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MEASURING COMPOSTING ODORS FOR DECISION MAKING

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The measurement of composting odors is often required for complaint response, permit compliance, site expansion planning, and verifying mitigation practices. Facility managers, engineers, and regulatory agencies often use odor measurements for decision making. With a functional knowledge of odor measurement methods, compost managers can integrate odor measurements into the facility's environmental management system.

Odor can be measured using standardized methods that are objective, quantifiable, dependable, and reproducible. Unfortunately, odors have measurable parameters that are not generally understood. The basic odor parameters are odor strength (concentration) and odor character (standard descriptors). Odor strength and character can be measured/quantified in an odor laboratory from a "whole air" bag sample that is collected at the odor source. Standard practices published by ASTM International (ASTM E679-04) and by the European Union (European Normalization Standard, EN 13725:2003), when followed by an odor laboratory, produce odor test results that have an "accuracy" equivalent to +/- 1.5 dBA using a sound measurement analogy.

Odors can also be measured in the ambient air on the composting site, at the fence line, and in the surrounding community. Odor observers using standard odor descriptors and using a field olfactometer (Scentometer device) can measure ambient odors within the context of a structured monitoring program or an odor control test.

This paper will present the basics of odor measurement in the laboratory and out in the real world. Several relevant case studies will be presented with example procedures and example data forms that have been used for documenting successful odor mitigation.

Introduction

Odors from composting facilities and related operations can affect surrounding communities. Estimating the effects of these odors requires quantifying the odors using laboratory and field odor testing. The quantification of odors is typically required for the following purposes:

1. Compliance monitoring for compliance assurance.
2. Determination of compliance for permit renewal.
3. Determination of baseline status for expansion planning.
4. Determination of specific odor sources during complaint investigation.

5. Monitoring operations for management performance evaluation.
6. Comparison of operating practices when evaluating alternatives.
7. Monitoring specific events or episodes for defensible, credible evidence.
8. Comparison of odor mitigation measures during tests and trials.
9. Determination of an odor control system's performance for warranty testing.
10. Verification of estimated odor impacts from dispersion modeling.

Odor is a serious issue in the management of a composting facility and, more so, odor is often the issue in public acceptance of composting facilities. The composting industry recognizes a wide variability in the odor from different composting operations. In the search for the key operational parameters that influence composting odor, the need to select and trust odor measurement methods is critical.

Research on composting operation odors includes identifying the origin, mechanisms, and parameters for odor production, quantifying odor generation, defining "low odor" processes, and measuring odor in the ambient air surrounding a facility. All of these research objectives need common, standard, and trustworthy "odor testing" methods (standard practices). Equally important to defining and accepting standard methods, is the need to understand the odor testing results for decision making within a facility's environmental management system.

Measuring Odors

Laboratory Olfactometry

Odors from a composting facility can affect the surrounding community and lead to nuisance complaints. Estimating the effects of compost odors often requires laboratory odor testing. In order to accomplish this testing, compost samples or air samples are collected and shipped overnight to an odor-testing laboratory. Engineers and managers can use the odor test results to help in their decision-making.

The most common odor parameter determined during odor testing is "odor concentration" (odor strength). This determination is made using an instrument called an "olfactometer." The standards followed for olfactometry are: ASTM Standard of Practice E679-04, "Determination of Odor and Taste Threshold by a Forced-Choice Ascending Concentration Series Method of Limits" and EN 13725:2003, "Air Quality – Determination of Odour Concentration by Dynamic Olfactometry" (EN refers to a European Normalization Standard). EN13725 supports and exceeds the standard practices of ASTM E679-04 and has become the de facto International Standard for odor/odour testing (ASTM 2004; CEN 2003).

During an odor test, the odor panelist (assessor) sniffs a dilute sample of the odor as it is discharged from the olfactometer as one of three sample presentations (one presentation with the dilute odor and two with odor free air), see Figure 1. The assessor sniffs all three of the presentations and must select the one of the three that is different from the other two, even if they must guess. This statistical approach is called "triangular forced-choice." The assessor continues to additional levels of higher concentration (lower dilution) presentations following this procedure (McGinley 2000).

