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A WIND TUNNEL STUDY OF FLOW CHARACTERISTICS NEAR MODEL SWINE PRODUCTION AND MANURE STORAGE FACILITIES

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1. INTRODUCTION

Transport of odor constituents, greenhouse gases (GHG), and particulates from animal production and manure storage facilities is a persistent environmental concern (Zahn et al., 1997; Ni et al., 2000; Lim et al., 2003). Local environmental conditions, especially wind speed and direction, vegetative cover, and topography affect the airflow patterns near animal production facilities. Due to the large number of potential building arrangements and varying land cover and topography, studies on the transport of air quality constituents and GHG from buildings of various types have been conducted in wind tunnels (Mirzai et al., 1994; Aubrun and Leitl, 2004).

Comprehensive measurement of airflow and trace gas transport at full-scale swine production facilities requires a large investment in sophisticated sensing equipment. Even when such resources are available, the data collected are only relevant as a case study, i.e. for one location under the conditions occurring during the measurement period. The objective of this study was to determine how swine housing unit orientation and distance from manure storage facilities affect trace gas (odor and GHG) transport.

2. METHODS

Measurements were made in the new low-speed wind tunnel of the Air Quality of Agricultural Systems (AQAS) research unit of the National Soil Tilth Laboratory in Ames, IA. The AQAS wind tunnel has an open circuit design and is capable of air velocities up to 15 m s^{-1} in a control section 0.46 m-tall, 1.22 m-wide, and 5.5 m-long. Models of swine finisher units, above-ground manure storage tanks, and earthen lagoons (all approximately 1/300th scale) were constructed and placed in the control section. The models and arrangements followed standard industry design. Finisher unit models were oriented parallel, at a 30° angle, and perpendicular to airflow. All measurements were made with the finisher unit models upstream from the manure storage models. Separation distance between the finisher units and storage models were 2h, 5h, and 10h (h = finisher unit height of 17.5 mm).

Four spires (38 cm-tall x 3.5 cm-wide at the base) at the entrance and oriented surface roughness (LEGO[†] baseplate) on the floor of the control section were used to create a surface boundary layer with appropriate characteristics (Irwin, 1981). A thermal anemometer system (IFA 300 Constant Temperature Anemometer System, TSI Inc., Shoreview, MN) with a 3D hot film probe (model 1299) was used to measure airflow characteristics in the lee of the models. The scan rate was 10 kHz. The scale models were placed in the center of the control section ~2.3 m downstream from the spires. Airflow was monitored for 26 sec. at each of 83 measurement points within a 400 x 215 mm (width x height) grid centered on the finisher unit models. The lowest measurement height was 15 mm above the LEGO baseplate.

3. RESULTS

Results are presented for an array of 4 model swine finisher units oriented parallel to the air stream. The models were 40 mm-wide and 200 mm-long with 10.2 mm-tall side walls, 2 mm-overhang, roof slope of 4/12, and peak height of 17.5 mm. These models scale to swine finisher buildings approximately 40 ft-wide

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[†] Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

and 200 ft-long with 8 ft side walls, a 17 ft peak height and foundation 2 ft above-grade. The models were constructed of balsa wood with LEGO plates attached to the bottom to allow positioning on the baseplate covering the floor of the control section.

Fig. 1 shows longitudinal velocity fields for the model array at distances 2h, 5h, and 10h downstream of the finisher unit models at a free stream velocity of 13 m s^{-1}. Flow distortion below 50 mm height is evident at 2h and 5h but little effect of the models is evident at 10h downstream.

