Evaluation of Field-based Odor Assessment Methods

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ABSTRACT

This study investigates the differences between field-based odor assessment methods that may be used to discriminate odors from livestock and food processing facilities. Field olfactometers have been praised for their low cost ($500 - $1200) and portability but criticized for their lack of control of inhalation rates by different panelists, the discomfort of glass inhalation tubes and the odor fatigue caused by poor nasal sealing or removing the scentometer between samples as compared to laboratory dynamic, triangular forced-choice olfactometers ($30,000). This study evaluated the variability of responses using these three field olfactometers compared to laboratory olfactometry, as well as field and lab odor intensity. Panel responses using laboratory dynamic, triangular force-choice olfactometry and Nasal Ranger field olfactometers were found to exhibit the least amount of variability across odor sources. Significant differences with poor correlation were found between field and laboratory odor intensity methods. Findings of this study should caution regulators, policy makers and investigators about establishing regulatory thresholds or reporting scientific data based on single odor analysis methods or techniques due to the variability in the performance of odor determination methods across the odorous sites investigated.

Keywords: odor, scentometer, olfactometry, field methods, “Nasal Ranger”

INTRODUCTION

Odor from dairies and other animal feeding operations is a major issue in Idaho and across the country. Economic pressures over the past two decades have caused dairies to expand or build new facilities in order to be profitable. At the same time, rural communities have seen the increase in the number of homes being built in traditional agricultural areas. As these two groups have grown, friction has risen in many areas due to issues of land use, water quality, road congestion, light pollution and odors (Church et al., 2003).

In 2002, Idaho adopted the Rules Governing Agriculture Odor Management. One of the major provisions of Idaho’s Odor Rule is the determination by the Idaho Department of Agriculture and the specific determination of an “agricultural operation using an accepted agricultural practice that generates odors in excess of level normally associated with such (a) practice.” In 2002, Idaho’s House Bill 726 was ratified and stated that “the

Department may determine by rule, the standards for which shall be judged on criteria that shall include intensity, duration, frequency, offensiveness and health risks." To date, the Department has not determined a procedure or methodology for making such a determination. Without such assessment procedures, the dairy and other agricultural industries must rely on subjectivity of Department inspectors and administrators for determining the level of offensive odors. In addition to the need for defensible regulatory tools, enhanced field odor assessment methods are needed to evaluate the effectiveness of odor control technologies in reducing offsite emissions (Sheffield, 2002). Additionally, these field methods may be used by livestock producers, food processors and wastewater operators to voluntarily and inexpensively monitor and assess odors from their farms.

Box scentometers were developed in the 1960s (Huey et al., 1960 and Barnebey-Cheney Company, 1962) as a simple, low-cost method for determining an odor concentration or Dilutions to Threshold (D/T). Field assessors sniff through the scentometer using a series of openings on the inlet of a charcoal filter. The number of holes that are open when an assessor detects an odor relates to number of dilutions of air required to abate the odor. States such as Colorado, Kentucky, Illinois and Wyoming (Sweeten, 1990) have established odor standards based using on box scentometers for determining the concentration of odors at property lines or residences. States have largely relied on box scentometers because of the unavailability of comparable assessment methods or tools.

