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Prediction of Formaldehyde Concentrations in Air Originating from Wood-Based Materials

Comparison of desiccator method with chamber method and perforator method

By

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Summary: Formaldehyde (FA) emissions from particleboards were measured by three methods: the desiccator method prescribed in Japanese Industrial Standard A 5908 (D-values), the perforator method in British Standard 5669 (P-values), and the chamber method (FA concentrations in air). The effect of board history on D-values and P-values was investigated. The effects of ventilation, board surface area, chamber volume and board history on FA concentrations in air were also investigated.

D-values depended more heavily on the board history than did P-values. The correlation between P-values and D-values also depended on the board history. P-values for wrapped boards were 6 to 8 times as large as D-values for the unwrapped boards conditioned for 7 to 15 days. When FA emission properties of boards were constant, FUJII's theoretical equation accurately represented the behavior of FA concentrations in air under the ventilated conditions: Q/S (air exchange volume per hour/board surface area) was the only variable affecting FA concentrations in air. The chamber volume did not directly affect FA concentrations in air. However, FA emission properties depended on the board history and it was noted that they also depended on temperature and relative humidity. The correlation between D-values (D) and FA concentrations in air (C) measured according to the method of ETB-rule in West Germany was expressed by the following equation: $C = 0.158\,D + 0.017$. Conversion formulas were developed, by using D-values, to allow the prediction of FA concentrations in air regardless of temperature, humidity and Q/S.

1. Introduction

One of the important problems concerning formaldehyde (FA) emissions from wood-based materials bonded with adhesives containing FA is FA concentrations in air in the dwelling environment where those materials are used. In Japan, however, FA emissions from particleboards and plywoods are measured by the desiccator method prescribed in Japanese Industrial Standard (JIS A 5908) and Japanese Agricultural Standard (JAS) of Plywood, respectively. These standards are only product standards. There is no regulation regarding FA concentrations in air in Japan at present. Therefore, it is very important to determine the correlation between FA emissions measured by the desiccator method (D-values) and FA concentrations in air.

Recently, large chamber methods, by which FA concentrations in air are measured under the ventilated condition simulating the dwelling environment, have been standardized in the United States and West Germany. In West Germany, FA concentrations

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in air originating from wood-based materials have been regulated since January 1988 according to the regulation on hazardous substances (Gafahrstoffverordnung). The regulation prescribes that the wood-based materials should not be marketed if the FA concentrations in air (C-values) measured by the chamber method according to ETB-rule (ETB-Richtlinie, 1980; TAMURA, 1987) exceed 0.1 ppm (BÖHME, 1988). This regulation is applied to all wood-based panels and products that are exported to West Germany. Therefore, it is necessary to determine the correlation between C-values and D-values.

However, it is difficult to determine this correlation because of the following reasons: D-values depend on the board history; the effect of the chamber volume on FA concentrations in air is not clear; the chamber volume prescribed in ETB-rule (40 m^3) is different from that in our institute of F.F.P.R.I. (14 m^3). Consequently, before determining the correlation, it is necessary to elucidate the variables affecting FA concentrations in air and establish the conditions corresponding to those prescribed in ETB-rule in the chamber with a volume of 14 m^3.

The main objectives of this work are as follows: to determine the effect of board history on D-values; to determine the effects of board history, ventilation, board surface area and chamber volume on FA concentrations in air; to determine the correlation between D-values and C-values; and to develop a method for predicting FA concentrations in air by using D-values.

The correlation between D-values and FA amounts measured by the perforator method (*e.g.*, British Standard 5669) was also investigated because the perforator method is standardized in many European countries and it is important to determine the correlation.

2. Experimental

2.1 Materials

Commercial particle boards as pressed (12 mm-thick) were examined. They were of U-type, P-type and P_0-type classified by Japanese Industrial Standard (JIS A 5908). Desiccator values of U-type and P-type boards are less than 5 mg/l, and those of P_0-type boards are less than 0.5 mg/l. Boards were wrapped with polyethylene sheets and stored until the tests.

