PNW 595

# Sampling Agricultural Odors

**By Ron E. Sheffield and Pius Ndegwa**

This bulletin will help livestock producers, technical specialists, regulators, and concerned citizens monitor odors from agricultural sources. Topics include selecting appropriate sampling devices, their costs, and how they work to objectively characterize odors.

## Sense of smell; why response varies

Odor perception is different for every person, almost as diverse as personality. Opinions we have about different odors are imprinted in our minds at a young age, and our odor memories determine how new odors are perceived. Odors have the ability to refresh memories suppressed for many years, which may be why odors are the best-remembered sensory stimuli for most people.

Odors can be good, bad, or neutral depending on memories surrounding them. It can be very difficult to change a person's opinion of a specific odor once it has been labeled. Over time, a small dose of that odor may be all that is required to trigger a response.

Odor receptors in humans are high up in the sinuses and connect to the most primitive parts of the brain. The olfactory organ (nose) is so powerful it can detect minute concentrations of odors undetected by many of today's most advanced gas chromatographers (odor sensing equipment).

People become accustomed to odors depending on exposure, which explains why odors have a different effect on livestock producers than on people who have little exposure to livestock farming.

The human nose has receptors that become saturated with long-term exposure to strong odors. When the receptor site becomes overwhelmed with an odor, it becomes odor fatigued, a condition that prevents the nose from perceiving that odor. It may take one-half hour or more for the receptor site to recover from odor fatigue even when exposure to the odor is discontinued. For this reason, people with long exposure periods to a certain strong odor are not as responsive to that odor.

## Odor descriptions

Odors have measures or identifiers other than good, bad, or neutral. They can be measured by using their concentration, character, intensity, persistence, frequency, and duration (Table 1).

- **Concentration**. There are two ways the threshold—the smallest detectable sensation—of odors can be measured: detection threshold (D/T) and recognition threshold (R/T). Odor concentrations, called odor units (ou), are defined as the volume of diluted air divided by the volume of odorous sample air at either detection or recognition.

  The detection threshold is how much an odor is diluted before it is undetectable by trained panelists. The recognition threshold is how much an odor must be diluted to a point where trained panelists can still recognize the odor.

- **Character.** Also known as odor quality, character is defined with descriptive quality terms. A standard odor descriptor, known as the Odor Wheel or Flavor Wheel, (Figure 1) was published by the International Association on Water Pollution Research and Control (IAWPRC). Similar wheels exist for beer, wine, and perfumes.

- **Intensity.** This is the strength of the odor above the threshold of an approved standard gas. The odor is usually compared to known concentrations of butanol—a flammable alcohol derived from butanes and used for solvents—to give a specific intensity value.

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The threshold can also be determined with an olfactometer—an instrument for measuring the keenness of somebody's sense of smell. It estimates odor units, which represent the number of times the air needs to be diluted before the odor is no longer detectable. Odor intensity decreases with dilution.

- **Duration or persistence.** The intensity of an odor will change with its concentration. The rate of change of intensity with concentration is not the same for all odors. The rate of change is the persistence. The persistence of an odor can be shown by a dose-response function. The dose-response function describes how long it can take to dilute an odor below its detection threshold. The more air it takes to dilute an odor the higher the persistence. Calculate odor duration by dividing the full strength odor intensity by the detection threshold.
- **Frequency.** The time between detected odor events. There is no analytical method to calculate or predict odor frequency.
- **Offensiveness.** This can also be described as hedonic tone. These terms describe smells that can significantly affect people. Mathematical models have been developed to estimate the concentration of specific gases downwind from a source. Odors are rated using a scale: –10 (very unpleasant) to +10 (very pleasant). A neutral odor is given a zero. This method accounts for breakdown of gases and dispersion during a variety of weather conditions. This scale also defines concentration or threshold of odors, or hedonic tone—a perceived level of pleasantness. See Table 1.

