Treating Ventilation Exhaust Air for Odor Control

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Summary and Implications

Odor control for swine facilities has focussed on storage and the land application phases of manure handling. A third component, ventilation exhaust air, has received little attention. This research was targeted at reducing odor emitted from ventilation exhaust air by filtering odor carrying dust particles. The ultimate objective is to develop a system that could be implemented easily, has a low maintenance schedule, and is inexpensive to operate.

Introduction

Many issues still remain concerning the conditions required to guarantee that a neighbor located a fixed distance from a livestock complex, will not detect odorous compounds beyond an accepted percent time of the year. Many factors contribute to our lack of answers in this area. Weather patterns, air temperature, air moisture levels, solar insolation, particulate concentration, etc., all synergistically interact to define the extent that a neighbor will detect odorous compounds from swine facilities.

Sources of odor emissions include land application of slurry, manure storages, and the building. Much of the current effort in source reduction has been devoted to minimizing odor release from land application and storage facilities.

As land application and storage odorous source reductions continue to progress, the only remaining source for odors becomes the building complex itself. Little, if any, attention has been devoted to the reduction of odorous compounds from the building. Currently, ventilation air is exhausted into the ambient atmosphere without prior treatment. This exhaust air contains odorous gases, moisture, animal dander, and feed dust particles, and can represent a very concentrated odorous sample. If left untreated could become a source for neighboring complaints. It is believed that low-cost, practical engineering solutions to building generated odors can be identified and implemented in both new and existing building ventilation systems.

Literature Review

Many researchers have examined odors from livestock facilities to determine the constituents that are most influential in olfactory perceptions. Hammond et al. (1979) found that the most important compounds were acids, phenols, and carbonyls. However, results indicated that odors occurring at large distances from animal facilities were amplified by the presence of dust particles. Hammond and Smith (1981) stated that if particles are removed from samples taken at swine houses, lagoons, and feedlots, they become almost odorless. They hypothesized that dust particles, holding absorbed odorants, more readily adhere to tissues in the nasal passages than the odorants molecularly dispersed in the gas phase. Hartung (1985) stated that filtering the dust from exhaust air can reduce odor emission from animal houses up to 65%.

Bioscrubbers and biofilters have been two main methods for treating ventilation exhaust air. Bioscrubbers require more initial capital investment and larger amounts of water than biofilters and therefore may not be practical for on-farm use in the United States. Biofilters are relatively economical and simple to install and maintain. Both bioscrubbers and biofilters transfer the odorous compounds from the gas to the liquid phase and then allow microbial action to break them down.

Noren (1985) used peat and heather over wooden slats to form a biofilter for animal housing. It was found that odors were absorbed and converted by microorganisms to odorless substances after the biofilter was allowed to mature. Gases were decreased at an average rate of 50% with an 80% removal rate when the biofilter was kept at an optimal moisture content. Pre-filtering of particulates was recommended to prevent clogging of the biofilter bed. Zeisiz and Munchen (1987) used several different materials including humus soil, composts, and peat. Dust filtering with a rock bed was attempted but required washing of rocks several times per year, which was often ignored. They recommended a filter mat, which still needs to be cleaned every 3 to 4 months but requires less effort than cleaning the rock bed. At this same interval, the biofilter should be loosened to reduce increased air resistance due to settling. O'Neill and Stewart (1985) summarized the effectiveness of biofilters showing the odor removal efficiency ranged from 50 to 90%.

A third option for odor reduction, in light of work by Hammond and Smith (1981), is dust filtration. Dust filtration of exhaust air from animal housing is not an easy task due to the volume of air flow and the size of the particles. Stroik and Heber (1986) monitored 11 commercial swine finishing houses and found dust concentrations up to 33 mg/m^3 with a mean for all houses of 7.5 mg/m^3. Particle counting indicated that 93.3% of the particles were smaller than 5.2 microns. Meyer and Manbeck (1986) monitored several different swine houses. The results are shown in table 1. Table 1 shows that the respirable portion (less than 4.7 microns) of dust in swine housing is a significant portion of the total dust. Dust this small would have a settling velocity of approximately 0.077 cm/s (Hinds, 1982) and would therefore require a specially designed filtration system to either filter out the particles or to allow them to settle.

