



Evaluation of NO₂ sorption of cedar wood (*Cryptomeria Japonica*) with difference of the specimen size and contact condition between NO₂ gas and specimen using new test system

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Abstract

We developed a new system for measuring the NO₂ sorption ability of Japanese cedar (*Cryptomeria japonica*) wood by referring to Japanese Industrial Standard for JIS R 1701-1 (Test method for air purification performance of photocatalytic materials, Japanese Standard Association, Tokyo, 2004). Aeration experiments were conducted using plated specimen, particle specimen, discoid specimen and wood powder with consideration of aeration condition and surface area which can contact with NO₂ gas. In the plated specimen, the NO₂ sorption ability was greatly affected by the thickness of longitudinal direction, and high NO₂ sorption ability of the transverse section was observed within a thickness range from the surface to ca. 3 mm. The average NO₂ sorption volume for discoid specimen for 5 h was approx. five times larger than that those for the plated and particle specimens, which the thickness of longitudinal direction was 1.5 mm. This means that the NO₂ sorption effect was especially high under the condition where the NO₂ gas passed through tracheid. Also, it was suggested that the interface area between NO₂ gas and specimen influenced to the NO₂ sorption ability. Furthermore, it was confirmed that the NO₂ sorption volume in discoid specimen and the grain size below 0.25–0.50 mm of wood powder reached the greatest.

Keywords Japanese cedar wood · Nitrogen dioxide (NO₂) sorption · Interface area · Tracheid

Introduction

Nitrogen dioxide (NO₂) is identified as a criteria air pollutant and affects human health, particularly the lungs and breathing passages. NO₂ concentration is especially high in urban areas [1]. In these areas, there are concerns about influences to the human body because of infiltration of outside air into

buildings and increasing of the indoor NO₂ concentration. Therefore, it is important to remove the indoor NO₂ for the comfortable and healthy living space.

As representative materials for NO₂ removal, it is known that activated carbon, photocatalyst and terpenes such as γ -terpinene and β -phellandrene from leaf oil have a high NO₂ sorption ability [2–6]. However, use of these materials is limited by the problems of time-consuming production, decline in function depending on the weather and time, and waste liquid and residue disposal. On the other hand, use of wooden materials is much less limited than these materials.

As an example, it has been observed that inside wooden buildings such as the Shosoin of Todai-ji temple, NO₂ concentration was lower than in the outside air, and that the NO₂ sorption ability of cedar wood (*Cryptomeria japonica*) was particularly high [7, 8]. The sorption ability of NO₂ by cedar wood has been a subject of great interest [9, 10]. The NO₂ sorption ability of cedar wood is particularly high in the heartwood and transverse section interfaces, and moisture in the cell walls also has an effect. It has been shown in this context that heartwood extractives, structural features of tissue, and moisture content of cedar wood are major

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contributing factors to NO₂ sorption [11]. When the influence of structural features of tissue is focused, in previous studies, NO₂ sorption ability was measured under only one condition which the NO₂ flows over the surface of transverse section in accordance with Japanese Industrial Standard for “Test method for air purification performance of photocatalytic materials” (JIS R 1701-1) [12] and the size of all specimens was 50 (radial) × 100 (tangential) × 15 (longitudinal) mm. This system was developed for photocatalytic materials, which are homogeneous materials, and the NO₂ sorption ability is evaluated by the sorption volume per surface area. However, the system is not fully satisfied for the evaluation of non-uniform and porous materials such as wood. In addition, NO₂ sorption ability of sawdust was measured with the other different systems [9]. Therefore, the influence of structural features of tissue in NO₂ sorption of cedar wood has not been evaluated comprehensively yet.

In this study, we developed the new system by referring to JIS R 1701-1 [12]. This newly developed system enables us to evaluate the NO₂ sorption ability of materials of various configurations and porous structure. Considering the structural features of tissue of cedar wood, NO₂ aeration experiments were conducted in the condition of not only flowing over the surface of transverse section but also passing through in the longitudinal direction and flowing on the surface of the specimen. There were also conducted with different grain sizes and lengths of longitudinal direction. Based on the obtained results, we tried to discuss the NO₂ sorption ability with different specimen sizes and contact condition between NO₂ gas and specimen.