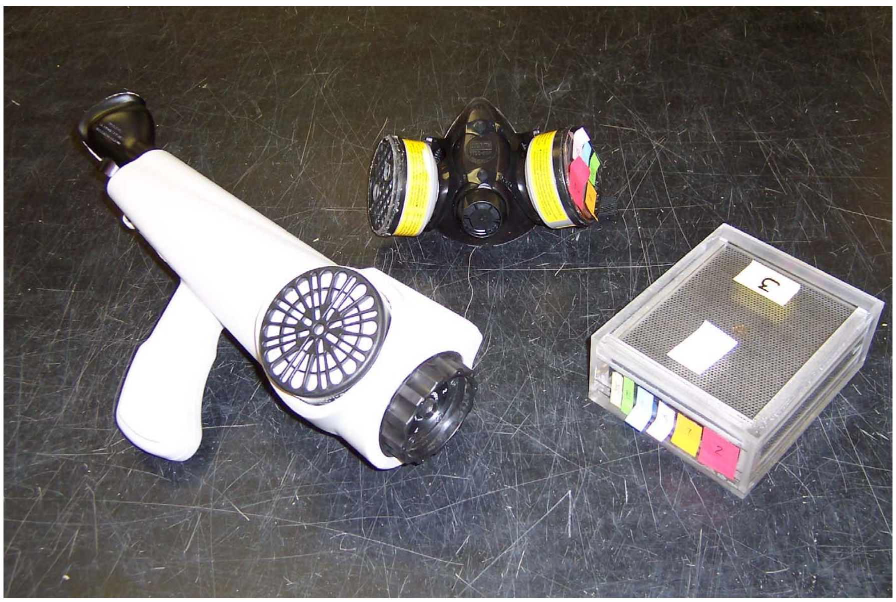
This study proposes to evaluate the differences between field-based odor assessment methods and laboratory-based dynamic, triangular forced-choice olfactometry (DTFCO) as measured on potential odor sources in south central Idaho. The study was not conducted to develop emission or odor ratings from these facilities, but rather focuses on the methods of how such assessments would most accurately be done in the future. Specifically, this study evaluated odor concentration (dilution to threshold) results determined by trained odor assessors using DTFCO and box scentometers to two new devices: a facial mask scentometer and a "Nasal Ranger" field olfactometer. Box scentometers (Figure 1) have been praised for their low cost ($500) and portability but criticized for their lack of control of inhalation rates by different panelists, the discomfort of glass inhalation tubes and the odor fatigue caused by poor nasal sealing or removing the scentometer between samples (Auvermann et al., 2002) . The facial mask field olfactometer ($200) are functionally similar to box scentometers, but rely on a full-face charcoal filtered respirator to prolong odor fatigue. The "Nasal Ranger" is a new device, developed by St. Croix Sensory, Inc. of Lake Elmo, Minnesota and is designed to combine the portability and relatively low-cost ($1500) of a scentometer with the sampling control of more expensive laboratory olfactometers. The "Nasal Ranger" relies on a pressure transducer to ensure that assessors maintain the required inhalation rate for the unit.

OBJECTIVES

To evaluate field-based odor evaluation techniques for their application in Idaho, specifically:

1. Determine the variability of odor concentrations from box scentometers, facial mask field olfactometer, "Nasal Ranger" evaluation methods and dynamic, triangular forced-choice olfactometry.
2. To correlate odor concentration to field and laboratory assessments of odor intensity, as compared to n-butanol standards.
3. To correlate the odor concentration found on 5 odor sources to the field measurements of ammonia and total reduced sulfur/hydrogen sulfide.

Figure 1. Field Olfactometers used in this study. (Nasal Ranger Field Olfactometer, Facial Mask Field Olfactometer and Box Scentometer from left to right).



METHODOLOGY

Odor was assessed in the field and collected once a week over a 6-week period (January and February, 2003) from five odor sources (Table 1).

Table 1. Description of Odor Sources.

ID	Type of Source	Description
1	Food Processor	Wastewater settling pond
2	Wastewater Pumping Station	Municipal and food processing wastewater
3	Dairy, Freestall	3,800-head facility with flush manure handling system
4	Dairy, Openlot	1,800-head open lot dairy
5	Beef Feedlot	1,000-head open lot beef feedlot

Odor assessments were conducted by a panel of trained assessors from the University of Idaho, the Idaho Department of Agriculture and the Idaho Department of Environmental Quality. Panelists were selected from a group of 55 candidates from the three organizations following ASTM Standard E 544-99, selecting for the highest accuracy to known n-butanol standards and least variable responses to unknown liquid odorous samples. From the results of the intensity evaluation, a panel of 8 field assessors and 2 alternates were selected and trained by University of Idaho personnel on how to operate the three field devices and to evaluate odor intensity using n-butanol. Additionally four Panel Assistants were trained to assist a pair of assessors and two technicians were trained and used to collect air and gas samples and to manage the team of panelists. Prior to beginning the study, two days of field training was conducted on 6 dairies that were not included in the study. A Quality Assurance/Quality Control (QA/QC) protocol was developed to describe how samples would be collected according to manufacture's guidelines, transported, entered, reviewed and reported.

On each sampling day, panelists conducted odor assessments using the box scentometer, facial mask field olfactometer, "Nasal Ranger" field olfactometer, and odor intensity (as compared to n-butanol). During each evaluation, the panelists were placed into pairs and worked with the panel assistants to operate each field device to determine the detection threshold (D/T) of the odor present at each site. Panelists were required to select the same D/T twice before the selection would be recorded by the assistants. At no time during the study would the panelist be told of their responses. The geometric mean of each D/T, using the following equation, for each of the devices was reported and used for data analysis (Table 2).

$$D/T_{geo} = 10^{\frac{\log D/T_n + \log D/T_{(n+1)}}{2}}$$

Table 2. Geometric Means of the Dilutions to Threshold for Field Odor Devices.

