Development of a Low Cost Biofilter on Swine Production Facilities

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Introduction

Odors from livestock production facilities are well recognized and, in the past, was assumed to be part of the business. However, with the trend towards larger and more concentrated animal production sites, odors are rapidly becoming an important issue for the livestock industry. The economic importance of the livestock industry to Minnesota makes it essential to find acceptable solutions to odor problems.

Odor sources on livestock facilities include buildings, manure storages, and land application of manure. Most odor complaints and odor control research has focused on emissions from manure storages. The current trend in Minnesota is to use deep pit storage beneath the slatted floor. Therefore, buildings are becoming a major source of odor emissions.

Biofiltration is an air pollution control technology that uses microorganisms to oxidize air contaminated with volatile organic compounds (VOC) and oxidizable inorganic gases and vapors (Janni et al., 1996). It is an effective and efficient means for removing low concentrations of biodegradable compounds from air. Biofiltration is a naturally occurring process in the soil. Its use for air pollution and odor control in industry has developed since the 1940’s.

Biofiltration use with livestock facilities began in Germany in the late 1960’s (Zeisig and Munchen, 1987) and in Sweden in 1984 (Noren, 1985). Scholtens et al. (1987) reported an average efficiency of about 70% from biofilters placed on piggery and calf sheds. In the United States little or no biofilter research and development for animal agriculture was reported in the literature. This paper reports on the construction, performance, and management of a low cost biofilter used to treat air from a continuously running pit fan on a swine farrowing barn.

Biofilter Construction

Figure 1 illustrates the construction and operation of the biofilter built and put into operation in October 1996. The biofilter treats exhaust air from a pit ventilation fan on a 36 crate farrowing barn. The barn has a total of four pit fans, one is used to provide the minimum ventilating rate. This fan operates continuously at maximum speed with a flow rate of 2,200 cubic feet per minute (cfm) at 0.25 in of H₂O static pressure.
Biofilter

Figure 1. Cross-section of biofilter showing ventilation air movement.

Six inch (15 cm) diameter round wooden fence posts were laid on the ground to form a distribution plenum. Perforated plastic slats 6 inch (15 cm) wide were placed on top of the posts to form a porous base for the biofilter bed. The bed was a 50:50 by weight mixture of University of Minnesota compost and dark red kidney bean straw. The University of Minnesota compost is solid waste from dairy and poultry research. Kidney bean straw, which was locally available, is quite stiff and does not decompose as readily as other straw. The compost and straw were mixed in a TMR mixer and placed on the plastic slats in a bed 12 inches (30 cm) deep. The hood from the exhaust fan was extended and connected to the air plenum below the biofilter bed.

A water sprinkler system was added to the biofilter in May 1997 as the bed began to dry-out. The sprinkler system consists of a grid of nozzles, one for every 20 square feet of bed surface area. The nozzles were connected by 0.5 inch (1.3 cm) diameter PVC plastic pipe placed on top of the bed (Fig. 2). During May and June the water was applied manually for 20 minutes every day without rain when the bed appeared to be dry. An automatic water control system is being developed which will monitor humidity in the bed and control the amount and timing of water application.

Empty bed contact time was estimated to be 8.8 sec when the biofilter was initially constructed. Adjusting for bed porosity, which was measured at 50%, the contact time is 4.4 sec.
Procedures

A hand held temperature probe was used to measure ambient and biofilter bed temperature once a month from October through March. In April a monitoring system was installed to measure biofilter bed, inlet, exhaust and ambient air temperatures with thermocouples connected to a data logger. Readings were taken every five minutes and averaged hourly. The bed temperature sensor was located approximately two inches (5 cm) from the top of the biofilter bed.

Biofilter performance was monitored once a month beginning in November. The pressure drop across the media bed was measured using a manometer. Three air samples were collected each month; air leaving the top of the biofilter bed, air entering the plenum beneath the bed, and air in the farrowing barn. Air samples collected on top of the bed were from a hood three feet (0.9 m) square with a two inch (5 cm) exhaust port placed on the surface of the bed. Air samples from beneath the bed were obtained by placing the collection hose near the connection of the vertical duct and plenum beneath the bed. Air samples in the barn were from a point three feet (0.9 m) above the floor in the barn center.

These samples were analyzed for hydrogen sulfide and ammonia concentration, and odor threshold level. Hydrogen sulfide was measured with a Jerome™ meter. Ammonia level was measured using colorometric gas detector tubes. Odor threshold level was determined using an odor panel and a triangular forced choice olfactometer.
RESULTS

Temperature
Results using the hand held temperature probe indicate that the biofilter bed temperature in the top two inches (5 cm) stabilized at 48°F (9°C) during the coldest winter months, January and February, even when ambient air temperatures went down to -25°F (-31°C). Snow did not accumulate on the bed surface, melting within a few hours after a snow fall, even after 18 inches (0.46 m) of snowfall. Figure 3 is a plot of temperatures recorded using the data logger during July 1997. The data suggests that the biofilter temperature at the center of the bed much less variable compared to the ambient and inlet temperatures.