Materials and methods

Materials

Cedar (*Cryptomeria japonica*) heartwoods harvested in Osaka Prefecture and Kumamoto Prefecture in Japan were used as materials. These woods were roughly 40 years old and natural-dried. In this study, specimens with four types, namely plated specimen (a) and particle specimen (b), discoid specimen (c), wood powder (d), were used as shown in Fig. 1. These specimens were prepared in consideration of the directional property of wood and the contact condition between NO₂ gas and each specimen. The (a) and (c) were prepared from a cedar wood harvested in Kumamoto Prefecture and the (b) and (d) were prepared from a cedar wood harvested in Osaka Prefecture. In the plated (a) and discoid (c) specimens, the proportion of late wood was 18.2% and the mean annual ring width was 4.51 mm. The plated specimens (a) were prepared three kinds of thickness in longitudinal direction, namely 1.5, 3.0 and 5.0 mm with the length of radial direction of 50 mm, and the tangential

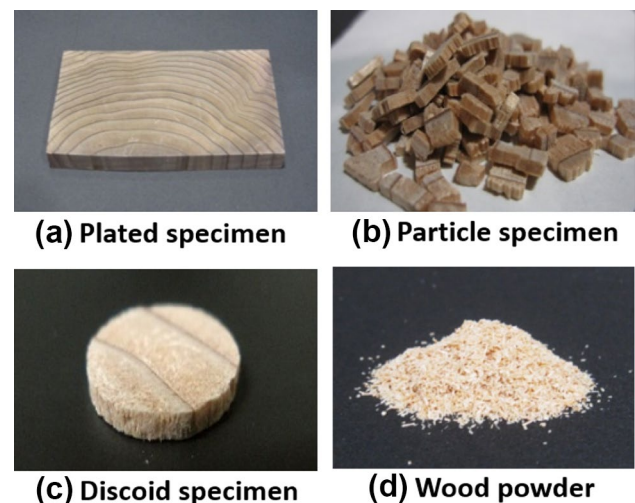


Fig. 1 Photo of each typical specimen. **a** The length of radial direction is 50 mm, tangential direction is 100 mm, and the thickness of longitudinal direction is 1.5, 3.0 and 5.0 mm. **b** The thickness of longitudinal direction is 1.5, 3.0 and 5.0 mm. **c** The thickness of longitudinal direction is 1.5 mm and the diameter is 10 mm. **d** Grain size is 0.020–0.075, 0.075–0.150, 0.15–0.25, 0.25–0.50 and 0.50–1.00 mm

direction of 100 mm. The 5.0-mm-thick specimen is the same size used in JIS R 1701-1 [12]. The particle specimens (b) were prepared by the disintegration of the plated specimens (a) with three thicknesses in longitudinal direction, thus the particle specimens provide the thicknesses, namely 1.5, 3.0 and 5.0 mm. In the discoid specimens (c), thickness of longitudinal direction was 1.5 mm and the diameter was 10 mm. The wood powders (d) were prepared five grain sizes, namely 0.020–0.075, 0.075–0.150, 0.15–0.25, 0.25–0.50 and 0.50–1.00 mm. The length of longitudinal direction in wood powder is shorter than 1.5 mm because these were made by a 1.5-mm-thick specimen in longitudinal direction. It was reported that the conditions of temperature and humidity are influenced to the NO₂ sorption capability [9, 10]. In a reference to experiments conducted by Tsujino et al. [9], all specimens were conditioned for at least 3 weeks in a desiccator at 20 °C and 56% relative humidity, and the moisture content of the specimens was adjusted to 10 ± 1% (w/w). Each density of specimen harvested in Osaka and Kumamoto Prefecture after conditioning was 0.48 and 0.49 g/cm³, respectively.

Setting of specimens

Four instruments were prepared for the specimens. Each plated specimen (Fig. 1a) was inserted into a folder by reference to JIS R 1701-1 [12] as shown in Fig. 2a. In this case, the air containing NO₂ (NO₂ gas) flows over the surface of transverse section in the same way as the previous

