Removal of odour and ammonia in ventilation air from growing-finishing pig units using vertical biofilters

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ABSTRACT

The aim of this study was to investigate the removal of odour and ammonia from outlet air using vertical biofilters in two units with growing-finishing pigs in the winter. Woodchips were used as media in the wall of the biofilters. The air from the pig units was humidified by a high-pressure water system before it reached the biofilters. A total of 56 odour and ammonia measurements were taken at an average outdoor temperature of 5.4 C. The biofilters significantly reduced the odour concentration (OU_E/m^3) in the outlet air ($P<0.001$). The measured odour removal efficiency averaged 60 %. In contrast, the biofilters did not reduce the ammonia concentration (ppm) significantly in the outlet air. The hedonic tone of the odour of the air was determined before and after the biofilter. The untreated air was recorded as more unpleasant than the air that had passed through the biofilters. In conclusion, the biofilters were capable of reducing the odour concentration in the outlet air from units with growing-finishing pigs in the winter. The biofilters' treatment of the air made the odour less unpleasant. However, the biofilters were not capable of reducing the ammonia concentration in the outlet air in the winter.

1 INTRODUCTION

In recent years, there has been a growing interest in reducing odour and ammonia from pig production in Denmark. This interest has been heightened by more stringent environmental regulations in Denmark, which were most recently intensified in January 2007 (Danish Ministry of the Environment, 2006). This has resulted in several companies developing technologies for odour and ammonia reduction of air from pig

units. In the United States, the research has mainly been on biological air treatment. Most of the focus has been on horizontal biological air filters in which the filter material consists of a mixture of woodchips and compost (Nicolai and Schmidt, 2004). However, these solutions have a large space requirement, and experiences have shown that they are a popular place for rodents. Therefore, research in the United States has recently focused on vertical biofilters, where the concept of woodchips and compost are used as filter material (Nicolai *et al.*, 2005). In comparison with the horizontal biofilters, the filter material is put into the wall of a vertical silo. The air from the pig facility enters the vertical biofilter and is then forced through the wall of the biofilter. Vertical biofilters reduce the space requirement and minimize the risk of rodents invading the biofilter. The present study was carried out to investigate the removal of odour and ammonia from outlet air using vertical biofilters in two units with growing-finishing pigs in the winter.

2 MATERIALS AND METHODS

2.1 Experimental setup

Two units, each housing 180 growing-finishing pigs, with partially slatted floors were used. Two vertical biofilters were placed outside the two units. The ventilation system was based on the principle of negative pressure ventilation. Fresh air entered the unit through a diffuse inlet in the ceiling. The outlet air was sucked out through the roof and into ventilation channels which were connected to the biofilters. The biofilters were round-shaped and hollow with an outer diameter of 3.90 m and a height of 4.60 m. The ventilation fan was placed in the channel directly before the filters, and the outlet air was forced through the filters. Woodchips were used as media in the wall of the biofilters (Figure 1).

Figure 1. Design of the vertical biofilters.

The wall of the biofilters was 0.70 m wide at the top and 0.30 m wide at the bottom to avoid variable airflow through the biofilter wall due to settling of the media over time. The design was in accordance with recommendations by Nicolai *et al.* (2005). Before the air from the pig units reached the inside of the biofilters, it was humidified by a high-pressure water system (Agrofilter GmbH, Alfstedt, Germany) to ensure that the woodchips were moistened. As the outlet air passed through the wall of the biofilters, dust, ammonia and odour compounds in the air stream were degraded and metabolized by the biofilm on the woodchips. The biofilters were set up by September 1st 2006. The measurement period went from February to March 2007 and included one batch of pigs. A total of 56 odour and ammonia measurements were taken on seven days spread over a period of four weeks during the measurement period.

2.2 Analytical methods

The odour samples were collected in 30 L Tedlar® odour bags. The bags were placed in an airtight container and filled by creating a vacuum in the airtight container with a pump. On each of the seven days of measurement, two pairwise odour samples were taken from the air stream before and after each biofilter, respectively. The first pairwise odour samples were taken between 11.00 a.m. and 11.30 a.m. and the second pairwise odour samples were taken between 12.30 p.m. and 1.00 p.m. The collection of odour samples and analyses of odour concentration (OU_E/m^3) were performed in compliance with European olfactometric standard EN:13725 (CEN, 2003). The ammonia concentration (ppm) was measured in the air stream before and after the filters using Kitagawa gas detector tubes 105SD (Komyo Rikagaku Kogyo K.K., Kawasaki-City, Japan). The relative humidity in the air stream was measured using a TSI VelociCalc Plus 8386 instrument (TSI Incorporated, Minnesota, U.S.A.). On the sixth day of measurement, one pairwise odour sample from the air stream before and after one biofilter was sent for analysis of hedonic tone of the odour. The hedonic tone describes the pleasantness or the unpleasantness of a given odour. The hedonic tone was determined at the concentration level of 1 to 15 OU_E/m^3. The determination of the hedonic tone was performed in compliance with the German guidance, VDI 3882, sheet 2. The ammonia concentration and the logarithmically transformed odour concentration were processed with an analysis of variance in the MIXED Procedure in SAS (SAS Inst. Inc., Cary, NC).

