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Treating Odor Emissions from Buildings

Biofilters

Concept. Biofiltration is an air-cleaning technology that uses microorganisms to break down gaseous contaminants and produce non-odorous end products. It is used successfully around the world for treating a wide range of air emissions from industrial sources. Biofiltration works well for treating odors because most odorous emissions are made up of compounds at low concentrations that are readily broken down by microorganisms.

The microorganisms in a biofilter break down (i.e., oxidize) airborne volatile organic compounds (VOCs) and oxidizable inorganic gases and vapors in the odorous exhaust air. The byproducts of the process are primarily water, carbon dioxide, mineral salts, some VOCs, and microbial biomass.

Description. Figure 41-4 illustrates a typical open face biofilter. Odorous air is exhausted from the building with wall or pit ventilation fans that are connected by a duct to the biofilter plenum. The plenum distributes the air evenly across the biofilter media. A supported porous screen holds the media above the plenum. The air passes through the media before it is exhausted to the atmosphere. As the air passes through the biofilter, the odorous gases contact the media and are absorbed onto the biofilm where they are degraded by aerobic microorganisms.

Biofiltration use on livestock facilities began in Germany in the late 1960s and in Sweden in 1984 (Zeisig and Munchen 1987, Noren 1985). Biofilters on pig and calf sheds had average efficiencies around 70% (Scholtens et al. 1987). Nicolai and Janni (1997) reported an average odor reduction of 78% (minimum of 29% in April and maximum of 96% in August) from a pilot-scale biofilter built to treat air exhausted from a pit fan on a farrowing barn in Minnesota. Hydrogen sulfide and ammonia concentrations were reduced an average of 86% and 50%, respectively. The pressure drop across the media (which indicates how much the filter media restricts airflow) ranged between 0.10 and 0.19 inches of water (25-47 Pa).

Data from a full-sized biofilter used to treat the exhaust air from a 700-sow gestation/farrowing swine facility were reported by Nicolai and Janni (1998b, c). The average odor reduction was 82% during the first 10 months of operation. During the same period, the average hydrogen sulfide reduction was 80% and ammonia reduction was 53%. Total pressure drop across the fans reached a maximum of 0.4 inches of water, 0.2 inches of that could be

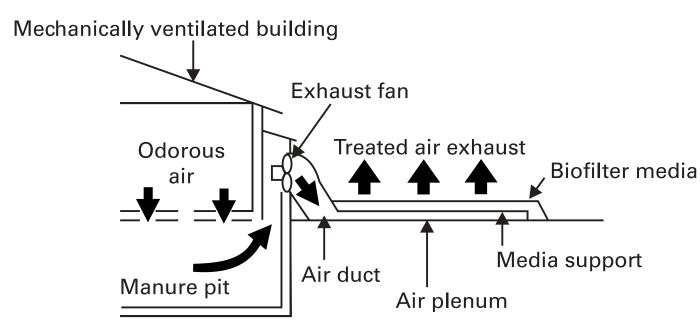

Figure 41-4. Typical open face biofilter layout.

attributed to the building's ventilation inlet system.

The amortized construction and operating costs over three years for this full-sized biofilter were $0.22 per piglet produced per year. Rodent control costs were $275 per year. Additional operating costs of $125 per year included sprinkling costs and costs of operating the higher power ventilating fans (Nicolai and Janni 1998b, c). In general, initial costs for a biofilter are approximately $0.10/cubic feet per minute (cfm) of ventilation air with annual operating costs of $0.02/cfm.

Design and management. Recent research has led to the following recommendations for biofilters used to treat air from swine and dairy facilities:

- Provide a residence time (amount of time the ventilation air is in contact with the media) of at least 5 seconds. This amount of time has resulted in 80% to 90% odor reductions; longer times do not increase this already high level of efficiency.
- Use a biofilter with a minimum depth of 10 inches.
- Ensure a flow rate of 20 cfm per square foot of biofilter area.
- Maintain the moisture level of the biofilter media at approximately 50% wet basis.
- Purchase fans with the capability of moving sufficient air exchange at a total static pressure (includes pressure drop of the barn's air inlets as well as the biofilter's media) of 0.4 inches of water. When designing a biofilter, consider this pressure drop and its impact on the ventilating system.
- Implement and maintain a rodent control program.
- Limit vegetative growth on the biofilter surface.