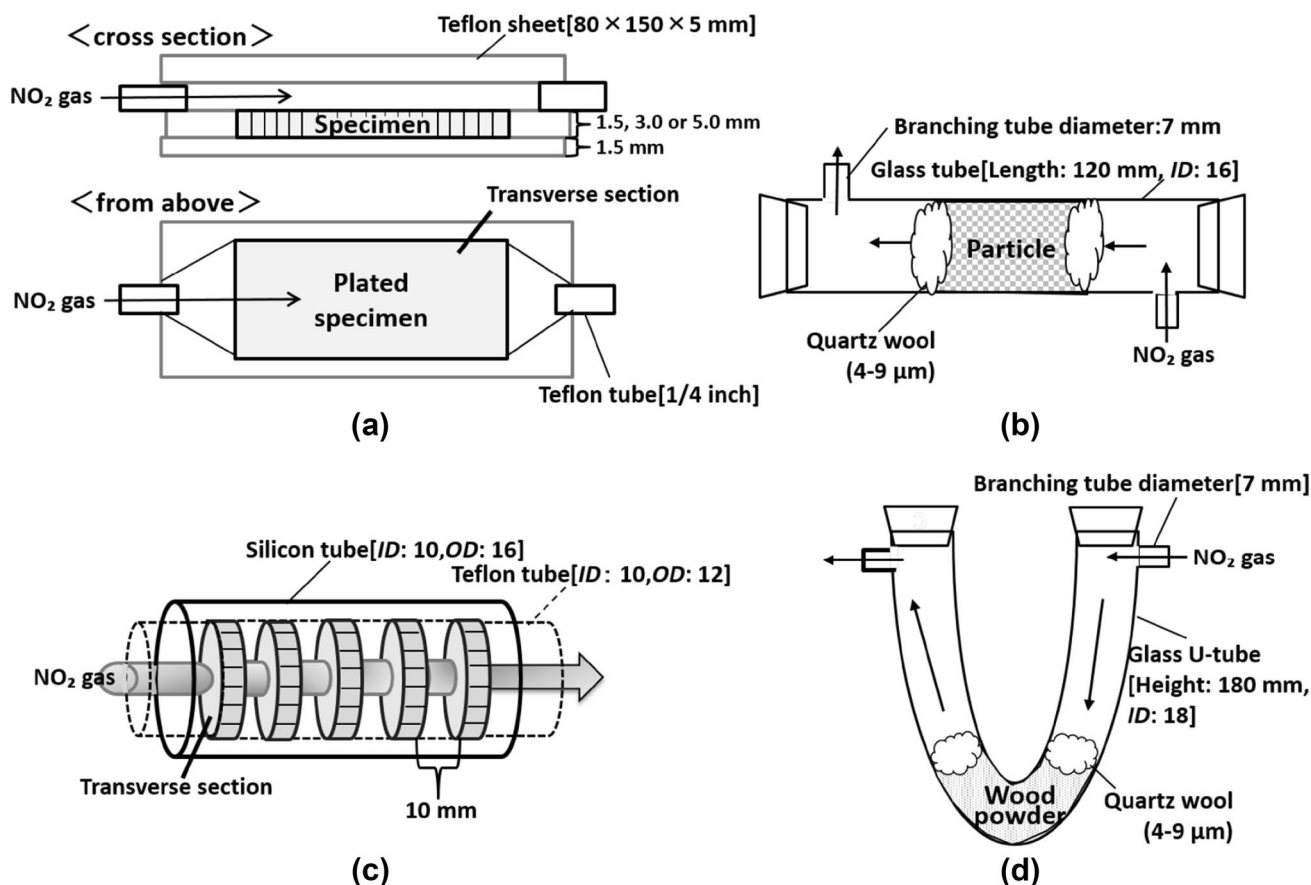


Fig. 2 The structure of instruments for plated specimen (a), particle specimen (b), discoid specimen (c) and wood powder (d). ID internal diameter (mm), OD outside diameter (mm)

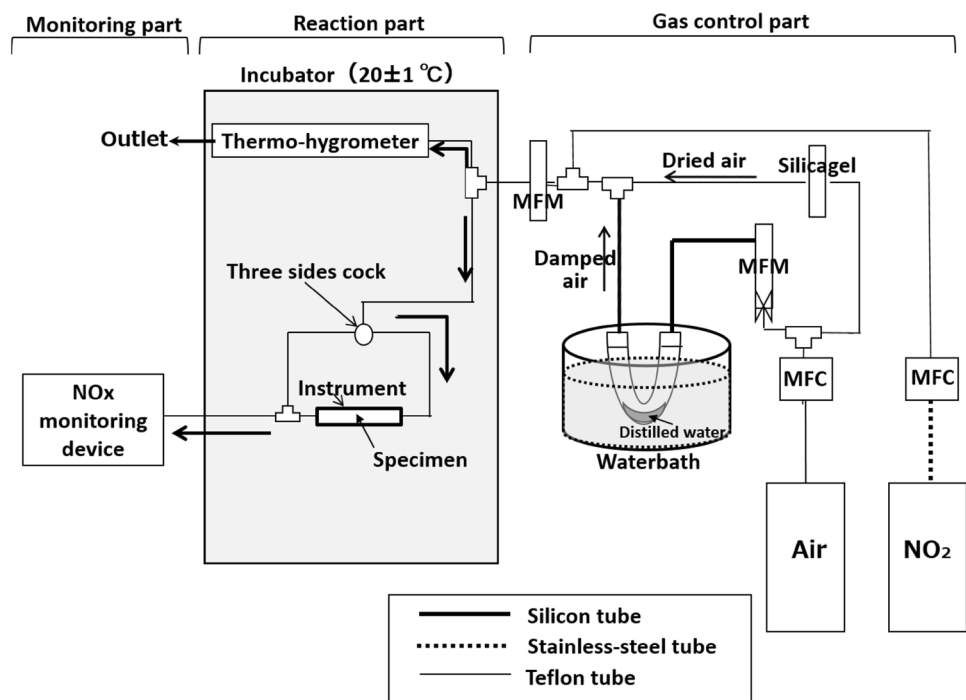
study [11]. In the particle specimen (Fig. 1b), a glass tube was used as shown in Fig. 2b. The glass tube was filled with 1.0 g of particle specimens. In this case, the NO₂ gas flows over the surface of each particle specimen regardless of the three sections. For the discoid specimens (Fig. 1c), a silicone tube, with an internal diameter of 10 mm and outside diameter of 16 mm, was used as shown in Fig. 2c. Five specimens were inserted vertically at intervals of 10 mm inside the tube based on the preliminary experiment. In this case, the NO₂ gas passes through the longitudinal direction. For wood powder specimens (Fig. 1d), a glass U-tube and glass tube were used as shown in Fig. 2b, d. The glass U-tube was filled with 0.5 g of wood powder with grain sizes of 0.15–0.25 mm or less. The glass tube was filled with 1.0 g of wood powder with grain sizes of 0.25–0.50 mm or more. To prevent the specimen from scattering, both ends of glass tube and glass U-tube were packed with quartz wool. In these cases, the tissue structure of the powder specimens was broken and the NO₂ flows over the surface of specimen regardless of the three sections.

