# Final Report to NPB
**December 1, 2006**

**I. Project Title:** Partitioning between pit and wall emission streams of hydrogen sulfide, ammonia, particulate matter, and odor from deep-pit pig finishing facilities for decision support in selecting emission control technologie**s.**
**NPB project #05-113**


**Principle Investigator:** Larry Jacobson
**Institution:** University of Minnesota


## II. Abstract:


Air quality and emission measurements for ammonia ($NH_3$), hydrogen sulfide ($H_2S$), odor, and particulate matter (or dust) under 10 microns in diameter ($PM_{10}$) were collected from one room of a mechanically tunnel ventilated barn that contained two 1200 head capacity rooms located side by side (total capacity of 2400 finishing pigs) for approximately six months. The study shows limited value and benefit for the use of pit fans in this deep-pit pig finishing room. Based upon similar ammonia and hydrogen sulfide concentrations that were measured in the center of the barn for all four (0, 4, 10, and 20 cfm/pig) pit ventilation cases used in the experimental protocol, it seems that exhausting a portion of the barn's ventilation air through the pit has little effect on the room's indoor air quality. The $NH_3$, $H_2S$, and odor emissions determined in this study show that a disproportionate amount, according to the airflow rates, of these two gases are exhausted from the barn through pit fans if they are operating. This fact should be noted if a producer wants or needs to reduce a pig barn $NH_3$, $H_2S$, and/or odor emissions, since there would be a benefit to treating only the pit fan exhaust air with an air emission control technology rather than all of the exhaust air (wall and pit). Finally the $PM_{10}$ concentrations and emissions from the pit fan air stream are lower than it is for the wall fans. The partitioning of the amount of airborne dust being emitted between the pit and wall fan airstreams has been unknown and is valuable for regulatory purposes and to assist in the design of emission control technologies that are used on either airstream.


## III. Introduction:

Air quality and emission measurements for ammonia ($NH_3$), hydrogen sulfide ($H_2S$), odor, and dust were collected from a mechanically tunnel ventilated barn that contained two 1200 head capacity rooms located side by side (total capacity of 2400 finishing pigs) for approximately six months. This facility is representative of numerous pig finishing barns that are being built in the upper Midwest. The barn had four 24" diameter pit fans per room (results in approximately 20 cfm/pig), which is a similar pit fan capacity used on curtain-sided pig finishing barns that are also common in the Midwest. A previous research project by the investigators questioned the need for higher pit ventilation rates. In this study, air emissions were partitioned into pit and wall fractions to assist producers in making informed decisions on emission control technologies such as biofilters or other "capture and treat" methods to optimize the pollutant reductions. Technologies like biofilters are designed and sized based on airflow and less on gas or odor concentrations. Minimizing the pit ventilation rates in these deep-pit barns would simplify the design and reduce the cost of any emission control technology implemented for these buildings. Also, by reducing the amount of ventilation air being exhausted from the pit, electrical energy costs would probably be reduced since pit fans are typically less efficient than wall fans.

## IV. Objectives

This research project quantified emissions of several key hazardous compounds, including $H_2S$, $NH_3$, and particulate matter under 10 microns in diameter ($PM_{10}$), and the nuisance parameter odor from a tunnel-ventilated, deep-pit, pig-finishing building over a six-month period (December - June). More importantly, airborne emissions were separated into two fractions, the portion that was emitted through the pit fans and the part exhausted through the wall fans. Indoor air quality was also monitored at several locations inside the barn.

Specific objectives of this research project were to:

1. Monitor the indoor air quality of the barn over this same period of time by semi-continuously measuring concentrations of $H_2S$, $NH_3$, $CO_2$, and $PM_{10}$ from several separate locations inside the barn.

2. Monitor semi-continuous emissions of $H_2S$, $NH_3$, $CO_2$, and $PM_{10}$ plus intermittent sampling of odor from the barn's pit and wall exhaust streams over an approximate 180-day period that would include both warm and cold ambient temperatures.