3 RESULTS AND DISCUSSION

During the days of measurement, the weight of the pigs increased from 43.1 to 69.8 kg. The measurements were taken at an average outdoor temperature of 5.4 °C and

ranged from between 2.9 and 8.4 °C. The biofilters significantly reduced the odour concentration (OU_E/m^3) in the outlet air during the winter period ($P<0.001$), and there was no statistical difference between the two biofilters regarding efficiency. The measured odour removal efficiency averaged 60 % (95 % confidence limits: 53 - 67). However, the removal efficiency in per cent depended on the odour concentration in the outlet air with high removal efficiency at a high odour concentration versus low removal efficiency at a low odour concentration. The odour concentration in the outlet air from the pig units generally increased over time. The relatively high variation in odour concentration in the pig facility during the period was apparently due to the growth of the pigs, which resulted in more faeces on the floors and walls and thereby an increasing odour concentration. The mean odour concentration in the outlet air from the pig units was 2065 OU_E/m^3 and ranged from between 1034 and 3604 OU_E/m^3 during the measurements. However, after the air had passed through the biofilters, the odour concentration was reduced to an average of 783 OU_E/m^3 and ranged from between 418 and 1447 OU_E/m^3 during the measurements (Figure 2).

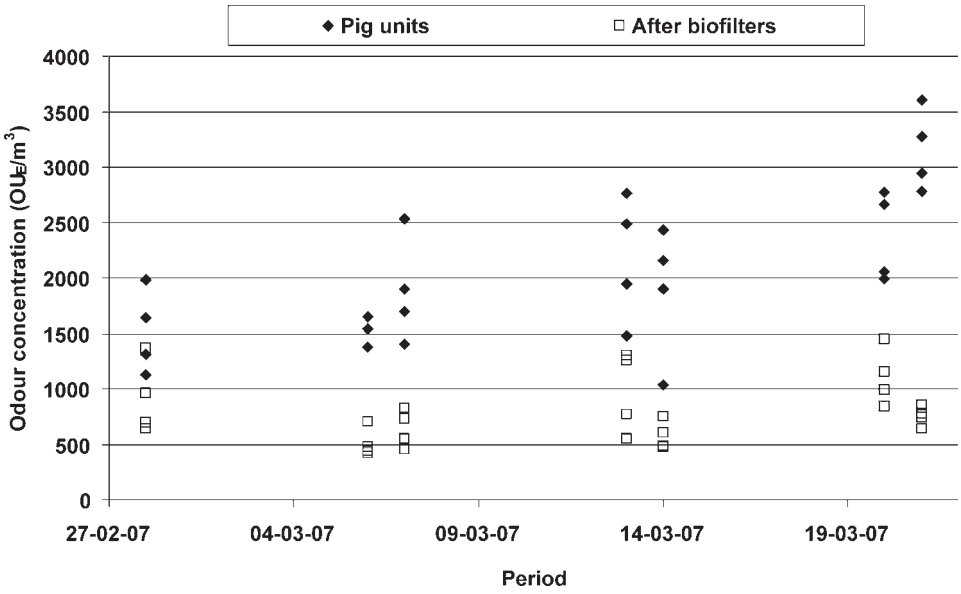

Figure 2. Odour concentration in the air from the pig units before and after it has passed through the biofilters.

In relation to the odour removal efficiency, the results of the hedonic tone showed that the odour panel perceived the odours as unpleasant to various extents since higher

concentrations were perceived as more unpleasant (Figure 3). However, the untreated air was recorded as more unpleasant than the air that had passed through the biofilters. In contrast, the biofilters did not reduce the ammonia concentration (ppm) significantly in the outlet air during the winter period. This was in contrast to Jensen *et al.* (2005) and Riis *et al.* (2006), who found an ammonia reduction with the use of biofilters. The average measured ammonia concentration in the outlet air from the pig units was 6.0 ppm and in the range of 3.5 to 9.5 ppm.