NO₂ sorption test

Apparatus

Figure 3 shows a new system developed for NO₂ sorption measurement. This system was constructed by referring to the system in JIS R 1701-1 [12] and comprises a gas control part for controlling humidity and NO₂ concentration, a reaction part for reacting the adjusted NO₂ and the specimen, and a monitoring part for monitoring the nitrogen oxides (NO_x) concentration after passing through the specimen. This system enabled to conduct and evaluate the aeration experiments in each specimen which the thickness and shape are different from the specimen used in JIS R 1701-1 [12] by changing the instrument (Fig. 2). Room temperature was adjusted to 20 ± 5.0 °C using an air-conditioner. Simulated research air composed of nitrogen and oxygen, the volume ratio of 4 to 1, was used to prevent contamination with other pollutants. It was controlled to a relative humidity of $58 \pm 5.0\%$ by mixing damped air

Fig. 3 Experimental system for NO₂ sorption test. MFC means the mass flow controller which control flow rate. MFM means the mass flow meter which monitor flow rate



and dry air. Because relative humidity is sensitive to temperature change, the U-tube for generating damped air was soaked into a water bath set to 20 °C. NO₂ concentration was adjusted to 1000 ppb by diluting simulated research air with pure NO₂ gas. This NO₂ concentration was adjusted by reference to the similar experiments conducted by Kawai et al. [11]. The flow rate of NO₂ gas was adjusted from 560 to 600 ml/min to obtain a constant gas flow, which is also different from the system in JIS R 1701-1 [12].

The reaction between wood specimen and NO₂ was performed in an incubator set to 20 ± 1.0 °C. NO₂ gas with the flow rate of 560 ml/min was passed through each instrument shown in Fig. 2 in which the specimens shown in Fig. 1 were set, and the remaining NO₂ gas was exhausted after measuring the temperature and humidity with a thermo-hygrometer. After passing through the instrument, the NO₂ concentration of the NO₂ gas was monitored using an automatic NO_x monitoring device (NA-721, Kimoto Electric Co., Ltd., Osaka, Japan). The concentration of nitric oxide (NO), generated due to the reaction between NO₂ and water [13], was also monitored.

The validity of this system was verified by flowing the 1000 ppb NO₂ gas into a U-tube packed only with quartz wool. The results showed that the concentration change of NO₂ was within 3%, and NO was not detected. Therefore, it was confirmed that NO₂ sorption test could be carried out using this system.

Evaluation method of NO₂ sorption ability

The variation over time in NO₂ concentration after passing through the specimen was monitored. The NO₂ sorption volume at each aeration time Q (μmol) was calculated using Eq. (1). The total NO₂ sorption volume at aeration time Q_{NO_2} (μmol) was calculated using Eq. (2). The average NO₂ concentration monitored with the instrument, before and after the experiment of each specimen, was taken to be the reference value for NO₂ concentration.

$$Q = ([\text{NO}_2]_0 - [\text{NO}_2]) \times 10^{-9} \times \frac{f}{22.4} \times 10^6, \quad (1)$$

$$Q_{\text{NO}_2} = \int \left\{ ([\text{NO}_2]_0 - [\text{NO}_2]) \times 10^{-9} \times \frac{f}{22.4} \times 10^6 \right\} dt, \quad (2)$$

where $[\text{NO}_2]_0$ is the reference value of NO₂ concentration (ppb), $[\text{NO}_2]$ is the NO₂ concentration after passing through the specimen (ppb), f is the NO₂ flow rate (560 ml/min), and 22.4 is the volume (l) of 1 mol of the gas in the standard state, t is the aeration time.

