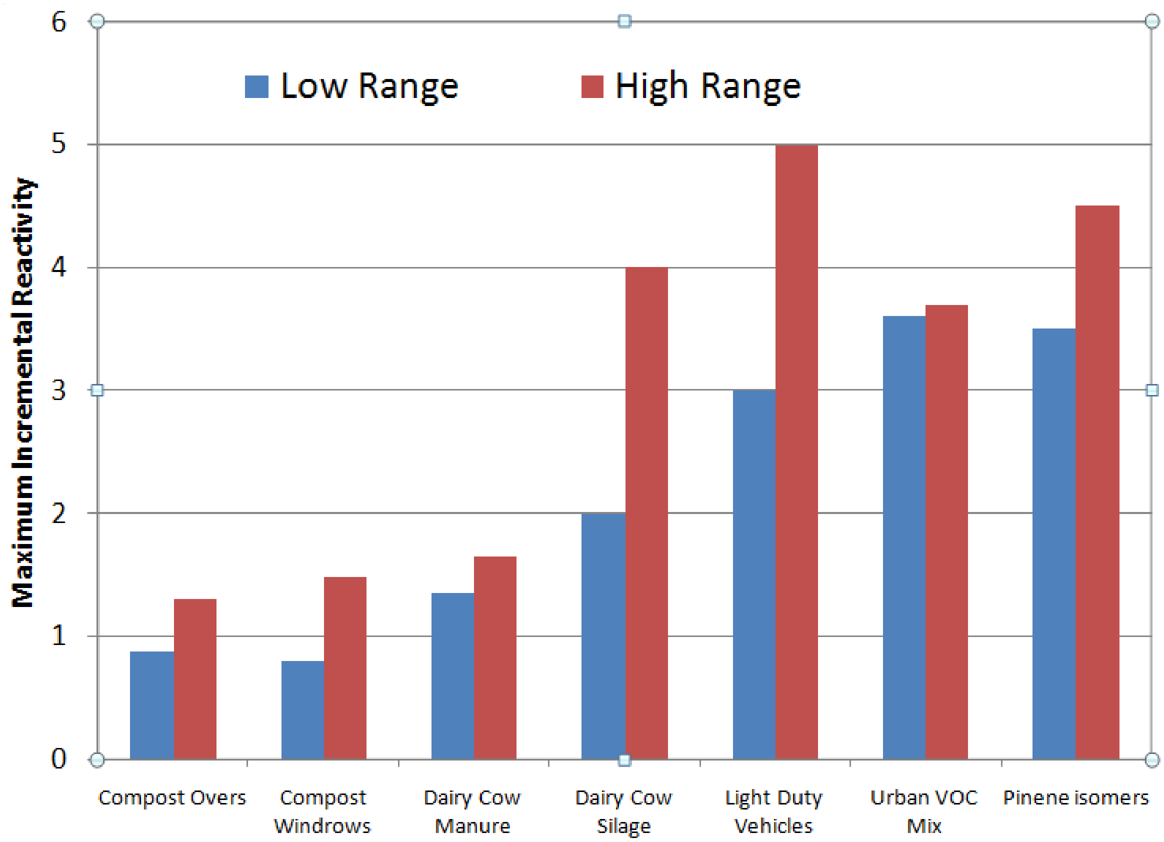
Table 2: Average reduction in ozone formation from pseudo-biofilter compost cap, in ppbv and in percent, two replicates. (See Appendix D for complete tables)

	Average O_3 reduction in ppbv	Average O_3 reduction in %	Method
5-Day Windrow	4.2	26.8%	MOChA only
5-Day Windrow	16.3	57.3%	MOChA and model
21-Day Windrow	16.4	36.1%	MOChA only
21-Day Windrow	23.0	50.4%	MOChA and model

As a means of comparison, ozone in the range of 140-210 ppb were observed in the MOChA chamber from the VOCs from the fermented animal feeds known as silage. Researchers commonly use a reactivity scale as a means to compare ozone formation potential from reactive compounds or emissions mixes. The MIR scale, which was devised by researchers at the

University of California, Riverside to project the importance of various hydrocarbons to ozone formation in air basins where ozone formation is sensitive to additional hydrocarbons, is the most commonly used comparison method. Chart 1 compares the MIR for composting pile emissions with known MIRs from other sources, including a key naturally occurring VOC, pinene.

Chart 1. Average Maximum Incremental Reactivity (MIR) of various VOC sources. (See bibliography)



The data tables in the appendices cover the following: (A) The compounds detected in composting pile emissions and their reactivity as rated on both the MIR and EBIR scales, (B) Physical-chemical characterization of the compost—both in the field (such as temperature and moisture saturation with a soil moisture probe), and with subsequent laboratory analysis (e.g. C and N content, organic matter content), as well as field dilution tunnel flow rates; (C) VOCs identified and quantified by gas canister sampling and GC-MS (gas chromatography coupled to mass spectrometry) according to EPA Method TO-15; (D) Aldehydes and alcohols quantified by more specialized techniques; aldehydes were captured in the DNPH sorbent tubes and derived using EPA Method TO-11A; small alcohols—the predominant VOCs—were measured using infrared determination with the INNOVA 1412 instrument. (E) Results from the MOChA experiments (ozone formation) in the field, including a comparison of the ozone formed and measured in the chamber with the ozone formation predicted by the model based on the results of the canister, sorbent tube and INNOVA sampling; (F) A full speciation of the complete spectrum of VOCs from the Modesto sampling runs, combining all of the analysis techniques, and including calculations of overall reactivity and percentages of emissions for each compound in each sample, and (G) A full speciation of the complete spectrum of VOCs from the Tulare sampling runs, combining all of the analysis techniques, and including calculations of overall reactivity and percentages of emissions for each compound in each sample.

Abbreviations, Acronyms & Glossary

EBIR: Equal Benefit Incremental Reactivity: an ozone yield scale derived by adjusting the NO_x emissions in a base case scenario so VOC and NO_X reductions are equally effective in reducing ozone.

INNOVA: Danish manufacturer of air quality monitoring instruments.

MIR: Maximum Incremental Reactivity, an ozone yield scale derived by adjusting the NO_x emissions in a base case to yield the highest incremental reactivity of the base reactive organic gas mixture.

MOChA: Mobile Ozone Chamber Assay, a portable ozone chamber devised at UC Davis and towed to sampling sites.

NO_x: Oxides of nitrogen, in air pollution terminology, generally refers to the combustion byproducts of nitric oxide (NO) and nitrogen dioxide (NO_2). It may also refer to nitrous oxide (N_2O).

OFP: Ozone Formation Potential, the reactivity or propensity of a volatile organic compound to form ozone when mixed with NOx.

SJVUAPCD: San Joaquin Valley Unified Air Pollution Control District.

VOC: Volatile organic compounds, organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere. A wide range of carbon-based molecules, such as aldehydes, ketones and other light hydrocarbons, are classified as VOCs.

Appendix A:

Composting Emission VOCs and Reactivity

There are several accepted scales for measuring the reactivity of organic compounds. MIR stands for the Maximum Incremental Reactivity scale. This tool was developed by William Carter at UC Riverside. MIR was designed for use in air pollution basins where additional hydrocarbons have been determined to have the predominant impact on ozone formation— that is, where NO_x is present in excess. MIR has become the default standard for measuring reactivity. EBIR stands for Equal Benefit Incremental Reactivity. This scale, also developed by Carter, was optimized for use in air basins where reduction of VOCs and NO_x are equally beneficial (rather than having NO_x in excess), and is appropriate for air basins which are not densely urbanized—such as the San Joaquin Valley. CAS# is the unique, internationally established label for a specific chemical, the Chemical Abstracts Service number. The molecular weight of each VOC is listed as grams per mole (g/mole) which is needed to convert from field & laboratory measurements, which are calibrated to volume dilutions (proportional to number) rather than mass.

VOC	CAS #	g/mole	MIR	EBIR
1,2,4-trimethyl benzene	95-63-6	120.19	8.87	1.65
1,2-diacetyl benzene	704-00-7	162.19	2.25	0.33
1-butene	106-98-9	56.11	9.73	2.37
1-heptanol	111-70-6	116.20	1.84	0.59
2-ethyl-1-hexanol	104-76-7	130.23	2.00	0.58
2-heptanone	110-43-0	114.19	2.36	0.75
2-methyl pentane	107-83-5	86.18	1.50	0.57
2-nonanone	821-55-6	142.24	1.08	0.32
2-pentanol	6032-29-7	88.15	1.61	0.57
2-pentanone	107-87-9	86.13	2.81	0.89
3,7-dimethyl-1-octanol	106-21-8	158.28	1.20	0.34
3-methyl-1,2-butadiene	598-25-4	68.12	10.29	2.44
3-methylbutanal (isovaleraldehyde)	590-86-3	86.13	4.97	1.23
4-methyl-2-pentanone	108-10-1	100.16	3.88	1.08
acetaldehyde	75-07-0	44.05	6.54	1.61
acetone	67-64-1	58.08	0.36	0.089
alpha-pinene	80-56-8	136.23	4.51	0.89
beta-pinene	127-91-3	136.23	3.52	0.79
branched C5 alkanes		72.15	1.45	0.65
branched C8 alkanes		114.23	1.45	0.46
branched C8 alkanes		114.23	1.45	0.46
butanal	123-72-8	72.11	5.97	1.48
C10 alkenes		140.27	3.31	0.83
C10 alkenes		140.27	3.31	0.83
C10 disubstituted benzenes		134.22	5.68	0.91

C10 ketones		156.27	0.90	0.25
C6 ketones		100.16	3.14	0.99
C6 ketones		100.16	3.14	0.99
C7 cyclic ketones		112.17	1.18	0.42
C8 cyclic ketones		126.20	1.05	0.37
C8 ketones		128.21	1.40	0.44
camphene	79-92-5	136.23	4.51	0.89
camphor	76-22-2	152.23	0.49	0.129
crotonaldehyde	4170-30-3	70.09	9.39	1.94
dichlorobenzene	106-46-7	147.00	0.178	-0.042
d-limonene	5989-27-5	136.23	4.55	0.96
ethanol	64-17-5	46.07	1.53	0.59
ethyl benzene	100-41-4	106.17	3.04	0.50
ethyl cyclohexane	1678-91-7	112.21	1.47	0.45
formaldehyde	50-00-0	30.03	9.46	1.27
furan	110-00-9	68.07	9.15	2.06
heptanal	111-71-7	114.19	3.69	0.92
hexanal	66-25-1	100.16	4.35	1.10
hexenal	6789-80-6	98.00	4.35	1.10
isobutene	115-11-7	56.11	6.29	1.18
isopentane	78-78-4	72.15	1.45	0.65
isopropyl alcohol	67-63-0	60.10	0.61	0.25
linalool	78-70-6	156.27	5.43	1.07
methanol	67-56-1	32.04	0.67	0.190
methoxybenzene; anisole	100-66-3	108.14	6.66	1.00
monochlorobenzene	108-90-7	112.56	0.32	-0.074
n-heptane	142-82-5	100.20	1.07	0.39
nonanal	124-19-6	142.00	3.16	0.77
octanal	124-13-0	128.21	3.16	0.77
o-cymene; 1-methyl-2-(1-methylethyl) benzene	527-84-4	134.22	5.49	0.89
o-xylene	95-47-6	106.17	7.64	1.16
pentenal	1576-87-0	84.00	5.08	1.29
phenol	108-95-2	94.11	2.76	-0.85
propionaldehyde	123-38-6	58.08	7.08	1.75
styrene	100-42-5	104.15	1.73	-0.48
terpene (monoterpenes)		136.23	4.04	
terpinolene	586-62-9	136.23	6.36	1.18
toluene	108-88-3	92.14	4.00	0.52
trans-2,5-dimethyl 3-hexene	692-70-6	112.21	4.82	1.29
trichlorobenzene	120-82-1	181.50	0.178	-0.042

trimethyl benzene	95-63-6	120.19	8.87	1.65
α-terpineol	98-55-5	154.25	4.63	0.89

Appendix B:

Physical Parameters of Compost Samples

Physical Characterization of Compost Samples - Modesto

	N (Total)	C (Total)	C/N Ratio	Density	Porosity	Moisture	Moisture	pH	T at ~3-4 ft	T at ~3-4 ft	Water Content	Organic Content	TOC
	%	%		g/ml	%	%Saturation	%Saturation	in water	°F	°F	% by wt	% by wt	%
11-May-10	5 Days Oversize					Morning	Afternoon		Morning	Afternoon			
Sample 1	1.02	22.6	22.16	0.52	46.84	50	-	8.9	120	138	41.34	69.20	40.14
Sample 2	0.91	20.6	22.64	0.35	58.76	30	-	8.59	126	130	26.81	42.47	24.64
Sample 3				0.40	42.46	100	-	8.71	119	120			
Average ± SD			**22.40**	**0.42 ± 0.09**	**49.35 ± 8.44**	**60 ± 36.1**	-	**8.7 ± 0.2**	**121.7 ± 3.8**	**129.3 ± 9.0**	**34.07 ± 10.27**	**55.84 ± 18.90**	**32.39 ± 10.96**
12-May-10	0-1 Day Oversize												
Sample 1	1.33	30.1	22.63	0.29	61.75	40	25	8.6	61	71	20.9	57.4	33.31
				0.18	64.86	25	25	8.7	67	77	31.6	63.4	36.76
				0.21	60.72	13	60	8.71	72	82			
Average ± SD			**22.63**	**0.23 ± 0.06**	**62.45 ± 2.15**	**26 ± 13.5**	**36.7 ± 20.2**	**8.6 ± 0.1**	**66.7 ± 5.5**	**76.7 ± 5.5**	**26.23 ± 7.57**	**60.40 ± 4.19**	**35.04 ± 2.43**
14-May-10	1 Day Oversize												
Sample 1	0.81	26.1	32.22	0.48	50.14	60	-	8.35	63	-	49.0	50.7	29.41
				0.33	61.08	60	-	8.65	70	-	47.2	52.6	30.52
				0.35	55.18	50	-	8.42	74	-			
Average ± SD			**32.22**	**0.39 ± 0.08**	**55.46 ± 5.48**	**56.7 ± 5.8**	-	**8.5 ± 0.2**	**69.0 ± 5.6**	-	**48.11 ± 1.25**	**51.66 ± 1.36**	**29.97 ± 0.79**

