A PLANT MATERIAL-BASED AIR PURIFICATION SYSTEM FOR SWINE ODOUR REDUCTION

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Keywords: Swine odour, Health symptom, Plant material-based air purification (PMAP), Hydrogen sulphide, Ammonia, Pig manure, Concentration, Olfactometer.

Abstract: Environmental odour not only serves as a warning of potential health risks, but the odour sensation themselves can also cause health symptoms , such as headaches, nausea, sore throat, cough, chest tightness, nasal congestion, shortness of breath, stress, drowsiness, asthma, chronic bronchitis, and alterations in mood. Swine odour consists of a mixture of volatile organic compounds (VOCs), hydrogen sulphide, ammonia as well as particulates which adsorbed odourous compounds. A plant material-based air purification (PMAP) system was evaluated for odour reduction in this study. The PMAP consisted of a mixture of plant materials which emit volatiles. Measurement was performed in two identical plastic boxes using pig manure, hydrogen sulphide and ammonia gases as odourous source. The PMAP device was placed in only one of the boxes. The results showed that PMAP reduced the intensity of swine odour by at least 50%, the concentration of hydrogen sulphide from 20 ppm to 0.2 ppm for a pure hydrogen sulphide source and from 0.4 to 0.02 ppm for a swine manure source. Similarly, the PMAP reduced ammonia concentration from 29 to near 0 ppm for a pure ammonia source and from 38 to 10 ppm for the swine manure source.

1 INTRODUCTION

The impact of swine odour on the environment is one of the major concerns to the general public.
Historically, unpleasant odours have been considered as warning signals of potential risk to human health, but not necessarily directly result in health effects (Phillips, 1992; Gardner, et al., 2000). Recent studies have demonstrated that odours may not only serve as a warning signal of potential health risk, but odour sensations themselves can evoke health symptoms, including headaches, nausea, sore throat, cough, chest tightness, nasal congestion, shortness of breath, stress, drowsiness, asthma, chronic bronchitis, and alterations in mood, etc. (Wing et al. 2000; Schiffman et al., 2005;). There are at least three mechanisms responsible for the health symptoms caused by the odour. (1) When the concentration of odorous compounds in the air is above the irritation threshold, it will directly produce the health symptoms by irritation. (2) When the concentration of odorous compounds is below the irritation or safety threshold but above the odour detection threshold, many health symptoms can also occur psychophysically. This psychophysical effect caused by odour sensation may occur at very low odorant concentrations. For example, H_2S gas has a rotten eggs smell. Its odour detection threshold ranges from 0.5 to 30 ppb while its irritation threshold ranges from 2.5 to 20 ppm (Schiffman et al., 2005). This means the average odour threshold of H_2S is about three orders of magnitude below its irritation threshold. (3) Copollutant in an odour mixture is responsible for some health symptoms (Donham, et

Zhou X., Zhang Q. and Huang A..
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DOI: 10.5220/0003127101200124
In *Proceedings of the International Conference on Biomedical Electronics and Devices* (BIODEVICES-2011), pages 120-124
ISBN: 978-989-8425-37-9

al., 1999).

How to reduce and eliminate the swine odour that evokes health complaints and impairs quality of life in neighbouring communities has attracted attention of researchers worldwide. Several techniques have been developed to reduce the swine odour emission, such as biofiltration, ozonation, covering the manure storage, and ultraviolet light (DeBruyn et al., 2001; Mann et al., 2002; Riley et al., 1989; Vohra et al., 2006).

The existing technologies have various drawbacks. For example, it is known that the ozone itself contributes to air pollution although ozone can oxidize odour compounds. In other words, the use of ozone to reduce swine odour may cause secondary pollution. Ultraviolet light used in the pig barn over a period of time may be harmful to both the pigs and operators and it is also expensive. The Biofiltration have been used to treat exhaust air from pig barns for odour reduction, but it might cause cross contamination if used inside the pig barns.

Plant-based aromatic materials have been used as air fresheners in many different parts of the world (Heath et al., 1992; Zeng et al., 2003). Recently, a process has been developed to produce a nano-crystalline material from extracts of several plants (or herbs) to air purification (Zhao et al., 2006). All the constituents in this material are naturally existing organic materials and environmentally friendly. The objectives of this study were to design and test a plant material-based air purification system to verify the efficiency of this systems in PMAP reducing the swine odour.

2 MATERIALS AND METHODS

Two identical plastic boxes with dimensions of 64 cm X 45 cm X 40 cm were used to conduct the experiment. Equal quantities of odour generating materials (sources) were placed into the two boxes, respectively. The boxes were then carefully sealed to prevent any air exchange with the ambient. A hole of 6 mm diameter was drilled on the center of the box lids for taking odour measurements from the boxes. The hole was sealed between the two measurements. For each test, one box was equipped with the PMAP. A small device, which includes about 18 g of PMAP material and a micro electrical fan to enhance the evaporation of material, was placed into only one of the boxes. The evaporation rate of PMAP material is about 1.5 mg per hour. The other box without PMAP used was the control.

