Development of an Odor Abatement System for Swine Manure Treatment Facilities

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Summary

This study was conducted to solve the problem of public grievance owing to odor of a pig farm. Odor emissions from pig production systems mainly originate from liquid manure storage and solid manure fermentation. The low-cost odor abatement system (OAS) for application at liquid manure storage tank and solid manure fermentation facilities was developed in this study. The OAS adapted odor removing principles of a biofilter and biotrickling filter. The OAS is very simplified in structure. The appearance of the OAS had a form of cylindrical or cubical shape. The system performance was monitored for about one year after stabilization. A 7 seconds empty bed contact time for the OAS was adapted to achieve the odor reduction levels. The commercial type of OAS was constructed with media comprised of wood chips. Moisture content always remained above 50% wet basis. Average ammonia removal efficiency for the developed design was 89% at the liquid manure storage tank. Also, the removal efficiency at a solid manure fermentation facility was 86% on ammonia.

(**Key words :** Bio-filter, Odor abatement system (OAS), Pig production, Public grievance, Ammonia emission)

INTRODUCTION

One of the hot issues for swine production in the Korea is to treat effectively the produced liquid and solid manure. Liquid manure is one important source for environmentally friendly production of crops and has been used widespread in recent years. The proportions of liquid manure application were 56.5% for rice paddy, 22.6% for dry field, 13.3% for orchard and 7.6% for others, respectively (Choi et al, 2006).

The controversial point of liquid manure utilization were malodor (54.1%), equipment possession (22.1%) and 23.8% for others (Choi et al, 2006). The size of the liquid manure bins owned by 93% of 60 farmers surveyed was 200 tons and was all in normal operation. Around 57% of the normally operated liquid manure bins were processed under aerobic condition. Fifty percent of the respondents utilized their liquid manure bin twice a year while 64% used commercial microbial products to enhance maturity of their liquid manure and abatement of malodorous emissions. Malodor gases emitted from livestock liquid manure bin, solid manure fermentation facilities, and their boundary depended upon the livestock liquid

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and solid manure processing condition. Swine production facilities were considered as the emission source of environmental gas such as ammonia and hydrogen sulfide (Phillips et al, 1995; Mann et al, 2002). Most objectionable odors from livestock operations are volatile compounds generated during the decomposition of manure. Aerobic biological treatment is the process of microbial degradation and oxidation of animal manure in the presence of oxygen. The odors from the aerobic treatment process are mainly associated with ammonia that is in the wastewater in the absence of nitrification. According to the some researchers, swine producers can expect up to 70% reduction in ammonia gas generation and concentration in the swine building with the use of additives (McCrory, D. F. and P. J. Hobbs, 2001). Swine manure represents a potentially important source of ammonia emissions, but little experimental data are available on ammonia production from swine slurry manure (Scotford et al, 1996; Young et al., 1997).

Malodor gases such as ammonia and hydrogen sulfide emitted from a liquid manure storage tanks, solid manure fermentation facilities and livestock production facilities causes many public grievances by offensive odor. The malodor gases from small-scale swine production farms is not a problem because the amounts of malodor gases are less than for large-scale swine production farms, the malodor gases emitted from swine production facilities rapidly spreads out in the atmosphere (Schmidt et al., 2004; Nicolai et al., 2004). So, it is difficult to smell the gases. But, odors emitted from a large-scale livestock production facility are often a nuisance to nearby residents. Whether or not it is proven that swine odors and gases contribute to public health and environmental problems, the presence of these emissions still has a negative overall effect on the quality of life of workers and neighbors of large-scale swine operations. Minimal data is available concerning the public health effects of odor because most odor studies investigate the impact of specific gases on human health rather than the responses on outcomes elicited from the presence of malodors air. So, it is imperative that the levels of odor and gas emissions be either reduced or controlled in both the indoor and outdoor environments of these facilities.

