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USE OF AN ELECTRONIC NOSE TO EVALUATE ODORS FROM SWINE OPERATIONS

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ABSTRACT

In this project, an AromaScan A32S electronic nose and a human panel at the Duke Taste and Smell Lab were used to evaluate the effectiveness of biofilters in reducing the malodors in the exhaust air from swine confinement facilities. Three experiments are reported: 1) detection threshold tests for the electronic nose and human panel for a significant component of swine slurry – acetic acid, 2) hedonic tone evaluation by the human panel and electronic nose in a benchtop biofilter setup for an synthetic swine slurry, and 3) field test of the electronic nose in an operational biofilter at a swine production facility. The feasibility of using an electronic nose to replace the human panel in these applications is demonstrated.

INTRODUCTION

Livestock industries are expanding rapidly in many areas of the globe, and this expansion is causing environmental concerns. In swine operations, for example, odors emanate from confinement building ventilation air, waste storage and handling systems including lagoons, and field applications of waste. Anaerobic microbial decomposition of livestock waste appears to be the source of the more objectionable smells. Odorous compounds identified in livestock wastes include sulfides, volatile organic compounds, alcohols, aldehydes, amines, fixed gases, nitrogen heterocycles, mercaptans, carbonyls, and esters. Reduction of odors emanating from livestock operations is desirable to improve relationships between producers and their neighbors.

Sensitive measurement techniques are important for characterizing and documenting swine odors, as well as evaluating the effectiveness of methods for reducing odor. At present, olfactometry, in which a human odor panel evaluates the odors, is the most precise approach for quantifying odors since the nose can detect compounds at concentrations that cannot be detected by any other method. Human assessment, however, can be time-consuming and expensive. In addition, odor samples degrade rapidly so human panels must perform evaluations shortly after collection for accurate assessment. Since swine odor abatement research is being conducted all around the nation on a 24-hour basis, odor testing with human panels is often impractical. For this reason, it would be helpful to determine if an electronic nose can substitute for human odor panels in evaluating methods for odor reduction.

EXPERIMENT 1: COMPARISON OF DETECTION THRESHOLDS FOR A HUMAN PANEL AND THE ELECTRONIC NOSE

A set of experiments was performed to evaluate and compare odors associated with swine production by both a human panel and an electronic nose. In the first experiment, detection threshold concentrations were determined for a major individual constituent in swine odor (i.e. acetic acid). Serial dilutions of acetic acid that differed by a factor of three and ranged from 5% to 0.0000094% v/v were presented to the human panel and the AromaScan® A32S E-Nose for evaluation. The electronic nose signals were preprocessed by computing the fractional change in resistance of each sensor with respect to its baseline resistance in reference air (steady-state $\Delta R/R$). The final response of each sensor was extracted to form a 32-dimensional feature vector. **Figure 1** shows the first two Principal Component projections of the dataset, along with the equiprobable contours at a cumulative probability of 0.997 (3 standard deviations) [Duda et al., 2000]. The samples with a numeric label of '13' are from the initial dilution of 5%. Lower numeric labels denote subsequent serial dilutions. The detection level for the AromaScan® A32S was 9 while the average for human subjects was 8.5.

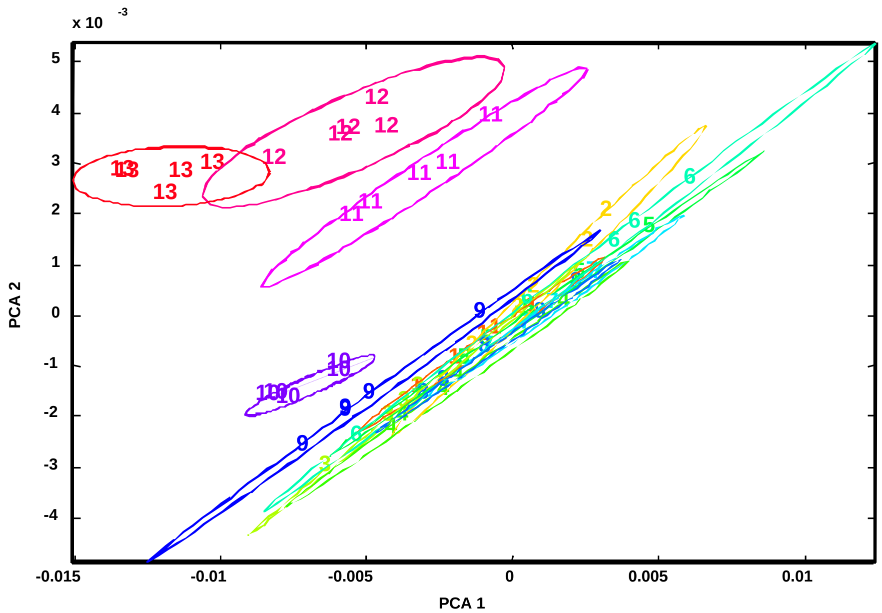

Figure 1. Principal Component Analysis for dilutions of acetic acid in mineral oil

