Title: Dispersion of Volatile Organic Compounds around Swine Production Facilities in the United States, **NPB #98-098**

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I. Abstract

Dispersion of odors, gases, and particulates from swine production and manure storage facilities creates a problem with neighbors. It is assumed that all materials emitted by production units rapidly move downwind of the facility; however, there is little direct information about the dispersion rates around swine facilities. This research project was designed to answer questions about the air flow around production units and manure storage facilities and then apply this information to an improved understanding of dispersion from swine production units. Understanding these issues is critical to be able to offer management solutions to changing the movement patterns of air around buildings and across manure storage units.

To address this problem we measured the turbulence around and within an earthen storage unit in central Iowa and downwind of a production unit in southern Utah. These measurements were made with 3-dimensional anemometers designed to measure the components of wind movement. These were coupled with measurements of air temperature and relative humidity profiles throughout the lower atmosphere. These data were placed into an atmospheric transport model that revealed that plumes of air moving downwind from production units vary within and across days due to wind speed and direction while the shape of the plume is dependent upon the air temperature profile and the underlying topography. Each production facility is unique in its dispersion characteristics; however, through the use of transport models based on local topography, air temperature profiles, stability of the atmosphere, and wind speed and direction, it is possible to define the shape of plume and movement patterns. These models can then be coupled with atmospheric loading rates of volatile organic compounds, gases, or particulates to estimate the downwind movement of a specific compound.

I. Background

Concerns about downwind movement of odors, gases, and particulates continue to be a source of debate between swine producers and neighbors. The assumption is that all production units produce the same level of atmospheric loading of volatile organic compounds, ammonia, methane, nitrous oxide, hydrogen sulfide, and particulates. It is further assumed that all production units are positioned on the landscape in such a way that creates a maximum downwind movement of these compounds. Observations around production units have shown that there is a large variation among days and often within days on the downwind movement patterns. However, these observations are more casual than quantitative. This lack of quantitative understanding of the movement patterns downwind of production units limits our ability to ascertain which management practices may yield the maximum effectiveness of alleviating complaints about odors. We also know that simple atmospheric dispersion models based on the Gaussian approach are not capable of handling this problem because of the violation of certain assumptions within this model. These problems include: lack of homogeneous terrain around the site, constant loading of the air, no interaction of the atmospheric constituent with the air, and a constant wind speed. These problems limit the ability of the Gaussian model to accurately predict downwind dispersion from swine production units. We also have a limited understanding of the movement patterns across the surface of an earthen storage unit. Without these sources of information it is difficult to provide guidance on potential management options for producers to increase dispersion.

III. Objectives

The objectives for this project were to: 1) Determine the air flow characteristics and turbulence around swine production and manure storage facilities; and 2) Determine the effect of flow and turbulence on the dispersion of gases that are emitted from buildings and manure storage systems.

III. Procedures

Manure storage units in the Midwest are typically located adjacent to corn and soybean fields. These are constructed with a berm that extends 2-4 m above the surrounding soil elevation and are surrounded by a small grass area; however, adjacent to this area are production crop fields. There is little known about the air flow across earthen storage units, and in order to address the first objective, we placed four 3-dimensional sonic anemometers around and within a manure earthen storage unit in central Iowa. The positions were on the top of the south and north berm, on the manure surface at 5 m from the south berm, and in the center of the manure storage unit. These measurements were made while the corn crop was present in the field and at maximum height. Measurements were made for 10 days during the late summer over a range of atmospheric conditions. The measurement interval was 10 hertz. During this time measurements were made of air temperature, wind speed, wind direction, and relative humidity at 15 minute

averages. Sonic anemometer data were used to estimate turbulent fluxes throughout the day.
A second experiment was conducted in southern Utah around a swine production unit in May 1998. Three sonic anemometers were placed at a height of 10 m on the northern edge of an eight building grow-finish complex and earthen storage unit. These instruments were positioned at 500 m, 1500 m, and 3000 m north of the unit. These towers included instruments to measure net radiation, wind speed, wind direction, air temperature, and relative humidity. These observations were made for 7 days. During this time radiosonde measurements were collected on two of the days at two-hour intervals from before sunrise until after sunset to measure the temperature and relative humidity profiles of the lower atmosphere. These data were necessary to provide the data for the atmospheric dispersion model. Detailed digital elevation maps were developed for the Utah site in order to provide a base layer of information for the model. Locations and dimensions of each building within the surrounding area were placed onto the digital elevation map in order to quantify the source strength relative to the movements of plumes generated at each site. Measurements of selected volatile organic compounds were made at the building site and at the three meteorological stations. These observation periods produce large amounts of data that require screening and verification and it is not necessary to continually record these data in order to address the project objectives.