13-May-10	6 Weeks Compost												
Sample 1	1.02	22.5	22.06	0.32	53.31	100	-	8.74	146	146	40.0	74.5	43.23
				0.29	53.71	100	-	8.95	145	147	26.3	46.4	26.94
				0.33	52.45	100	-	8.73	140	145			
Average ± SD			**22.06**	**0.32 ± 0.02**	**53.16 ± 0.62**	**100 ± 0**		**8.8 ± 0.1**	**143.7 ± 3.2**	**146.0 ± 1.0**			

Physical Characterization of Compost Samples - Tulare

	N (Total)	**C (Total)**	**C/N Ratio**	**Density**	**Porosity**	**Moisture**	**Moisture**	**pH**	**T at ~3-4 ft**	**T at ~3-4 ft**	**Water Content**	**Organic Content**	**TOC**
	%	**%**		**g/ml**	**%**	**%Saturation**	**%Saturation**	**in water**	**°F**	**°F**	**% by wt**	**% by wt**	%
2-Jun-10	5 Days Windrow with Cap					Morning	Afternoon		Morning	Afternoon			
Sample 1	0.48	19.6	40.83	0.40	52.6	50	100	8.78	124	134	15.4	46.9	27.20
Sample 2				0.26	52.0	85	100	8.76	134	130	18.1	58.7	34.03
Sample 3				0.27	56.9	90	100	8.78	138	138			
Average						75	100	8.8	132	134	16.73	52.78	30.61
SD						21.8	0.0	0.0	7.2	4.0	1.89	8.33	4.83
Average ± SD			**40.83**	**0.31 ± 0.08**	**53.82 ± 2.67**	**75 ± 21.8**	**100 ± 0**	**8.8 ± 0.1**	**132 ± 7.2**	**134 ± 4**	**16.73 ± 1.89**	**52.78 ± 8.33**	**30.61 ± 4.83**
3-Jun-10	5 Days Windrow without Cap												
Sample 1	1.30	22.7	17.46	0.38	62.8	100	100	8.56	135	134	30.4	38.5	22.33

Sample 2				0.45	53.8	100	100	8.65	130	136	34.9	39.3	22.78
Sample 3				0.42	51.0	100	100	8.71	135	138			
Average						100.0	100.0	8.6	133.3	136.0	32.65	38.88	22.55
SD						0.0	0.0	0.1	2.9	2.0	3.13	0.55	0.32
Average ± SD			**17.46**	**0.42 ± 0.02**	**55.85 ± 6.16**	**100 ± 0**	**100 ± 0**	**8.6 ± 0.1**	**133 ± 2.9**	**136 ± 2**	**32.65 ± 3.13**	**38.88 ± 0.55**	**22.55 ± 0.32**
4-Jun-10	21 Days Windrow without Cap												
Sample 1	1.12	19.7	17.59	0.34	51.3	90	100	8.8	140	138	49.9	42.6	24.69
Sample 2				0.44	56.3	100	100	8.5	142	138	48.7	41.9	24.32
Sample 3				0.34	62.0	100	100	8.64	136	138			
Average						96.7	100.0	8.6	139.3	138.0	49.35	42.25	24.51
SD						5.8	0.0	0.1	3.1	0.0	0.85	0.46	0.26
Average ± SD			**17.59**	**0.37 ± 0.06**	**56.53 ± 5.33**	**96.7 ± 5.8**	**100 ± 0**	**8.6 ± 0.1**	**139 ± 3.1**	**138 ± 0**	**49.34 ± 0.85**	**42.25 ± 0.46**	**24.51 ± 0.26**
5-Jun-10	21 Days Windrow with Cap												
Sample 1	1.24	25.1	20.24	0.57	45.4	100	100	8.59	140	136	37.3	43.0	24.95
Sample 2				0.36	56.4	100	100	8.65	142	140	39.1	46.4	26.89
Sample 3				0.35	51.4	100	80	8.76	144	140			
Average						100.0	93.3	8.7	142.0	138.7	38.23	44.68	25.92
SD						0.0	11.5	0.1	2.0	2.3	1.28	2.37	1.37
Average ± SD			**20.24**	**0.42 ± 0.12**	**51.05 ± 5.47**	**100 ± 0**	**93 ± 11.5**	**8.7 ± 0.1**	**142 ± 2.0**	**138.7 ± 2.3**	**38.23 ± 1.28**	**13.33 ± 0.80**	**7.73 ± 0.46**

Appendix C:

Canister VOCs

Modesto Composting	10-May-10	11-May-10	11-May-10	12-May-10	12-May-10	13-May-10	13-May-10	14-May-10
May 2010	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**
ppbv	2-3 Days oversize	5 Days Oversize	5 Days Oversize	0-1 Day Oversize	0-1 Day Oversize	6 Weeks Compost	6 Weeks Compost	1 Day Oversize
2 Methyl 1-propene				0.12	0.12			
Butene			0.17					
Decene			0.08			0.11	0.17	
Dimethyl hexene			0.19		0.07		0.15	
Ethyl cyclohexane	0.08				0.14	0.09		
Ethyl Hexane		0.14	0.30			0.24	0.46	0.23
Dimethylcyclopentane						0.16		
Methyl butanal					0.75	0.19		0.12
Pentenal					0.20	0.11	0.04	
Hexanal		0.80			1.70	0.20	0.40	
Furfural		0.06	0.32					
Hexenal					0.19	0.11	0.10	
Heptanal	0.10	1.10		0.12	2.20	0.40	0.40	
Octanal		1.20	0.30	0.20	2.40	0.50	0.70	0.10
Nonanal		0.30	1.00		1.30	0.80	1.00	
Pentanol		0.09			0.18	0.14	0.11	
Ethyl hexanol	0.10		0.10		0.10			
2 Pentanone	0.15				0.08		0.20	
Hexanone						0.20		
2 Nonanone						0.20		

Decanone			0.10			0.70		
Toluene						0.11	0.14	
Ethyl benzene						0.08		
Xylene	0.52	0.03	0.09		0.04	0.43		
Styrene						0.21		
Trimethylbenzene					0.06	0.22	0.07	0.04
Trimethylbenzene	0.03	0.05	0.06	0.05		0.22		
Alpha pinene							0.06	
Limonene							0.05	
Camphor				0.10				
Chlorobenzene						0.08		
Tetrachloroethane						0.04		
1,3-Dichlorobenzene						0.29		
1,4-Dichlorobenzene						0.37		
Benzyl chloride				0.17		0.14		
1,2-Dichlorobenzene				0.06		0.40	0.11	
1,2,4 Trichlorobenzene						1.56	0.29	
Total VOC ppbv	0.98	3.78	2.71	0.81	9.53	8.30	4.45	0.49

Tulare Composting	2-Jun-10	2-Jun-10	3-Jun-10	3-Jun-10	3-Jun-10	4-Jun-10	4-Jun-10	5-Jun-10	5-Jun-10
Jun-10	**Morning**	**After-noon**	**Morning**	**Morning-(duplicate)**	**After noon**	**Morning**	**After noon**	**Morning**	**After noon**
ppbv	5 Days Windrow	5 Days Windrow	5 Days Windrow	5 Days Windrow	5 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow
	with Cap	with Cap	without Cap	without Cap	without Cap	without Cap	without Cap	with Cap	with Cap
2 Methyl 1-propene					2.00			1.10	1.70
Butene isomer					0.16				
Methyl butadiene					0.19				
Decene					0.30				
Dimethyl hexene					0.30	1.00			
Methyl Butane		0.70							0.20
Pentane isomer		0.10			0.10	0.10			0.10
Ethyl cyclohexane						2.00			
Ethyl Hexane					0.30	3.50			
Heptane			0.05				0.04	0.04	
Octane					0.20	3.10			
Methylcyclopentane						0.40			
Methyl butanal			0.18	0.15		0.22		0.16	0.16
Pentenal	0.30								
Hexanal	0.10			0.20	0.80	0.40			0.10
Hexenal					0.30				
Heptanal	0.10			0.30	1.00	0.80		0.10	0.20
Octanal	0.20	0.20		0.50	1.00	1.20		0.30	0.20
Nonanal				0.20	1.10	1.10	0.20	0.20	0.20
Pentanol						0.30			
Heptanol					0.24	0.05		0.14	0.10
Ethyl hexanol	0.20			0.10	0.60	0.60		0.60	0.50
allyl anisol	1.60	0.30				1.10	0.40	0.60	0.20
2 Pentanone			0.10		2.40	0.20		0.20	

Methyl Isobutylketone, MIBK			0.10		0.54	0.12		0.09	0.16
Hexanone						0.70			
Heptanone					3.40	1.80			
Cyclohexanone	0.23		0.18	0.12	0.52	0.17		0.16	
Methyl heptanone	0.75	0.15	0.24	0.19	1.29			0.24	0.66
Methyl cyclohexanone					0.50			0.10	
Octanone					1.10	3.10			
Methyl heptene 2-one				0.19	1.48				
Ketone compound			1.33						
2 Nonanone					1.10	1.90			
Decanone		0.10		0.10					
Toluene					0.40				
Ethyl benzene	0.02	0.02	0.01			0.71	0.02	0.02	0.10
Xylene	0.11	0.12	0.13	0.40		0.00		0.08	0.33
Styrene + Xylene		0.03			0.30		0.02	0.09	0.37
C3-benzene, TMB isomers	0.10	0.06							0.33
C3-benzene, TMB isomers	0.07	0.10		0.07			0.14	0.03	0.38
1 Methyl, 3-1-methyl ethyl benzene/ Cymene	0.07	0.03	0.18	0.11	1.36	1.04	0.02	1.47	0.68
Isopropenyl tolune								0.22	
Acetyl benzene					0.62	0.28			
Phenol		0.04		0.08					
Chlorobenzene									0.08
Bornyl chloride					0.41				
Dichlorobenzene Isomers								0.30	0.65
Dichlorobenzene								0.24	0.53

Isomers									
Trichlorobenzene			0.11	0.13				0.00	2.11
alpha-Pinene			0.49	0.09	3.19	0.66	0.10	1.32	2.44
Camphene			0.08		0.69	0.19		0.30	0.45
Pinene Isomer						0.01	0.07	0.05	0.69
B-Pinene			0.25		0.82	0.28	0.06	0.26	0.42
Carene isomers			0.25		1.24			0.83	0.75
Limonene			0.70	0.20	5.70	3.20		5.00	3.80
Eucalyptol			0.26	0.10	1.16	2.51		2.85	1.91
Terpinine						0.21	0.08	0.36	0.09
cis-Linalool oxide						0.59		2.44	
Fenchone					0.22			0.31	0.08
Thujone					0.28	0.28		0.30	0.06
Camphor			2.40	2.70					
Terpineol					1.16	2.14	0.04	0.00	0.10
Terpineol								1.64	
Terpineol isomer					0.34				
Biogenic						0.26	0.15	0.62	
Furan								0.24	0.30
2 Pentyl furan					0.60			0.25	0.32
Total VOC ppbv	3.84	1.96	7.02	5.93	39.42	36.21	1.35	23.25	21.45

Appendix D:

Aldehydes and Alcohols

Aldehydes & Alcohols – Modesto Compost Facility

Date	Windrow type		Acetone	Form-aldehyde	Acet-aldehyde	Croton-aldehyde	Butyl-aldehyde	Wood alcohol	Ethanol	Iso-propanol
11-May-10	5 Days Oversize	Morning	1.22	1.38	0.81	0.70	-	50	120	50
11-May-10	5 Days Oversize	Afternoon	1.89	1.68	0.97	1.22	0.10	160	50	100
12-May-10	0-1 Day Oversize	Morning	1.30	1.11	0.80	0.29	-	240	50	50
12-May-10	0-1 Day Oversize	Afternoon	0.70	0.59	0.34	-	-	100	50	200
13-May-10	6 Weeks Compost	Morning	1.83	1.10	0.84	-	-	260	50	120
13-May-10	6 Weeks Compost	Afternoon	1.48	0.86	0.50	-	-	280	50	190
14-May-10	1 Day Oversize	Morning	2.71	1.68	1.53	-	-	100	50	100

Aldehydes & Alcohols – Tulare Compost Facility

Date	Windrow type		Acetone	Form-aldehyde	Acet-aldehyde	Proion-aldehyde	Butyl-aldehyde	Wood alcohol	Ethanol	Iso-propanol
			ppbv	ppbv	ppbv	ppbv	ppbv	ppbv	ppbv	ppbv
2-Jun-10	5 Days Windrow with Cap	Morning	1.37	1.09	0.90	-	0.14	200	50	100
2-Jun-10	5 Days Windrow with Cap	Afternoon	1.76	1.57	0.92	-	0.32	100	100	50
3-Jun-10	5 Days Windrow without Cap	Morning	6.04	3.24	1.94	0.25	2.47	500	50	50
3-Jun-10	5 Days Windrow without Cap	Afternoon	4.89	3.07	1.71	0.25	1.09	100	50	600
4-Jun-10	21 Days Windrow without Cap	Morning	3.79	1.02	1.18	-	0.12	300	250	150
4-Jun-10	21 Days Windrow without Cap	Afternoon	5.39	1.01	0.93	-	0.40	100	50	50
5-Jun-10	21 Days Windrow with Cap	Morning	5.15	1.75	1.50	0.19	0.44	300	50	50
5-Jun-10	21 Days Windrow with Cap	Afternoon	3.85	0.95	0.72	0.31	0.17	100	50	50

Appendix E:

MOChA Runs & Calculations

Net ozone formation is measured inside the MOChA chamber. To determine the ozone formed by the source, emissions modeled from the mini-surrogate, or background atmosphere, must be subtracted out. Those calculations are in the second table.

