Developing a Credible Odor Monitoring Program

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Abstract. *Odors are the cause for most air pollution complaints reported by citizens living near livestock facilities. In communities across the country odor issues are addressed in a variety of ways. Often odor regulations and ordinances place a limit on the strength of ambient odor. The strength of odor in the ambient air is measurable using either a 1-butanol intensity referencing scale or a "Scentometer" (field olfactometer) device. These standard methods and procedures can be utilized by facility personnel to conduct proactive odor monitoring.*

A credible odor monitoring program must begin with proper training of odor observers (inspectors or investigators). This training must prepare the observer to make observations in accordance with standard procedures and to record pertinent information in a standard, clear format. The trained odor observers must also be provided with an understanding of how to prepare and present the monitoring reports to supervisors, facility managers, officials, and the general public.

This paper will discuss the following topics: 1) elements of an odor monitoring plan, 2) odor observer training, 3) odor observer sensitivity testing, and 4) standard methods and practices for objectively quantifying ambient odors. This paper will present case studies of odor monitoring programs in the U.S. and Canada. Results of these case studies will be discussed along with a discussion of the benefits of the program in each specific case.

Keywords. Odor, odour, monitoring, olfactometry, Scentometer, training, CAFO's, environmental

Introduction

Odors are the cause for most air pollution complaints reported by citizens living near odorous facilities, such as wastewater treatment plants, landfills, composting operations, food & byproduct processes, factories, and agricultural activities, e.g. livestock facilities. A conceptual model for what makes an odor episode become a citizen complaint is the "Citizen Complaint Pyramid," shown in Figure 1. Four parameters make up the hierarchy in this pyramid: 1) character/offensiveness, 2) strength, 3) duration, and 4) frequency.

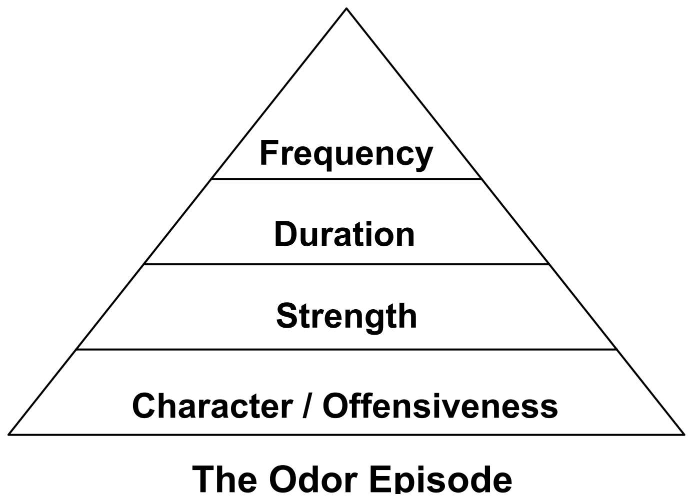

Figure 1. The Citizen Complain Pyramid

The **character** of the odor is the actual description of what the odor smells like. This parameter is sometimes called the "quality" or "offensiveness" of the odor. **Strength** of the odor refers to the overall intensity or concentration of the odor. The stronger the odor, the more likely a citizen is to be annoyed. Even pleasant odors, such as perfumes, can be annoying at high odor strength. **Duration** is the elapsed time of each odor episode. Longer duration odor episodes can lead to more drastic changes in plans around a citizen's home or community. Episodes of very short duration may be over before a citizen changes plans. Finally, **frequency** refers to how often the citizen experiences odor episodes. The more frequent the intrusion into the citizen's life, the more annoying each experience becomes.

The cumulative effect of these four parameters: **character, strength, duration, frequency** creates the nuisance experience and the likely citizen complaint. This conceptual model helps define odor episodes and assists in the development of a credible odor monitoring program.

Odor Monitoring Program Components

A credible odor monitoring program requires four main components:

1) qualified odor observers (trained inspectors/investigators),

2) objective observational methods (how to describe and measure odors),

3) standard monitoring practices (routine survey/inspection routes), and

4) standard data collection and reporting forms.

Qualified Odor Observers

Any odor monitoring program must first start with available personnel becoming odor observers. These personnel must receive training related to odors and odor observation. The essential elements of the training curriculum provides the students with a basic understanding and working knowledge of nasal anatomy, odor chemistry, odor parameters, odor observation techniques, meteorology, standard field procedures and documentation formats (McGinley, et al, 1995). The training prepares the odor observer to be consistent in observations and to be aware of and adjust to variable field conditions.

An odor observer's olfactory sensitivity is a factor in making observations of odor strength in the ambient air. A standardized nasal chemosensory test method determines the olfactory threshold of an individual and allows comparison of the individual's olfactory sensitivity to normative values.

