Prospects for Development of Simplified Evaluation Methods used in Odor Management

Masahiro Osako
National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki Pref. 305-8506, Japan
Tel +81-298-50-2835 Fax +81-298-50-2830 E-mail mosako@nies.go.jp

1. Introduction

As the functional requirements for odor evaluation methods differ according to the application purpose, not only is the selection of an adequate evaluation method important but so is its application to the corresponding purpose to appropriately conduct odor management. In this paper, odor evaluation methods were first divided and categorized according to the technical functions and application purposes. Emphasis was placed on the importance of “simplification” of the evaluation method to efficiently carry out odor management. Finally, it was proposed that an application concept using simplified odor evaluation methods, such as odor sensor systems including electric noses, detection tubes and basic olfactory measurements, should be designed to cost-effectively control odor problems.

2. Categories of odor evaluation methods

Odor evaluation methods could be categorized from various standpoints. In Japan, a typical category consists of instrumental and sensory methods, as shown in Fig. 1. The category for instrumental (machinery) methods includes gas chromatography (GC), gas chromatography/mass spectrometer (GC/MS), detection tube, devices for monitoring a specified constituent, and odor sensors. The latter three instrumental methods are regarded as simplified methods.

In the sensory, or olfactory, methods there is the triangular odor bag method as a legally designated method for regulation, the dynamic olfactometer as a standardized method in Europe and the subjectively direct indication for rating odor intensity or hedonic tone.

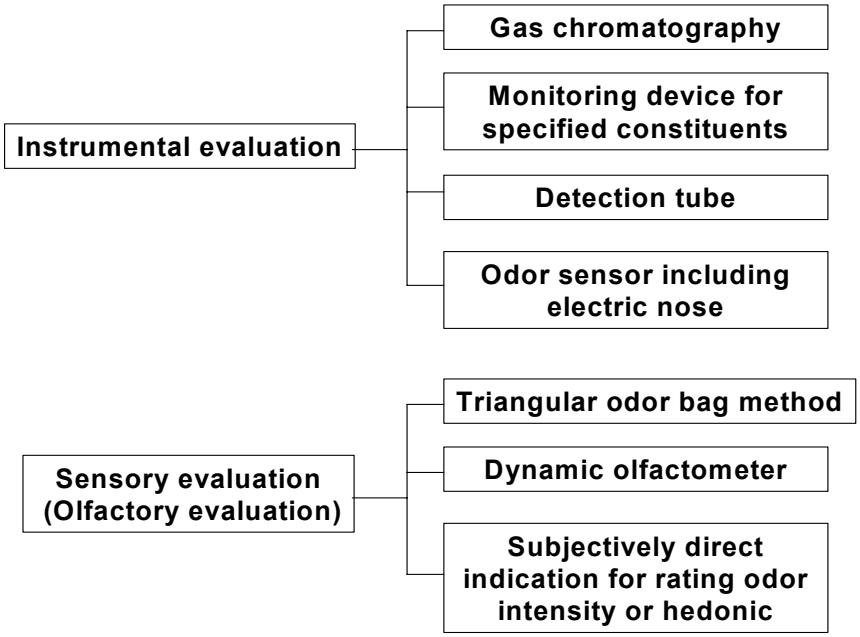

Figure 1 General categorization for odor evaluation methods

The sense of odor involves three principal factors: concentration of odorous substances, sensory odor intensity and odor quality including hedonic tone. Thus, the odor evaluation method can be categorized from these three aspects as shown in Table 1.

Table 1 Categorization of odor evaluation methods from the viewpoint of indicator objectives

Objective of indicator	Higher accuracy ⇔ Lower accuracy	
	Legally obligatory method	Simplified evaluation method
Concentration of individual constituent	Gas chromatography	Detection tube Monitoring device for specified constituents
Odor index, odor unit and odor intensity	Triangular odor bag method	Simplified olfactory methods Odor sensor including electric nose Sensory direct indication for odor intensity
Odor quality including hedonic tone		Sensory direct indication for odor hedonic tone Electric nose

On the other hand, it is possible to divide odor evaluation methods into three categories, as shown in Table 2, from the viewpoint of application purpose. According to Table 1, the three categories are legal evaluation for compliance, evaluation for voluntary management and evaluation for characterization of odor emission source. It

is understandable that in each category, the requirements associated with accuracy and cost are different depending upon the application purpose. Therefore, a unified method that does not relate to the purpose should not be applied. We should have the rationality to select/utilize an evaluation method suitable to the purpose.