Many studies are being conducted to determine the feasibility of using bio-filters that withstand various weather conditions and corrosion of malodor gases at swine production facilities. Bio-filtration is not a new technology, but is an adoption of natural atmospheric cleaning processes (Nicolai et al, 1998; 1999). Bio-filters use microorganisms to convert gaseous contaminants to carbon dioxide, water vapor, and organic biomass. Bio-filters may be self-inoculating, inoculated with activated sludge, compost, or induced with bacterial species. Most bio-filters used in agricultural settings use compost as the source of microorganisms. Bio-filters are categorized by the configuration (open or closed) and flow sequence (up-flow, down-flow, or horizontal flow). Up-flow open bio-filters are most common in animal production since they are generally more economical (Sadaka et al., 2002). This study was conducted to abate the malodor gases such as ammonia and hydrogen sulfide emitted from the liquid manure storage tank and solid manure fermentation facilities of a swine production farm. Pine woodchips were used as a bio-filter media and horizontal flow was adapted. The empty bed contact time was 7 seconds. Water for moisturizing of the filter media was supplied at the top of the filter layer using an aquatic pump.

MATERIALS AND METHODS

1. Filter media of the Odor Abatement System

Bio-filtration is an air treatment process where contaminants and odor causing agents are filtered through a biologically active media. Bio-filter media of the system is an important factor. Bio-filter media may consist of compost, activated carbon, bulking agent, buffering agent and inorganic additives. Woodchips were used as a bio-filter media to minimize compaction during the bio-filtration process and to maintain porosity and the aerobic conditions. Woodchips were mixed with activated pig slurry. Fig. 1 shows the photo of the pine woodchips used in this study.

2. Pressure drop

The pressure drop through a filter media results from the superficial velocity of air flowing through the filter media. The filter bed should be designed to minimize pressure drop and energy consumption and be operated for many years before replacement is required. In order to abate the malodor gas, odorant air has to passes through a packed filter reactor filled with biologically active media. If filter media is compressed, the air flow pressure drop will increase causing operational problems. Fig. 2 shows the schematic diagram of the measurement system for the air flow resistance. The system for pressure drop measurement of the filter bed material consisted of an air pressure gauge, fan speed controller, mesh screen to support filter media, air supply pump, and hot-wire anemometer. A flow from the air pump was controlled using the fan speed controller. A true residence time is to be affected by the porosity of the filter media. To simplify the design process, an empty bed contact time (EBCT) can be calculated as the filter bed volume divide by the air flow rate :

$$EBCT = Vm/Va \qquad (1)$$

Where : EBCT = empty bed contact time(s), Vm = bio-filter media volume(m^3), Va = airflow rate(m^3/s).

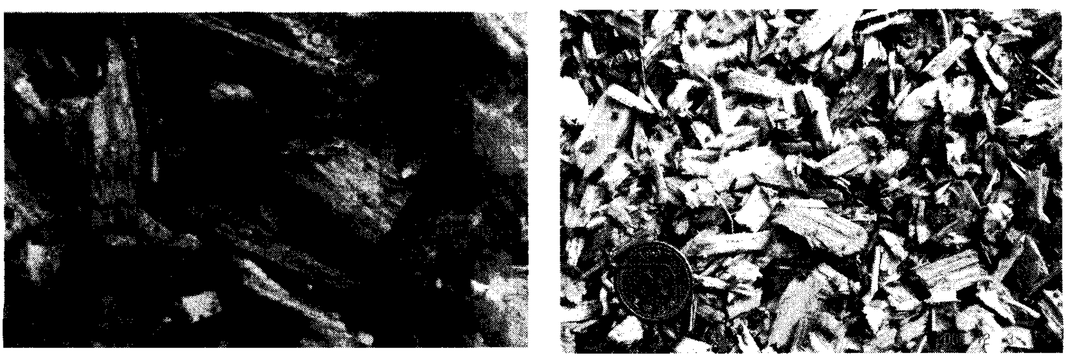

Fig. 1. The pine woodchips used in bio-filtration.