In this experimental system, moisture exists in air and in the specimen. Therefore, some amount of NO might be generated by the reaction between NO₂ and water [13]. The NO₂ being consumed by this reaction is not absorbed to the wood. Considering this, the NO generation volume G_{NO} (μmol) was calculated using Eq. (3), and the actual volume of NO₂

sorption to the specimen was calculated using Eq. (4). These equations referred to JIS R 1701-1 [12].

$$G_{\text{NO}} = \int \left\{ [\text{NO}] \times 10^{-9} \times \frac{f}{22.4} \times 10^6 \right\} dt, \quad (3)$$

$$Q_{\text{sor}} = Q_{\text{NO}_2} - G_{\text{NO}}, \quad (4)$$

where $[\text{NO}]$ is NO concentration (ppb) after passing through the specimen.

Using Eqs. (5) and (6), the NO_2 sorption volume per unit weight $Q_{W_{\text{sor}}}$ ($\mu\text{mol/g/h}$) and per unit transverse section area $Q_{A_{\text{sor}}}$ ($\mu\text{mol/cm}^2/\text{h}$) in a unit aeration time were calculated from the NO_2 sorption volume Q_{sor} calculated with Eq. (4).

$$Q_{W_{\text{sor}}} = \frac{Q_{\text{sor}}}{W \times T}, \quad (5)$$

$$Q_{A_{\text{sor}}} = \frac{Q_{\text{sor}}}{A \times T}, \quad (6)$$

where W is the specimen weight (g), A is the transverse section area (cm^2) and T is the total aeration time (h). $Q_{W_{\text{sor}}}$ was used for all specimens and $Q_{A_{\text{sor}}}$ was used for plated and discoid specimens.

Measurement of specific surface area

To elucidate the relationship between specific surface area and NO_2 sorption volume, specific surface area was measured for three types of wood powder (0.02–0.075, 0.075–0.15 and 0.15–0.25 mm). Nitrogen (N_2) adsorption isotherms on the specimens were determined at -196°C using a specific surface area and porosimetry instrument (ASAP2020, Micromeritics Instrument Corp., GA, United States of America). Specimen volume was set to 9 cm^3 . The specific surface area (m^2/g) was calculated from the isotherm data using the Brunauer, Emmet and Teller (BET) model, and dividing by the weight of the specimen used for measurement [14].

Data analysis

For the NO_2 sorption volume, values were obtained for 5 h conforming to JIS R 1701-1 [12] and 24 h for observing behavior over the long term, and then each value was taken to be the average of three trials. For the obtained results, an unpaired t test or one-way analysis of variance (ANOVA) was conducted as a test of differences between conditions. If a significant difference was found as a result of analysis of variance, then a multiple comparison test was conducted

using Tukey HSD. In all cases, the value of significance probability was 5%.

Results and discussion

The influence of thickness in longitudinal direction

Figure 4 shows the variation over time in NO_2 sorption volume of plated specimen with different thicknesses in the longitudinal direction. The order of NO_2 sorption volume after passing through each plated specimen was $5.0 > 3.0 > 1.5\text{ mm}$. Although there was a gentle and stable decrease after the initial stage, there was no major change in NO_2 sorption volume. The behavior which the NO_2 sorption volume was high at the initial stage and then gradually decreased was confirmed to be almost the same qualitatively as in previous research using plated specimen and sawdust [9, 11]. In JIS R 1701-1 [12], NO_2 sorption ability is evaluated in 5 h only but we confirmed that NO_2 sorption continued for 24 h without major quantitative change after that in this study. The other specimen also showed quite similar variation although each NO_2 sorption volume was different. Therefore, the following discussion of the NO_2 sorption volume was on the results in 5 h.

Figure 5 shows the average NO_2 sorption volume per unit time and transverse section area for plated specimens with different thicknesses in the longitudinal direction. The average NO_2 sorption volume increased as thickness in the longitudinal direction increased. To evaluate the influence of thickness of longitudinal direction on NO_2 sorption volume, one-way ANOVA was performed. The results showed significant differences between thicknesses ($p = 0.008$), which suggests that the reaction interface between NO_2 and wood specimens is not just the apparent surface of the specimens but the internal surface area along the tracheid. Multiple comparisons showed that the sorption volume for

