

## Quantifying volatile organic compound (VOC) emissions from composting operations

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Add emissions to the list of things to test for during composting. Over the past decade more and more regulatory agencies have begun to require that composters measure both volatile organic compounds (VOCs) and ammonia emissions. This started in California in regions where Air Quality Management Districts (AQMDs) were not meeting air quality standards for reducing smog. Quantifying air emissions is becoming an increasingly common component in permitting and operating permits for compost facilities in the US and Canada. In other words, these requirements are not going away in the near future. In fact, they may be coming to an air quality district near your operation.

While compost operators have been monitoring emissions of odorous compounds as a way to keep neighbors happy and keep their gates open, measuring emissions as a component of regulatory compliance is a different deal. A majority of regulations are concerned with all non-methane, non-ethane organic compounds (NMNEOC) and ammonia, whether they smell like rotten eggs or perfume. A subset of this broad class of compounds as well as ammonia can react with nitrogen oxide (NO<sub>x</sub>) to form ground level ozone and smog. This potential is the basis for current regulations. Regulations have opted for measuring VOCs in bulk rather than asking for concentrations of specific compounds of high concern. Regulations fall into two basic categories: those that require measurement via sample collection and analysis from operating facilities or those that use default values as a means to permit creation or expansion of compost facilities. In both cases, these regulations have been seen as a constraint to the larger goal of organics diversion from landfills and expanding use of composts to promote soil carbon sequestration and soil health (Thao et al. 2011)

### *BOX*

*What are VOCs?*

*“Volatile organic compound” is the broad term used to describe any carbon-containing chemical that will evaporate. A subset of these compounds can be detected by smell, with an even smaller subset having an odor that would be considered offensive. Another subset (with some potential overlap) contains compounds that can harm people if they are exposed in high enough doses for long enough periods of time. Another subset, which regulators are concerned with, can contribute to the formation of smog and ground-level ozone. It is important to realize that most of the VOCs coming off of compost piles are light alcohols (80%) with minimal odor, human health impact or smog forming potential (Green 2010). Figure 1 below demonstrates that the variety of forms composting emissions come in. All of these are compounds subject to compost air emissions regulations in states with compost emissions standards, however, most of them are not the smog and ground-level ozone-forming subset that are actually driving these regulations.*

While regulations are currently focused on NMNEOCs, there is a potential for regulations to expand to include requirements to measure gases that have high climate impacts. Methane and nitrous oxide are the two primary gases that have been detected during composting that would fall into this category.

