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EFFECT OF ENVIRONMENTAL DEFLECTOR ON AIR EXCHANGE IN SLURRY PIT AND CONCENTRATION DISTRIBUTION IN A TWO-DIMENSIONAL VENTILATION CHAMBER

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Abstract

Variations of air exchanges in slurry pit with four angles of an environmental deflector, namely 0° (parallel to the side wall or without deflector), 30°, 45° and 90°, were investigated using a tracer gas method. The investigations were performed in a two-dimensional ventilation chamber in the Air physics Lab, University of Aarhus. Ventilation rates used in the experiments were 100 and 200 m³/h. The experiment results showed that using the deflectors of 30°, 45° and 90° the airflow patterns were obviously changed in the room space near the slatted floor and in the head space of the pit compared with the setup without deflector. It was also found that of all the deflector angle performances with respect to air-exchange ratio and concentration distribution, the deflector position of 45° in two airflow rates cases behaved better with the lowest pit ventilation and the highest concentration in the head space.

Key words: ventilation, slurry pit, environmental deflector, tracer gas

1. Introduction

The interaction between air movements in the room and in the slurry channel affects the odorant and ammonia transport in and total emission from ventilated livestock production buildings. Air motion is manipulated mainly by the ventilation, and its pattern is related to the distribution of contaminant inside the building (Arogo, et al., 1997; Zhang and strøm,1999; Demmers, et al. 2000; Morsing et al., 2008). Ventilation effectiveness was affected by many factors, such as inlet and outlet locations (Zhang et al. 2001, Chung and Hsu, 2001), Pen partitions (Bjerg et al. 2000), slat orientations and manure depths (Buiter and Hoff,1998), locations of the pollutant source (Demmers, et al. 2000), ventilation rates (Buiter and Hoff,1998, Demmers, et al. 2000), ventilation methods (Yang et al. 2004) and so on. The

ventilation effectiveness will affect on local air mixings and consequently on emission from the ventilated room space. Furthermore, Local air velocities play important roles on contaminant emission. Zhang et al. (1994) indicated that increasing the air velocities over the manure surface result in increased ammonia releasing from manure pits. Therefore, reducing the air ventilation in slurry pit to decrease the ammonia transport in and emission from livestock building became more interested.

The objective of this study was to apply an airflow deflector in room to adjust the air movements in the room and slurry pit. Four angles of the deflector, namely 0° (parallel to the side wall or without deflector), 30°, 45° and 90°, were investigated in a two-dimensional ventilation chamber in the Air physics Lab, University of Aarhus. The key objective of this study is to evaluate the ventilation effectiveness for the positions of deflector.

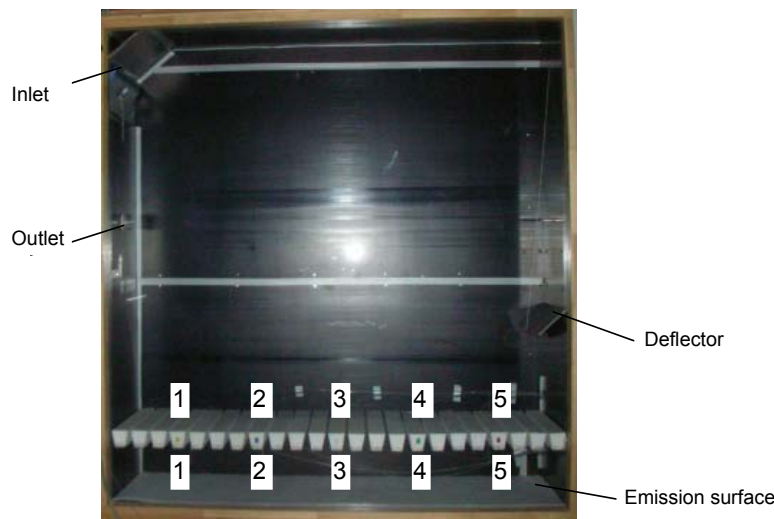


Figure 1. Two-dimensional ventilation chamber and concentration sampling positions.