EXPERIMENT 2: EVALUATION OF LABORATORY BIOFILTER ON SYNTHETIC SLURRY

To evaluate the performance of various odor remediation materials, we developed a bench-top biofilter, consisting of a PVC tube (1-inch in diameter by 3.9-inches in length) packed with earth, wood chips, small twigs and straw. In order to test this biofilter setup, we conducted a benchtop odor remediation experiment with a synthetic slurry [Persaud et al., 1996]. Serial dilutions (1/1, 1/3, 1/9, 1/27 and 1/81) of the headspace above the slurry, as well as serial dilutions of the biofiltered synthetic slurry and biofiltered blank air (room air as a control) were presented to both a human panel and the AromaScan® A32S electronic nose. The human subjects generated scores for Intensity, Irritation and

Pleasantness using the 9-point scale shown in **Table 1.** The electronic nose signals were preprocessed in a similar fashion to the acetic acid experiment reported earlier.

The average response of the human panel and the 32 e-nose sensors for each of the 15 dilutions (5 dilutions of three odor sources) is shown in **Figure 2.** Each sensor is represented by one feature as reported above (steady-state ΔR/R). Note for the human panel, biofiltering reduced the intensity, irritation, and unpleasantness of the odor. However, the panel's ratings of the biofiltered slurry and blank air were quite similar.

Table 1: Hedonic Tone Odor Rating Scales.

Scale	Odor Intensity	Irritation Intensity	Pleasantness
8	Maximal	Maximal	Extremely Unpleasant
7	Very Strong	Very Strong	Very Unpleasant
6	Strong	Strong	Moderately Unpleasant
5	Moderately Strong	Moderately Strong	Slightly Unpleasant
4	Moderate	Moderate	Neutral
3	Moderately Weak	Moderately Weak	Slightly Pleasant
2	Weak	Weak	Moderately Pleasant
1	Very Weak	Very Weak	Very Pleasant
0	None at all	None at all	Extremely Pleasant