## V. Materials and Methods

A mechanically ventilated 2400-head deep-pit pig-finisher barn, located in southern Minnesota with both wall and pit ventilation fans, was used for this project. Several fixed pit ventilation rates (0, 4, 10, and 20 cfm/pig) were used for two-hour periods during the six month long study. The project measured concentrations of $H_2S$, $NH_3$, $CO_2$, and $PM_{10}$ using an instrument trailer that was capable of semi-continuously monitoring these airborne contaminants at multiple locations, including wall and pit fans exhaust, an interior room location, and an ambient (background) site (figure 1). Odor measurements were also taken monthly from these same sampling locations. Fan operation status and the barn's static pressures (pressure transducers) were recorded with the trailer instrumentation to determine the pit and wall ventilation rates for the selected pit operation levels. Emissions were calculated by multiplying the ventilation rate (determined with fan operation data) by the concentrations of $NH_3$, $H_2S$, $CO_2$, odor, and $PM_{10}$. Duplicate odor samples were collected in 10-liter Tedlar bags monthly and were analyzed at the University of Minnesota Air Quality Laboratory within 24 hours of collection. Emission rates of $H_2S$, $NH_3$, $CO_2$, $PM_{10}$, and odor were collected and divided into pit and wall exhaust fractions for these time blocks.

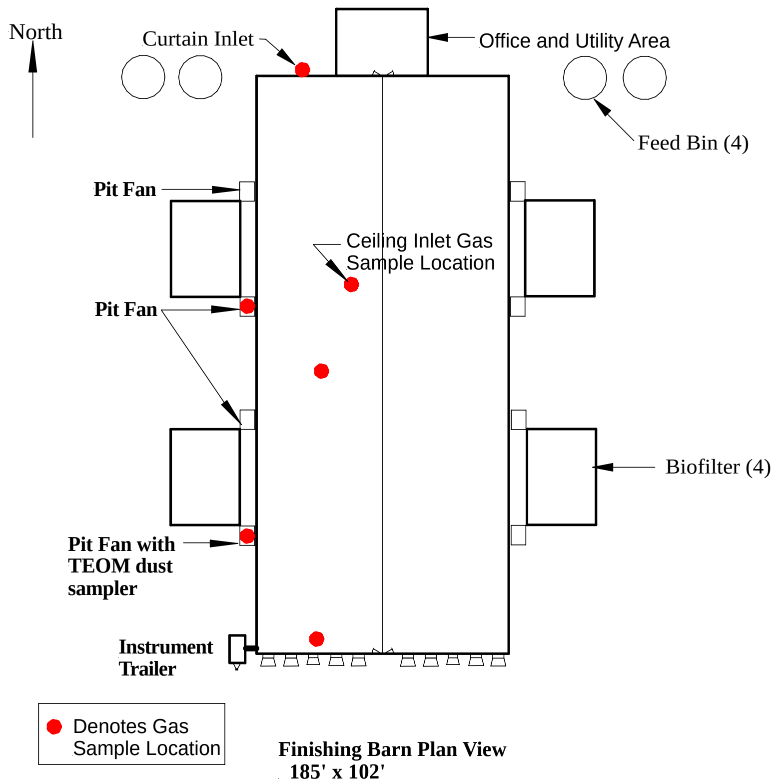


Figure 1. Plan and End Views of Deep-Pit Double-Wide Finishing Barn.

## VI. Results

The results from this project are displayed in figures 2 to 5 that are given below. Each figure groups the concentration and emission for a particular airborne contaminant presented into winter, spring, and summer periods. The winter data was collected from January 26 to March 4, 2006. The barn had the finished pigs removed and new pigs added (or "turned") in mid March of 2006. The spring data was gathered from April 14 to May 15, which represented when the barn was transitioning from the ceiling (winter) inlet to curtain (summer) inlet ventilation. The summer data was collected from May 17 to June 30. Mean gas, PM, and odor concentrations and emissions are displayed for the four pit ventilation rates with attached error bars that represent one-standard deviation from the mean values.

Although not shown, $CO_2$ levels and airflow rates through the barn are quite similar for the 0, 4, and 10 cfm/pig pit ventilation rates categories. The $CO_2$ level for the 20 cfm/pig pit ventilation rate was slightly lower and thus airflow rates were higher for this setting. This is quite understandable for the winter and even spring periods since the experimental protocol forced all four pit fans to operate at the 20 cfm/pig rate even if the barn's ventilation control was not calling for that much airflow during cold outside temperatures. The 20 cfm/pig pit ventilation rate also resulted in a greater airflow rate for the room during the summer period probably due to the presence of only large capacity (1-36" and 4 - 50" diameter blade) wall fans rather that the smaller capacity (24" diameter) pit fans.

