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A Collaborative Approach between Japan and China for Implementing Interlaboratory Evaluation of Olfactometry

Takaya Higuchi [1,*], Weifang Li [2], Jing Geng [2], Gen Wang [2] and Kumiko Shigeoka [3]

[1] Graduate School of Sciences and Technology for Innovation, Yamaguchi University, 2-16-1, Tokiwadai, Ube, Yamaguchi 755-8611, Japan
[2] State Environmental Protection Key Laboratory of Odor Pollution Control, Tianjin Academy of Environmental Sciences, No.17, Fukang Road, Nankai District, Tianjin 300191, China
[3] Japan Association on Odor Environment, Shinyou-building 11F, 2-14-2, Takadanobaba, Shinjuku-ku, Tokyo 169-0075, Japan
* Correspondence: takaya@yamaguchi-u.ac.jp

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Abstract: Odor measurement is a crucial element of odor management and regulation. This paper introduced a collaborative implementation of interlaboratory evaluation of olfactometry between Japan and China. An international comparison of olfactometry using the triangular odor bag method was carried out for the first time between Japan and China in 2018. A total of 134 olfactometry laboratories (130 Japanese and 4 Chinese) participated in the test, and the odor index of the test odorant (dimethyl disulfide with a concentration of 10.7 ppm) was measured three times at each laboratory. In the interlaboratory evaluation, a reference value and repeatability and reproducibility standard deviations were determined on the basis of measurement results of 13 'excellent qualified laboratories' designated by the Japan Association on Odor Environment. Evaluation results of trueness and precision of the 133 laboratories that conducted duplicate or triplicate measurements showed that 110 (108 Japanese and 2 Chinese) and 104 (102 Japanese and 2 Chinese) laboratories (82.7% and 78.2%) conformed to the criterion of trueness and precision, respectively, and 87 (86 Japanese and 1 Chinese) laboratories (65.4%) conformed to both. Based on the meaningful experiences in 2018, a continuous international collaboration between Japan and China in the field of olfactometry should be implemented for the improvement of the quality of olfactometry laboratories and the reliability of odor measurement in both countries.

Keywords: triangular odor bag method; odor index; interlaboratory evaluation; excellent qualified laboratory; trueness; precision; dimethyl disulfide

1. Introduction

Odor is a sensory response to the inhalation of air containing chemical substances. Since our sense of smell and emotional response to it are affected by life experience, living environment and physiological conditions, people may have different sensations and emotional responses to the same odorous compounds [1]. Odors discharged from various human activities could cause annoyance and severe damage to residents. Although odor emissions may not lead to direct health-related problems, they can affect the quality of life, which in turn can lead to indirect problems such as nausea, headache, and psychological stress [1,2].

Since odor measurement is a crucial element of odor management and regulation, it is necessary to develop a reliable odor measurement method. Environmental odors consist of a wide variety of odorous compounds. This is the reason why a comprehensive evaluation of odors using the human sense of smell as well as instrumental analysis of individual chemicals is indispensable [3].

Odor regulation based on the 'odor index,' a sensory index of odor determined by the triangular odor bag method (TOBM), was introduced in the Offensive Odor Control Law in 1995 in Japan [4]. The odor index is the logarithm of odor concentration, multiplied by ten. Odor concentration is the dilution ratio when odorous air is diluted by odor-free air until the odor becomes unperceivable. TOBM was first developed by the Tokyo metropolitan government in 1972 [5,6] and notified by the Japan Environment Agency in 1995 [7]. It is a static air dilution method, and the measurement is made in a three-fold dilution descending series. In the TOBM, three odor bags are filled with odor-free air, and odorous air is injected into one of them until a given dilution ratio is obtained. A panel member sniffs three odor bags and chooses one bag that is likely to contain odorous air. The dilution is continued until it becomes impossible for all the panel members to identify the bag with odorous air. Then, the odor concentration and odor index are calculated [8].

After the introduction of odor regulation based on the odor index, problems related to the interpretation of measurement results have been reported by the municipalities. For instance, the odor index measured by a municipality differs from that measured by an odor emitting facility, and that makes the administration of legislative measures difficult. Therefore, the development of a quality control system for olfactometry and the standardization of the measurement procedure has become necessary, especially in the 2000s. In 2000 and 2001, an interlaboratory comparison of olfactometry using the TOBM was carried out, and a quality control procedure for olfactometry was established in Japan [9,10]. Since 2002, nationwide interlaboratory evaluation of olfactometry has been carried out using different kinds of odorants [11–14].

TOBM has been introduced into other Asian countries, including South Korea and China [15]. In China, odor concentrations determined by the TOBM have been adopted as one of odor regulation items for the emission source and the site boundary. The rapid urbanization in recent years caused a large number of odor issues in China, and the significance of quality control for olfactometry has been recognized. In 2018, an international comparison of olfactometry was carried out for the first time between Japan and China. This paper introduces a collaborative implementation of interlaboratory evaluation of olfactometry between Japan and China and discusses the results.