An atmospheric transport model developed by the Army Research Laboratory was used for the simulation of the dispersion characteristics. This model utilizes digital terrain, wind speed, and lower atmospheric soundings to determine the shape and behavior of plumes. This model has been used for this study in scientific cooperation and is not yet available for general use by the scientific community.

V. Results

Air flow around manure storage units

Placement of manure storage units on the landscape typical of the Midwest creates a condition that induces rapid dispersion from the manure surface. As air flows over the surrounding area and encounters the earthen storage unit there is a creation of a negative pressure because of the differences in surface elevation between the manure surface and the surrounding land or crop area. The berm causes the air to rise, and when the air moves over the manure surface, there is a creation of rapid turbulence near the windward berm because of this elevation difference. The presence of a tall crop, e.g., corn, adjacent to the manure storage unit further increases this height differential and causes more mixing. The effect is to induce a condition in which the gases that are emitted from the manure surface are placed into an atmospheric environment that causes rapid dispersion. The assumption is that this mixing would lead to continued dispersion and mixing that would further reduce the concentration; however, the presence of the corn or soybean canopies tends to retard the continued dispersion and allow for gases to be concentrated in the lower atmosphere above the crop canopies.

Slowing the air flow over the manure surface would reduce the movement of gases into the atmosphere and provide an environment where there may be enhanced interactions with the atmosphere that reduce concentrations. This effect is not constant for all emissions and will require further understanding of the atmospheric chemistry of volatile organic compounds and nitrogen gases. Decreasing the transport of gases into the atmosphere may be sufficient in many facilities to alleviate concerns.

Dispersion across complex terrain
Data collected from southern Utah and placed into the dispersion model revealed that movement of plumes of gases generated at the building and manure storage site varied throughout the day and across days. The largest difference was caused by changes in wind speed and direction. Wind speed and direction caused the shape of the plume to change in response to relatively minor changes in topography. Under stable conditions, plumes generated from different buildings remained as separate plumes that followed the landscape; however, as the wind speed increased, the plumes interacted with each other but didn=t form a single plume. This is surprising since the popular assumption is that plumes would often interact and form a single plume. The presence of objects on the landscape, e.g., shelterbelts or fence rows of taller vegetation, caused the plumes to change direction under low wind speed conditions typical of late night and early morning. During the day, these objects were not as evident in their effect. The implications of these simulations, coupled with observations, are that plumes generated from exhaust fans may not form a single plume downwind of a building and that plumes from buildings and manure storage units may remain separate as they move across the landscape. These more detailed models, when applied to production units, may explain the large variation often noted by producers.

Implications for the pork industry
The implications of this research are that positioning of buildings and manure storage units on the landscape may be one of the larger factors in determining how gases and particulates are dispersed. There is no single variable that explains variation among facilities; however, we now understand that gases emitted from the surface of the manure storage units may be rapidly moved into the atmosphere because of the large turbulence over the manure surface. This turbulence is induced by the position of the earthen manure storage unit on the landscape that is surrounded by tall vegetation typical of the Midwest. Reducing this mixing rate through reduced wind speed could reduce atmospheric loading and further reduce the downwind concentration to levels that are acceptable to neighbors.

Movement across the landscape of plumes generated from buildings and manure storage units is complex. The approach of using a realistic atmospheric dispersion model to provide insights for producers to evaluate the role of position on the landscape, wind movement patterns, or shelterbelts to enhance mixing and reduce downwind concentrations of gases has promise. This approach needs further refinement for different locations and evaluation under other production sites in order to increase the confidence in the model results. However, the use of this type of model could allow producers to explore potential scenarios and develop a strategy specific to their operation. The benefit would be improved air quality surrounding swine production units and decreased complaints from neighbors about the unit.