## Odor measurement

Odors are a combination of many different gases in extremely low concentrations. The slightest difference in composition can alter the way a person perceives the odor.

### Odor wheel helps define an odor's character (quality)

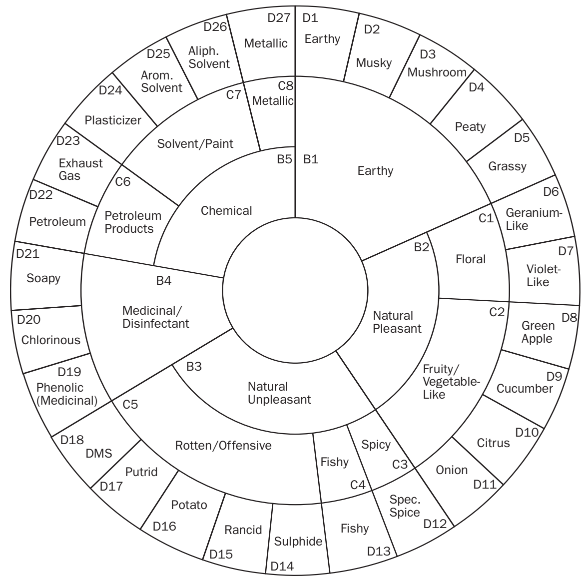


**Figure 1.** Odor or flavor wheel helps human odor panelists define odors they are detecting and a code to represent each odor. Form in Appendix B recommends use of this wheel to describe an odor's character, or quality.

Reprinted from American Water Works Association (AWWA) Research Foundation 1987 publication *Identification and Treatment of Tastes and Odors in Drinking Water.*

To distinguish among different odors, the concentrations of gases must be measured. Determining the exact composition of an odor is very difficult, expensive, and time consuming.

Two common approaches are used to measure odors:

- Gas measurement (equipment) and
- Odor measurement (people)

Both methods have pros and cons. The main difficulty associated with these methods is the poor correlation between odor and the combination and concentration of different

**Table 1.** Analytical methods for quantifying odor include the following:

| Odor Test | Definition | Analytical Methods |
|---|---|---|
| Intensity (strength) | Strength of an odor sample above the detection threshold. | N-butanol |
| Duration / persistence | Measure of how easily the odor can be diluted in air: Full strength intensity divided by threshold concentration. | N-butanol and D/T (dilution-to-threshold) |
| Frequency | Return interval (hours, days) of a detected odor. | No analytical measure. |
| Offensiveness /Hedonic tone | Measure of unpleasantness of an odor. Typically displayed as a scale: -10 (unpleasant) to +10 (pleasant). | Odor panel |
| Character descriptor | Description of an odor. Trained panelists use standardized terms such as sulfide, rancid, putrid, or phenolic. | Odor panel |
| Detection threshold concentration (D/T) | Volume of non-odorous air needed to dilute a unit volume of air to the point where panelists begin to detect an odor. | Olfactometry; field olfactometer; scentometer |
| Recognition threshold concentration (R/T) | Volume of non-odorous air needed to dilute a unit volume of air to the point where panelists begin to recognize an odor. R/T >/= D/T. | Olfactometry |

gases that are present in the air. Suppliers for the equipment discussed in this section can be found in Appendix A.

## Gas measurement methods—equipment

Gas measurement determines the concentrations of individual gases in the air. When taking gas measurements, it is vital to understand that data relayed by the instrument is an average and will constantly vary with time. The person analyzing the data may also influence the readings. Sampling devices must be calibrated and maintained frequently to assure accurate readings. Seven methods of gas measurements are described in order of cost—least expensive to most expensive (Table 2).

**1) Diffusion badges (also called patches)**

Badges or patches are single-use indicators made of cardboard or plastic. When exposed to a specific gas, the chemical indicator will change color. Patches are not very precise as they only show an average value over time, and are best used for source identification and characterization. Badges cost about $1.00 each.