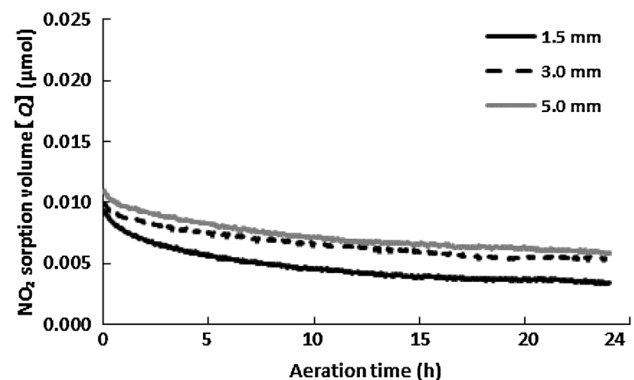


Fig. 4 Variation over time in NO_2 sorption volume, Q of plated specimen with different thicknesses of longitudinal direction. ($n = 3$)

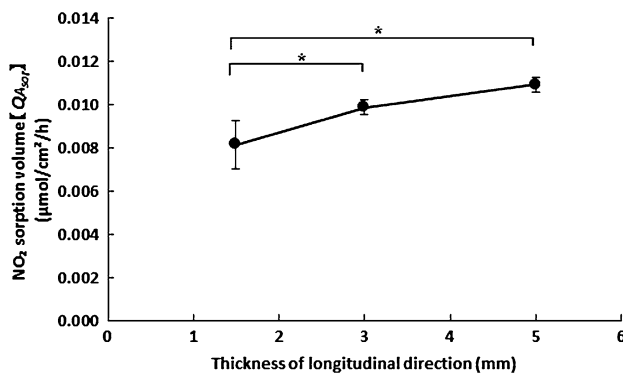


Fig. 5 NO_2 sorption volume per unit transverse section area and time, $Q_{A_{sor}}$ in plated specimen which is different thickness of longitudinal direction. The error bars show standard deviation ($n=3$). *: $p < 0.05$ (Tukey HSD method)

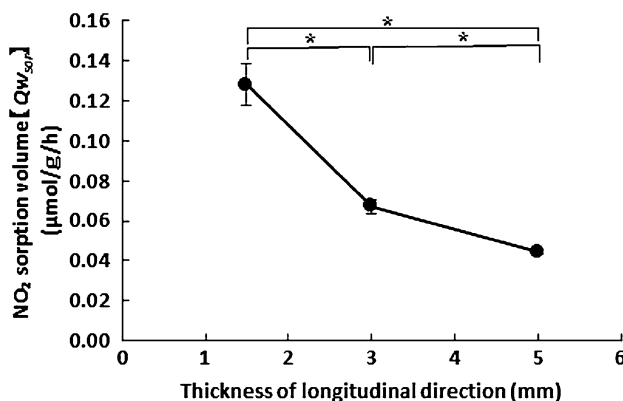


Fig. 6 NO_2 sorption volume per unit weight and time, $Q_{W_{sor}}$ in plated specimen which is different thickness of longitudinal direction. The error bars show standard deviation ($n=3$). *: $p < 0.05$ (Tukey HSD method)

1.5-mm-thick specimen was significantly less than for 3.0- and 5.0-mm-thick specimens, but no significant difference was evident between 3.0- and 5.0-mm-thick specimens. In previous study using concrete coated with photocatalyst under the system by referring to JIS R 1701-1 [12], the NO_x including NO_2 removal volume per unit surface area and time in 12 h showed approx. $0.04 \mu\text{mol}/\text{cm}^2/\text{h}$ [15]. Although the aeration time in previous study was different from that in this study, we compared these values as reference. As a result, the value in previous study is 5 times higher than that of plated specimen in the result of this study. In JIS R 1701-1 [12], the NO_2 sorption ability is evaluated by the sorption volume per surface area because the photocatalytic materials provide the surface coated with photocatalyst in a thin layer. However, the results shown in Fig. 5 indicated the influence of thickness of longitudinal direction in NO_2 sorption volume of cedar wood. Then we tried to calculate NO_2 sorption volume

per unit time and weight to evaluate the influence of the thickness of specimen. The results are shown in Fig. 6.

Figure 6 shows the average NO_2 sorption volume per unit time and weight. The average NO_2 sorption volume decreased as the specimen thickness in the longitudinal direction increased. One-way ANOVA showed a significant difference between thicknesses ($p < 0.001$). Multiple comparisons showed significant differences between all thicknesses. Although specimens with thickness of 1.5 and 3.0 mm had the same volume per unit weight, NO_2 sorption volume of 1.5-mm-thick specimen was $0.130 \mu\text{mol}/\text{g}/\text{h}$, which showed about twice as much as that of 3.0-mm-thick specimen ($0.067 \mu\text{mol}/\text{g}/\text{h}$). Furthermore, it showed about three times as much as that of 5.0-mm-thick specimen ($0.045 \mu\text{mol}/\text{g}/\text{h}$). These results indicate that NO_2 sorption volume in the plated specimen had a correlation with the length of longitudinal direction. These also mean that the sorption effect was greater closer to the surface of the transverse section.

