Development of the Odormat for Sewage Odour Measurement

Lawrence C C KOE
Director, Environmental Engineering Research Centre
School of Civil & Environmental Engineering
Nanyang Technological University
Block N1, #B3b-18
50, Nayang Avenue
Singapore 639798

Jurn Wei CHAI
Aromatrix Pte Ltd
1 Bukit Batok Street 22, #03-02
GRP Industrial Building
Singapore 659592

Keywords
Olfactometer, odour, odor measurement

Abstract
With today's increasing levels of development, residential areas are inevitably built closer to odour generating facilities, such as sewage treatment and chemical industrial plants. Odour measurements, which provide important information in the planning of the plants and odour treatment facilities, are needed to underpin the numerous decisions that will have to be made to reduce odour nuisance. The use of dynamic olfactometry is widely regarded as a favoured sensory technique for quantifying odour. In recent years, emphasis has been directed towards standardizing equipment and techniques of odour sampling and measurement so that results can be compared between laboratories and between different olfactometers with some degree of reliability. This paper describes the development of a computerized olfactometer for sewage odour measurement in Singapore.

1. INTRODUCTION

The increasing standard of living in Singapore over the last 30 years has resulted in an increasing demand for a cleaner and healthier living and working environment. Due to the scarcity of land resources, parts of the residential and commercial areas are located in close proximity of the odour generating zones, such as the sewage treatment plants. Dynamic olfactometry has played a key role in helping environmental engineers to understand odorous emission characteristics of the plants so that proper odour treatment systems can be designed to contain malodours within the boundaries of the plants. Odour inventory study using dynamic olfactometry has become a common and regular practice in the maintenance and evaluation of odour treatment facilities.

The strength or concentration of an odour sample is measured by the number of dilutions with odour-free air required to render it barely detectable by an odour observer. Odour concentration is typically expressed in terms of odour units per cubic metre of odour-free air[2] (ou/m^3) (1). This is the amount of odour necessary to contaminate 1 m^3 of clean, odour-free air to the threshold level of the observer (2). The number of dilutions to threshold, otherwise known as the dilution factor, Z, is computed as:

$$Z = \frac{(F1 + F2)}{F2} \tag{1}$$

where F1 = flow of odour-free air
F2 = flow of odorous air.

Both F1 and F2 are expressed in units of volume or flowrates. Hence Z is a dimensionless ratio (3). However, Z is numerically equal to the term "ou/m^3" since the number of dilutions to threshold level is a measure of the odour concentration. The device used to deliver the diluted odour sample to the odour observers is known as an olfactometer.

2. METHODOLOGY

In 1984, a manual dynamic olfactometer was developed under the supervision of Professor Lawrence Koe at the National University of Singapore. It works on the principle of dynamic dilution by continuously increasing the flowrates of an odorous sample with odour-free air until the mixture reaches its threshold odour level and becomes detectable by an odour observer. The first dynamic olfactometer is largely made up of manual components as shown in Figure 1, such as stainless steel rotameters and air valves, which require the operator to adjust and monitor the gas flowrates during odour measurement. With its unique dilution technique, the manual dynamic olfactometer was built to deliver high dilution rates to measure the high odour concentrations of foul gases typically found in sewage treatment plants and food and chemical industries in the excess of thousands of odour units.

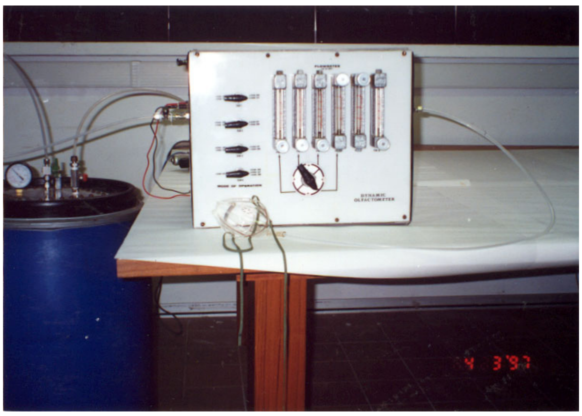

Figure 1. Manual dynamic olfactometer

During odour measurement, odorous air is first collected and contained in chemically inert sampling bags with about 10- to 40- litre capacity. The actual odour contents in the bag are preserved by subjecting the sampling bag to pressure in a special vessel, resulting in direct delivery of the sample to the olfactometer without passing through any air pumps. Odorous air sample is dynamically diluted with continuous odour-free air and the mixture is presented to the odour observer at a constant flowrates of 20 litres per minute. The concentration of the odorous air is gradually increased until the odour threshold becomes detectable by an odour observer. The odour concentration of the odorous sample is expressed as the number of dilutions with odour-free air required to render it detectable by the odour observers.