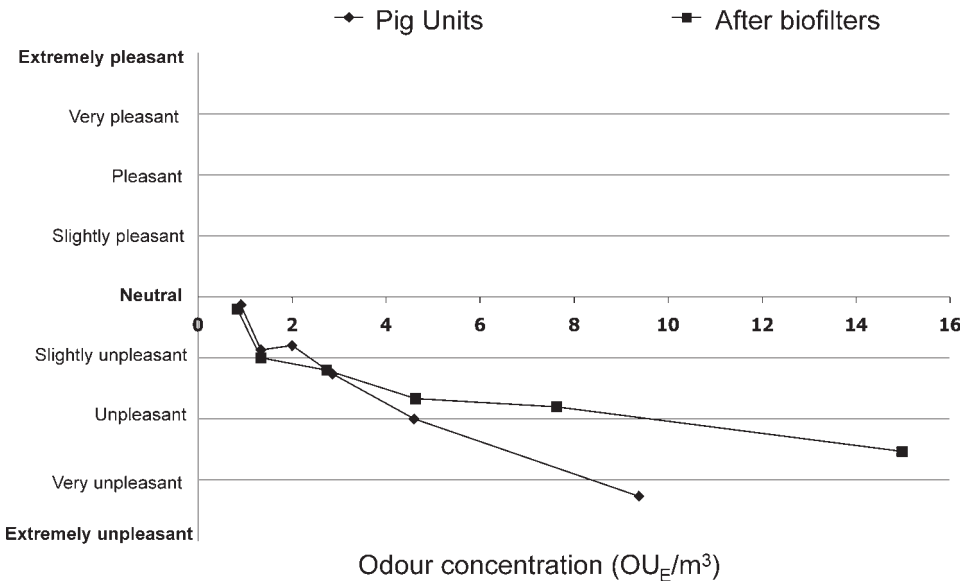

Figure 3. Hedonic tone of the odour in the air from the pig units before and after it has passed through the biofilters.

During the measurement period, the high-pressure water system ran for 8.5 hours a day in relation to the timetable in Table 1. The consumption of water was 170 litres of water added to the air of each biofilter per day. However, the consumption of water was no more than the amount of water that continuously evaporated from the biofilters. This means that there was no accumulation of water in the bottom of the biofilters.

Table 1.
Timetable for the high-pressure water system during the measurement period (February to March 2007).

Start	Stop
1.00 AM	2.00 AM
7.00 AM	8.00 AM
9.00 AM	10.00 AM
11.00 AM	2.30 PM
4.00 PM	5.00 PM
7.00 PM	8.00 PM

In Figure 4, the relative humidity in the air is shown for the air before and after it has passed through the biofilters. The average measured relative humidity in the air before it reached the biofilters was 67.3 % and ranged from between 58.3 and 76.0. After the air had passed through the biofilters, the relative humidity was increased to 86.6 % and ranged from between 72.3 and 97.4. Humidifying the air by the high pressure water system increased the relative humidity in the air by an average of 24.5 % (95 % confidence limits: 20.7 - 28.3). Appropriate humidification is necessary to achieve a good odour reduction with biofilters, which was also experienced by Jensen *et al.* (2005), Riis *et al.* (2006) and Nicolai and Smith (2004).

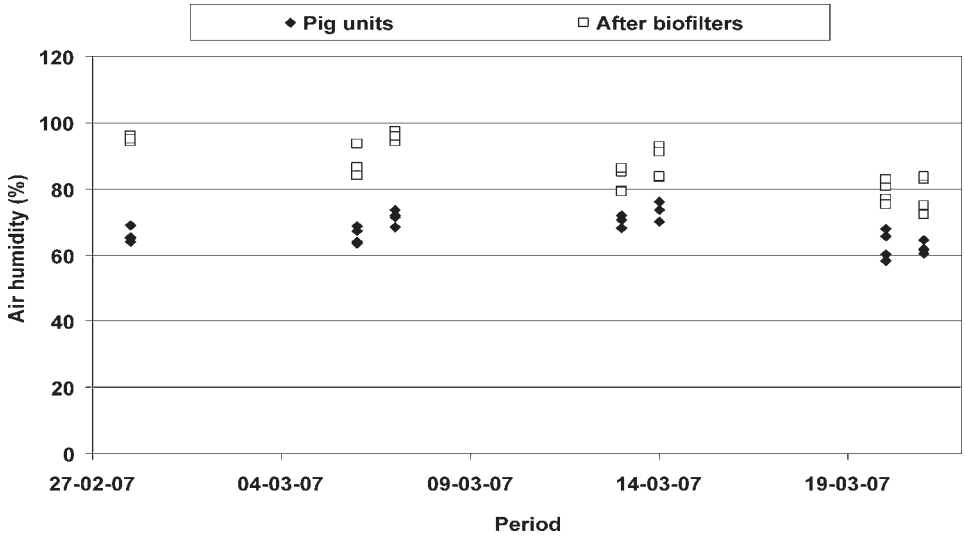

Figure 4. Relative humidity in the air from the pig units before and after it has passed through the biofilters.

In conclusion, the vertical biofilters with woodchips as media were capable of reducing the odour concentration in the outlet air from units with growing-finishing pigs during the winter period. Based on the measurements of the hedonic tone, the biofilters treatment of the air made the odour less unpleasant. However, the biofilters were not capable of reducing the ammonia concentration in the outlet air in the winter.

4 ACKNOWLEDGEMENTS

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