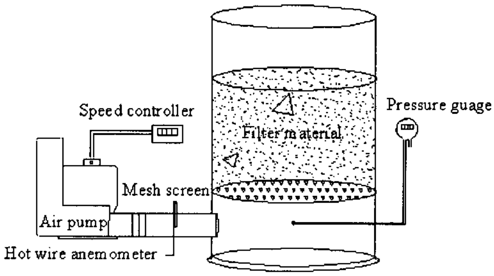

Fig. 2. A schematic diagram of the measurement system for the air flow resistance.

3. Empty bed contact time

In order to get maximum odor abatement efficiency from a filter, the air passing through the filter must contact the filter media for a given amount of time. This amount of time is known as the residence time or empty bed contact time. The correct empty bed contact time is an important variable to know in the design of an efficient filter. There are many research results about empty bed contact time to abate the malodor gas emitted from livestock production facilities. Nicolai and Janni (1998) showed that there was no significant increase in odor reduction with residence times of 6 seconds or more for either dairy or swine. However, odor reduction was less than optimal at less than 4 second residence time. Haug (1993) suggested that an empty bed residences time from 30 to 60 seconds is recommended for composting facilities. For agricultural applications, however, it has been argued that an empty bed residence time of 5 seconds is adequate for odor reduction (Zeisig and Munchen, 1987; Nicolai and Janni, 1998, 1999). The empty bed contact time for commercial application at a liquid manure storage tank and solid manure fermentation facilities in this study was determined to be more than 7 second as result of the laboratory bench-scale experiment.

4. Bench-scale experiment

To test the odor abatement efficiency of the filter bed material by EBCT variation, the bench-scale filter system was established in the laboratory. The source of malodor to treat was liquid manure carried from a swine production farm. The bench-scale filter system consisted of 3-way solenoid valve, ammonia sensor (PACⅢ, Drager, Germany), carbon dioxide sensor (GMT222, Vaisala, Finland), pressure gauge, blower, inverter, and liquid manure storage tank. The depth of the filter media was 30cm. The empty bed contact time was set at 5, 7, and 9 seconds.

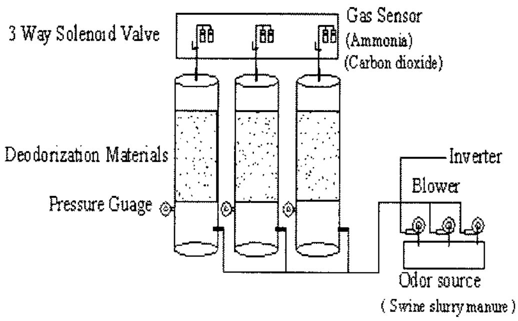

Fig. 3. A schematic diagram of bench-scale odor-reducing system.

Water for moisturizing of filter bed material was sprayed once a day at the top of the filter material. The ammonia gas concentration of air originating from the liquid manure tank and deodorized air were measured continuously. The measurement interval was two minutes. The ammonia and carbon dioxide sensor was calibrated with a standard gas before the experiment.

5. Commercial scale system design

The commercial-scale OAS was developed based on the results of the bench-scale experiment. The commercial filter system has a cylindrical form. The EBCT was set at 7 seconds. The horizontal depth of filter media was 60cm. Water for moisturizing of the bed material was continuously sprayed at the top of the filter material. The filtrating water through the filter media was collected at the storage tank of the filter system and recycled. Odor air was transferred from the odor source to the inlet of the filter system. Odor emitted from manure storage facilities was filtered through a biologically active media. The filter media used in the system was pine woodchips. The media was inoculating fermented pig slurry manure.

RESULT AND DISCUSSION

1. Distribution of the size of the wood chip

Fig. 3 shows the distribution rate of the particle size of the pine woodchips using the filter media. Particle distribution of the material investigated was 15.4 percent at 2.00 ~3.35mm, and 53.2 percent at more than 5.6mm. The particle size of the filter material is critical in filter design. For a filter to operate efficiently, the filter material must provide a suitable environment for microbial growth and maintain a high porosity to allow air to flow easily. The woodchips provided the porosity and structure while the fermentative liquid manure provided microorganisms, nutrients, and moisture holding capacity.

