Evaluation of a Biotrickling Filtration System for Treatment of Exhaust Air from a Swine Barn

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Biotrickling filters are considered to be the next development for animal housing since they are easier to manage and are smaller in size compared to other exhaust air filtration technologies. Various configurations of biotrickling filters and bioscrubbers have been studied and showed a very good potential for controlling emissions from pig buildings. A number of operating conditions have been specified for biotrickling filters (Deshusses and Gabriel, 2005). Design values have been suggested for bed height, bed cross-sectional area, packing nominal size, empty bed residence time (EBRT), pressure drop, air temperature, liquid recycle rate, pH of the recycled liquid, and some typical control parameters. However, further work is needed in order to realize the best design that will perform effectively when installed in actual swine production facilities.

The main objective of this study was to develop an air cleaning technology that will reduce the offensiveness of the exhaust air from a swine grower-finisher facility. The specific objective of this study was to evaluate the effectiveness of this air treatment unit (ATU) in a commercial-scale pig facility.

Previous phases were used as basis for the design of a commercial-scale ATU (Figure 1) that was evaluated in this study. Each ATU consists of two vertical walls of plastic porous material with a sprinkler system supplying water from the top of the wall; as water trickles down the wall, the exhaust air is passed across the wall. Because the water is continuously recirculated over the wall, a biofilm forms on the surfaces of the porous wall material, and the combined action of the microorganisms in the biofilm and the wetted filter media results in the cleaning of the exhaust air that passed through the wall.

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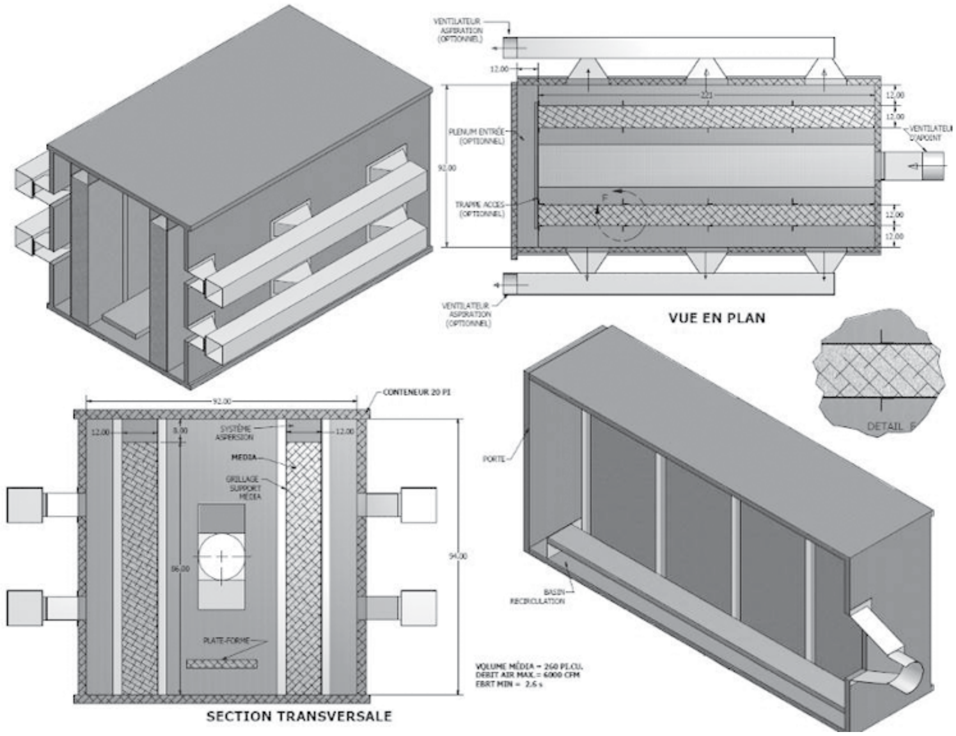

Figure 1. Conceptual diagram of the interior of each air treatment unit.

Animal and room preparation

Three grow-finish rooms at the PSC barn facility were used for this study. Each room had a total floor area of 5.49 x 14.63 m (18 x 48 ft), with six pens of 1.98 x 4.11 m (6.5 x 13.5 ft.) each. Each room was mechanically-ventilated with 3 exhaust fans at one end of the room (outside wall). For this experiment, a total of 60 grower pigs (10 per pen) at starting weight of about 20-25 kg was brought into each room.

