

ENVIRONMENT

Title: Comparative Analysis of Odor Evaluation and Aerosol Monitoring Techniques
NPB #03-151

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Abstract

An experiment was conducted at the Institut de Recherche et de Développement en Agroenvironnement (IRDA) in Québec, Canada to determine the relationship between odor as measured by a trained odor panel and key parameters as measured using equipment owned by IRDA and Michigan State University (MSUCEM). A part of the project was to compare the measurements of the two types of equipment. The experimental set-up was six different treatments with two replications with four finishing pigs in closely controlled environmental chambers. The treatments were different manure handling systems. While there was no one value which was useful in predicting the odor units per pig, a prediction equation was developed which accounts for 70% of the variation in odor from one treatment to another. Dust was not a significant predictor. The two measuring systems gave very consistent although slightly different results.

I. Introduction

The MSUCEM project is a part of a large project in Québec, Canada. It is very common in Canada to manage swine manure in a liquid form. Because of environmental considerations, other techniques are being evaluated. These considerations are closely related to the phosphorus surplus and odor and gas emissions. One of the difficulties producers and researchers face is that while it is relatively simple (although expensive in some cases) to measure some gases, measuring odor is not simple. The objectives of this project were to compare gas and dust measurement systems with an odor measurement system.

These research results were submitted in fulfillment of checkoff funded research projects. This report is published directly as submitted by the project's principal investigator. This report has not been peer reviewed

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II. Objectives

Stated objectives from original proposal

This project was designed to provide an in-depth cumulative assessment of odor evaluation and aerosol monitoring techniques/technologies through olfactometry analysis, profiling of volatile fatty acids, determination of noxious and greenhouse gases and an evaluation of the concentration and size parameters of particulate contamination produced within swine production facilities.

- 1) To provide a comprehensive correlation analysis of trained olfactometry panel evaluation with currently available air quality monitoring techniques:
 - a. GC/MS analysis to profile volatile fatty acids (C2-C9) within swine production facilities.
 - b. Michigan State University Continuous Emissions Monitoring System (MSUCEM) utilizing multi-gas photo-acoustic infra-red and chemiluminescent technologies for the determination of facility gases.
 - c. Institut de Recherche et de Développement en Agroenvironnement Direct Injection Analysis System (IRDA) utilizing gas chromatography (flame ionization and electron capture detection), electrochemical processes and non-dispersive infrared spectroscopy for the determination of facility gases.
 - d. Particulate contamination as determined by optical and gravimetric methods
- 2) To provide an in-depth comparative evaluation of technologies currently utilized for monitoring aerial contaminants within livestock production facilities:
 - a. To evaluate the effectiveness and efficiency of utilizing solid phase microextraction and sorbent tube sampling methods for gas chromatography profiling of volatile fatty acids (C2-C9).
 - b. To compare the MSUCEM and the IRDA systems for the evaluation of noxious and greenhouse gases.
 - c. To assess the utilization of dual wavelength Nephelometer technology (indirect optical method) for particulate matter analysis (concentration and sizing) compared to traditional gravimetric systems.

III. Material and Methods

The objective of the global project in Canada was to compare the gases emitted, dust generated, and odors generated of six different under slat manure management systems. There were 6 treatments with 5 distinctly different systems:

- Pull plug (control): This is the manure management system that is the most used in Québec.
- Conventional flat scraper (S): This is a common system in Québec.
- Cemagref (France) belt system: A special mesh belt under slats drives the solids to one end and the liquid is stored in a conventional pit.
- V-shaped scraper (V): Manure management system used at Michigan State University. This system consists of isolating liquid from solid using a V-shaped scraper and a V-shaped channel. Two scraping frequencies are studied.
- V-shaped scraper daily (J): This is the V-shaped system but the manure is scraped more often (daily).
- Belt (C): This system was studied at North Carolina State University. This system consists of uses an inclined belt. Solid stays on the belt, while the liquid flows off the belt and is captured in a gutter.

There were 12 rooms measuring 1.2 x 2.4 x 2.4 m. The floor is fully slatted and the ventilation rates are similar and continuously monitored. All of 12 rooms are airtight. Figure 1 below shows the layout of the project.

