COMPARISON OF BIOFILTER RESIDENCE TIME

By

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Summary:
Residence time is a critical factor in determining the size of an open face biofilter. Four test biofilters were constructed with media comprised of yard waste compost and brush chips to compare 8 s. and 4 s. residence time. Biofilter performance was monitored for ten months by measuring pressure drop, moisture content, odor threshold, hydrogen sulfide, and ammonia concentrations. Odor reduction efficiency for the 8 and 4 second residence time biofilters is 91% and 87% respectively. Hydrogen sulfide reduction efficiency is 97% and 96%. Ammonia reduction efficiency is 82% and 74%. There is no significant difference between an 8 s. and a 4 s. empty bed contact time for odor, hydrogen sulfide, and ammonia removal. Based on current information, the design residence time for biofilters on swine buildings is 4 to 5 seconds. Further research is needed to determine the minimum effective residence time for open face biofilters on livestock facilities.

Keywords:
Biofilters, Biofiltration, Swine, Odor, Hydrogen sulfide, Ammonia
INTRODUCTION

Pork production facilities generate odors. Those odors can be a nuisance to rural and urban neighbors near facilities. In a growing number of cases, concerns about odors and potential odors have caused the pork industry to experience governmental restrictions on growth and negative relations between residential neighbors and producers. These restrictions on growth and potential conflicts with neighbors will limit the business opportunities for the pork industry.

Most of the odor reduction research in the past has focused on emissions from outside manure storages. One alternative to outside storages is to store manure below slatted barn floors in deep pits. Odors from barns with deep pits as well as barns where the manure is removed are a major part of the total odors coming from a pork production site (Jacobson et al., 1997).

Biofilters reduce odor emissions (Janni et al., 1996). Since many biofilter applications are in the industrial market, little information is available for designing low cost systems for agriculture use. Nicolai et al. (1997) developed a low cost biofilter for swine production facilities. Average odor and hydrogen sulfide removal for that design was between 75 and 90 percent.

One critical factor in determining biofilter size is the residence time. An indicator of the residence time is empty bed contact time, which is determined by dividing the volume of the empty filter bed by the airflow rate. An 8.8 s. empty bed contact time was used to achieve the odor reduction levels with the Nicolai et al. (1997) design. Zeisig (1987) reported adequate odor reduction could be achieved with 5 s. empty bed contact time.

The objectives of this research was to determine the effect different air contact times (4 s. and 8 s.) have on odor, hydrogen sulfide, and ammonia emission.

MATERIALS AND METHODS

Figure 1 shows the layout of four 5ft. x 7ft. biofilters constructed in September, 1997 next to a 640 head capacity deep pitted nursery barn. An air mixing duct was constructed to receive exhaust air from three 1200 cfm pit fans. Four 250 cfm blowers mounted inside the air mixing duct moved air to each biofilter. Excess air from the pit fans was allowed to exit from one end of the mixing duct.

Each biofilter consisted of a 6 in. deep plenum beneath a media support floor. This plenum received air from the blowers in the mixing duct. Two of the four biofilters had 12 in. deep media and two had 6 in. deep media. The empty bed contact time for these two depths is 8 and 4 s.
The biofilter media was 50% by weight yard waste compost and 50% brush wood chips. Since these biofilters were the open face type and followed the type of construction developed by Nicolai et al. (1997), they were exposed to Minnesota weather conditions.

Biofilter performance was monitored by comparing untreated air samples from each end of the air mixing duct to treated air samples which were collected from beneath a 1 m square flux hood on top of each biofilter. Air samples were analyzed using a dynamic olfactometer to determine odor detection threshold (Nicolai et al., 1997). Hydrogen Sulfide gas concentration was measured with a Jerome™ meter. Ammonia gas concentration was measured with NH₃ detector tubes. Air pressure differential on one blower and temperatures of the bed, untreated air, and treated air were continuously recorded on a dataloger system. Moisture content was determined by drying media samples and reported as a percent of dry matter.
RESULTS AND DISCUSSION

Odor threshold levels
Figure 2 shows odor detection threshold levels of air samples from before and after biofilter treatment. Samples were taken over a ten month period from September 1997 until June 1998. Odor levels are reported in odor units, which is the maximum dilutions of the sample air in clean air that will still allow trained odor panelists to detect the presence of an odor.

Odor was reduced an average of 91% for the 12 inch deep biofilter and 87% for the 6 inch deep biofilter. The probability of variation in depth was 0.3750 using the nova statistical analysis. Thus, there was no significant difference in odor reduction between the two depths at the 5% level.

Odor reduction efficiency improved from 82% to 97% for both biofilter media depths from startup to January. This efficiency increase was expected as the microorganisms, which oxidize the VOC’s, multiplied and adapted to their new environment. Odor reduction efficiency for April was less than average (reductions of 84% for the 12 in. biofilter and 68% for the 6 in. biofilter). Warmer and dryer weather conditions during this period caused the biofilter media moisture content to be reduced. Inlet odor values were lower during the summer months as additional wall fans operated, thereby increasing the nursery ventilation rates.

Hydrogen Sulfide

Figure 3 shows hydrogen sulfide concentrations of inlet and exhaust air from 12” and 6” deep biofilters.

Figure 3 shows hydrogen sulfide concentration through the two different biofilter media depths. Hydrogen sulfide is reported in parts per billion. Hydrogen sulfide emissions were reduced an
average of 97% for the 12 in. deep biofilter and 96% for the 6 in. deep biofilter. The probability of variation in depth was 0.3875 using the nova statistical analysis. Thus, there was no significant difference in hydrogen sulfide reduction between the two media depths at the 5% level. Since the biofilters had lower moisture contents during April the hydrogen sulfide removal efficiency was reduced.

**Ammonia**

![Ammonia Concentrations](chart.png)

Figure 4  Ammonia concentrations of inlet and exhaust air from 12" and 6" deep biofilters.

Figure 4 shows ammonia concentration of inlet and exhaust air from the 12 inch and the 6 inch deep biofilters. Ammonia is reported in parts per million. The average ammonia reduction for each biofilter type was 82% for 12 in. and 74% for 6 in.. The probability of variation in depth was 0.1041 using the nova statistical analysis. Thus, there was no significant difference in ammonia reduction between the two depths at the 5% level.

**Pressure Drop**

Average pressure drop across the 12 in. biofilters was .045 in. of water and across the 6 in. biofilter it was .025 in. of water. Laboratory pressure tests with this media at 250 cfm air flow rates show the pressure drop per foot of depth to be between .04 and .1 in.
Media Moisture Content
Moisture content in all biofilters remained above 40% except during April when they were near 30%. No additional water sprinkling was provided for the biofilter.

One 6 in. biofilter was covered to prevent moisture addition for one month during June 98. The media dried to 5.25% moisture. This reconfirms Medina et al. (1994) findings that beds with peat or compost media, which tend to hold moisture, will dry out due to high air flow rates. Odor, hydrogen sulfide, and ammonia removal percentages after drying were 75%, 71%, and 33% respectively.

CONCLUSION

Significant odor, hydrogen sulfide, and ammonia reduction was achieved by the biofilters. There was no significant difference between an 8 s. and a 4 s. empty bed contact time for odor, hydrogen sulfide, and ammonia removal. Therefore, the recommended empty bed contact time for swine facilities is 4 to 5 s. Further research is needed to determine the minimum effective residence time for open face biofilters on livestock facilities.

REFERENCES