**2) Indicator and diffusion tubes—one per gas type**

Glass tubes are packed with a chemical medium and sealed on both ends. To take a reading, seals are removed from both ends. A handheld air pump is attached to one end. The pump will pull air into the tube and allow it to react with chemicals in the tube. A color change determines the presence and relative concentration of a particular gas. This type of sample is known as a grab sample.

Diffusion tubes are also used to take gas samples. The diffusion tube takes an average sample of gases in the air. To take a sample, one end of the tube must be opened to allow air to enter. Then the tube is hung or positioned in a place where it can be monitored. Six to eight hours later, the amount of color change in the tube is noted. Indicator and diffusion tubes allow only one gas to be sampled at a time, but are available for a many gases. Both of these methods are moderately inexpensive, between $0.50 and $1.50 per sample.

**3) Handheld monitors for sulphur**

The Jerome Meter Model 631-x is a portable handheld electronic instrument used to measure concentrations of reduced sulfur compounds such as hydrogen sulfide ($H_2S$) in the air. To make a measurement, this meter samples the air for several seconds. During this time, it measures sulfur concentrations by the electric resistance of a gold-leaf metal strip, which is exposed to outside air.

This device is fairly expensive and requires calibration. Jerome meters cost about $12,000, and require an annual calibration (an additional $1,000), but allow for monitoring between 0.003 – 50.000 ppm with a resolution of 0.001 ppm. Data logging cards installed in Jerome meters allow continuous monitoring.

**4) Fenceline monitors—a month at a time**

Several reasonably low-cost devices have recently been introduced to monitor reduced sulfur compounds, i.e. $H_2S$, for up to a month at a time. Battery powered, these devices have onboard data loggers and may be programmed for a variety of sampling periods.

- The Jerome 860 is a portable long-term reduced-sulfur analyzer with an effective range of 0.0 – 200 ppm, and a resolution of 0.2 ppm, (~$1,800).
- OdaLog provides two models: high range (Figure 6), and low range (Figure 7) data loggers. The high range OdaLog (~$1300) has a range of 0 to 200 ppm and a resolution of 0.1 ppm, while the low range OdaLog (~$3000) operates between 0 to 2 ppm, with a resolution of 0.01 ppm. The low range OdaLog also has a single test mode that can evaluate individual odor sources.
- The Jerome 651; ~$13,000) is the most precise fence line monitoring system for reduced sulfur compounds, with a range of 0.003 – 50.000 ppm and a resolution of 0.001 ppm.

Calibration studies conducted by the University of Idaho show that results from these devices are very precise, but results under-predict known concentrations of standard gasses. Fence-line monitors are best for odor source identification and monitoring of relative reductions in sulfur emissions, but they should not be used for research or regulatory reporting.

**5) MDA single-point monitor—best for trends**

The MDA (Methylenedianiline) monitor is a commercial device used to identify concentrations of individual compounds in the air for an extended period of time. This meter runs a tape that chemically reacts with the air causing a color change. Tapes typically last for 2,900 samples, or one month when sampling on 15-minute intervals. Different tapes can be purchased for varying concentrations and gas compounds.

- Zellweger SPMs (Single Point Monitor—see Figure 9) cost more than $15,000 for the unit, and tapes cost $75 to $100 each. Recent studies in Idaho show MDAs to be relatively precise, but they lack the accuracy needed for research or regulatory purposes, and should only be used to track general trends or evaluate relative differences between treatments or operations. The accuracy of the measurement refers to how close the measured value is to the true or accepted value. Precision refers to how close together a group of measurements actually are to each other.

**6) Electronic sensors—for manholes, storage ponds**

Electronic sensors vary greatly in precision and in methods used to take samples. This type of device is often used to measure single gas concentrations over a relatively small sample area. Sensors are useful for monitoring known odor sources as close to the emission as possible, such as manholes, mixing chambers, or edges of storage ponds. Sensors

**Table 2.** Seven gas-measuring methods range in cost from 50-cents per sample to $130,000 for equipment used in research labs. This table summarizes how each type works.