Figure 1. AC'SCENT Olfactometer (St. Croix Sensory) showing assessor sniffing on the left side while a laboratory technician is monitoring the test on the right.

Therefore, "odor concentration" or odor strength is a number derived from the laboratory dilution of collected odors. The dilution ratio (total presentation volume divided by odor sample volume) at each sample presentation level is used to calculate the concentration of the evaluated sample.

The individual thresholds of eight to ten assessor responses are averaged to determine the detection threshold for which 50% of individuals will observe the presence of an odor. The "detection threshold" value that is obtained from odor testing is derived from the dilution ratios, and is therefore dimensionless. However, the pseudo-dimensions of "Odor Units" (O.U.) or "Odor Units per Unit Volume" are commonly applied. For example: "Odor Units per cubic meter."

It should be noted that the dilution of the actual odor emission sample by the olfactometer is the physical process that occurs in the atmosphere down wind of the odor source. The "receptor" (citizen in the community) receives and sniffs the diluted odor. The dilution ratio is an estimate of the number of dilutions needed to make the actual odor emission "non-detectable" (Detection Threshold). If the receptor detects the odor, then the odor in the atmosphere is above the receptor's detection threshold level.

Because "odor concentrations" from different source types cannot be "added" nor can they be "averaged," odor modeling must be conducted with caution. The input to the model is the odor emission rate in O.U./sec calculated from the result of laboratory olfactometry testing and the source volumetric emissions rate. The resulting "odor concentration" value of "1", calculated by a dispersion model, represents the odor detection threshold that was determined using the "best estimate criteria." A value of less than 1 represents "no odor" or "sub-threshold." A value of greater than 1 represents "odor" at a "supra-threshold" level.

Field Olfactometry

In 1958, 1959, and 1960 the U.S. Public Health Service sponsored the development of an instrument and procedure for field olfactometry (ambient odor strength measurement) through Project Grants A-58-541; A-59-541; and A-60-541 (Huey, et. al. 1960). The first field olfactometer, called a Scentometer, was manufactured by the Barnebey-Cheney Company and subsequently manufactured by the Barnebey Sutcliffe Corporation.

A field olfactometer creates a series of dilutions by mixing the odorous ambient air with odor-free (carbon-filtered) air. The U.S. Public Health Service method defined the dilution factor as Dilution to Threshold, D/T. Like the laboratory olfactometry threshold value, the

Dilution-to-Threshold ratio is a measure of the number of dilutions needed to make the odorous ambient air non-detectable.

The method of producing Dilution to Threshold (D/T) ratios with a field olfactometer consists of mixing two volumes of carbon-filtered air (two carbon filters) with specific volumes of odorous ambient air.

The method of calculating Dilution to Threshold (D/T) for a field olfactometer is:

$$\text{Dilution Factor} = \frac{\text{Volume of Carbon Filtered Air}}{\text{Volume of Odorous Air}} = \mathbf{D/T}$$

Two commercially available field olfactometers include the original Scentometer (Figure 2A) and the Nasal Ranger® (Figure 2B), introduced in 2002 (McGinley, M.A. 2003; McGinley, C.M. 2003).