2.2 Measurement of formaldehyde emissions by the desiccator method and the perforator method

Boards (45 by 45 cm) were unwrapped and conditioned for 0 to 15 days at 20°C and 40 % relative humidity (RH), and board history was changed. Immediately after the conditioning, specimens were cut from the boards and formaldehyde (FA) emissions were determined by the perforator method (British Standard 5669) and the desiccator method (JIS A 5908) using a room temperature of 20°C. Some of the specimens after the initial conditioning for 7 days were wrapped again and conditioned for another 7 days. FA emissions for these specimens were determined after the conditioning and compared to those for the unwrapped boards.

2.3 Measurement of formaldehyde concentrations in air in a large chamber

The details of the chamber and the method for measuring FA concentration in air have been reported previously (INOUE, 1986). The volume of the chamber was 14 m^3, not 40 m^3 as prescribed by ETB-rule in West Germany. FA in the chamber was absorbed in distilled water and FA concentrations in water were determined by acetylacetone fluorometric analysis.

Except for the chamber volume, ETB-rule test conditions were used as follows: temperature, 23 ± 1°C; relative humidity, 45 ± 5% RH; ventilation rate, 1 h^{-1}; loading rate (the ratio of board surface area to chamber volume), 1 m^2/m^3.

The effects of ventilation and board surface area on FA concentrations in air were determined for U-type boards by the following procedure: air exchange volume per hour was changed from 8 to 28 m^3/h; board surface area was changed from 7 to 14 m^2; FA concentrations were measured. The effect of chamber volume on FA concentrations was determined for U-type boards by the following procedure: air (0.13 m^3) was pumped into polyethylene bags (97 by 110 cm); thirty-one bags were placed in the chamber; which reduced the free air volume of the chamber to approximately 10 m^3; FA concentrations were measured.

2.4 Measurement of formaldehyde concentrations in air in a small chamber

The apparatus shown in Fig. 1 was set up in a room at 23°C. The requirements of the apparatus are: to be able to control the temperature, relative humidity and ventilation of fresh air free from FA. The size of the specimen was 6 by 6 by 1.2 (thickness) cm and its surface area was about 0.01 m^2. One to five specimens were placed in a desiccator (No. 9 in Fig. 1) with a volume of 0.01 m^3. The conditions in the desiccator were maintained at 23 ± 1°C and 45 ± 5% RH. Air exchange volume per hour (Q) was changed from 0.011 to 0.11 m^3/h, *i.e.*, ventilation rate (N) was changed from 1.1 to 11 h^{-1}. The surface area of the specimen (S) was changed from 0.01 to 0.05 m^2, *i.e.*, loading rate (L) was changed from 1 to 5 m^2/m^3.

FA in the desiccator was absorbed in distilled water (No. 11 in Fig. 1), and FA concentrations in water were determined by acetylacetone fluorometric analysis.

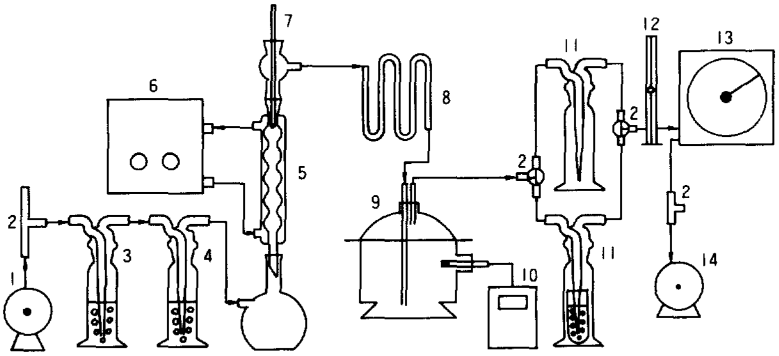

Fig. 1. Small chamber for measuring formaldehyde concentrations in air.

Notes: 1: Ventilation pump, 2: Stop cock (three-way), 3: Sulfuric acid, 4: Distilled water, 5: Condenser, 6: Cooling water circulator, 7: Thermometer, 8: Stainless steel pipe, 9: Desiccator, 10: Thermometer and hygrometer, 11: Impinger for liquid collection, 12: Flow meter, 13: Integrating flowmeter, 14: Suction pump.

The effect of ventilation on the FA concentrations in air was determined by the following procedures which minimized the change of FA emission properties depending on board history. Specimens were placed in the desiccator under the condition of $Q/S = 1.1$, and FA concentrations were determined 5 to 16 days later. The Q/S ratio was then changed to 0.54 and the measurements were taken on the following day. This procedure was repeated for a Q/S ratio of 2.2.