Device	Unit D/T	Geometric D/T	Device	Unit D/T	Geometric D/T	Device	Unit D/T	Geometric D/T
Box Scentometer	350	350	Facial Mask Field Olfactometer	170	170	Nasal Ranger Field Olfactometer	60	60
	170	243.9		31	72.6		30	42.4
	31	72.6		15	21.7		15	21.2
	15	21.7		7	10.2		7	10.2
	7	10.2		2	3.7		4	5.3
	2	3.7		<2	1.4		2	2.8
	<2	1.4		---	---		<2	1.4

Gas concentrations in the field were estimated using a Jerome Meter Model 631-X, for total reduced sulfur/hydrogen sulfide, and Drager diffusion tubes for ammonia. Gas samples were taken at a height of 1.5 meters over a 15-minute sampling period. During each assessment two - 10.0 liter air samples will be collected in new Tedlar bags via a vacuum chamber and sampling tube at a height of 1.5 meters. One air sample was transported to the University of Idaho Odor and Manure Laboratory and was analyzed the same day by each of the panelists for odor intensity, as compared to prepared n-butanol standards, and reported as equivalent concentration of n-butanol in parts per million. The second air sample was shipped overnight to the Odor Assessment Laboratory at West Texas A&M University (WTAMU) in Canyon, Texas. The sample was analyzed by a trained odor panel using a dynamic, triangular forced-choice olfactometer for dilutions to threshold and odor intensity. The WTAMU laboratory used an AC'SCENT olfactometer manufactured by St.Croix Sensory and a presentation flow rate (20-lpm).

Data from this study was analyzed using a univariate analysis of variance following a completely randomized block design. The mean D/T and odor intensity for each device and method was evaluated using the raw D/T and their log transformation using SPSS (2002). Comparison of mean responses for each device and method were blocked by site and evaluated using a Least Significant Difference (LSD) test. The relationship between odor concentration, intensity, ammonia and total reduced sulfur/hydrogen sulfide at each site was evaluated using Pearson's Correlation Coefficient.

RESULTS & DISCUSSION

A significant difference between the mean dilutions to threshold was found between the four olfactometers tested at five different odorous sites in southern Idaho. A univariate analysis of variance was conducted on the dilutions to threshold (DT) and the log of the dilutions the threshold (log DT) for each olfactometer blocked by the odor sites.

Additionally, a comparison of difference of means illustrated the differences between the performance of each olfactometer across the various odor sources (Table 5). The Least Squared Difference was found to be more conservative test while evaluating the DT compared to the log DT.

The variability of responses of panelists was found to be lowest using the Nasal Ranger and the dynamic, triangular forced choice olfactometer. The comparison of standard deviations of the log of the dilutions to threshold was found to be significantly lower with the laboratory olfactometer compared to all other devices when analyzing odor from the food processor and open-lot dairy. The Nasal Ranger was found to have the least variability from samples from the wastewater pumping station, freestall flush dairy and beef feedlot. The difference between the variability of responses provided by the laboratory olfactometer and the Nasal Ranger is largely due to the range of available dilutions and the incremental difference in dilutions between readings or sub-sample events, thus the use of the log relationship is more appropriate even if it is more liberal in its analysis. No significant difference was found between the panel responses, using the raw scores, using the Nasal Ranger and the facial mask. On all sites the panelist responses using the Scentometer had the greatest variability and lowest precision.

Odor Intensity

Odor intensity was compared using prepared concentrations of n-butanol and two teams of trained panelists. The University of Idaho team assessed the odor intensity in the field and in the laboratory from a 10-L Tedlar bag sample. Additionally, the Odor Assessment Laboratory at West Texas A&M analyzed a simultaneously collected 10-L sample. A univariate analysis of variance determined that there was a significant difference between the mean intensity concentrations across sites. A further, LSD test (Table 3) indicated significant differences between each of the odor intensity methods used.

Table 3. Mean Dilutions to Threshold and Odor Intensity.