The formula for Net Ozone Formation is: $(\Delta O_3) = (O_3^{final} - O_3^{initial}) - (NO^{final} - NO^{initial})$ An NO decrease means ozone is being consumed by NO becoming NO2.

Modesto Compost Facility MOChA runs

Date	Time	Windrow Type		T	RH	NOx	NO	NO2	O3	Net Ozone Formation
				ºC	%	ppbv	ppbv	ppbv	ppbv	ppbv
11-May-10	10:00:56 AM	5 Days Oversize	Initial	19.5	45.3	49.8	17.0	34.0	21.4	33.4
	12:55:50 PM		Final	23.4	32.1	46.16	7.95	39.14	45.71	
11-May-10*	2:11:32 PM	5 Days Oversize	Initial	23.6	29.7	49.8	16.1	35.3	20.6	30.3
			Final	24.4	28.8	47.4	7.7	40.8	42.4	
c										
12-May-10	9:14:45 AM	0-1 Day Oversize	Initial	22.8	32.0	45.9	15.4	31.2	16.9	51.0
	12:09:51 PM		Final	30.2	18.3	41.7	4.9	37.2	57.4	
12-May-10*	1:30:20 PM	0-1 Day Oversize	Initial	29.6	23.8	48.6	14.6	35.0	17.6	43.8
			Final	27.9	26.6	41.5	4.4	38.1	51.2	
13-May-10	9:54:44 AM	6 Weeks Compost	Initial	24.5	31.0	48.6	15.0	34.1	16.1	63.9
	12:49:50 PM		Final	27.3	25.7	41.3	3.9	37.9	68.9	

13-May-10	2:10:10 PM	6 Weeks Compost	Initial	28.8	26.6	48.1	14.5	34.6	19.2	67.7
	5:05:04 PM		Final	29.1	25.6	39.7	3.9	36.7	76.4	

***Afternoon was dusty and windy. Some dust entered the chamber and settled on the lights, potentially influencing UV light intensity in the chamber**

Modesto Compost Facility MOChA and Model Calculations

		Modeled Mini-Sur. Alone	Canister Model Net Ozone	Canister Model - Mini-Sur.	MOChA Net Ozone	MOChA - Mini-Sur.	Average Net Ozone
May 11 a.m.	5-Day Overs	54.0	65.9	11.9	33.4	-20.6	-4.4
May 11 p.m.	5-Day Overs	54.0	77.7	23.7	30.3	-23.7	0.0
May 12 a.m.	0-1 Day Overs	48.6	59.4	10.8	51.0	2.4	6.6
May 12 p.m.	0-1 Day Overs	48.6	45.6	-3.0	43.8	-4.8	-3.9
May 13 a.m.	6 Weeks Compost	48.6	64.8	16.2	63.9	15.3	15.7
May 12 p.m.	6 Weeks Compost	54.0	69.0	15.0	67.7	13.7	14.4

Mini-sur stands for mini-surrogate, the background gas mixture added to the MOChA chamber which is designed to mimic the air in the San Joaquin Valley on a typical summer day.

Tulare Compost Facility MOChA runs

The formula for Net Ozone Formation is: $(\Delta O_3) = (O_3^{final} - O_3^{initial}) - (NO^{final} - NO^{initial})$ An NO decrease means ozone is being consumed by NO becoming NO2.

Date	Time	Windrow type		T	RH	NOx	NO	NO2	O3	Net Ozone Formation
				°C	%	ppbv	ppbv	ppbv	ppbv	ppbv
2-Jun-10	9:33:24 AM	5 Days Windrow with Cap	Initial	25.8	33.8	48.75	16.46	33.24	17.12	71.89
	12:28:18 PM		Final	27.7	30.4	42.46	3.81	39.48	76.37	
2-Jun-10	1:48:13 PM	5 Days Windrow with Cap	Initial	27.8	35.7	62.35	19.40	44.06	22.62	67.05
	4:43:07 PM		Final	29.9	30.6	51.36	4.00	47.67	74.28	
3-Jun-10	10:58:53 AM	5 Days Windrow without Cap	Initial	26.7	48.0	47.87	16.51	32.09	20*	65.20
	1:53:47 PM		Final	31.1	33.1	38.82	3.31	35.98	72*	
3-Jun-10	3:13:21 PM	5 Days Windrow without Cap	Initial	30.9	32.3	49.99	15.53	35.41	20.10	76.72
	6:08:15 PM		Final	32.5	28.9	37.37	2.38	36.30	83.67	
4-Jun-10	8:48:13 AM	21 Days Windrow without Cap	Initial	25.0	48.2	42.7	14.7	29.4	15.8	99.1
	11:42:55 AM		Final	26.9	41.8	33.1	2.5	31.4	102.7	
4-Jun-10	1:00:14 PM	21 Days Windrow without Cap	Initial	29.6	40.5	48.6	15.0	35.1	23.3	118.7
	3:54:56 PM		Final	31.9	32.9	32.3	1.9	31.2	128.9	
5-Jun-10	7:51:28 AM	21 Days Windrow with Cap	Initial	22.8	57.3	48.5	16.1	33.4	16.4	75.8
	10:46:22 AM		Final	29.4	33.7	41.2	2.7	39.4	78.7	
5-Jun-10	11:59:39 AM	21 Days Windrow with Cap	Initial	30.6	38.5	49.3	13.7	36.4	19.2	79.5
	2:54:33 PM		Final	35.6	26.4	39.4	2.8	37.9	87.8	

Tulare Compost Facility MOChA and Model calculations

		Modeled Mini-Sur. Alone	Canister Model Net Ozone	Canister Model - Mini-Sur.	MOChA Net Ozone	MOChA - Mini-Sur.	Average Net Ozone
June 2 a.m.	5-day Windrow with Cap	45.9	51.8	5.9	71.9	26.0	15.9
June 2 p.m.	5 Day Windrow with Cap	70.2	90.0	19.8	67.1	-3.1	8.3
June 3 a.m.	5-Day Windrow no Cap	54.0	100.6	46.6	65.2	11.2	28.9
June 3 p.m.	5-Day Windrow no Cap	56.7	92.6	35.9	76.7	20.0	28.0
June 4 a.m.	21-Day Windrow no Cap	62.1	116.3	54.2	99.1	37.0	45.6
June 4 p.m.	21-Day Windrow no Cap	64.8	102.6	37.8	118.7	53.9	45.9
June 5 a.m.	21-Day Windrow with Cap	45.9	64.8	18.9	75.8	29.9	24.4
June 5 p.m.	21-Day Windrow with Cap	51.3	65.1	13.8	79.5	28.2	21.0

Mini-sur stands for mini-surrogate, the background gas mixture added to the MOChA chamber which is designed to mimic the air in the San Joaquin Valley on a typical summer day.

Appendix F:

Modesto Total Speciation,

Reactivity Calculations & Percentages

Modesto Composting	5/11/2010	5/11/2010	5/12/2010	5/12/2010	5/13/2010	5/13/2010	5/14/2010
May 2010	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**
ppbv (nL/L)	5 Days Oversize	5 Days Oversize	0-1 Day Oversize	0-1 Day Oversize	6 Weeks Compost	6 Weeks Compost	1-Day Oversize
Wood alcohol	50.00	160.00	240.00	100.00	260.00	280.00	100.00
Isopropanol	50.00	100.00	50.00	200.00	120.00	190.00	100.00
Ethanol	120.00	50.00	50.00	50.00	50.00	50.00	50.00
Acetone	1.22	1.89	1.30	0.70	1.83	1.48	2.71
Formaldehyde	1.38	1.68	1.11	0.59	1.10	0.86	1.68
Acetaldehyde	0.81	0.97	0.80	0.34	0.84	0.50	1.53
Octanal	1.20	0.30	0.20	2.40	0.50	0.70	0.10
Nonanal	0.30	1.00	0.00	1.30	0.80	1.00	0.00
Heptanal	1.10	0.00	0.12	2.20	0.40	0.40	0.00
Hexanal	0.80	0.00	0.00	1.70	0.20	0.40	0.00
Crotonaldehyde	0.70	1.22	0.29	0.00	0.00	0.00	0.00
1,2,4 Trichlorobenzene	0.00	0.00	0.00	0.00	1.56	0.29	0.00
Ethyl Hexane	0.14	0.30	0.00	0.00	0.24	0.46	0.23
Methyl butanal	0.00	0.00	0.00	0.75	0.19	0.00	0.12
Decanone	0.00	0.10	0.00	0.00	0.70	0.00	0.00
Xylene	0.03	0.09	0.00	0.04	0.43	0.00	0.00
1,2-Dichlorobenzene	0.00	0.00	0.06	0.00	0.40	0.11	0.00
Pentanol	0.09	0.00	0.00	0.18	0.14	0.11	0.00
Dimethyl hexene	0.00	0.19	0.00	0.07	0.00	0.15	0.00
Hexenal	0.00	0.00	0.00	0.19	0.11	0.10	0.00
Trimethylbenzene	0.00	0.00	0.00	0.06	0.22	0.07	0.04
Furfural	0.06	0.32	0.00	0.00	0.00	0.00	0.00
Trimethylbenzene	0.05	0.06	0.05	0.00	0.22	0.00	0.00
1,4-Dichlorobenzene	0.00	0.00	0.00	0.00	0.37	0.00	0.00
Decene	0.00	0.08	0.00	0.00	0.11	0.17	0.00
Pentenal	0.00	0.00	0.00	0.20	0.11	0.04	0.00
Benzyl chloride	0.00	0.00	0.17	0.00	0.14	0.00	0.00
1,3-Dichlorobenzene	0.00	0.00	0.00	0.00	0.29	0.00	0.00
2 Pentanone	0.00	0.00	0.00	0.08	0.00	0.20	0.00
Toluene	0.00	0.00	0.00	0.00	0.11	0.14	0.00
2 Methyl 1-propene	0.00	0.00	0.12	0.12	0.00	0.00	0.00
Ethyl cyclohexane	0.00	0.00	0.00	0.14	0.09	0.00	0.00
Styrene	0.00	0.00	0.00	0.00	0.21	0.00	0.00

Hexanone	0.00	0.00	0.00	0.00	0.20	0.00	0.00
Ethyl hexanol	0.00	0.10	0.00	0.10	0.00	0.00	0.00
2 Nonanone	0.00	0.00	0.00	0.00	0.20	0.00	0.00
Butene	0.00	0.17	0.00	0.00	0.00	0.00	0.00
Dimethylcyclopentane	0.00	0.00	0.00	0.00	0.16	0.00	0.00
Butylaldehyde	0.00	0.10	0.00	0.00	0.00	0.00	0.00
Camphor	0.00	0.00	0.10	0.00	0.00	0.00	0.00
Ethyl benzene	0.00	0.00	0.00	0.00	0.08	0.00	0.00
Chlorobenzene	0.00	0.00	0.00	0.00	0.08	0.00	0.00
Alpha pinene	0.00	0.00	0.00	0.00	0.00	0.06	0.00
Limonene	0.00	0.00	0.00	0.00	0.00	0.05	0.00
Tetrachloroethane	0.00	0.00	0.00	0.00	0.04	0.00	0.00
TOTAL/ppbv	**227.89**	**318.58**	**344.31**	**361.16**	**442.07**	**527.30**	**256.41**

Modesto Composting	5/11/2010	5/11/2010	5/12/2010	5/12/2010	5/13/2010	5/13/2010	5/14/2010
May 2010	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**
mass conc. (ng/L)	5 Days Oversize	5 Days Oversize	0-1 Day Oversize	0-1 Day Oversize	6 Weeks Compost	6 Weeks Compost	1-Day Oversize
Wood alcohol	63.07	201.84	302.76	126.15	327.99	353.22	126.15
Isopropanol	118.30	236.59	118.30	473.19	283.91	449.53	236.59
Ethanol	217.65	90.69	90.69	90.69	90.69	90.69	90.69
Acetone	2.79	4.32	2.97	1.60	4.18	3.38	6.20
Formaldehyde	1.63	1.99	1.32	0.70	1.30	1.02	1.98
Acetaldehyde	1.41	1.68	1.39	0.59	1.45	0.87	2.66
Octanal	6.06	1.51	1.01	12.11	2.52	3.53	0.50
Nonanal	1.68	5.59	0.00	7.27	4.47	5.59	0.00
Heptanal	4.95	0.00	0.54	9.89	1.80	1.80	0.00
Hexanal	3.15	0.00	0.00	6.70	0.79	1.58	0.00
Crotonaldehyde	1.94	3.37	0.80	0.00	0.00	0.00	0.00
1,2,4 Trichlorobenzene	0.00	0.00	0.00	0.00	11.15	2.08	0.00
Ethyl Hexane	0.65	1.35	0.00	0.00	1.08	2.07	1.04
Methyl butanal	0.00	0.00	0.00	2.53	0.66	0.00	0.41
Decanone	0.00	0.62	0.00	0.00	4.31	0.00	0.00
Xylene	0.12	0.36	0.00	0.16	1.78	0.00	0.00
1,2-Dichlorobenzene	0.00	0.00	0.33	0.00	2.31	0.62	0.00
Pentanol	0.32	0.00	0.00	0.62	0.48	0.39	0.00
Dimethyl hexene	0.00	0.85	0.00	0.30	0.00	0.68	0.00