Three identical air treatment units (ATUs) were installed outside of the rooms; the exhaust air from each room was ducted to each ATU and passed through the biotrickling filter inside each unit (Figure 2). Monitoring equipment and sensors were installed in the rooms and in each unit to collect data on gas and dust levels, environmental parameters, as well as operational parameters such as airflow rates, water and energy consumption.

The trial ran for 12 weeks. During the trial, the following parameters were monitored:

1. gas (NH3), dust, and odour levels
2. environmental parameters (air temperature, relative humidity, airflow rates)
3. pig performance (average daily gain, health record and mortality rates)
4. operational parameters (water and energy consumption).

Figure 2. Photo of actual set-up showing the plenum enclosing the barn exhaust fans and the duct connecting the plenum to the air treatment unit.

Additionally, on each sampling week, air samples were collected into 10-L Tedlar bags before and after each ATU and sent to an olfactometry laboratory for odour analysis. Furthermore, two total dust samplers were installed in each ATU to assess the impact of the ATUs on dust levels at the exhaust.

Effect on ammonia concentration

Table 1 shows the weekly average NH_3 concentration before (inside the room) and after each air treatment unit. The difference in NH_3 levels before and after the unit was statistically significant ($p<0.0001$) which means that the air filtration unit was able to significantly reduce levels of ammonia in the exhaust airstream before being released to the environment. It was also observed that NH_3 concentration before the treatment units increased significantly ($p<0.0001$) as the trial progressed while the fluctuations of NH_3 at the exhaust of the units were not significant ($p=0.059$). This observation implies that the air filtration units worked effectively even at the start of the trial; however, the reduction in NH_3 levels during the initial part of the trial was not that high because the incoming NH_3 levels were relatively low compared to the latter part of the trial when pigs were nearly market weights and NH_3 levels inside the room tended to be very high, thus, resulting to higher NH_3 removal percentage.

This observation is more evident in Figure 3 when actual levels of ammonia before (initial) and after (final) each ATU and temperature of air passing through the ATU were plotted over a 24-hour period; the data presented in the figure were extracted from week 11 results when ammonia sampling was done continuously for three days. Considering two factors (time and air temperature) that may influence reduction of ammonia, regression analysis revealed a significant relationship ($p=0.0001$) between NH_3 reduction and air temperature but not with time ($p=0.8187$) (i.e., over a 24-hr period). As shown in Figure 3, NH_3 levels at the biotrickling filter exhaust were almost the same over the 24-hr period regardless of the initial NH_3 concentration in the rooms.

Effect on dust and odour concentration

Levels of total dust before and after the air treatment units are shown in Table 1. Significant reduction ($p<0.0001$) in dust levels was observed after the exhaust air had passed through the treatment units. Similar to ammonia, dust levels after the treatment units were not significantly different ($p=0.183$) over the monitored weeks; however, dust levels inside the rooms (before the units) increased significantly ($p<0.0001$) with time. This has resulted to higher dust reduction achieved at the latter part of the trial when pigs were nearing market weights. Maximum dust reduction was about 92%, which was achieved on week 12 while the least reduction was about 65% during week 3.

As shown in Table 1, the impact of the air treatment units on odour concentration was not as readily evident compared to ammonia and dust, though statistically significant reduction ($p=0.017$) in overall odour levels was observed after passing through the treatment units. On average, odour concentration inside the room (before treatment)

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Table 1. Average weekly concentration of ammonia, total dust, and odour concentration before and after each ATU and the corresponding removal efficiency (RE).

Parameter		Weekly average		
		Before	After	RE (%)
Ammonia, ppm	Mean	27.6	7.6	62.3
	SD	12.4	1.1	17.7
	Min	8.4	6.3	22.0
	Max	48.0	9.6	76.8
Dust, mg/m³	Mean	0.899	0.177	77.6
	SD	0.410	0.077	8.8
	Min	0.255	0.089	65.2
	Max	1.301	0.266	91.9
Odour, OU/m³	Mean	815	553	4.4
	SD	419	208	81.1
	Min	241	306	-165.6
	Max	1443	936	75.0