Use a biofilter with a minimum depth of 10 inches. Ensure a flow rate of 20 cfm per square foot… . Maintain…moisture …at approximately 50% wet basis.

While media selection is important, many common materials can be used for a biofilter, including dark red kidney bean straw and compost (Nicolai and Janni 1997), shredded wood and compost (50% by weight) (Nicolai and Janni 1998a, b, c), and even shredded wood and soil (50% by weight). Shredded wood is used to increase porosity, making it easier for the air to flow through the biofilter. Wood maintains biofilter porosity longer than straw. Compost and soil are a source of microorganisms and nutrients.

Continual excessive moisture can lead to increased airflow resistance (pressure drop) and limited oxygen exchange that could create anaerobic zones. Insufficient moisture leads to drying, microbe deactivation, and channeling, which reduce contaminant removal efficiency.

If present, mice and rats will burrow through the warm media in cold winter months, causing channeling and poor treatment. Rabbits, woodchucks, and badgers have also been suspected of burrowing through and nesting in biofilters.

Finally, excessive vegetative growth on the biofilter surface can reduce its efficiency by causing channeling and limiting oxygen exchange. Root systems can cause plugging, and noxious weeds need to be removed before they produce seed. Excessive vegetative growth may also detract from the site's aesthetic appearance.

Summary. Biofilters effectively reduce odor, hydrogen sulfide, and ammonia emissions from mechanically ventilated livestock buildings. While simple in appearance, they are rather complex biological systems that need to be designed and managed properly to perform well and prevent ventilation problems. Research is continuing to demonstrate their performance and to

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Windbreak walls work by reducing the forward momentum of airflow from fans, which is beneficial during low-wind conditions... .

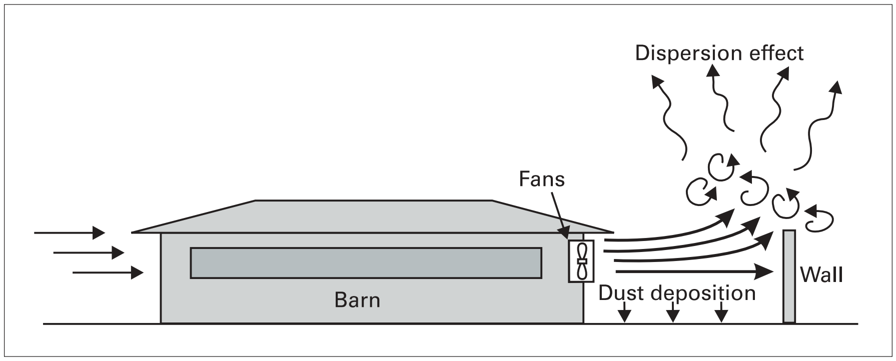

Figure 41-5. A tunnel-ventilated barn with a windbreak wall.

develop better design and management recommendations.

Windbreak walls

Walls erected downwind from the fans that exhaust air from tunnel-ventilated poultry buildings are being used on more than 200 farms in Taiwan to reduce dust and odor emissions onto neighboring land. These structures, known as windbreak walls, provide some blockage of the fan airflow in the horizontal direction. They can be built with various materials covering a wood or steel frame; plywood and tarps are common. The walls are placed 10 to 20 ft downwind of the exhaust fans of tunnel-ventilated barns (Figure 41-5).

Another variation of the windbreak wall is called a straw wall. These systems have been used in North Dakota and elsewhere. They are made with wooden structures and "chicken wire." Straw is placed inside the structures, providing a barrier to dust and other air emissions. They may also offer some filtration capability.

Windbreak walls work by reducing the forward momentum of airflow from fans, which is beneficial during low-wind conditions, because odorous dust settles out of the airflow and remains near the barn. In addition, the walls provide a sudden, large vertical dispersion of the exhausted odor plume that acts to mix fresh outside air into the odor plume at a faster rate than would naturally occur, providing additional dilution potential.