2. Materials and methods

2.1 2D chamber

A two-dimensional ventilation chamber in the Air physics Lab, University of Aarhus was established to investigate the performances of environmental deflector on pit ventilation (Fig.1). The chamber was with inside dimensions 2.18 m×2.41 m × 0.62 m. The front face was made of laminated glasses, and the back and side plywood surfaces were painted in dark colours in order to facilitate visualization of airflow patterns with illuminated smoke. An adjustable flap wall inlet was installed in one side wall beneath the ceiling and the room air was exhaust via an opening at the middle of the side wall. The deflector was installed at the

side wall opposed to the inlet wall 0.8 m above the slatted floor. Four angles of the deflector, namely 0° (parallel to the side wall or without deflector), 30°, 45° and 90°, were used in the investigations.

2.2 Experiment set up and Measurement

The ventilation rates used in the experiments were 100 and 200 m³/h. A constant CO₂ tracer gas flux of 50 ml/min was supplied in a conditioning space under the emission surface, given a height of the pit headspace was 280 mm. A reference point, which is at 20 mm beneath the emission surface, in the conditioning space was used to monitor the CO₂ concentration in the air before it defused via the emission surface to the slurry channel. Besides the concentration measurements for the inlet air and exhaust air, the CO₂ concentrations were also measured at five sampling positions 150 mm above the slatted floor upper surface and five sampling positions 150 mm under the slatted floor lower surface (Fig.1).

The inlet velocities were measured by a single-dimensional Laser Doppler anemometer (DANTEC measurement technology, Denmark). Air Flow Tester (Dräger Sicherheitstechnik GmbH, Germany) was used to generate smoke and indicate the direction of local airflow to provide a quick visualization of the path of the airstreams and pressure differentials. The CO₂ concentration at the reference point was monitored by Testo 400 (Testo GmbH & Co., Germany). CO₂ concentration at outlet was measured by an infrared gas analyzer, while CO₂ concentrations at five points above /under the slatted floor and at inlet were measured by INNOVA 1312 Photoacoustic Multi-gas Monitor (Innova Air Tech Instruments A/S, Denmark) with a dynamic range of five orders of magnitude and a range drift of ±2.5% of measured value per 3 months (measurement at 20°C, 1013 mbar, and relative humidity 60%). The sampling period for a recorded data was 20 s.

During the experiment, CO₂ concentrations at the five sampling points under the slatted floor were measured till at the stable constant concentration, and then changed to measure the five sampling points above the slatted floor, where the data recording was also continued till the stable constant concentration condition.

2.3 Evaluation method

In order to describe the air exchange rates in the slurry channel under different experimental conditions, the ratio between air exchange rate in the pit and room ventilation rate was applied to evaluate the effects of the deflectors. This air exchange ratio is expressed as

$$R_{pr} = \frac{Q_{pit}}{Q_{out}} = \frac{C_{outlet} - C_{inlet}}{C_{pit} - C_{room}} \quad (1)$$

where, Q_{pit} is the pit ventilation airflow rate; Q_{out} is the design airflow rate, 100m³/h and 200 m³/h; C_{outlet} , C_{inlet} , C_{pit} and C_{room} are average CO₂ concentration at outlet, inlet and under the slatted floor and above the slatted floor.

The less the value of the R_{pr} , the more effective the deflector positions is for contaminant control.

To evaluate local ventilation effectiveness affected by the deflector, the local ventilation effectiveness factors (V_{EF}) defined by Zhang et al. (2001) was used,

$$V_{EFi} = \frac{C_{outlet} - C_{inlet}}{C_i - C_{inlet}} \quad (2)$$

where, C_i is the average CO₂ concentration at i th sampling positions above/below the slatted floor.

The dimensionless factor V_{EF} used in this study is to interpret the local concentration distribution above/below slatted floor compared with that at outlet for different deflector positions. The more the value of the V_{EF} above the slatted floor near the outlet side, the deflector position is more effective; the less the value of the V_{EF} below the slatted floor near the outlet side, the deflector position is more effective.