Table 2 Categorization of odor evaluation methods from the viewpoint of application purposes

Category	Outline	Examples of the evaluation method
Evaluation for compliance	Obligatory method based on the law. Necessary to ensure sufficient accuracy for judgment in legal action. Generally expensive method.	Triangular odor bag method, dynamic olfactometer, gas chromatography, etc.
Evaluation for voluntary management	Not obligatory. Use in voluntary management. Easier and cheaper methods are better. Highly accurate methods are not always necessary. Highly frequent monitoring is possible.	Detection tube, odor sensor, subjectively direct rating for intensity or hedonic tone, etc.
Evaluation for characterization of odor emission source	Characterization of time-dependent change of odor emission from the odor source, detailed composition of odorous constituents and contribution of constituents to sensory magnitude of odor.	Continuous monitoring using odor sensor, GC-olfactometer, GC/MS, electric nose

3. International movement on odor evaluation methods

In Japan, the instrumental method using GC was legally adopted due to concentration standards for regulation against individual constituents in complex odors, based on the Offensive Odor Control Law. It was confirmed, however, that the impact of complex odors could not be controlled using the individual constituent concentration as an indicator to reproduce the actual phenomena. Therefore, in 1995 additional regulation standards based on an “odor index” evaluated by olfactory measurement called “triangular odor bag method” was set up. In addition, the Ministry of the Environment recently carried out offensive odor controls emphasizing the odor index regulation.

On the other hand, from the beginning, European countries have conversely taken greater account of odor evaluation by the olfactory method using the dynamic olfactometer, and have adopted the “odor unit” as a standard unit corresponding to the so-called “odor concentration” in Japan. Standardization of the dynamic olfactometer method was recently accomplished in CEN.

The olfactory method would have a higher cost to ensure higher accuracy whereas it is the better method for reproducing the actual impact caused by complex odors.

Therefore, while the olfactory method is a basis of odor evaluation, odor emission control using odorous constituents as “reference odors” that correlate to the odor unit specified at each emission source, is performed for easy and cost-efficient management. For instance, at the sewage treatment plant hydrogen sulfide (H_2S) has been applied as a reference odor in order to control the emission. In addition, the feasibility of applying a kind of simplified monitoring system using plural sensors called “electric noses” has been studied in the field of odor control and so on.
In summary, simplification is progressing in order to attain a low-cost method, whereas olfactory evaluation has become a basis in the strategy for odor control, according to recent international trends.

4. Simplified evaluation method as a tool for odor control

In the future field of odor control, various evaluation methods from highly accurate to simplified measurements should be developed and applied according to the respective objectives. Administrative or academic authorities should propose not only a framework for the evaluation strategy but also details of the application program, including how to use various methods concretely. Figure 2 illustrates an example of a program for monitoring the odor emission source, consisting of the odor sensor method as a simplified evaluation and the olfactory method as an evaluation for compliance. This efficient program allows the highest level of control to be accomplished.
In 2000, the Japanese Odor Research and Engineering Association (JOREA) established the “Research Group for Standardization of Simplified Odor Evaluation Technologies”. The objective of the research activities is to standardize the required functions of simplified evaluation technology, the functional items to be indicated, the testing methods for them and the application program. An application manual based on the research results will be published in 2003.

