Selection of appropriate chamber and introduction of comparative sources in normative sensory evaluation method for building products in Japan

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SUMMARY

It is important to establish an evaluation method for odors emitted from building products for good perceived air quality. In Japan, there is no normative evaluation method, so we aimed to establish a quantitative and normative evaluation method on odor emissions from building products. As the first step, we compared a 20-L chamber and a CLIMPAQ chamber to select an appropriate small-chamber for sampling odorous emissions (Experiment 1) and found no significant difference of odor index of the gaseous emissions sampled between the two chambers. We also manufactured a device to train members of a panel to evaluate the perceived intensity of building product odor by comparing the intensity of acetone, and developed a suitable panel training method (Experiment 2). Applying this method, each acetone-air-mixture concentration level was found to be stable over time with little deviation (within ±10 mg/m³) and most panelists were able to evaluate each acetone level with a 90% confidence interval.

IMPLICATIONS

This study involves the first known experiment of training panel for evaluating the perceived intensity of building products in Japan.

KEYWORDS

Perceived air quality, building material odor, perceived intensity, panel test, emission test, sensory measurements

INTRODUCTION

Various odors are present in indoor air, caused by emissions from people-related, activity-related and building material-related odor sources. These odors may affect the productivity and comfort of occupants. Therefore, it is important to evaluate and control indoor odors in order to achieve good indoor air quality (IAQ).

Some studies have been carried out on the measurement of odor quality in an odor space (Berglund et al., 2002, 2009). Building materials, in particular, may release odors that are related to odorous chemical compounds. These building material odors have the potential to adversely affect perceived air quality (PAQ). In Europe, in order to reduce this potential for contamination, odors emitted from building materials have been evaluated by the Chamber for Laboratory Investigations of Materials, Pollution and Air Quality (CLIMPAQ) using sensory measurements (Sakr et al., 2003; Gunnarsen et al., 1994).

In addition, an ISO draft on evaluating building material odor has been proposed and is under investigation. In the ISO draft, perceived intensity and acceptability are suggested factors for
the evaluation standard. In particular, perceived intensity is a parameter used to assess intensity based on a comparable scale. As smelling capability varies from person to person, the use of comparative sources, in which all panel members evaluate the sample air in comparison to the same references, reduces the influence of subjective perception of the test results. The intensity of odorous substances in the air is decided by comparing them with different specified intensities of the reference substance acetone (15 different mixes of acetone concentrations in the range between 20 mg/m³ [0 pi] and 320 mg/m³ [15 pi]). A panel needs to be trained on the comparative scale of perceived odor intensity as a function of the reference concentrations.

On the other hand, in Japan, the triangular odor bag method, which is the standard method specified by the Offensive Odor Control Law, is normally used for sensory evaluation testing. Yamanaka used this method to evaluate the odors emitted from building materials (Yamanaka et al., 2009). However, there is no normative evaluation method for evaluating building material odor in Japan.

We aimed at establishing a quantitative and normative evaluation method on odor emissions from building products. As the first step, we compared a 20-L chamber and a CLIMPAQ chamber to select an appropriate small-chamber for sampling odorous emissions (Experiment 1). We also manufactured a device to train panel members to evaluate the perceived intensity of building product odor by comparing the intensity of acetone, and developed a suitable panel training method (Experiment 2).

**METHODS**

In the Experiment 1, a 20-L chamber and a CLIMPAQ chamber (1005mm×250mm×220mm) were used for the emission test. A polyvinyl chloride (PVC) flooring was used as a test material. Area specific air flow rate was 1.3 m³/h·m². The air exchange rate, air temperature and relative humidity of the chamber were adjusted at 0.5 times per hour, 23±0.5 °C and 50±5, respectively. Clean air was provided via an oil-free compressor and mass-flow controller using silica gel as a drying agent and activated carbon for volatile organic compound (VOC) absorption. Some of the drying air was passed through pure water for humidification.

After 3 days from the beginning of the emission test, the gaseous emissions were measured by sampling 2 L (sampling rate: 100 ml/min) of air through Tenax TA and Carboxen 1000 absorbent, with the qualitative analysis performed using GC-FID. In addition, a 5-L odor bag including the gaseous emissions was evaluated by Fragrance & Flavor Analyzer (SHIMADZU, Odor identification apparatus FF-2020). This analyzer is a smell identification device, like human sensory evaluation, by which the “quality” and “strength” of smell can be expressed.

In the current study, the odor index, which is the logarithm of the dilution rate at which the panel can no longer sense any odor in the sampling odor bag, multiplied by 10 (odor index = 10×log (Dilution Rate)), was investigated by this device.

In the Experiment 2, Our manufactured acetone gas dilution and distribution (AGDD) device for training panel members to evaluate the perceived intensity of building product odor by comparing the intensity of acetone, which is composed of a supply air distribution unit, source of acetone and dosing device (Müller et al., 2008), was set in the center of the floor of a large test chamber. A vertical plug flow is applied in the large test chamber with a volume of 19.7 m³ (2.7 m × 2.7 m × 2.7 m) whose internal surfaces and ventilation ducts are made of electro-
polished stainless steel. The ventilation system includes a supply opening over the entire floor surface and an exhaust opening across the entire ceiling. Coarse, medium and high efficiency particulate air filters and chemical filters for gaseous materials are incorporated into the clean supply system. The air exchange rate, air temperature and relative humidity of the chamber were adjusted at 7 times per hour, 24±0.5 ºC and 50±5, respectively.

