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Keywords
Airflow, Air Sampling, Biosecurity, Compost, SPME, VOC

Disciplines
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Air sampling methods for VOCs related to field-scale biosecure swine mortality composting

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Abstract

Monitoring specific volatile organic compounds (VOCs) as markers of biosecure carcass degradation is a promising method to test progress and completion of the composting process. The objective of this study was to test the feasibility of using existing aeration ducts in composting units as practical sampling locations. The secondary objective was to test the feasibility of using marker VOC concentrations in aeration ducts to elucidate information about airflow patterns inside composting units. Marker VOC concentrations were significantly higher in the upper-aeration duct and this duct can typically be used to collect air samples instead of placing special air sampling probes inside the composting units. Occasionally, the airflow direction inside composting units can change. Marker VOC concentrations can be used to decide the airflow direction inside the composting units. In this study, higher VOC concentrations were measured from the upper aeration duct, and this duct was shown to be an outlet.

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Keywords. Airflow, Air Sampling, Biosecurity, Compost, SPME, VOC

1. Introduction

Iowa has led the USA in swine production for decades. Iowa inventory of all hogs and pigs in March 2010 was 19 million head which accounts for 30% of U.S. inventory (64 million head) (NASS, 2010). The intensive production of swine in one area inevitably results in the production of high number of animal carcasses. In case of an emergency situation such as fire, flooding, ventilation failure or disease outbreak, handling carcasses becomes a serious problem. The problem becomes more serious when carcasses are capable of spreading diseases to soil, plants, animals and humans (Imbeah, 1997, Kalbasi et al., 2005, Wilkinson, 2007, Stanford et al., 2009).

In the avian influenza outbreak in British Columbia (Canada) in 2004, approximately 1.25 million birds were infected and two flocks of the birds were disposed by composting. The first stage of the composting was conducted in the poultry houses. After five days, the windrows were re-formed and covered with vapor barriers, wood shavings, and black plastic sheets (Spencer et al., 2004). Glanville et al. (2009) investigated an application of this biosecure composting system to dispose diseased swine carcasses using field-scale composing units.

One of the major problems associated with biosecure composting is the safety concerns about exposure of diseased carcasses to the environment until carcass degradation is completed. Since the visual inspection of the carcasses is not possible, VOC production inside the composting units was monitored to determine the progress and completion of the composting process (Akdeniz et al., 2010a and b). Akdeniz et al. (2010a) evaluated and monitored VOC production inside the biosecure field-scale composting units. Akdeniz et al.

(2010b) conducted a laboratory scale composting study to supplement the field results. In these pioneering studies, it was reported that three VOCs (dimethyl disulfide, dimethyl trisulfide and pyrimidine) are marker compounds of swine carcass degradation and monitoring these VOCs is a promising and non-invasive method to test the progress and completion of the composting process. In the field scale composting study, VOCs were sampled through specially-constructed probes which allowed drawing air samples from the center of the composting units (Akdeniz et al., 2010a). Nevertheless, in an emergency situation, it is not possible to construct special gas sampling probes to collect VOC samples. In this study, practical VOC sampling locations that can be used in an emergency situation were investigated.

Another problem associated with the biosecure composting units was unstable airflow pattern. In the field-scale composting study, the swine carcasses were placed on top of the 30 cm plant (envelope) material and covered with an additional 60 cm of the same plant material used in the base (Glanville et al., 2009). In this type of biosecure composting systems, upward airflow (entering through lower duct and exiting through upper duct) is desirable since in upward airflow, air passes through the carcass layer and then the top plant layer where it is biofiltered before being exhausted. In previous studies, occasional periods of downward flow were observed. Odor emissions were observed during these periods as odorous air did not move through the clean biofilter material above the carcasses but instead through leachate contaminated layers beneath the carcasses and then out the lower ducts without benefit of biofiltration. In addition to determining the progress and completion of the biosecure composting process, in this study, marker VOC concentrations were used to determine airflow patters inside the composting units.

The objectives of the study were: (i) to test upper and lower aeration ducts in composting units as practical air sampling locations of marker VOCs and (ii) to test the feasibility of using marker VOC concentrations in aeration ducts to elucidate information about airflow patterns inside passively-ventilated composting units.