If pure dust filtration (ie. a dry filter) can be designed and proven to work successfully, then past problems associated with biofilters can be avoided. The objective of this research project is to develop and test full-scale biomass filters for exhaust-air dust removal and subsequent odor reduction.

Materials and Methods

A full-scale biomass filter testing chamber has been developed to study methods for reducing odorous gas emissions from swine facilities. The testing apparatus has been designed to evaluate treatment effects on ventilation exhaust-air in a full-scale production setting. This facility is shown in figure 1. The testing facility is located at the ISU Swine Nutrition and Management Research Center (SNMRC); attached as an annex to the existing four-room nursery complex. The nursery complex was chosen because, as was shown in table 1, it has in general the highest particulate load.

The nursery complex contains four individual rooms each ventilated separately to the ambient atmosphere. Four separated chambers (15 x 11 x 7 ft; L x W x H) have been constructed at the exhaust end of each of the four nursery rooms (fig. 1). The front-end of the testing facility contains a 6-ft. wide common hallway. This hallway was required to mix the exhaust air from all four nursery rooms before being drawn through each of the four independent testing chambers. This was done because the nursery rooms will contain various numbers and sizes of pigs and thus side-by-side tests would be difficult to accomplish, and secondly, this procedure will allow for four biofilters to be tested simultaneously, all receiving the same inlet contaminant air.

Each of the four testing chambers have been fitted with a single-speed blower and a variable speed blower. Static pressure, total dust concentration, humidity, and temperature monitoring is available for each of the four chambers.

Biomass filtration

At present, work has been conducted to quantify the dust and odor reduction capabilities of biomass filtration designs. Biomass filtration has been designed using cornstalk residue in the arrangement shown in figure 2.

Figure 2 shows a biomass filter appropriately defined as a cascade impactor. With this design, dust-laden exhaust air will impact several cornstalk biomass filters. Dust filtration with this design is accomplished by filtration within the biomass bed. In addition, dust particles will settle from the airstream as it changes direction between biomass beds.

Biomass filter efficiency

Filter efficiency is evaluated by determining the reduction in odor levels between the filter inlet air and the filter exhaust air, η_f, defined as;

$$\eta_f = \left(\frac{O_{T,in} - O_{T,out}}{O_{T,in}}\right) 100$$

where O_T is defined as the odor threshold value. The forced choice olfactometer located and developed at the ISU Agricultural and Biosystems Engineering Department is used for evaluating odor threshold.

Results and Discussion

Tables 2 and 3 summarize dust and odor threshold data collected to date. Dust concentrations are shown in table 2 and odor threshold concentrations are shown in table 3. Odor samples are collected periodically and dust samples are collected, on average, three times per week. Dust reduction from the biomass filter has varied from a low of 46.0% to a high of 83.4%, with an average of 62.0%. The ventilation rate through the filter has averaged 2,860 CFM, representing a ventilation rate between mild and hot weather ventilation for one of the nursery rooms.

Table 3 summarizes the odor threshold measurements collected to date. For odor threshold, the mixing hallway odor was measured along with the filter inlet and outlet odor threshold levels. As shown in table 3, odor threshold reduction between the mixing hallway (B in figure 1) and the filter outlet has varied between 51.7 and 90.1%. As shown in table 3, significant reduction in odor threshold was measured between the mixing hallway and the inlet to the filter. This was probably due to excessive dust settling that occurs in the mixing hallway. Between the filter inlet and outlet, odor threshold reductions varied between 43.4 and 84.2%.

Energy use is a big concern with any filtration strategy. For the cascade impaction filter tested, the pressure difference across the filter has never exceeded 0.014 in. wg, well within the capability of current axial-type fans used for livestock ventilation.

Conclusions

Based on initial data collected on a cornstalk biomass filter, promising results related to dust and odor threshold reduction was found. With the cascade impaction filter, very few restrictions to exhaust airflow exist implying that little additional fan energy expense would be required to operate the filter. Future work is being conducted on other biomass filters using soybean residue. The ultimate objective is to develop a system that is very inexpensive and requires infrequent maintenance.

