Effectiveness of Polyethylene Bottles as Containers for 1-Butanol Odour Intensity Reference Solutions

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Abstract. Odours discharged from various human activities may cause severe damage to residents. For appropriate evaluation of environmental odours, it is necessary to develop a reliable odour measurement scale. Odour intensity, a kind of main sensory odour characterization parameters, reflects people's perception of odours and contributes to effective odour management. In the past study, Japanese conventional six-point odour intensity scale was reconsidered and a new series of six dilution steps of 1-butanol prepared in Erlenmeyer flasks and explanatory labels were proposed. In this study, polyethylene (PE) bottles were selected as containers for 1-butanol odour intensity reference solutions for convenience in on-site handling. Effectiveness of PE bottles were inspected based on comparative odour intensity measurements using Erlenmeyer flasks and PE bottles. Applicability of PE bottles for odour intensity measurement of hydrogen sulfide was also investigated. The results suggested that PE bottles could be substituted for Erlenmeyer flasks as containers for 1-butanol reference solutions, especially in the middle intensity level. Although odour intensity evaluation of hydrogen sulfide was accompanied by greater variation, mean odour intensities were relatively discriminable. In conclusion, the effectiveness of PE bottles as containers for 1-butanol odour intensity reference solutions was suggested.

Keywords: environmental odour, odour intensity, 1-butanol, polyethylene bottle, reference solution.

1. Introduction

Odours discharged from various human activities may cause severe damage to 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 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 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 order to ensure equal intervals between odour intensity levels, Japanese conventional six-point odour intensity scale was reconsidered and a new series of six dilution steps of 1-butanol prepared in Erlenmeyer flasks and explanatory labels were proposed as shown in **Table 2** with reference to the static scale of ASTM E544-10 (Higuchi *et al*., 2015). In this study, polyethylene (PE) bottles were proposed instead of Erlenmeyer flasks as containers for 1-butanol odour intensity reference solutions for convenience in on-site handling. Effectiveness of PE bottles were inspected based on comparative experiments of odour intensity measurement using Erlenmeyer flasks and PE bottles. Applicability of PE bottles for odour intensity measurement of hydrogen sulfide was also investigated.

2. Containers for 1-butanol odour intensity reference solutions

Wide-mouth Erlenmeyer flasks with a capacity of 500 mL have been used as containers for 1-butanol odour intensity reference solutions in conventional odour intensity measurement. They are, however, breakable and bulky in on-site handling. In order to improve these problems, PE bottles with a capacity of 530 mL were selected as new containers for 1-butanol reference solutions. PE bottles fulfill essential conditions as follows:

1) They have no odour,
2) No odour is adsorbed on their surface,
3) They are cheap and easily obtained,
4) Diameter of the bottle mouth is as same as that of Erlenmeyer flask, and
5) They are reusable.

PE bottle, shown in **Figure 1**, has a mouth diameter of 40 mm.

Table 1. Six-pint 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

Table 2. Six-pint 1-butanol odour intensity reference 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 1. Polyethylene (PE) bottle

3. Materials and methods

3.1. Comparative odour intensity measurement using Erlenmeyer flasks and PE bottles

Odour intensity measurement was carried out to investigate if PE bottles could be substituted for Erlenmeyer flasks as containers for 1-butanol reference solutions. Six wide-mouth Erlenmeyer flasks with a capacity of 500 mL were prepared and reference solutions of 1-butanol, shown in **Table 2**, were placed into them. The volume of each solution was 200 mL and the top of the flask was covered with aluminum foil. The panel members gently shook flasks to ensure equilibrium and sniffed one by one to memorize odour intensity impressions. After taking a break of 3 minutes, the panel members sniffed 1-butanol sample solutions in PE bottles and judged odour intensity according to the 1-butanol reference scale. Three sample solutions with a concentration of 10, 600 and 2600 ppm, which correspond to odour intensity level of 1, 2 and 3, respectively, were presented. A total of 20 panel members joined the experiment. Odour intensity was evaluated 5 times repeatedly for each sample.

3.2. Odour intensity measurement of hydrogen sulfide

Odour intensity of hydrogen sulfide was measured to investigate the applicability of PE bottles for the evaluation of typical odorous substance. Six PE bottles were prepared and reference solutions of 1-butanol, shown in **Table 2**, were placed into them. The volume of each solution was 200 mL and the top of the bottle was tightly capped. The panel members gently shook bottles to ensure equilibrium and sniffed one by one to memorize odour intensity impressions. After taking a break of 3 minutes, the panel members sniffed diluted hydrogen sulfide in polyethylene terephthalate bags and judged odour intensity according to the 1-butanol reference scale. Four hydrogen sulfide samples with a concentration of 0.006, 0.02, 0.06 and 0.2 ppm were presented. A total of 20 panel members joined the experiment. Odour intensity was evaluated 5 times repeatedly for each sample.

4. Results and discussion

4.1. Comparative odour intensity measurement using Erlenmeyer flasks and PE bottles

Figure 2 depicts odour intensities of three 1-butanol sample solutions presented in PE bottles. Mean odour intensities of five repetitions were 0.9, 2.3 and 3.1 for sample solutions of intensity level 1, 2 and 3, respectively. Mean odour intensities at fifth repetition were 0.8, 2.3 and 3.1. The percentages of panel members who replied correct odour intensity at fifth repetition were 30%, 40% and 40% for sample solutions of intensity level 1, 2 and 3, respectively. These results suggest that PE bottles can be substituted for Erlenmeyer flasks as containers for 1-butanol reference solutions, especially in the middle intensity level. Lower percentage of correct reply at low intensity level might be caused by indistinct odour perception.

