Biofiltration-Mitigation Odor and Gas Emissions from Animal Operations

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Species: Swine, Dairy
Use Area: Animal Housing
Technology Category: Biofilter
Air Mitigated Pollutants: Hydrogen Sulfide, Ammonia, Methane, Volatile Organic Compounds, Odors

Description:

A biofilter is simply a porous layer of organic material, typically wood chips or a mixture of compost and wood chips, that supports a population of microbes. Odorous building exhaust air is forced through this material and is converted by the microbes to carbon dioxide and water. The compounds in the air are transferred to a biofilm that grows on the filter material.

Biofiltration can reduce odor and hydrogen sulfide (H_2S) emissions by as much as 95% and ammonia by 65%. (Sun et al., 2000; Nicolai et al., 2006)The method has been used in industry for many years and was recently adapted for use in livestock and poultry systems. Biofilters work in mechanically ventilated buildings or on the pit fans of naturally ventilated buildings. Biofilters can also treat air vented from covered manure storage units.

Key factors influencing biofilter performance are the amount of time the odorous air spends in the biofilter and the moisture content of the filter material. Design issues include the amount of air treated, sizing of the biofilter bed, selecting fans to push the air through the biofilter, choosing biofilter media, moisture control, operation and management, and cost of construction and operation.

Mitigation Mechanism:

The odorous air exhausted by a fan from the building is uniformly distributed beneath the biofilter media then passes through a bed packed with organic carrier materials, i.e. media consisting of wood chips and/or compost. The odorous and gaseous compounds in the air are transferred to a biofilm that surrounds media particles in the bed where the microorganisms break down the compounds. The compounds provide the nutrients necessary for microorganism growth. Several processes take place in the biofilter system to remove odorous compounds (Jordening and Winter, 2005). They include:

1. Transferring the odorous compounds in the air to the liquid phase surrounding each particle of the organic material.
2. Migration of the odorous compounds from the bulk liquid phase to the biologically active phase or biofilm that grows on the filter material.
3. Degradation of the pollutant by the microbes takes place in the biofilm where the biodegradable gas is oxidized into carbon dioxide, water, mineral salts, and biomass (more microorganisms).
4. The end products from the microbes migrate back through the liquid phase and emitted into the air phase. The cleaned exhaust air then leaves the biofilter.

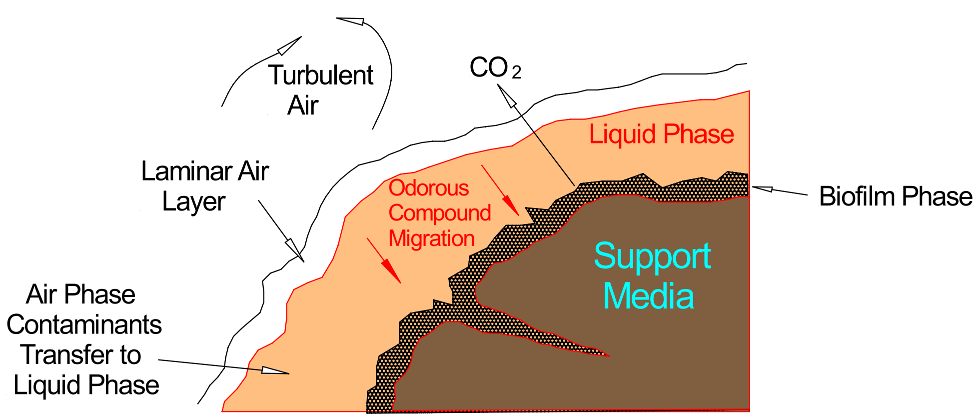

Figure 1 Biofilter Process

An important control parameter is the moisture content of the overall carrier material, which must be between 40% and 60% (wet basis). To avoid microorganism dehydration, the organic carrier material requires moisture application.

Biofilters are effective in reducing odorous compounds, volatile organic compounds, hydrogen sulfide, ammonia, methane, and volatile fatty acids. Odor and hydrogen sulfide emissions can be reduced from livestock facilities by 85% to 95% while ammonia and methane may be 50% to 90% depending on operating parameters (Nicolai and Janni, 2000; Sun et al., 2000; Nicolai et al., 2006; Nicolai and Thaler, 2007).