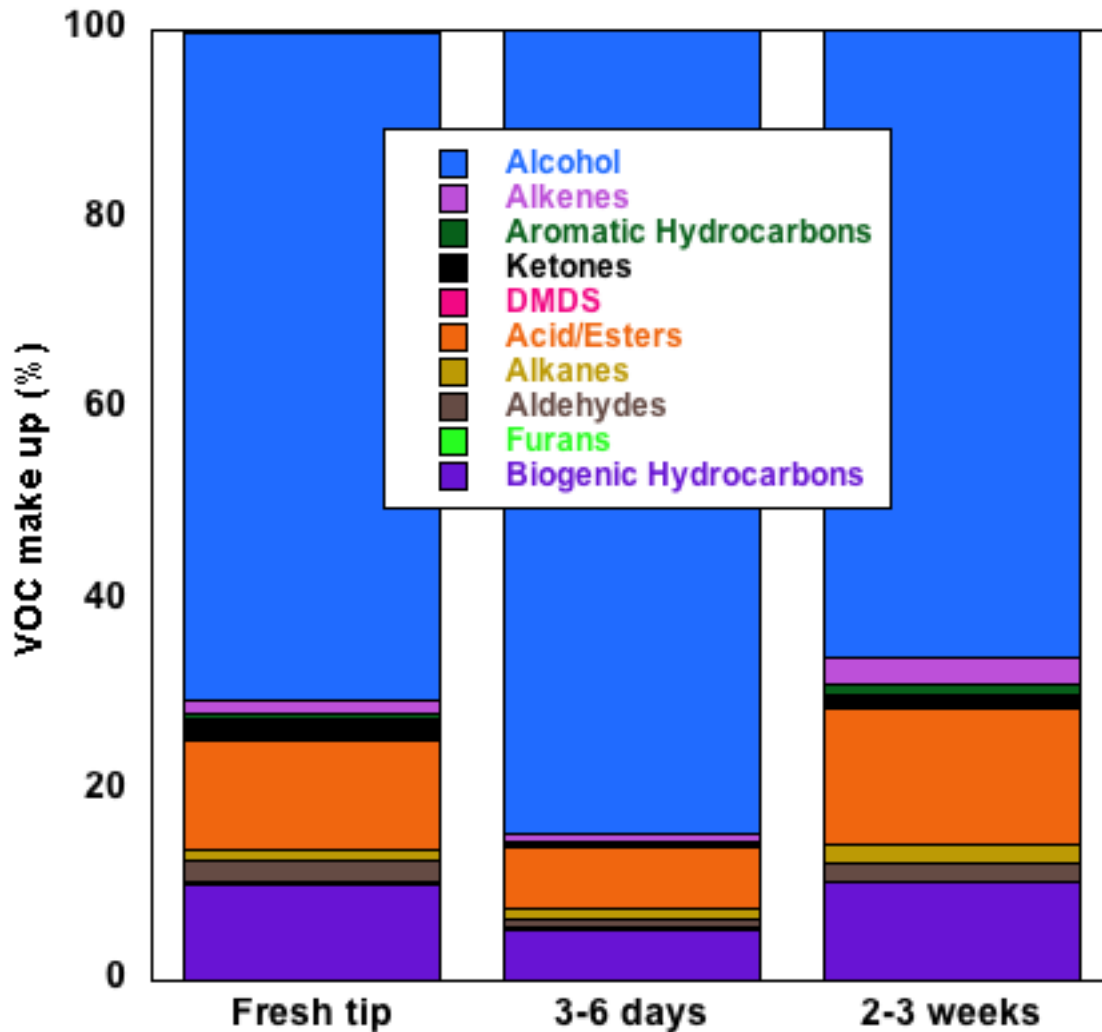


Figure 1 - A profile of VOCs over time from a green waste composting operation. These samples were collected using wind tunnels and flux chambers with gas collected in Summa cannisters and charcoal tubes and analyzed with a GC-MS. About 90% of the measured VOCs were non-ozone-forming (Kumar et al., 2011).

One of the main concerns with the existing methods and requirements for VOC sampling is the high cost of sample collection. A second concern is that point-in-time samples collected over very small areas, as is currently required, may not reflect what is actually going on during composting. Emissions will be different over time and under different aeration or turning events, as shown in the graphs in Figures 2 and 3 below. Point-in-time samples provide, at best, a short-term localized glimpse of what emissions are actually occurring. Think of it as taking a picture

of a single letter and trying to extrapolate a paragraph from that letter. A description of measurement methods makes this clear.

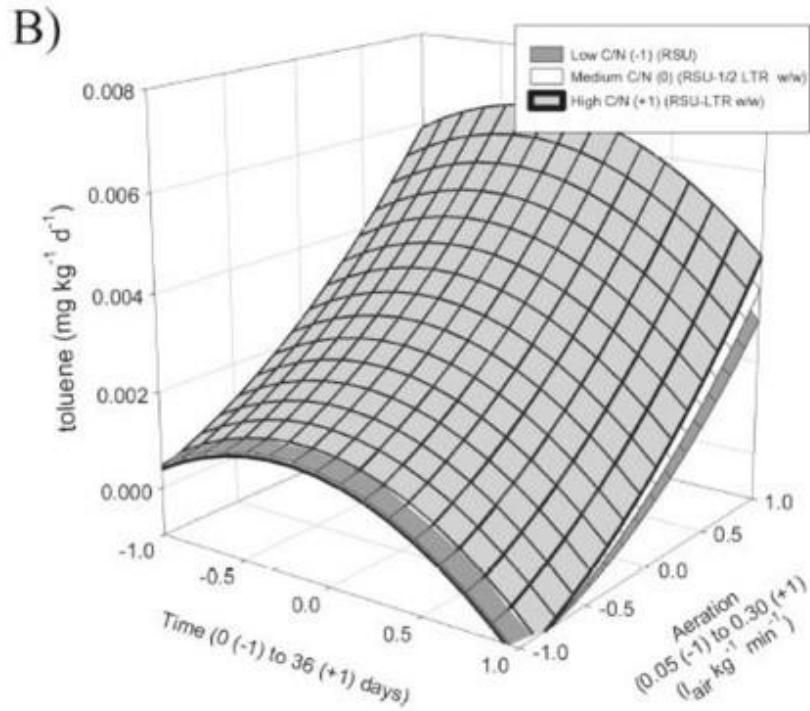


Figure 2 – Toluene emissions are variable over time and with different aeration (Delgado-Rodriguez et al., 2011)