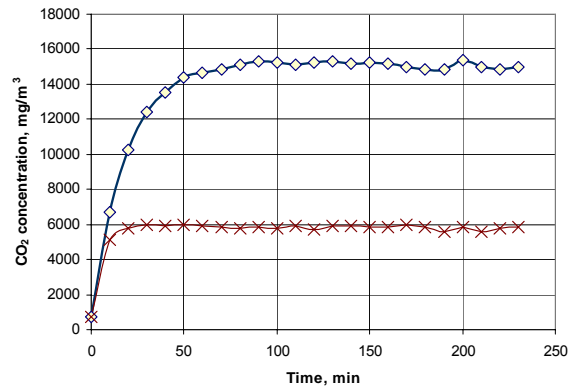


Figure 2. CO₂ concentration at the reference position of the mixing space with deflector position of 90°, where, ×, room ventilation rate of 200m³/h, and ◇, 100m³/h

3. Results and discussion

3.1 Averaging period of constant concentration

The average period of constant concentration at the reference point and at sampling points took place after the CO₂ releasing about 40 min for 200 m³/h set-up and about 70 min for 100 m³/h set-up. CO₂ concentration profile at the reference point was shown in Fig.2.

The CO₂ concentration during averaging period at the reference position for 100m³/h varied from a minimum of 14832.2 mg/m³ to a maximum of 15353.7 mg/m³ with percentage variations from 1.6% to 1.8% relative to the average concentration; during the averaging period for 200m³/h varied from a minimum of 5588.8 mg/m³ to a maximum of 5982.3 mg/m³ with percentage variations from 2.6% to 4.2% relative to the average concentration. It is also found that the CO₂ concentration during averaging period at the reference position for 100m³/h is nearly three times of that for 200 m³/h.

3.2 Pit ventilation ratio

Pit ventilation ratios at different deflector positions based on Eq.1 for different room ventilation rates were shown in Fig.3.

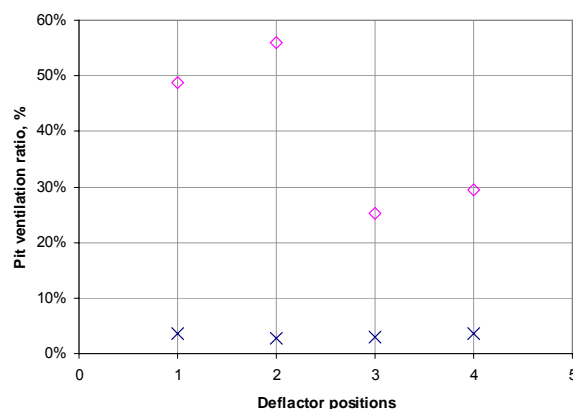


Figure 3. Pit ventilation ratio at different deflector positions and room ventilation rates, where, positions 1=0°, 2=30°, 3=45° and 4=90°; x, 100m³/h, and diamond, 200m³/h

The pit ventilation ratios varied dramatically with deflector positions for the ventilation rate of 200 m³/h and got higher value at deflector position of 30° and lower value at 45°. Compared with the 200 m³/h condition, the pit ventilation ratios were consistently lower for 100m³/h with the largest deviation among deflector positions was below 1%. The Fig. 3 indicated that the deflector position of 45° gave the lower pit ventilation ratio when the two room ventilation rates were concerned.

3.3 Local ventilation effectiveness factor

When the specific locations above/below the slatted floor became the concerned positions, the ventilation effectiveness for different deflector positions was evaluated by local ventilation effectiveness factors shown in Fig.4.