Hexenal	0.00	0.00	0.00	0.74	0.44	0.37	0.00
Trimethylbenzene	0.00	0.00	0.00	0.30	1.04	0.35	0.18
Furfural	0.24	1.27	0.00	0.00	0.00	0.00	0.00
Trimethylbenzene	0.23	0.30	0.21	0.00	1.02	0.00	0.00
1,4-Dichlorobenzene	0.00	0.00	0.00	0.00	2.14	0.00	0.00
Decene	0.00	0.46	0.00	0.00	0.58	0.94	0.00
Pentenal	0.00	0.00	0.00	0.67	0.37	0.13	0.00
Benzyl chloride	0.00	0.00	0.83	0.00	0.71	0.00	0.00
1,3-Dichlorobenzene	0.00	0.00	0.00	0.00	1.70	0.00	0.00
2 Pentanone	0.00	0.00	0.00	0.27	0.00	0.69	0.00
Toluene	0.00	0.00	0.00	0.00	0.41	0.49	0.00
2 Methyl 1-propene	0.00	0.00	0.27	0.27	0.00	0.00	0.00
Ethyl cyclohexane	0.00	0.00	0.00	0.62	0.38	0.00	0.00
Styrene	0.00	0.00	0.00	0.00	0.86	0.00	0.00
Hexanone	0.00	0.00	0.00	0.00	0.81	0.00	0.00
Ethyl hexanol	0.00	0.51	0.00	0.51	0.00	0.00	0.00
2 Nonanone	0.00	0.00	0.00	0.00	1.12	0.00	0.00
Butene	0.00	0.38	0.00	0.00	0.00	0.00	0.00
Dimethylcyclopentane	0.00	0.00	0.00	0.00	0.61	0.00	0.00
Butylaldehyde	0.00	0.29	0.00	0.00	0.00	0.00	0.00
Camphor	0.00	0.00	0.60	0.00	0.00	0.00	0.00
Ethyl benzene	0.00	0.00	0.00	0.00	0.34	0.00	0.00
Chlorobenzene	0.00	0.00	0.00	0.00	0.35	0.00	0.00
Alpha pinene	0.00	0.00	0.00	0.00	0.00	0.32	0.00
Limonene	0.00	0.00	0.00	0.00	0.00	0.27	0.00
Tetrachloroethane	0.00	0.00	0.00	0.00	0.24	0.00	0.00
Total mass conc. (ng/L)	**424.18**	**553.97**	**522.01**	**735.88**	**754.00**	**920.60**	**466.40**

Modesto Composting	5/11/2010	5/11/2010	5/12/2010	5/12/2010	5/13/2010	5/13/2010	5/14/2010
May 2010	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**
using MIR, ng Ozone/L	5 Days Oversize	5 Days Oversize	0-1 Day Oversize	0-1 Day Oversize	6 Weeks Compost	6 Weeks Compost	1-Day Oversize
Wood alcohol	42.41	135.70	203.55	84.81	220.52	237.48	84.81
Isopropanol	72.66	145.32	72.66	290.64	174.38	276.10	145.32
Ethanol	332.06	138.36	138.36	138.36	138.36	138.36	138.36
Acetone	0.99	1.54	1.06	0.57	1.49	1.20	2.21
Formaldehyde	15.38	18.82	12.44	6.61	12.31	9.65	18.73

Acetaldehyde	9.21	10.98	9.07	3.88	9.48	5.70	17.40
Octanal	19.13	4.78	3.19	38.25	7.97	11.16	1.59
Nonanal	5.30	17.65	0.00	22.95	14.12	17.65	0.00
Heptanal	18.23	0.00	1.99	36.45	6.63	6.63	0.00
Hexanal	13.73	0.00	0.00	29.18	3.43	6.87	0.00
Crotonaldehyde	18.24	31.62	7.55	0.00	0.00	0.00	0.00
1,2,4 Trichlorobenzene	0.00	0.00	0.00	0.00	1.99	0.37	0.00
Ethyl Hexane	0.93	1.96	0.00	0.00	1.56	2.99	1.50
Methyl butanal	0.00	0.00	0.00	12.56	3.28	0.00	2.02
Decanone	0.00	0.55	0.00	0.00	3.87	0.00	0.00
Xylene	0.94	2.76	0.00	1.22	13.63	0.00	0.00
1,2-Dichlorobenzene	0.00	0.00	0.06	0.00	0.41	0.11	0.00
Pentanol	0.52	0.00	0.00	1.01	0.78	0.62	0.00
Dimethyl hexene	0.00	4.09	0.00	1.46	0.00	3.26	0.00
Hexenal	0.00	0.00	0.00	3.22	1.91	1.61	0.00
Trimethylbenzene	0.00	0.00	0.00	2.66	9.22	3.15	1.60
Furfural	0.80	4.20	0.00	0.00	0.00	0.00	0.00
Trimethylbenzene	2.08	2.65	1.91	0.00	9.04	0.00	0.00
1,4-Dichlorobenzene	0.00	0.00	0.00	0.00	0.38	0.00	0.00
Decene	0.00	1.53	0.00	0.00	1.92	3.11	0.00
Pentenal	0.00	0.00	0.00	3.39	1.90	0.65	0.00
Benzyl chloride	0.00	0.00	2.41	0.00	2.08	0.00	0.00
1,3-Dichlorobenzene	0.00	0.00	0.00	0.00	0.30	0.00	0.00
2 Pentanone	0.00	0.00	0.00	0.75	0.00	1.94	0.00
Toluene	0.00	0.00	0.00	0.00	1.63	1.98	0.00
2 Methyl 1-propene	0.00	0.00	1.67	1.67	0.00	0.00	0.00
Ethyl cyclohexane	0.00	0.00	0.00	0.92	0.56	0.00	0.00
Styrene	0.00	0.00	0.00	0.00	1.50	0.00	0.00
Hexanone	0.00	0.00	0.00	0.00	2.54	0.00	0.00
Ethyl hexanol	0.00	1.02	0.00	1.02	0.00	0.00	0.00
2 Nonanone	0.00	0.00	0.00	0.00	1.20	0.00	0.00
Butene	0.00	3.69	0.00	0.00	0.00	0.00	0.00
Dimethylcyclopentane	0.00	0.00	0.00	0.00	0.66	0.00	0.00
Butylaldehyde	0.00	1.73	0.00	0.00	0.00	0.00	0.00
Camphor	0.00	0.00	0.29	0.00	0.00	0.00	0.00
Ethyl benzene	0.00	0.00	0.00	0.00	1.03	0.00	0.00
Chlorobenzene	0.00	0.00	0.00	0.00	0.11	0.00	0.00
Alpha pinene	0.00	0.00	0.00	0.00	0.00	1.43	0.00

Limonene	0.00	0.00	0.00	0.00	0.00	1.23	0.00
Tetrachloroethane	0.00	0.00	0.00	0.00	0.05	0.00	0.00
TOTAL MIR ng Ozone/L	**552.59**	**528.94**	**456.20**	**681.58**	**650.24**	**733.25**	**413.54**
mean MIR reactivity by mass	**1.30**	**0.95**	**0.87**	**0.93**	**0.86**	**0.80**	**0.89**

(mass Ozone/mass VOC)

Modesto Composting	5/11/2010	5/11/2010	5/12/2010	5/12/2010	5/13/2010	5/13/2010	5/14/2010
May 2010	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**
using EBIR, ng Ozone/L	5 Days Oversize	5 Days Oversize	0-1 Day Oversize	0-1 Day Oversize	6 Weeks Compost	6 Weeks Compost	1-Day Oversize
Wood alcohol	8.08	25.85	38.78	16.16	42.01	45.24	16.16
Isopropanol	18.49	36.97	18.49	73.94	44.37	70.25	36.97
Ethanol	196.46	81.86	81.86	81.86	81.86	81.86	81.86
Acetone	0.09	0.14	0.09	0.05	0.13	0.11	0.20
Formaldehyde	19.50	23.85	15.77	8.37	15.60	12.23	23.75
Acetaldehyde	14.86	17.72	14.65	6.26	15.31	9.20	28.08
Octanal	14.75	3.69	2.46	29.49	6.14	8.60	1.23
Nonanal	4.08	13.61	0.00	17.69	10.89	13.61	0.00
Heptanal	16.79	0.00	1.83	33.59	6.11	6.11	0.00
Hexanal	15.09	0.00	0.00	32.07	3.77	7.55	0.00
Crotonaldehyde	35.38	61.35	14.64	0.00	0.00	0.00	0.00
1,2,4 Trichlorobenzene	0.00	0.00	0.00	0.00	-0.08	-0.02	0.00
Ethyl Hexane	0.43	0.90	0.00	0.00	0.72	1.37	0.69
Methyl butanal	0.00	0.00	0.00	15.48	4.04	0.00	2.49
Decanone	0.00	0.14	0.00	0.00	0.95	0.00	0.00
Xylene	1.09	3.20	0.00	1.41	15.78	0.00	0.00
1,2-Dichlorobenzene	0.00	0.00	0.00	0.00	-0.02	0.00	0.00
Pentanol	0.30	0.00	0.00	0.58	0.44	0.36	0.00
Dimethyl hexene	0.00	5.27	0.00	1.88	0.00	4.20	0.00
Hexenal	0.00	0.00	0.00	3.54	2.10	1.77	0.00
Trimethylbenzene	0.00	0.00	0.00	4.38	15.17	5.18	2.63
Furfural	0.71	3.73	0.00	0.00	0.00	0.00	0.00
Trimethylbenzene	3.42	4.36	3.14	0.00	14.88	0.00	0.00
1,4-Dichlorobenzene	0.00	0.00	0.00	0.00	-0.02	0.00	0.00
Decene	0.00	1.28	0.00	0.00	1.60	2.59	0.00
Pentenal	0.00	0.00	0.00	4.37	2.45	0.83	0.00

Benzyl chloride	0.00	0.00	0.92	0.00	0.79	0.00	0.00
1,3-Dichlorobenzene	0.00	0.00	0.00	0.00	-0.01	0.00	0.00
2 Pentanone	0.00	0.00	0.00	0.67	0.00	1.73	0.00
Toluene	0.00	0.00	0.00	0.00	0.86	1.04	0.00
2 Methyl 1-propene	0.00	0.00	1.97	1.97	0.00	0.00	0.00
Ethyl cyclohexane	0.00	0.00	0.00	0.42	0.25	0.00	0.00
Styrene	0.00	0.00	0.00	0.00	-0.72	0.00	0.00
Hexanone	0.00	0.00	0.00	0.00	2.51	0.00	0.00
Ethyl hexanol	0.00	0.60	0.00	0.60	0.00	0.00	0.00
2 Nonanone	0.00	0.00	0.00	0.00	0.39	0.00	0.00
Butene	0.00	8.73	0.00	0.00	0.00	0.00	0.00
Dimethylcyclopentane	0.00	0.00	0.00	0.00	0.23	0.00	0.00
Butylaldehyde	0.00	2.56	0.00	0.00	0.00	0.00	0.00
Camphor	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Ethyl benzene	0.00	0.00	0.00	0.00	0.52	0.00	0.00
Chlorobenzene	0.00	0.00	0.00	0.00	-0.01	0.00	0.00
Alpha pinene	0.00	0.00	0.00	0.00	0.00	1.28	0.00
Limonene	0.00	0.00	0.00	0.00	0.00	1.19	0.00
Tetrachloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total EBIR*ng/L	**349.52**	**295.80**	**194.62**	**334.79**	**289.00**	**276.27**	**194.06**
Mean EBIR by mass	**0.82**	**0.53**	**0.37**	**0.45**	**0.38**	**0.30**	**0.42**

Modesto Composting	5/11/2010	5/11/2010	5/12/2010	5/12/2010	5/13/2010	5/13/2010	5/14/2010
May 2010	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**
% of total emissions	5 Days Oversize	5 Days Oversize	0-1 Day Oversize	0-1 Day Oversize	6 Weeks Compost	6 Weeks Compost	1-Day Oversize
Wood alcohol	21.94%	50.22%	69.70%	27.69%	58.81%	53.10%	39.00%
Isopropanol	21.94%	31.39%	14.52%	55.38%	27.15%	36.03%	39.00%
Ethanol	52.66%	15.69%	14.52%	13.84%	11.31%	9.48%	19.50%
Acetone	0.54%	0.59%	0.38%	0.19%	0.41%	0.28%	1.06%
Formaldehyde	0.60%	0.53%	0.32%	0.16%	0.25%	0.16%	0.65%
Acetaldehyde	0.36%	0.30%	0.23%	0.09%	0.19%	0.10%	0.60%
Octanal	0.53%	0.09%	0.06%	0.66%	0.11%	0.13%	0.04%
Nonanal	0.13%	0.31%	0.00%	0.36%	0.18%	0.19%	0.00%
Heptanal	0.48%	0.00%	0.03%	0.61%	0.09%	0.08%	0.00%
Hexanal	0.35%	0.00%	0.00%	0.47%	0.05%	0.08%	0.00%
Crotonaldehyde	0.31%	0.38%	0.08%	0.00%	0.00%	0.00%	0.00%
1,2,4	0.00%	0.00%	0.00%	0.00%	0.35%	0.06%	0.00%