2. Pressure drop of the filter media

As the airflow rate through the filter increases, the force needed to push the air through the media increases. This force is measured as the static pressure difference from the inlet of the filter to the atmosphere. This static pressure can be thought of as the resistance to air flow through the filter material. To decrease the static pressure drop, the media depth can be decreased. If it is not possible, the filter area must be increased, thus increasing the EBCT. Increasing the EBCT means a better filter efficiency, a lower pressure drop, more filter media, a larger filter area. It is important to control the filter media moisture. Inadequate moisture can allow the media to dry out, deactivating the microbes,

Fig. 4. A schematic diagram of the commercial type OAS (left), application liquid manure storage tank (middle, Anseong), and solid manure fermentation facility (right, Cheonan).

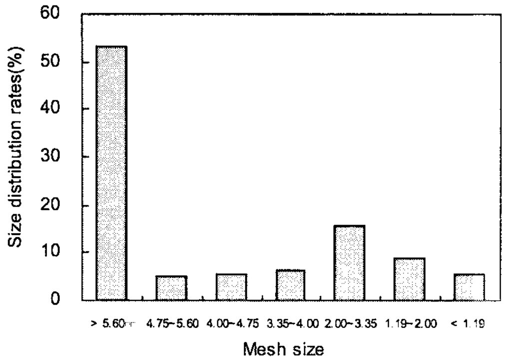

Fig. 5. The distribution of the filter media by size.

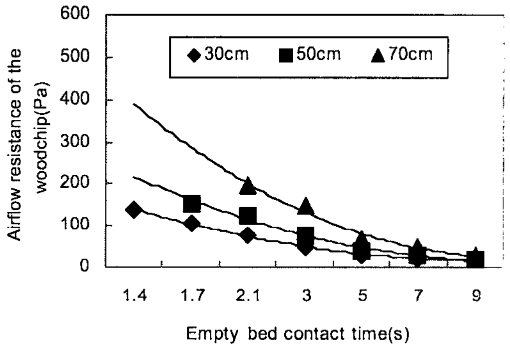

Fig. 6. Pressure drop of the bed materials for the various empty bed contact times at media bed depths of 30 cm, 50 cm, and 70 cm.

and creating cracks and channeling of air, which results in a reduction of filter efficiency. Moisture contents of this odor abatement system always were maintained from 40 percent to 63 percent wet basis. Moisture was supplied by sprinkling water directly onto the bed material.

3. Abatement efficiency for the bench scale filter system

Fig. 7 showed the removal efficiency for the bench-scale filter system when the empty bed contact time was 5 seconds, 7 seconds, and 9 seconds. The filter performance was monitored about 40 days in summer. Ammonia concentration during the testing period was 6.5 ppm on average, and ranged from 3.0 ppm to 24.2 ppm. Outlet ammonia concentration of the filter was 0.6 ± 0.9 ppm at 5 seconds, 0.4 ± 0.7 ppm at 7 seconds, and 0.4 ± 0.6 ppm at 9 seconds empty bed contact time. The average removal efficiency of ammonia was 92.7 % (60 ~ 100%) at 5 seconds, 94.8 % (70 ~ 100%) at 7 seconds, and 95.2 % (73 ~ 100%) at 9 seconds empty bed contact time. The static pressure of the filter system was not varied during the testing period.

