Odor Quantification Methods & Practices at MSW Landfills

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ABSTRACT

The measurement of odors from municipal solid waste (MSW) landfills is usually a requirement for compliance monitoring, planning, site expansion and review of operational practices. Additional purposes for quantification of MSW landfill odors include trials and testing of topical and area dispersed odor counteractant sprays and other alternative practices.

Sources of odorous emissions are a challenge to control by MSW landfill management. When odors impact the surrounding community, regulators attempt to enforce compliance. Emission sources, that include hauling trucks, specific odorous materials (i.e. sludge), landfill gas, cell cover breaches and other on-site activities, are difficult to identify and to compare on a relative basis. Presenting the greatest challenge for odor control is the open working face of the MSW landfill.

Portable and laboratory gas monitoring sometimes lead to identifying an odorous source because of the chemical differences between the emissions. However, because of the many potential odorous sources and their chemical similarities or complexities, odor measurement is the direct way to compare and quantify the various source contributions. After all, it is the odors that impact the community. Specific odorous emissions can be collected from surfaces and from the ambient air. These samples, shipped to an odor laboratory, can be evaluated for odor concentration and odor quality (i.e. descriptors). However, many of the odors occurring at MSW landfills can not be collected for laboratory odor evaluation.

Field observation by operators, inspectors and citizens provide a cost effective means to quantify odors from MSW landfills. Using simple word intensity scales or butanol intensity scales with standard odor descriptor nomenclature, direct field observation is a dependable practice for quantification of odors from MSW landfills.

This paper presents specific methods and practices for quantification of odors from MSW landfills by regulators, operators and the community for purposes of monitoring, planning and testing.

INTRODUCTION

Communities and regulators readily know that municipal solid waste (MSW) landfill operations yield odorous emissions. MSW landfills can emit odors in varying degrees from many potential sources that may include[1]:

1) Arriving and queuing hauling trucks
2) On-site vehicles and heavy equipment
3) Biodegraded household waste
4) Sewage sludge
5) Working face
6) Fugitive odorous dust
7) Temporary cover
8) Capped cells
9) Access road construction
10) Leachate collection systems
11) Leachate treatment systems
12) Monitoring wells
13) Gas well construction
14) Gas wells and collection piping
15) Gas treatment systems
16) Gas flares
17) Associated landfill activities, ie. yard waste and composting.
18) Adjacent unrelated landfill activities and businesses

Each of these potential odorous sources varies in the following ways:

⇒ emission type (surface or point source)

⇒ emission rate ("odor units" per second)

⇒ odor strength (concentration and intensity)

⇒ odor persistence (dose-response relationship)

⇒ odor character (descriptors and Hedonic Tone)

⇒ frequency of occurrence (random or repeating)

⇒ duration of emission (episode or activity related)

⇒ circumstances (temporary condition, emergency release, construction, etc.).

Quantification of odors from MSW landfills is typically prescribed for the following purposes:

1. Compliance monitoring (compliance assurance)
2. Determination of compliance (permit renewal)
3. Determination of status (base line data for expansion planning)
4. Determination of specific odor sources (investigation of complaints)
5. Verification of complaints (notice of violation)
6. Monitoring daily operations (management performance evaluation)
7. Comparison of operating practices (evaluating alternatives)
8. Monitoring specific events or episodes (defensible credible evidence)
9. Determination of an odor counteractant's efficacy (scientific testing)
10. Determination of an odor counteractant's cost effectiveness (cost minimization)
11. Comparison of odor counteractants and other methods (cost accountability)
12. Verification of odor dispersion modeling (model calibration)

Each of these purposes dictates a need for dependable and reproducible methods and practices for odor quantification. The trend in the United States and internationally is toward a recognition that odor is a legitimate air pollutant and odor can be controlled. Therefore, regulators and operators of MSW landfills are faced with practical needs for odor quantification, whether the purpose is solely for complaint investigation (i.e. public relations) or for permit renewal (i.e. facility survival).

The **methods** of odor quantification address the purpose of the work (i.e. site specific criteria). The **practices** of odor quantification address the scientific procedures (i.e. ASTM Standard Practices). For example, a MSW landfill may need to conduct routine odor monitoring because of a permit condition. The purpose of the odor quantification demands a method that will satisfy the permit conditions. The *method* that would be selected might be a schedule of routine odor observations at specific locations around the property line and within the community. In this example, the odor quantification *practice* that would be selected might be the use of ASTM E544 (1988), Standard Practice for Referencing Suprathreshold Odor Intensity.