**1. Diffusion badge**
*Uses:* Best used for source identification
*Cost:*$1 per sample

**2. Indicator and diffusion tubes**
*Uses:* Glass tubes are packed with chemical medium and sealed on both ends. When used, tube takes an average sample of gases in the air and changes color. Only one gas can be sampled at a time. tubes exist for many gases.
*Cost:* $.50 to $1.50 per sample

**3. Handheld monitors for sulphur**
*Uses:* This portable handheld Jerome 631 instrument measures concentrations of reduced sulphur compounds such as hydrogen sulfide in the air. Requires calibration.  Data logging cards allow continuous monitoring.
*Cost:* $12,000


**4. Fenceline monitors**
*Uses:* Jerome 860 is a portable long-term reduced-sulphur analyzer with an effective range of 0.0 to 200 ppm and a resolution of 0.2 ppm.
*Cost:* Up to $1,800.


**Odalog gas data logger**
*Uses:* High range OdaLog gas data logger has a range of 0 to 200 ppm and 0.1 ppm resolution
*Cost:* Cost: Up to $1,300

**Odalog low-range gas data logger**

*Uses:* Low range OdaLog gas data logger operates between 0 to 2 ppm with a 0.01 ppm resolution. Single test mode can evaluate individual odor sources
*Cost:* Up to $3,000

**Jerome 860**
*Uses:* Jerome 651 Fenceline hydrogen sulfide monitoring system, the most precise for reduced sulphur compounds, has a range of 0.003 to 50.000 ppm and a 0.001 ppm resolution
*Cost:* Up to $13,000


**5. MDA single-point monitor—best for trends**
*Uses:* Zellweger SPM identifies concentrations of individual compounds in the air for up to a month. Lacks accuracy for regulatory purposes.
*Cost:* At least $15,000 plus up to $100 per tape

**6. Electronic sensors—for manhole covers, storage ponds**
*Uses:* Vary greatly in precision and methods used to take samples. Useful for monitoring known odor sources close to emission.
*Cost:* $1,000 to $2,000

**7. Gas chromatograph/mass spectrometer**
*Uses:* Best for laboratory research. Can measure gas concentrations in extremely small samples. Portable models now available
*Cost:* $60,000 to $130,000

may be equipped with data loggers for long term monitoring or with alarms to set to activate if concentrations get too high. Electronic sensors cost between $1,000 and $2,000 depending on the chemicals and features desired.

**7) Gas chromatograph/mass spectrometer, for research**
The gas chromatograph/mass spectrometer (GC/MS) is most often used in laboratory research. This instrument can measure gas concentrations in extremely small samples. The sample is injected into a gas stream passing through a GC/MS column. The column absorbs and desorbs chemicals in the air at different rates to separate them, and the gas then passes through a detector that identifies the amount of chemicals in the sample. This is the most expensive instrument in use today, with costs from $60,000 to $130,000. Portable models are now available.

## Odor measurement and techniques—for use by people

Measuring and evaluating odors is very difficult, but researchers have found a number of reliable methods. Here are six common methods human evaluators use to measure odor.

**1) Electronic nose**
A wide variety of these devices are commercially available to test for non-agricultural odors. Devices measure odors by selecting and measuring specific chemical compounds. Electronic noses are currently used in several industrial quality control applications for the processing of perfumes, fish, silicone chips, and food products, where only a handful of odorous compounds are likely to be present. Because of the complexity related to the gases and odorous compounds related to livestock manure, no electronic nose has been developed for testing in agricultural settings.

**2) Scentometer—States use this type for regulatory monitoring ($550)**
The scentometer is a hand-held portable device (Figure 2) that measures odor levels in the air, or the number of dilutions-to-thresholds (D/T). It is a rectangular, clear plastic box with two nasal ports, two chambers of activated carbon with air inlets, and several different-sized odorous air inlets.

