RESEARCH REPORT
ENVIRONMENT

Title: **Release and Dispersion of Volatile Organic Compounds and Trace Gases** From Swine Manure Systems in Iowa, Arkansas, and North Carolina – NPB #97-1911

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Abstract

Release of gaseous compounds from swine manure storage systems has been poorly quantified; however, the perception of intensive amounts of gases is one of the larger problems for the pork industry. There is little quantitative evidence to compare among production units in different locations and little information to guide the development of any comprehensive understanding of swine manure storage systems. This study was designed to begin the development of a series of comparisons of swine manure lagoons in Iowa, Arkansas, and North Carolina. These sites were selected because of the ability to locate manure storage units with similar characteristics and the wide range in climatic conditions among sites. At each site a similar set of instrumentation was installed. This consisted of a unit that floated in the center of the lagoon and collected air samples through a series of Tenax TA® and Carboxen-569® organic carbon absorbing materials. Also in the center of the lagoon a platform with environmental equipment was deployed along with instrumentation around the edge of the lagoon.

Data collection commenced in April of 1997 and continued through October 1998. There was large variation in the emission rates of the different volatile organic compounds; however, there was consistency in the volatile organic compounds emitted. The reason for these responses is due to the reaction of the lagoon to environmental conditions. In an intensive monitoring effort on methane it was found that the emission rates of methane varied by a factor of three throughout the day with the largest emissions during the middle of the day. The temperature profiles recorded within the lagoon are indicative of an active biological system that is generating heat. There are differences among locations in the temperature within lagoons; however, this is more a function of the general environment than management differences. These data show that lagoons are active biological systems producing a complex mixture of volatile organic compounds. Producers will be able to utilize this information to show that anaerobic lagoons behave consistently among locations and that changes in management (loading rate, liquid level) are minor factors in emission rates.

Introduction:

Anaerobic storage of manure into lagoons or earthen storage units has become the preferred method of handling swine manure. These manure storage systems provide a treatment system that reduces the mass of nitrogen that has to be moved to a land application. However, there have continued to be complaints about many of these systems because of their release of volatile organic compounds that offend many people. The assumption is that these types of manure storage units produce large volumes of gases that travel extensively across the landscape. There has been little information to compare among manure storage units within a production area and no information comparing emission rates or environmental differences among locations. In 1996 we developed a method to measure the volatile organic compound emission rate from swine manure storage systems that was described by Zahn et al. (1997). They identified 27 different VOC's produced from swine manure storage systems. These data were collected from a swine production unit in Iowa and represented a small portion of the year and only one location.

Emissions of trace gases (methane and nitrous oxide) are of interest because of the implications of these gases on climatic change. However, there is little quantitative evidence regarding these gases from swine manure storage in the upper Midwest. Observations have been made of lagoon behavior with changes in color or turnover throughout the year; however, there is no quantitative evidence about the environmental conditions that exist within manure storage systems. This study was designed to begin to develop a more comprehensive understanding of the temperature patterns and the emission rates within lagoons at three different locations in the United States.

Objectives:

The lack of methods available to compare among systems or locations limits our ability to understand the dynamics of swine manure storage systems. Methods that quantitatively describe the generation and emission of VOC's and trace gases from manure storage systems into the environment will provide a valuable tool for environmental assessment. To address these information needs this study was designed with the following objectives:

1. Quantify the flux of volatile organic compounds (VOC's) and trace gases from swine lagoons and storage basins as a function of climate and management;
2. Quantify the dispersal of VOC's and trace gases from swine lagoons as a function of meteorological conditions; and
3. Develop and evaluate a dispersal model for VOC's and trace gases that can be used to assess the impact of lagoon placement on potential transport across the landscape.

Procedures:

Sites for this study were selected in Iowa, Oklahoma, and North Carolina. These production units had similar lagoon design and size of production facilities. We had to locate cooperators who would provide access to the lagoons and we had to ensure that the lagoons were secure so that instrumentation could be left on site throughout the year. These sites had to be well-maintained so that excessive growth of vegetation around the site would not be a factor in the observed dispersion rates and environmental conditions. A similar set of instrumentation was developed for each site and deployed in April 1997. This early deployment allowed capture of the spring conditions and allowed for instrumentation to be fully operational before the summer period.

Collection of the VOC's was accomplished with a unit that floated on the surface of the lagoon. A 0.5 m^2 Plexiglass® chamber that extended into the liquid was positioned between two floats. This unit was attached to a cable that suspended the air lines for replenishing the air volume within the chamber and permitted the unit to be moved to the edge of the lagoon for service and removal of the thermal desorption tubes. These tubes were placed in the chamber to collect air for a 4-hour period. Previous results confirmed that this length of time was sufficient to collect a sample that could be analyzed. Data collection was completed on two days of every month for two 4-hour periods during the day. Immediately after sample collection the tubes, which

contained a mixture of Tenax TA® and Carboxen-569® (Supelco, Bellefonte, PA), were frozen and shipped back to the laboratory in Ames for analysis. Analysis of the trapped VOC's on the thermal desorption tubes was completed using a Dynatherm model 890 thermal desorper coupled to a Tremetrics model 9001 gas chromatograph with a flame ionization detector. These methods are fully described in Zahn et al. (1997).