2. Materials and Methods

2.1. Interlaboratory Evaluation Test

In 2018, a total of 134 olfactometry laboratories (130 Japanese and 4 Chinese) participated in the interlaboratory evaluation test. A small-sized gas cylinder filled with dimethyl disulfide at a concentration of 10.7 ppm was delivered to laboratories. Regarding Chinese laboratories, gas cylinders prepared in Japan were handed by Japanese delegates at the conference held in Beijing, China to Chinese counterparts in November 2018, and delivered to 4 laboratories. In Japan, the test was organized by the Japan Association on Odor Environment (JAOE), and the entry for the test was open to all the motivated laboratories. On the other hand, only 4 representative laboratories joined in China since this was the first collaborative trial between both countries and the number of gas cylinders provided by the JAOE was limited. Dimethyl disulfide was used as an odorant in the test since it is one of the typical offensive odors and stable for a required period at a given concentration level in a gas cylinder. The odor index was measured three times consecutively in a day at each laboratory in accordance with the official procedure of the TOBM.

2.2. Data Analysis

Statistical data of the test odor, including a reference value and repeatability and reproducibility standard deviations, were calculated using measurement results of 'excellent qualified laboratories' [14] in accordance with JIS Z 8402-2 [16]. An excellent qualified laboratory is examined by the Judging

Committee in the JAOE from the perspective of measurement accuracy in the past five years. In the interlaboratory evaluation test in 2018, excellent qualified laboratories that had renewed their registration over two consecutive periods of validity (10 years), as of December 2018, were chosen. Then, laboratories that carried out three consecutive measurements (triplicate measurements) of the odor index in a day in the interlaboratory evaluation test in 2018, led by an operator who had 100 or more olfactometry experiences per year, were chosen. On the basis of the measurement results of these laboratories, a reference value and repeatability and reproducibility standard deviations were determined, and an interlaboratory evaluation of olfactometry, including trueness and precision, was conducted in accordance with JIS Z 8402-6 [17].

3. Results and Discussion

3.1. Odor Index and Statistical Data of Excellent Qualified Laboratories

There were 16 laboratories that had renewed their registration as excellent qualified laboratories over two consecutive periods of validity, as of December 2018. Among them, 13 laboratories carried out triplicate measurements of the odor index in one day in the interlaboratory evaluation test in 2018, led by an operator who had 100 or more olfactometry experiences per year. The odor index and its mean values and standard deviations of 13 laboratories are shown in Table 1. The mean value of all the odor index data was 42.1. On the basis of odor index data in Table 1, a reference value and repeatability and reproducibility standard deviations were determined in accordance with the calculation procedure designated in JIS Z 8402-2 [16]. As a result, a reference value was calculated to be 42.1, and repeatability and reproducibility standard deviations were 0.825 and 3.07, respectively. Then, the maximum permissible level of the standard deviation and the permissible range of the mean value in triplicate odor index measurements were calculated to be 1.4 and 42.1 ± 6.0, respectively, in accordance with JIS Z 8402-6 [17].

Table 1. Odor index (triplicate measurement results) and its mean values and standard deviations (SD) of 13 laboratories.

Laboratory	Odor Index			Mean *	SD *
A	45	44	44	44.1	0.722
B	45	45	45	44.9	0.000
C	45	44	45	44.5	0.722
D	36	37	37	37.0	0.722
E	44	42	44	43.2	0.722
F	41	40	41	40.7	0.722
G	42	42	45	43.2	1.44
H	37	36	35	36.2	1.25
I	44	44	45	44.1	0.722
J	40	41	41	40.7	0.722
K	41	41	41	41.2	0.000
L	47	46	45	46.2	1.25
M	41	41	41	41.2	0.000
Mean *				42.1	0.692
SD *				2.99	

* Mean value and SD were calculated using odor index before rounding to the integer.

3.2. Distribution of Mean Odor Index

The distribution of the mean odor index of 134 laboratories is depicted in Figure 1. Among 134 laboratories, 3 Japanese laboratories conducted duplicate odor index measurements and one Chinese laboratory conducted a single measurement. The remaining 130 laboratories (127 Japanese and 3 Chinese) conducted triplicate measurements. The minimum and the maximum values were 31.2 and 50.7, respectively. The mean value was 40.3, which was close to the reference value (42.1). On the other hand, the standard deviation was 3.81, which was larger than the reproducibility standard deviation (3.07).