Ammonia ($NH_3$) concentrations in pig buildings are often used as an indicator of the indoor air quality for pigs and a suggested threshold value from 10 to 20 ppm is suggested. Mean $NH_3$ concentrations in both the barn's center and tunnel fan end met the 20 ppm criteria for all three time periods (figure 2). $NH_3$ concentrations in the center of the room were similar for each seasons for all four pit ventilation rates including the case when no pit fans (0 cfm/pig) were operating. The $NH_3$ concentrations at the tunnel end of the barn did decrease with increasing pit ventilation but this was most apparent during warm weather operation (spring and summer) and probably more a function of the air inlet (end wall curtain) design than where air is exhausted. Ammonia wall fan emissions show a steady decrease as the pit ventilation rates increase while the pit fan emissions show the opposite trend. Pit and wall $NH_3$ emissions are approximately equal for the 10 cfm/pig pit ventilation rate during the winter and spring periods and for the 20 cfm/pig pit ventilation rate during the summer. This is the case even though more air is being removed by the wall fans than the pit fans, especially during the warm weather situations.

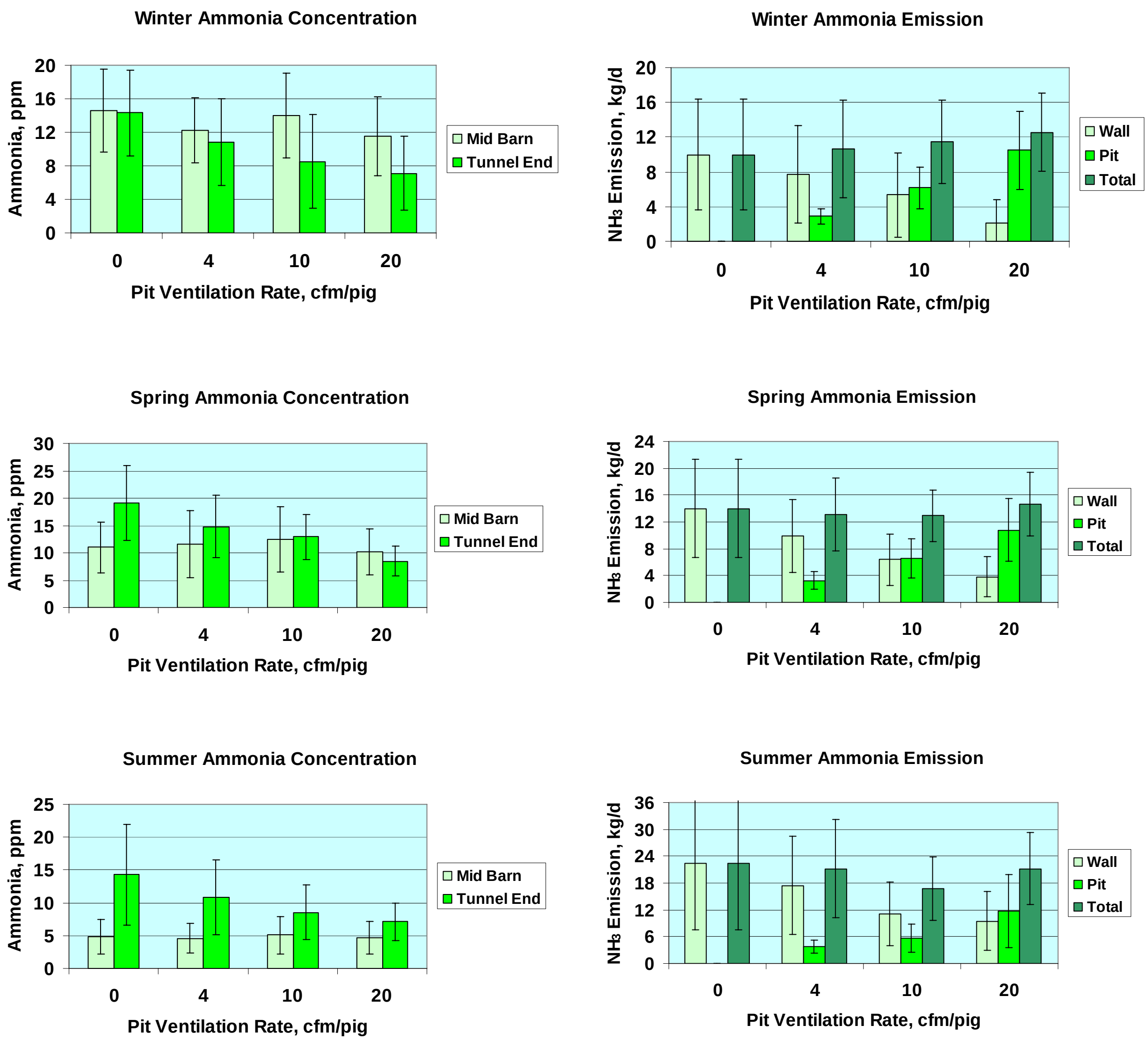


Figure 2. Ammonia concentrations and emissions for the winter, spring, and summer periods

Hydrogen sulfide ($H_2S$) concentrations in pig buildings are not commonly used as an indicator of indoor air quality and are typically below 1 ppm (1000 ppb). Mean $H_2S$ concentrations in both the barn's center and tunnel fan end were below 1000 ppb for all three time periods (figure 3). Like ammonia, the $H_2S$ concentrations in the center of the barn were similar for each season for all four pit ventilation rates including the case when no pit fans (0 cfm/pig) were operating. Also the $H_2S$ concentrations at the tunnel end of the barn did decrease slightly with increasing pit ventilation but, as stated for ammonia, this probably is more a function of the air inlet (end wall curtain) design than where the air is being exhausted. Hydrogen sulfide wall fan emissions also shows a steady decrease as the pit ventilation rates increase while the pit fan emissions show the opposite trend and the pit and wall $NH_3$ emissions are approximately equal for the 10 cfm/pig pit ventilation rate during the winter and spring periods and for the 20 cfm/pig pit ventilation rate during the summer.