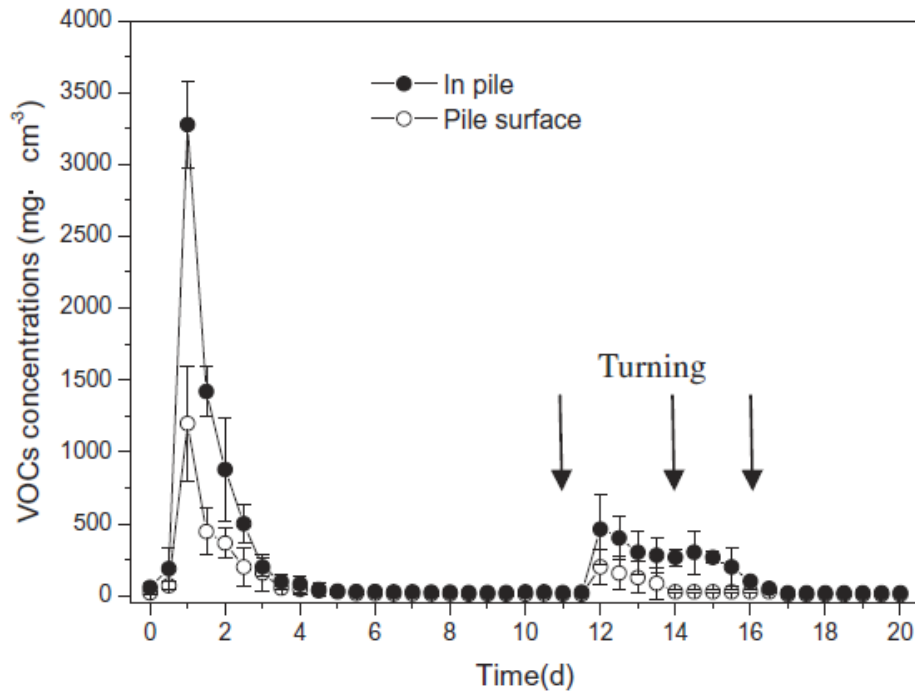


Figure 3 – VOC concentrations over time, with a turning event (Shen et al., 2012)

## How to measure VOCs

The first issue with sampling ammonia and VOCs is where to collect the sample. Options fall into three categories:

1. Direct emissions consist of air samples taken from the surface of the compost pile with sampling equipment in physical contact with the feedstocks. Compost piles in commercial facilities generally cover hundreds to thousands of square feet and active composting takes place over multiple weeks. As the size of the different sampling equipment is typically under 0.1% of the surface area of compost piles and sampling times are generally a few hours at most, sampling directly from the surface of a pile limits the ability to understand how measured emissions will vary over space and time. Two tools for taking direct measurements, the flux chamber and the wind tunnel, are shown in Figure 4 below.

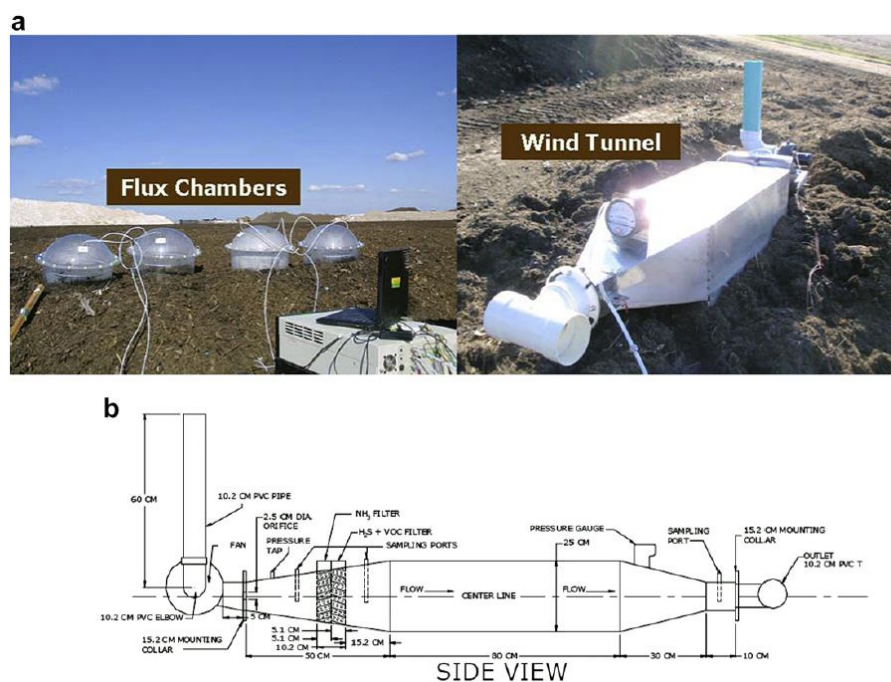


Figure 4 – Flux chambers and a wind tunnel are placed on the surface of the compost pile for direct emissions sampling (Kumar et al 2011)