2. Materials and methods

The innovative composting system used during the 2004 avian influenza outbreak in British Columbia (Spencer et al., 2004) was modified and applied for composting of swine mortalities. The experiments were conducted from April to June at the Livestock Environment Building and Research Center of Iowa State University, Ames, Iowa. Three plant (envelope) materials, wood shavings, soybean straw, and alfalfa hay were used to cover swine carcasses. The dimensions of the composting units were 1.2 (height) × 2 × 2 m. The units were loaded with approximately 250 kg swine carcasses (four or five carcasses). The outsides of the units were insulated with Styrofoam plastic (5 cm thick). The composting units were aerated using passive aeration tubes beneath the swine carcasses. Plastic barriers were tightly placed on the top of each unit to minimize the risk of spreading pathogens to the surrounding environment. The plastic barriers were nailed to the side walls of the composting units. A schematic of the biosecure composting units was shown in Fig. 1. The details of the composting units were reported in Glanville et al. (2009) and Akdeniz et al. (2010a). In this study, only one lower and one upper aeration duct were open. The additional aeration ducts (Fig. 1) were sealed to prevent over-aeration and thus over-drying. The O_2 concentrations of the composting units exceeded 10% levels at all times in all layers (Glanville et al., 2009).

Air samples were drawn from the composting units using a pump (SKC 224-PCXR4, Eighty Four, PA) and flow meter (Dry Cal, DC-Lite, Bios, Butler, NJ). Air samples were collected inside 250 mL glass sampling bulbs (Supelco, Bellefonte, PA), and then the marker VOCs (dimethyl disulfide, dimethyl trisulfide, and pyrimidine) were sampled using an 85 µm Carboxen/PDMS (Polydimethylsiloxane) SPME (solid phase microextraction) fiber (Supelco, Bellefonte, PA) in a 1 h sampling time. SPME samples were run using a 6890N GC-5975 MS (Agilent Inc., Wilmington, DE) system. The details of VOC sampling and analysis were reported in Akdeniz et al. (2009) and Akdeniz et al. (2010a and b).

To test practical marker VOC sampling locations (objective 1), air samples were drawn from five different locations of the composting units. The specially-constructed vertical probes made from PVC (polyvinyl chloride) piping were placed in the center of the test units and were used to collect VOC samples from the bottom (plant), middle (decaying swine carcass), and top (plant) layers (depths) of the test units (Akdeniz et al., 2010a). In addition to these sampling locations, VOC samples were also collected from the upper and lower aeration ducts representing a much simpler alternative to the specially-constructed probes with air sampling lines (Fig. 1). Air samples were collected in the third week of the composting process since first three weeks are known to be the most active phases of the process (Haug, 1993; Akdeniz et al., 2010a).

To test airflow patterns inside the composting units (objective 2), measured marker VOC concentrations from the upper and lower ducts were compared. The aeration duct with lower marker VOC concentration was assumed to be an inlet.

Three independent composting units were prepared for each envelope material (3 composting units×3 envelope materials=9 composting units). Analysis of variance

(ANOVA) tests were conducted using JPM software version 6.0.2 from SAS (SAS Institute Inc, Cary, NC). Concentrations of marker VOCs collected from bottom, middle, and top layers and upper and lower aeration ducts were compared using Tukey's honestly significant differences (HSD) at the significance level $P \leq 0.05$. The relative standard deviation (% RSD) was obtained by dividing the standard deviation by the average and then multiplying this value by 100.

3. Results and discussion

Measured concentrations of the marker compounds for five different sampling locations are shown in Fig. 1. The sampling locations can be ranked from the highest concentration to the lowest as follows: middle layer ≈ upper aeration duct > top layer> bottom layer ≈ lower aeration duct (Fig. 2). The relative standard deviation of the data ranged from 0.2 to 22.04%. Marker VOC concentrations were significantly higher in the middle layer and upper aeration duct of the test units compared to the other sampling locations. The high concentrations of the marker compounds in the middle (carcass) layer were expected since these compounds were found to be produced by decaying swine carcasses (Akdeniz et al., 2010b). The high concentrations of the upper aeration duct indicated that this duct serves as an air outlet, and that marker VOCs produced in the middle layer were carried there by the passive airflow inside the composting units. The second highest concentrations of the marker compounds were measured from the top layer. It is challenging to explain the difference in concentrations between the top layer and upper-aeration duct. Although there is no solid evidence, it might be caused due to preferential flow through macro-pores or channels in the top layer of the compost material. The fresh air introduced through the bottom duct may have flowed upward where the density of the cover material was lower compared to other zones. Based on these findings, it can be concluded that middle layer and the air outlet are the best sampling locations to collect air samples. In case of an emergency situation when there is no time to construct gas sampling probes to collect samples from the middle layer, the air outlet (in this study the upper aeration duct) can be used to collect air samples. In this study, one upper and one lower aeration duct were open and the additional aeration ducts were sealed. Even if the additional ducts were not sealed, still upper aeration duct could be used to collect samples. In this type of systems, upward airflow is expected as it is predicted by chimney flow theory, i.e., air inside chimney has a lower density than cooler outside air which causes the chimney air to rise and flow through the carcass layer and then through the upper plant material).