3. Results and Discussion

3.1 Effects of board history on D-values and P-values and their correlation

Fig. 2 shows the effects of board history on D-values and P-values when boards were conditioned at 20°C and 40% RH. When unwrapped boards were conditioned, D-values decreased more rapidly than P-values. When the specimens taken from the boards conditioned for 7 days were wrapped again and conditioned, D-values increased but P-values changed little. Therefore, the effect of board history on D-values is different from that on P-values. This result indicates that the FA measured by the desiccator method was different from that by the perforator method as TOMITA (1985) indicated. It is considered that the FA concentration as measured by the desiccator method depends upon the FA emission properties of board surface, whereas the FA concentration as measured by the perforator method depends upon the FA extracted with toluene from boards as a whole. Therefore, it is necessary to consider board history in order to obtain the correlation between D-values and P-values.

Fig. 3 shows the correlations of P-values with D-values for wrapped boards and

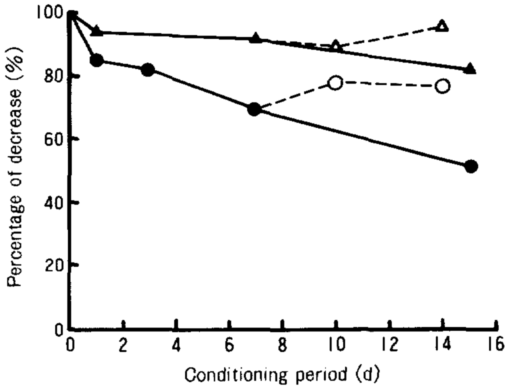

Fig. 2. Changes of desiccator values and perforator values with time.

Legend : ● : Desiccator values for the boards unwrapped and conditioned.
○ : Desiccator values for the boards wrapped and conditioned.
▲ : Perforator values for the boards unwrapped and conditioned.
△ : Perforator values for the boards wrapped and conditioned.

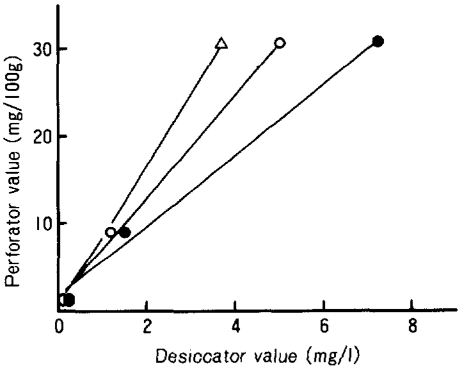

Fig. 3. Correlation between desiccator values and perforator values.

Notes : Perforator values were measured for the wrapped boards.
Desiccator values were measured for the wrapped boards (●), and the unwrapped boards conditioned for 7 days (○) and 15 days (△).

D-values for the boards unwrapped and conditioned. There are linear correlations between P-values for wrapped boards and D-values for the boards conditioned for fixed periods. However, the longer the unwrapped conditioning period of the boards before measuring D-values was, the larger the ratio of P-values to D-values was. In this study, P-values for wrapped boards were about 4 times as large as D-values for wrapped boards, and about 6 times and 8 times as large as D-values for the boards unwrapped and conditioned for 7 and 15 days, respectively. TOMITA (1984) showed that the ratio was 5 to 6 when boards were wrapped and conditioned for 1 to 3 weeks, and TOMIMURA (1984) showed that the ratio was about 10 when boards were unwrapped and conditioned for more than 2 months. Therefore, the change of the ratio with the board conditioning is not so different from those of the previous reports. Since the desiccator method prescribes, according to JIS, the board conditioning for more than 7 days, P-values were expected to be 6 to 8 times as large as D-values in this study.

3.2 Variables affecting formaldehyde concentrations in air

3.2.1 Theoretical equations for formaldehyde concentrations in air

FUJII *et al.* (1973) gave the following equation for FA concentrations in air under ventilated conditions :

$$C=\frac{m}{a+Q/S}$$

Where :

C : Steady state concentration of FA in air (ppm).
m : FA release rate per unit area ($\mathrm{cm^3/h \cdot m^2}$).
a : FA absorption coefficient (m/h).
Q : Air exchange volume per hour ($\mathrm{m^3/h}$).
S : Board Surface area ($\mathrm{m^2}$).