In the routine clinical evaluation of patients with olfactory disorders, one commercially available psychophysical testing method is known as Sniffin' Sticks, shown in Figure 2. Sniffin' Sticks, manufactured by Burghart of Germany, are non-dispensing felt tip marker pens. One nasal chemosensory testing mode can determine a person's odor threshold based on the standard odorant 1-butanol.

Figure 2. The St. Croix Sensory Odor Pen Testing Kit, manufactured by Burghart. Included in the kit are a blindfold, latex gloves, and the set of 14 odor pens (red) and two blank pens.

It is assumed that olfactory sensitivity varies as a result of random fluctuations in factors such as alertness, attention, fatigue, health status, and the possibility of variable presentation techniques of the testing stimulus source. Even though the determination of an individual's olfactory threshold is a one-time testing task, the precision of the result is based on the number of times the individual takes a test. Therefore, it is recommended that each odor observer be tested once to "learn the testing procedure", then tested three times within one month to establish a base line for the observer, and to continue testing monthly to establish a cumulative (monitoring program) average for the observer. Note that an individual's general condition of health, e.g. common cold and seasonal allergies, needs to be considered in the timing and applicability of the testing.

The results of a published multi-clinic investigation of 1,000 subjects (Kobal, et. al., 2000) and a published study of state agency personnel (Lay, et. al., 2004) provide normative values for the general population and can be used to develop performance criteria for field odor observers. In general, the Sniffin' Sticks "odor pen" Number 8 represents the 50%tile of the general population and odor pens Number 3 and 13 represent the lower 5%tile and upper 5%tile of the general population, respectively.

Objective Observational Methods

Trained odor observers need to describe and measure ambient odors using standard terminology and measurement practices. When the odor observers are proficient in quantifying (describing and measuring) ambient odors the odor monitoring program will be successful and credible.

Odor Descriptors

Odors can be objectively described using standard categories and a 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 American and British brewing and sensory scientists developed a "Beer Flavor Wheel" as a tiered system for describing the flavor (taste and odor) of beers (Meilgaard, et. al., 1982). In the 1980's, the California wine industry developed a wine aroma wheel for the characterization of wines (Noble, 1984). A descriptor wheel is constructed with general categorical descriptors at the center of the wheel and more specific descriptors placed towards the wheel rim.

St. Croix Sensory had developed an odor descriptor wheel for use with environmental odor samples (St. Croix Sensory, 2003). In 2003, Dr. I.H. (Mel) Suffet presented a paper outlining an odor wheel for the wastewater industry (Suffet, 2003). Dr. Suffet's team at the UCLA School of Public Health is also developing odor wheels for composting facilities and general urban odors.

Depending on the community and the type of odorous activities present, an odor monitoring program needs to use a standard odor wheel, a custom odor descriptor wheel, or custom list of odor descriptors in general categories. The descriptor list will be a "consensus list" developed by the odor observer personnel and "facility personnel". It is essential for the observers to know the descriptor list or wheel and have an understanding of each descriptor in the list. Exemplars of the descriptors, real life items or examples, may be provided for reference. For example, the descriptor **rubber,** in the general category **chemical**, could have a piece of rubber from the local hardware store as an exemplar for the term.

Odor Measurements Using Intensity

Odor strength can be measured and quantified directly in the ambient air by trained observers using one of two standard methods. The first method utilizes an odor intensity referencing scale (OIRS) using the standard odorant, 1-butanol. The second method utilizes a field olfactometer, which dynamically dilutes the ambient air with carbon-filtered air in distinct ratios known as Dilution-to-Threshold dilution factors (D/T's).

Odor intensity referencing compares the odor in the ambient air to the odor intensity referencing scale (OIRS), a series of concentrations of 1-butanol as described in ASTM international E544-99 (ASTM, 1999). The odor observer sniffs the odorous ambient air and compares it to the OIRS. The person making the observation should use a carbon-filtering mask to refresh the olfactory nerves between observations. Without the use of a carbon-filter mask, the observer's olfactory sense may become adapted to the surrounding ambient air or become fatigued from any odor in the surrounding air. The adaptation of an observer's olfactory sense is a common phenomenon when attempting to evaluate ambient odors.

The ability to calibrate one's sense of smell is a learned technique, not unlike the calibration of the sense of hearing in music or the sense of sight in air emission opacity reading. Observers can learn the ASTM E544 OIRS procedure with training and field practice.

The OIRS serves as a standard practice to objectively quantify the odor intensity of the ambient air. To allow comparison of results from different data sources and to maintain a reproducible method, the one reports either the equivalent 1-butanol concentration or the scale number on the OIRS with the scale range and starting point (McGinley, 2000). Field odor observers, using a standard odor intensity referencing scale (OIRS), can provide measured, dependable, and repeatable observations of ambient odor intensity.