Trichlorobenzene							
Ethyl Hexane	0.06%	0.09%	0.00%	0.00%	0.05%	0.09%	0.09%
Methyl butanal	0.00%	0.00%	0.00%	0.21%	0.04%	0.00%	0.05%
Decanone	0.00%	0.03%	0.00%	0.00%	0.16%	0.00%	0.00%
Xylene	0.01%	0.03%	0.00%	0.01%	0.10%	0.00%	0.00%
1,2-Dichlorobenzene	0.00%	0.00%	0.02%	0.00%	0.09%	0.02%	0.00%
Pentanol	0.04%	0.00%	0.00%	0.05%	0.03%	0.02%	0.00%
Dimethyl hexene	0.00%	0.06%	0.00%	0.02%	0.00%	0.03%	0.00%
Hexenal	0.00%	0.00%	0.00%	0.05%	0.03%	0.02%	0.00%
Trimethylbenzene	0.00%	0.00%	0.00%	0.02%	0.05%	0.01%	0.01%
Furfural	0.03%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%
Trimethylbenzene	0.02%	0.02%	0.01%	0.00%	0.05%	0.00%	0.00%
1,4-Dichlorobenzene	0.00%	0.00%	0.00%	0.00%	0.08%	0.00%	0.00%
Decene	0.00%	0.03%	0.00%	0.00%	0.02%	0.03%	0.00%
Pentenal	0.00%	0.00%	0.00%	0.06%	0.03%	0.01%	0.00%
Benzyl chloride	0.00%	0.00%	0.05%	0.00%	0.03%	0.00%	0.00%
1,3-Dichlorobenzene	0.00%	0.00%	0.00%	0.00%	0.07%	0.00%	0.00%
2 Pentanone	0.00%	0.00%	0.00%	0.02%	0.00%	0.04%	0.00%
Toluene	0.00%	0.00%	0.00%	0.00%	0.03%	0.03%	0.00%
2 Methyl 1-propene	0.00%	0.00%	0.03%	0.03%	0.00%	0.00%	0.00%
Ethyl cyclohexane	0.00%	0.00%	0.00%	0.04%	0.02%	0.00%	0.00%
Styrene	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%
Hexanone	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%
Ethyl hexanol	0.00%	0.03%	0.00%	0.03%	0.00%	0.00%	0.00%
2 Nonanone	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%
Butene	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%
Dimethylcyclopentane	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%
Butylaldehyde	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%
Camphor	0.00%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%
Ethyl benzene	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%
Chlorobenzene	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%
Alpha pinene	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%
Limonene	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%
Tetrachloroethane	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
TOTAL	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Modesto Composting	5/11/2010	5/11/2010	5/12/2010	5/12/2010	5/13/2010	5/13/2010	5/14/2010
May 2010	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**
Cumulative %	5 Days	5 Days	0-1 Day	0-1 Day	6 Weeks	6 Weeks	1-Day Oversize

	Oversize	Oversize	Oversize	Oversize	Compost	Compost	
Wood alcohol	21.94%	50.22%	69.70%	27.69%	58.81%	53.10%	39.00%
Isopropanol	43.88%	81.61%	84.23%	83.07%	85.96%	89.13%	78.00%
Ethanol	96.54%	97.31%	98.75%	96.91%	97.27%	98.62%	97.50%
Acetone	97.07%	97.90%	99.12%	97.10%	97.68%	98.90%	98.56%
Formaldehyde	97.68%	98.43%	99.45%	97.27%	97.93%	99.06%	99.21%
Acetaldehyde	98.03%	98.73%	99.68%	97.36%	98.12%	99.16%	99.81%
Octanal	98.56%	98.83%	99.74%	98.03%	98.24%	99.29%	99.85%
Nonanal	98.69%	99.14%	99.74%	98.39%	98.42%	99.48%	99.85%
Heptanal	99.18%	99.14%	99.77%	99.00%	98.51%	99.55%	99.85%
Hexanal	99.53%	99.14%	99.77%	99.47%	98.55%	99.63%	99.85%
Crotonaldehyde	99.84%	99.52%	99.86%	99.47%	98.55%	99.63%	99.85%
1,2,4 Trichlorobenzene	99.84%	99.52%	99.86%	99.47%	98.90%	99.69%	99.85%
Ethyl Hexane	99.90%	99.62%	99.86%	99.47%	98.96%	99.77%	99.94%
Methyl butanal	99.90%	99.62%	99.86%	99.67%	99.00%	99.77%	99.99%
Decanone	99.90%	99.65%	99.86%	99.67%	99.16%	99.77%	99.99%
Xylene	99.91%	99.68%	99.86%	99.68%	99.26%	99.77%	99.99%
1,2-Dichlorobenzene	99.91%	99.68%	99.87%	99.68%	99.35%	99.79%	99.99%
Pentanol	99.95%	99.68%	99.87%	99.73%	99.38%	99.81%	99.99%
Dimethyl hexene	99.95%	99.74%	99.87%	99.75%	99.38%	99.84%	99.99%
Hexenal	99.95%	99.74%	99.87%	99.80%	99.41%	99.86%	99.99%
Trimethylbenzene	99.95%	99.74%	99.87%	99.82%	99.46%	99.88%	100.00%
Furfural	99.98%	99.84%	99.87%	99.82%	99.46%	99.88%	100.00%
Trimethylbenzene	100.00%	99.86%	99.89%	99.82%	99.50%	99.88%	100.00%
1,4-Dichlorobenzene	100.00%	99.86%	99.89%	99.82%	99.59%	99.88%	100.00%
Decene	100.00%	99.88%	99.89%	99.82%	99.61%	99.91%	100.00%
Pentenal	100.00%	99.88%	99.89%	99.88%	99.64%	99.91%	100.00%
Benzyl chloride	100.00%	99.88%	99.94%	99.88%	99.67%	99.91%	100.00%
1,3-Dichlorobenzene	100.00%	99.88%	99.94%	99.88%	99.74%	99.91%	100.00%
2 Pentanone	100.00%	99.88%	99.94%	99.90%	99.74%	99.95%	100.00%
Toluene	100.00%	99.88%	99.94%	99.90%	99.76%	99.98%	100.00%
2 Methyl 1-propene	100.00%	99.88%	99.97%	99.93%	99.76%	99.98%	100.00%
Ethyl cyclohexane	100.00%	99.88%	99.97%	99.97%	99.78%	99.98%	100.00%
Styrene	100.00%	99.88%	99.97%	99.97%	99.83%	99.98%	100.00%
Hexanone	100.00%	99.88%	99.97%	99.97%	99.87%	99.98%	100.00%
Ethyl hexanol	100.00%	99.91%	99.97%	100.00%	99.87%	99.98%	100.00%
2 Nonanone	100.00%	99.91%	99.97%	100.00%	99.92%	99.98%	100.00%
Butene	100.00%	99.97%	99.97%	100.00%	99.92%	99.98%	100.00%

Dimethylcyclopentane	100.00%	99.97%	99.97%	100.00%	99.96%	99.98%	100.00%
Butylaldehyde	100.00%	100.00%	99.97%	100.00%	99.96%	99.98%	100.00%
Camphor	100.00%	100.00%	100.00%	100.00%	99.96%	99.98%	100.00%
Ethyl benzene	100.00%	100.00%	100.00%	100.00%	99.97%	99.98%	100.00%
Chlorobenzene	100.00%	100.00%	100.00%	100.00%	99.99%	99.98%	100.00%
Alpha pinene	100.00%	100.00%	100.00%	100.00%	99.99%	99.99%	100.00%
Limonene	100.00%	100.00%	100.00%	100.00%	99.99%	100.00%	100.00%
Tetrachloroethane	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Appendix G:

Tulare Total Speciation, Reactivity Calculations & Percentages

Tulare County Compost & Biomass, Inc May 2010 ppbv (nL/L)	3-Jun-10 Morning 5 Days Windrow without Cap	3-Jun-10 Afternoon 5 Days Windrow without Cap	2-Jun-10 Morning 5 Days Windrow with Cap	2-Jun-10 Afternoon 5 Days Windrow with Cap	4-Jun-10 Morning 21 Days Windrow without Cap	4-Jun-10 Afternoon 21 Days Windrow without Cap	5-Jun-10 Morning 21 Days Windrow with Cap	5-Jun-10 Afternoon 21 Days Windrow with Cap
Wood alcohol	500	100	200	100	300	100	300	100
Isopropanol	50	600	100	50	150	50	50	50
Ethanol	50	50	50	100	250	50	50	50
Acetone	6.04	4.89	1.37	1.76	3.79	5.39	5.15	3.85
Limonene	0.45	5.70	0.00	0.00	3.20	0.00	5.00	3.80
Formaldehyde	3.24	3.07	1.09	1.57	1.02	1.01	1.75	0.95
Acetaldehyde	1.94	1.71	0.90	0.92	1.18	0.93	1.50	0.72
Eucalyptol	0.18	1.16	0.00	0.00	2.51	0.00	2.85	1.91
alpha-Pinene	0.29	3.19	0.00	0.00	0.66	0.10	1.32	2.44
Heptanone	0.00	3.40	0.00	0.00	1.80	0.00	0.00	0.00
Butylaldehyde	2.47	1.09	0.14	0.32	0.12	0.40	0.44	0.17
1 Methyl, 3-1-methyl ethyl benzene/ Cymene	0.15	1.36	0.07	0.03	1.04	0.02	1.47	0.68
2 Methyl 1-propene	0.00	2.00	0.00	0.00	0.00	0.00	1.10	1.70
allyl anisol	0.00	0.00	1.60	0.30	1.10	0.40	0.60	0.20
Octanone	0.00	1.10	0.00	0.00	3.10	0.00	0.00	0.00
Ethyl Hexane	0.00	0.30	0.00	0.00	3.50	0.00	0.00	0.00
Terpineol	0.00	1.16	0.00	0.00	2.14	0.04	0.00	0.10
Octanal	0.25	1.00	0.20	0.20	1.20	0.00	0.30	0.20
Methyl heptanone	0.21	1.29	0.75	0.15	0.00	0.00	0.24	0.66
Octane	0.00	0.20	0.00	0.00	3.10	0.00	0.00	0.00
cis-Linalool oxide	0.00	0.00	0.00	0.00	0.59	0.00	2.44	0.00
2 Nonanone	0.00	1.10	0.00	0.00	1.90	0.00	0.00	0.00
Carene isomers	0.12	1.24	0.00	0.00	0.00	0.00	0.83	0.75
Nonanal	0.10	1.10	0.00	0.00	1.10	0.20	0.20	0.20
2 Pentanone	0.05	2.40	0.00	0.00	0.20	0.00	0.20	0.00
Ethyl hexanol	0.05	0.60	0.20	0.00	0.60	0.00	0.60	0.50
Camphor	2.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptanal	0.15	1.00	0.10	0.00	0.80	0.00	0.10	0.20
Trichlorobenzene	0.12	0.00	0.00	0.00	0.00	0.00	0.00	2.11
Ethyl cyclohexane	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00
B-Pinene	0.12	0.82	0.00	0.00	0.28	0.06	0.26	0.42

Camphene	0.04	0.69	0.00	0.00	0.19	0.00	0.30	0.45
Terpineol	0.00	0.00	0.00	0.00	0.00	0.00	1.64	0.00
Methyl heptene 2-one	0.09	1.48	0.00	0.00	0.00	0.00	0.00	0.00
Hexanal	0.10	0.80	0.10	0.00	0.40	0.00	0.00	0.10
Dimethyl hexene	0.00	0.30	0.00	0.00	1.00	0.00	0.00	0.00
Cyclohexanone	0.15	0.52	0.23	0.00	0.17	0.00	0.16	0.00
2 Pentyl furan	0.00	0.60	0.00	0.00	0.00	0.00	0.25	0.32
Biogenic	0.00	0.00	0.00	0.00	0.26	0.15	0.62	0.00
Proionaldehyde	0.25	0.25	0.00	0.00	0.00	0.00	0.19	0.31
Methyl Isobutylketone, MIBK	0.05	0.54	0.00	0.00	0.12	0.00	0.09	0.16
Dichlorobenzene Isomers	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.65
Thujone	0.00	0.28	0.00	0.00	0.28	0.00	0.30	0.06
Xylene	0.27	0.00	0.11	0.12	0.00	0.00	0.08	0.33
Acetyl benzene	0.00	0.62	0.00	0.00	0.28	0.00	0.00	0.00
Methyl Butane	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.20
Ethyl benzene	0.01	0.00	0.02	0.02	0.71	0.02	0.02	0.10
Pinene Isomer	0.00	0.00	0.00	0.00	0.01	0.07	0.05	0.69
Styrene + Xylene	0.00	0.30	0.00	0.03	0.00	0.02	0.09	0.37
Dichlorobenzene Isomers	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.53
C3-benzene, TMB isomers	0.03	0.00	0.07	0.10	0.00	0.14	0.03	0.38
Terpinine	0.00	0.00	0.00	0.00	0.21	0.08	0.36	0.09
Methyl butanal	0.17	0.00	0.00	0.00	0.22	0.00	0.16	0.16
Hexanone	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00
Ketone compound	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fenchone	0.00	0.22	0.00	0.00	0.00	0.00	0.31	0.08
Methyl cyclohexanone	0.00	0.50	0.00	0.00	0.00	0.00	0.10	0.00
Furan	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.30
Heptanol	0.00	0.24	0.00	0.00	0.05	0.00	0.14	0.10
C3-benzene, TMB isomers	0.00	0.00	0.10	0.06	0.00	0.00	0.00	0.33
Methylcyclopentane	0.00		0.00	0.00	0.40	0.00	0.00	0.00
Bornyl chloride	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00
Pentane isomer	0.00	0.10	0.00	0.10	0.10	0.00	0.00	0.10
Toluene	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00
Terpineol isomer	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00
Decene	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00
Pentenal	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
Hexenal	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00

Pentanol	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Isopropenyl toluene	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00
Methyl butadiene	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00
Butene isomer	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00
Decanone	0.05	0.00	0.00	0.10	0.00	0.00	0.00	0.00
Heptane	0.02	0.00	0.00	0.00	0.00	0.04	0.04	0.00
Chlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Phenol	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Total ppbV	**620.41**	**800.43**	**357.33**	**256.52**	**742.31**	**209.08**	**432.29**	**227.45**