HOETJER gave the following equation and it was demonstrated by, for example, LEHMANN (1987) that the equation explained well the behavior of FA concentrations in air under the ventilated conditions.

$$C_s=\frac{C_{eq}}{1+\frac{1}{k}\frac{N}{L}}$$

where :

C_s : Steady state concentration of FA in air (ppm).
C_{eq} : Equilibrium FA concentration (ppm) under nonventilated conditions.
k : FA transfer coefficient (m/h).
N : Ventilation rate ($\mathrm{h^{-1}}$).
L : Loading rate ($\mathrm{m^2/m^3}$), *i.e.*, the ratio of board surface area (S) to chamber volume (V).

These two equations are shown to be the same when $C_{eq}=m/a$; $k=a$; $N=Q/V$ and $L=S/V$ (therefore $N/L=Q/S$). One difference between the two equations is that FUJII's equation does not include the variable of chamber volume (V). If the chamber volume is not a variable affecting FA concentrations in air as shown by FUJII, then the concentrations measured by ETB-rule can be applied regardless of the chamber volume.

However, in order to measure the concentrations in different chamber volume, it is necessary to demonstrate that FA concentrations in air do not change with changes in the chamber volume or to verify FUJII's equation.

3.2.2 Effect of board history on formaldehyde concentrations in air

Fig. 4 shows the change of FA concentrations in air in a small chamber when boards were unwrapped and conditioned at 20°C and 40% RH. The FA concentrations for the boards conditioned for 3 days decreased rapidly at the beginning of the test and they showed little decreases after 7 days. However, the FA concentrations for the boards conditioned for 15 days decreased after the conditioning and during the test. True steady-state concentrations were not observed in this experiment, the test period of one month being very short. This indicates that FA emission properties of boards, which are expressed as m and a in FUJII's equation, depended on the board history. It was verified by our previous study of plywoods that both m and FA concentrations in air decreased with the board conditioning. Therefore, it should be taken into account that apparent steady-state FA concentrations are only observed when m and a show a certain value, which depend on the board history.

3.2.3 Effects of ventilation and board surface area on formaldehyde concentrations in air

If the FA concentrations in air are y_1 and y_2 when Q/S (air exchange volume per hour/board surface area) conditions are x_1 and x_2, respectively, the concentrations are expressed by the following equations :

$$y_1 = m/(a+x_1)$$
$$y_2 = m/(a+x_2)$$

Then m and a can be calculated by the following equations :

$$m = (y_1y_2x_2 - y_1y_2x_1)/(y_1 - y_2)$$
$$a = (y_2x_2 - y_1x_1)/(y_1 - y_2)$$

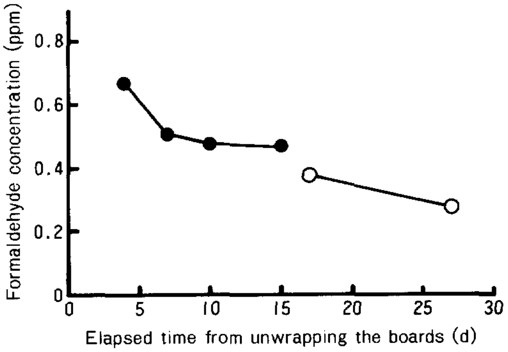

Fig. 4. Change of formaldehyde concentrations in air in a small chamber with time.

Legend : ● : Concentrations after 3-days, unwrapped conditioning.
○ : Concentrations after 15-days, unwrapped conditioning.

Notes : Conditions in the chamber were 23°C, 45% RH, 0.01 m^2 (board surface area) and 0.01 m^3/h (air exchange volume per hour).

Therefore, FA concentration (y_3) under all the Q/S conditions (x_3) can be calculated by the following equation :

$$y_3 = m/(a+x_3)$$

Consequently, when FA concentrations in air are determined under two different conditions, theoretical curves showing the concentrations under all the Q/S conditions can be drawn. If the calculated concentrations are equal to the actually measured concentrations, FUJII's equation will be verified.