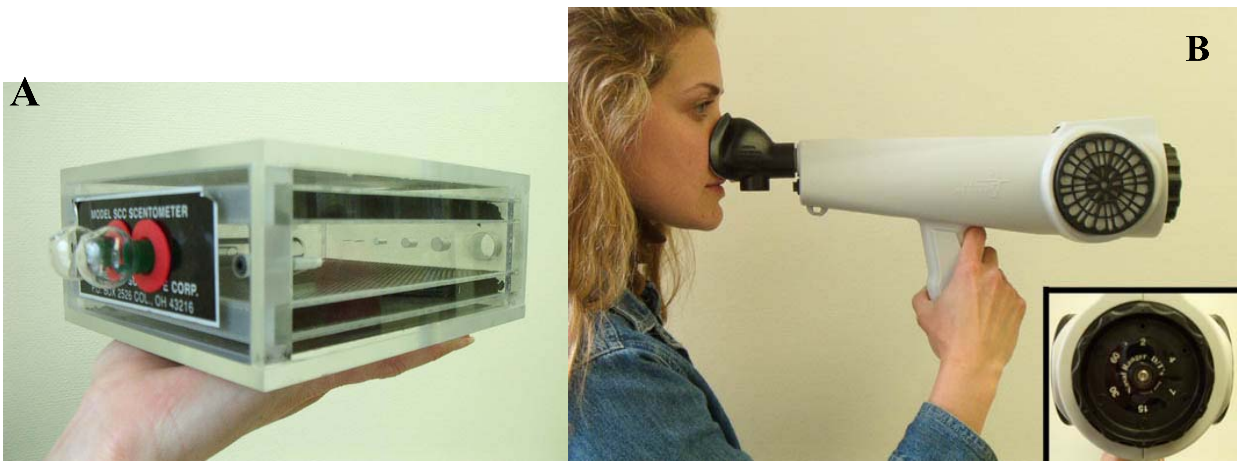


Figure 2. (A) The Scentometer Field Olfactometer (Barneby Sutcliffe Corp.). Note the two glass nostril ports to the left and the series of orifices at the back of the unit to the right of the photo. (B) The Nasal Ranger Field Olfactometer (St. Croix Sensory). The inset picture shows the orifice dial, which is located at the right side of the Nasal Ranger in this photo.

The field olfactometer instrument, the “Dilution to Threshold” (D/T) terminology, and the method of calculating the “D/T” are referenced in a number of existing agencies’ odor regulations and permits. Therefore, a field olfactometer instrument, in the hands of trained odor observers, is a realistic and proven method for measuring the strength of ambient odors. Common “Dilution-to-Threshold” (D/T) ratios used to set ambient odor guidelines are: D/T’s of 2, 4, and 7 (CPDEH 1999; CT-DEP 2002; MO-DNR 2003; WY-DEQ 2002). Field olfactometers typically have additional D/T’s (dilution ratios) such as 15, 30, 60 and higher dilution ratios.

Field olfactometry with a calibrated field olfactometer is a cost effective means to measure odor strength. Facility operators, community inspectors, and neighborhood citizens can confidently measure odor strength at specific locations around a facility’s property line and within the community when using a calibrated field olfactometer.

Odor Intensity

Perceived odor intensity is the relative strength of the odor above the recognition threshold (suprathreshold). ASTM E544-99, "Standard Practice for Referencing Suprathreshold Odor Intensity," presents a method for referencing the intensity of ambient odors (ASTM 1999). The assessor in the laboratory or the observer of ambient air compares the observed intensity of an odor sample to a specific concentration level of the standard odorant, n-butanol.

The odor intensity result is expressed in parts per million (PPM) of butanol (n-butanol). A larger value of butanol means a stronger odor, however, not in a simple numerical proportion. The butanol concentrations provide a referencing scale for documentation and communication in a reproducible format (McGinley 2000). Common butanol intensity referencing scales include:

- 12-point static scale starting at 10-ppm butanol with a geometric progression of two,
- 10-point static scale starting at 12-ppm with a geometric progression of two,
- 8-point dynamic scale starting at 12-ppm with a geometric progression of two, and
- 5-point static scale starting at 25-ppm with a geometric progression of three.

Odor Persistency

Odor Persistency is a term used to describe the rate at which an odor's perceived intensity decreases as the odor is diluted (i.e. in the atmosphere downwind from the odor source). Odor intensities decrease with concentration at different rates for different odors. Odor intensity is related to the odorant concentrations by the "power law," Steven's Law (Stevens 1960, 1962):

$$I = k\,C^n$$

The persistency of an odor can be represented as a "Dose-Response" function, which is determined in the laboratory from intensity measurements of an odor at various dilutions and at full strength. Plotted as a straight line on a log-log scale, the result is a linear equation specific for each odor sample (Dravnieks 1980, 1986).