Environmental conditions were recorded with a series of meteorological equipment placed around the lagoon and a series of temperature profiles within the lagoon. Four meteorological stations were placed around the lagoon, one on each side midway between the corners. Each unit had a temperature, relative humidity, and windspeed sensor positioned at 1 m above the surface and one unit had a solar radiation and wind direction sensor. These data were collected every 10 seconds and averaged over a 30-minute period. Once a week these data were retrieved from the data loggers (CR-10, Campbell Scientific Inc., Logan, UT). To measure the environmental conditions within the lagoon a series of temperature probes were placed at 2, 5, 10, 20, 50, 100, and 200 cm below the surface. These sensors were placed onto a floating unit and the temperature probes placed within a sealed PVC tube. This was done to prevent exposure of the temperature probes to lagoon mixture. This floating unit also carried a set of meteorological instruments to measure air temperature, relative humidity, and windspeed at 1 and 2 m above the lagoon surface. These data were collected every 10 seconds and averaged and stored every 30 minutes. Data collection commenced in the spring of 1997 and continued through October 1998.

Trace gases were measured with a tunable infrared gas analyzer (Campbell Scientific Inc., Logan, UT). This unit was used only on the Iowa site because of the intensive personnel requirements. Measurements were collected over the center of the lagoon at two heights above the surface, 0.5 and 1.5 m, through a high volume pump that pulled the air sample through the analyzer located at the side of the lagoon. The residence time in the tube was calculated to be less than 1 second, and the switching pumps between the two heights allowed for a differential sample to be collected. Observations were made only for methane since the laser had to be tuned for only one gas at a time. Measurements of methane fluxes between the two heights were coupled with eddy correlation measurements. These data were necessary to estimate the dispersion coefficient for methane in air and the emission rate of methane from the lagoon. These observations were made in July and August 1997 and September 1998.

Results:

1. Quantify the flux of volatile organic compounds (VOC's) and trace gases from swine lagoons and storage basins as a function of climate and management.

We observed the same 27 VOC's from lagoons that Zahn et al. (1997) had earlier reported. These were found from the three sites in the study; however, the emission rates among these compounds varied with the time of year more than the location. These observations would suggest that the biological activity of the lagoon system is a larger factor in determining the emission rate than location or management. Observations from the Iowa site with more intensive sampling revealed variations among days with moderate changes in the environmental conditions with no changes in the loading rate of manure or changes in diet that would affect manure quality. These results suggest that emission rates from lagoons are complex interactions with the biological system present within the lagoon and that to fully understand these dynamics will require continual measurement of the emission rates of selected compounds from the lagoon surface. The methodology we developed affords a simple method of sample collection, and we have refined the method for sample analysis to be more automated and allow for greater incorporation of quality assurance/quality control factors into the process.

Observations of methane from the Iowa lagoon showed emission rates that varied throughout the day and across days. Fluxes were related to overall environmental conditions; however, these studies were confined to the summer period and did not include the late fall or early winter period. Observed emission rates of methane ranged from 1.2 to 2 ppm with the ambient level approximately 0.7 ppm. The emission rate exhibited a diurnal trend, which was related more to the increase in the windspeed over the surface than changes in the temperature within the lagoon. These methane levels from lagoons are smaller than have been reported from other studies

and this difference may be due to overall environmental conditions among studies. There have been few direct observations of methane emission from swine lagoons, and comparisons among locations are difficult.

Observations of temperature within the manure volume provided a large amount of insight into the dynamics of lagoons because of the continual measurement of temperature profiles. Throughout the year the temperature profiles within the lagoon follow in a general sense the ambient environmental conditions. However, the biological activity within the lagoon produces a sufficient amount of energy to modify the temperature profile from a liquid volume to a more isothermal profile in specific layers. For example, the upper 20 cm of the lagoon is often isothermal with temperature differences that are less than $2^{o}C$, while the expected temperature difference of a water body over this depth would be over $10^{o}C$. These behaviors are evidence of the energy being produced by the biological activity within the lagoon. It was not within the scope of this study to identify the types of microbiological populations to relate these to the anaerobic digestion process.

Meteorological observations collected around the edges of the lagoon revealed that there was evaporation of water occurring from the lagoon. There was an increase in the relative humidity on the downwind side of the lagoon by as much as 10-20% and a slight decrease in air temperature. This increase in relative humidity was dependent upon the overall windspeed conditions. If the winds were above 5 m s^{-1}, the observed increase was less than if the winds were more calm. The larger windspeeds were associated with more rapid mixing around the lagoon. Increased windspeed is related to greater mixing in the atmosphere and less potential downwind complaints about odor. The observations of the meteorological conditions surrounding the lagoon and the temperature profiles within the lagoon are a unique set of observations across different sites.