Mean standard deviations of five repetitions were 0.68, 0.77 and 0.62 for sample solutions of intensity level 1, 2 and 3, respectively. Standard deviations at fifth repetition were, however, 0.57, 0.64 and 0.55. These results imply that the variation in odour intensity evaluation tend to be reduced with the increase of repetition.

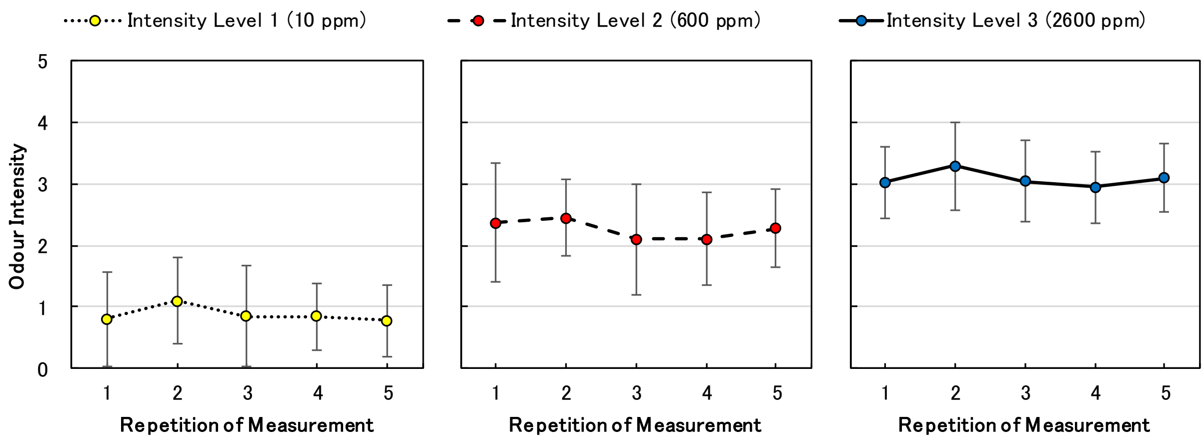

Figure 2. Odour intensities of three 1-butanol sample solutions in PE bottles
Circles and bars represent mean values and standard deviations, respectively.

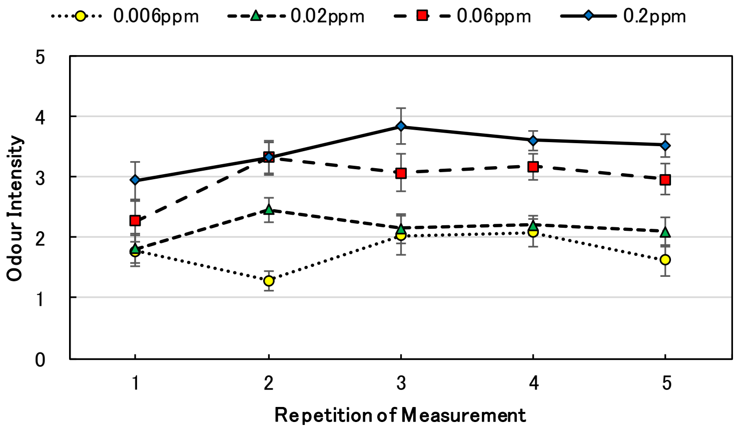

Figure 3. Odour intensities of four hydrogen sulfide samples

Circles and bars represent mean values and standard errors, respectively.

4.2. Odour intensity measurement of hydrogen sulfide

Figure 3 shows odour intensities of four hydrogen sulfide samples. Mean odour intensities at fifth repetition were 1.6, 2.1, 3.0 and 3.5 for samples with a concentration of 0.006, 0.02, 0.06 and 0.2 ppm, respectively. Standard errors at fifth repetition were 0.25, 0.25, 0.26 and 0.19. The variation of mean odour intensity over five repetitions was greater than that of 1-butanol solutions shown in **Figure 2**. These results suggest that, when 1-butanol solutions are used as reference odours, odour intensity evaluation of different odorous substances is accompanied by greater variation. Mean odour intensities are, however, relatively discriminable.

5. Conclusions

In this study, PE bottles were selected as containers for 1-butanol odour intensity reference solutions for convenience in on-site handling. Effectiveness of PE bottles were inspected based on comparative odour intensity measurements using Erlenmeyer flasks and PE bottles. The results suggested that PE bottles could be substituted for Erlenmeyer flasks as containers for 1-butanol reference solutions, especially in the middle intensity level. Applicability of PE bottles for odour intensity measurement of hydrogen sulfide was also investigated. As a result, mean odour intensities of hydrogen sulfide were relatively discriminable although odour intensity evaluation was accompanied by greater variation than that of 1-butanol solutions. In conclusion, the effectiveness of PE bottles as containers for 1-butanol odour intensity reference solutions was suggested. A comparative investigation on the reliability of odour intensity measurement between the method proposed in this study and other methods adopted in the world would be necessary in future.

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