IMPROVEMENT OF SENSORY ODOUR INTENSITY SCALE USING 1-BUTANOL FOR ENVIRONMENTAL ODOUR EVALUATION

HIGUCHI T., UCHIDA N., SEKINE M., IMAI T., YAMAMOTO K. and KANNO A.

Graduate School of Science and Engineering, Yamaguchi University
2-16-1, Tokiwadai, Ube, Yamaguchi 755-8611, Japan
E-mail: takaya@yamaguchi-u.ac.jp

ABSTRACT

Odours discharged from various human activities may cause severe damage to local residents. For appropriate evaluation of environmental odours, it is necessary to develop a reliable odour measurement scale. Since environmental odours consist of many different odorous compounds, comprehensive evaluation of odours using human sense of smell as well as instrumental analysis of individual chemicals is indispensable. Odour intensity reflects people's perception of odours and contributes to effective odour management. Several odour intensity scales have been developed and used for decades in the world. In Japan the six-point odour intensity scale was developed more than 40 years ago. In the measurement six or more panel members sniff a testing odour directly and classify their impressions in accordance with the scale in 0.5 segments. This scale is very easy-to-use, acceptable to local residents and applicable to any fields at any time. On the other hand, the independent judgments of the panel members are subjective and equal intervals between intensity levels are not necessarily ensured. Some countries have developed their unique odour intensity scales. ASTM E544-10 in the U.S.A. describes dynamic and static scales both designed to compare the odour intensity of the sample with the odour intensities of a series of 1-butanol concentrations. In the static scale method dilutions of 1-butanol in water are prepared in Erlenmeyer flasks and presented for odour intensity comparison. In this study Japanese conventional six-point odour intensity scale was reconsidered and a new series of six dilution steps of 1-butanol and explanatory labels were proposed to ensure equal intervals between odour intensity levels with reference to the static scale of ASTM E544-10.

First of all, 1-butanol dilution steps in which adjacent odour intensity can be discriminated were determined. The results imply that adjacent odour intensity of 1-butanol dilution steps with a ratio of at least 5.3 can be discriminated. Then, 1-butanol dilution steps that ensure equal intervals between odour intensity levels were determined. After a great deal of trial and error, 1-butanol dilution steps that ensure almost equal intervals between odour intensity levels were determined. These dilution steps consist of 1-butanol solutions with a concentration of 0, 10, 600, 2600, 9000 and 22500 ppm (vol/vol). Appropriate explanatory labels for 1-butanol dilution steps were determined. The validity of the new odour intensity scale was confirmed by odour intensity measurement tests using 1-butanol as quasi environmental odour. These results suggest that the new odour intensity scale can be practically useful for all people related to environmental odour evaluation.

Keywords: odour intensity, 1-butanol, environmental odour

1. Introduction

Odours discharged from various human activities may cause severe damage to local residents. For appropriate evaluation of environmental odours, it is necessary to develop a reliable odour measurement scale. Since environmental odours consist of many different odorous compounds, comprehensive evaluation of odours using human sense of smell as well as instrumental analysis of individual chemicals is indispensable. Odour intensity is one of main odour characterization parameters (Naddeo *et al.*, 2013), and remarkably common and important sensory indicator of environmental odours. Odour intensity reflects people's perception of odours and contributes to effective odour management. Several odour intensity scales have been developed and used for decades in the world.

In Japan the six-point odour intensity scale shown in Table 1 was developed more than 40 years ago and the regulation standards based on the Offensive Odour Control Law were set equivalent to the odour intensity that ranges from 2.5 to 3.5 on this scale (Higuchi and Nishida, 1995). In the measurement six or more panel members sniff a testing odour directly and classify their impressions in accordance with the scale in 0.5 segments. After discarding the maximum and the minimum values, the remaining values are averaged (Iwasaki, 2004). This scale is very easy-to-use, acceptable to local residents and applicable to any fields at any time. On the other hand, the independent judgments of the panel members are subjective and equal intervals between intensity levels are not necessarily ensured.