	Test	DT				Intensity (mg/l n-butanol)		
	Method[1]	DTFCO	Nasal Ranger	Mask	Scent.	Field	UI Lab	WTAMU Lab
All Sites	mean	234.48	15.88	30.79	76.30	4166.28	1298.81	3861.39
	st. dev.	520.96	17.56	41.97	102.17	4067.40	1964.62	4748.44
	st.dev of log	0.60	0.51	0.55	0.71	--	--	--
Site 1	mean	55.54[bx]	17.87[aw]	20.57[aw]	70.21[cy]	3034.88[b]	1202.38[a]	4986.84[c]
	st. dev.	53.65	18.01	22.24	103.21	2498.56	1780.86	6067.46
	st.dev of log	0.39	0.55[c]	0.44	0.73	--	--	--
Site 2	mean	179.80[cy]	14.49[aw]	21.79[abwx]	38.39[bx]	5104.65[b]	1767.86[a]	4400.00[b]
	st. dev.	288.90	14.57	31.50	61.66	4736.27	3459.43	5903.28
	st.dev of log	0.69	0.49	0.57	0.64	--	--	--
Site 3	mean	656.11[cz]	25.02[aw]	66.47[abx]	157.70[by]	7651.16[c]	1642.86[a]	3619.05[b]
	st. dev.	989.57	23.35	65.77	135.9	5416.61	1614.66	4506.17
	st.dev of log	0.79	0.52	0.60	0.58			
Site 4	mean	181.98[cy]	14.45[aw]	27.70[abw]	75.02[bx]	2742.86[b]	1000.00[a]	3048.61[b]
	st. dev.	183.69	17.62	34.40	82.75	1693.94	627.20	3272.49
	st.dev of log	0.39	0.52	0.53	0.68	--	--	--
Site 5	mean	124.22[cz]	8.63[aw]	19.04[abx]	45.63[by]	2367.65[b]	897.96[a]	3320.65[c]
	st. dev.	274.90	8.28	21.20	66.59	1761.64	914.18	3346.92
	st.dev of log	0.49	0.44	0.48	0.67	--	--	--

[1] DTFCO = Dynamic, Triangular Forced Choice Olfactometry; Nasal Ranger = Nasal Ranger Field Olfactometer; Mask = Facial Mask Field Olfactometer; Scent. = Scentometer.
[a,b,c,d] = statistically similar as compared by Least Significant Difference of raw data at alpha = 0.05 level.
[w,x,y,z] = statistically similar as compared by Least Significant Difference of log transformed data at alpha = 0.05 level.

The samples collected in the field and analyzed after a few (1-5) hours at the University of Idaho Laboratory was found to show lower intensity thresholds as well as smaller standard deviations across all of the sites studied. Intensities assessed in the field, at all sites, were statistically greater than those evaluated in the laboratory. Generally, intensities analyzed in the field and those after longer storage time, due to transport to the WTAMU laboratory, had similar agreement. The field odor intensity evaluation provided a more liberal threshold resulting in higher n-butanol scores compare to the short-term laboratory analysis using the same panelists. Additional studies are needed to investigate the role of detention time within Tedlar bags on odor intensity determined by the same panelist to fully understand this phenomena.

Table 4. Total Reduced Sulfur/Hydrogen Sulfide (TRS/H_2S) and Ammonia (NH3) concentrations from five odorous sources in Idaho.

Site		TRS/H_2S (ppm)	NH3 (ppm)
Site 1- Food Processor	mean	0.07	0.008
	st. dev.	0.10	0.004
Site 2 – Waste Water Pumping Station	mean	0.00	0.039
	st. dev.	0.00	0.031
Site 3 – Freestall Flush Dairy	mean	1.18	0.208
	st. dev.	1.08	0.304
Site 4 – Open Lot Dairy	mean	1.15	0.033
	st. dev.	0.87	0.014
Site 5 – Beef Feedlot	mean	1.46	0.019
	st. dev.	1.06	0.010

Correlations

A Pearson's correlation analysis was conducted between the various olfactometers, odor intensity methods and measurements of ammonia and TRS/H_2S for each of the five odorous sites (Table 5). No strong correlations (>0.750) were found between all of the sites and any two of the parameters tested. Additionally, the relationship between each of the olfactometers varied between each of the odorous sites investigated. No relationship was found between olfactometers at the wastewater pumping station. This may be due to the predominance of hydrogen sulfide at the site (Table 4) resulting in a moderate correlation between odor intensity measured in the field and TRS/H_2S.

