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The effect of different geometrical wind tunnels in aerodynamic characteristics and ammonia mass transfer process in aqueous solution

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Introduction

The wind-tunnel is widely used to measure ammonia emissions from extensive surfaces. Many studies have been done in wind tunnel to assess the effects of wind speed and other micrometeorological parameters on ammonia emission rates. It is difficult to compare these emission rates with those determined by other researchers using different geometry of wind tunnels. Besides, there is very limited knowledge available on emission rate affected by height of the wind tunnels though this knowledge is crucial for modeling and estimation of ammonia and odour emissions from manure surface in livestock buildings or from the open fields.

The tunnel height can modified the wind speed gradient and the turbulent transfer conditions above the emission surface in the same wind speeds. A larger aerodynamic roughness can lead to a larger exchange. The objective of this investigation is focused on the effects of wind tunnel of three geometrical sizes on ammonia emission with different air velocity and turbulence intensity. However, the effect on the structure of boundary layer on emission surface in different sizes of wind tunnels is also investigated.

Materials and Method

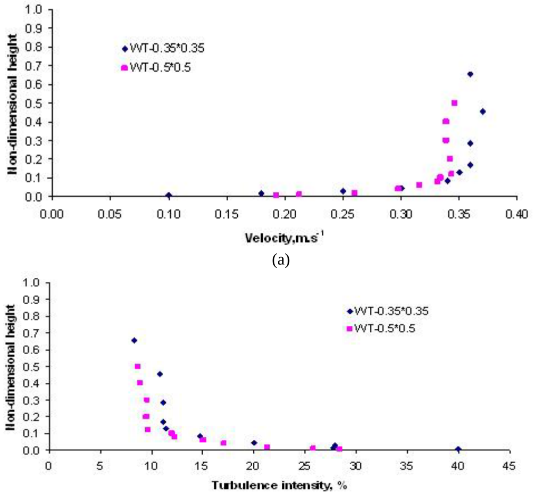
Experimental investigation:

Experiment was carried out in wind tunnels at Air physics lab, Aarhus University, Denmark under isothermal condition. Three different sizes of wind tunnels were used for this study with four inlet velocities (0.1, 0.2, 0.3 and 0.4 m.s^{-1}) (Figure 1). Different perforated plates were installed at the inlet to generate three turbulence levels over the liquid surface. The ammonia buffer solution contained concentration of TAN 6700-16500 mg.l-1 and pH level 8.8-9.0 was used in three wind tunnels as ammonia source.

Non-dimensional heights were used to show different profiles which is calculated from the height of measuring points from emission surface divided by actual height of wind tunnels. The NH_3 emission rate is determined by the calculated ventilation rate and the difference between NH_3 concentrations in inlet and outlet and dividing by emission surface area.

Statistical modelling:

Inverse Gaussian distribution is used to model this data.The inverse Gaussian describes the distribution of the time in a Brownian motion with positive drift takes to reach a fixed positive level. Dependent variables were considered for this analysis: ammonia emission (mg.s^{-1}m^{-2}). Inlet velocity, turbulence intensity and wind tunnel sizes were taken as independent variables



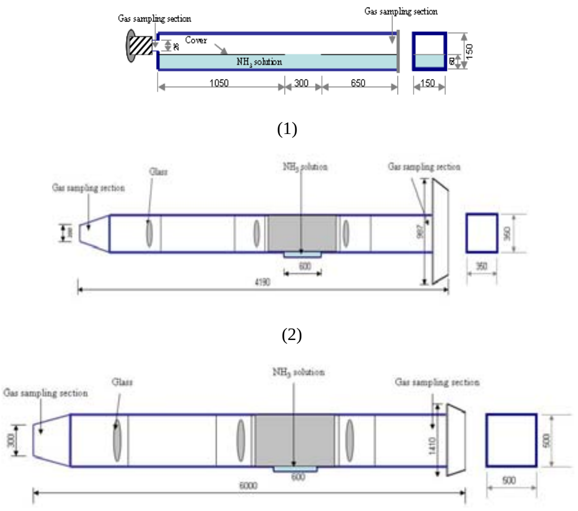
(a)

(b)

Figure 2: (a) Velocity profile and (b) Turbulence intensity profile above the middle of emission surface for inlet velocity 0.3 m/s of two wind tunnels of cross section 0.35m*035m and 0.5m*0.5m at the distances from inlet 1.45m and 2.1m respectively.

Conclusions

Velocity, turbulence intensity as well as wind tunnel size has affect on ammonia emission. The emission rates measured in the three wind tunnels of different geometric sizes shows that smaller wind tunnel gives higher emission than larger wind tunnels. This could be function of the different velocity and turbulence profile. More investigation is needed to confirm this phenomena. This may be done through CFD modeling by extending further velocity range, turbulence scale and wind tunnel sizes in fixed pH and TAN of emission sources.



(1)

(2)

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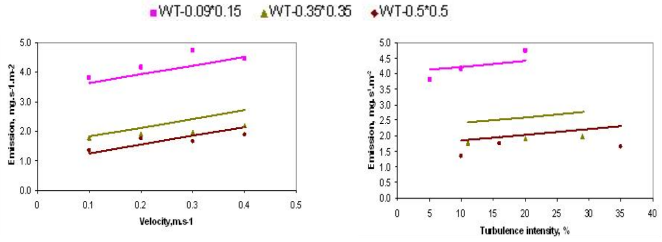
Figure 1: Three different sizes of wind tunnels (all dimensions are in mm)

Results and discussion

Airflow characteristics

The wind speed and turbulence intensity, with respect to non-dimensional height from the surface are represents in Figure 1 and 2. Wind speed is three times lower in bottom profile than for the top profile, which means that the shear stress was more intense in the bottom and so the turbulence for both wind tunnels (Figure 2). The profiles in the two tunnels are different. The velocity gradient is greater in the wind tunnel of cross section 0.35*0.35. Turbulence level is also very high in the wind tunnel 0.35*0.35 than large one because of very low velocity close to emission surface.



(a)

(b)

Figure 3: Ammonia emission in different wind tunnel sizes (a) in different inlet velocities at 10% turbulence intensity and (b) in different turbulence intensities at inlet velocity 0.3 m.s^{-1}. (dot- measured value, line -modeled value)

Ammonia emission

If we consider the characteristics of velocity and turbulence intensity in the tunnels, the emission rate measured in the large wind tunnel would be expected to be less than those in the small wind tunnels. We found that ammonia emission increases with the velocity. Increasing turbulence intensity also increase the emission. Experimental value shows that smaller wind tunnel gives higher emission than large wind tunnels (Figure 3 a & b). Higher TAN in buffer solution does not show significant increase of emission rate in wind tunnel 0.35*035 than other two wind tunnels.

$$E = 3.14 + 2.99\,V + 0.0186\ TI \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$E = 1.33 + 2.99\,V + 0.0186\ TI \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$E = 0.76 + 2.99\,V + 0.0186\ TI \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Additive model with inverse Gaussian distribution quite fit well. Emission equation 1, 2 and 3 are established for wind tunnel 0.09*0.15, 0.35*0.35 and 0.5*0.5 respectively. Model shows that emission gives in the wind tunnels 0.35*0.35 and 0.5*0.5 are lower than the wind tunnel 0.09*0.15 by factor -1.81 and -2.38 respectively. This could be because of higher velocity and turbulence intensity in the small tunnels.

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