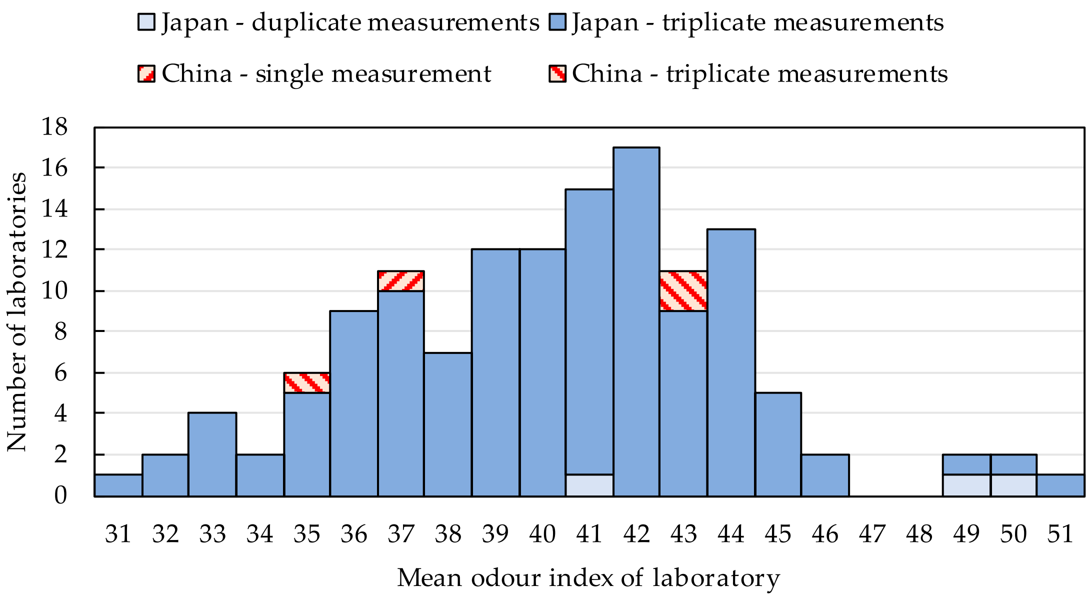

Figure 1. Distribution of mean odor index of 134 laboratories.

3.3. Evaluation of Trueness and Precision

On the basis of the abovementioned reference value, and repeatability and reproducibility standard deviations, measurement results of 133 laboratories with duplicate or triplicate odor index measurements were evaluated, including trueness and precision, in accordance with JIS Z 8402-6 [17]. One Chinese laboratory with a single odor index measurement was excluded because the evaluation of precision was unfeasible. The evaluation results of trueness and precision of 133 laboratories are summarized in Table 2. As mentioned in Section 3.1, the maximum permissible level of the standard deviation and the permissible range of the mean value in triplicate odor index measurements were 1.4 and 42.1 ± 6.0, respectively. Therefore, a laboratory with the standard deviation of 1.4 or less was concluded to be conformable to the criterion of precision, and that with the mean value within 42.1 ± 6.0 was concluded to be conformable to the criterion of trueness. Among 133 laboratories, 110 (108 Japanese and 2 Chinese), and 104 (102 Japanese and 2 Chinese) laboratories (82.7% and 78.2%) conformed to the criterion of trueness and precision, respectively, and 87 (86 Japanese and 1 Chinese) laboratories (65.4%) conformed to both.

Table 2. The evaluation results of trueness and precision of 133 laboratories with duplicate or triplicate odor index measurements.

		Trueness		**Total**
		Conformable	**Unconformable**	
Precision	Conformable	87 (65.4%) Japan: 86 China: 1	17 (12.8%) Japan: 16 China: 1	104 (78.2%) Japan: 102 China: 2
	Unconformable	23 (17.3%) Japan: 22 China: 1	6 (4.5%) Japan: 6 China: 0	29 (21.8%) Japan: 28 China: 1
Total		110 (82.7%) Japan: 108 China: 2	23 (17.3%) Japan: 22 China: 1	133 (100.0%) Japan: 130 China: 3

4. Conclusions

In 2018, an international comparison of olfactometry using the TOBM was carried out for the first time between Japan and China. Evaluation results of trueness and precision of 133 laboratories showed that 110 (108 Japanese and 2 Chinese) and 104 (102 Japanese and 2 Chinese) laboratories (82.7% and 78.2%) conformed to the criterion of trueness and precision, respectively, and 87 (86 Japanese and 1 Chinese) laboratories (65.4%) conformed to both. In China, only four representative laboratories participated in the test, which implied an insufficiency of the generality. The development of a nationwide quality control system is an essential factor for reliable odor measurement. Furthermore, understanding and interpreting the distribution of widespread interlaboratory evaluation data are indispensable to recognize the present situation and to solve the problems. Based on the meaningful experiences in 2018, a continuous international collaboration between Japan and China in the field of olfactometry should be implemented for the improvement of the quality of olfactometry laboratories and the reliability of odor measurement in both countries.

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