Some countries have developed their unique odour intensity scales including VDI 3882 Part 1 (VDI, 1992) in Germany and ASTM E544-10 (ASTM, 2010) in the U.S.A. According to VDI 3882 Part 1, odour intensity measurements are carried out with dynamically diluting olfactometers. The category scale of odour intensity is primarily an ordinal number scale and a specified ranking is assigned to its categories. ASTM E544-10 describes dynamic and static scales both designed to compare the odour intensity of the sample with the odour intensities of a series of 1-butanol concentrations. In the dynamic scale method a dynamic-dilution apparatus is used and vapor dilutions are prepared by continuous mixing of vapors of 1-butanol and odourless air. In the static scale method dilutions of 1-butanol in water are prepared in Erlenmeyer flasks and presented for odour intensity comparison. At least eight independent judgments of the panel members are obtained and averaged geometrically with respect to the 1-butanol concentrations of the matching points. A geometric progression scale with a ratio of two is recommended and odour intensity levels are clearly defined in both methods.

In this study Japanese conventional six-point odour intensity scale is reconsidered and a new series of six dilution steps of 1-butanol and explanatory labels are proposed to ensure equal intervals between odour intensity levels with reference to the static scale of ASTM E544-10.

Table 1: Six-point odour intensity scale.

Level	Odour Intensity
0	No odour
1	Barely perceivable (Detection threshold)
2	Faint but identifiable (Recognition threshold)
3	Easily perceivable
4	Strong
5	Extremely strong

2. Materials and methods

2.1. Determination of 1-butanol dilution steps

First of all, 1-butanol dilution steps in which adjacent odour intensity can be discriminated were determined. Two wide-mouth Erlenmeyer flasks with a capacity of 500 mL were prepared and adjacent reference solutions of 1-butanol were placed into them. The volume of solution was 200 mL and the top of each flask was covered with aluminium foil between sniffings. The panel members gently shook flasks prior to each sniffing in order to ensure equilibrium and odour intensity was evaluated by the magnitude estimation method. Experiments were conducted using 1-butanol dilution steps with a ratio of 3, 4, 5.3 and 5.6. Experimental results were evaluated using Wilcoxon signed rank test.

Then, 1-butanol dilution steps that ensure equal intervals between odour intensity levels were determined. Seven groups of reference solutions with different dilution steps were prepared and presented to the panel members. The panel members sniffed each flask and evaluated perceived odour intensity by placing a magnetic strip on a line segment with a length of 250 mm on a whiteboard as shown in Figure 1 (Takemura *et al.*, 2009). Magnetic strips labelled A to F corresponded to 1-butanol dilution steps. After the evaluation, the distance between magnetic strips was measured.

