PERFORMANCE OF AN ELECTROSTATIC DUST COLLECTION SYSTEM IN SWINE FACILITIES

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ABSTRACT

An investigation of an electrostatic precipitator dust collection system was conducted to determine its ability to remove dust particles from common swine facilities. The system was installed in farrowing and nursery settings, and dust levels were subsequently measured in rooms both with and without the precipitators. It was determined that the collectors reduced total dust levels in the nursery environment by 58% (with a 36% reduction in respirable particles), and in the farrowing environment by 45% (with a 50% reduction in respirable particles). Throughout this study it was evident that the construction, installation, and operation of this collection system was not only technically feasible, but was also practical for commercial swine production operations.

Keywords
Dust Control, Evaluation, Particulate Matter, Swine Housing

INTRODUCTION

Modern swine confinement housing has helped livestock producers to specialize and to mechanize, and thus to raise hogs efficiently and economically (Mutel et al., 1986). These systems, however, because they are highly dense and intensive, can generate several challenges that, if not properly addressed, can adversely affect both animals and humans, and include drafts on small pigs, toxic gases, elevated humidity levels, and high dust concentrations (Meyer, 1987).

Dust, a major problem in swine confinements, originates from multiple sources within the swine environment itself, including dry animal skin, hair, feces, and feed particles (Bundy, 1989; Donham and Gustafson, 1982), and can be influenced by many factors, such as air temperature, humidity, flow rate, type and amount of feed provided, and animal activity (Butera et al., 1991; Dawson, 1990; Heber and Stroik, 1987; Qi et al., 1992). In warm weather, high ventilation rates reduce airborne dust levels; in cold weather, however, low ventilation rates lead to high dust levels accumulating inside buildings (Carpenter and Moulsley, 1986). This occurs because ventilation systems are typically temperature-controlled, not contaminant-controlled.

Many studies have been devoted to quantifying dust particle concentrations typically encountered in swine facilities, and have produced greatly varied results. Heber and Stroik (1987) investigated 11 commercial swine finishing units and found total aerial dust concentrations ranging from 212,000 to 73,550,000 particles/m^3, with an average level of 11,209,000 particles/m^3. Honey and McQuitty (1979) investigated aerial dust levels in a chamber that simulated a swine environment, and found average total dust concentrations of 5,160,000 particles/m^3, with 71% of the particles less than 5 µm in aerodynamic diameter, and thus within the respirable range (i.e., small enough for deep lung penetration). Additionally, numerous studies have examined mass concentrations of airborne swine dust, and have found levels ranging from one to 100 mg/m^3 (Carpenter, 1986), 1.19 to 6.73 mg/m^3, with 15.5% of the dust within the respirable range (Donham and Gustafson, 1982), 6.3 to 7.6 mg/m^3 (Donham et al., 1986), 0.36 to 38.2 mg/m^3 (Heber and Stroik, 1987), 10 to 20 mg/m^3 (Mutel et al., 1986), and 2.4 to 16 mg/m^3 (Popendorf and Donham, 1991), to name but a few.

In 1986, it was estimated that over 700,000 people in the United States were exposed to hazardous levels of swine confinement dust. Further, it has been estimated that over 70% of all of those who were exposed to confinement dust suffered from various respiratory disorders, including organic toxic dust syndrome, chronic bronchitis, hypersensitivity pneumonitis, and occupational asthma (Donham and Gustafson, 1982; Mutel et al., 1986; Popendorf and Donham, 1991). The people who were primarily exposed to swine dust included workers, family members of these workers, and veterinarians (Donham and Gustafson, 1982). The people most at risk for developing respiratory disorders, however, were those with long-term exposure to the dust (i.e., producers and other personnel who worked eight-hour days for several years) (Mutel et al., 1986). Swine dust particles are hazardous to human health because a substantial proportion lie below 5 µm in diameter, and thus are "respirable", because their small size allows for significant deep lung penetration, deposition, and consequent accumulation (Bundy and Hazen, 1973; Dorman, 1974).

In addition to affecting human health, swine dust also generates other problems. It does adversely affect the health of the swine themselves. The size and shape of the dust particles, as well as the gas molecules that have been absorbed from the air (e.g., ammonia, hydrogen sulfide, and carbon dioxide) can cause airway irritation and respiratory disease, especially pneumonia. In fact, it has been estimated that between 35 and 60% of all swine raised in confinement conditions suffer from pneumonia (Chiba et al., 1987). Additionally, swine dust can carry and promote large aggregations of microorganisms, including viruses and bacteria (both gram-positive and gram-negative), especially Staphylococcus, Micrococcus, Endotoxin, and Rotavirus (Bundy, 1989; Butera et al., 1991; Donham, 1991; Fu et al., 1989; Thorne et al., 1992). Swine dust also harbors odorous substances, such as volatile fatty acids, phenols, and carbonyl compounds (Bundy and Hazen, 1975; Hammond et al., 1981; Heber et al., 1988). Furthermore, swine dust can accelerate the deterioration of buildings and of the mechanical components housed within. In combination with high humidity levels, which are typically found in swine environments, swine dust deposits on, and causes abrasion to, all exposed surfaces in a swine facility, and thus accelerates the corrosion process (Bundy and Hazen, 1973; Davis and Cornwell, 1991). In addition to contributing to the deterioration of the building structure and the equipment inside the facility, dust can severely impair the performance of ventilation systems by accumulating on timers, thermostats, fans, motors, vents, ducts, and shutters, and can either cause these components to perform poorly or to completely fail (Carpenter, 1986).