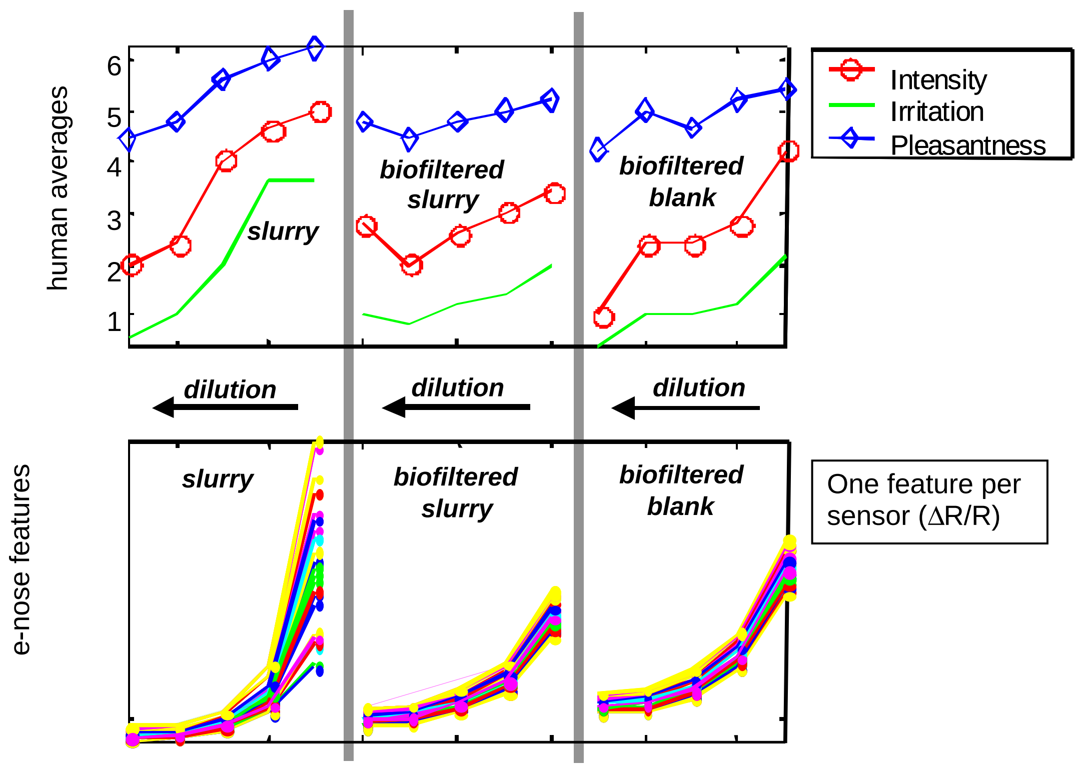

Figure 2. Average human and e-nose response in the synthetic-slurry biofiltration experiment

These results indicate that the biofilter is capable of performing odor remediation, since both the human panel and electronic nose generate lower scores to the biofiltered synthetic slurry. In order to establish whether the electronic nose could be used to replace a human panel in odor-remediation scenarios, we performed Partial Least Squares regression [Geladi and Kowalski, 1986] to predict the average response of the human panel from the 32-dimensional average response of the electronic nose. To establish the predictive accuracy of this model we performed cross-validation, in which one of the fifteen dilutions was removed from the training data and predicted only after the PLS model had been obtained. **Figure 3** shows the performance of the model on both training and test data for the 15 leave-one-out validation runs. The correlation coefficient between predictions and true values on test data for Intensity, Irritation and Pleasantness are 0.90, 0.94 and 0.86, respectively. Hence, the prospects for using an electronic nose to replace the human panel in this application are quite good.

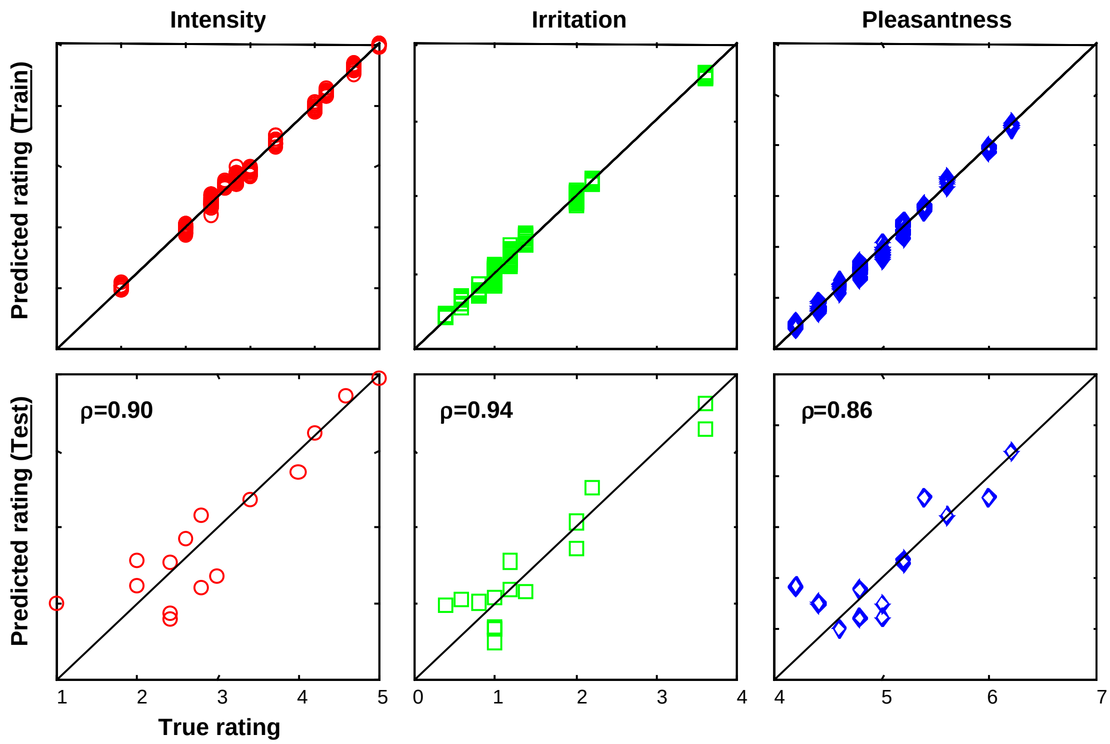

Figure 3. True vs. predicted human panel ratings for synthetic-slurry biofiltration for training data (top) and test data (bottom)