Pressure Drop
The air pressure differential across the biofilter was 0.14 inches of H₂O (35 Pa) during the first four months of operation. It decreased to 0.10 inches of H₂O (25 Pa) after six months. Channeling of air around the outside edges was observed. Six mil plastic was placed around the edges under the biofilter media to prevent channeling. After fixing the channeling, the pressure differential increased to 0.19 inches of H₂O (47 Pa).
Moisture Control
The cold temperatures during the winter months reduced evaporation. With the additional moisture from snow melt there was no need to add water during the winter to maintain the biofilter media moisture content. A water sprinkler system was built in May 1997 because the bed was drying out as the average ambient air temperature increased. During May and June very little rain fell and the sprinkler system was operated manually for twenty minutes each day. July 1997 was a very rainy month and the sprinkler system was not used.

Odor threshold levels
Figure 4 shows a bar graph of odor detection threshold taken from three locations during the nine months of operation. The odor threshold is expressed in odor units which is defined as the lowest volumetric concentration ratio of the total sample (odorous plus odor-free air) and odorous sample for detection. Odor detection thresholds inside the barn ranged from 120 to 854 odor units. Except for June 1997, odor levels inside the barn were always less than the levels in the inlet air below the biofilter which ranged from 128 to 685 odor units. The higher odor levels in the inlet air were expected because the inlet air passes closer to the stored manure and picks up more odorous compounds. Odor levels in the treated air leaving the biofilter ranged from 20 to 208 odor units. Odor was reduced an average of 78% ranging from 29% in April to 96% in July. It is believed that the biofilter was less effective in April because the bed was drying out. No analysis was obtained in May because the olfactometer was not operating.

Hydrogen Sulfide
Figure 5 shows hydrogen sulfide concentrations in air samples taken from three locations during nine months of operation. Hydrogen sulfide concentrations inside the barn ranged from 130 to 510 parts per billion (ppb). Inlet air concentrations ranged from 320 to 1,200 ppb while the
treated biofilter exhaust air ranged from 1 to 220 ppb. Hydrogen sulfide concentrations were reduced as the air passed through the biofilter an average of 86% ranging form 39% in May to 98% in July. Air entering the biofilter during the winter months had a greater hydrogen sulfide concentration than the air entering during the summer months, because only the minimum ventilating fan was operating during the winter months, moving much less air and allowing hydrogen sulfide levels to increase.

Hydrogen sulfide is heavier then air causing a higher concentration near the pit storage surface. This also explains in part why hydrogen sulfide levels were higher in the inlet air entering the biofilter compared to the air inside the barn. The air samples taken inside the barn were collected at 3 feet (0.9 m) above the floor whereas the below the filter air was coming from just above the manure surface.

![Graph of H2S concentrations](image)

**Figure 5.** Hydrogen sulfide concentrations of air inside the farrowing barn and entering and exiting a biofilter.

**Ammonia**

Figure 6 shows ammonia concentration from three locations around the biofilter during nine months of operation. Ammonia concentrations inside the barn ranged from 1 to 10 parts per million (ppm). Inlet air concentrations ranged from 5 to 19 ppm while the treated biofilter exhaust air ranged from 0 to 14 ppm. Ammonia concentrations were reduced as the air passed through the biofilter an average of 50% ranging form 28% in March to near 100% in July. Ammonia levels were higher during the colder months of winter because the air exchange rate through the building was less.
Figure 6. Ammonia concentrations of air inside the farrowing barn and entering and exiting a biofilter.

**Cost**

This experimental biofilter cost approximately $75.00 for materials to construct because many of the components were readily available from the producer and therefore not directly purchased. A biofilter constructed similarly from new materials was estimated to cost $500.00.

A cost estimate, construction and operating, was prepared for a biofilter for a 700 sow facility to produce weaned piglets. The estimate was for a biofilter that would treat all ventilation exhaust from both the gestation, and farrowing barns. Construction costs were based on a design similar to the experimental unit except that wooden pallets replaced the slats and post support structure, and fans capable of operating at higher static pressure were used. The construction and operating cost was estimated to be $0.28 per piglet produced. Equipment life was assumed to be ten years with the bed being replaced every three years.

**Future research**

There are very few biofilters used to control odors from animal housing facilities. More design information and operation information is needed. Some of the areas needing research to provide design information are:

1. Determine the relationship of pressure differential versus air flow for various depths and biofilter bed material.
2. Determine the minimum exhaust air contact time to the filter medium required to obtain adequate odor reduction for various livestock species.
3. Investigate practical dust reducing techniques in the exhaust air to prevent biofilter clogging. Determine practical moisture applying system for the biofilter. Factors to consider are quantity, application timing, and method of applying moisture.
Conclusion

A low cost biofilter using compost and kidney bean straw was very effective reducing odor threshold levels and removing hydrogen sulfide and ammonia from air from a manure storage pit below a swine farrowing barn. Odor thresholds were reduced by an average of 78%, hydrogen sulfide concentrations were reduced by an average of 86%, and ammonia concentrations were reduced by an average of 50%. Moisture addition was needed during mild and warm weather. Biofilter construction and operating costs can be competitive for today’s swine producers. To develop design specifications and recommendations future research needs determine pressure differentials for various types and depths of biofilter media, minimum contact time for sufficient odor reduction, adequate dust control to reduce plugging, and recommended operating and management practices.

References