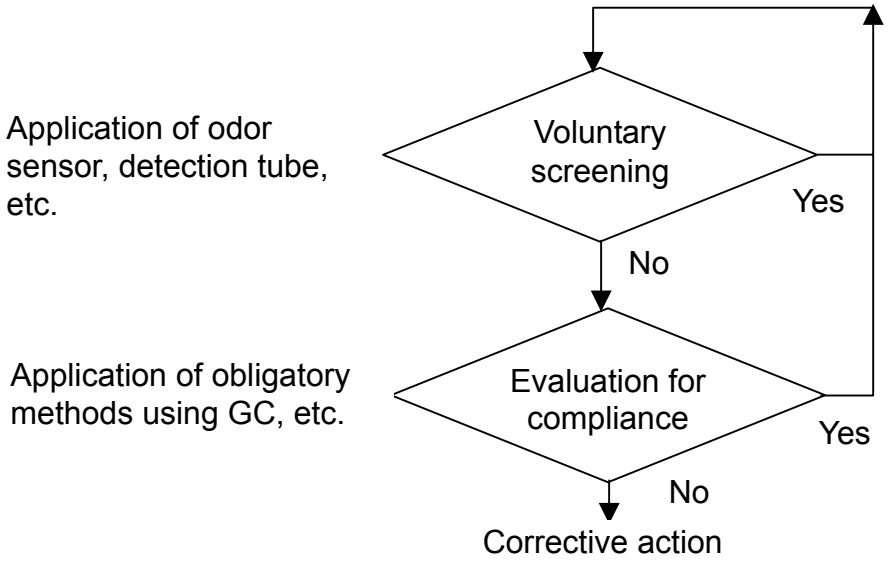

Figure 2 An example of a program for monitoring odor emission source

5. Manual to promote the application of simplified odor evaluation technologies

JOREA is producing a manual to promote the application of simplified odor evaluation technologies. One of the most important items included in the manual contents will be the standardization of testing methods for the basic functions of evaluation technologies in addition to the determination of functional items to be commonly indicated on the products. Another item emphasized in the manual will be the set-up of criteria used to judge the validity of their use in actual application.

According to the tentative manual, the functional items to be commonly indicated on the product in the case of the odor sensor, including the odor recognition device (the so-called electric nose), are shown in Tables 3 and 4. Furthermore, standardization of an appropriate method to measure each item is ongoing.

Table 3 Examples of functional items to be indicated in odor sensors

Indicating item	Detailed item	
Functional indicators	Minimum detectable limit (sensitivity)	
	Maximum measurable concentration	
	Measurable range	
	Response characteristics	Response rate
		Recovery rate
		Standard time required to reach stable state
Confident indicators (accuracy)	Reproducibility	Simultaneously repeated reproducibility
		Reproducibility within a day
		Reproducibility between different days
	Dependence on temperature/humidity	Temperature
		Humidity
	Interfering gaseous substances	Positive interference
		Negative interference
	Influence of gas pressure	
Durable indicators	Range of measurable temperature	
	Range of measurable humidity	
	Influence of corrosive gas	
	Influence of gas causing other deterioration	
	Lifetime of sensor	
	Durable time for continuous use	

Table 4 Examples of functional items to be indicated in odor recognition device (electric nose)

Functional, confident and durable indicators
Range of measurable concentration, Minimum detectable limit, Recognition ability, Measurement time, Interval time between measurements, Reproducibility within a day, Influence of humidity and temperature, etc.

On the other hand, the criteria used to judge whether or not the use of the evaluation method in actual application is valid should be set up to ensure nationwide use. According to the tentative manual, the following criteria are proposed for application of the odor sensor to prediction of the odor index.

Standard error of predicted value, based on the correlation equation (calibration equation) between indicated values by the sensor and measured odor index values for the odor index should be within ±5 in unit scale of the odor index.

6. Simplification of olfactory measurement method

In the triangular odor bag method formally adopted in Japan, not only are more than six subjects needed for a panel, but more or less odor bags are also consumed, and the expense becomes higher. However, application of such an accurate and expensive method is not always necessary for voluntary monitoring and thus reduction of the cost by simplification of the triangular odor bag method should be accomplished, even if the accuracy somewhat deteriorates.

JOREA has been developing simplified olfactory methods capable of estimating the odor index. Presently, two types of methods using odor bags are tentatively proposed in the manual. They are the 6-4 selection and the 2-1 selection method. Both methods allow remarkably reduced expense. An outline of the procedures are described below.