2. Indirect emissions consist of samples collected somewhere within a composting operation but not in direct contact with the pile. Indirect samples have similar concerns as direct samples – namely, only collecting a fraction of the total air in a facility. Indirect samples, especially with online monitoring equipment, have the ability to capture variation over space and time; however, this potential would depend on use of sample capture detection equipment such as electronic noses and can be biased due to external air influences.
3. Fenceline monitoring refers to samples collected from the property boundary. This type of sampling has typically been done to assess odors from a facility. For VOCs, fenceline sampling has all of the errors associated with direct and indirect sampling, with more additional air and wind thrown in.

The second issue with measuring VOCs and ammonia is how to actually collect and analyze the air sample. The methodologies for sample collection and analysis that have become the *de facto* standard methods for many compost facilities in the western US are the South Coast Air Quality Management District (SCAQMD) Methods 25.3 and 207.1, for NMNEOCs and ammonia, respectively. These methods are a modified EPA flux chamber method outlined in SCAQMD's Rule 1133.3 *Emission Reductions from Greenwaste Composting Operations*. A flux chamber is placed on top of the compost pile and a carrier gas is introduced into the chamber at a controlled rate. Emissions from the pile enter the chamber and are pushed by the carrier gas into a cold trap, which traps low-concentration VOCs. The rest of the emissions are ultimately collected into a SUMMA canister, where an inert gas purges any CO<sub>2</sub> out of the container. The SUMMA canister and cold trap are pictured in Figure 5 below. An alternative collection device to the flux chamber is a wind tunnel. Somewhat larger than a flux chamber, the wind tunnel also requires a carrier gas. In this case the gas moves in a fixed direction. Sample collection is the same. Two separate samples (the condensate trap sample and the container sample) are then taken to a lab for analysis.

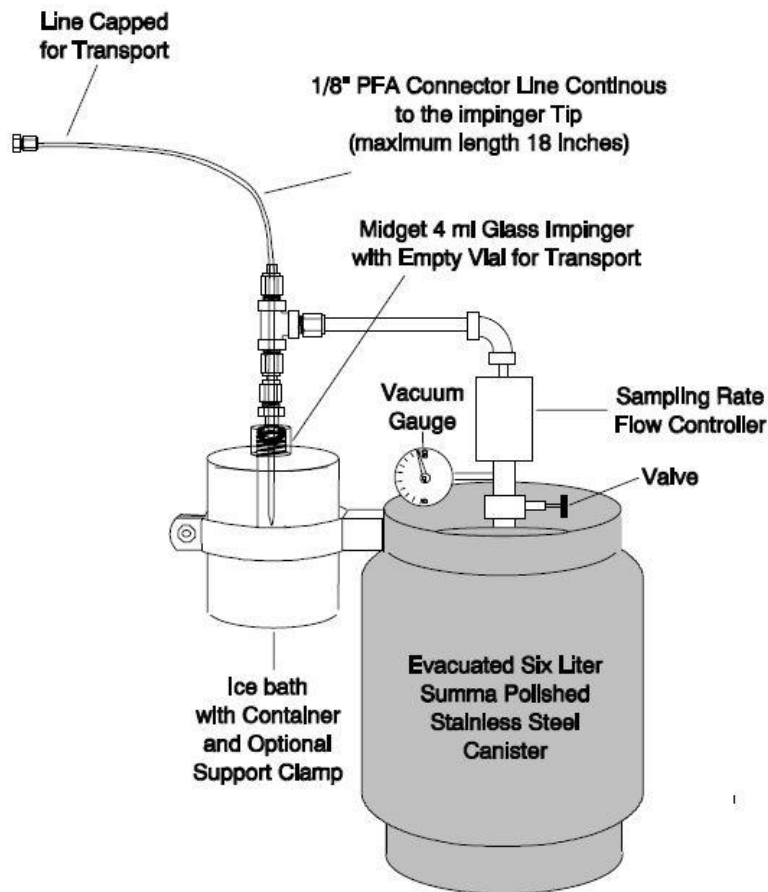
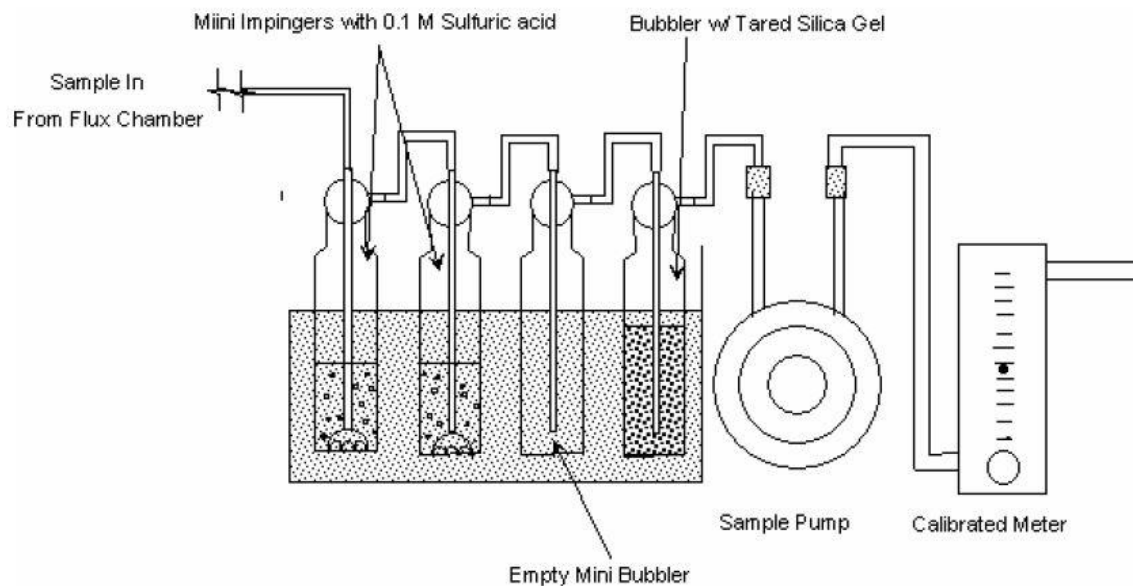