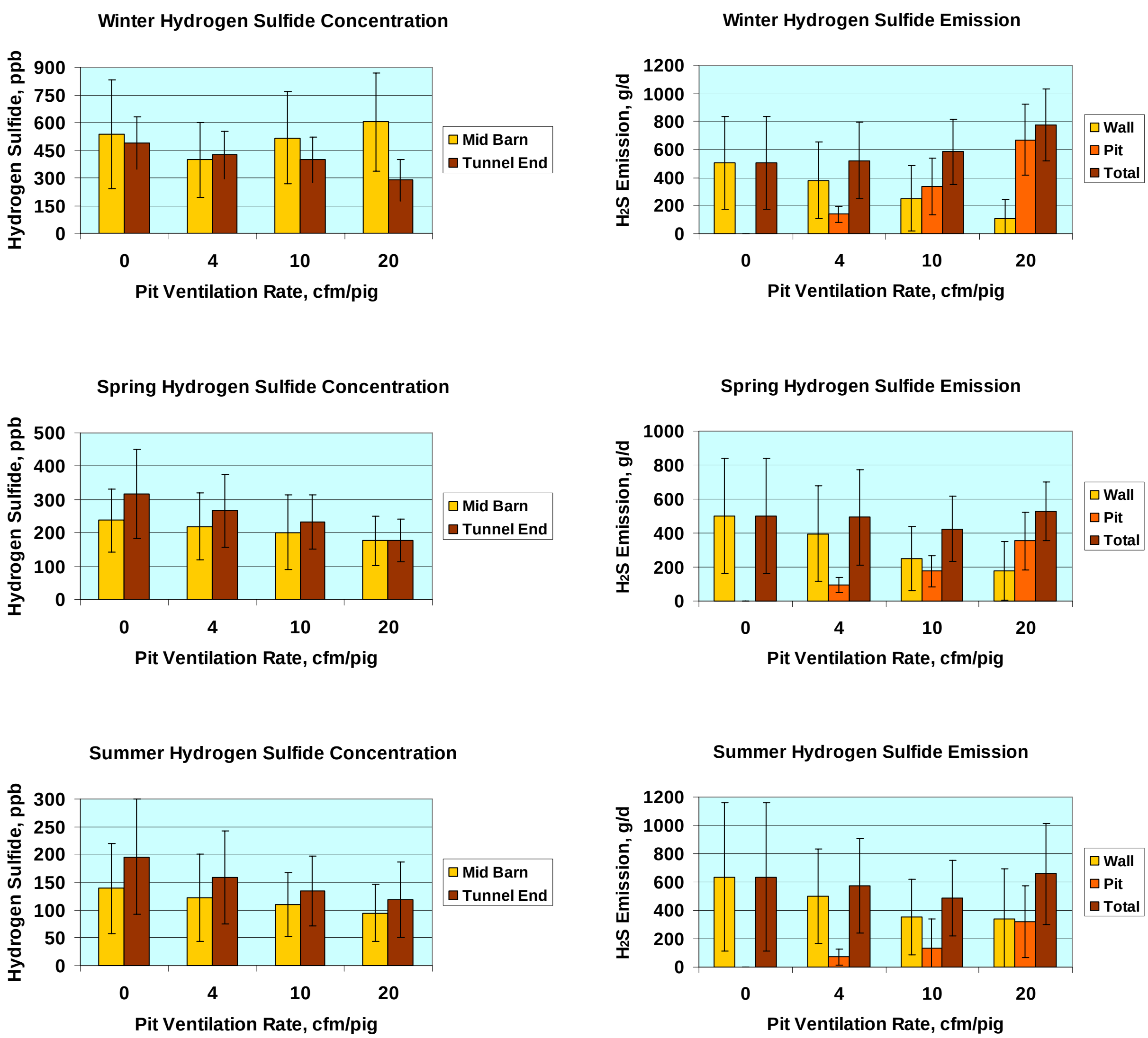


Figure 3. Hydrogen sulfide concentrations and emissions for winter, spring, and summer

Particulate matter (or dust) under 10 microns in diameter ($PM_{10}$) is an airborne contaminant that has not been commonly measured or reported in pig buildings. $PM_{10}$ concentration inside the barn is a concern for human and, to a certain extent, animal respiratory health, plus PM emissions in general are becoming a concern for regulatory agencies like EPA because particulate matter can contribute to the formation of acidic particles when these small dust particles come into contact with certain gases like ammonia. For this study, $PM_{10}$ concentrations do not vary much between the pit and wall exhaust streams except during the winter when there are very low dust concentrations in the pit exhaust air (figure 4). Because more of the airflow through the barn is delivered by the wall than by the pit fans in the cases shown, most of the $PM_{10}$ emissions are through the wall fans except for the 20 cfm/pig pit ventilation rate for the winter and spring periods.