Significant relationships were found between the concentration of NH_3 and TRS/H_2S. This relationship is likely due to two reasons. First, NH3 has a documented and inconsistent interference with the Jerome Meter-Model 631 (Arizona Instruments, 2002). Secondly, it is not uncommon for high concentrations of ammonia and hydrogen sulfide to be found together on odorous sites where large amounts of carbonaceous wastes are stored in anaerobic conditions.

On the dairy sites, TRS/H_2S concentrations derived from the Jerome-631 were significantly related to the odor concentration found by the DTFCO and were moderately related to the average concentration found by panelists using the Nasal Ranger. Additionally, the concentration determined by the Nasal Rangers were moderately related to the concentration of ammonia at the dairy and food processing sites.

The relationship between equalivent concentrations of n-butanol determined by the three odor intensity methods was neither strong or consistent between odor sites. Moderate correlations were found between intensity methods at the food processor and the freestall flush dairy but no significant relationship was found between the methods and the other two sites. Moderate to strong relationships were found between the 30-hour intensity samples analyzed by West Texas A&M and TRS/H_2S. Additionally, the odor intensity determined by West Texas A&M was moderately correlated to the ammonia on all sites except the freestall flush facility.

The lack of strong and consistent relationships between the parameters used in the study sheds light on the difficulty of conducting odor assessments. First, the relationships between parameters or odor methods, DTFCO for example, was found to be inconsistent between sites making the implementation or use of one odor determination method difficult to be assessed on a single threshold or used across various odor sources and anticipating consistent performance. Secondly, the nature of each odor source and dominate emitted compound invalidates the use of a single odor detection method for regulatory or self-monitoring purposes. More research is needed to advise regulators, policy makers and facility managers on the least variable and consistent odor detection method for their facility.

Conclusions

A 6-week study of five odorous sources in Idaho was conducted to quantify the variability of field and laboratory olfactometry methods and their correlation to odor intensity, as well as ammonia and hydrogen sulfide concentrations. The comparison of four olfactometers indicated that the use of laboratory dynamic, triangular force-choice olfactometry or Nasal Ranger field olfactometers resulted in the least amount of variability across odor sources. Significant differences with poor correlation was found between odor intensity methods and the use of Tedlar bags for storage of field samples. Lastly, moderate correlations were found between field ammonia and hydrogen sulfide sampling methods and the olfactometry and odor intensity methods used. Lastly, findings of this study should caution regulators, policy makers and investigators about establishing regulatory thresholds or reporting scientific data based on single odor analysis methods or techniques due to the variation in the results found by trained panelists across the five odorous sites investigated.

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Table 6. Pairwise comparison of the relationships between olfactometry and odor intensity methods, ammonia and total reduced sulfur/hydrogen sulfide for 5 sites in Idaho as determined by Pearson's Correlation Coefficient.