Figure 5 – The ice bath and Summa canister used for VOC sampling in SCAQMD Method 25.3 (South Coast Air Quality Management District, 2000)



*Figure 6 – Mini impingers used for quantifying ammonia in SCAQMD Method 207.1 (South Coast Air Quality Management District, 2006)*

In the lab the samples are separated for ammonia and VOC analysis. The ammonia concentration is calculated by titration (South Coast Air Quality Management District, 2006). The impingers used in this process are shown in Figure 6 above. The VOC concentration (ppmC) is calculated by essentially burning the sample. The different carbon compounds will all volatilize and burn. A flame ionization detector (FID) is used to calculate the VOCs based on how much carbon has burnt for each sample (South Coast Air Quality Management District, 2000). This protocol results in three separate analyses for two air samples from one sampling event, adding to the time requirements and costs for regulatory compliance. This sampling method costs between \$1,000 and \$1,500 per sample location. Depending on the size of the facility, dozens of samples can be required. Although it is possible to calculate concentrations of individual compounds using similar equipment (different VOCs will have different ignition temperatures), this would result in greater expense per sample and is not currently required.

There are variations on these methods available. One example is EPA Method TO-12. Here ambient air is collected and pre-concentrated in a cryogenic chamber. Compounds are collected in a trap filled with argon that allows methane and other gases (non-VOC) to pass through. The trap is heated and the gases within the trap are analyzed with a FID (USEPA 1999).

In other areas default emission factors (EFs) are used to estimate total compost emissions in lieu of sampling for regulatory compliance. While this approach removes the financial burden associated with sampling, it can result in regulators reducing allowed compost throughput based on predicted emissions. In cases where AQMDs use EFs, the factors are typically based on older data and a very limited number of data points, as demonstrated by the published EFs in Table 1 below. This would fall into the comparing apples to oranges category of regulatory restrictions. In certain cases, facilities are only required to sample treated emissions, using default factors to

estimate uncontrolled emissions, allowing the facilities to estimate the effectiveness of their control systems (biofilters, etc.).

**Table 1.** An example of published compost emissions factors (EFs).

Group	Operation type/feedstock	VOC EF (lb/wet ton feedstock)	NH <sub>3</sub> EF (lb/wet ton feedstock)	Data points Used to Calculate EF (n)
<i>Regulatory Bodies</i>				
SCAQMD	Co-composting (Rule 1133.2)	1.78	2.93	3
	Green waste (Rule 1133.3)	4.25	0.46	Unknown
SJVAPCD (Clements <i>et al.</i> , 2010)	Stockpiled green waste, food waste and grape pomace	1.06	-	4
	Windrow composting green waste, food waste and grape pomace	5.71	-	4
	Windrow composting green waste, food waste and grape pomace	-	1.01*	3
	Windrow co-composting biosolids, animal manure, and poultry litter (taken from SCAQMD Rule 1133.2)	1.78	2.93	3
California Air Resources Board	Active composting green waste	3.58	-	9
	Active composting green waste	-	0.78	5
	Active co-composting green waste with biosolids/manure	1.78	2.93	3
	Stockpiled green waste	0.20	-	4
*NH <sub>3</sub> EF calculated by WA DOE using three data points from SJVAPCD				