Two sets of tests were performed; one used pig manure to generate odour and the other used pure hydrogen sulphide or ammonia as the odour source. In the first set of tests, about 80 ml of pig manure from the Animal Research Unit of the Department of Animal Science, University of Manitoba was transferred into a glass bottle, and shacked for homogeneity purposes. Then it was divided equally into two wide mouthed glass bottles, which were then placed into the two boxes, respectively as the swine odour sources. In the second set of tests, the pure H_2S was generated by the reaction of Al_2S_3 and H_2O in the wide mouthed glass bottles and the pure NH_3 from an ammonia water solution.

An AC' SCENT International Olfactometer (St. Croix Sensory, Inc., Stillwater, MN, USA) was used to measure the odour concentration of air in the test boxes. Five panelists were selected following the EU Standard EN 13725 (CEN 2003) based on their specific sensitivity to reference odourant n-butanol. The odour concentration was determined by the triangular forces choice method (ASTM E679-04).

Table 1: Concentration of swine odour with and without PMAP for the 2 sets of the samples.

Sample	Odour concen. (OU/m^3)	Reducing (%)
S1- with PMAP	1413	50.0
S1- without PMAP	2825	
S2- with PMAP	1072	66.9
S2- without PMAP	3235	

In the tests with pig manure, two sets of samples were taken from the two boxes for the olfactometer analysis. For the first set, the odour samples were taken from the two boxes after the swine manure was sealed 18 hours, into two 10-L Tedlar bags using a vacuum chamber (AC'SCENT Vacuum chamber, St. Croix Sensory Inc., Stillwater, MN, USA). When sampling, a bag was placed in the chamber and the inlet of the bag was connected to a Teflon probe which was inserted into one of the two boxes through the hole on the box lid. Each sample was taken in two steps: (i) fill the bag with 2 L of odorous air and then evacuated to “coat” the bag, and (ii) draw odorous air into the bag until the bag was 75% full. Following the same sampling procedure, the second set of samples was taken 8 hours after the first set of sample. Each set of sample has two samples from the two boxes, respectively.

The H_2S concentration was measured with a Jerome Meter (JEROME 631-X Hydrogen Sulfide Analyzer manufactured by Arizona Instruments) in ppm with an accuracy of 0.001 ppm. After the two boxes were sealed and the power of the PMAP device was turned on, the experimental time was started to count. Every 15 minutes the data were taken from both boxes.

The ammonia (NH_3) concentration was tested with an ammonia detector tube produced by Gastec Inc. with range from 0.5 to 50 ppm. A 0.1 ml NH_3 water solution put in a small glass container as NH_3 source. After two boxes were sealed and the power of PMAP device was turned on for 3 hours an open end of Ammonia detector tube was put into the 6 mm hole in the lid of the boxes. The concentration data were taken with a 100 ml pump.

3 RESULTS AND DISCUSSION

3.1 Reduction of Swine Odour

Table 1 shows results of swine ordour concentration of two sets of the samples with and without PMAP treatment after 18 and 26 hours for the first (S1) and second set (S2) of sample. The odour in the control box without PMAP treatment reached a very high concentration of 2825 OU/m^3 in 18 h and 3235 in 26 h. These odour levels are much higher than what normally exists in pig barns. In comparison, the odour in box treated by PMAP was 1413 and 1072 OU/m^3 at 18 and 26 h, respectively. In other words, the PMAP reduced the swine odour concentration by 50% at 18 h and 67% at 26 h. It is particularly interesting to note that odour in the control box increased from 2825 to 3235 OU/m^3, or 15%, within 8 h; whereas, the odour in the treated box decreased from 1413 to 1072 OU/m^3, or -24% within 8 h. This trend demonstrates that very high efficiency of PMAP to reduce the swine odour.

It is also worth to note that the olfactometer measures the odour concentration, not odour quality (offensiveness). During the measurement, the panellists noticed that the sample with the PMAP treatment had a sweet smell, which was quite different from the smell of the swine odour. This means the odour concentration for the samples with PMAP treatment included the scent of materials in the PMAP itself. Therefore, the actually rate of reducing swine odour might be higher than what was measured by the olfactometer.

3.2 Reduction of H_2S

Variations of H_2S concentration from swine manure in the two test boxes with time are shown in Figure 1. The concentration of H_2S in the control box without the PMAP quickly (30 minutes) reached the maximum of 0.45 ppm, and then slowly decreased to 0.23 ppm in about 7 hours, while the concentration of H_2S in the box with the PMAP decreased sharply from about 0.4 ppm to 0.02 ppm within 3 hours. The reduction rate of H_2S was about 95% within the 3 hours.