Site		DTFCO[2]	NR	Mask	Scent	I	I-UI	I-WT	NH_3	TRS/H_2S
Site 1- Food Processor	DTFCO	1.000	-0.027	0.085	0.309*	0.159	0.069	0.219	0.303	0.321*
	NR	-0.027	1.000	0.563*	0.305*	0.578*	0.339*	0.380*	0.496*	0.479*
	Mask	0.085	0.563*	1.000	0.286	0.412*	0.352*	0.367*	0.511*	0.495*
	Scent	0.309*	0.305*	0.286	1.000	0.186	0.132	0.305	0.041	0.161
	I	0.159	0.578*	0.412*	0.186	1.000	0.506*	0.433*	0.613*	0.692*
	I-UI	0.069	0.339*	0.352*	0.132	0.506*	1.000	0.045	0.418*	0.459*
	I-WT	0.219	0.380*	0.367*	0.305	0.433*	0.045	1.000	0.669*	0.802*
	NH_3	0.303	0.496*	0.511*	0.041	0.613*	0.418*	0.669*	1.000	0.915*
	TRS/H_2S	0.321*	0.479*	0.495*	0.161	0.692*	0.459*	0.802*	0.915*	1.000
Site 2 – Waste Water Pumping Station	DTFCO	1.000	0.219	0.147	0.055	0.136	0.055	0.190		0.231
	NR	0.219	1.000	0.174	0.038	-0.041	0.175	0.288		-0.142
	Mask	0.147	0.174	1.000	0.155	0.158	-0.005	0.212		0.197
	Scent	0.055	0.038	0.155	1.000	0.048	0.048	0.054		-0.096
	I	0.136	-0.041	0.158	0.048	1.000	0.242	-0.033		0.562*
	I-UI	0.055	0.175	-0.005	0.048	0.242	1.000	-0.019		0.145
	I-WT	0.190	0.288	0.212	0.054	-0.033	-0.019	1.000		0.475*
	NH_3	*No ammonia was detected during the 6 visits*								
	TRS/H_2S	0.231	-0.142	0.197	-0.096	0.562*	0.145	0.475*		1.000
Site 3 – Freestall Flush Dairy	DTFCO	1.000	0.518*	0.440*	0.462*	0.515*	0.391*	0.574*	-0.221	0.812*
	NR	0.518*	1.000	0.218	0.335*	0.440*	0.264	0.516*	-0.005	0.597*
	Mask	0.440*	0.218	1.000	0.603*	0.382*	0.506*	0.457*	-0.302*	0.487*
	Scent	0.462*	0.335*	0.603*	1.000	0.324*	0.353*	0.389*	-0.306*	0.540*
	I	0.515*	0.440*	0.382*	0.324*	1.000	0.461*	0.444*	-0.271	0.696*
	I-UI	0.391*	0.264	0.506*	0.353*	0.461*	1.000	0.558*	-0.246	0.466*
	I-WT	0.574*	0.516*	0.457*	0.389*	0.444*	0.558*	1.000	-0.121	0.645*
	NH_3	-0.221	-0.005	-0.302*	-0.306*	-0.271	-0.246	-0.121	1.000	-0.347*
	TRS/H_2S	0.812*	0.597*	0.487*	0.540*	0.696*	0.466*	0.645*	-0.347*	1.000
Site 4 – Open Lot Dairy	DTFCO	1.000	0.499*	-0.121	0.192	0.091	-0.041	0.532*	0.518*	0.613*
	NR	0.499*	1.000	-0.027	-0.226	0.343*	0.265	0.090	0.339*	0.418*
	Mask	-0.121	-0.027	1.000	0.153	0.110	0.076	-0.116	0.021	0.049
	Scent	0.192	-0.226	0.153	1.000	-0.049	-0.174	0.256	0.181	0.088
	I	0.091	0.343*	0.110	-0.049	1.000	0.221	-0.182	0.100	0.316
	I-UI	-0.041	0.265	0.076	-0.174	0.221	1.000	0.379	-0.149	0.014
	I-WT	0.532*	0.090	-0.116	0.256	-0.182	-0.379	1.000	0.506*	0.548*
	NH_3	0.518*	0.339*	0.021	0.181	0.100	-0.149	0.506*	1.000	0.743*
	TRS/H_2S	0.613*	0.418*	0.049	0.088	0.316	0.014	0.548*	0.743*	1.000
Site 5 – Beef Feedlot	DTFCO	1.000	0.274	0.341*	0.444*	0.225	-0.031	-0.090	0.272	0.292
	NR	0.197	1.000	0.249	0.308*	0.080	0.196	0.274	0.152	0.247
	Mask	0.341*	0.249	1.000	0.187	-0.008	0.054	-0.003	0.288*	0.258
	Scent	0.444*	0.308*	0.187	1.000	0.050	0.108	0.071	0.327*	0.298*
	I	0.225	0.080	-0.008	0.050	1.000	0.247	0.423*	0.164	0.282*
	I-UI	-0.031	0.196	0.054	0.108	0.247	1.000	0.272	0.203	0.179
	I-WT	-0.090	0.197	-0.003	0.071	0.423*	0.272	1.000	0.638*	0.763*
	NH_3	0.272	0.152	0.288*	0.327*	0.164	0.203	0.638*	1.000	0.863*
	TRS/H_2S	0.292	0.247	0.258	0.298*	0.282*	0.179	0.763*	0.863*	1.000

[1] * = Correlation is significant at 0.05 level

[2] DTFCO = Dynamic, Triangular Forced Choice Olfactometry; NR = Nasal Ranger Field Olfactometer; Mask = Facial Mask Field Olfactometer; Scent = Scentometer, I – Odor Intensity (field), I-UI = Odor Intensity by University of Idaho Odor Lab, I-WT = Odor Intensity by West Texas A&M Odor Lab, NH_3 = ammonia, and TRS/H^2S = total reduced sulfur/hydrogen sulfide.