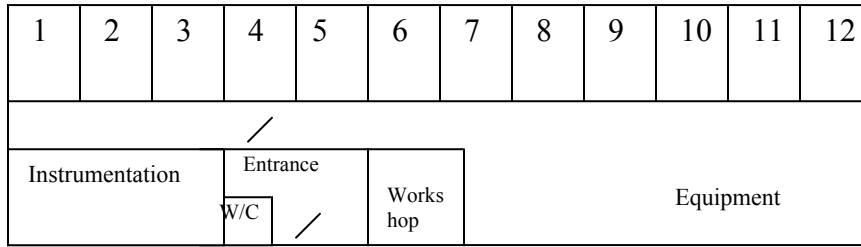


Figure 1 : General view of the experimental units

For each room, a treatment was allocated. There were 2 repetitions per treatment per test. In each room, there were 4 growing pigs. Each test lasted for 8 weeks.

This project is designed to provide an in-depth cumulative assessment of odor evaluation and aerosol monitoring techniques through olfactometry analysis, profiling of volatile fatty acids, determination of some specific noxious and greenhouse gases and an evaluation of the concentration and size parameters of particulate contamination produced within swine production facilities.

The Canadian project offered an opportunity to compare the MSUCEM and traditional gas measurement analyzer. Due to the MSUCEM configuration, 6 rooms were monitoring by two gas analyses systems. This set up allowed an accurate comparison between two gas analyzers.

IRDA

The IRDA system analyzed ammonia (NH₃), methane (CH₄), nitrous oxide (N₂O) and carbon dioxide (CO₂). CH₄, N₂O and CO₂ were analyzed by a chromatograph (GC) and ammonia is analyzed by NDIR. Measurements (concentration) were recorded every 2 hours.

MSUCEM

The heart of this system is an INNOVA 1314 multi-gas photo-acoustic infra-red monitor programmed for the evaluation of NH₃, CH₄, CO, CO₂ and N₂O. The accuracy of these measurements is ensured by the 1314's ability to compensate for temperature and pressure fluctuation, water-vapor interference and interference for other gases present in the sampling environment. The MSUCEM utilizes a California Analytical Instrument 400CLD chemiluminescent analyzer with a heated converter to monitor total NO_x, including NO and NO₂. The MSUCEM records the values electronically every 10 minutes.

Odor Analyses

For the first 8 week trial period, samples were taken for 3 treatments in duplicate as well as for ambient outside air. In the second 8 week trial period, samples were taken from all 12 rooms in addition to ambient outside air. The sample air was pumped into a 25 L Tedlar bag over a 10 minute period and sent overnight to the laboratory for analysis. Concentration measurements were made with a dynamic forced-choice olfactometer.

SPME—GC/MS

A total of 24 samples were taken using solid phase micro-extraction samplers for GC/MS analysis. This represented two rooms for each treatment with replication. Each SPME fiber was exposed for 10 minutes. Due to damage to SPME fibers, only 21 of the samples were usable.

IV. Results

Data was obtained with the equipment as described above with the exception of the nephelometer dust data. Dust data was obtained using traditional gravimetric means. A total of 16 odor analyses were conducted where there was complete data for comparison to other measurements. Complete data for comparison meant that there were simultaneous data from IRDA, MSUCEM, SPME, and the odor panel.

- A. IRDA compared to MSUCEM. Comparison results between the IRDA gas measurement system and the MSUCEM were very consistent. The MSUCEM had been sent for calibration to California Analytical Instruments immediately prior to use on this project. IRDA consistently reported N_2O concentrations about twice that of the MSUCEM, but both were very low. The average over a three day period in trial two for IRDA was 0.347 ppm and for MSUCEM was 0.175 ppm. Methane (CH_4) concentrations for the IRDA equipment consistently were about 83% of those reported by the MSUCEM, but once again the values were very low (4.2 and 5.1 ppm respectively). A sample of simultaneous plots is shown for methane in Figure 2. There was less than 10% difference in the reported values of CO_2 between the two systems with IRDA consistently 91% of the MSUCEM. The averages of these values were 912 ppm and 1008 ppm respectively. Lastly, NH_3 values between the two systems showed the values from the MSUCEM higher than that of IRDA with respective average values of 5.96 ppm and 3.30 ppm. While there is a difference between the two systems, the absolute values of the concentrations are low.