This brief discussion highlights the variability in regulations governing emissions from composting. It is also important to understand that emissions will vary based on feedstocks, time, temperature, the specific point sampled on the pile and a myriad of other factors. This has been shown in the peer reviewed literature as well as from operating facilities (Degaldo-Rodriguez *et al.*, 2011).

**Table 2.** Range in compost emissions analytical results over one sampling event.

Sample Number		23
Average	<i>NMEOC</i>	14.3
Minimum	<i>ppmv from</i>	2.4
Maximum	<i>biofilter</i>	30.3
Std. Deviation	<i>surface</i>	7.4

**Table 3.** Range in uncontrolled emissions from one facility over four sampling events.

Year	NMNEOC	NH <sub>3</sub>
	<i>EF (lbs/ton)</i>	
2007	4.26	0.67
2009	1.65	0.42
2011	4.89	0.32
2013	2.18	0.74

For this project, we interviewed two of the largest, long-running compost facilities required to perform compost emissions analyses. As an example of some of the variability inherent in compost emissions analyses, Tables 2 and 3 above provide emissions data from these facilities. Table 2 summarizes data from one sampling event at an indoor ASP facility at which all process

air is treated through one large biofilter and Table 3 summarizes data from an outdoor ASP operation that uses a biofilter cap for emissions control. Table 2 indicates that samples collected from a biofilter during one sampling event ranged from 2.4-30.3 ppmv, with a standard deviation of 7.4. NMEOC ppmv - or varied by more than an order of magnitude, making it difficult to say what an emissions profile over time really looks like. Sampling from a biofilter has the advantage of some level of homogenization as the forced air is collected and dispersed through a consistent medium. In an operating facility sampling of uncontrolled emissions would likely reflect multiple stages of composting with some variations in temperature and humidity.

As an example of year-to-year variability, Table 3 indicates that emissions analysis indicated an almost 3-fold difference in VOC emissions from one test to the next without any significant changes in operation at the site in that time period.

### ***What this means to an operating facility***

At these two facilities, the AQMDs in which they are located require that emissions are reduced by 80% through different control technologies. Each facility is required to sample both uncontrolled (untreated) and controlled emissions. Both have consistently been able to meet the emissions reductions specified in the regulations. Frequency and number of samples required will be based on how big you are and where you are. A larger facility can be required to collect between 50-70 samples per sampling event, with a net cost of well over \$50,000. This is a fair chunk of change for numbers that may or may not represent actual emissions. The good news is that data from both facilities show control measures to be highly effective in meeting the required regulatory reductions.

### ***Silver bullets?***

Many regulations specify methods for measurements. These technologies would have to be accepted by regulatory agencies before they could replace existing methods. There are a number of alternatives out there to existing sampling technologies. It is not clear however, that any of them represent a viable alternative to what is already in place. You can use a hand-held tube such as the one depicted in Figure 7 to measure a particular compound. This is great and cost effective for the particular compound but does not provide you a number that you can show a regulator. You can also use hand held FIDs or PIDs (photoionization detector) rather than sending samples to a laboratory for analysis. In the two cases we found of side-by-side comparisons of NMNEOC and ammonia between hand-held devices and the SCAQMD methods, no correlations between results was found.



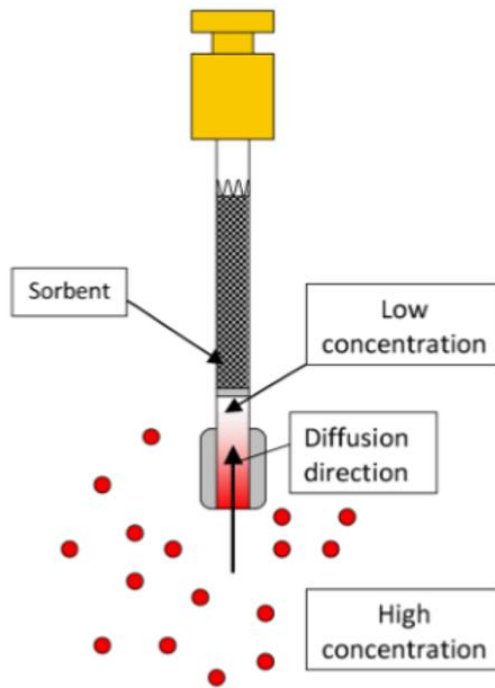


Image: Gradko environmental

Figure 7 – A passive sorbent sampling tube (Gradko Environmental, n.d.)