Applicability:

The air to be treated must be controlled in a duct system and pressurized to pass through the biofilter media. Therefore biofilters are suited to mechanically ventilated applications, such as power ventilated swine barns, dairy manure collection pits that are power ventilated, covered manure storage structures that are power ventilated.

Two configurations of biofilters are being used to treat exhaust air from swine buildings. They are a horizontal bed (figure 2) and a vertical bed (figure 3). Horizontal biofilters on swine barns have been shown to reduce odors from exhaust fans and are less expensive than vertical (Nicolai and Janni, 2000, Nicolai and Thaler, 2007). The media bed is typically 12 to 18 inches deep. Horizontal deep-bed biofilters are an option when space is limited and centrifugal fans can be used.

But in some situations, there is not enough area to construct a large horizontal biofilter designed for large airflows. Vertical biofilters offer an advantage because they utilize less surface area than a horizontal for the same airflow. The media in a vertical biofilter is placed between two support structures in which the treated air passes through horizontally.

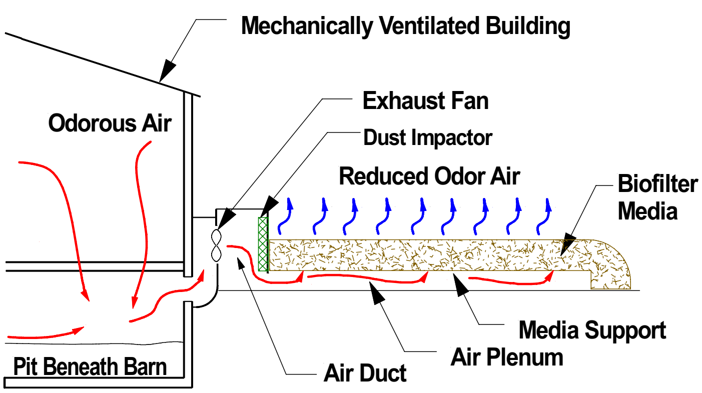

Figure 2 Horizontal Biofilter

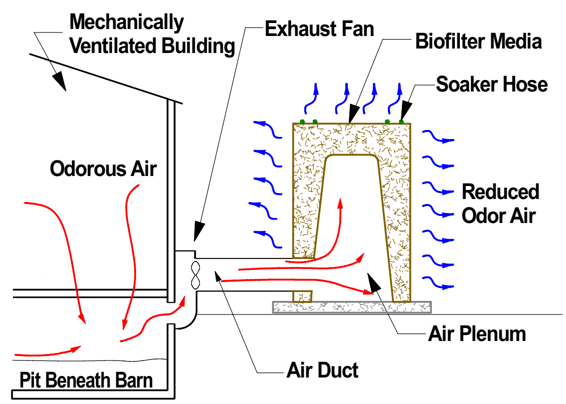

Figure 3 Vertical Biofilter

Figures 2 and 3 illustrates elements of an open-bed biofilter. They are:

- a mechanically ventilated space with biodegradable gaseous emissions;
- an air handling system to move the odorous exhaust air from the building or manure storage through the biofilter;
- an air plenum to distribute the exhaust air evenly beneath the biofilter media;
- a structure to support the media above the air plenum;
- porous biofilter media to act as a surface for microorganisms to live on, a source of some nutrients, and as a structure where moisture can be applied, retained, and available to the microorganisms.

Limitations:

Naturally Ventilated Buildings

Biofilters are only effective when there is a captured air stream. This air stream is typically the fan exhaust from mechanically ventilated buildings or the exhaust from nonporous covered manure storage. The air emissions through the sidewall of a naturally ventilated building typically cannot make use of a biofilter.

However, some naturally ventilated buildings use some mechanical ventilation in combination with natural ventilation. The mechanical portions of the ventilation may include pit fan exhaust and sidewall fans that operate to provide minimum ventilation in the winter. For these types of facilities it is possible to install biofilters on the exhaust fans.

The amount of odor reduction achieved in naturally ventilated barns is variable. During the cool months when most of the ventilation air passes through the exhaust fans and subsequently the biofilter, odor reduction is similar to that of mechanically ventilated buildings, or approximately 80-95%. However, during the summer months the primary means of providing air exchange through the barn is by natural ventilation (curtains and/or ridge vents). During these times, the odor reduction provided by a biofilter on the pit and wall fans is less, depending on the percentage total ventilation air treated. However, during warm weather the much greater natural ventilation air exchange rate through the barn leads to lower gas and odor concentrations.