Over the years, the performance and features of the first manual dynamic olfactometer has become inadequate in meeting the more stringent needs for greater accuracy and reliability in odour measurement. In addition, emphasis has been directed towards standardizing equipment and techniques of odour sampling and measurement so that results can be compared between laboratories and between different olfactometers with some degree of reliability. Harreveld (4) and O'Brien et al. (5) highlighted the performance of olfactometers as one of the factors of olfactometry that is required to be standardized. In 1990, the European Committee for Standardization (CEN) formed a technical committee (TC264), which developed a draft standard for olfactometery.

In 1997, the manual dynamic olfactometer was upgraded as shown in Figure 2. The version II manual dynamic olfactometer was developed with more accurate rotameters to enable odour concentrations of air samples to be measured in a high quality controlled procedure such that results are reliable and accurate.

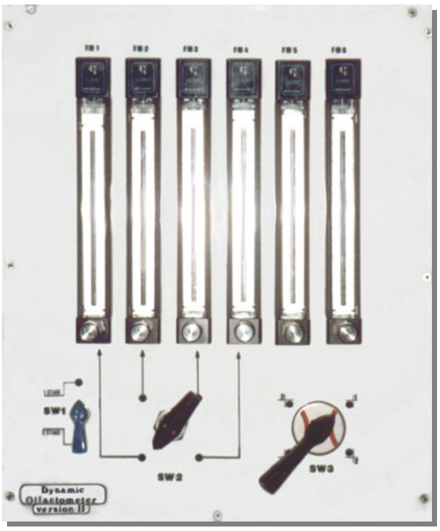

Figure 2. An upgraded version II dynamic olfactometer

Following the successful development of the version II dynamic olfactometer, a computerised dynamic olfactometer, named the Odormat was designed and built to ease the process of odour evaluation with a fully integrated automation to minimize human errors. The Odormat was developed using the unique technology of the first manual dynamic olfactometer as shown in Figure 3 and it conformed to the CEN standard. It was designed with large dilution range of $2^2 - 2^{18}$, which allowed odours that are encountered in most odours generating industries, such as sewerage treatment plants, food and chemical processing factories to be accurately measured without the need to pre-dilute the odorous air sample.

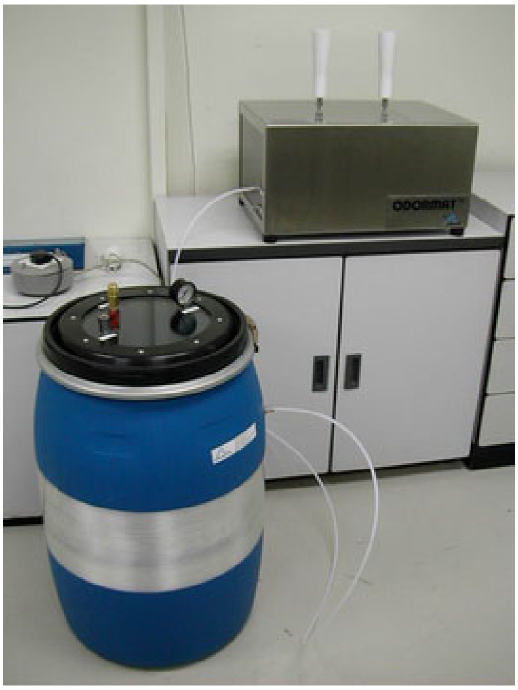

Figure 3. Computerised dynamic olfactometer (Odormat)

The Odormat was constructed of components entirely made of stainless steel and polytetrafluoroethylene (PTFE). It is capable of delivering dilutions in the range of 2^2 to 2^{18}. The CEN has specified a minimum upper limit of 2^{14} and a maximum lower limit of 2^7 (4). Odours are presented to human observers utilizing dynamic olfactometry following a “force-choice” ascending concentration series method. In this method, the odour observers are presented with a diluted odour sample and one blank sample of odour-free air. The observers must choose which sample contains the odour, even if they must guess. This approach is called the “forced-choice” presentation method. After the observers make a selection, they are presented with the next set of odour sample and blank. However, this next odour sample is at a higher concentration. The observers continue with additional higher levels of sample presentation following these methods. This statistical approach of increasing levels of sample presentation is called “ascending concentration series”.