One possible problem associated with collecting VOC samples from an aeration duct is that the airflow pattern inside the composting unit may alternate from the upward to downward. These variations are likely due to the change in plant material porosity, temperature, and ambient wind velocity and direction. Thus, it is important to determine which aeration duct serves as an outlet before deciding on the VOC sampling location. Airflow direction inside the composting units can be determined by collecting VOC samples from the upper and lower aeration ducts. If the lower aeration duct serves as an outlet, then the marker VOC concentrations should be higher at this location. In this system, upward airflow is desirable since it helps to biofilter the air. If the airflow direction is found to be downward, it could be changed to upward by employing additional aeration ducts at different heights and locations. Proper sealing of the plastic barriers with the composting units is also needed to encourage upward passive aeration through the compost material.

More studies are needed to develop practical passive airflow control methods for biosecure composting systems.

4. Conclusions

No significant difference was found in marker VOC concentrations measured from the middle layer (depth), where the carcasses are located, and the upper-aeration duct. These two locations are both recommended but the upper-aeration duct might be a more practical location to sample marker VOCs. However, the upper aeration duct may not always be a reliable sampling location as the airflow direction inside the composting unit could change depending on many internal and external factors. The airflow direction of the composting units can be determined by sampling marker VOCs. In this study, higher concentrations of the VOCs were measured from the upper aeration duct so this duct was shown to be an outlet (upward airflow).

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References

Akdeniz, N., Koziel, J.A., Ahn, H.K., Glanville, T.D., Crawford, B.P., Raman, R. D., 2009. Air sampling and analysis for VOCs related to field-scale mortality composting operations. J. Ag. Food Chem. 57, 5658-5664.

Akdeniz, N., Koziel, J.A., Ahn, H.K., Glanville, T.D., Crawford, B.P., 2010a. Field scale evaluation of volatile organic compound production inside biosecure swine mortality composts. Waste Manage. 30: 1981-1988.

Akdeniz, N., Koziel, J.A., Ahn, H.K., Glanville, T.D., Crawford, B.P., Raman, R. D., 2010b. Laboratory scale evaluation of volatile organic compound emissions as indication of swine carcass degradation inside biosecure composting units. Bioresour. Technol. 101: 71-78.

Glanville, T.D., Ahn, H.K., Crawford, B.P., Koziel, J.A., Akdeniz, N., 2009. Perfomance evaluation of a biosecure emergency composting system for disposal of swine carcasses. ASABE Annual International Meeting, St Joseph, MI paper no. 096342.

Haug, R.T., 1993. The Practical Handbook of Compost Engineering. Lewis Publishers, Boca Ratan, FL.

Imbeah, M., 1997. Composting piggery waste: A review. Bioresour. Technol. 63, 197-203.

Kalbasi, A., Mukhtar, S., Hawkins, S.E., and Auvermann, B.W., 2005. Carcass composting for management of farm mortalities: A review. Compost Sci. Utilization 13, 180-193.

NASS (National Agricultural Statistics Service), 2010. Agricultural Statistics Board, U.S. Department of Agriculture. Online available at http://usda.mannlib.cornell.edu/usda/current/HogsPigs/HogsPigs-03-26-2010.pdf (access date 5/21/2010).

Spencer, J.L., Rennie, B., Guan. J., 2004. Emphasis on biosecurity for composting poultry and manure during an outbreak of highly pathogenic avian influenza in British Columbia. Canadian Animal Health Net Bulletin. Winter 2004, edition 9, 21-23.

Stanford, K., Hao, X., Xu, S., McAllister, T.A., Larney, F., Leonard, J.J., 2009. Effects of age of cattle, turning technology and compost environment on disappearance of bone from mortality compost. Bioresour. Technol. 100, 4417-4422.

Figure captions

Fig. 1. The cross-sectional view of the biosecure composting units. Aeration ducts, air sampling locations and air sampling from the middle layer (depth) are shown. The size of the gas sampling probe was enlarged to clearly show sampling locations and tubes. The diameter and height of the probe was 0.4 and 1.2 m, respectively.

Fig. 2. Comparison of mean (N=3) marker VOC concentrations during third week of composting at five different sampling locations. Means (within a compound) that are not associated with the same letter are significantly different ($P \leq 0.05$). The method detection limits were 1.1, 5.5, and 0.011 ppbv for dimethyl disulfide, dimethyl trisulfide, and pyrimidine, respectively.