Air is drawn in through the activated carbon and into the panelist's nose. The ratio of ambient air to filtered air at which the individual detects an odor is the dilutions-to-threshold.

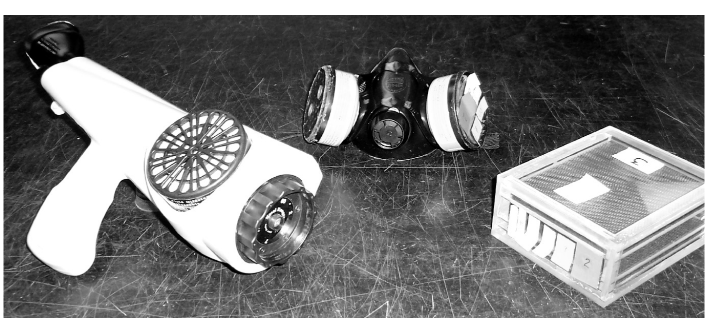

**Figure 2.** From left to right are a Nasal Ranger, facial mask field olfactometer, and scentometer odor quantification device.

*Disadvantages.* Panelists using the scentometers have noted some disadvantages; they often mention leaking and poor sealing of the glass nasal inserts. Also, the device does not control or monitor the flow or amount of air inhaled by each panelist when a sample is taken. However, even with these limitations, several states use the scentometer as regulatory tool for monitoring excessive industrial and agricultural odors.

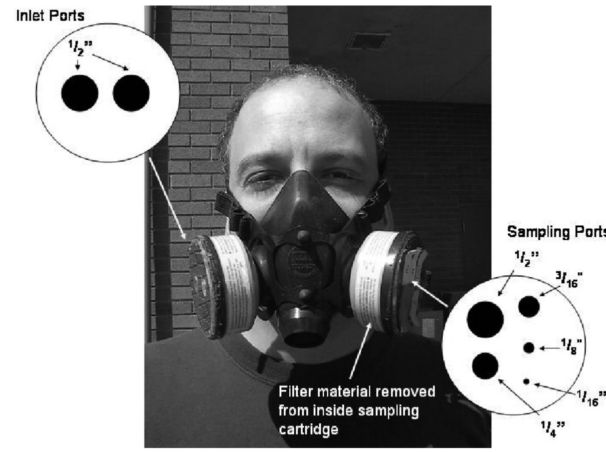


**Figure 3.** Constructing a facial mask field olfactometer requires respirators and cartridges that can be found at most paint or fertilizer supply companies.

**3) Facial mask field olfactometer—homemade, measures air dilutions**
Facial mask field olfactometers are functionally similar to scentometers, but rely on a half-face charcoal-filtered respirator to prolong odor fatigue. These homemade, low-cost ($100) devices, which are modifications of conventional partial face respirators, use the same whole diameters and D/T as the scentometers.

To make a facial mask field olfactometer (Figure 3), cut two plastic discs the size of the opening of the desired respirator cartridge. For the inlet disc, cut two 1/2" inlet holes in the center of the disc and epoxy the disc around the edges of the cartridge. Next, without damaging the opening surface of a cartridge, remove the filter material. Then drill 1/2", 1/4", 3/16", 1/8", and 1/16" holes in the second plastic disc (see Table 3) and epoxy it to the hollow cartridge. Label and place non-odorous laboratory or masking tape over the holes. This will allow measurement of 2, 7, 15, 31, and 170 dilutions of air, respectively (Table 3).

**Table 3.** Table lists size of sampling ports and dilutions to-threshold for the facial mask olfactometer in figure 3.

| Hole Size | Dilution to Threshold |
|---|---|
| 1/2" | 2 |
| 1/4" | 7 |
| 3/16" | 15 |
| 1/8" | 31 |
| 1/16" | 170 |

**4) Nasal Ranger combines portability, low cost**
The Nasal Ranger (Figure 2) is a new field olfactometer developed by St. Croix Sensory, Inc. of St. Paul Minnesota. The Nasal Ranger is designed to combine the portability and relatively low-cost ($1,500) of a scentometer with the sampling control of the more expensive laboratory olfactometer.