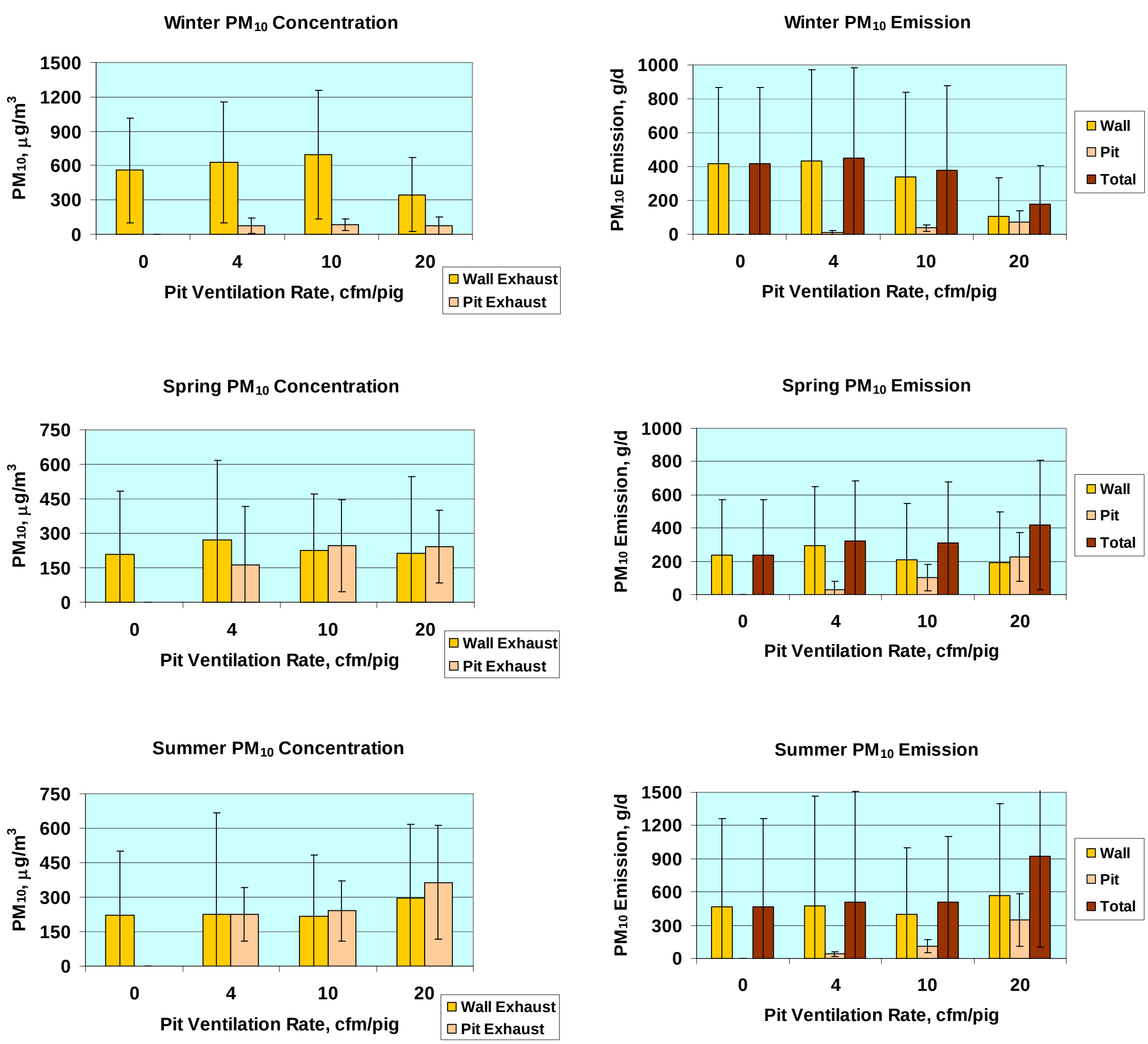


Figure 4. $PM_{10}$ concentrations and emissions for winter, spring, and summer

Odor concentrations and emissions collected in this study were not as conclusive as for $NH_3$, $H_2S$, and $PM_{10}$ since odor was only measured intermittingly (monthly) and odor concentration was determined through olfactometry's dilution threshold and not hedonic tone or pleasantness. Still pit exhaust air does have a higher odor concentration (as measured by dilution threshold) than wall exhaust air (figure 5). When reviewing the odor emissions from this barn, we do see that the pit air stream does contribute considerably to the overall barn odor emissions (please note the vertical log scale for odor emissions). This fact should be noted when considering using some type of odor control technology which might be best located on pit fans, if they are used, compared to the wall fans.