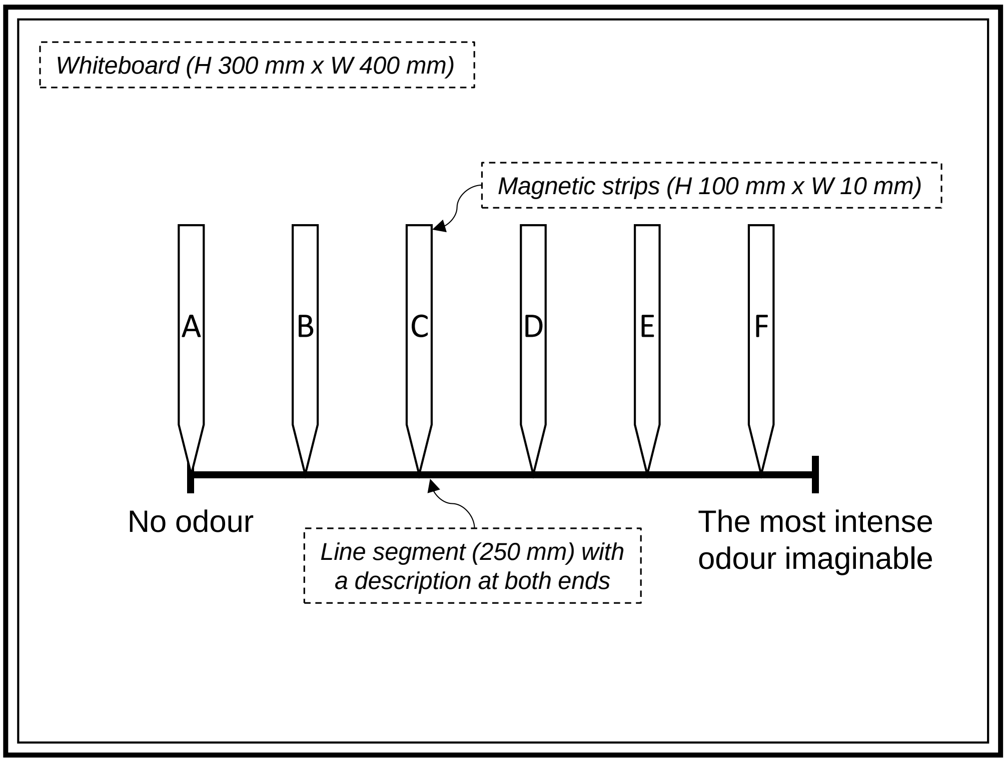

Figure 1: Odour intensity evaluation using a whiteboard and magnetic strips.

2.2. Determination of explanatory labels for 1-butanol dilution steps

Appropriate explanatory labels for 1-butanol dilution steps proposed in 2.1 were determined. Wide-mouth Erlenmeyer flasks with a capacity of 500 mL were prepared and reference solutions of 1-butanol were placed into them. The volume of solution was 200 mL. The panel members sniffed each flask and chose the most appropriate explanatory label from 13 choices on the evaluation sheet. Choices were selected from the conventional six-point odour intensity scale and papers related to sensory evaluation of odour and noise.

3. Results and discussion

3.1. Determination of 1-butanol dilution steps

Experimental results of odour intensity estimation at dilution steps with a ratio of 3 and 4 showed no statistical difference between adjacent reference solutions, suggesting that adjacent dilution steps can be hardly discriminated with a ratio of 3 and 4. On the other hand, odour intensities of adjacent reference solutions with a ratio of 5.3 and 5.6 showed statistical difference ($p<0.05$). These findings imply that adjacent odour intensity of 1-butanol dilution steps with a ratio of at least 5.3 can be discriminated.

After a great deal of trial and error, 1-butanol dilution steps that ensure almost equal intervals between odour intensity levels were determined as shown in Figure 2. These dilution steps consist of 1-butanol solutions with a concentration of 0, 10, 600, 2600, 9000 and 22500 ppm (vol/vol). The coefficient of determination of the regression line was 0.9989 and standard deviations were smaller in lower ranges and larger in higher ranges.

