Odor Evaluation Fundamentals and Applications for Indoor Air Quality Research

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ABSTRACT

Sensory Evaluation is practiced daily in the foods, beverage, and fragrance industries for decision making that affects billion dollar markets. Standards practiced in these industries have protocols and techniques similar to the protocols, methods, and standards for odor evaluation.

The internationally accepted statistical concepts that are used for odor evaluation allow for analysis to be accomplished in the laboratory setting. The determination of odor concentration (detection and/or recognition thresholds), intensity, and descriptor identification is routinely conducted under controlled laboratory conditions with trained assessors.

Environmental engineers around the world have been using olfactometry for over 25 years for a variety of applications. Odor evaluations are more recently being used by engineers, designers, industrial hygienists, researchers, and many others in the following applications: forensic investigations, product development, product verification, and building material acceptability.

1.0 INTRODUCTION

Odor evaluation involves standard practices for quantifying odor parameters (concentration, intensity, persistence, and character descriptors). Internationally accepted statistical concepts and methods that are used for odor evaluation yield reliable analytical data. Odor parameters are routinely quantified under controlled laboratory conditions with trained assessors (sensory panel members).

Environmental engineers, designers, industrial hygienists, researchers, and others utilize odor evaluations in their work for forensic investigations, product development, product verification, and building material acceptability. Four brief case studies are presented to show examples of how odor evaluations can be used for indoor air quality research.

2.0 THE ODOR SAMPLE

The first step of an odor study is to develop an appropriate sampling or sample preparation protocol. All variables must be identified and prioritized for the study. Investigators must consider process conditions or conditions of use, depending on the nature of the analysis. These parameters must be known in order to collect or prepare representative samples for odor analysis.

Sample preparation can be a grab or integrated "air" sample or a material or coupon sample. When an odorous air sample is needed, the sample is collected in a 10-liter Tedlar® gas sample bag. The Tedlar bag is placed into a vacuum chamber (vacuum case) for sample collection. If the sample is collected at a location other than the odor laboratory, the sample is express shipped to the laboratory for evaluation.

In addition to collecting a sample for odor evaluation, the study's protocol may require a companion sample (i.e. duplicate) to be collected in a Tedlar gas sample bag or stainless steel canister for associated chemical laboratory analysis (e.g. VOC's).

Many projects require preparation of the odor sample, material, or coupon in the laboratory just prior to analysis. For example, a study of paint odors would require the laboratory to "paint" coupons, which would then be presented to the assessors for odor evaluation.

3.0 THE ODOR PANEL

Odor evaluation panels are organized and scheduled in order to maintain panel lengths not to exceed a period of three hours. Limiting panel length minimizes the fatigue of assessors (panelists).

The odor laboratory needs to be an odor free, "non-stimulating" space. Each odor assessor, when working on odor evaluations, focuses on the assigned task of observing the odor sample. Extraneous noise and activities in the evaluation area introduce distractions and can break the focus of the odor assessor.

The holding or waiting area of the assessors should be separated, as much as possible, from the evaluation area. The assessors are provided water for drinking during the waiting time between evaluations, however, eating, gum chewing, or other beverages and food are not permitted. A comfortable and relaxing waiting area enhances a low stress environment for the assessors. Attention to the assessors' comfort and working environment nurtures their commitment and dedication to quality performance.

Odor panels consist of individuals (panelists / assessors) that are trained following the "Guidelines for Selection and Training of Sensory Panel Members" (ASTM Special Technical Publication 758). Assessors are recruited from the community at large. Persons who use tobacco products, who may be or are pregnant, or who have chronic allergies or asthma are not candidates for the odor panel. "Odor panel rules" are part of the assessors' agreement to participate in odor evaluations.

Each assessor is tested to determine their individual olfactory sensitivity using standard odorants. The assessors receive training that consists of olfactory awareness, sniffing techniques, standardized descriptors, and olfactometry responses. Assessors are also required to attend supplemental and re-certification courses. From the pool of "on call" assessors, a minimum of six are selected for a scheduled odor panel. Each odor panel should represent, as much as possible, a cross section of age and gender.

With proper "care and feeding" (nurturing and training) of the assessors, the communication between the assessor and the panel leader is clear, concise, and efficient. A well organized odor panel, that is conducted efficiently, ensures quality odor evaluations.