Tulare County Compost	2-Jun-10	2-Jun-10	3-Jun-10	3-Jun-10	4-Jun-10	4-Jun-10	5-Jun-10	5-Jun-10
& Biomass, Inc	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**
May 2010	5 Days Windrow	5 Days Windrow	5 Days Windrow	5 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow
ng/L	without Cap	without Cap	with Cap	with Cap	without Cap	without Cap	with Cap	with Cap
Wood alcohol	630.75	126.15	252.30	126.15	378.45	126.15	378.45	126.15
Isopropanol	118.30	1419.57	236.59	118.30	354.89	118.30	118.30	118.30
Ethanol	90.69	90.69	90.69	181.37	453.43	90.69	90.69	90.69
Acetone	13.80	11.19	3.14	4.02	8.68	12.32	11.77	8.80
Limonene	2.41	30.57	0.00	0.00	17.16	0.00	26.82	20.38
Formaldehyde	3.83	3.63	1.29	1.86	1.20	1.19	2.07	1.12
Acetaldehyde	3.36	2.96	1.56	1.59	2.04	1.61	2.61	1.25
Eucalyptol	1.11	7.24	0.00	0.00	15.61	0.00	17.75	11.90
alpha-Pinene	1.55	17.12	0.00	0.00	3.56	0.52	7.09	13.10
Heptanone	0.00	15.28	0.00	0.00	8.09	0.00	0.00	0.00
Butylaldehyde	7.01	3.10	0.39	0.90	0.34	1.14	1.26	0.49
1 Methyl, 3-1-methyl ethyl benzene/ Cymene	0.77	7.19	0.36	0.13	5.49	0.12	7.79	3.59
2 Methyl 1-propene	0.00	4.42	0.00	0.00	0.00	0.00	2.43	3.76
allyl anisol	0.00	0.00	6.81	1.28	4.68	1.70	2.55	0.85
Octanone	0.00	5.55	0.00	0.00	15.65	0.00	0.00	0.00
Ethyl Hexane	0.00	1.35	0.00	0.00	15.74	0.00	0.00	0.00
Terpineol	0.00	7.03	0.00	0.00	13.01	0.27	0.00	0.64
Octanal	1.26	5.05	1.01	1.01	6.06	0.00	1.51	1.01
Methyl heptanone	1.06	6.43	3.75	0.74	0.00	0.00	1.18	3.26
Octane	0.00	0.90	0.00	0.00	13.94	0.00	0.00	0.00
cis-Linalool oxide	0.00	0.00	0.00	0.00	3.61	0.00	15.04	0.00
2 Nonanone	0.00	6.16	0.00	0.00	10.64	0.00	0.00	0.00

Carene isomers	0.68	6.84	0.00	0.00	0.00	0.00	4.56	4.12
Nonanal	0.56	6.15	0.00	0.00	6.15	1.12	1.12	1.12
2 Pentanone	0.17	8.14	0.00	0.00	0.68	0.00	0.68	0.00
Ethyl hexanol	0.26	3.08	1.03	0.00	3.08	0.00	3.08	2.56
Camphor	15.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptanal	0.67	4.50	0.45	0.00	3.60	0.00	0.45	0.90
Trichlorobenzene	0.85	0.00	0.00	0.00	0.00	0.00	0.00	15.07
Ethyl cyclohexane	0.00	0.00	0.00	0.00	8.84	0.00	0.00	0.00
B-Pinene	0.66	4.39	0.00	0.00	1.50	0.31	1.40	2.24
Camphene	0.22	3.69	0.00	0.00	1.00	0.00	1.60	2.39
Terpineol	0.00	0.00	0.00	0.00	0.00	0.00	9.95	0.00
Methyl heptene 2-one	0.48	7.46	0.00	0.00	0.00	0.00	0.00	0.00
Hexanal	0.39	3.15	0.39	0.00	1.58	0.00	0.00	0.39
Dimethyl hexene	0.00	1.33	0.00	0.00	4.42	0.00	0.00	0.00
Cyclohexanone	0.59	2.06	0.89	0.00	0.66	0.00	0.64	0.00
2 Pentyl furan	0.00	3.62	0.00	0.00	0.00	0.00	1.51	1.94
Biogenic	0.00	0.00	0.00	0.00	1.42	0.83	3.38	0.00
Proionaldehyde	0.56	0.56	0.00	0.00	0.00	0.00	0.43	0.71
Methyl Isobutylketone, MIBK	0.20	2.13	0.00	0.00	0.46	0.00	0.36	0.63
Dichlorobenzene Isomers	0.00	0.00	0.00	0.00	0.00	0.00	1.74	3.75
Thujone	0.00	1.71	0.00	0.00	1.70	0.00	1.85	0.39
Xylene	1.12	0.00	0.45	0.50	0.00	0.00	0.35	1.37
Acetyl benzene	0.00	3.96	0.00	0.00	1.80	0.00	0.00	0.00
Methyl Butane	0.00	0.00	0.00	1.99	0.00	0.00	0.00	0.57
Ethyl benzene	0.03	0.00	0.07	0.09	2.98	0.06	0.09	0.40
Pinene Isomer	0.00	0.00	0.00	0.00	0.06	0.40	0.28	3.71
Styrene + Xylene	0.00	1.25	0.00	0.13	0.00	0.10	0.37	1.53
Dichlorobenzene Isomers	0.00	0.00	0.00	0.00	0.00	0.00	1.37	3.09
C3-benzene, TMB isomers	0.16	0.00	0.31	0.48	0.00	0.68	0.13	1.78
Terpinine	0.00	0.00	0.00	0.00	1.11	0.42	1.91	0.48
Methyl butanal	0.56	0.00	0.00	0.00	0.74	0.00	0.55	0.56
Hexanone	0.00	0.00	0.00	0.00	2.76	0.00	0.00	0.00
Ketone compound	3.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fenchone	0.00	1.35	0.00	0.00	0.00	0.00	1.91	0.49
Methyl cyclohexanone	0.00	2.21	0.00	0.00	0.00	0.00	0.44	0.00
Furan	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.80
Heptanol	0.00	1.12	0.00	0.00	0.22	0.00	0.64	0.48

C3-benzene, TMB isomers	0.00	0.00	0.46	0.31	0.00	0.00	0.00	1.56
Methylcyclopentane	0.00	0.00	0.00	0.00	1.36	0.00	0.00	0.00
Bornyl chloride	0.00	1.82	0.00	0.00	0.00	0.00	0.00	0.00
Pentane isomer	0.00	0.28	0.00	0.28	0.28	0.00	0.00	0.28
Toluene	0.00	1.45	0.00	0.00	0.00	0.00	0.00	0.00
Terpineol isomer	0.00	2.05	0.00	0.00	0.00	0.00	0.00	0.00
Decene	0.00	1.66	0.00	0.00	0.00	0.00	0.00	0.00
Pentenal	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00
Hexenal	0.00	1.16	0.00	0.00	0.00	0.00	0.00	0.00
Pentanol	0.00	0.00	0.00	0.00	1.04	0.00	0.00	0.00
Isopropenyl toluene	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00
Methyl butadiene	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Butene isomer	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00
Decanone	0.31	0.00	0.00	0.62	0.00	0.00	0.00	0.00
Heptane	0.09	0.00	0.00	0.00	0.00	0.16	0.15	0.00
Chlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
Phenol	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.00
Total ng/L	**903.23**	**1849.55**	**602.93**	**441.91**	**1379.70**	**358.08**	**730.00**	**458.95**
Tulare County Compost	2-Jun-10	2-Jun-10	3-Jun-10	3-Jun-10	4-Jun-10	4-Jun-10	5-Jun-10	5-Jun-10
& Biomass, Inc	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**
May 2010	5 Days Windrow	5 Days Windrow	5 Days Windrow	5 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow
MIR*ng/L	without Cap	without Cap	with Cap	with Cap	without Cap	without Cap	with Cap	with Cap
Wood alcohol	424.07	84.81	169.63	84.81	254.44	84.81	254.44	84.81
Isopropanol	72.66	871.91	145.32	72.66	217.98	72.66	72.66	72.66
Ethanol	138.36	138.36	138.36	276.72	691.80	138.36	138.36	138.36
Acetone	4.91	3.98	1.12	1.43	3.09	4.38	4.19	3.13
Limonene	10.99	139.16	0.00	0.00	78.12	0.00	122.07	92.77
Formaldehyde	36.22	34.33	12.16	17.56	11.35	11.24	19.59	10.62
Acetaldehyde	21.97	19.37	10.22	10.41	13.33	10.56	17.06	8.15
Eucalyptol	1.33	8.67	0.00	0.00	18.71	0.00	21.27	14.26
alpha-Pinene	7.00	77.15	0.00	0.00	16.04	2.36	31.95	59.02
Heptanone	0.00	36.08	0.00	0.00	19.10	0.00	0.00	0.00
Butylaldehyde	41.87	18.55	2.32	5.38	2.04	6.81	7.51	2.94
1 Methyl, 3-1-methyl ethyl benzene/ Cymene	4.22	39.53	1.99	0.73	30.17	0.68	42.79	19.70
2 Methyl 1-propene	0.00	27.80	0.00	0.00	0.00	0.00	15.29	23.63

allyl anisol	0.00	0.00	45.36	8.50	31.18	11.34	17.01	5.67
Octanone	0.00	7.75	0.00	0.00	21.85	0.00	0.00	0.00
Ethyl Hexane	0.00	1.95	0.00	0.00	22.76	0.00	0.00	0.00
Terpineol	0.00	32.57	0.00	0.00	60.25	1.25	0.00	2.95
Octanal	3.98	15.94	3.19	3.19	19.13	0.00	4.78	3.19
Methyl heptanone	1.11	6.72	3.92	0.77	0.00	0.00	1.23	3.41
Octane	0.00	1.30	0.00	0.00	20.16	0.00	0.00	0.00
cis-Linalool oxide	0.00	0.00	0.00	0.00	19.61	0.00	81.72	0.00
2 Nonanone	0.00	6.62	0.00	0.00	11.44	0.00	0.00	0.00
Carene isomers	2.24	22.60	0.00	0.00	0.00	0.00	15.07	13.62
Nonanal	1.77	19.42	0.00	0.00	19.42	3.53	3.53	3.53
2 Pentanone	0.48	22.89	0.00	0.00	1.91	0.00	1.91	0.00
Ethyl hexanol	0.51	6.14	2.05	0.00	6.14	0.00	6.14	5.12
Camphor	7.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptanal	2.49	16.57	1.66	0.00	13.26	0.00	1.66	3.31
Trichlorobenzene	0.15	0.00	0.00	0.00	0.00	0.00	0.00	2.69
Ethyl cyclohexane	0.00	0.00	0.00	0.00	13.02	0.00	0.00	0.00
B-Pinene	2.32	15.46	0.00	0.00	5.28	1.09	4.91	7.87
Camphene	0.98	16.62	0.00	0.00	4.49	0.00	7.22	10.76
Terpineol	0.00	0.00	0.00	0.00	0.00	0.00	46.07	0.00
Methyl heptene 2-one	0.67	10.42	0.00	0.00	0.00	0.00	0.00	0.00
Hexanal	1.72	13.73	1.72	0.00	6.87	0.00	0.00	1.72
Dimethyl hexene	0.00	6.39	0.00	0.00	21.29	0.00	0.00	0.00
Cyclohexanone	1.85	6.48	2.80	0.00	2.09	0.00	2.00	0.00
2 Pentyl furan	0.00	1.77	0.00	0.00	0.00	0.00	0.74	0.95
Biogenic	0.00	0.00	0.00	0.00	12.96	7.62	30.89	0.00
Proionaldehyde	3.97	3.98	0.00	0.00	0.00	0.00	3.08	5.06
Methyl Isobutylketone, MIBK	0.77	8.25	0.00	0.00	1.79	0.00	1.39	2.43
Dichlorobenzene Isomers	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.67
Thujone	0.00	1.53	0.00	0.00	1.53	0.00	1.66	0.35
Xylene	8.55	0.00	3.47	3.84	0.00	0.00	2.70	10.44
Acetyl benzene	0.00	8.90	0.00	0.00	4.05	0.00	0.00	0.00
Methyl Butane	0.00	0.00	0.00	2.87	0.00	0.00	0.00	0.82
Ethyl benzene	0.09	0.00	0.21	0.28	9.06	0.19	0.26	1.22
Pinene Isomer	0.00	0.00	0.00	0.00	0.26	1.60	1.14	15.02
Styrene + Xylene	0.00	2.16	0.00	0.23	0.00	0.17	0.64	2.65
Dichlorobenzene Isomers	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.55

C3-benzene, TMB isomers	1.43	0.00	2.75	4.27	0.00	6.00	1.17	15.82
Terpinine	0.00	0.00	0.00	0.00	7.04	2.67	12.12	3.05
Methyl butanal	2.79	0.00	0.00	0.00	3.70	0.00	2.71	2.77
Hexanone	0.00	0.00	0.00	0.00	8.68	0.00	0.00	0.00
Ketone compound	4.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fenchone	0.00	1.22	0.00	0.00	0.00	0.00	1.71	0.44
Methyl cyclohexanone	0.00	2.60	0.00	0.00	0.00	0.00	0.52	0.00
Furan	0.00	0.00	0.00	0.00	0.00	0.00	5.96	7.34
Heptanol	0.00	2.07	0.00	0.00	0.40	0.00	1.17	0.88
C3-benzene, TMB isomers	0.00	0.00	4.08	2.72	0.00	0.00	0.00	13.82
Methylcyclopentane	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00
Bornyl chloride	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00
Pentane isomer	0.00	0.41	0.00	0.41	0.41	0.00	0.00	0.41
Toluene	0.00	5.81	0.00	0.00	0.00	0.00	0.00	0.00
Terpineol isomer	0.00	9.48	0.00	0.00	0.00	0.00	0.00	0.00
Decene	0.00	5.48	0.00	0.00	0.00	0.00	0.00	0.00
Pentenal	0.00	0.00	5.04	0.00	0.00	0.00	0.00	0.00
Hexenal	0.00	5.04	0.00	0.00	0.00	0.00	0.00	0.00
Pentanol	0.00	0.00	0.00	0.00	1.68	0.00	0.00	0.00
Isopropenyl toluene	0.00	0.00	0.00	0.00	0.00	0.00	6.52	0.00
Methyl butadiene	0.00	5.15	0.00	0.00	0.00	0.00	0.00	0.00
Butene isomer	0.00	3.54	0.00	0.00	0.00	0.00	0.00	0.00
Decanone	0.28	0.00	0.00	0.55	0.00	0.00	0.00	0.00
Heptane	0.10	0.00	0.00	0.00	0.00	0.17	0.16	0.00
Chlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
Phenol	0.41	0.00	0.00	0.42	0.00	0.00	0.00	0.00
Total MIR*ng/L	**814.43**	**1797.24**	**557.36**	**497.77**	**1709.89**	**367.50**	**1015.52**	**678.72**
Average MIR	**0.90**	**0.97**	**0.92**	**1.13**	**1.24**	**1.03**	**1.39**	**1.48**
(mass Ozone/mass VOC)								
Tulare County Compost	2-Jun-10	2-Jun-10	3-Jun-10	3-Jun-10	4-Jun-10	4-Jun-10	5-Jun-10	5-Jun-10
& Biomass, Inc	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**
May 2010	5 Days Windrow	5 Days Windrow	5 Days Windrow	5 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow
EBIR*ng/L	without Cap	without Cap	with Cap	with Cap	without Cap	without Cap	with Cap	with Cap
Wood alcohol	80.78	16.16	32.31	16.16	48.47	16.16	48.47	16.16
Isopropanol	18.49	221.83	36.97	18.49	55.46	18.49	18.49	18.49
Ethanol	81.86	81.86	81.86	163.72	409.30	81.86	81.86	81.86
Acetone	0.44	0.36	0.10	0.13	0.28	0.39	0.37	0.28