Based on the results of Figs. 5 and 6, the average NO_2 sorption volume varied depending on differences in thickness in the longitudinal direction, for both unit transverse section area and weight at a given time. Whereas significant difference was evident between 1.5- and 3.0-mm-thick specimens evaluated using either method, there was no significant difference between 3.0- and 5.0-mm-thick specimens, and the difference in sorption values between these specimens were extremely small, $\sim 0.01 \mu\text{mol}$. This implied that the NO_2 sorption effect is high in a range of ~ 3 mm from the surface of the transverse section. This was almost same average length to the cedar tracheid [16], thus it was suggested that the interface between tracheid and air plays a larger role in NO_2 sorption. Furthermore, it seemed that the NO_2 sorption of cedar wood should be evaluated with the sorption volume unit per weight.

Effect of aeration condition on NO_2 sorption ability

The wood has directional property because of its tissue structure. Considering it, NO_2 sorption ability would be affected by the aeration condition. We tried to evaluate the influence of tissue structure by comparing the average NO_2 sorption volume per unit time and weight among plated specimen, particle and discoid specimen with a thickness in longitudinal direction of 1.5 mm. The aeration condition, which means contact condition between NO_2 and surface of specimen, of each specimen was different. The results are shown in Fig. 7 which is expressed the sorption volume per unit weight and time. The average NO_2 sorption volumes for discoid specimens for 5 h were 5.24 times values for the plated and particle specimens, and were significantly

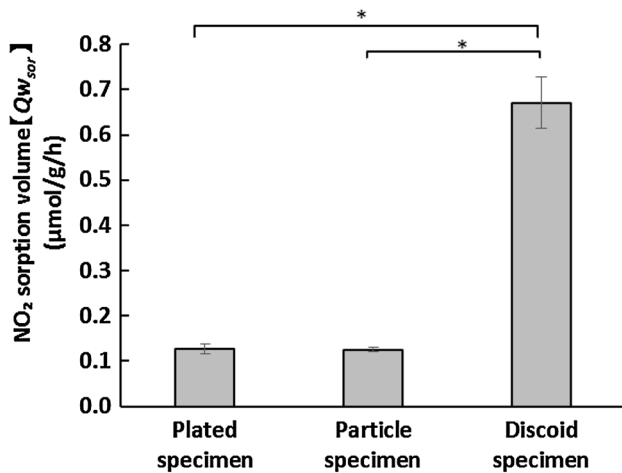


Fig. 7 NO₂ sorption volume per unit weight and time, $Q_{w_{sor}}$ in plated, particle and discoid specimen with the 1.5 mm thick of longitudinal direction. The error bars show standard deviation ($n=3$). *: $p < 0.05$ (Tukey HSD method)

larger ($p < 0.001$). It is thought that NO₂ sorption volume is greatly affected by gas permeability. Generally, gas permeability in the longitudinal direction is much higher than that in the tangential or radial direction [17]. It is conjectured that the diffusion rate of NO₂ gas in discoid specimen was higher than that in the other specimen. Therefore, it was easier for the NO₂ gas to contact with extractives, the surface of the tracheid and the moisture which contributed to the NO₂ sorption ability. We expected that NO₂ sorption volume of particle specimen is larger than that of plated specimen because the surface area of particle specimen which can contact with the NO₂ is larger than that of plated specimen due to NO₂ flows on the surface regardless of the section under the aeration condition in particle specimen. However, NO₂ sorption volume of particle and plated specimen was 0.126 and 0.128 μmol/g/h, respectively, and almost same volume. Considered of this result, we need to consider of interface area between NO₂ and specimen and the effect of the surface in each aeration condition more in detail. In particle and plated specimen, the NO₂ sorption volume per unit time and weight of the specimen which the length of longitudinal direction is 1.5, 3.0 and 5.0 mm, was compared. The results are shown in Fig. 8. NO₂ sorption volume of 1.5-mm-thickness in plated and particle specimens was 0.128 and 0.126 μmol/g/h, respectively, and no significant difference was observed. It seemed to be related to that the effect of NO₂ sorption was greater closer to the surface of the transverse section as we suggested in Fig. 6. However, in 3.0- and 5.0-mm-thick specimens, the NO₂ sorption volume of particle specimen was 1.7 and 2.3 times significantly larger than that of plated specimen, respectively ($p < 0.05$). It seemed that the influence of length of longitudinal direction was small in particle specimen. It is considered that the