4.0 ODOR EVALUATIONS

4.1 THRESHOLDS

Odor samples are evaluated and quantified to determine "odor concentration" (odor strength) using an instrument called an "olfactometer" with an odor panel. These odors are evaluated in accordance with ANSI (American National Standards Institute) and ASTM (American Society for Testing and Materials) standard practices. Specifically, the standard followed internationally for olfactometry is ASTM Standard of Practice E679-91, Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series of Limits.

The odor assessors sniff (observe) the dilute sample as it is discharged from the olfactometer as one of three sample presentations. The assessors sniff all three sample presentations and must select one of the three that is different from the other two. This statistical approach is called "triangular forced-choice". The assessors declare to the panel leader, by pushing an appropriate button, if the selection is a "guess", "detection", or "recognition" as defined in ASTM E679-91.

The assessor is then presented with the next set of three sample choices, one of which contains the diluted odor sample. However, this next set of three samples presents the odor at a higher concentration (i.e. two times higher). The assessor continues to additional higher levels of sample presentation following the "triangular forced-choice" procedure and the required designation of "guess", "detection", and "recognition". This statistical approach of increasing levels of sample presentation is called "ascending concentration series."

The "odor concentration" or "odor strength" is a number derived from the laboratory dilution of the sample odor. The dilution ratio at each sample presentation level is used to calculate the dilution ratio of the evaluation sample.

Since the "detection threshold" value that is derived from the odor evaluation of the sample is actually derived from dilution ratios, it is, therefore, dimensionless. However, the pseudo-dimensions of "Odor Units" are commonly applied.

Odor concentration values have been reported by practitioners using nomenclature such as DT (detection threshold), RT (recognition threshold), D/T (dilution to threshold), ED50 (Effective Dosage at 50th percentile), Z (dilution ratio variable), BET (best estimate threshold), or OU (Odor Units).

It should be noted that the dilution of the actual odorous emissions is the physical process of the dilution of odorous emissions from a source that occurs in the ambient air or in a ventilated room. The "receptor" (citizen down wind or occupant in a room) 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 threshold level (suprathreshold).

4.2 INTENSITY

Samples can also be evaluated and quantified for other odor parameters to assist in the odor study. The odor intensity of a sample is the relative strength of the odor above the threshold (suprathreshold). The intensity of an odor is referenced on the ASTM Odor Intensity Referencing Scale described in ASTM E544-75,88, Standard Practice for Referencing Suprathreshold Odor Intensity. This standard specifies the internationally accepted reference odorant n-butanol. The odor intensity of a sample is expressed in parts per million (ppm) n-butanol. A larger value of n-butanol means a more intense odor. The Odor Intensity Referencing Scale (OIRS) serves as a standard method to quantify the intensity of odors for documentation and comparison purposes.

4.3 PERSISTENCE

The odor persistence of a sample can be quantified and represented as a "dose-response" function. Persistency is a term used in conjunction with intensity. The perceived intensity of an odor will change in relation to its concentration. However, the rate of change in intensity versus concentration is not the same for all odors. This rate of change is termed the persistency of the odor.

The dose-response function of an odor is determined from intensity measurements of the odor sample at full strength and at several dilution levels above the threshold level. The plotted values as logarithms of the intensity and dilution ratio are the dose-response function. The slope illustrates the persistency.

4.4 CHARACTER DESCRIPTORS

The character of a sample is evaluated by the odor assessors and reported using "odor descriptors." Odor character is also known as "odor quality." Odor descriptors provide a referencing vocabulary for the odor character / odor quality. Numerous "standard" odor descriptor lists are available to use as referencing vocabulary. One standard "list" published by the International Association on Water Pollution Research and Control (IAWPRC) is the "Flavor Wheel." A flavor wheel is a simple method to assign descriptors. The three to five most frequently assigned odor descriptors by the evaluating odor panel are reported for referencing purposes.

4.5 HEDONIC TONE

A sample can also be assigned an average "Hedonic Tone" by the odor panel. Hedonic Tone is a measure of the pleasantness or unpleasantness of an odor sample. The Hedonic Tone is independent of its character and intensity. An arbitrary but common scale for ranking odors by Hedonic Tone is the use of the 20 point scale with –10 the most unpleasant smell the assessor has ever experienced and +10 the most pleasant smell the assessor has ever experienced.