Odor Hedonic Tone

Hedonic Tone is a measure of the pleasantness or unpleasantness of an odor. [Hedonic Tone is derived from the word "hedonistic", the Greek word *hedone* meaning pleasure.] The hedonic tone is independent of the odor's character. An arbitrary scale for ranking odors by hedonic tone is the 21-point scale:

-10 -------------------- 0 ---------------- +10
Unpleasant Neutral Pleasant

An assessor uses her/his personal experience and memories of odors as a hedonic tone referencing scale. During training, assessors become aware of their individual odor experience and memory referencing. The reported hedonic tone value from an odor testing laboratory is an average of individual hedonic tone values assigned by the assessors.

Odor Characterization

Odors can be objectively described using standard categories and standard reference vocabulary. A standard practice for odor description is to provide observers with a standard list of descriptor terms, which are organized with like terms in categories or groups (Harper, 1968).

In the 1970's and 1980's the beer and wine industries separately developed odor & flavor wheels as a tiered system for characterizing product samples (Meilgaard, et. al. 1982; Noble 1984). St. Croix Sensory has developed an odor descriptor wheel for use with environmental odor samples (St. Croix Sensory, 2003). Dr. Suffet's team at the UCLA School of Public Health has developed odor wheels for drinking water, wastewater industry odors, and for composting odors (Suffet 2003).

Odor monitoring of a facility, whether through odor samples evaluated by a laboratory or with field observers, should include a standard published odor wheel, a custom odor descriptor wheel, or a list of odor descriptors in general categories. It is essential for the odor observers to know the list or wheel content and have an understanding of each descriptor in the list. Exemplars of the descriptors may be provided as references.

Ambient Odor Monitoring

Standard odor monitoring practices include four elements: 1) monitoring protocol, 2) area map, 3) monitoring route, and 4) data collection and reporting. The odor monitoring program incorporates these elements into a working plan that is clearly understood and used by the observers and can be easily explained to the general public.

The monitoring protocol is a written document that describes the purpose of the odor monitoring program (e.g. proactive to improve community quality of life), the scope of the odor monitoring (e.g. eighteen months), resources required (e.g. dollars and personnel hours), references (e.g. previous enforcement actions), geographic area (e.g. parts of the community involved), detailed procedures (e.g. when and how frequent to conduct odor monitoring), and outcomes (e.g. how the data will be summarized and the results used).

The area map of the community will need to clearly show the geographic extent of the odor monitoring and the key community features (i.e. buildings, parks, streets, rivers, ravines, etc.). Figure 3 is an example community map illustrating the basic community features, which include commercial area, residential area, factory, wastewater treatment plant, and park.

The odor monitoring route is the path that the odor observers follow as they carryout their odor observation activities. The odor monitoring route needs to include a list of each odor monitoring location, details of each location (including GPS coordinates, if possible), and a location code number. The area map will have the location code numbers identified.

An odor monitoring program will have standard data collection forms constructed in a format that is convenient to use by the observer and easy to read by others.

Figure 4 is an example "County Environmental Dept." Odor Report for 1/4/03, which presents a completed odor monitoring form using the map in Figure 3. This form has three parts. Part One is the list of observation locations with columns for the strength measurement (D/T in this example), odor descriptors, and additional observational comments. Part Two is the weather conditions information that includes sky conditions, precipitation, wind direction, wind speed, temperature, relative humidity, and barometric pressure. Part Three includes additional space for observational comments and the observer's name, signature and code number, if used by the odor monitoring program.

The completed example data form uses the location code number with a brief optional description of each location. The example data form illustrates how the odor observer has recorded the odor strength (D/T concentration from a field olfactometer), the odor descriptors as code numbers (eases data entry), the probable odor sources, and the weather conditions.