Before the panel training, the basic performance of the AGDD device, e.g. the stability of air velocity and acetone concentration in each diffuser, was confirmed. And in order to select panelists with normal olfactory function, each panelist was screened using five standard dilution liquids developed by Takagi et al. in 1972 in Japan. Any panelist who identified correctly all five standard odorants was deemed to have passed the panel screening test. Four men and six women participated in the panel training as panelists.

The training consists of five training days. The training schedule is shown in Table 1. Panel training was carried out in the large test chamber as shown in Fig. 2. Each acetone sample was provided by the AGDD device. A fresh air sample and a building material odor were sampled in 3-L bags using the emission test system shown in Fig. 3. In case of building material odor, tatami, which is a traditional Japanese flooring material, was used as a test material. Area specific air flow rate was 1.3 m³/h·m². The air exchange rate, air temperature and relative humidity of the chamber were adjusted at 0.5 times per hour, 23±0.5 ºC and 50±5, respectively.

RESULTS
In the experiment 1, the identified major chemical compounds were phenol, n-decane, 1-hexanol 2-ethyl. The odor index investigated by the Fragrance & Flavor Analyzer was 16.7 (in case of 20-L chamber), 16.4 (in case of CLIMPAQ chamber). This result indicates that there was no significant difference in the odor intensity of PVC sampled from the 20-L chamber and the CLIMPAQ chamber.

Table 1. Training schedule: A~J indicate each panel. (EX: Exercises, EV: Evaluation)

<table>
<thead>
<tr>
<th>Training Day</th>
<th>Objective</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>EX, EV</td>
<td>Two acetone samples (in EX), four acetone samples (in EV)</td>
</tr>
<tr>
<td>Day 2</td>
<td>EX, EV</td>
<td>Six acetone samples</td>
</tr>
<tr>
<td>Day 3</td>
<td>EV</td>
<td>Four acetone samples, one fresh air sample (Sample A), one building material odor (Sample B)</td>
</tr>
<tr>
<td>Day 4</td>
<td>EV</td>
<td>One building material odor (Sample B)</td>
</tr>
</tbody>
</table>

Figure 2. Test chamber and AGDD device.  Figure 3. Emission test system using the CLIMPAQ chamber.
In the experiment 2, the air velocity and air flow at each diffuser of the AGDD device. The averaged velocity and air flow were 0.51 m/s and 0.85 l/s. During the period of the panel training, the air temperature and relative humidity of the large test chamber were about 26 °C and 50%, respectively. The average air temperature in the cooling device of the AGDD device was about 19 °C.

When the preset perceived intensities from the each diffuser of AGDD were presented to each panel member, each panel member smelled them and reported a perceived intensity (pi). The measured pi values of the panel members were plotted in a diagram as shown in Fig. 4. The tolerance field of pi values was calculated for the target 90% confidence interval. The area between the dotted lines represents the core area. The area between the dotted lines and the continuous lines is the rim area. Finally the area external to the continuous lines is the outside area. The results of the tolerance field of pi values indicate that the number of panel members who have low performance in discriminating different acetone concentration decreased over time. This tendency can be confirmed in Fig. 5, which presents the evaluation variability of panel members on each training day.

The average perceived intensity value of tatami was about 13.5 pi on the 4th and 5th training day. After 1 week (after 8 days from the beginning of the emission test) and 3 weeks (after 22 days from the beginning of the emission test) from finishing training, the average perceived intensities of tatami decreased and were 10.5 pi and 9.2 pi, respectively.

![Figure 4](image-url)
DISCUSSION
In the experiment 1, it is necessary to confirm the odor index using sensory measurements. In the experiment 2, the average perceived intensity of tatami decreased over time, one reason for this is that the emission rate of chemical compounds from tatami decreased over time. However, there was no significant decline between 1 week and 3 weeks in the 95% confidence interval shown in Fig. 6. Therefore, further investigation is required to confirm the correlation between the emission rate of chemical compounds and perceived intensity. In addition, it is necessary to confirm how long the precision of the trained panel’s olfactory sense is valid.

Figure 5. Box and whisper diagram showing the evaluation variability of each panel member on each training day. The central box represents the values from the lower to upper quartile (25 to 75 percentile). The middle line represents the median. The horizontal line extends from the minimum to the maximum value. The means are plotted as black circles (●). A indicates a fresh air sample. B indicates a building material odor.

Figure 6. Temporal changes in each perceived intensity on building materials
CONCLUSION
Emission tests for PVC floorings were performed in each test chamber. After 3 days, the gaseous emissions were sampled in 3-L sampling bags and then analyzed by a fragrance & flavor analyzer. As a result, there was no significant difference of odor index of the gaseous emissions sampled from the two different chambers. We investigated whether concentrations of acetone (15 different mixes of acetone concentrations in the range between 20 mg/m³ [0 pi] and 320 mg/m³ [15 pi]) emitted from six diffusers of the device were well controlled. Ten persons participated in the training as panelists. They were trained on the comparative scale of perceived odor intensity using this device for 5 days. During this period, we investigated whether they could make accurate reproducible measurements with a small standard deviation. As a result, each acetone- air-mixture concentration level was stable over time with little deviation (within ±10 mg/m³). And, each panelist could evaluate each acetone level with 90% confidence interval through the training. Also, tatami odor was evaluated by trained panel members. The average perceived intensity value of tatami was about 13.5 pi (after 2 days from the beginning of the emission test). Further investigation is required to confirm the perceived intensity of various materials and the correlation between the perceived intensity and the odor intensity suggested by triangular odor bag method in Japan.

REFERENCES