Site specific conditions often place significant limitations on the ability of regulators and MSW landfill operators to implement a program of odor quantification. Local terrain and local meteorology are common constrains that challenge method development and sometimes limit the choices of odor quantification practices.

METHODOLOGIES

Ten methods are commonly used by MSW landfills and regulators responsible for permitting. The term **"protocol"** is often applied to the method that is selected for a specific program or requirement. The following methods or protocols are presented in brief exemplary form as a guide.

(1) **Point Source Sampling** - The operations on a MSW landfill site may include leachate treatment, gas cleaning, enclosed transfer operations or other buildings or processes that have a specific point emission source. The point source may be a stack, roof exhaust or building side vent. The sampling of the potentially odorous point sources involves the collection of the air from the point source in a Tedlar gas sample bag using a vacuum chamber, sometimes called a sampling lung[2]. The bag is placed in the vacuum chamber with a Teflon tubing line placed in the exhaust stream. A pump is used to create a vacuum in the chamber, which causes the odorous air sample to flow into the bag. The bag is first partially filled, then emptied and finally filled with the sample. This method, called "conditioning the bag", is believed to minimize the loss of odor on the bag's inside surface. The odorous air sample is express shipped to an odor laboratory for evaluation of the odor parameters, ie. odor concentration and descriptors.

(2) **Surface Sampling** - A MSW landfill contains a number of surfaces that have the potential to emit odorous gases, i.e. daily cover, temporary cover or capped cells. The collection of odors from surfaces requires the use of a device called a flux hood[3]. A simple flux hood is a bowl inverted on to the surface that is to be sampled. Odor free air is supplied to the flux hood during sampling from the flux hood. Several methods of surface sampling have been used by investigators. One alternative method utilizes a portable wind tunnel[4]. Any of these methods are available for use at a MSW landfill and the choice will be dictated by the site specific conditions and the data requirement needs.

(3) **On-Site Monitoring** - Operators have the unique ability to monitor odors throughout the day. Operator monitoring can include odor observations of arriving materials (i.e. sludge), the working face, the leachate collection system and the gas wells. Monitoring on-site can also involve odor observations from selected predetermined locations. Sample locations might be at and around the working face, on closed cells and adjacent to leachate systems.

(4) **Complaint Response** - The use of "Odor Complaint Hot Lines" is a common method used by MSW landfills and communities. A "Hot Line" phone system provides citizens with direct access to register a "complaint" and other relevant information. A complaint response plan, with designated "on call" inspectors, produces opportunities for observing odor episodes and for tracking odors to the contributing sources.

(5) **Random Monitoring** - A frequently used method for odor monitoring is the "random inspection" approach. This method is also called the "unannounced inspection". The random monitoring method leads to a compilation of data that can be correlated with meteorological information and on-site activities. Regulators often find that random monitoring is the only cost effective method available for compliance determination.

(6) **Scheduled Monitoring** - Well planned scheduled monitoring can be limited to a daily drive around the MSW landfill site or a daily visit to several predetermined monitoring locations. The data from scheduled monitoring can be used to correlate the many parameters which potentially influence odor episodes. Meteorological conditions and on-site operating activities need to be recorded during the monitoring. The use of a versatile data base will facilitate the analysis of the data.

(7) **Citizen Monitoring** - The implementation of citizen monitoring can be part of an interactive community outreach program for a MSW landfill. The primary function of citizen monitoring is to obtain information, through accurate record keeping, that represents real conditions in the residential community. The citizens recruited would be trained to measure odors using an intensity scale and to assign standard odor descriptors. The citizen monitors can assist in determining prevalent times which odors occurs and prevalent weather conditions of odor episodes. Citizen monitors also help in understanding the odor intensity level at which an odor is considered a nuisance (i.e. first becomes a nuisance).

(8) **Citizen Jury** - Occasionally a citizen "jury" is impaneled to evaluate odors associated with a MSW landfill. A typical citizen jury would be gathered to observe odors at specific locations and asked to respond to the following question with a YES or NO: "In your opinion, do the odors witnessed at this location on this day and at this time have the intensity and character which would interfere with the normal conduct of business or cause material, physical discomfort to a person ?"