The assignment of a Hedonic Tone value to an odor sample by an odor assessor is "subjective" to them. An assessor uses his/her personal experiences and memories of odors as a referencing scale. The assessors, during training, become aware of their individual odor experiences and memory referencing.

5.0 CASE STUDIES

Four brief case studies will be discussed to show examples of how odor evaluations can be used in indoor air quality research. The first is an example of odors from new carpeting, the second is a study of odors from paints, the third is a project comparing carpet cleaners, and the fourth is the performance test of an odor reducing air filtration system.

5.1 NEW CARPET ODOR

The purpose of this odor study was to investigate the reasons for a high percentage of customer complaints regarding a new style of carpeting, which we will call carpet A. Many customers have chosen carpet A because they have confirmed the marketing claims that a new manufacturing process makes the carpet less odorous than traditionally manufactured carpet. Carpet B is a popular carpet sample that is manufactured with traditional methods.

Carpet distributors report that rolls of carpet A in their warehouses smell less than rolls of carpet B. However, they report three times the number of odor and health/discomfort complaints from customers who purchase carpet A.

The protocol for the odor study requires that carpet emissions be collected in an environmental chamber. The odorous air samples are then evaluating by an odor panel for detection thresholds, full strength intensity, and persistence.

The following are results of the evaluation:

	A	B
Detection Threshold	710	250
Intensity as ppm n-butanol	150	800
Slope of Dose-Response Function (m)	-0.87	-1.10
Correlation Coefficient (r)	-0.98	-.98

The results show why customers were choosing carpet A over B, and the data also gives a plausible explanation why the customers are filing more complaints regarding carpet A. The full strength intensity of sample A is lower than sample B, therefore, when customers smelled the carpet samples in the showroom, they noted that carpet A smelled less intense than carpet B. This result most likely influenced most customers to choose carpet A.

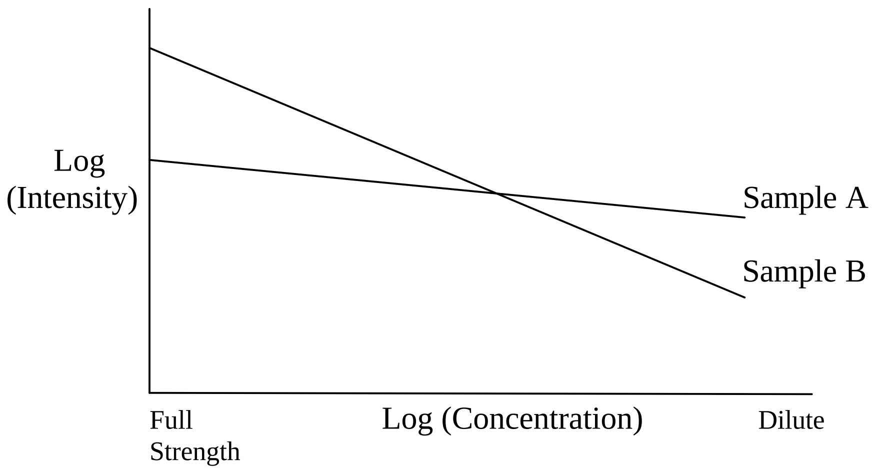

Figure 1. Dose-Response (Persistency) of Samples A and B.

The detection threshold results along with the persistency (dose-response slopes) results explain why carpet A resulted in more customer complaints of health concerns and odors. The detection threshold of Sample A is higher than Sample B. This result means that it takes more dilutions to make Sample A non-detectable. This translates to needing more room air exchanges to dilute the emissions from carpet A. Further, Figure 1 shows how Sample A has a flatter persistency slope than Sample B. This result means that Sample A will have a greater “hang time” and will thus stay more intense as it becomes diluted. These results show that while carpet A seems to be the better choice in the showroom, only odor analysis could explain why carpet A was leading to more odor complaints and unsatisfied customers than carpet B.

5.2 PAINT ODORS

An odor study was conducted to quantify the intensity of paint odors during a 12 hour drying time. Three white paint formulations were investigated. The laboratory prepared a series of 12-in^2 "coupons" with equal coverage of paint. The painted "coupons" were placed in environmental chambers where they dried. The assessors then observed the paint samples and reported the odor intensity directly from the can and at 1 hr., 2hrs., 4 hrs., 8 hrs., and 12 hrs drying times.