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Table 1. Summary of dust analysis from swine housing (Meyer and Manbeck, 1986).

Growth Phase	Average Total Dust	Range of Total Dust	Average Respirable	Range of Respirable	Average Respirable	Range Respirable
	mg/m^3	mg/m^3	% of total	% of total	mg/m^3	mg/m^3
Farrowing	1.23	0.4-3.0	63.0	45.3-80.0	0.2-1.36	0.78
Nursery	2.74	1.1-5.1	19.6	11.2-49.6	0.2-1.44	0.49
Finishing	1.99	0.6-4.5	-	-	-	-
Gestation/ Breeding	0.77	0.3-1.2	46.8	31.3-62.2	0.38-0.43	0.40

Table 2. Dust removal of cascade impaction biomass filter.

Day of Operation	Total Dust In* (mg/m^3)	Total Dust Out (mg/m^3)	Dust Reduction (%)
5	1.35	0.73	46.0
12	0.52	0.10	80.0
16	0.31	0.10	66.7
22	0.24	0.06	79.0
28	0.54	0.18	66.7
29	0.19	0.09	49.7
34	1.33	0.43	67.7
36	0.41	0.21	49.0
40	0.52	0.21	75.3
42	0.21	0.05	75.0
43	0.21	0.05	75.0
47	0.10	0.05	50.0
49	0.21	0.10	50.0
50	0.31	0.05	83.4

* refers to total dust entering the filter, after the mixing hallway. Mixing hallway dust concentrations not available.

Table 3. Odor threshold reduction of the cascade impaction biomass filter.

Day of Operation	Hallway Odor Threshold	Inlet Odor Threshold	Outlet Odor Threshold	Percent Odor Threshold Reduction*
6	89	76	43	51.7 (43.4)
16	724	456	72	90.1 (84.2)
35	362	216	76	79.0 (64.8)

* first number represents odor threshold reduction between outlet and mixing hallway; number in parenthesis represents odor threshold reduction between filter inlet and outlet.