Case Studies

Case Study I – Odor Assessment of a Co-Composting Facility

The first case study involves monitoring odors surrounding the Edmonton Waste Management Centre in the City of Edmonton, Alberta, Canada. The Edmonton Waste Management Centre includes a landfill, landfill gas treatment, leachate treatment plant, sludge storage lagoons, solid waste-biosolids co-composting facility and solid waste recycling facility. In addition the Centre is surrounded by a variety of industries including three chemical plants, two asphalt plants, three feed mills, a rendering plant, a mushroom farm, a chicken farm, and a sewage treatment plant.

In 1997 the City of Edmonton developed a program to objectively monitor odors in the surrounding community. The odor monitoring program consisted of training City odor inspectors, recruiting citizen odor observers, developing a standard odor survey route, preparing standard odor survey forms, and analyzing/reporting the odor monitoring data.

The odor monitoring program focused on 25 potential odor sources and established 21 odor monitoring locations as part of the routine odor survey route. A standard map was selected for locating the potential odor sources and each of the monitoring locations. All data was collected on a standard "Inspector Log Form". The City odor inspectors conducted odor observations at least once per day during the years 1997 to 1998 and again during the years 2000 to 2003.

Significant conclusions of the Edmonton odor monitoring program include (Bowker, 2004):

- Sources with the highest frequency of odor detection were the biosolids lagoons, composting facility, large chemical plant, feed mills, and the mushroom farm.
- Sources with the highest average odor strength were the biosolids lagoons, asphalt plant, and mushroom farm.
- Some sources caused high strength odors that only impacted a local area, while other sources caused low strength odors that impacted a large area of the community.
- There was limited correlation between weather conditions and frequency or strength of odor.
- The odor monitoring program provided a comprehensive inventory of odor sources and the odor descriptors of each source.