Figure 2 is a graph of the data collected for all three paint formulations. In their can, paint Samples 1 and 2 are both perceived as more odorous than Sample 3. However, Sample 2 dries to an odor level as low as Sample 3 after four hours. Therefore, after a four hour drying time with adequate ventilation, both Samples 2 and 3 are comparable. Sample 3 overall represents the lowest odor paint during drying.

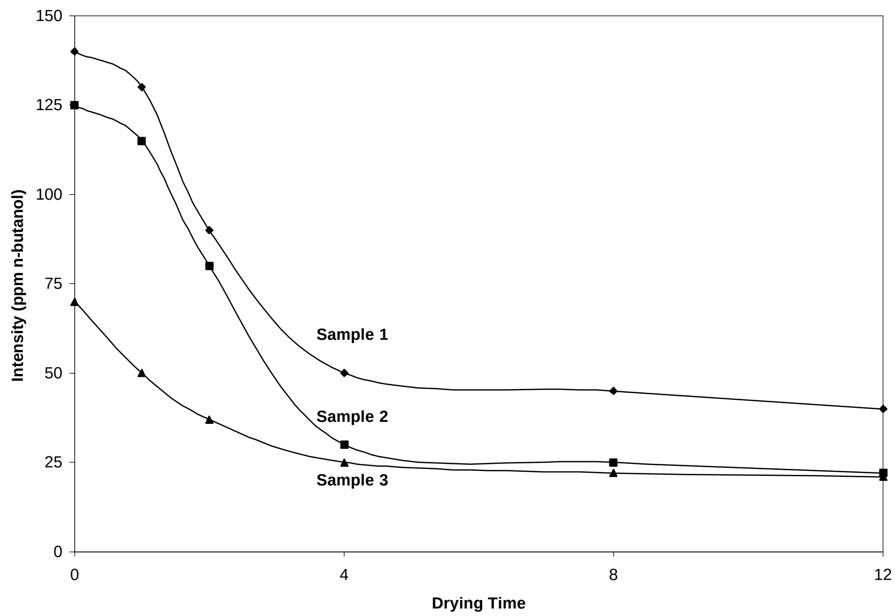

Figure 2. Paint Odor Intensity During Drying.

5.3 HOUSEHOLD CARPET CLEANERS

Carpet cleaners are used to clean soiled carpets as well as eliminate the odors caused by the soiling. A study was conducted to investigate the difference in odor removal effectiveness of three carpet cleaners. Small sections of carpeting were soiled and then cleaned. Assessors observed a soiled section of carpet (control) as well as the three sections cleaned with the different cleaners. The assessors reported the odor character descriptors observed as well as the relative strength (1 = faint to 5 = strong) of each character.

Figure 3 displays the character descriptors as well as the strength of each character for the three carpet cleaners and the soiled carpet control. The Control was characterized with a 4 intensity "Foul" descriptor. Cleaner #1 removed the "Foul" character and added a "Chemical" character at an intensity of 3. Cleaner #2 reduced the "Foul" character to an intensity of 1 and added a "Floral" character with an intensity of 4. Cleaner #3 removed all of the foul character and added a "Floral" character with an intensity of 3. In this illustration the character descriptors have been simplified. For detailed reporting the "Floral" descriptor would be represented by additional descriptors such as: Fragrant, Citrus, Rose, Geranium, etc.