Limonene	10.59	134.18	0.00	0.00	75.33	0.00	117.70	89.45
Formaldehyde	45.92	43.52	15.41	22.26	14.39	14.25	24.84	13.46
Acetaldehyde	35.47	31.26	16.50	16.80	21.51	17.04	27.53	13.15
Eucalyptol	0.46	2.99	0.00	0.00	6.45	0.00	7.33	4.91
alpha-Pinene	6.24	68.82	0.00	0.00	14.31	2.10	28.50	52.65
Heptanone	0.00	27.10	0.00	0.00	14.35	0.00	0.00	0.00
Butylaldehyde	62.11	27.51	3.45	7.98	3.02	10.10	11.14	4.37
1 Methyl, 3-1-methyl ethyl benzene/ Cymene	3.75	35.14	1.77	0.65	26.83	0.60	38.04	17.51
2 Methyl 1-propene	0.00	32.78	0.00	0.00	0.00	0.00	18.03	27.86
allyl anisol	0.00	0.00	45.22	8.48	31.09	11.31	16.96	5.65
Octanone	0.00	3.43	0.00	0.00	9.66	0.00	0.00	0.00
Ethyl Hexane	0.00	0.90	0.00	0.00	10.45	0.00	0.00	0.00
Terpineol	0.00	29.00	0.00	0.00	53.63	1.12	0.00	2.63
Octanal	3.07	12.29	2.46	2.46	14.75	0.00	3.69	2.46
Methyl heptanone	0.41	2.49	1.45	0.29	0.00	0.00	0.46	1.26
Octane	0.00	0.60	0.00	0.00	9.25	0.00	0.00	0.00
cis-Linalool oxide	0.00	0.00	0.00	0.00	20.90	0.00	87.10	0.00
2 Nonanone	0.00	2.12	0.00	0.00	3.67	0.00	0.00	0.00
Carene isomers	1.87	18.83	0.00	0.00	0.00	0.00	12.56	11.34
Nonanal	1.36	14.97	0.00	0.00	14.97	2.72	2.72	2.72
2 Pentanone	0.42	20.40	0.00	0.00	1.70	0.00	1.70	0.00
Ethyl hexanol	0.30	3.58	1.19	0.00	3.58	0.00	3.58	2.99
Camphor	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptanal	2.29	15.27	1.53	0.00	12.21	0.00	1.53	3.05
Trichlorobenzene	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.11
Ethyl cyclohexane	0.00	0.00	0.00	0.00	5.89	0.00	0.00	0.00
B-Pinene	1.83	12.20	0.00	0.00	4.16	0.86	3.87	6.21
Camphene	0.87	14.82	0.00	0.00	4.00	0.00	6.44	9.60
Terpineol	0.00	0.00	0.00	0.00	0.00	0.00	41.02	0.00
Methyl heptene 2-one	0.29	4.61	0.00	0.00	0.00	0.00	0.00	0.00
Hexanal	1.89	15.09	1.89	0.00	7.55	0.00	0.00	1.89
Dimethyl hexene	0.00	8.23	0.00	0.00	27.44	0.00	0.00	0.00
Cyclohexanone	1.83	6.40	2.77	0.00	2.06	0.00	1.98	0.00
2 Pentyl furan	0.00	0.23	0.00	0.00	0.00	0.00	0.10	0.12
Biogenic	0.00	0.00	0.00	0.00	26.72	15.72	63.68	0.00
Proionaldehyde	6.96	6.98	0.00	0.00	0.00	0.00	5.40	8.87
Methyl Isobutylketone,	0.83	8.91	0.00	0.00	1.93	0.00	1.50	2.62

MIBK								
Dichlorobenzene Isomers	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.03
Thujone	0.00	0.38	0.00	0.00	0.38	0.00	0.41	0.09
Xylene	9.90	0.00	4.02	4.45	0.00	0.00	3.13	12.08
Acetyl benzene	0.00	2.95	0.00	0.00	1.34	0.00	0.00	0.00
Methyl Butane	0.00	0.00	0.00	1.86	0.00	0.00	0.00	0.53
Ethyl benzene	0.05	0.00	0.11	0.14	4.54	0.10	0.13	0.61
Pinene Isomer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Styrene + Xylene	0.00	-1.05	0.00	-0.11	0.00	-0.08	-0.31	-1.28
Dichlorobenzene Isomers	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.02
C3-benzene, TMB isomers	2.35	0.00	4.52	7.02	0.00	9.87	1.92	26.03
Terpinine	0.00	0.00	0.00	0.00	8.33	3.16	14.33	3.61
Methyl butanal	3.44	0.00	0.00	0.00	4.56	0.00	3.34	3.42
Hexanone	0.00	0.00	0.00	0.00	8.58	0.00	0.00	0.00
Ketone compound	2.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fenchone	0.00	0.30	0.00	0.00	0.00	0.00	0.42	0.11
Methyl cyclohexanone	0.00	1.08	0.00	0.00	0.00	0.00	0.22	0.00
Furan	0.00	0.00	0.00	0.00	0.00	0.00	12.28	15.13
Heptanol	0.00	1.23	0.00	0.00	0.24	0.00	0.70	0.52
C3-benzene, TMB isomers	0.00	0.00	6.71	4.48	0.00	0.00	0.00	22.75
Methylcyclopentane	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.00
Bornyl chloride	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.00
Pentane isomer	0.00	0.27	0.00	0.27	0.27	0.00	0.00	0.27
Toluene	0.00	3.05	0.00	0.00	0.00	0.00	0.00	0.00
Terpineol isomer	0.00	8.44	0.00	0.00	0.00	0.00	0.00	0.00
Decene	0.00	4.56	0.00	0.00	0.00	0.00	0.00	0.00
Pentenal	0.00	0.00	6.50	0.00	0.00	0.00	0.00	0.00
Hexenal	0.00	5.54	0.00	0.00	0.00	0.00	0.00	0.00
Pentanol	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00
Isopropenyl toluene	0.00	0.00	0.00	0.00	0.00	0.00	5.90	0.00
Methyl butadiene	0.00	12.58	0.00	0.00	0.00	0.00	0.00	0.00
Butene isomer	0.00	8.38	0.00	0.00	0.00	0.00	0.00	0.00
Decanone	0.07	0.00	0.00	0.14	0.00	0.00	0.00	0.00
Heptane	0.04	0.00	0.00	0.00	0.00	0.06	0.06	0.00
Chlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Phenol	-0.35	0.00	0.00	-0.36	0.00	0.00	0.00	0.00
Total EBIR*ng/L	**388.89**	**972.50**	**266.75**	**275.29**	**985.66**	**205.83**	**719.08**	**485.27**

Average EBIR	**0.43**	**0.53**	**0.44**	**0.62**	**0.71**	**0.57**	**0.99**	**1.06**

Tulare County Compost	3-Jun-10	3-Jun-10	2-Jun-10	2-Jun-10	4-Jun-10	4-Jun-10	5-Jun-10	5-Jun-10
& Biomass, Inc	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**
May 2010	5 Days Windrow	5 Days Windrow	5 Days Windrow	5 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow
Percent of Emissions	without Cap	without Cap	with Cap	with Cap	without Cap	without Cap	with Cap	with Cap
Wood alcohol	80.59%	12.49%	55.97%	38.98%	40.41%	47.83%	69.40%	43.97%
Isopropanol	8.06%	74.96%	27.99%	19.49%	20.21%	23.91%	11.57%	21.98%
Ethanol	8.06%	6.25%	13.99%	38.98%	33.68%	23.91%	11.57%	21.98%
Acetone	0.97%	0.61%	0.38%	0.69%	0.51%	2.58%	1.19%	1.69%
Limonene	0.07%	0.71%	0.00%	0.00%	0.43%	0.00%	1.16%	1.67%
Formaldehyde	0.52%	0.38%	0.30%	0.61%	0.14%	0.48%	0.41%	0.42%
Acetaldehyde	0.31%	0.21%	0.25%	0.36%	0.16%	0.45%	0.35%	0.32%
Eucalyptol	0.03%	0.15%	0.00%	0.00%	0.34%	0.00%	0.66%	0.84%
alpha-Pinene	0.05%	0.40%	0.00%	0.00%	0.09%	0.05%	0.31%	1.07%
Heptanone	0.00%	0.42%	0.00%	0.00%	0.24%	0.00%	0.00%	0.00%
Butylaldehyde	0.40%	0.14%	0.04%	0.12%	0.02%	0.19%	0.10%	0.08%
1 Methyl, 3-1-methyl ethyl benzene/ Cymene	0.02%	0.17%	0.02%	0.01%	0.14%	0.01%	0.34%	0.30%
2 Methyl 1-propene	0.00%	0.25%	0.00%	0.00%	0.00%	0.00%	0.25%	0.75%
allyl anisol	0.00%	0.00%	0.45%	0.12%	0.15%	0.19%	0.14%	0.09%
Octanone	0.00%	0.14%	0.00%	0.00%	0.42%	0.00%	0.00%	0.00%
Ethyl Hexane	0.00%	0.04%	0.00%	0.00%	0.47%	0.00%	0.00%	0.00%
Terpineol	0.00%	0.14%	0.00%	0.00%	0.29%	0.02%	0.00%	0.05%
Octanal	0.04%	0.12%	0.06%	0.08%	0.16%	0.00%	0.07%	0.09%
Methyl heptanone	0.03%	0.16%	0.21%	0.06%	0.00%	0.00%	0.05%	0.29%
Octane	0.00%	0.02%	0.00%	0.00%	0.42%	0.00%	0.00%	0.00%
cis-Linalool oxide	0.00%	0.00%	0.00%	0.00%	0.08%	0.00%	0.57%	0.00%
2 Nonanone	0.00%	0.14%	0.00%	0.00%	0.26%	0.00%	0.00%	0.00%
Carene isomers	0.02%	0.15%	0.00%	0.00%	0.00%	0.00%	0.19%	0.33%
Nonanal	0.02%	0.14%	0.00%	0.00%	0.15%	0.10%	0.05%	0.09%
2 Pentanone	0.01%	0.30%	0.00%	0.00%	0.03%	0.00%	0.05%	0.00%
Ethyl hexanol	0.01%	0.07%	0.06%	0.00%	0.08%	0.00%	0.14%	0.22%
Camphor	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Heptanal	0.02%	0.12%	0.03%	0.00%	0.11%	0.00%	0.02%	0.09%
Trichlorobenzene	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.93%
Ethyl cyclohexane	0.00%	0.00%	0.00%	0.00%	0.27%	0.00%	0.00%	0.00%