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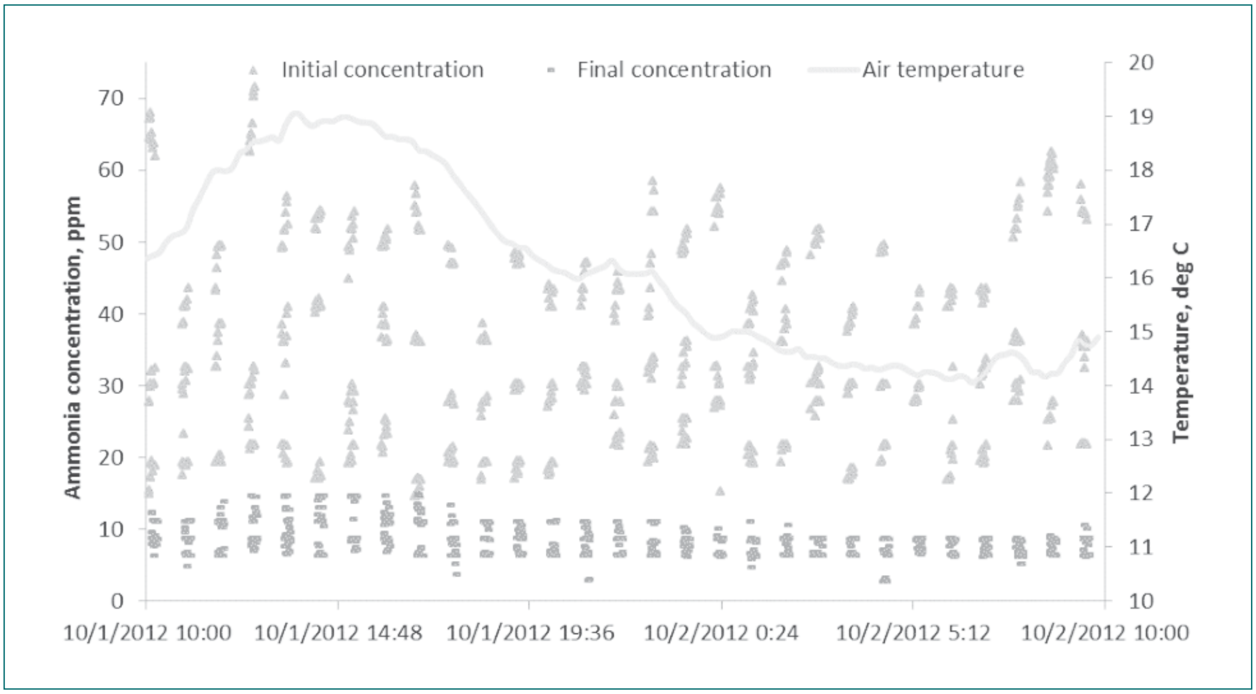

Figure 3. Variation in ammonia and exhaust air temperature over a 24-hr period in week 11.

was about 815 ± 419 OU/m³ and was reduced to about 553 ± 208 OU/m³ after the air treatment units. Variations in odour levels after the treatment units were not significant (p=0.119) while odour variations inside the room were significant (p=0.006).

Water consumption

The water consumption associated with the air treatment units are presented in Table 2. On average, the air treatment units consumed about 537.5 ± 113.3 liters of water per day with ATU 1 had the highest (663.0 L/day) while ATU 3 had the least (442.9 L/day). Wide variations in water consumption between ATUs can be attributed to the differences in frequency of replenishing the water in each particular unit, i.e., draining about 2 inches depth of water from the unit and then adding the same volume, to maintain the water electrical conductivity below 7.5 µS. Throughout the trial, the water in ATU 1 was replenished 16 times compared to 11 times for ATU 3; this could be related to NH3 removal because as shown in Table 2, ATU 1 had the highest NH3 removal efficiency while ATU 3 had the least. Draining and then adding water into the ATU was not done every day as it was dependent on the water electrical conductivity readings in each unit; this was required almost every day for some units but for others this was done at two to three days interval.

Table 2. Water consumption associated with each air filtration unit.

Replicate	Average NH3 removal efficiency, %	Water consumed, L/day (Mean ± SD)
ATU 1	72.2	663.0 ± 498.2
ATU 2	65.0	506.6 ± 427.3
ATU 3	49.6	442.9 ± 419.1
Average		537.5 ± 113.3

The Bottom Line

Based on the findings from this trial, the following conclusions can be made:

1. The biotrickling air treatment units installed at the exhaust of swine grow-finish rooms were effective in reducing the levels of ammonia, dust, and odour by about 77%, 92% and 75%, respectively.
2. The biotrickling units were able to reduce the levels of ammonia even at the initial stage of the trial, with the ammonia levels after the filter almost remaining the same throughout the trial. Hence, the percent reduction in ammonia increased as the initial ammonia concentration entering the filter increased.
3. Water consumption tended to increase as the biotrickling units remove more contaminants from the air.

Acknowledgements

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