(1) 6-4 selection method

In this method, two subjects are used. In the first step, six odor bags comprising two controls (non-odorous) and four steps of dilution ratio, are provided together for each subject. The four steps consist of the four odor bags prepared by gradually diluting the original sample odor by the three-times series (for instance, dilution ratios of 100, 300, 1,000 and 3,000). Thereafter, the two subjects select four bags with odor quality of the sample from the six bags provided. If the odor bag with the lowest dilution ratio is selected in addition to one or more wrong bags, the test is finished and then the threshold for the subject can be calculated. In the case of selecting all correct bags, the next four higher steps of dilution ratio are prepared, and in the case of not selecting the lowest dilution ratio (starting dilution ratio), the reverse four lower steps are prepared. For further clarification, an example associated with the results obtained from a subject's selection and the subject's threshold calculated as a logarithmic mean value is shown in Table 5.

Table 5 An example of the results obtained by the 6-4 selection method

No. of odor bag	1	2	3	4	5	6
Dilution ratio	100	No odor	1000	300	No odor	3000
Selection (answer)	○			○	○	○
Calculation of Individual threshold	(log300 + log1000)/2 = 2.74					

(2) 2-1 selection method

In this method, two subjects are needed and one odorous bag from a pair of prepared bags is chosen by each subject. The dilution is performed by the three-times series. Namely, the procedure is similar to the triangular odor bag method with the exception of the number of odor bags and the subject.

The research group on simplified odor evaluation in JOREA has investigated availability of these two methods through application to sample odors taken at actual odor sources. The results show the correlation between the triangular odor bag test and the above two simplified methods, as illustrated in Figure 3. There are good correlations between both. Results obtained from these two simplified methods seem somewhat higher than the triangular bag method. Incidental correct answers are assumed to affect this tendency.

As for the accuracy and time consumption of these two methods, the simplified methods could shorten the measurement time to half of that needed for the triangular odor bag method. However, according to a report by JOREA (2002), their accuracy was somewhat lower than the triangular method in a comparative examination using ethyl acetate as a standard substance.

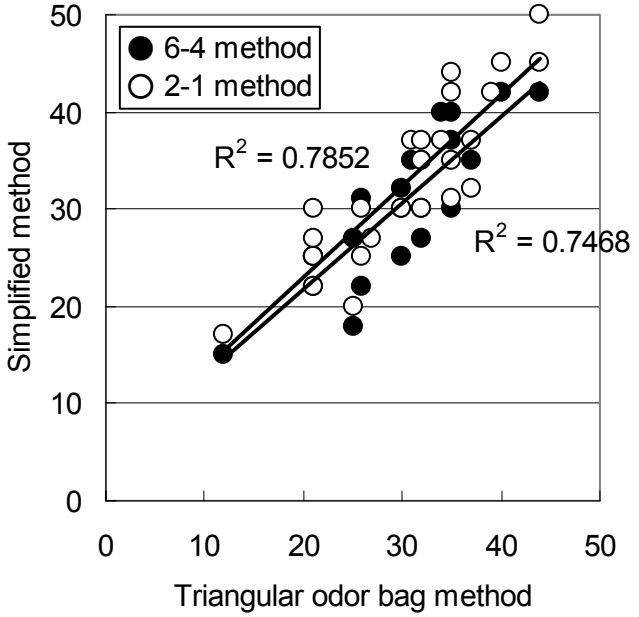

Figure 3 Correlation in the odor index between the triangular odor bag and the simplified method.

7. Concluding remarks

Offensive odor causes a sensory nuisance that results in resident's complaints, albeit without physical damage in most cases. In that sense, offensive odor control to prevent complaints is the most substantial purpose given to our task. In this case, highly frequent monitoring using a simplified and rapid evaluation method with lower expense has more advantages for reliable control than the legally specified method with higher expense.

JOREA is presently carrying out work to complete their manual as soon as possible. Through the manual, it is expected that the proper method for simplified odor evaluation would be widely used.

I would like to express my great respect for the research activities of the Research Group for Standardization of Simplified Odor Evaluation Technologies in JOREA.

References

1) Research Group for Standardization of Simplified Odor Evaluation Technologies in JOREA: A tentative manual
2) JOREA: Final report of Investigation on quality control and safety management in olfactory measurement methods (2002)