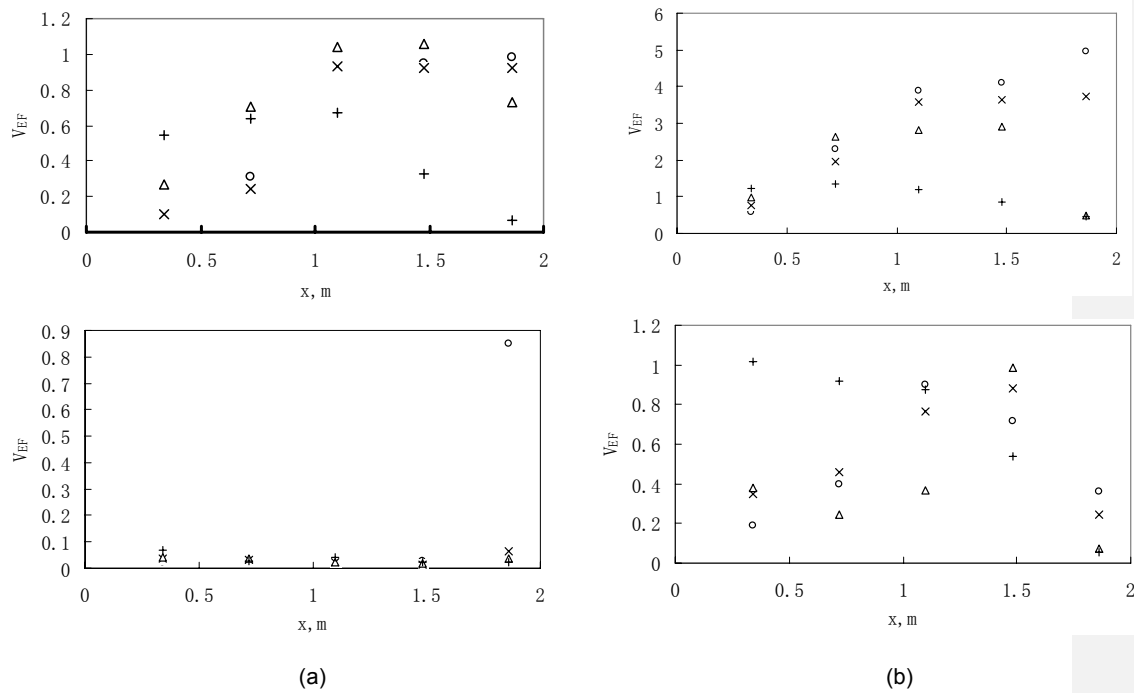


Figure 4. Local ventilation effectiveness factors above the slatted floor (up) and below the slatted floor (bottom) for room ventilation rate of 100m³/h (a) and 200m³/h (b), (o) stands for deflector position of 0°; (x) stands for 30°; (Δ) stands for 45° and (+) stands for 90°.

The results showed that using the deflector positions of 30°, 45° and 90° the ventilation effectiveness factors were obviously varied in the room space near the slatted floor and in the head space of the pit compared with the setup of 0° (without deflector). The ventilation effectiveness factors for the two ventilation rates were substantially different with the values lower for 100 m³/h and higher for 200 m³/h (Fig. 4), however, this conclusion is different against the conclusion drawn from Zhang et al. (2001), which suggested that ventilation effectiveness was less affected by ventilation rate.

In Fig. 4a, the average effectiveness factor for 45° at the position above the slatted floor was larger and below the slatted floor was smaller than for other deflector positions,

respectively. In Fig. 4b, the average effectiveness factor for 45° at the position below the slatted floor was smaller than that for other deflector positions. Hence, deflector position of 45° is more effective. However, the value at the position above the slatted floor was somewhat lower than the positions of 0° and 30° and deserves further investigation.

4. Conclusions

(1) Deflector can adjust the air motion in the room space near the slatted floor and in the head space of the pit.

(2) Deflector position of 0° (parallel to the side wall or without deflector), 30°, 45° and 90° were used in the investigation, 45° among them in two airflow rates cases behaved better with the lowest pit ventilation and the highest concentration in the head space.

(3) Ventilation rates have obvious influence on pit ventilation and local ventilation effectiveness factor.

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