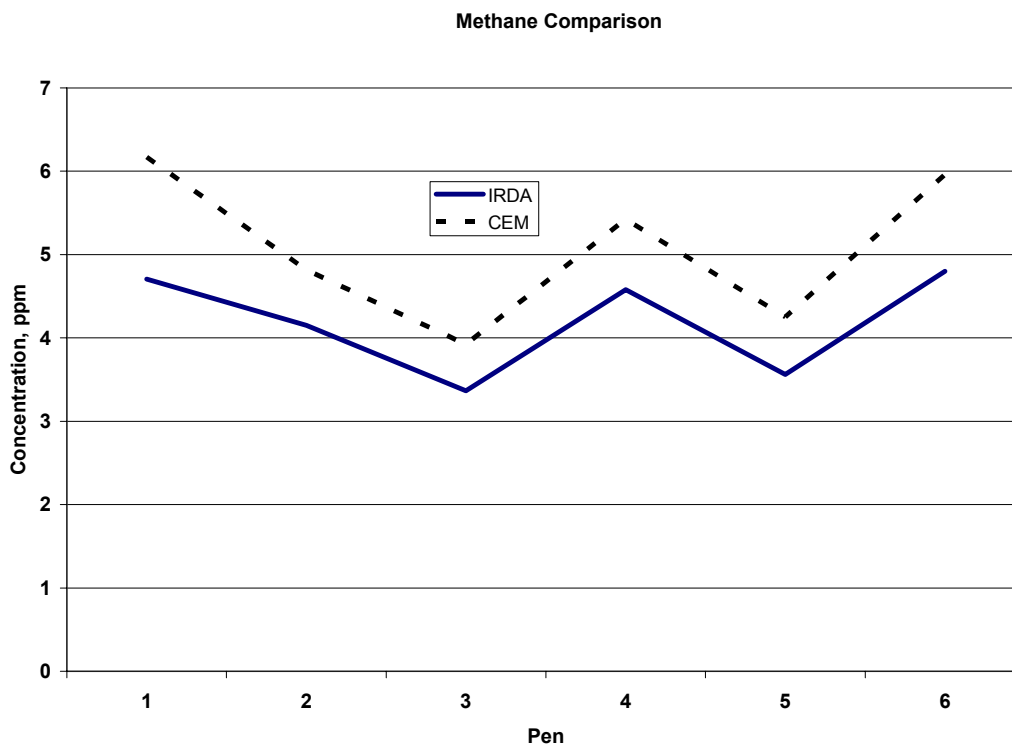


Figure 2. Sample simultaneous plot between IRDA and MSUCEM for methane.

- B. SPME results compared to gas concentrations. The following compounds were analyzed with the SPME GC/MS technique: phenol, ethylphenol, methylphenol, indole, and skatole. With one exception, indole and skatole concentrations were below detection limits. The correlation matrix for hedonic tone is shown in Table 1.

Table 1. Correlations involving hedonic tone.

	<i>Hedonic Tone</i>	<i>phenol</i>	<i>methyl-phenol</i>	<i>ethyl-phenol</i>	<i>CH₄</i>	<i>NH₃</i>	<i>Dust mg/m³</i>
Hed Tone	1						
phenol	-0.13073	1					
m-phenol	0.046143	0.203171	1				
e-phenol	-0.39975	0.800076	0.267804	1			
CH ₄	-0.68917	0.337828	-0.36119	0.601971	1		
NH ₃	-0.20121	-0.04516	-0.3069	-0.23327	-0.09545	1	
mg/m ³	-0.25731	0.515764	-0.13059	0.556749	0.575172	-0.37772	1

This matrix shows that there is a reasonably strong negative correlation between methane (CH₄) and hedonic tone.

The correlation matrix for odor units is shown in Table 2. This matrix shows that there is strong negative correlation between methane and odor units and moderate correlation between methylphenol and dust to odor units.

Table 2. Correlation matrix for odor units.