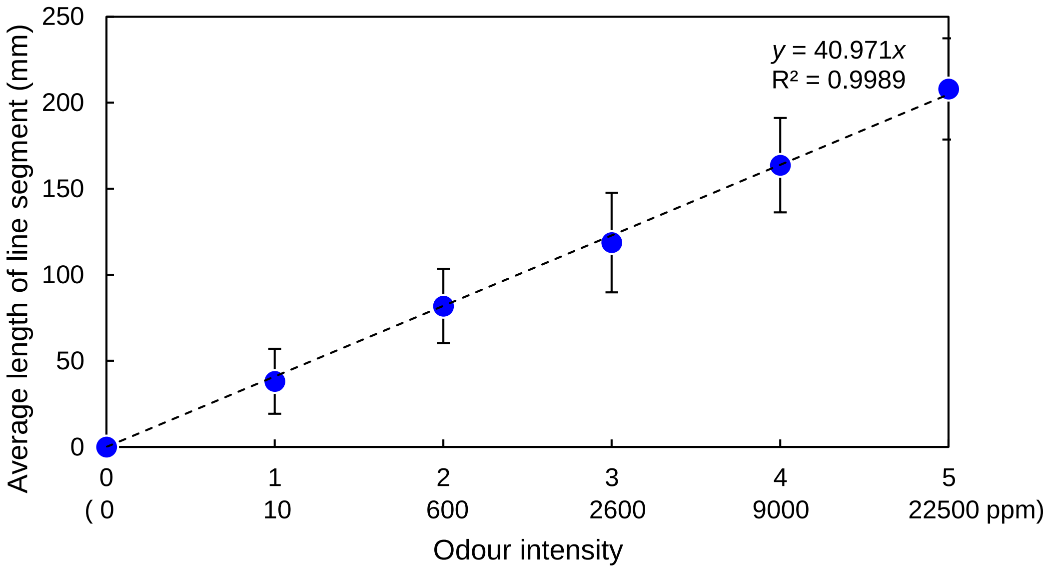

Figure 2: Relationships between 1-butanol dilution steps (0, 10, 600, 2600, 9000 and 22500 ppm (vol/vol)) and average length of line segment. Thirty panel members participated in the experiment. Bars and a dashed line represent standard deviations and the regression line, respectively.

3.2. Determination of explanatory labels for 1-butanol dilution steps

Since the panel members showed wide discrepancies in the explanatory labels, it was impossible to determine appropriate labels directly. The explanatory label that was not a general expression, covered multiple odour intensity levels and caused a wide variation among individuals was considered to be inappropriate and discarded from the choices. After reconsideration of the choices with reference to these conditions, four explanatory labels were considered to be inappropriate and discarded. Experiments for the determination of explanatory labels were conducted again using the remaining 9 choices. Statistical tests based on the binomial distribution were applied to the results and explanatory labels for odour intensity levels were determined as shown in Table 2.

The validity of the new odour intensity scale was confirmed by odour intensity measurement tests using 1-butanol as quasi environmental odour. Odour intensity of three samples which correspond to reference solutions of level 1, 3 and 5 on the new scale was measured. As a result, correct intensity values were significantly chosen by the panel members as shown in Figure 3 (p<0.01). These results suggest that the new odour intensity scale can be practically useful without concern about olfactory adaptation and loss of memory.

Table 2: Six-point 1-butanol odour intensity referencing scale.

Level	1-butanol concentration in water (ppm (vol/vol))	Odour intensity
0	0	No odour
1	10	Faint
2	600	Easily perceivable
3	2600	Slightly strong
4	9000	Strong
5	22500	Very strong

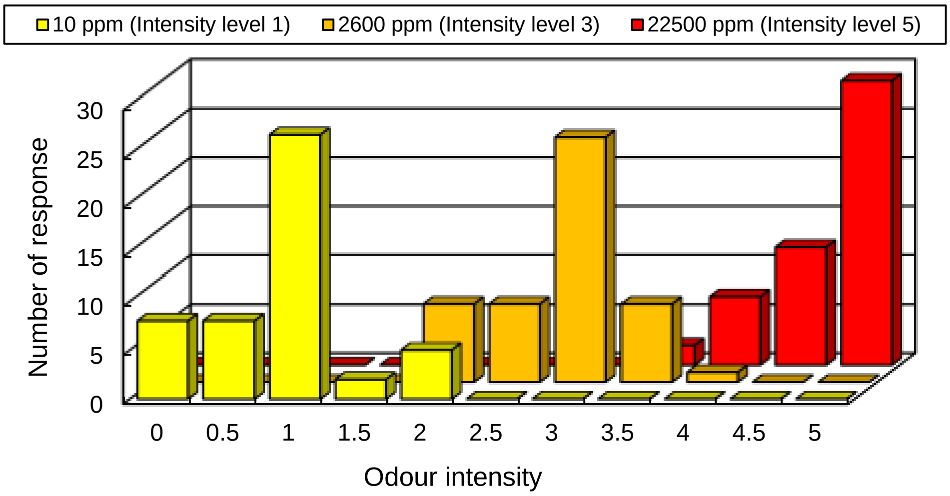

Figure 3: The number of response to three 1-butanol solutions.

4. Conclusions

Japanese conventional six-point odour intensity scale was reconsidered and a new series of six dilution steps of 1-butanol and explanatory labels were proposed. The new scale will be practically useful for all people related to environmental odour evaluation.

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