Consequently, there is a need to develop an efficient, practical, and inexpensive method of dust removal from swine environments, in order to preserve human health, swine health, and housing longevity. Control of this dust can be accomplished by essentially two methods: dust can be controlled at its source (i.e., prior to becoming airborne) or it can be removed from the air (i.e., after it has left the source). Methods of source removal have included the addition of fat (Chiba et al., 1985; Chiba et al., 1987) and oil (Bundy and Gast, 1986; Dawson, 1990; Heber and Martin, 1988) to feed rations. Methods of mechanical removal from the air have included the use of ventilation (Bundy and Hazen, 1975; Liao and Feddes, 1990; Wathes et al., 1983), filters (Carpenter et al., 1986; Carpenter and Fryer, 1990; Carpenter and Moulsley, 1986), and wet scrubbers (Feddes et al., 1991; Licht and Miner, 1979; Pearson, 1987), and have all met with varied success.

Another method to accomplish dust removal is to employ electrostatic precipitators, which are devices that impart electric charges to dust particles, then push the particles out of the air stream using electromagnetic forces. Electrostatic collectors typically exhibit high efficiencies and low operating costs, and offer the potential to remove dust particles from swine housing and thus to produce an improved atmosphere for swine production. Studies have examined electrostatic precipitator performance in swine environments, and results seem to be promising. Bundy and Veenhuizen (1987) achieved 90% particle (i.e., simulated dust) reduction, while Veenhuizen (1989) achieved a 54% reduction in actual dust levels. Even though research has shown that electrostatic precipitators can reduce dust levels substantially, they often produce unexpected, and unwanted, subsidiary effects, such as charged particles collecting on all metal interior surfaces, not just on the collector plates (Bundy and Hoff, 1992). Therefore, the objective of this study was to determine the operational performance of an electrostatic precipitator system of novel design for use in swine housing environments.

MATERIALS AND METHODS

Two farrowing rooms and two nursery rooms, located at a swine facility in central Iowa, were selected for study. One room of each served as an experimental room (i.e., contained four dust collectors, electrically connected in parallel, hung from the center of the ceiling), while one room of each served as a control (i.e., contained no dust collectors). The farrowing rooms were each the same size, contained similar equipment, and each contained nine sows and litters. The farrowing rooms were each 15.8 m (52 ft) long, 4.3 m (14 ft) wide, and 2.6 m (8.5 ft) high. Farrowing crates were located on wire-mesh raised decks, under which were shallow gravity-drain gutters for manure removal. Similarly, the nursery rooms were each the same size, contained similar equipment, and each contained 125 nursery pigs. The nursery rooms were each 15.8 m (52 ft) long, 3.7 m (12.25 ft) wide, 2.6 m (8.5 ft) high, and contained 24 nursery pens (1.2 m [4 ft] in length by 1.2 m [4 ft] in width) which were also situated on wire-mesh raised decks, under which were shallow gravity-drain gutters for manure removal.

Each room contained two 45.7 cm (18 in), 248.6 W (1/3 hp) exhaust fans. The experimental approach used during this study was that used by Phillips and Thompson (1989) in their study of dust levels in swine housing: the temperature control/ventilation systems were set identically for both farrowing rooms, and for both nursery rooms, to ensure that similar environmental conditions existed between the experimental and control environments.

Each electrostatic precipitator unit (Figures 1 and 2) consisted of a discharge electrode constructed from a single strand of 0.3 mm (0.01 in) diameter stainless steel wire, and a grounded collection electrode fabricated from a 10.2 cm (4 in) diameter steel pipe, which was located 17.8 cm (7 in) below the wire. The discharge wire and the collection pipe were supported by 6.4 mm (0.25 in) thick PVC end plates. A dust collection tray, installed under the pipe, was constructed from one-half of a 20.3 cm (8 in) diameter, 3.2 mm (0.13 in) thick, PVC pipe cut longitudinally. Additionally, an ionization guard was located above the wire to direct electrons and charged dust particles down toward the collection electrode, and consisted of one-half of an 8.9 cm (3.5 in) diameter, 3.2 mm (0.13 in) thick, PVC pipe cut longitudinally. Each dust collector unit was 3.05 m (10 ft) in overall length. To charge the precipitators, and provide negative ionization at the discharge wire (which imparts electrical charges to passing dust particles), the electrodes of the collectors were connected to a -24 kV, 50 mA, rectified a.c. power supply unit.