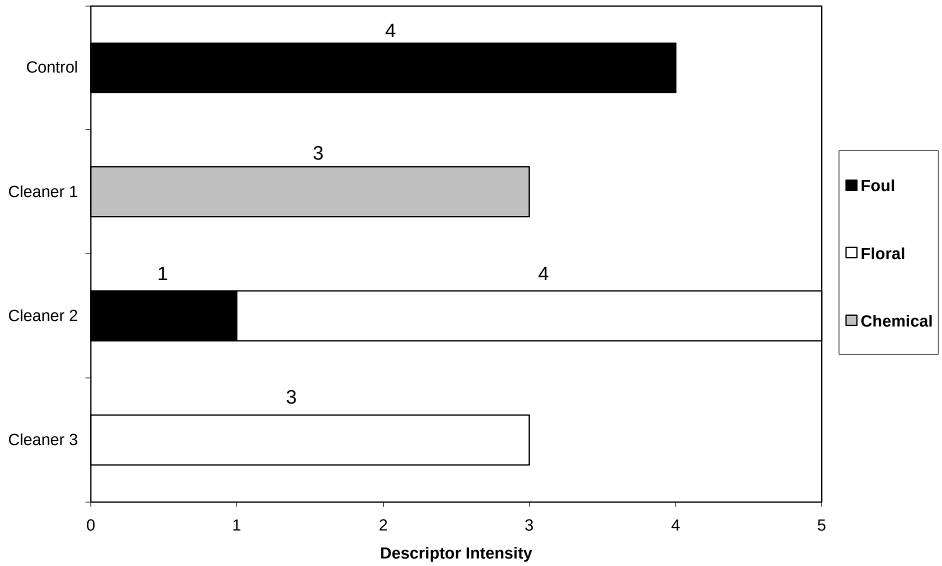

Figure 3. Carpet Cleaner Odor Descriptors.

5.4 ODOR FILTRATION

An odor reducing air filtration system was studied to test the reduction of common odors. Common household odors were created inside an environmental chamber. The air in the chamber was passed through an air filtration system that is designed to reduce odors. Air samples were collected in the room at 10-minute intervals for one hour. The samples were quantified for odor detection thresholds using an odor panel of assessors.

Figure 4 shows the detection thresholds (odor concentration) over time while the air in the room was circulated through the filtration system. The initial odor level in the room was evaluated and the odor concentration (detection threshold) was reported to be 180 (Odor Units). The filtration system achieved 70% odor reduction within 30 minutes and 80% odor reduction within one hour.

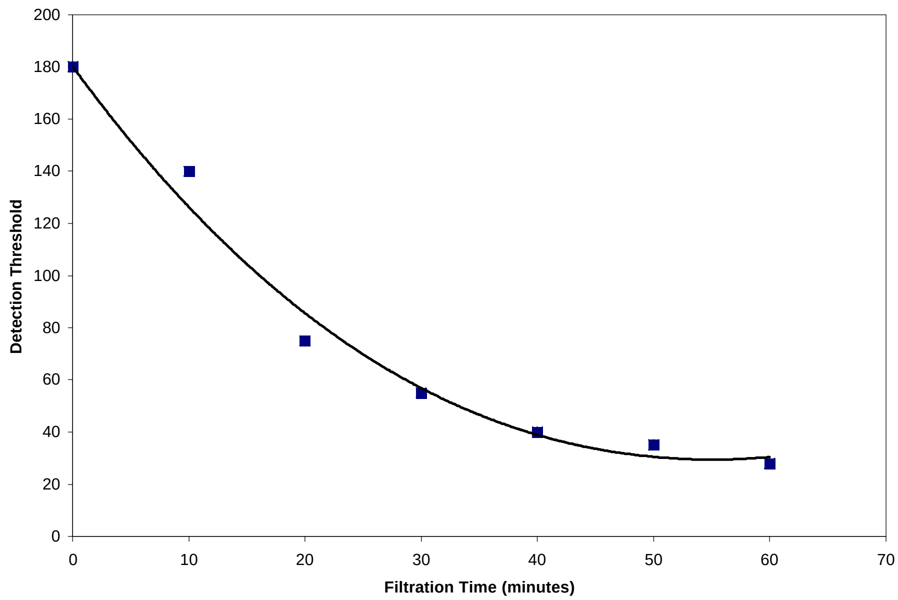

Figure 4. Air Filtration Performance

6.0 CONCLUSIONS

Odor quantification methods and protocols follow international standards and are routinely practiced by many industries. The four case studies presented illustrate the utility of odor analysis and evaluation data. The persistence odor parameter provides quantifiable data when comparing building material odors. The intensity odor parameter is useful for the study of volatile compound release, such as paint drying, solvent evaporation, or adhesive curing. The use of odor character descriptors provides insight and understanding for studies with malodors as well as fragrances, i.e. cleaning agents. The odor concentration parameter of detection threshold documents changes in odorant concentration (odorous molecules) and quantifies performance.

These examples show that a data base of odor results developed for a specific product line or for general product research can serve as evidence for resource allocation of product engineering, research and development, and capital equipment for odor prevention and thus minimize customer and/or occupant complaints and concerns.

7.0 REFERENCES

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