(9) **Intensive Odor Survey** - An in-depth evaluation of on-site odor generation and off-site odor impact might be needed for a MSW landfill in preparation for a permit review or facility expansion. Extensive data collection of odors, related meteorological conditions and site operations will identify which sources and operations cause odors and which ones that do not cause odors. All potential odor sources can be ranked and their relative odor contributions determined. Short term trials of odor counteractants also may require an intensive period of data collection using odor monitoring practices.

(10) **Plume Profiling** - Odor dispersion monitoring can be supplemented with odor plume profiling. Several inspectors spaced cross wind and down wind from the odor source can be assigned to measure odor intensity. Multiple plume profiles, during differing wind conditions, can be used to "calibrate" a dispersion model or verify model predictions.

STANDARD PRACTICES

Four standard practices directly applicable for quantification of MSW landfill odors are:

⇒ Odor Characterization by Descriptors

⇒ Word Scale Odor Intensity

⇒ Suprathreshold Odor Intensity

⇒ Odor Threshold Concentration

⇒ Odor Persistence

Characterization by Descriptors

The character of an odor is reported by an observer using "standard odor descriptors". Odor character is also known as "odor quality". Odor descriptors provide a referencing vocabulary or standard nomenclature for reporting, comparing and contrasting.

Numerous "standard" odor descriptor list are available to use as referencing nomenclature. One standard published by the International Association on Water Pollution Research and Control (IAWPRC) is a "flavor wheel" for natural waters[5]. An adaptation of this IAWPRC "flavor wheel" is a grouping of odor descriptors applicable for MSW landfills, as in Table 1.

A standard list of odor descriptors provides odor inspectors, monitors, operators and citizens with a common (i.e. similar) vocabulary for evaluation, reporting and communicating.

Word Scale Odor Intensity

Odor intensity is a measure of the relative strength of an odor above the threshold. Odor intensity can be assigned a word descriptor or a number on a "5" or "10" scale. A common word scale is:

0 No Odor

1 Very Faint

2 Faint

3 Noticeable

4 Strong

5 Very Strong

Intensity word scales are also used with only "end point" word descriptors, i.e.

Light ---------- **Strong**

1 2 3 4 5

The citizen odor monitor typically finds the word intensity scale easy to understand and use. A MSW landfill would best use the same intensity word scale in order to facilitate communication and summarizing of data.

Suprathreshold Odor Intensity

Odor intensity quantification can be accomplished using an "Odor Intensity Referencing Scale"[6] (OIRS). Odor intensity referencing compares the odor in the ambient air to the odor intensity of a series of concentrations of a reference odorant. A common reference odorant is n-butanol. The inspector, investigator, monitor or operator observes the odor in the ambient air and compares it to the OIRS[7]. The person making the observation must use a carbon filtered mask to "refresh" their olfactory sense between observations (sniffing). Without the use of a carbon filtered mask the observer's olfactory sense would become fatigued or would adapt to the odors in the surrounding ambient air.

Using the OIRS, the intensity of the observed air is expressed in "parts per million" of n-butanol. A larger value of butanol means a stronger odor. The OIRS serves as a standard practice to quantify the intensity of odors for documentation and comparison purposes.

Odor Threshold Concentration

The odor concentration is a number derived from a laboratory dilution of a sample odor[8]. Dilution of the odor is the physical process that occurs in the atmosphere down wind of the odor generating source. The "receptor" (citizen in the community) sniffs the diluted odor. The dilution ratio is an estimate of the number of dilutions needed to make the odor "non-detectable" (threshold).

Samples of ambient air that have been collected on-site and surrounding a MSW landfill can be evaluated at an odor laboratory using trained panelists (assessors). The odor panelists observe the sample using an instrument called an olfactometer. The testing procedure produces threshold values that are called "detection threshold" and "recognition threshold". The detection threshold represents the dilution ratio needed to make the sample "detection free". The recognition threshold represents the dilution ratio needed to make the sample "odor free". The differences between the detection threshold and recognition threshold may only be significant in odor dispersion modeling. However, when comparing sample results, one type of threshold must be used consistently.