This device uses readily available charcoal filters to clean the ambient air. Flow control is maintained by a static pressure sensor and LEDs (light-emitting diodes), which provide feedback to the persons sniffing to indicate whether they should increase or decrease their sniffing. The static pressure target range is equivalent to 14 to 18 liters per minute (LPM) sniffing rate, enabling the unit to be attached to a pump and directly calibrate dilution ratios.

The sniffing mask on the Nasal Ranger is equipped with an inlet and outlet with check valves, allowing the assessor to keep the unit over the nose during an entire test.

**5) Dynamic, triangular forced-choice olfactometer—for teams of panelists**
Olfactometers are sophisticated meters that dilute and deliver field collected air samples to panelists in a laboratory (Figure 4). Typically, teams of eight panelists sniff three ports or samples of air and attempt to determine the one that contains the sample odor.

The odor sample starts out very diluted and continues to get stronger with the next set. If panelists are not able to identify the odor, they move to the next set of three until the odor is detected or recognized.

Olfactometers cost about $50,000 for the unit and associated software. Established labs typically charge $200 to $1,000 per sample.

**6) Field sniffers or odor detectors at the source**
This method of evaluating odors at the source or at the point of a complaint uses trained panelists (Figure 5). Field sniffers need to "calibrate" their noses in order to be consistent as an individual and in a group situation. Panelists travel to the site and evaluate the odor on a numerical scale. Sniffers should wear charcoal masks or respirators, and only remove them to sniff the air when taking a reading. This is done to prevent odor fatigue and desensitization.Table 4

## Recommendations for air sampling for agricultural odors
Sampling for odors, like sampling for water and feed quality, is a balance between accuracy, precision, cost, the time required to take samples, and the intended use for the data. Examples: on-farm odor source identification, research, or litigation.

The variability of odor perception and the emission from a source compounds the difficulty of collecting samples representative of the odor emitted. Odor sampling methods vary depending on the type or objective of the sampling being conducted.


**Figure 4.** St. Croix Sensory Ac'Scent Olfactometer is portable and costs about $50,000. Labs charge up to $1,000 per sample.

**Figure 5.** Field sniffers evaluate agricultural odors in southern Idaho using Nasal Rangers.

## Odor characterization and source identification
When an odorous site is identified, a characterization of the odor must be conducted. Samples must be taken both upwind and downwind to identify sources and to identify the most probable odorous compounds. Useful tools vary with the goal.

- **Source identification.** Use badges/patches placed around the perimeter of the source to identify upwind sources and most probable odor plume path.
- **Gas quantification.** Use diffusion tubes, handheld sensors, or fenceline monitors to take samples around the perimeter of the source to help identify upwind sources and most probable odor plume path.
- **Odor quantification (concentration, character, intensity).** Samples are best taken by trained odor panelists upwind and within the most probable odor plume path.

**Table 4.** Six odor-measurement methods currently in use and requiring human participants cost from $100 to $50,000.

| Odor measurement method | Currently available | Cost (approximate) |
|---|---|---|
| Electronic nose | No | NA |
| Scentometer | Yes | $550 |
| Facial mask field olfactometer (Figure 11) | Yes | $100 |
| Nasal Ranger (Figure 10) | Yes | $1,500 |
| Dynamic, triangular forced-choice olfactometer (Figure 12) | Yes | $50,000 for unit, software. Labs charge $200 - $1,000 per sample |
| Field sniffers or odor detectors (Panel of humans participating) | Yes | Costs are by the hour and number of people wearing charcoal masks) |

## Facility monitoring: establish a schedule

Once the most probable odor path is found and the likely odor sources on the farm are identified, a regular monitoring schedule should be established. When possible, measure odors to correspond with times when most complaints occur and at various points on and off the farm (source, property line, and receiver site/house). See an example field data sheet on page 8.
Recommended tools include:

- **Weather stations.** Weather data is critical when responding to odor complaints or to distinguish from other odor sources. Wind speed, wind direction, and temperature should be collected using a continuous recording weather station.
- **Handheld weather sensors** can help odor panelists assess a variety of weather conditions depending on the model used. Costs—$80 to $200—vary with number of functions.
- **Gas quantification.** Gas data is collected only to support and fill in the gaps of odor data. For hydrogen sulfide and other reduced-sulfur compounds, use one of these within the most probable plume path: OdaLog, an OdaLog - Low Range, Jerome 860, Jerome 651, Jerome 631 with continuous monitoring, or MDA.

  Ammonia is best sampled with a low range (0 to 5 ppm) diffusion tube. Place fenceline monitors in areas where the greatest numbers of complaints occur.
- **Odor quantification.** Use a field olfactometer and a regular systematic protocol to sample for odor concentration and intensity compared to n-butanol. Identify sampling sites upwind, downwind, and near odor sources.

## Summary

Odors constitute a great liability to livestock producers. Odors are the number one complaint of neighbors near confined animal operations. Understanding how these odors occur and what technologies are most appropriate for a particular farm is crucial for reducing odor complaints.

Following the guidelines presented in this bulletin will allow producers, neighbors, and technical specialists to speak quantitatively about the of potential odor emissions from animal operations.

Regular monitoring of odors and common odorous gasses allows producers to gauge the severity of odor complaints and to track the success or shortcomings of mitigation efforts.



## APPENDIX A: Monitoring Equipment Suppliers

| | |
|---|---|
| **Diffusion badges** | |
| **Diffusion tubes** | RAE Diffusion Tubes & Pumps<br>RAE E-Commerce<br>ecommerce.raesystems.com |
| | Drager Diffusion Tubes & Pumps<br>SKC West<br>www.skcinc.com |
| **Jerome sensors** | Arizona Instrument<br>www.azic.com<br>800-528-7411 |
| **OdaLog** | Detection Instruments Corporation<br>www.detectioninstruments.com<br>602-797-0630 |
| **MDA** | Detection & Measurement Systems, Inc<br>www.detect-measure.com<br>713-541-9800 |
| **Scentometer** | Barnebey & Sutcliffe Corporation<br>www.calgoncarbon.com<br>810-482-1153 |
| **Nasal Ranger** | St. Croix Sensory<br>www.nasalranger.com<br>800-879-9231 |
| **Weather sensors** | AccuWeather's AccuMall<br>www.accumall.com<br>814-235-8541 |
| | Ben Meadows Company<br>www.benmeadows.com<br>800-241-6401 |
| | Forestry Suppliers, Inc<br>www.forestry-suppliers.com<br>800-430-5566 |

## APPENDIX B: Sample Odor Data Sheet

Date: ____________ Odor Panelist: ______________________(Name or ID Number) Time: _________ am / pm

Sampling Location: ______________________________________________

Distance from Odor Source: ______________________________________________

Comments: ______________________________________________

______________________________________________

______________________________________________

**Weather**
Wind speed:______ Direction: ___________ Temp: _______ ° Humidity: _________ Conditions: ______________

**Ammonia readings**
Tube type: _______ Detection range: ________

Range ________No. of pumps _________Concentration ____________

**Jerome meter readings**

_________ _________ _________ _________

_________ _________ _________ _________

**Odor concentrations:** Dilutions to Threshold (circle one)
Nasal Ranger: 60 30 15 7 4 2 <2

**Odor characterization**
Odor intensity (n-Butanol): (circle one)
0 1 2 3 4 5 6 >6
Odor character
Primary description (from Odor Wheel) ______________________

Secondary description (your own words) ______________________

Odor "threshold": Similar to a pain threshold – on a scale of 1 to 10, 10 being the worst smell you have ever experienced or could imagine, this is a ________.

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