4. Abatement efficiency for the commercial-scale OAS

The developed filter systems were installed at the pig farm liquid manure storage tank and solid manure fermentation facility. The commercial-scale OAS has an open configuration and horizontal flow sequence. The system discharges treated gas from the filter directly

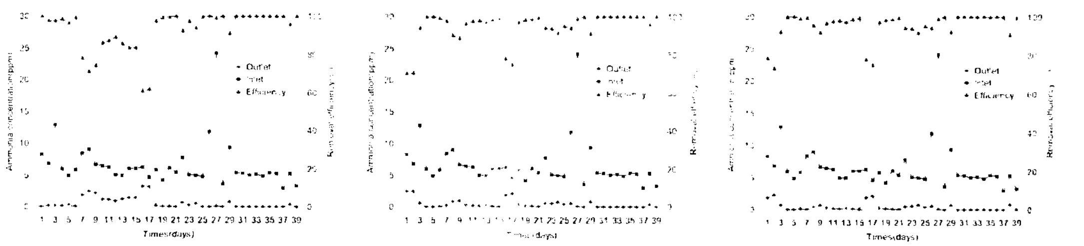

Fig. 7. The variation of ammonia concentration at inlet and outlet, and the removal efficiency of the wood chip materials in various empty bed contact time: 5 second (left), 7 second (middle), 9 second (right).

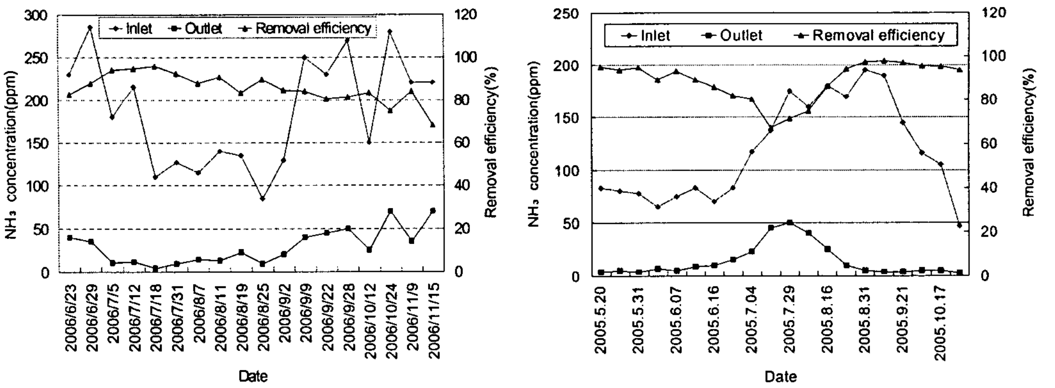

Fig. 8. The variation of ammonia concentration at inlet and outlet, and the removal efficiency of the bio-filter installed at the liquid manure storage tank (left) and solid manure fermentation facility (right).

to the atmosphere. In order to get optimum odor reduction and static pressure from the filter, the air passing through the filter should have proper empty bed contact time. The EBCT was controlled at 7 seconds. The pressure drop and moisture content of the filter was not varied during the testing period (about 1 year). Inlet and outlet ammonia concentrations are given in Fig. 8. Inlet ammonia concentrations ranged from 47 ppm to 195 ppm with an average of 118 ppm at the liquid manure storage tank, and from 85 ppm to 285 ppm with an average of 187 ppm at the solid manure fermentation facility. Outlet ammonia concentrations ranged from 3 ppm to 50 ppm with an average of 14 ppm at the liquid manure storage tank, and from 5 ppm to 70 ppm with an average of 29 ppm at the solid manure fermentation facility. Consequently, ammonia concentration reduction ranged from 67 % to 97 % with an average of 89 % at the liquid manure storage tank, and from 68 % to 96 % with an average of 86 % at the solid manure fermentation facility.

CONCLUSION

Odors emitted from pig production facilities are a nuisance to neighbors. This study was carried out to solve the public grievance by odor of a pig farm. A 7 second empty bed contact time for the OAS was adapted to achieve the odor reduction levels. Moisture content of the filter media always should be maintained above 50% wet basis for proper abatement efficiency of odor gases. Ammonia concentration reduction ranged from 67% to 97% with an average of 89% at the liquid manure storage tank, and from 68% to 96% with an average of 86% at the solid manure fermentation facility. Further research is needed to determine the life of filter media for open-face OAS on livestock facilities.

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