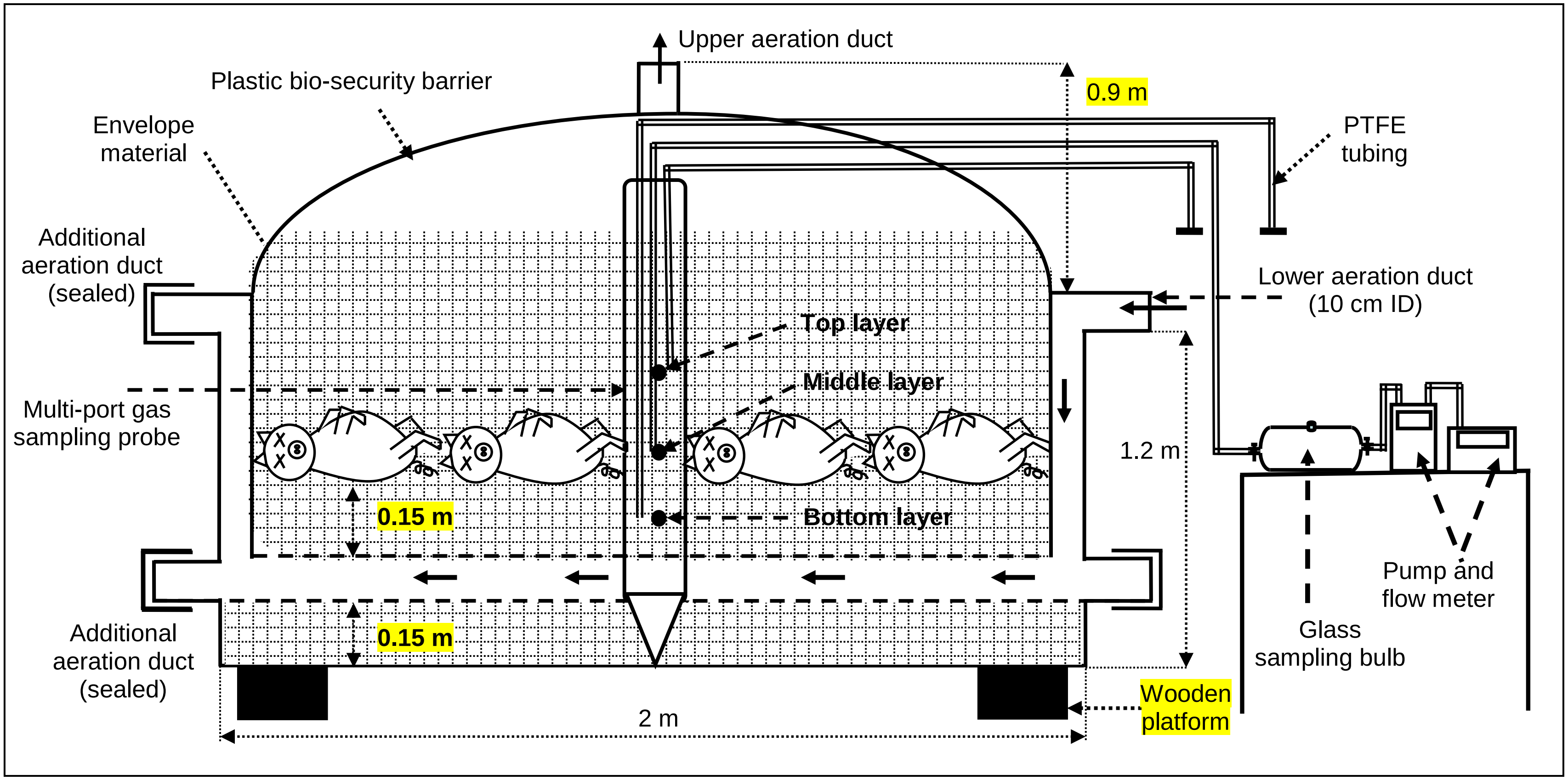
Upper aeration duct
Plastic bio-security barrier
0.9 m
Envelope material
PTFE tubing
Additional aeration duct (sealed)
Lower aeration duct (10 cm ID)
Top layer
Middle layer
Multi-port gas sampling probe
1.2 m
0.15 m
Bottom layer
Pump and flow meter
Glass sampling bulb
0.15 m
Additional aeration duct (sealed)
Wooden platform
2 m

Fig. 1.