Odor Measurements Using Concentration (D/T)

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. 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 3A) and the Nasal Ranger® (Figure 3B), introduced in 2002 (McGinley, M.A., 2003; McGinley, C.M., 2003).

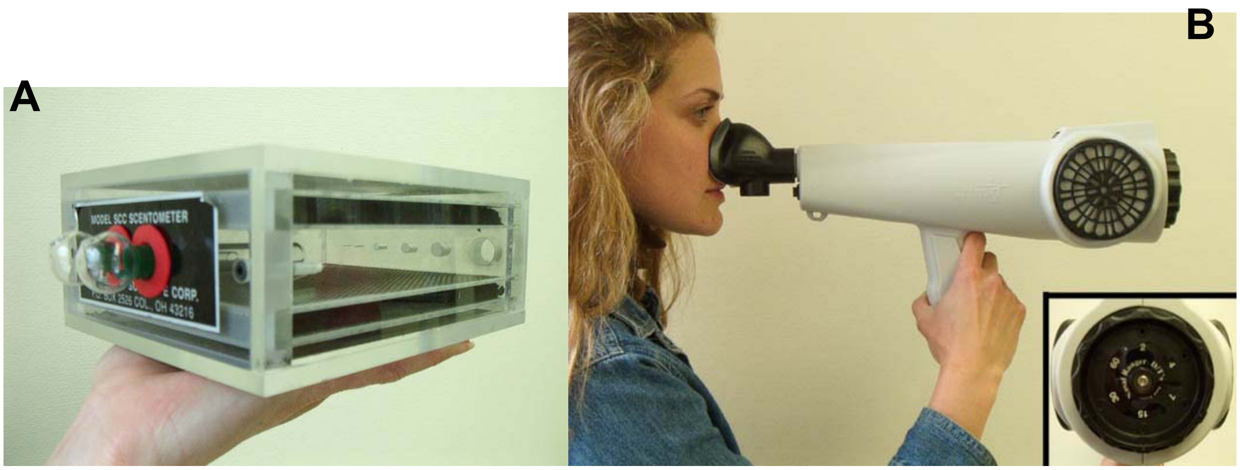

Figure 3. (A) The Scentometer Field Olfactometer (Barneby Sutcliffe Corp.). Note the two glass nostril ports to the left and the series of orifices at the back of the unit to the right of the photo. (B) The Nasal Ranger Field Olfactometer (St. Croix Sensory). The inset picture shows the orifice dial, 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. 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.

Standard Monitoring Practices

Standard odor monitoring practices include four elements: 1) monitoring protocol, 2) area map, 3) monitoring route, and 4) data form. 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 4 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.

Data Collection and Reporting

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 5 is an example “County Environmental Dept.” Odor Report for 1/4/03, which presents a completed odor monitoring form using the map in Figure 4. 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.

