Measurement and Regulation of Odors in the USA

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Abstract
This paper will present highlights of the current approaches used in the USA relative to odor regulations and guidelines. The issue of odor standardization has progressed significantly during the last few years. In the USA, the Air & Waste Management Association's EE-6 Odor Committee has forwarded its guidelines to the American Society of Testing Materials (ASTM) as a suggested replacement for ASTM Method E679-91. Among other things, the guidelines recommend a minimum flow rate of 3 liters per minute (lpm) for olfactometers. However a large number of odor laboratories in the USA have adopted the European Standard approach of a 20 lpm flow rate. The author asks whether current olfactometry based odor regulatory standards in the USA standards will now be inconsistent with the higher D/T (OU) levels that may be associated with the higher flow rates used as part of the European Standard approach?

1. Introduction
Odors are increasingly the cause of complaints to environmental regulatory agencies in the USA. One reason for this increase is the fact that more homes are being built near waste processing facilities such as wastewater treatment plants and landfills due to a lack of buildable land. Also as home prices have risen significantly in recent years, many residents have become less tolerant to even occasional odors or other nuisance conditions that are perceived to have an impact on property values. In addition, in agricultural areas of the USA there has been a dramatic increase in corporate large-scale confined animal feeding operations. Because most of these animal facilities do not really have significant odor treatment systems in place, there has been a significant increase in complaints and regulations relative to animal feeding operations in the USA.

2. Types of Odor Regulatory Approaches Used in the USA
There are generally a number of different approaches that are commonly used in the USA to regulate odors.

(1) The use of ambient air limits for individual compounds such as hydrogen sulfide as used in the state of Minnesota (see Table 1 below). The existence of so many different odorous compounds associated with WWTPs and particularly most

livestock operations creates serious potential problems when using individual compounds as the basis for assessing odors. In addition, detection and odor annoyance thresholds cited in the literature and in regulations vary widely for compounds such as hydrogen sulfide.

Table 1. Examples of Ambient Standards for Odor Causing Compounds
(all agencies listed are state agencies unless otherwise noted) *from Mahin, 2001 (1)*

Location	Compound	Ambient Odor Standard
California	Hydrogen sulfide	30 ppbv* (1-hour average)
Connecticut	Hydrogen sulfide Methyl mercaptan	6.3 ug/m^3 2.2 ug/m^3
Idaho	Hydrogen sulfide	10 ppbv (24 hour average) 30 ppbv (30 min. average)
Minnesota	Hydrogen sulfide	30 ppbv (30 minute average)** 50 ppbv (30 minute average)***
Nebraska	Total reduced sulfur	100 ppb (30 minute average)
New Mexico	Hydrogen sulfide	10 ppbv (1 hour avg.) or 30 - 100 ppbv (30 minute avg.)
New York State	Hydrogen sulfide	10 ppbv (14 ug/m^3) 1-hour average
New York City	Hydrogen sulfide	1 ppbv (for wastewater plants)
North Dakota	Hydrogen sulfide	50 ppbv (instantaneous, two readings 15 min. apart)
Pennsylvania	Hydrogen sulfide	100 ppbv (1 hour average) 5 ppbv (24 hour average)
Texas	Hydrogen sulfide	80 ppbv (30 minute avg.) - residential/commercial & 120 ppbv - industrial, vacant or range lands

* - parts per billion by volume
** - not to be exceeded more than 2 days in a 5-day period
*** - not to be exceeded more than 2 times per year

(2) General regulatory language that prohibits off-site nuisance or annoyance conditions as determined by field inspectors in response to complaints from the public. Some agencies have implemented procedures whereby inspectors rate the intensity of the odor in the field, based on an intensity scale. Six point scales are sometimes used with 1 = very weak, 2 = weak, 3 = distinct, 4 = strong, 5 = very strong and 6 = extremely strong. The advantage to this approach is its simplicity and the fact that it is not a theoretical value predicted by a model. One disadvantage for both this approach and the hydrogen sulfide hand-held meter approach is that odor nuisance conditions occur much more frequently in the evening and early morning when regulatory staff are usually not working.

(3) Off-site limits based on levels predicted by dispersion modeling and using the dynamic olfactometry approach with the criteria reported as odor units (OU),

OU/m^3 or dilutions/threshold (D/T). The terms D/T, OU/m^3 and OU will be used interchangeably in this paper since they all represent the same concept (see Table 2 below).