Figure 2 shows variation of H_2S concentration from the pure H_2S source in the two boxes, again with and without the PMAP, respectively. The H_2S concentration in the control box without the PMAP quickly reaches the maximum, close to 24 ppm, and

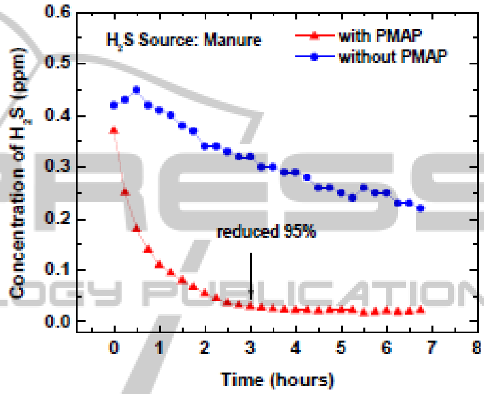

Figure 1: Concentration of H2S for the pig manure source with and without PMAP varies with time. The time starts to be counted form the source sealed and the power of PMAP device was turned on.

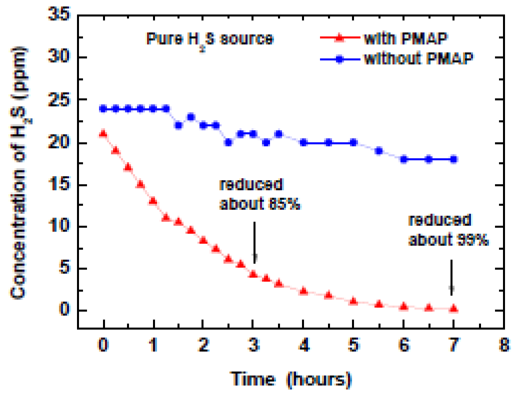

Figure 2: Concentration of H_2S for pure H_2S source with and without PMAP varies with time. The time starts to be counted form the source sealed and the power of PMAP device was turned on.

then slowly decreases to 20 ppm in about 5.5 hours; the concentration of H_2S in the box with the PMAP was sharply reduced and decreases to 3 ppm (reduced by about 85%) within 3 hours and was reduced to 0.2 ppm (a reduction of about 98%) within 5.5 hours. Above two experiments, used pig manure and pure H_2S as odour sources, were more than 2 replications.

The profiles of the curves in Figure 1 and Figure 2 are similar, which indicates that no matter if H_2S is from swine manure or from the chemical reaction, the PMAP could remove it from the air efficiently.

The H_2S is one of main gases in the swine odour and it has been used as an odour indicator of swine odour (Zhang at. el., 2003). The above result showed that the H_2S concentration decreased with time, suggesting the mechanism of swine odour reduction by the PMAP was by reducing its components, not by "masking".

3.3 PMAP Reduced Concentration of NH_3

Table 2 listed the results of concentration of NH_3 in the two boxes after 3 hours. For the pure ammonia source, the NH_3 concentration in the control box without the PMAP was 29 ppm (average of two replications), whereas, the concentration of NH_3 in the box with PMAP was near 0 ppm (both replications) (table 2).

When pig manure was placed in the test boxes, the NH_3 concentration with and without PMAP was measured to be 38 and 10 ppm, respectively (table 2) after 3 hours.

Table 2: Concentration of NH_3 measured with a NH_3 detector tube after PMAP power on for 3 hours.

NH_3 Source	Concentration of NH_3	
	With PMAP	Without PMAP
Pure NH_3	29 ppm	~ 0 ppm
Swine manure	38 ppm	10 ppm

It was noticed that the PMAP could not reduce the NH_3 concentration to zero for the swine manure as the NH_3 source. This was because of the swine manure was continuously emitting NH_3.

It is known that the high NH_3 levels in pig barns decrease pig's health and productivity (Diekman et al., 1993). Therefore, using the PMAP not only improves the indoor air quality in pig barns but also has the potential in improve pig's health and productivity.

4 CONCLUSIONS

The laboratory experiment shows that the PMAP consisting of a nano-crystalline plant extracts could reduce the swine odour by at least 50%. The measurement results also demonstrated that the PMAP could reduce the concentrations of hydrogen sulphide and ammonia efficiently. This indicates that the mechanism of PMAP to reduce the swine odour was not masking. The PMAP provides a promising approach to reduce the swine odour inside the pig barns, thus improving the health of workers as well as pigs.

Based on above results the future research has first conducted field test to confirm the laboratory results on PMAP material in pig barn. Secondly, It will conduct further research to identify the active components in PMAP to reduce the odour efficiently. At last, the future research will investigate the mechanism of the odour reduction by PMAP.

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