Fig. 5 shows the effect of Q/S on FA concentrations in air under various conditions of ventilation and board surface area. The curves in Fig. 5 are the theoretical curves obtained from the concentrations in a small chamber under the conditions of $Q/S=0.5$ and $Q/S=2.2$. Under the condition of $Q/S=1.1$, the experimental concentrations corresponded well to the theoretical concentrations (the theoretical curves). Therefore, it is verified that the theoretical equations explain well the effect of ventilation on FA concentrations in air.

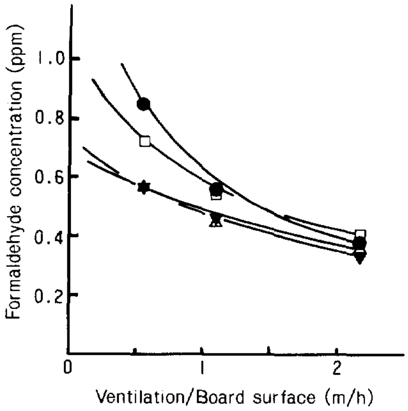

Fig. 5. Effect of ventilation and board surface on formaldehyde concentrations in air in a small chamber.

Legend of board surface and elapsed time from the beginning of the test :

● : 0.03 m^2, 5 to 8 days.
□ : 0.05 m^2, 10 to 12 days.
△ : 0.02 m^2, 12 to 14 days.
▼ : 0.03 m^2, 16 to 18 days.

When board surface area was changed, the theoretical curves shifted down with time. However, similar curves were obtained 12 to 18 days after the beginning of the test, even if the board surface area was changed. It was considered that this downward shift of theoretical curves was due to the change of FA emission properties (m and a) of boards with time. Fig. 6 shows the change of the concentrations with time when ventilation and board surface area were constant ($Q=0.011$ m^3/h and $S=0.01$ m^2 : $Q/S=1.1$ m/h) and also variable. The concentrations at $Q/S=1.1$ decreased along a uniform curve, even if the board surface area changed from 0.01 to 0.05 m^2. The concentrations under the other Q/S conditions decreased along the other curves. This result means that the variables affecting the concentrations are Q/S and the elapsed time after the beginning of the test, and the concentrations are at the same level when Q/S and the elapsed time are equal, even if board surface area changes.

Therefore, it is concluded that the theoretical equations explain well the effects of ventilation and board surface area on FA concentrations in air under the ventilated conditions, *i.e.*, Q/S is the only variable affecting FA concentrations in air when FA emission properties are constant. However, it is necessary to note that FA emission properties change with time.

3.2.4 Formaldehyde concentrations in air in a large chamber

Fig. 7 shows the FA concentrations measured in a large chamber. The concentrations decreased rapidly at the beginning of the test, and thereafter they decreased

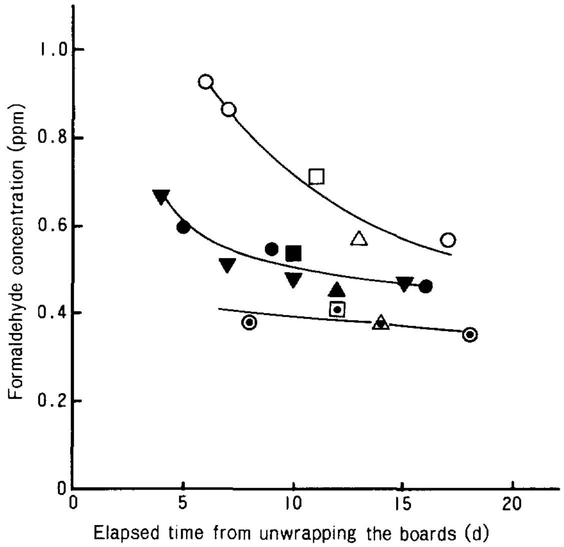

Fig. 6. Change of formaldehyde concentrations in air with time when ventilation and board surface were varied.