Cost:

Costs to install a biofilter include the cost of the materials—fans, media, ductwork, plenum and labor. Typically, cost for new horizontal biofilter on mechanically ventilated buildings will be between $150 and $250 per 1,700 m^3/hr (1,000 cfm). A vertical biofilter is approximately 1.5 times the cost of a horizontal biofilter.

Annual operation/maintenance of the biofilter is estimated to be $5-$10 per 1,700 m^3/hr (1,000 cfm). This includes the increase in electrical costs for fans to push the air through the biofilter and the cost of replacing the media after 5 years.

Both capital costs and operation and maintenance costs are quite variable. High-cost situations are those where biofilters are retrofit on naturally ventilated buildings to filter air from pit fans or from additionally installed fans for mild weather ventilation.

Implementation:

Biofilter design

Biofilter designs are based on the volumetric flow rate of air to be treated, media characteristics, biofilter size (area) constraints, and cost. These parameters all play a role in the efficient cleaning in economical operation of the biofilter:

Airflow rate – Biofilters should be sized to treat the maximum ventilation rate—typically the warm weather rate—of the building. This ventilation rate is dependent on the type, size, and number of animals in the building. Proper ventilation design procedures can be found in MWPS-32, *Ventilation systems for livestock housing*. To achieve pit gas odor reduction through biofiltration, up-drafting through the slatted floor should be eliminated when the curtains are open. For example, in a curtain-sided swine finishing barn, a minimum ventilation rate of 75 to 85 m^3/hr (45 to50 cfm) per pig is recommended to achieve complete down-draft when the curtains are opened.

Biofilters treating air from a manure storage unit will treat a lesser volume of air with a higher concentration of odorous gases. Typical airflow rates from covered manure storage are 0.01 cfm per square foot of surface area.

Media characteristics – For a biofilter to operate efficiently, the media must provide a suitable environment for microbial growth and maintain a high porosity to allow air to flow easily. Critical properties of media material include (1) porosity, (2) moisture holding capacity, (3) nutrient content, and (4) slow decomposition.

In a biofilter, the relationship between airflow rate and static pressure depends on the type of media and media depth. Figure 4 shows this relation between Unit Airflow Rate (UAR, the amount of airflow per square foot of biofilter surface) and Unit Pressure Drop (UPD, the static pressure drop per foot of biofilter media depth) for a variety of materials tested in the lab. The lines shown are for media with different percent voids. Percent void is a measure of the amount of open pore space in the media.

As airflow rate increases, the pressure drop through the media increases i.e. as airflow increases it takes more pressure to push the air through the media. Also, as porosity increases, the pressure drop decreases. This porosity is both a function of the original media, compaction of the media, and media moisture content.

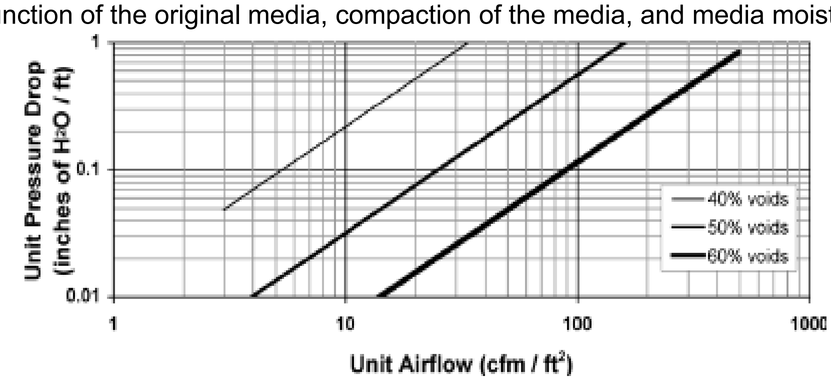

Figure 4 Media unit pressure drop and unit flow rate relations for various biofilter media.

To decrease this pressure drop and increase airflow, the media depth can be decreased. If this is not possible, the biofilter area must be increased, thus increasing the EBCT. Increasing the EBCT means a better filter efficiency, a lower pressure drop, more biofilter media, and a larger biofilter area. Building a larger biofilter can be justified due to the less powerful fans needed and the reduced operating cost of these fans.