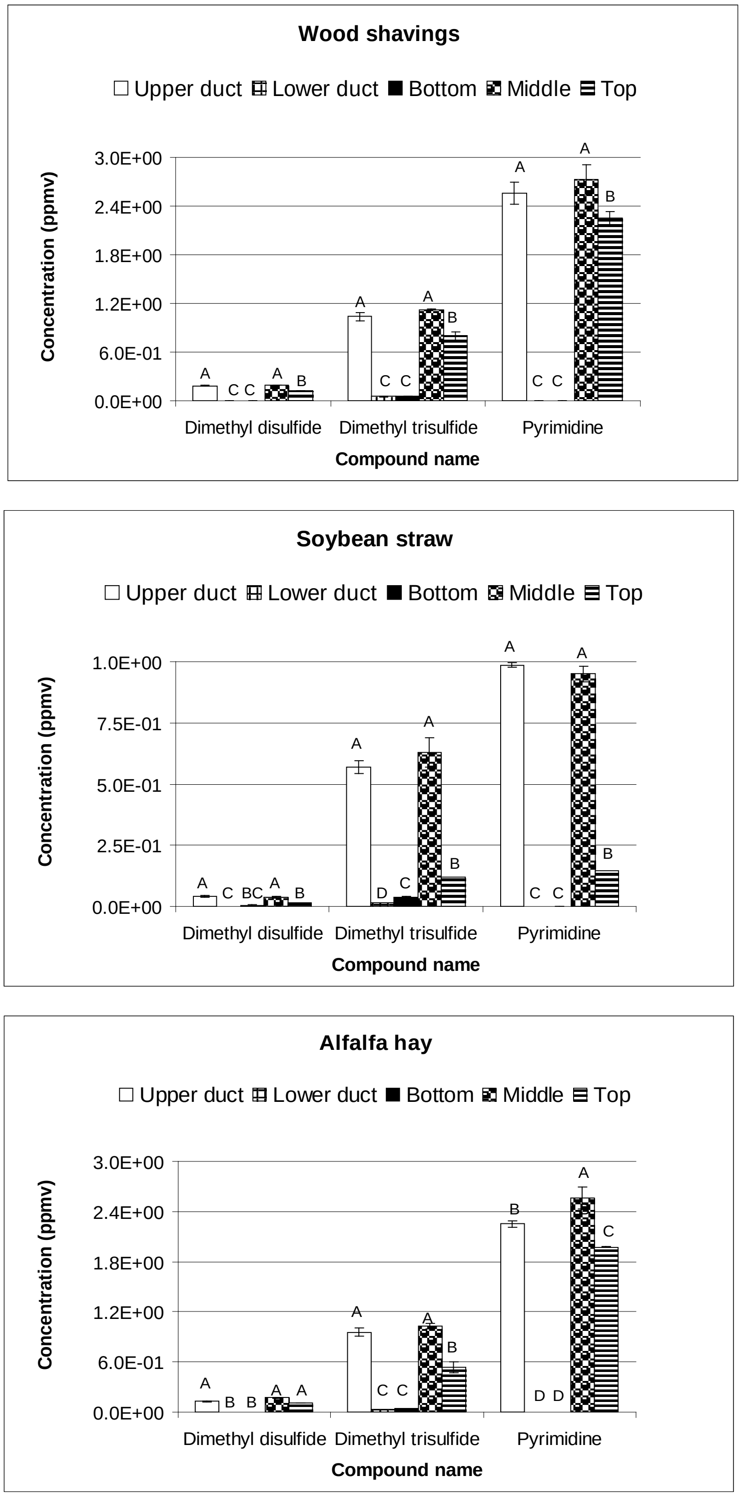
Wood shavings
☐ Upper duct ⊞ Lower duct ■ Bottom Middle Top
Concentration (ppmv)
3.0E+00
2.4E+00
1.8E+00
1.2E+00
6.0E-01
0.0E+00
Dimethyl disulfide
Dimethyl trisulfide
Pyrimidine
Compound name
Soybean straw
☐ Upper duct ⊞ Lower duct ■ Bottom Middle Top
Concentration (ppmv)
1.0E+00
7.5E-01
5.0E-01
2.5E-01
0.0E+00
Dimethyl disulfide
Dimethyl trisulfide
Pyrimidine
Compound name
Alfalfa hay
☐ Upper duct ⊞ Lower duct ■ Bottom Middle Top
Concentration (ppmv)
3.0E+00
2.4E+00
1.8E+00
1.2E+00
6.0E-01
0.0E+00
Dimethyl disulfide
Dimethyl trisulfide
Pyrimidine
Compound name

Fig. 2.