An Integrated Approach to Measuring Emissions from Confined Animal Feeding Operations at the Whole Facility Scale

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Abstract

Agricultural operations produce a variety of particulates and gases that influence air quality. Agriculture, through wind erosion, tillage and harvest operations, burning, diesel-powered machinery and animal production operations, is a source of particulate matter that can enter human lungs and cause pulmonary problems. Animal production operations can be a source of gaseous emissions such as ammonia, odor-causing volatile organic compounds, hydrogen sulfide, greenhouse gases (methane, nitrous oxides) and airborne pathogens. These emissions can negatively impact human health, property values, and the environment. The presence of buildings and other structures often make whole facility measurement capability a requirement for understanding the source strength and characteristics. The ability to use standoff methods to determine the movement and concentrations of emissions on a whole facility basis opens new capabilities for model development and verification.

An integrated system to measure whole facility emission was designed to characterize the complex structures and temporally dependent emission rates often associated with production operations. This approach combines state of the art standoff measurement techniques with standard point source monitoring equipment to provide the calibrated, high spatial and temporal frequency data required to develop and validate the models required for emission reduction and regulation. This effort includes the design, construction and operation of a new multi-wavelength lidar developed to map and track particle emissions. The lidar incorporates a laser emitting simultaneous, pulsed NdYAG laser radiation at 355, 532 and 1064 nm at a pulse frequency of 10 kHz. The system also includes open path FTS measurements for integrated chemical concentrations, and state-of-the-art point measurements of turbulence, particulate and gas concentrations.

This approach was evaluated in a multidisciplinary atmospheric study at a swine production farm in Iowa. Aerosol plumes emitted from the facility were prominent phenomena, and their variations with temperature, turbulence, stability and feed cycle were studied, using arrays of particle samplers and turbulence detectors. Other lidar measurements focused on air motion as seen by long duration scans of the farm region. Successful operation of this system confirms the value of the multidimensional approach for the determination of agricultural emissions in the complex terrain often accompanying production facilities.

Lidar Studies

Emissions of gases and particulates from animal production facilities are of concern because of the potential environmental and health implications. However, the measurement of the emission rate of different gases or particulates has proven to be difficult because of the differences among facilities, variations within a facility caused by differences in building management (ventilation fans), and the interactions among buildings caused by the altered wind flow regime induced by buildings in close proximity to one another. Observations of ammonia concentration observed at different distances and heights above the ground surface adjacent to a 400 head grow-finish swine

production facility throughout a production cycle revealed large variations within a day and among days (Hatfield and Pfeiffer, 2005). Much of this variation could not be explained by simple differences in wind speed or wind direction. This prompted a study that utilized a lidar system to measure the dispersion of particulates from this facility coupled with detailed measurements of the turbulence components of wind (Eichinger et al., 2005, Unpublished data).

The use of the lidar system to measure the complete air volume above this facility began to reveal the complexity of air flow and dispersion surrounding production facilities. It was observed that the vertical velocities of wind were 1-5 m s-1, which is much larger than expected. The turbulence regime surrounding the buildings was extremely variable depending upon the wind direction. These observations revealed how quickly a plume of particulates was emitted and dispersed from the facility (Eichinger, W., 2005, Unpublished data). These observations also began to reveal that single point observations located adjacent to a facility may not be capturing the air volume required for an accurate measurement of the emission rates.

These preliminary studies have prompted the development of a more sophisticated lidar system to provide a measure of the particulate size fraction and potentially the gaseous composition of the air volume surrounding an animal production facility. To more accurately quantify the emissions from animal facilities it is necessary to quantify the turbulence regime in order to understand the rate and pattern of dispersion and couple these mechanisms with an improved estimate of the composition of the atmosphere. The goal of these studies is to describe the development of an improved method to quantify the emission rates and dispersion patterns from animal production facilities.

References

Hatfield, J.L. and R.L. Pfeiffer. 2005. Evaluation of Technologies for Ambient Air Monitoring at Concentrated Animal Feeding Operations. Paper #86, AWRA Proceedings on Air Quality Monitoring. CD ROM