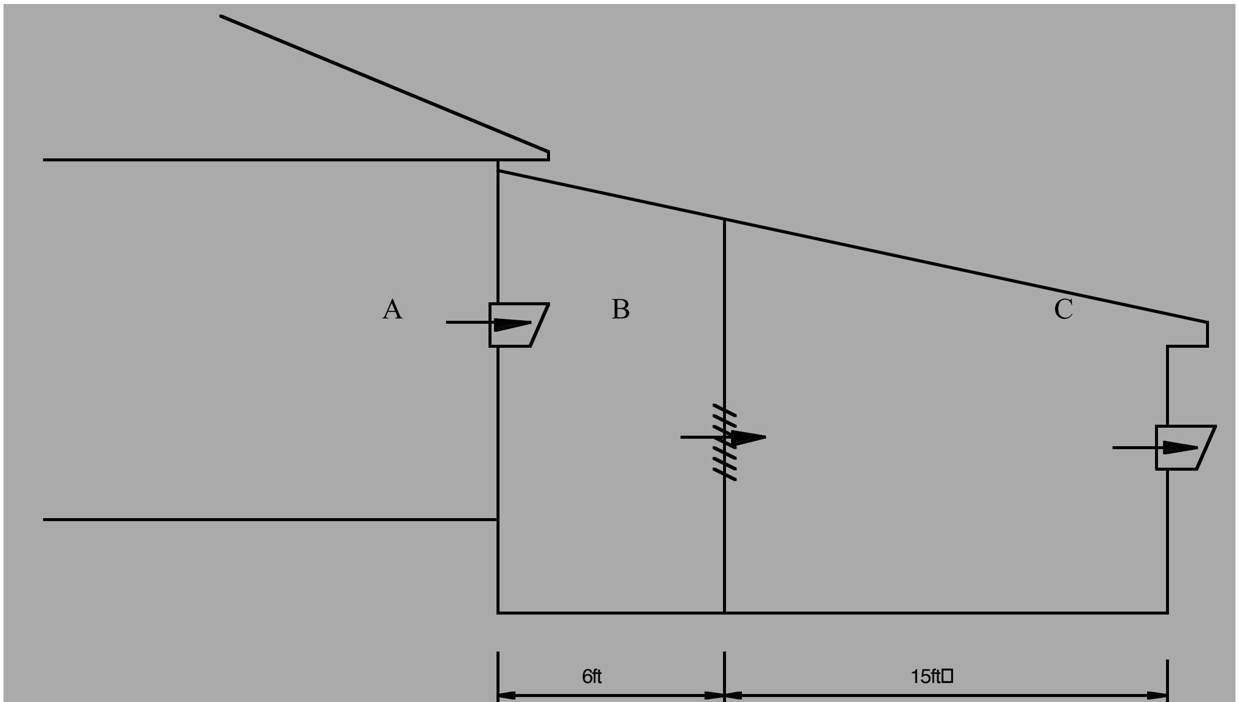

Figure 1. Schematic of the production-scale testing facility located at the ISU Swine Nutrition and Management Research Center. A: existing swine nursery room (4 total; 144 pigs/room capacity); B: testing chamber mixing hallway; C: biomass filtration testing laboratory.

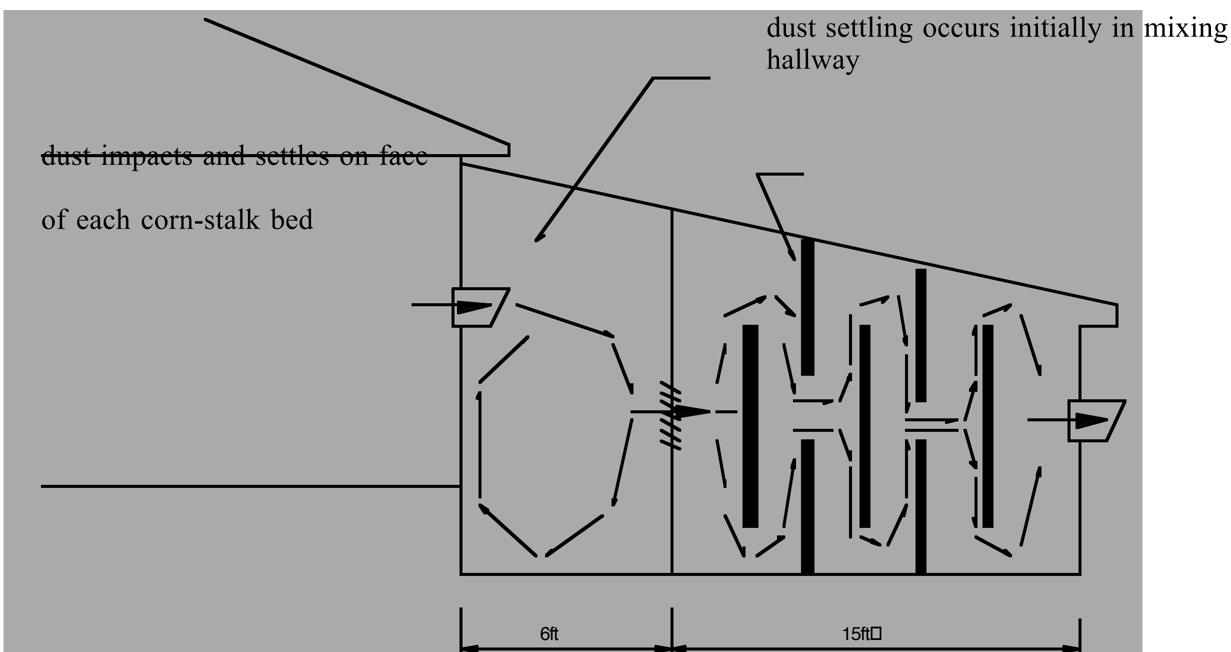

Figure 2. Schematic of the cascade impaction biomass filter tested. Dust settling initially occurs within the mixing hallway and further filtered as exhaust air traverses through the biomass beds. Biomass component initially tested consists of baled corn-stalks with each bed 3.5 inches thick.