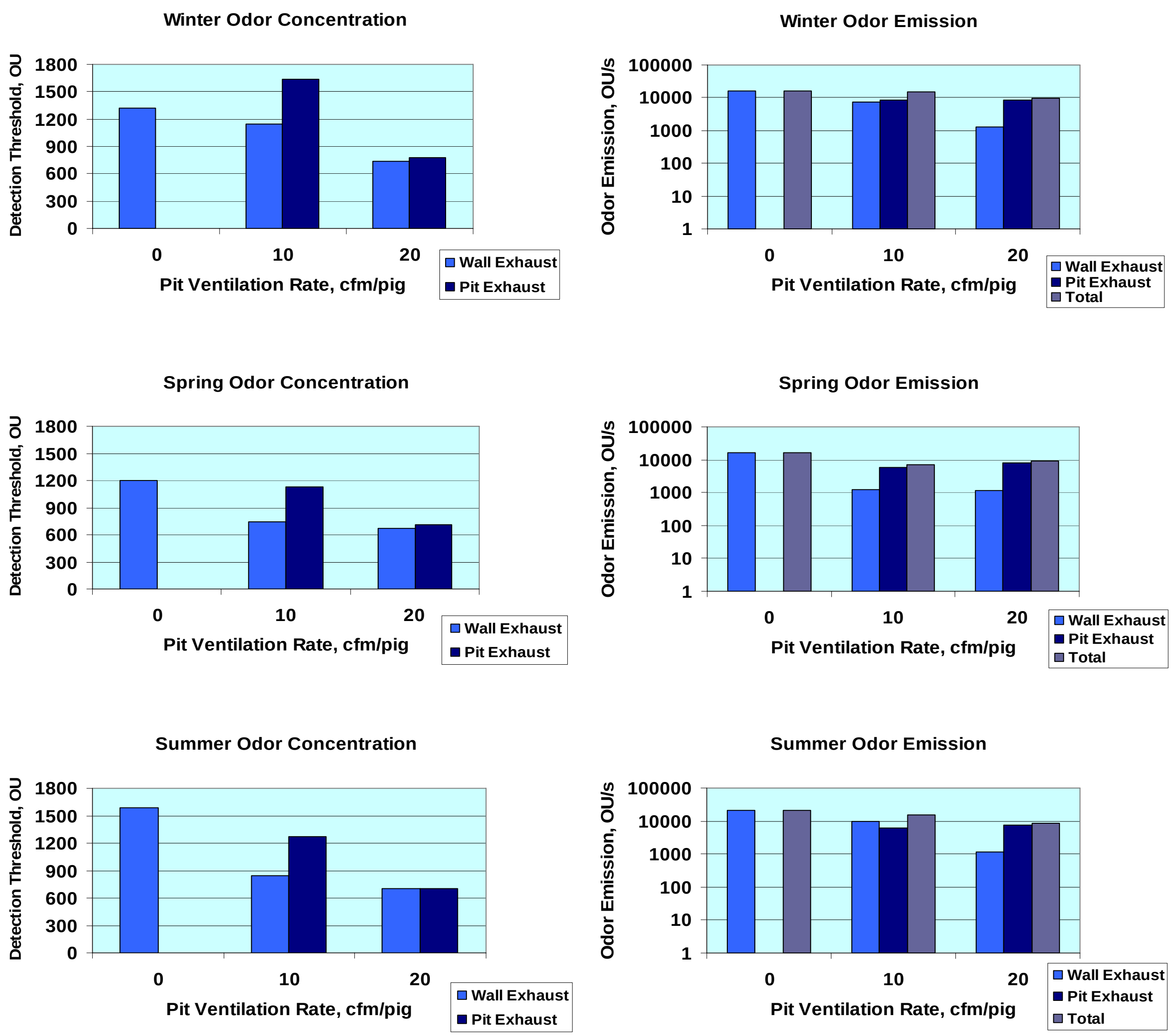


Figure 5. Odor concentrations and emissions for winter, spring, and summer

## VII. Discussion

The study shows limited value and benefit for the use of pit fans in a deep-pit pig finishing barn. Based upon the similar ammonia and hydrogen sulfide concentrations that were measured in the center of the barn for all four (0, 4, 10, and 20 cfm/pig) pit ventilation cases, it seems that exhausting a portion of the barn's ventilation air through the pit has little effect on the room's indoor air quality. The $NH_3$, $H_2S$, and odor emissions determined in this study show that a disproportionate amount, according to the airflow rates, of these two gases are exhausted from the barn through pit fans if they are operating. This fact should be noted if a producer wants or needs to reduce a pig barn $NH_3$, $H_2S$, and/or odor emissions, since there would be a considerable benefit to treating only the pit fan exhaust air with an air emission control technology rather than all of the exhaust air (wall and pit). Finally the $PM_{10}$ concentrations and emissions from the pit fan air stream are lower than it is for the wall fans. The partitioning of the amount of airborne dust being emitted between the pit and wall fan airstreams has not been measured before and is valuable for regulatory purposes and to assist in the design of emission control technologies that are used for either location or pathway.

## VIII. Lay Interpretation:

The results of this study show limited benefit to exhausting a portion of air through the pit rather than through the wall for deep-pit pig finishing barns. This conclusion comes from similar indoor air quality (as determined by concentrations of ammonia and hydrogen sulfide) made inside one room of a double-wide, deep-pit, pig finishing barn in southern Minnesota that operated its four pit fans in two-hour intervals at 0, 4, 10, and 20 cfm/pig over a six month time period. Gas and odor emissions were also determined for this commercial pig finishing room and were separated into pit and wall airstreams. These results would allow pork producers to strategically decide to use just wall fans for deep-pit barns or if emissions of gases or odor are of concern, to utilize some pit fans that have air emission control technologies like biofilters to considerably lower the barn's emissions. Also, the particulate matter concentrations and emissions, or dust levels, in pit fan exhaust air are considerably lower than what is found in wall fan exhaust. This fact would also be beneficial for the design and maintenance of air control technologies on pit fan exhaust air.

Further information from this study maybe obtained by contacting:

Larry D. Jacobson,
Professor and Extension Engineer
Dept. of Bioproducts and Biosystems Engineering
University of Minnesota
St. Paul, MN 55108
Phone: 612-625-8288
Email: jacob007@umn.edu