While not quite silver bullets, there are modifications to the SCAQMD methods available that would generate two samples rather than three from each sampling point by eliminating the need for a condensate trap (by heating the sample line) and analyzing the contents of the SUMMA canister as a single sample. There have been some air emissions studies that have used larger sample hoods in an attempt to capture variations across a pile, such as that shown in Figure 8 below (Amlinger, Peyr and Cuhls, 2008). While larger, these hoods still represent only a small fraction of total pile size. The goal of these larger hoods is to potentially reduce the number of samples required and lower costs. Side by side comparisons with existing methods have not been conducted.

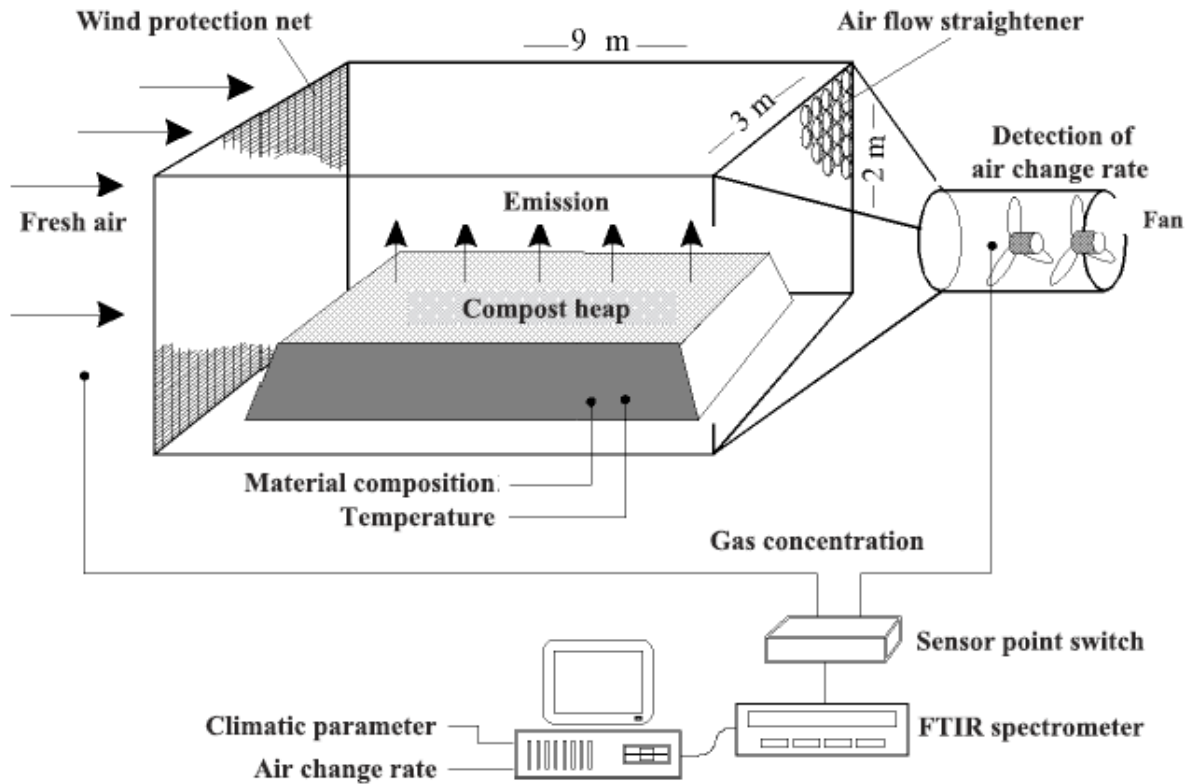


Figure 8 – A sampling hood that covers an entire compost heap (Amlinger, Peyr and Cuhls, 2008)

One technology with some promise is the electronic nose (e-nose), shown in Figure 9. The device is typically placed above a compost pile (indirect sample) and sensors within the device can offer real-time monitoring of emissions over time. Here time is defined as multiple samples per minute across weeks. E-noses have been used in the peer reviewed literature much more extensively than in real life. Typically, real life applications are for odor monitoring and conflict resolution between facilities and their neighbors, rather than VOC and ammonia measurement. At the present time, e-nose technology would not represent a cost savings.



Figure 9 – an electronic nose (Sensigent, n.d.)