Legend of board surface and *Q*/*S* (air exchanged volume per hour/board surface) :
▼ : 0.01 m^2, 1.1 m/h. △ : 0.02 m^2, 0.54 m/h. ▲ : 0.02 m^2, 1.1 m/h.
◬ : 0.02 m^2, 2.2 m/h. ○ : 0.03 m^2, 0.54 m/h. ● : 0.03 m^2, 1.1 m/h.
◉ : 0.03 m^2, 2.2 m/h. □ : 0.05 m^2, 0.54 m/h. ■ : 0.05 m^2, 1.1 m/h.
⊡ : 0.05 m^2, 2.2 m/h.

gradually. True steady-state concentration was not observed in this experiment. However, the effect of ventilation on the concentrations accorded with the theoretical equations when the board surface area was constant and ventilation changed from 8 to 28 m^3/h in a relatively short time of three days (No. 1, No. 2 and No. 3 in Fig. 7, and Fig. 8). Even though board surface area changed, the concentrations did not change under the same *Q*/*S* conditions (No.3 and No. 4, and No. 1 and No. 5 in Fig. 7). Moreover, when the polyethylene bags were placed in the chamber and the free volume of the chamber was changed from 14 m^3 to 10 m^3 (in this case, air exchange volume per hour was fixed at 8 m^3/h but the ventilation rate changed from 0.57 to 0.8 h^{-1}), the concentrations did not change (No. 5 and No. 6 in Fig. 7).

These results show that the theoretical equations explain well the effects of ventilation and board surface area on the FA concentrations in air, *i.e.*, *Q*/*S* is the only variable affecting FA concentrations in air when FA emission properties (*m* and *a*) of boards are constant. The chamber volume does not affect FA concentrations in air directly. However, FA emission properties depend on the board history.

It is known that temperature and humidity affect FA concentrations in air, but it is proper to consider that these variables affect FA emission properties of boards directly.

Therefore, it is concluded that FA concentrations in air measured by the method prescribed in ETB-rule (C-values) will agree with those measured in chambers of different volumes when the same temperature, humidity and *Q*/*S* as prescribed in ETB-rule are chosen.

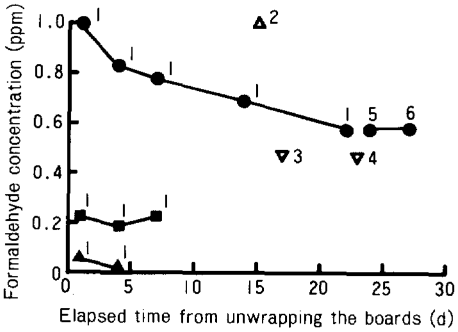

Fig. 7. Change of formaldehyde concentrations in air in a large chamber with time.

Legend : ●, △ and ▽ : U-type boards, ■ : P-type boards, ▲ : P_0-type boards.
Notes : The number on each plot shows test conditions.

No.	Volume of chamber (m³)	Ventilation (m³/h)	Board surface (m²)	Ventilation / Board surface (m/h)
1	14	14	14	1.0
2	14	8	14	0.57
3	14	28	14	2.0
4	14	14	7	2.0
5	14	8	7	1.1
6	10	8	7	1.1

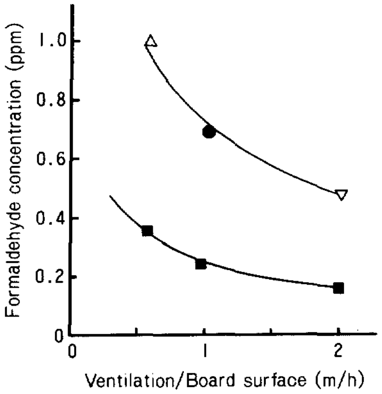

Fig. 8. Effect of ventilation and board surface on formaldehyde concentrations in air in a large chamber.

Legend : ●, △ and ▽ : U-type boards, ■ : P-type boards.

3.3 Correlation between D-values and C-values

Fig. 9 shows the correlations between D-values for the boards unwrapped and conditioned for 7 days and FA concentrations in air in a large chamber with a volume of 14 m^3 under the same test conditions as defined by ETB-rule except for the chamber

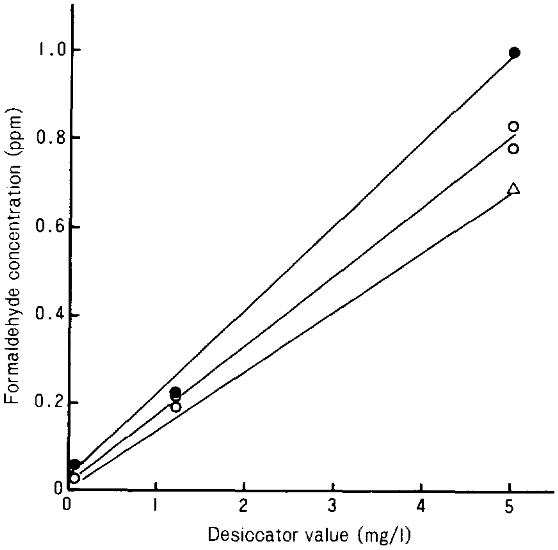

Fig. 9. Correlation between desiccator values and formaldehyde concentrations in air.