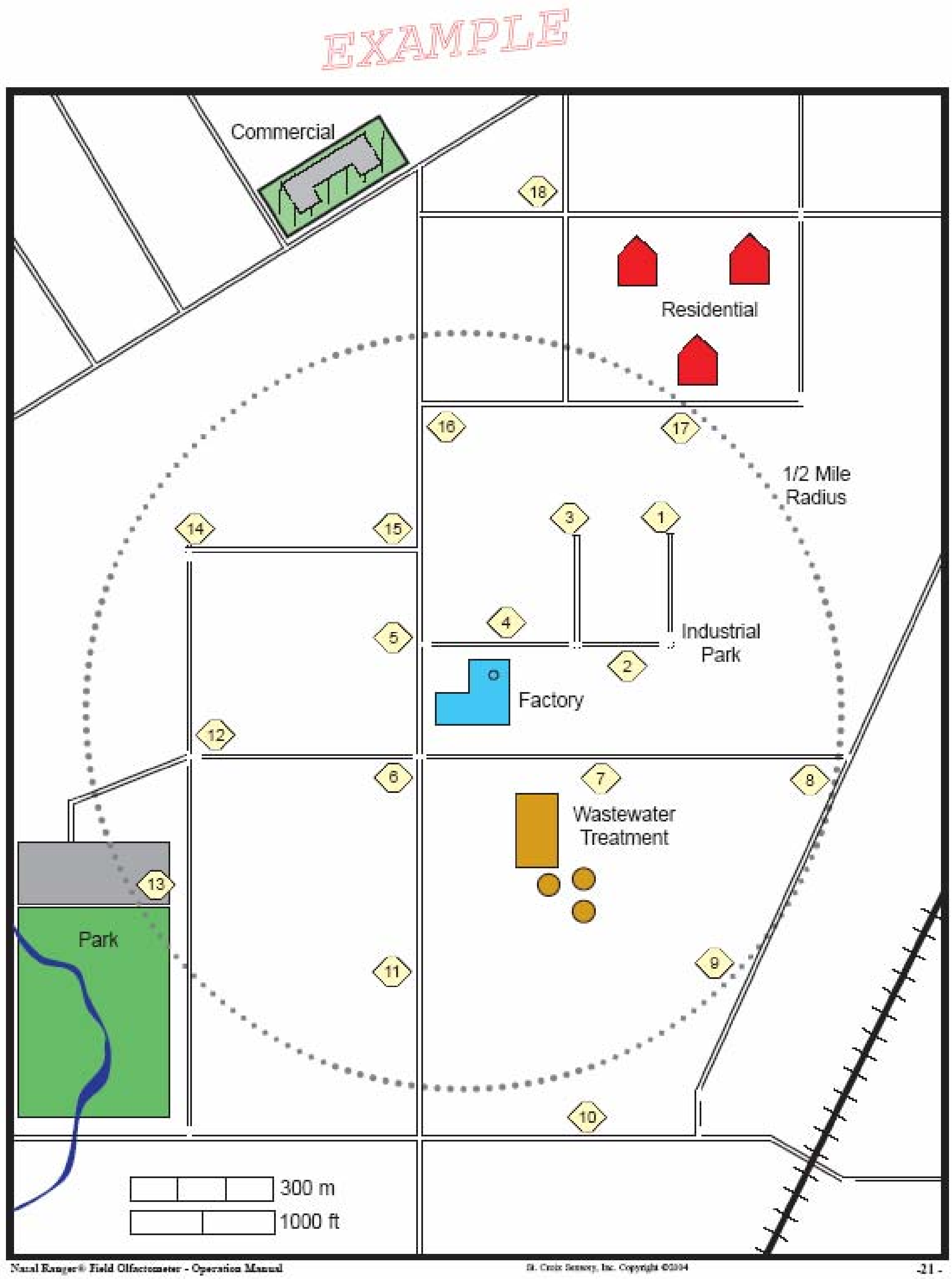


Figure 3. Example community map showing numbered odor observation locations.

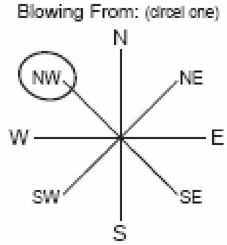
EXAMPLE

NASAL RANGER	COUNTY ENVIRONMENTAL DEPT.								Date: 1/4/05	
Time	Location	D/T 60	30	15	7	4	2	<2	Descriptors	Comments
7:05 AM	1 - INDUSTRIAL PARK							X		
7:10 AM	2 - " "						X		718	FACTORY 'A'
7:15 AM	3 - " "							X		
7:20 AM	4 - " "				X				718, 723	FACTORY 'A'
7:25 AM	5 - INTERSECTION					X			705	FACTORY 'A'
7:30 AM	6 - INTERSECTION							X		
7:35 AM	7 - CO. RD. 20		X						718, 723, 515	'A' + WWTP
7:40 AM	8 - INTERSECTION			X					718, 723	FACTORY 'A'
7:45 AM	9 - JUNCTION RD.				X				718, 723, 515	'A' + WWTP
7:50 AM	10 - CO. RD. 28			X					718, 515, 601	'A' + WWTP
7:55 AM	11 - DIVISION AVE.					X			718, 601	'A' + WWTP
8:00 AM	12 - INTERSECTION							X		
8:05 AM	13 - PARKING LOT					X			104, 304	VEGETATION
8:10 AM	14 - INTERSECTION						X		707	HIGHWAY
8:15 AM	15 - INTERSECTION							X		
8:20 AM	16 - INTERSECTION							X		
8:25 AM	17 - HOUSING DEVEL.						X		201	APPLE TREES
8:30 AM	18 - 3RD + OAK					X			706, 404	COFFEE SHOP

Weather Conditions

	Precipitation:	Wind Speed:
[ ] Sunny	[ ] None	[ ] Calm
[ ] Partly Cloudy	[X] Fog	[X] Light Breeze (1-5 mph)
[ ] Mostly Cloudy	[ ] Rain	[ ] Moderate Wind (5-15 mph)
[X] Overcast	[ ] Sleet	[ ] Strong Winds (15 or higher mph)
[ ] Hazy	[ ] Snow	

Wind Direction
Blowing From: (circle one)



Temperature: 55 °F/°C Relative Humidity: 60 % Barometric Pressure: 30.1

Comments: ______________________________

Code: 008 Name: NIGEL MACKENZIE Signature: Nigel MacKenzie

Figure 4. Example odor monitoring data collection form.