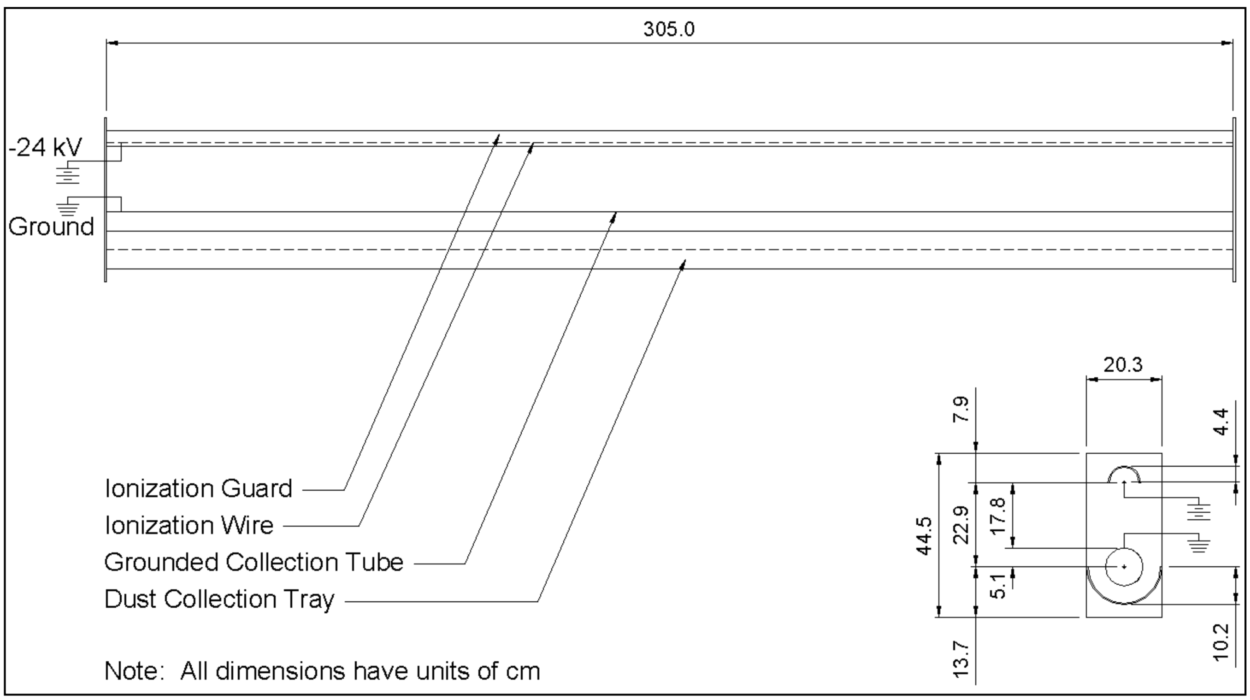

Figure 1. Schematic of an electrostatic precipitator unit.