(4) Best available control technology (BACT) or similar approaches that specify required levels of odor treatment controls for new or upgraded large facilities.

(5) The American Society of Agricultural Engineering (ASAE) document Engineering Practice 379.1 "Control of Manure Odors" recommends setbacks from livestock facilities of 0.4 to 0.8 km for neighboring residences and 1.6 km to residential development (2).

Table 2 Examples of OU/m3 (D/T) Limits Used from Mahin (1)

Location	Off-site standard or guideline	Averaging times
Allegheny County Wastewater Treatment Plant (WWTP)	4 D/T (design goal)	2-minutes
San Francisco Bay Area Air Quality District	5 D/T	Applied after at least 10 complaints within 90-days
State of Colorado	7 D/T (Scentometer)	
State of Connecticut	7 D/T	
State of Massachusetts	5 D/T*	
State of New Jersey	5 D/T **	5-minutes or less
State of North Dakota	2 D/T (Scentometer)	
State of Oregon	1 to 2 D/T	15-minutes
City of Oakland, CA	50 D/T	3-minute
City of San Diego WWTP	5 D/T	5-minutes
City of Seattle WWTP	5 D/T	5-minutes

* draft policy and guidance for composting facilities
** for biosolids/sludge handling and treatment facilities

The European Committee for Standardization or CEN has developed a standard method for odor laboratory measurement using olfactometry. The standard, which is to be called "Air Quality – Determination of Odour Concentration by Dynamic Olfactometry" will be referred to in this paper as the "European Standard" (3). In the USA, several universities and WWTP districts follow the European standard's basic tenets including: Duke University, Iowa State University, the University of Minnesota, Purdue University, the Los Angeles County Sanitation District and the Minnesota Metropolitan Council (4).

A study conducted for the California Air Resources Board (USA) included the review of six published studies that related to recognizability, unpleasantness and annoyance associated with a variety of unpleasant odors. The analysis concluded that for unpleasant odors the threshold of annoyance is at approximately five times the threshold of detection (5). California's South Coast Air Quality Management District's states that at 5 D/T (OU/m^3) people become consciously aware of the presence of an odor and that at 5 to 10 D/T odors are strong enough to evoke registered complaints (6)(7). It should be pointed out that there are questions as to whether these assumptions are still valid given the apparent increased sensitivity of the European Standard laboratory methods compared to ASTM Method E 679-91 (8). Given the background OU/m^3 levels commonly reported and because of the residual odor associated with Tedlar and similar bags, the olfactometric approach should not be used for ambient air odor analysis but rather for impact predictions using dispersion modeling.

3. Air & Waste Management Association Guidelines for Odor Sampling and Measurement

A subcommittee of the EE-6 Odor Committee of the Air and Waste Management Association (A&WMA) was formed to develop a set of guidelines or recommended practices for the standardization of odor sampling procedures and odor measurement techniques by dynamic dilution olfactometry. The A&WMA EE-6 Subcommittee on the Standardization of Odor Measurement prepared a document titled Guidelines for Odor Sampling and Measurement by Dynamic Dilution Olfactometry August 23, 2002 (9). The EE-6 Odor Committee has submitted the Guidelines to the ASTM as a more detailed odor testing replacement method for the current ASTM method E679-91 (Standard Practice for Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Methods of Limits) (8).

The method accepts the use of forced choice or non-forced choice sample presentation method in an ascending concentration triangular method (one diluted odor sample and two blanks per presentation) or a binary method (one diluted odor sample and one blank per presentation). To reduce the variability obtained, the guidelines recommend that panelists also indicate their basis for the choice: pure guess, possible difference or recognize the presence of an odor.

The guidelines recommend that the flow rates of the olfactometer should be calibrated regularly using a primary volume-measuring device (i.e. soap bubble flow meter). To obtain consistent and accurate values, the flow rates of both the dilution (odor-free) air and the sample flows should be measured at all delivery settings several times and averaged to ensure stability.

The guidelines state that screening for detection of n-butanol and at least one other odorant should be conducted using aqueous solutions. Initially, a sub-threshold concentration of the selected odorant in distilled water is compared to two bottles containing only distilled, odor-free (triangular presentation) water. The candidate is asked to pick the bottle containing the odorant. A series of similar triangular presentations are made in an ascending series with the odorant concentrations doubling at each step.