EXPERIMENT 3: EVALUATION OF DEPLOYED BIOFILTER AT A SWINE FACILITY

A final experiment was performed using odorous samples collected in Tedlar® bags at the NC State Animal and Poultry Waste Management Center, which has an experimental full-scale biofilter. Full concentration samples as well as 1/3 and 1/9 dilutions were collected before and after biofiltration. In addition, ambient air from the surroundings (~0.5 miles downwind) and air directly from the house fan exhaust were also collected. The electronic nose transient response to five samples from each of the eight odors is shown in **Figure 4.** Note that the sample taken directly from the fan exhaust gives the strongest sensor response. The next highest response is from the air sample taken before the biofilter unit. The third highest responses are from the biofiltered air and the ambient air samples. These signals were then analyzed. Computation of the first two Principal Components from the final fractional response of the array yields the scatter plot shown in **Figure 5.** It is interesting to notice the structure of the clusters, which provides linear separability between biofiltered and unfiltered odors (dashed line). The two solid arrows indicate the direction of increasing concentration for both groups of odors. The full concentration biofiltered odor and the downwind ambient air are also clustered together.

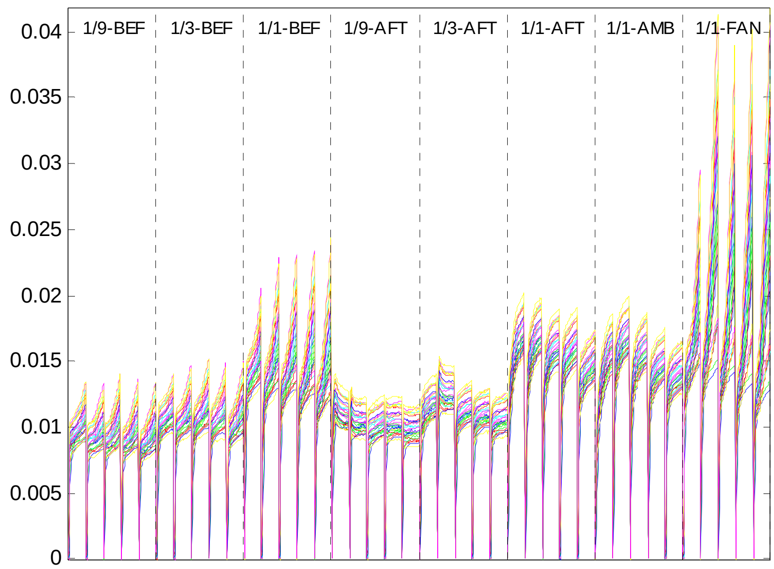

Figure 4. E-nose sensor response for odor abatement field data.

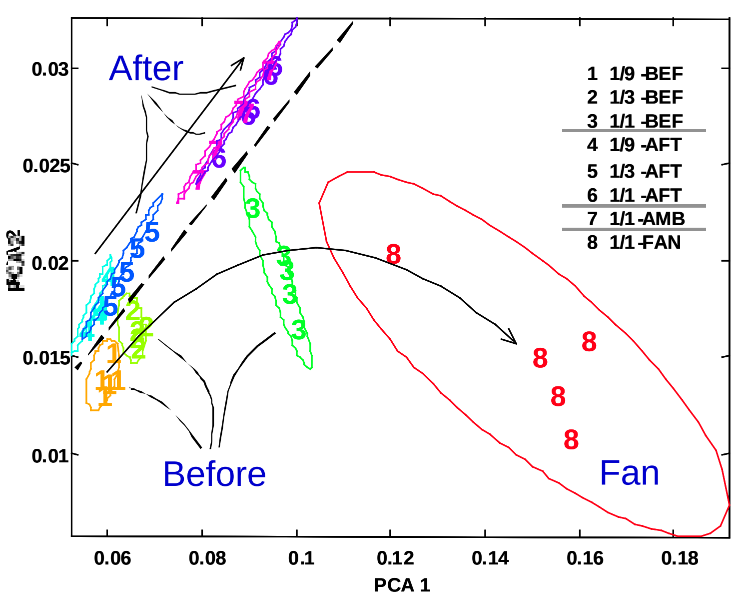

Figure 5. Principal Components for odor abatement field data

CONCLUSIONS

The main findings of this study are that the AromaScan® A32S electronic nose can differentiate between different dilutions of the components of swine odor, between synthetic slurry, biofiltered slurry, and biofiltered blank/control samples, and between biofiltered and unfiltered air at a swine facility. Good correlation was obtained between the electronic nose and the hedonic ratings by the human panel of synthetic and biofiltered synthetic swine slurry. This encouraging result gives promise that the electronic nose will be able to replace the human panel for real-time odor monitoring of animal production facilities.

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