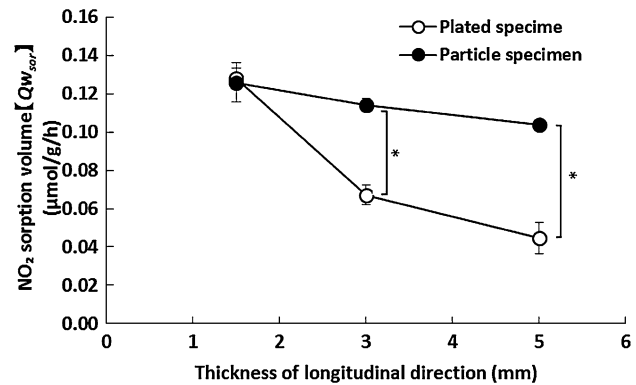


Fig. 8 NO₂ sorption volume per unit weight and time, $Q_{w_{sor}}$ in plated and particle specimen. The error bars show standard deviation ($n=3$). *: $p < 0.05$ (unpaired t test)

particle specimen contacted with NO₂ regardless of the three sections of specimen, therefore, the interface area of particle specimen was larger than that of plated specimen and the structure of tracheid did not have a big role in the aeration condition of particle specimen. However, these need to be more considered in detail to clarify the mechanism of NO₂ sorption in the interface between NO₂ and specimen.

NO₂ sorption ability of wood powder with different grain sizes

The length of longitudinal direction of wood powder is shorter than 1.5 mm as described in the section of Materials, and it was expected that the tissue structure of wood was broken. By comparing wood powder with different grain sizes, we tried to evaluate the influence of the interface

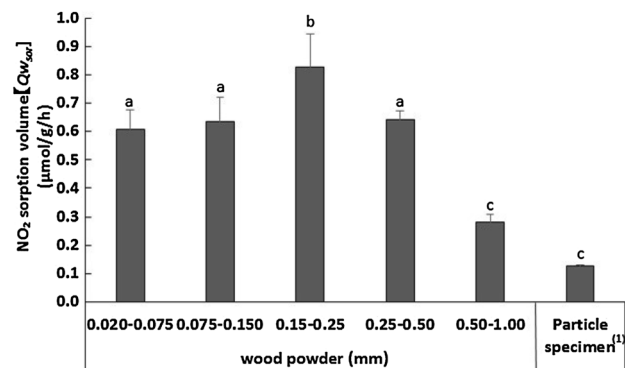


Fig. 9 NO₂ sorption volume per unit weight and time, $Q_{w_{sor}}$ in wood powder with different grain sizes and particle specimens of 1.5 mm thick of longitudinal specimen. The error bars show standard deviation ($n=3$). The symbols with different letters indicate significantly different [$p < 0.05$, (Tukey HSD method)]. (1) The thickness of longitudinal direction is 1.5 mm

area in NO₂ sorption. The results were shown in Fig. 9. The result of 1.5-mm-thick particle specimen was also shown in the figure. With grain sizes larger than 0.15–0.25 mm including the 1.5-mm-thick particle specimen, sorption volume increased as grain size decreased. It was suggested that the interface area which was influenced to the ability was larger as grain size decreased. With grain sizes below 0.15–0.25 mm, it decreased to almost the same values (~0.6 µmol/g/h), regardless of grain size. One-way ANOVA did not show a significant difference between 0.020–0.075 and 0.075–0.150 mm. To evaluate the influence of interface area in more detail, the relationship between NO₂ sorption volume per unit weight and time and the specific surface area below 0.15–0.25 mm of wood powder was compared. The specific surface area in three wood powder grain sizes varies between 1.27 and 1.65 m²/g. However, one-way ANOVA did not show a significant difference between grain sizes. There was no correlation between specific surface area and NO₂ sorption volume. The NO₂ sorption per unit weight and time in discoid specimen was 0.67 µmol/g/h as shown in Fig. 7 and One-way ANOVA including the value of discoid specimen did not show a significant difference between discoid specimen and the wood powder below 0.25–0.50 mm grain size. It was speculated that the NO₂ sorption ability reached its greatest at the grain sizes below 0.25–0.50 mm. Based on the above results, especially in the wood powder below 0.25–0.50 mm grain size and discoid specimen, it would be necessary to elucidate with consideration of the pore size and microstructure in more detail. Also, we will examine the influence of temperature and moisture content as a next step.

Conclusions

We developed a new system to measure the NO₂ sorption under the various conditions and evaluated the NO₂ sorption ability of cedar wood in different specimen sizes and gas contact conditions. Conclusions were summarized below.

1. When the NO₂ gas flew over the surface of transverse section, the NO₂ sorption volume depended on the thickness of longitudinal direction and NO₂ sorption effect was high, especially, in the range of ca. 3 mm from the surface of transverse section.
2. NO₂ sorption volume depended on the interface area of the specimen which can contact with NO₂.
3. It was inferred that NO₂ sorption ability reached its greatest in discoid specimen and wood powder of the grain size below 0.25–0.50 mm.

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