The second screening procedure involves familiarization of the potential candidates with the olfactometric procedures and determines each individual's detection threshold for: a standardized concentration on n- butanol and an odor sample or prepared standard representative of the specific project.

The screening samples should be run in triplicate. To be accepted as a panelist, the geometric mean of the individual detection thresholds should be within 0.5 and 2 times the accepted reference value for the reference material used. After all panelists have evaluated a series of dilutions for the test sample, individual panelists' best estimate thresholds (BET) are determined. The BET for a panelist is the geometric mean of that dilution level (or equivalent concentration) at which the first point (highest dilution level) of a consistently correct series of (+) responses (with some degree of certainty) and the dilution level prior to this point. All responses indicated by the panelists as being guesses are disregarded.

3.1 Olfactometer Flow Rates

The guidelines state that the airflow rate from the olfactometer sniff ports must be regulated at a **minimum** of 3 liters per minute (lpm) to account for the variability of individual breathing/sniffing volumes and techniques during olfactory evaluations. The resultant face velocity at the cup face should be between 1 -10 cm/sec.

In the effort to reach international consensus on the standardization of odor measurement techniques, flow rate has probably been the most controversial issues (10). An earlier draft version of the EE-6 Odor Committee guidelines recommended a flow rate of 8 lpm (11). The final version includes a minimum flow rate but no maximum so that the 20 lpm flow rate used in the European Standard approach would still be consistent with the guidelines.

The guidelines also state that smelling chambers should be a cylindrical shape or an ergonomically shaped nasal mask and must be made out of a non-reactive, odor-free material (glass or Teflon). The cup design must allow for an even flow profile at the face of the cup. The diameter of the chambers must be between 5 and 10 cm to allow full insertion of the panelists' nose into the chamber and result in a face velocity that is barely perceptible by the panelists. Note: high flow rates and high face velocities may result in notable discomfort of the panelists.

3.2 Odor Sample Collection

The guidelines state that odor samples should be collected using a sampling line made of an odor-free, chemically inert and non-reactive material (i.e. Teflon or similar). The samples should be collected into gas sampling bags made of Tedlar. This material has been specified because it is the best at maintaining sample integrity and has the lowest background odor. New bags should be purged with odor-free air prior to use to ensure that there is no contamination due to manufacturing “bag” odor. This is especially critical with the collection of low level or ambient odor samples.
Re-use of sampling bags may be possible with low odor (i.e. less than 50 D/T) samples. Pre-used bags should be purged continuously with odor-free air for a minimum of 24 hours and tested to ensure that they are acceptable prior to re-use.

The sample bag must be half filled at least once and emptied prior to collecting the final sample in order to precondition the sampling line and the interior walls of the sampling bag. The guidelines state that if pre-dilution of the sample is necessary due to an excessively high odor level, high temperature, or high humidity of the sample gas, pre-conditioning of the sample bag with the diluted sample is also required.

The sampling train should allow for transfer of the gas through the sampling line directly into the sample bag without going through any potential sources of contamination such as rotameters, pumps etc. The recommended method for sample collection is the “evacuated drum” or “sampling lung” where the sample bag is placed within a rigid, leak-proof container. The air inside the container is evacuated using a pump, which causes the bag to fill with sample at a rate equal to the container evacuation rate. Pre-dilution of the sample may be required to prevent condensation in the bag if the sample gas contains a significant amount of moisture

4. Conclusions

- The issue of odor standardization has progressed significant during the last few years. The CEN European Standard has become the official olfactometry odor analysis approach for a number of countries. In the USA, the A&WMA EE-6 Odor Committee has forwarded its guidelines to the American Society of Testing Materials (ASTM) as a suggested replacement for ASTM Method E679-91. In addition, an interlaboratory comparison of seven olfactometry laboratories was conducted in Japan in late 2000 (12).
- The A&WMA guidelines are similar to the European Standard but they do allow quite a bit of flexibility in what olfactometer flow rates cab be used. This could potentially be a problem when attempting to compare data and results from different olfactometry laboratories.
- With the A&WMA guidelines now final, an important issue needs to be analyzed in the future. Current OU/m^3 (D/T) odor regulatory standards in the USA have traditionally been based on lower olfactometry flow rates used in the past. Will these regulatory standards now be inconsistent with what are believed by some to be the higher D/T (OU) levels associated with the higher olfactometric flow rates associated with the European Standard? There appears to be a need for studies in the future that would compare results from analysis of odor samples using varying olfactometry flow rates.

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