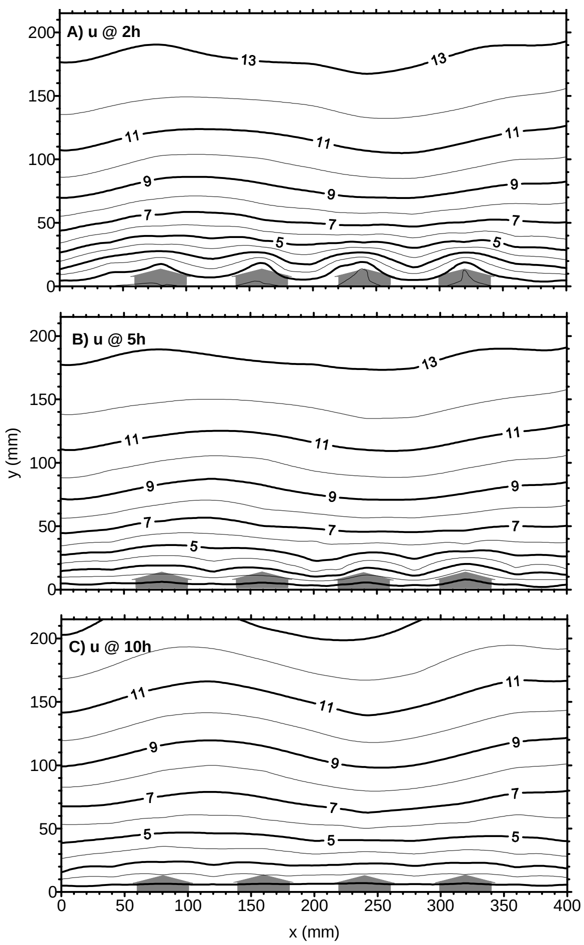

Fig. 1. Longitudinal mean velocity fields 2h, 5h, and 10h downstream from 4 40 mm-wide x 17.5 mm-tall building models centered at 80, 160, 240, and 320 mm on the x axis.

The effect of the building models on turbulence intensity is much more pronounced (Fig. 2). Although free stream values of turbulence intensity are from 20-40, values near the models are much higher (>100) with localized areas of very intense turbulence. Unlike for mean velocity, the enhanced turbulence intensity appears to persist on to 10h. The high turbulence intensity near the surface and its persistence downstream may indicate that the LEGO baseplate with 3 mm-diameter cylindrical pegs 1.8 mm-tall at 8 mm intervals may be aerodynamically too rough for the scale of the model confinement buildings used in this study.

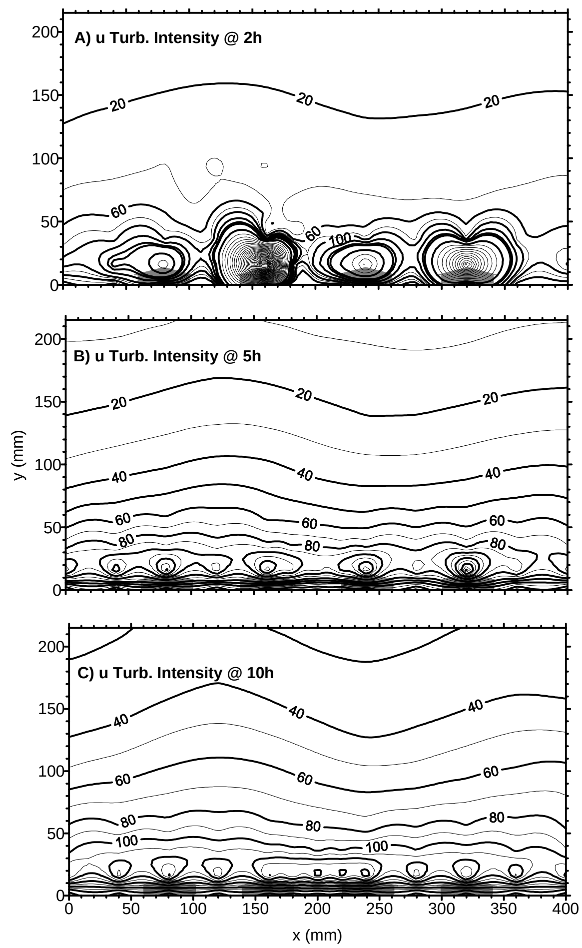

Fig. 2. Longitudinal turbulence intensity as for same physical setting and dataset as Fig. 1.

4. CONCLUSIONS

Preliminary data from wind tunnel experiments indicate pronounced localized effects of scale model swine finisher buildings on airflow characteristics. Further experiments with different model arrangements will be coupled with measurements of mass transport from above- and below-ground manure storage facility models at varying distances from the building models. These studies will be used to develop recommendations for swine production facility layout and air quality monitoring sensor deployment to minimize air quality impacts and improve monitoring strategies.

5. ACKNOWLEDGEMENTS

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