B-Pinene	0.02%	0.10%	0.00%	0.00%	0.04%	0.03%	0.06%	0.18%
Camphene	0.01%	0.09%	0.00%	0.00%	0.03%	0.00%	0.07%	0.20%
Terpineol	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.38%	0.00%
Methyl heptene 2-one	0.02%	0.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hexanal	0.02%	0.10%	0.03%	0.00%	0.05%	0.00%	0.00%	0.04%
Dimethyl hexene	0.00%	0.04%	0.00%	0.00%	0.13%	0.00%	0.00%	0.00%
Cyclohexanone	0.02%	0.07%	0.06%	0.00%	0.02%	0.00%	0.04%	0.00%
2 Pentyl furan	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.06%	0.14%
Biogenic	0.00%	0.00%	0.00%	0.00%	0.04%	0.07%	0.14%	0.00%
Proionaldehyde	0.04%	0.03%	0.00%	0.00%	0.00%	0.00%	0.04%	0.14%
Methyl Isobutylketone, MIBK	0.01%	0.07%	0.00%	0.00%	0.02%	0.00%	0.02%	0.07%
Dichlorobenzene Isomers	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.07%	0.28%
Thujone	0.00%	0.03%	0.00%	0.00%	0.04%	0.00%	0.07%	0.03%
Xylene	0.04%	0.00%	0.03%	0.05%	0.00%	0.00%	0.02%	0.14%
Acetyl benzene	0.00%	0.08%	0.00%	0.00%	0.04%	0.00%	0.00%	0.00%
Methyl Butane	0.00%	0.00%	0.00%	0.27%	0.00%	0.00%	0.00%	0.09%
Ethyl benzene	0.00%	0.00%	0.00%	0.01%	0.10%	0.01%	0.00%	0.04%
Pinene Isomer	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%	0.01%	0.30%
Styrene + Xylene	0.00%	0.04%	0.00%	0.01%	0.00%	0.01%	0.02%	0.16%
Dichlorobenzene Isomers	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	0.23%
C3-benzene, TMB isomers	0.01%	0.00%	0.02%	0.04%	0.00%	0.07%	0.01%	0.17%
Terpinine	0.00%	0.00%	0.00%	0.00%	0.03%	0.04%	0.08%	0.04%
Methyl butanal	0.03%	0.00%	0.00%	0.00%	0.03%	0.00%	0.04%	0.07%
Hexanone	0.00%	0.00%	0.00%	0.00%	0.09%	0.00%	0.00%	0.00%
Ketone compound	0.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fenchone	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.07%	0.04%
Methyl cyclohexanone	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%
Furan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%	0.13%
Heptanol	0.00%	0.03%	0.00%	0.00%	0.01%	0.00%	0.03%	0.05%
C3-benzene, TMB isomers	0.00%	0.00%	0.03%	0.03%	0.00%	0.00%	0.00%	0.14%
Methylcyclopentane	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%	0.00%
Bornyl chloride	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pentane isomer	0.00%	0.01%	0.00%	0.04%	0.01%	0.00%	0.00%	0.04%
Toluene	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Terpineol isomer	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Decene	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pentenal	0.00%	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%
Hexenal	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Pentanol	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%	0.00%
Isopropenyl toluene	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%
Methyl butadiene	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Butene isomer	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Decanone	0.01%	0.00%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%
Heptane	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.01%	0.00%
Chlorobenzene	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%
Phenol	0.01%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Tulare County Compost	3-Jun-10	3-Jun-10	2-Jun-10	2-Jun-10	4-Jun-10	4-Jun-10	5-Jun-10	5-Jun-10
& Biomass, Inc	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**
May 2010	5 Days Windrow	5 Days Windrow	5 Days Windrow	5 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow	21 Days Windrow
Cumulative %	without Cap	without Cap	with Cap	with Cap	without Cap	without Cap	with Cap	with Cap
Wood alcohol	80.59%	12.49%	55.97%	38.98%	40.41%	47.83%	69.40%	43.97%
Isopropanol	88.65%	87.45%	83.96%	58.47%	60.62%	71.74%	80.97%	65.95%
Ethanol	96.71%	93.70%	97.95%	97.46%	94.30%	95.66%	92.53%	87.93%
Acetone	97.68%	94.31%	98.33%	98.14%	94.81%	98.24%	93.72%	89.62%
Limonene	97.76%	95.02%	98.33%	98.14%	95.24%	98.24%	94.88%	91.29%
Formaldehyde	98.28%	95.41%	98.64%	98.76%	95.38%	98.72%	95.28%	91.71%
Acetaldehyde	98.59%	95.62%	98.89%	99.11%	95.54%	99.16%	95.63%	92.03%
Eucalyptol	98.62%	95.76%	98.89%	99.11%	95.87%	99.16%	96.29%	92.87%
alpha-Pinene	98.67%	96.16%	98.89%	99.11%	95.96%	99.21%	96.60%	93.94%
Heptanone	98.67%	96.59%	98.89%	99.11%	96.21%	99.21%	96.60%	93.94%
Butylaldehyde	99.06%	96.72%	98.93%	99.24%	96.22%	99.40%	96.70%	94.02%
1 Methyl, 3-1-methyl ethyl benzene/ Cymene	99.09%	96.90%	98.95%	99.25%	96.36%	99.41%	97.04%	94.31%
2 Methyl 1-propene	99.09%	97.14%	98.95%	99.25%	96.36%	99.41%	97.29%	95.06%
allyl anisol	99.09%	97.14%	99.39%	99.36%	96.51%	99.60%	97.43%	95.15%
Octanone	99.09%	97.28%	99.39%	99.36%	96.93%	99.60%	97.43%	95.15%
Ethyl Hexane	99.09%	97.32%	99.39%	99.36%	97.40%	99.60%	97.43%	95.15%
Terpineol	99.09%	97.46%	99.39%	99.36%	97.69%	99.63%	97.43%	95.20%
Octanal	99.13%	97.59%	99.45%	99.44%	97.85%	99.63%	97.50%	95.28%
Methyl heptanone	99.16%	97.75%	99.66%	99.50%	97.85%	99.63%	97.56%	95.57%
Octane	99.16%	97.78%	99.66%	99.50%	98.27%	99.63%	97.56%	95.57%
cis-Linalool oxide	99.16%	97.78%	99.66%	99.50%	98.35%	99.63%	98.12%	95.57%
2 Nonanone	99.16%	97.91%	99.66%	99.50%	98.60%	99.63%	98.12%	95.57%
Carene isomers	99.18%	98.07%	99.66%	99.50%	98.60%	99.63%	98.31%	95.90%
Nonanal	99.20%	98.21%	99.66%	99.50%	98.75%	99.72%	98.36%	95.99%

2 Pentanone	99.21%	98.51%	99.66%	99.50%	98.78%	99.72%	98.41%	95.99%
Ethyl hexanol	99.21%	98.58%	99.72%	99.50%	98.86%	99.72%	98.55%	96.21%
Camphor	99.63%	98.58%	99.72%	99.50%	98.86%	99.72%	98.55%	96.21%
Heptanal	99.65%	98.71%	99.74%	99.50%	98.97%	99.72%	98.57%	96.29%
Trichlorobenzene	99.67%	98.71%	99.74%	99.50%	98.97%	99.72%	98.57%	97.22%
Ethyl cyclohexane	99.67%	98.71%	99.74%	99.50%	99.24%	99.72%	98.57%	97.22%
B-Pinene	99.69%	98.81%	99.74%	99.50%	99.27%	99.75%	98.63%	97.41%
Camphene	99.69%	98.89%	99.74%	99.50%	99.30%	99.75%	98.70%	97.60%
Terpineol	99.69%	98.89%	99.74%	99.50%	99.30%	99.75%	99.08%	97.60%
Methyl heptene 2-one	99.71%	99.08%	99.74%	99.50%	99.30%	99.75%	99.08%	97.60%
Hexanal	99.73%	99.18%	99.77%	99.50%	99.35%	99.75%	99.08%	97.65%
Dimethyl hexene	99.73%	99.22%	99.77%	99.50%	99.49%	99.75%	99.08%	97.65%
Cyclohexanone	99.75%	99.28%	99.84%	99.50%	99.51%	99.75%	99.11%	97.65%
2 Pentyl furan	99.75%	99.36%	99.84%	99.50%	99.51%	99.75%	99.17%	97.79%
Biogenic	99.75%	99.36%	99.84%	99.50%	99.55%	99.82%	99.32%	97.79%
Proionaldehyde	99.79%	99.39%	99.84%	99.50%	99.55%	99.82%	99.36%	97.93%
Methyl Isobutylketone, MIBK	99.80%	99.45%	99.84%	99.50%	99.56%	99.82%	99.38%	97.99%
Dichlorobenzene Isomers	99.80%	99.45%	99.84%	99.50%	99.56%	99.82%	99.45%	98.28%
Thujone	99.80%	99.49%	99.84%	99.50%	99.60%	99.82%	99.52%	98.31%
Xylene	99.84%	99.49%	99.87%	99.55%	99.60%	99.82%	99.54%	98.45%
Acetyl benzene	99.84%	99.57%	99.87%	99.55%	99.64%	99.82%	99.54%	98.45%
Methyl Butane	99.84%	99.57%	99.87%	99.82%	99.64%	99.82%	99.54%	98.54%
Ethyl benzene	99.84%	99.57%	99.87%	99.83%	99.73%	99.83%	99.54%	98.58%
Pinene Isomer	99.84%	99.57%	99.87%	99.83%	99.73%	99.86%	99.56%	98.89%
Styrene + Xylene	99.84%	99.60%	99.87%	99.84%	99.73%	99.88%	99.58%	99.05%
Dichlorobenzene Isomers	99.84%	99.60%	99.87%	99.84%	99.73%	99.88%	99.63%	99.28%
C3-benzene, TMB isomers	99.85%	99.60%	99.89%	99.88%	99.73%	99.94%	99.64%	99.45%
Terpinine	99.85%	99.60%	99.89%	99.88%	99.76%	99.98%	99.72%	99.49%
Methyl butanal	99.87%	99.60%	99.89%	99.88%	99.79%	99.98%	99.76%	99.56%
Hexanone	99.87%	99.60%	99.89%	99.88%	99.89%	99.98%	99.76%	99.56%
Ketone compound	99.98%	99.60%	99.89%	99.88%	99.89%	99.98%	99.76%	99.56%
Fenchone	99.98%	99.63%	99.89%	99.88%	99.89%	99.98%	99.83%	99.60%
Methyl cyclohexanone	99.98%	99.69%	99.89%	99.88%	99.89%	99.98%	99.85%	99.60%
Furan	99.98%	99.69%	99.89%	99.88%	99.89%	99.98%	99.91%	99.73%
Heptanol	99.98%	99.73%	99.89%	99.88%	99.89%	99.98%	99.94%	99.78%
C3-benzene, TMB isomers	99.98%	99.73%	99.92%	99.91%	99.89%	99.98%	99.94%	99.92%
Methylcyclopentane	99.98%	99.73%	99.92%	99.91%	99.95%	99.98%	99.94%	99.92%
Bornyl chloride	99.98%	99.78%	99.92%	99.91%	99.95%	99.98%	99.94%	99.92%

Pentane isomer	99.98%	99.79%	99.92%	99.94%	99.96%	99.98%	99.94%	99.96%
Toluene	99.98%	99.84%	99.92%	99.94%	99.96%	99.98%	99.94%	99.96%
Terpineol isomer	99.98%	99.88%	99.92%	99.94%	99.96%	99.98%	99.94%	99.96%
Decene	99.98%	99.92%	99.92%	99.94%	99.96%	99.98%	99.94%	99.96%
Pentenal	99.98%	99.92%	100.00%	99.94%	99.96%	99.98%	99.94%	99.96%
Hexenal	99.98%	99.96%	100.00%	99.94%	99.96%	99.98%	99.94%	99.96%
Pentanol	99.98%	99.96%	100.00%	99.94%	100.00%	99.98%	99.94%	99.96%
Isopropenyl toluene	99.98%	99.96%	100.00%	99.94%	100.00%	99.98%	99.99%	99.96%
Methyl butadiene	99.98%	99.98%	100.00%	99.94%	100.00%	99.98%	99.99%	99.96%
Butene isomer	99.98%	100.00%	100.00%	99.94%	100.00%	99.98%	99.99%	99.96%
Decanone	99.99%	100.00%	100.00%	99.98%	100.00%	99.98%	99.99%	99.96%
Heptane	99.99%	100.00%	100.00%	99.98%	100.00%	100.00%	100.00%	99.96%
Chlorobenzene	99.99%	100.00%	100.00%	99.98%	100.00%	100.00%	100.00%	100.00%
Phenol	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Source Reference Notes (bibliography)

Papers on ozone formation using the mobile chamber:

Cody J. Howard, Wenli Yang, Peter G. Green, Frank Mitloehner, Irina L. Malkina, Robert G. Flocchini, Michael J. Kleeman. *Direct Measurements of the Ozone Formation Potential from Dairy Cattle Emissions Using a Transportable Smog Chamber*, Atmospheric Environment 2008. Vol 42, issue 21, pp 5267-7

Anuj Kumar, Wenli Yang, Cody J. Howard, Michael J. Kleeman, Doniche Derrick, Peter G. Green, *Assessment of the Ozone Formation Potential from Pesticide Solvents Using a Mobile Ozone Chamber Approach*, Journal of ASTM International 2008 (5) 7.

Cody J. Howard, Anuj Kumar, Frank Mitloehner, Kimberly Stackhouse, Peter G. Green, Robert G. Flocchini, and Michael J. Kleeman, *Direct Measurements of the Ozone Formation Potential from Livestock and Poultry Waste Emissions*, Environmental Science and Technology 44, pp 2292-2298 (2010).

Cody J. Howard, Anuj Kumar, Irina Malkina, Frank Mitloehner, Peter G. Green, Robert G. Flocchini, and Michael J. Kleeman, *Reactive Organic Gas Emissions from Livestock Feed Contribute Significantly to Ozone Production in Central California*, Environmental Science and Technology 44, pp 2309-2314 (2010).

Anuj Kumar, Cody Howard, Doniche Derrick, Irina L. Malkina, Frank M. Mitloehner, Michael J. Kleeman, Wenli Yang, Robert G. Flocchini and Peter G. Green, *Determination of volatile organic compound emissions and ozone formation potential from spraying solvent-based pesticides*, Journal of Environmental Quality (in press). Special Issue on Pesticide Formulations likely early 2011.

Irina L. Malkina, Anuj Kumar, Peter G. Green, and Frank M. Mitloehner, *Identification and quantifitation of volatile organic compounds emitted from dairy silages and other feedstuffs*, Journal of Environmental Quality (in press).

Anuj Kumar, Chris Alaimo, Robert Horowitz, Frank Mitloehner, Michael J. Kleeman, and Peter G. Green, *Volatile Organic Compound Emissions from Compost: Characterization and Ozone Formation*, Atmospheric .Environment. Under final, minor revisions prior to acceptance.

Key papers by William Carter on ozone reactivity:

Author(s): Atkinson, R; Carter, WPL, *Kinetics and Mechanisms of the Gas-Phase Reactions of Ozone with Organic Compounds Under Atmospheric Conditions*, Chemical Reviews, Volume: 84, Issue: 5, Pages: 437-470, 1984

Carter, WPL, *Development of Ozone Reactivity Scales for Volatile Organic Compounds*, Journal of the Air & Waste Management Association, Volume: 44 Issue: 7 Pages: 881-899 : July 1994

Carter, WPL, Pierce, JA, Luo, DM et al, *Environmental Chamber Study of Maximum Incremental Reactivities of Volatile Organic Compounds*, Atmospheric Environment, Volume: 29 Issue: 18 Pages: 2499-2511 September 1995

Carter, WPL; Luo, DM; Malkina, IL *Investigation of the atmospheric reactions of chloropicrin*, Atmospheric Environment, Volume: 31 Issue: 10 Pages: 1425-1439 May 1997

For a complete list of all William Carter's papers and reports:

http://www.engr.ucr.edu/~carter/wplcpubs.htm

Links to all his programs including list of reactivities:

http://www.engr.ucr.edu/~carter/wplcpubs.htm

Direct link to all reactivities:

http://www.engr.ucr.edu/~carter/SAPRC/scales07.xls