In addition to the determination of odor thresholds, an odor laboratory can conduct evaluations for the following odor parameters:

- Odor Intensity using the n-butanol Odor Intensity Referencing Scale
- Odor Quality using Standard Character Descriptors
- Odor Hedonic Tone (Pleasantness verses Unpleasantness)
- Odor Persistency (Dose-Response)

A field procedure exists, known as the "Scentometer", for the estimating of ambient odor threshold[9]. The Scentometer, a small portable box device, has been in use since its development in 1959[10]. The Scentometer, when used by an experienced technician, estimates the odor concentration using a dilution threshold technique. Holes in the Scentometer box, specially sized, allows ambient air to enter through charcoal filters and directly to the user's sniffing ports. The Scentometer, a single user device, is limited primarily by wind conditions that affects the air entering the open holes in the sniffing chamber.

Odor Persistence

Persistency is a term used in conjunction with intensity. The intensity of an odor will change in relation to its concentration. However, the rate of change in intensity verses concentration is not the same for all odors. This rate of change is termed the persistency of the odor.

The persistency of an odor can be measured in an odor laboratory as a "dose-response" function. The dose-response function is determined from the intensity of an odor at full strength and at several dilution levels above the threshold level. The plotted values as logarithms of the intensity and dilution ratios makeup the dose-response function. In a simplified form for comparing two odors, i.e. odor with and without counteractant, the plots of the two samples might have different slopes. As illustrated in Figure 1, the odor with the flatter slope would have a greater persistency, i.e. greater "Hang Time" (slang) in the ambient air.

CONCLUSIONS

MSW landfill odor data collection and analysis address four basic questions:

1) **What** are the odors ? (Description)
2) **When** are the odors ? (Relation to time, activity, episode …)
3) **Where** are the odors ? (In the Community)
4) **What does or does not cause** the odors ? (Sources, activity …)

MSW landfill odors can be quantified using ten (10) site specific **methods** (protocols) for sample collection and direct observation.

1. Point Source Sampling
2. Surface Sampling
3. On-Site Monitoring
4. Complaint Response
5. Random Monitoring
6. Scheduled Monitoring
7. Citizen Monitoring
8. Citizen Jury
9. Intensive Odor Study
10. Plume Profiling

Standard **practices** for odor quantification at MSW landfills include: characterization by descriptors, intensity by word and butanol scales, threshold evaluation, and odor persistence.

MSW landfills have the opportunity to embrace standard methods and practices of odor quantification for purposes of self improvement, survival and growth. Proactive odor management strategies with ongoing monitoring and aggressive odor control will provide assurances of favorable public acceptance, regulatory compliance and informed management decision making.

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Table 1. Grouping of Odor Descriptors for MSW Landfills.

Group 1:	Earthy	Mushroom	Mouse-like
	Musty	Peat-like	Chalk-like
	Moldy	Grassy	Cork-like
	Musk	Herbal	Bark-like
	Stale	Ashes	Woody
Group 2:	Floral	Eucalyptus	Carnation
	Fragrant	Geranium	Rose
	Flowery	Violet	
	Perfume	Lavender	
Group 3:	Fruity	Apple	Vegetable
	Citrus	Pear	Honey Dew
	Orange	Strawberry	Cucumber
	Lemon	Pineapple	Celery
Group 4:	Spicy	Garlic	Vanilla
	Cinnamon	Onion	Almond
	Mint	Pepper	Maple
	Peppermint	Dill	Pine
	Anise	Cloves	Coconut
Group 5:	Fishy	Prawns/Shrimp	Amine (hair perm solution)

Table 1 (cont.). Grouping of Odor Descriptors for MSW Landfills.

Group 6:	Sewage	Garbage	Foul
	Septic	Rotten	Sour
	Putrid	Decayed	Vinegar
	Rancid	Raw Meat	Pungent
	Fecal	Blood	Burnt
	Urine	Cadaverous	Swampy
	Sulfurous	Rotten Eggs	Mercaptan
Group 7:	Medicinal	Chlorinous	Alcohol
	Disinfectant	Soapy	Ether
	Phenol	Caster Oil	Anesthetic
	Camphor	Ammonia	Menthol
Group 8:	Chemical	Petroleum	Tar
	Solvent	Car Exhaust	Oily
	Paint	Diesel	Pine Oil
	Aromatic	Gasoline	Plastic
	Varnish	Creosote	Vinyl
	Turpentine	Kerosene	Metallic

Figure 1. Odor Persistence Illustrated.