The data and observations taken by Bottcher et al. (1998) using scentometers at a full-scale windbreak wall site in North Carolina showed that

- Dust builds up on wall surfaces.
- The walls redirect airflow from the building exhaust fans upward.
- When wind speeds are low and blowing from the buildings toward the lagoon, the walls move the fan airflow upward so that it blows 10 ft or more above the lagoon surface. Without the windbreak wall in place, the fan air flows directly on top of the lagoon surface.
- Dust and odor levels are greater in the airflow from the fans than they are 10 ft downwind of the windbreak wall, because the fan airflow is deflected upward.

...tall wind barriers placed around a manure storage or lagoon...[may] reduce odor emissions... .

A model study done in Iowa predicted that tall wind barriers placed around a manure storage or lagoon would reduce odor emissions (Liu et al. 1996). Anecdotal evidence suggests a swine farm located in Minnesota benefited when a steel wall was built around an earthen storage basin. Although the operating cost of windbreak walls is relatively low, periodic cleaning of odorous dust from the walls is necessary for sustained odor control, unless rainfall is sufficient to clean the walls. Installation of windbreak walls is estimated to cost at least $1.50 per pig space (e.g., $1,500 for a building that houses 1,000 pigs).

Summary. Research to evaluate windbreak walls and barriers for dust and odor control is continuing. However, it is difficult to determine the effectiveness of windbreak walls. As wind speed and direction shift, the airflow from building fans changes direction. As a result, it is difficult to measure odor downwind. Also, windbreak walls may not be suited for animal buildings equipped with multiple fans at non-uniform locations around the building.

Research to evaluate windbreak walls and barriers for dust and odor control is continuing.

Biomass filters

Researchers at Iowa State University have tested biomass filters as a means of removing odorous dust from swine buildings (Hoff et al. 1997a). Biomass filters use the principle that dust, if removed from the ventilation exhaust stream, will capture a large portion of the odors with it. Hoff et al. (1997b) were able to demonstrate a relationship between scrubbing dust and odors in controlled laboratory experiments and in a full-scale field trial. Using inexpensive material, a biomass filter removes odorous dust from the air stream. The biomass consists of either chopped cornstalks or corn cobs (Figure 41-6), but other materials can be used. Both odor and dust levels were significantly reduced: odor by 43% to 90% and dust by 52% to 83%. These reductions occurred with low resistance to airflow at cold weather ventilation rates.

Using inexpensive material, a biomass filter removes odorous dust from the air stream.

Figure 41-6. Biomass filter composed of sandwich panels of chopped cornstalks outside of swine nursery.

Biomass filters are a cross between biofilters and ...windbreak walls... .

Summary. Biomass filters are a cross between biofilters and the windbreak walls previously described. Instead of a horizontal filter bed as shown for the biofilter design, the filter material is vertical like the windbreak wall design but connected to the building so the exhaust air is forced through the biomass filter materials. The cost of this dust and odor control technology is not as well documented as other listed control technologies, but it is probably similar to biofilters in both initial and operating costs.

Natural windbreaks

Rows of trees and other vegetation known as shelterbelts, which have historically been used for snow and wind protection in the Midwest, may have value as odor control devices for all species and systems. Similarly, natural forests and vegetation near animal facilities in other sections of the country may serve the same purpose. These shelterbelts also create a visual barrier. A properly designed and placed tree or vegetative shelterbelt could conceivably provide a very large filtration surface (Sweeten 1991) for both dust and odorous compound removal from building exhaust air and odor dispersion and dilution, particularly under stable nighttime conditions (Miner 1995, NPPC 1996). Currently, a few studies are addressing the total impact of vegetative barriers on odor reduction from animal farms, but many people already attest to their value. Shelterbelts are inexpensive, especially if the cost is figured over the life of the trees and shrubs, but it may take 3 to 10 years to grow an effective vegetative windbreak.

...it is generally believed that windbreaks reduce odors by dispersing and mixing the odorous air with fresh air.

Summary. Although not confirmed by solid research, it is generally believed that windbreaks reduce odors by dispersing and mixing the odorous air with fresh air. Windbreaks on the downwind side of animal houses create mixing and dilution. Windbreaks on the upwind side deflect air over the houses so it picks up less odorous air. Producers should avoid placing dense windbreaks so close to naturally ventilated buildings that cooling breezes and winds exchanging the air in these buildings are eliminated or greatly reduced. A minimum distance of 100 feet, or five to ten times the tree height, from a naturally ventilated building is recommended.