	<i>Odor Units/m3</i>	<i>Hedonic Tone</i>	<i>phenol</i>	<i>methyl-phenol</i>	<i>ethyl-phenol</i>	<i>CH₄</i>	<i>NH₃</i>	<i>Dust mg/m³</i>
OU/m3	1.0000							
Hed T	0.3964	1.0000						
phenol	-0.1405	-0.1307	1.0000					
m-phenol	0.4831	0.0461	0.2032	1.0000				
e-phenol	-0.2350	-0.3998	0.8001	0.2678	1.0000			
CH ₄	-0.7602	-0.6892	0.3378	-0.3612	0.6020	1.0000		
NH ₃	0.2658	-0.2012	-0.0452	-0.3069	-0.2333	-0.0955	1.0000	
mg/m ³	-0.4942	-0.2573	0.5158	-0.1306	0.5567	0.5752	-0.3777	1.0000

- C. Regression analysis. A regression analysis was performed to see if multiple measured inputs could be used to predict odor units. When using phenol, methylphenol, ethylphenol, methane, ammonia, and dust as independent variables, a prediction equation with an R² of 0.79 (adjusted R² of 0.65) was found. However, dust and methylphenol were the least significant predictors and when eliminated, the regression R² dropped to 0.78 but the adjusted R² rose to 0.70. The values of the regression coefficients are shown in Table 3. The table also shows the order of significance. All are highly significant.

Table 3. Regression coefficients for odor prediction.

		Order of significance
Intercept	2.451232	
phenol	-0.00016	4
e-phenol	0.008047	2
CH ₄	-0.09107	1
NH ₃	0.014543	3

V. Discussion

In general, the objectives of the project were met. A comprehensive correlation analysis of trained olfactometry panel results with measured parameter values from the facilities was conducted. While no individual measured parameter was a good predictor of odor units, four of the parameters together accounted for 78% of the total variation. A prediction equation for odor units can be derived from the correlation coefficients using concentrations of phenol, methylphenol, methane and ammonia. One sub-objective was to profile the fatty acids, and that analysis is still underway. It requires manual integration of the GC traces, and is very time consuming. However, full analyses of phenol, methylphenol, ethylphenol, indole, and skatole were performed. The MSUCEM methodology for measuring NH_3 , CH_4 , CO , CO_2 and N_2O was compared with the IRDA methodology. While the values were not exactly the same in spite of considerable calibration effort, they were very consistent with each other. The solid phase microextraction (SPME) method of collecting data for analysis by GC/MS proved to be effective and reliable. Of the total of 24 collection attempts, 21 resulted in extractable data. The nephelometer system was not functional for this experiment, but dust data was collected by traditional gravimetric means.

While the prediction equation gives reasonably good results, the coefficients were a bit surprising. Methane is the strongest of the parameters, and it is negatively correlated with odor units. This means that the more methane detected, the less is the odor. Since methane is associated with anaerobic activity and anaerobic activity generally leads to strong odors, that result is surprising. It should be noted, however, that the conditions in this trial were very clean and ventilation was well controlled. That is evidenced by the fact that carbon dioxide levels were 1200 ppm or less.

Dust was the weakest of the parameters in the prediction of odor. Removing it had little impact of the prediction. This may be an anomaly of the systems being investigated and the way in which air is collected for analysis by the odor panel.

VI. Lay Interpretation

Relative to this project, what one really wants to know about a swine facility is whether odor from the unit can be predicted, how good the prediction would be, and how difficult it will be to predict it. It is of value to know whether different sophisticated methods of measuring parameters assumed to be important in odor characterization can be compared and whether they give similar results. Finally, it would be useful to know how much a factor dust is in odor. The results of this research lead us to say that dust is not significant in predicting odor. It was the weakest of all the items chosen for analysis. The devices used to measure gases in the facility gave very consistent although slightly different results. They both worked well, and results were easy to analyze. Finally, in this experiment, odor units (strength of odor) could be predicted with reasonable accuracy given four measurements in order of significance: concentration of methane, concentration of ethylphenol, concentration of ammonia, and concentration of phenol. Two of the concentrations (methane and ammonia) are easy to obtain and two (ethylphenol and phenol) are difficult to obtain.