The most significant variable in the delivery of the odour stimulus to the nose is the flow rate from the olfactometer and the face velocity of the air. The Odormat operates in accordance to the CEN standard at a presentation flow rate of 20 litres/min with a face velocity of 0.5 m/s. The odour observers are selected strictly based on the observers’ sensitivity towards a standard reference odorant as specified in the CEN standard. Each potential observer must be tested to n-butanol on the olfactometer a minimum of 10 times. The individual's average threshold measurement of n-butanol must be in the range of 20 – 80 ppb. The antilog of the standard deviation must be less than 2.3 (4).

A set of stringent laboratory accuracy and repeatability performance criteria was specified in CEN standard. Harreveld (4) has proposed a set of criteria for the Accuracy (A) and Repeatability (r) in the CEN standard for olfactometry:

- A < 0.217
- r < 0.477

To verify the accuracy and repeatability of the odour measurement conducted with the three dynamic olfactometer, a series of odour evaluation using standard reference gas, n-butanol was carried out. A panel of qualified odour observers, in the age group of 18 – 26, was selected for the tests. Standard 18.8 ppm n-butanol was used as reference gas in the test. Ten odour measurements were conducted using the standard n-butanol gas over a period of one month.

3. RESULTS

Tables 1, 2 and 3 summarize the results of the odour performance evaluation using the standard 18.8 ppm n-butanol gas. The odour thresholds of standard 18.8 ppm n-butanol gas measured with the first dynamic olfactometer, version II dynamic olfactometer and the Odormat were found to be 471 ppb, 114 ppb and 46.6 ppb respectively.

Table 1. Summary of the performance evaluation of the first dynamic olfactometer

Reference gas	n-butanol
Mean Group threshold (ppb)	471
Log (threshold)	2.6939
Standard Deviation of Log (threshold)	0.0414
CEN threshold for n-butanol, ppb (4)	40
Repeatability Criteria: r < 0.477 ?	**0.107** **yes**
Accuracy, A Criteria: A < 0.217 ?	**1.116** **no**

Table 2. Summary of the performance evaluation of the version II dynamic olfactometer

Reference gas	n-butanol
Mean Group threshold (ppb)	114
Log (threshold)	2.0569
Standard Deviation of Log (threshold)	0.0747
CEN threshold for n-butanol, ppb (4)	40
Repeatability Criteria: r < 0.477 ?	**0.238** **yes**
Accuracy, A Criteria: A < 0.217 ?	**0.508** **no**

Table 3. Summary of the performance evaluation of the Odormat

Reference gas	n-butanol
Mean Group threshold (ppb)	46.6
Log (threshold)	1.6683
Standard Deviation of Log (threshold)	0.0867
CEN threshold for n-butanol, ppb (4)	40
Repeatability Criteria: r < 0.477 ?	**0.276** **yes**
Accuracy, A Criteria: A < 0.217 ?	**0.128** **yes**

The continuous research and development of the Odormat technology over the last 20 years has resulted in significant improvement on the performance and quality of odour measurement. The results of the repeatability and accuracy of odour measurement using the Odormat were found to be 0.276 and 0.128 respectively, which were well within the CEN requirement ($r < 0.477$ and $A < 0.217$).

4. CONCLUSIONS

The research and development of dynamic olfactometry in Singapore over the last 20 years has successfully resulted in developing a new generation of computerised dynamic olfactometer that measures odour concentration with improved accuracy and repeatability, which were tested to satisfy the stringent requirements in the CEN standard.

References

1) Koe, L.C.C.; Brady, D.K. J. Env. Eng., 1986, 112(2), 311-327
2) Arthur, C.S. Air Pollution: Measuring, Monitoring, and Surveillance of Air Pollution, Vol. 3, 3rd ed., pp. 335-336, Academic Press, 1976
3) Manual of Practice No. 22, Odour Control for Wastewater Facilities; Water Pollution Control Federation, Washington, D.C., 1979, pp 3-34
4) Harreveld, A.P., European standardisation of olfactometry, Project Research Amsterdam B.V., UK, May 1993
5) O'Brien, M.A, Guidelines for Odour Sampling and Measurement by Dynamic Dilution Olfactometry, Draft, AWMA EE-6 Subcommittee on the Standardisation of Odour Measurement, revised May 1993