Legend of the elapsed time from the beginning of the test to the measurement of the concentrations in air :

● : 1 day, ○ : 4 to 7 days, △ : 15 days.

Notes : Desiccator values were measured for the boards unwrapped and conditioned for 7 days.

volume. FA concentrations in air at the earlier stage of the test had a linear correlation with D-values. However, the correlation between D-values and FA concentrations in air depended on the board history because both D-values and FA concentrations in air depended on the board history. The following equation was obtained in this study showing the relationship between D-values for the boards unwrapped and conditioned for 7 days (D_7, in mg/l) and FA concentrations in air 4 to 7 days after the beginning of the test (C_{4-7}, in ppm) :

$$C_{4-7} = 0.158\, D_7 + 0.017 \quad (r = 0.998)$$

The desiccator method (JIS) prescribes board conditioning for more than 7 days and ETB-rule prescribes that FA concentrations in air should be measured at the steady state or 240 hours after the beginning of the test. Therefore, the correlation between D-values and C-values would be approximately expressed by this equation.

From this equation, C-values of P_0-type boards, of which D-values are less than 0.5 mg/l, would be less than 0.096 ppm, which is less than the standard value (0.1 ppm) prescribed by the regulation relating to hazardous substances (Gefahrstoffverordnung) in West Germany. Therefore, P_0-type boards would pass the standard in West Germany. However, the coefficients of the equation may change with surface treatments, thickness and board history.

The ratio of FA concentrations in air in a large chamber to those in a small chamber was about 1.1 to 1.2. The causes of this difference between the concentrations in a large chamber and those in a small chamber are not clear, but it is considered that one of the causes is the direct effect of board edges on FA emission properties.

3.4 Prediction of formaldehyde concentrations in air by D-values

If the correlation between C-values and FA concentrations in air under all the conditions is obtained, FA concentrations in air under all the conditions will be predictable by using D-values as the correlation between D-values and C-values has been obtained.

In this study the ratio of FA concentrations in air under the condition of $Q/S=2$ to those of $Q/S=1$ is about 0.7 (one week after) to 0.75 (two weeks after the beginning of the test). The ratio of the concentrations under the condition of $Q/S=0.5$ to those of $Q/S=1$ is about 1.5 (one week after) to 1.25 (two weeks after the beginning of the test). These coefficients are not appreciably different from those obtained by the previous research (LEHMANN, 1987).

MATSUMOTO (1972) showed that FA concentrations in air had a linear correlation to relative humidity and that the coefficient of the concentration change per relative humidity was 0.8% when relative humidity was 80% RH (MATSUMOTO, 1974). MYERS *et al.* (1981) showed that raising relative humidity at 25°C from approximately 25% to 75% brought about an increase in FA concentrations by an average factor of 1.5. This means that the coefficient of the concentration change per relative humidity is 1% at 25% RH. When the coefficients are converted into those at 45% RH, they are 1.11% and 0.83% ; and the mean value is approximately 1%. Therefore, FA concentrations in air under all the conditions of relative humidity can be calculated by the following equation :

$$C_{\mathrm{hn}}=C_{\mathrm{n}}+C_{\mathrm{n}}\,(h-45)/100=C_{\mathrm{n}}\,(55+h)/100$$

Where :

C_{hn} : FA concentration in air (ppm) at 23°C, h% RH and $Q/S=n$.

C_{n} : FA concentration in air (ppm) at 23°C, 45% RH and $Q/S=n$.

h : Relative humidity (% RH).