Porosity can also be affected by age of the media. Over time the media decomposes and settles which reduces pore space. Any activity that causes compaction, such as walking on the media, also will reduce pore space.

Retention or Empty Bed Contact Time (EBCT) – Retention time is the amount of time that the air is in contact with the biofilter media. A longer retention time gives the biofilter a longer time for the odorous gases to be absorbed into the liquid phase resulting in more odor reduction but will also require a larger area for the biofilter. Retention time depends on the specific gas (or gases) being treated and concentration of the gas (gases). EBCT is determined by dividing the volume of the media (m^3 or ft^3) by the airflow rate (m^3/s or ft^3/s).

Maintenance

Attention is needed in four areas—moisture content, weed control, rodent control, and assessing pressure drop. None of these management issues takes significant amounts of time, but all are important for proper biofilter operation.

Moisture content – Biofilter moisture management requires some on-the-job training. Typically, no moisture measurements are needed. Rather, the feel and look of the filter material will be indicators of too much or too little water. During cold weather the media moisture content is fairly constant (from heated exhaust air) and remains at approximately 50%. However, in the summer a media watering system is needed. A standard lawn sprinkling system is fairly effective. However, because the media dries from the bottom and is watered from the top, it is necessary to dig down into the media to check moisture content. Dampness should be felt one-half to three-quarters of the way down through the depth of the media. If dampness is felt throughout the depth of the media, then the watering system is providing too much water. If, however, only the top few inches are damp then the water needs to be increased. Often, watering is done at night for one or two hours to reduce evaporation losses.

Water can be applied through surface irrigation i.e. sprinkling the top of the media. On a horizontal biofilter sprinkling provides direct control but can lead to ‘fingered’ downward flow. A finer droplet size tends to improve water distribution. Excess moisture is generally not a problem because the additional moisture drains through the media or evaporates due to the constant airflow through the biofilter. For a vertical biofilter configuration, a soaker hoses on the top surface allow the water to be evenly distributed.

Weeds – Weed growth on the biofilter surface can reduce efficiency by causing air channeling and limiting oxygen exchange. Roots can contribute to plugging of biofilter pores. Weeds on a biofilter also reduce the aesthetic appearance of the livestock site. A systemic herbicide or some other means should be used.

Rodents – A good rodent control program is essential. Mice and rats burrow through the warm media during the cold winter months, causing channeling and poor treatment. Rabbits, woodchucks, and badgers have been suspected of burrowing through and nesting in biofilters. Fortunately, most livestock and poultry operations currently have a good rodent control program. These programs are not very expensive.

Assessment of pressure drop – Over time the degradation of the media material, dust buildup in the media, and media settling will cause the pressure drop across the media to increase. As pressure drop increases the amount of air moved by the ventilation fans decreases, eventually resulting in poor building ventilation. The type of biofilter media and the dustiness of the exhaust air will both affect the length of time before the media plugs and the pressure drops become excessive.

Unfortunately, no long-term studies have been conducted to determine just how long this will take, but it is estimated that most biofilters will last 5 to 10 years or more. Poor building ventilation at maximum ventilation rates will likely be the first sign of biofilter plugging. A manometer can be used to check the pressure drop across the biofilter. Depending on the design of the biofilter and the ventilation fans selected, an increase in the pressure drop across the media of over 50% of the design pressure drop indicate the need to replace the media. The maximum pressure drop must be measured at maximum ventilation rates.

Technology Summary:

Biological treatment fills the need for an economical means of treating low concentration odorous and other compounds coming from building emissions. The concept of biological air treatment involves bringing the air in close contact with a water phase that contain active microorganism.

The need to keep biofilters moist is a significant design consideration. Large amounts of air pass through biofilters causing a slow but steady drying that eventually disrupts the microbial activity.

The Technology Summary is meant to be a basic summary of your entire paper including Mitigation Mechanism, Applicability, Limitations, and Economics, as well as other important points made in your paper.

Additional Resources:

SDSU. 2005. Biofilters. South Dakota State University, Brookings, SD 57007. Available at: http://agbiopubs.sdstate.edu/pub_description.cfm?Item=FS925-C. Accessed 1 April 2008.

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