On the futuristic end of things, there are some newer technologies to measure emissions indirectly with a relatively high degree of precision, but they are not yet commonly used and can be very expensive. One example is the Proton Transfer Reaction Time of Flight Mass Spectrometry (PTR-TOF-MS) method. Equipment is located in a van with a ‘snorkel’ on top. The van is driven around the emissions source while its equipment quantifies VOCs and reports results every second. A flux can be generated if a meteorological station is set up at the source. The second newer technology is the micrometeorological mass balance (MMB) method, wherein towers are set up around an emissions source, and they measure emissions with cavity ring-down spectrometers (Vergara, personal communication, August 23, 2019). The towers also have instruments to measure wind speed and direction attached to them. The total emissions from a source are calculated as the difference between upwind and downwind emissions.

### ***Conclusions/ recommendations***

If our goal really is to divert organics from landfills to compost piles, it would make sense to streamline regulatory requirements for composting, including those for VOC monitoring. There are multiple ways that this could be accomplished with minimal potential for compromised air quality near composting facilities. If emission factors are used instead of sampling, the development of a new standard table of EFs based on multiple studies and multiple sampling events from operating facilities would provide a much more robust basis for regulations. The data set from operating facilities could also be used to develop a better understanding of emissions based on feedstocks, local climate and operating parameters. These could then be used to further refine either sampling requirements or emission factors. Additional research could be conducted to confirm field results.

Another alternative could be using a combination of best management practices (BMPs) and emission factors. Process conditions have a large effect on emissions from composting. If regulators focused more on requiring BMPs, and if EFs were updated to accurately reflect emissions under different management practices, the combination could be more effective at diverting organic waste from landfills and reducing emissions of VOCs and NH<sub>3</sub> in a way that is both practical and cost-effective.

The desire to protect air quality in the vicinity of compost operations is commendable. We would encourage regulators to work with academics, source testing companies and composters to develop reasonable practices for both controlling and monitoring emissions. In this piece we've talked about comparing apples to oranges. Let's not lose sight of all the benefits associated with composting (protect the orchard as a whole) rather than splitting hairs over some potentially rotten fruit.

## References

- Amlinger, F., S. Peyr, and C. Cuhls. 2008. Greenhouse gas emissions from composting and mechanical biological treatment. *Waste Management & Research*. 26: 47-60.
- Delgado-Rodríguez, M., M. Ruiz-Montoya, I. Giraldez, R. López, E. Madejón, and M. Jesús Díaz. 2011. Influence of control parameters in VOCs evolution during MSW trimming residues composting. *J. Agriculture and Food Chemistry* 59: 13035-13042.
- Gradko Environmental. Photo of a passive sorbent tube. Gradko International Ltd. Winchester, SO23 0RH, United Kingdom. <file:///C:/Users/User/Downloads/how-do-sorbent-tubes-work.pdf>. Accessed 2 September 2019.
- Green, P. 2010. An investigation into the potential for ground-level ozone formation resulting from compost facility emissions. Contractor's report for CalRecycle. December 2010.
- Kumar, A., C. Alaimo, R. Horowitz, F. Mitloehner, M. Kleeman, and P. Green. 2011. Volatile organic compound emissions from green waste composting: characterization and ozone formation. *Atmospheric Environment*. 45: 1841-1848. 2011.
- Sensigent. Image of an electronic nose device. Sensigent. <http://sensigent.com/instrument.html>. Accessed 23 June 2020.
- Shen, Y., T.B. Chen, D. Gao, G. Zheng, H. Liu, and Q. Yang. 2012. Online monitoring of volatile organic compound production and emission during sewage sludge composting. *Bioresource Tech*. 123:463-470.
- South Coast Air Quality Management District. 2000. Method 25.3, determination of low concentration non-methane non-ethane organic compound emissions from clean fueled combustion sources.
- South Coast Air Quality Management District. 2006. Method 207.1, determination of ammonia emissions from stationary sources. Source Test Engineering/Laboratory Services, Monitoring and Analysis.
- Thao, K., K. Chan, B Clements, J. Sweet, D. Lowe-Leseth, G. Heinen, and L. Van de Water. 2011. *San Joaquin Valley Unified Air Pollution Control District final draft staff report – proposed new Rule 4566 (organic material composting operations)*. August 18, 2011.
- USEPA. 1999. Compendium of methods for the determination of toxic organic compounds in ambient air – second edition. Compendium Method TO-12, EPA US EPA, EPA/625/R-96/010b. USEPA, Office of Res. And Dev., Cincinnati, OH.
- Vergara, Sintana. Assistant Professor. Humboldt State University. Personal communication, August 23, 2019