2. Quantify the dispersal of VOC's and trace gases from swine lagoons as a function of meteorological conditions.

Observations were made of the dispersion of VOC's from the Iowa lagoon because of the limited availability of equipment. It was found that the variation of the VOC's was related to the source concentration; however, this was complicated by the interaction of the VOC's with the atmosphere. These studies were conducted for two time periods during the summer with observations for 2 days. During these observations it was noticed that dispersion of VOC's was dependent upon the overall windspeed conditions; however, the larger problem was the collection technique. Observations made with the thermal desorption tubes for 4-hour intervals did not always provide sufficient concentrations of the analytes for detection on the gas chromatograph. It is difficult to assess whether the dispersion characteristics are related to atmospheric conditions or measurement technique when the concentrations often border on the threshold of detection. We tried various collection intervals with thermal desorption tubes and have concluded that we need to increase the air volume sampled by 100 times in order to collect sufficient samples downwind of a lagoon. These observations need to be made for a minimum of a 4-hour period to capture the emission characteristics of a particular lagoon or production unit.

3. Develop and evaluate a dispersal model for VOC's and trace gases that can be used to assess the impact of lagoon placement on potential transport across the landscape.

Dispersion studies were limited by the observations collected during the course of the study. The traditional method for dispersion modeling has been to use the Gaussian model, which assumes some standard relationships. These critical factors for the model include: constant windspeed across the surface; no interaction of the constituent with the atmosphere; uniform surface conditions; and a relatively uniform emission rate. Through our observations in this study we found that windspeed varied around the lagoon depending upon the time of day and time of year. Variation throughout the day was caused by the interaction of the surrounding vegetation with the general airflow patterns and the stability of the atmosphere. If the surface was rough and non-evaporating, then there was more variation among the four sides of the lagoons than if the surrounding areas were completely covered with actively growing vegetation. In Iowa, we found that lagoons with corn and soybean adjacent to the lagoon had lower windspeeds at the edge because the crop provided a windbarrier. However, under high windspeeds there was increased turbulence and the variation among sides increased. Lagoons with large short grass areas adjacent to the lagoon tend to provide the most stable wind

patterns throughout the year. If there are large changes in the characteristics of the surrounding vegetation throughout the year, then there appears to be a different dispersion pattern during the year. These differences complicate the use of a Gaussian model.

Observations of the dispersion coefficient collected with the eddy correlation equipment during the operation of the trace gas analyzer showed a large diurnal variation. This was attributed to the windspeed patterns and heating of the surface of the lagoon. Lagoon surfaces with floating solid material or crusts behave differently than liquid surfaces. The crust warms during the day and creates an unstable condition that promotes the rate of mixing of the air at the lagoon surface. These factors affect how rapidly the gases that are released by the biological activity within the lagoon are transported into the atmosphere. Interactions of a lagoon surface with the overlying atmosphere have not been studied because of the inability to place a variety of instruments around and within the lagoon. This study has begun to develop a data base of environmental conditions within and surrounding lagoons.

Implications for Producers:

Emission of VOC's from lagoons in Iowa, Oklahoma, and North Carolina were observed to vary with time of year and within a day. These were related to the temperature patterns within the lagoon, which was indicative of the amount of biological activity. To fully characterize the emission of VOC's and trace gases from lagoons will require a more continuous monitoring effort of selected sites. This study has begun to understand the limitations of our current knowledge base. Environmental conditions surrounding manure storage systems have a large impact on potential emission rates; however, the biological activity within the manure storage system creates a unique environment that leads to variation in the type of VOC emitted. The observations collected during this study have only begun to define how these studies need to be conducted in order to fully understand how manure storage systems could be managed to reduce potential neighbor complaints.

Producers need to understand that the variation observed among days and within days is critical to understanding how lagoons behave. These variations require that any observation of VOC's that are offensive need to be made for more than short periods of time. The movement patterns of these compounds downwind of the site are not easily predicted or understood, and simple dispersion models may lead to incorrect conclusions about impacts on neighbors. The knowledge base we collected will help with this process.

Publications:

Zahn, J.A., J.L. Hatfield, Y.S. Do, A.A. DiSpirito, D.A. Laird, and R.L. Pfeiffer. 1997. Characterization of volatile organic emissions and wastes from a swine production facility. J. Environ. Qual. 26:1687-1696.

Publications under preparation from this project:

Hatfield, J.L., J.A. Zahn, and J.H. Prueger. Atmospheric and temperature patterns surrounding swine lagoons in three states. Transactions of American Society of Agricultural Engineers.

Zahn, J.A., J.L. Hatfield, R.L. Pfeiffer, and J.H. Prueger. Volatile organic compound emissions from swine manure storage systems. J. Environmental Quality.