The City of Edmonton found that the odor monitoring program provided an in depth assessment of the new co-composting facility and prompted efforts to abate odors from the most significant sources. The City plans to continue the odor monitoring program for the foreseeable future, with greater focus on conducting surveys in response to complaints and conducting surveys during peak complaint periods.

Case Study II – Land Application of Biosolids

The second case study involves monitoring odors around biosolids land application sites. In the summer of 2003, the Western Lake Superior Sanitation District (WLSSD - Duluth, MN) conducted a study to document odor strength, extent, and duration at eighteen biosolids land applications sites (Hamel, et.al., 2004).

Odor measurements were recorded at all WLSSD agricultural land application sites receiving biosolids from 16 May to 16 July 2003. The odor strength was measured at the sites as Dilution-to-Threshold (D/T) values using a field olfactometer. The odors were also characterized by descriptors using a standard odor character list.

Odor observations were made during a wide variety of weather conditions and varying times of day and early evening. Samples were collected at least one day a week. The odor observations were made at predefined locations at each site. One observation was made at the property boundary, the nearest road, and the nearest residence. Additional observations were made when more than one residence was located close to the site. When a biosolids stockpile was present, observations were always made along the plume line at 2 feet upwind of the stockpile and 2-ft, 20-ft, 40-ft, 60-ft downwind and at the property line downwind.

The odor monitors were trained in field olfactometer operation and other essential elements of odor observations. The monitors were also qualified based on their scores with an odor sensitivity testing kit as described previously and shown in Figure 2.

Kathleen Hamel presented a paper at the Water Environment Federation (WEF) Biosolids Conference in February 2004, which detailed the results of this project. The conclusions of this project were:

- Field stored biosolids produce a strong odor over a small area downwind of stockpiles, usually within 20 feet of the stockpile;
- Odors will diminish each day that the stockpile is undisturbed;
- Spreading the biosolids releases strong odors;
- Wetted biosolids (from rain) can produce a much stronger odor during spreading;
- After spreading, weak to moderate odors can last from 1-day to 1-week;
- Odors are reduced considerably if the biosolids are incorporated into the field immediately;
- Odors can reach 7 D/T at nearby residences, however, only a small percentage of the time (5%);
- Odors can reach 15 D/T at the property boundary.

While the results presented are intuitive, the data has produced quantified values that now serve as a baseline for future testing and can be used in odor related discussions with the community. The results supported the need for WLSSD to develop an odor response plan to address individual concerns, monitor odor levels, address changes in odor levels, and develop field practices that minimize odors.

Conclusions

Of the five senses, odor is the most evocative and least understood. In millennium past, the "practice of odor" was in the hands of wizards, magicians, and experts. Today, odor, odor control, and odor nuisance can be understandable subjects for facility operators, facility managers, engineering practitioners, and citizens.

Odor is measurable and quantifiable using standard practices as published by the ASTM International (ASTM E679 and E544) and by the European Union. The European Normalization Standard, EN 13725, has become the de facto "International Standard" for odor/odour testing.

Managers and engineer of compost facilities can use odor-testing results for decision-making. The measurement of odors is often a requirement for complaint response, compliance monitoring, planning, site expansion and review of operational practices. This testing dictates a need for dependable and reproducible methods and practices, which is achieved through standardized laboratory testing and field monitoring procedures.

With the knowledge of fundamental odor testing and related statistical concepts, field practitioners, design engineers, facility operators and managers, and anyone else interested in odors can analyze, interpret, and present odor testing data in correct and useful ways.

Research on composting odors includes identifying the origin, mechanisms, and parameters for odor production, quantifying odor generation, defining "low odor" processes, and measuring odor in the ambient air surrounding facilities. All of these objectives depend on standard and trustworthy "odor testing" methods (standard practices). Equally important to defining and accepting standard methods, is the need to understand the odor testing results for decision making within the Environmental Management System.

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