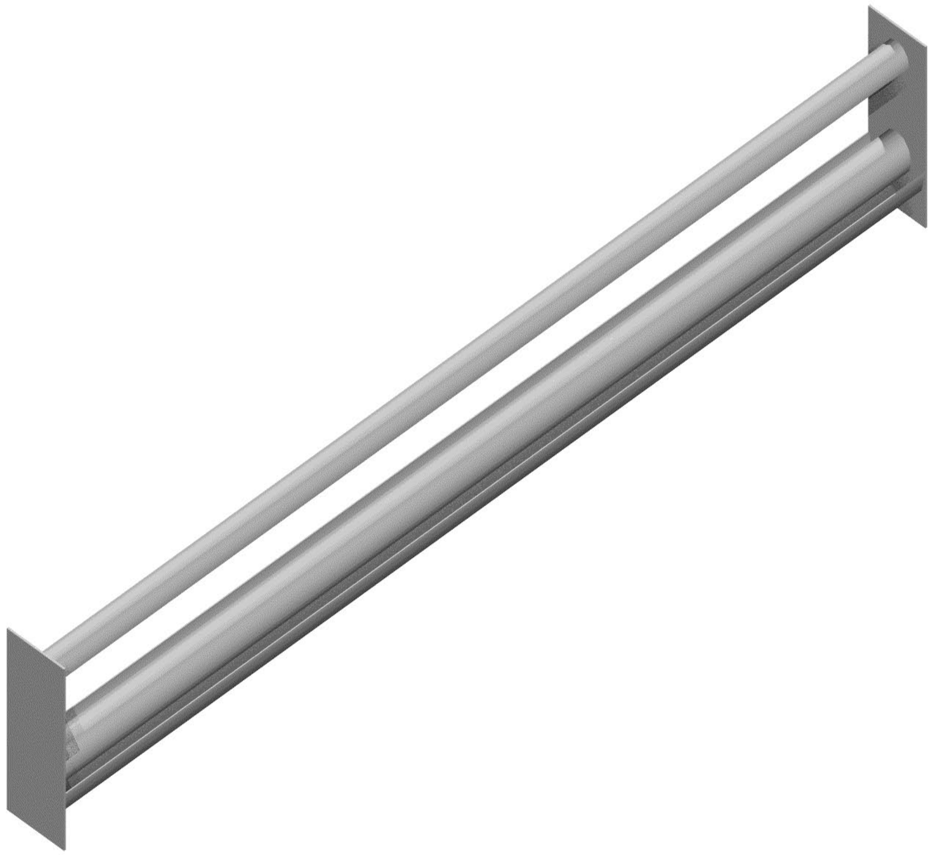

Figure 2. Isometric view of an electrostatic precipitator unit.

The environment in each of the rooms was monitored by measuring dust particle levels with a laser particle counter. With this device, airborne dust concentrations with an aerodynamic diameter between 0.5 and 3.0 μm, and greater than 3.0 μm, were simultaneously determined. Particles between 0.5 and 3.0 μm were considered respirable, and particles greater than 3.0 μm were considered nonrespirable. To measure particle concentrations, the counter was placed in the center of each room, and was positioned 1.3 m (4.3 ft) above the floor in the farrowing room, and 0.9 m (3 ft) above the floor in the nursery room. These locations allowed for the concurrent measurement of dust levels in the breathing zones of both humans and animals (Barber, et al., 1991; Bundy and Hazen, .1973; Butera, et al., 1991). Thirty-six readings were taken in each room, five days per week, for a period of six weeks during summer conditions. This resulted in a total of 1080 data points for each particle size range for each room under investigation. Resulting dust levels for the control and experimental rooms, for each respective setting, were then compared to determine the performance of the electrostatic precipitator systems. All data were subsequently subjected to ANOVA analysis ($\alpha = 0.05$) to determine if the differences between the experimental and control dust concentrations were significant.

RESULTS AND CONCLUSIONS

The results of the study are shown in Table 1. For each swine environment, all particle concentrations, including respirable particles, were significantly reduced ($\alpha = 0.05$) by use of the electrostatic precipitator units. Respirable particles in the farrowing setting were reduced by 50%, and in the nursery by 36%. Nonrespirable particles were reduced by 66% in the farrowing environment, and by 55% in the nursery. This led to an overall average reduction in total dust levels of 45% in the farrowing setting and 58% in the nursery. In both settings the dust collectors attained better removal performance for the upper particle size range. Further, the data show that the dust collectors in the farrowing room, for each respective particle size range, had better performance than in the nursery room. This may, in fact, be attributable to differences in ventilation rates between the two environments. Also, as seen by the coefficient of variation values, very low variability was observed in the particle count data.

Through this study it was further determined that between 67 and 76% of all dust particles present in the farrowing and nursery environments under investigation were in the respirable range (including both the control and experimental conditions). Many estimates have been made concerning the fraction of respirable dust particles in swine facilities, and most range from 43 to 95% (Bundy and Hazen, 1973; Meyer, 1987). Thus, results from this study are in agreement with previous findings.

Additionally, during this study it was concluded that these electrostatic precipitator units were relatively simple in design and construction, straightforward to install and operate, performed well, and thus are very feasible for use commercial swine operations.

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Table 1. Farrowing and nursery dust concentrations (particles/m^3).†

Particle Size (µm)	0.5 - 3.0		> 3.0		Respirable (%)
Environment	Mean	CV (%) ‡	Mean	CV (%) ‡	
Farrowing					
Experimental *	4,612,654 [a]	0.18	1,463,251 [c]	0.44	76
Control *	9,237,915 [b]	0.11	4,245,230 [d]	0.21	69
Reduction (%)	50		66		
Nursery					
Experimental *	4,163,042 [e]	0.14	1,444,791 [g]	0.19	74
Control *	6,464,947 [f]	0.14	3,207,116 [h]	0.19	67
Reduction (%)	36		55		

† Differing letters within a given particle size/swine environment combination indicate a significant difference between experimental and control conditions for a given swine environment at the α = 0.05 level.
‡ CV, the Coefficient of Variation, is defined as the ratio of the standard deviation to the mean (in %) and provides a measure of the relative dispersion of the data about the mean value.
* Each swine setting at each experimental condition consisted of 1080 data points for each particle size range (i.e., n = 1080 for each particle size range for each experimental setting, N = 8640 in total).

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