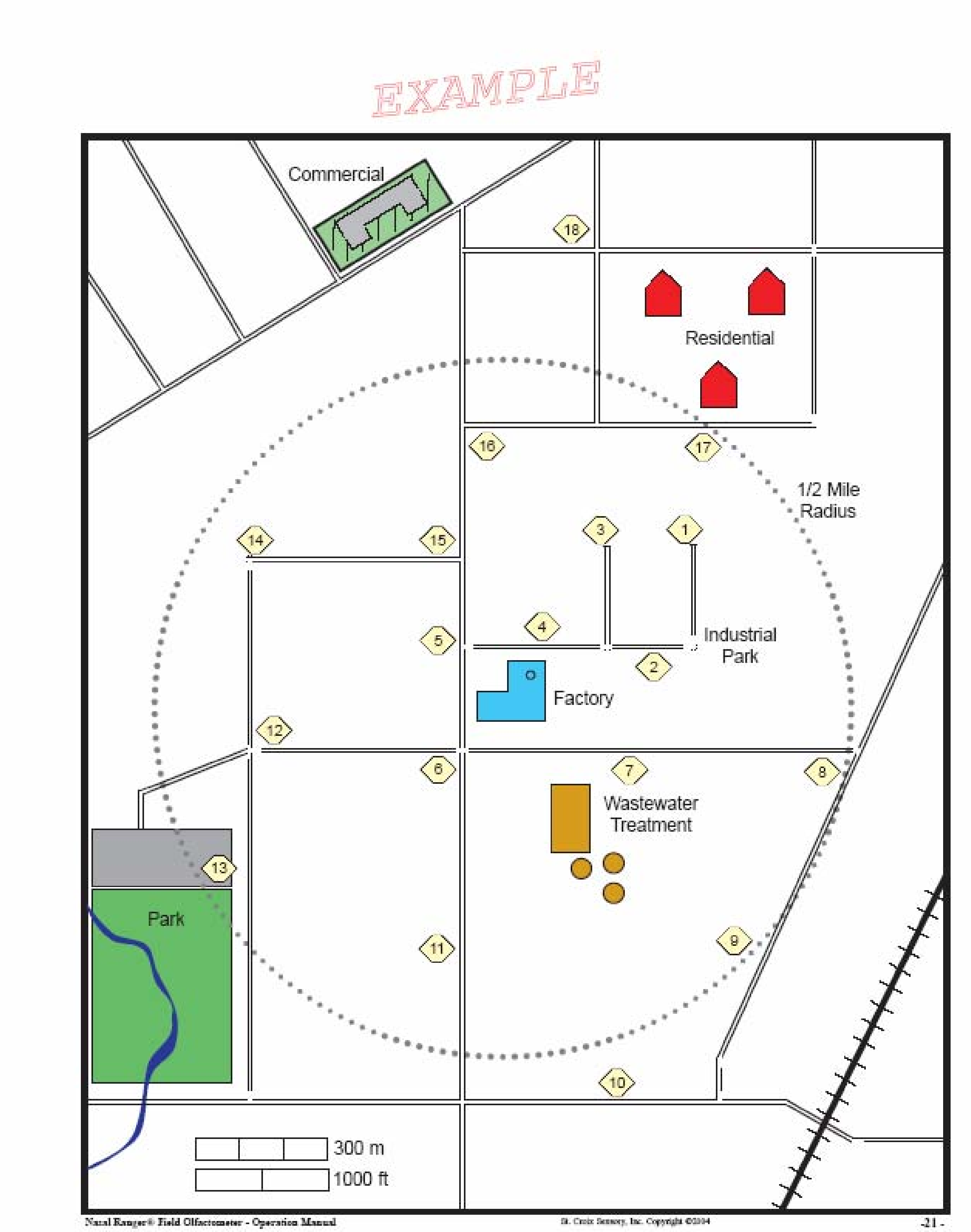

Figure 4. Example community map showing numbered odor observation locations.

EXAMPLE

NASAL RANGER	COUNTY ENVIRONMENTAL DEPT.								Date: 1/4/03	
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		710	FACTORY 'A'
7:15 AM	3 - " "							X		
7:20 AM	4 - " "				X				710, 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						710, 723, 515	'A' + WWTP
7:40 AM	8 - INTERSECTION			X					710, 723	FACTORY 'A'
7:45 AM	9 - JUNCTION RD.				X				710, 723, 515	'A' + WWTP
7:50 AM	10 - CO. RD. 28			X					710, 515, 601	'A' + WWTP
7:55 AM	11 - DIVISION AVE.					X			710, 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 Direction Blowing From: (circle one)	Wind Speed:
☐ Sunny	☐ None	N	☐ Calm
☐ Partly Cloudy	☒ Fog	(NW) NE	☒ Light Breeze (1-5 mph)
☐ Mostly Cloudy	☐ Rain	W E	☐ Moderate Wind (5-15 mph)
☒ Overcast	☐ Sleet	SW SE	☐ Strong Winds (15 or higher mph)
☐ Hazy	☐ Snow	S	

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

Comments: ______

Code: 008 Name: NIGEL MACKENZIE Signature: Nigel MacKenzie

Nasal Ranger® Field Olfactometer - Operation Manual St. Croix Sensory, Inc. Copyright ©2004 - 20 -

Figure 5. Example odor monitoring data collection form.

Case Studies

Case Study I – Community Odor Impact Assessment

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.

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.

Conclusion

Odors are one of the top causes for air pollution complaints from citizens. Facilities must address odors through complaint response and proactive monitoring. A credible odor monitoring program needs four main components: 1) qualified odor observers, 2) objective observational methods, 3) standard monitoring practices, and 4) standard data collection and reporting forms.

Any odor monitoring program must start with training and screening of potential odor observers from a pool of available personnel. An odor training course provides the observers with the essential knowledge and understanding of olfactory anatomy, odor chemistry, odor measurement and odor observation techniques. An odor test kit can be used to define the olfactory sensitivity of the observers and can provide a criteria for qualification of the observers.

Trained odor observers need to describe and measure odors using objective observational methods. These include standard odor descriptor wheels or descriptor lists for standard terminology, and standard measurement of odor strength utilizing either an odor intensity scale (ASTM E544) or a field olfactometer (Diltuion-to-Threshold, D/T).

Standard monitoring practices include four elements: 1) monitoring protocol, 2) area map, 3) monitoring route, and 4) data form. 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.

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

With a credible odor monitoring program in place, a facility will be addressing odor concerns of the community while collecting valuable information that will assist in implementing odor control alternatives and evaluating/monitoring the effectiveness of these controls.

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