It was reported that raising temperature from 25°C to 30°C increased FA concentrations in air by a factor of 1.5 (INOUE, 1986) ; from 20°C to 30°C increased the concentrations by a factor of 2.3 (MATSUMOTO, 1974) ; and from 25°C to 40°C increased the concentrations by a factor of 3.8 (MYERS, 1981). Assuming that raising temperature by 1°C increases the concentrations by a factor of x, the following equations are obtained :

$$x^5=1.5\;;\;x^{10}=2.3\;;\;x^{15}=3.8$$

From these equations, x is about 1.09. Therefore, the concentrations at any temperature can be calculated by the following equation :

$$C_{\mathrm{thn}}=C_{\mathrm{hn}}\times 1.09^{(t-23)}$$

Where :

C_{thn} : FA concentration in air (ppm) at t°C, h% RH and $Q/S=n$.

t : Temperature (°C).

When temperature and relative humidity affect one of FA emission properties (m), these conversion formulas for the change of temperature and relative humidity can be applied to the prediction of FA concentrations under any Q/S condition. Table 1 shows the conversion formulas for the prediction of FA concentrations in air using D-values. Applying the formulas consecutively from the top of the table, FA concentration in air

Table 1. Conversion formulas to predict formaldehyde concentrations in air.

Conditions			Conversion formulas
Temperature (°C)	Humidity (% RH)	Q/S (m/h)	
23	45	1	$C=0.158\,D+0.017$
23	45	2	$C_n=(0.7\sim0.75)\times C$
23	45	0.5	$C_n=(1.5\sim1.25)\times C$
23	h	n	$C_{hn}=C_n\times(55+h)/100$
t	h	n	$C_{thn}=C_{hn}\times1.09^{(t-23)}$

Q : Air exchange volume per hour (m^3/h).
S : Board surface area (m^2) .
C : Formaldehyde concentration in air (ppm) four to seven days after the beginning of the test at 23°C, 45% RH and $Q/S=1$.
D : Desiccator value (mg/l) for the board conditioned for seven days.
C_n : Formaldehyde concentration in air (ppm) at 23°C, 45% RH and $Q/S=n$.
C_{hn} : Formaldehyde concentration in air (ppm) at 23°C, h% RH and $Q/S=n$.
C_{thn} : Formaldehyde concentration in air (ppm) at t°C, h% RH and $Q/S=n$.

can be predicted under any temperature, any relative humidity and any Q/S condition.

4. Conclusion

(1) Desiccator values were more dependent on board history than were perforator values. The correlation between these two values depended on the board history. In this study, the perforator values for wrapped boards were 6 to 8 times as large as the desiccator values for the boards unwrapped and conditioned for 7 to 15 days.

(2) When formaldehyde emission properties of boards, which depended on the board history, were constant, theoretical equations represented well the behavior of formaldehyde concentrations in air under the ventilated conditions : Q/S (ratio of air exchange volume per hour to board surface area) was the only variable affecting formaldehyde concentrations in air. The chamber volume was not a direct variable. However, formaldehyde emission properties of boards depended on board history, and it is considered that they also depend on temperature and humidity.

(3) The correlation between desiccator values (D) and formaldehyde concentrations in air measured by ETB-rule (C) was expressed by the following equation : $C=0.158\,D+0.017$.

(4) The variables affecting formaldehyde concentrations in air were taken into account and conversion formulas were developed, by using desiccator values, to allow the prediction of formaldehyde concentrations in air regardless of temperature, humidity and Q/S.

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木質材料から放散するホルムアルデヒド気中濃度の予測

—デシケータ法，チャンバ法及びパーホレータ法の比較—

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摘　　要

パーティクルボードから放散するホルムアルデヒド（FA）を3種類の方法，すなわち，日本工業規格（JIS A 5908）で規定されるデシケータ法（*D* 値），英国規格（BS 5669）で規定されるパーホレータ法（*P* 値），及びチャンバ法（FA 気中濃度）により測定した。*D* 値及び *P* 値に対する材料の履歴の影響を調べた。また，FA 気中濃度に対する換気量，材料表面積，チャンバ容積及び材料の履歴の影響を調べた。

D 値は *P* 値よりも材料の履歴による変化が大きく，そのため，*P* 値と *D* 値との相関関係も材料の履歴により変化した。密閉状態の材料の *P* 値は，開放状態で7〜15日間養生した材料の *D* 値の6〜8倍であった。材料の FA 放散特性が一定のとき，藤井らにより示された理論式は換気下の FA 気中濃度の挙動をよく示していた。すなわち，材料の FA 放散特性が一定のとき，気中濃度に影響する唯一の因子は *Q*/*S*（換気量/材料表面積）で，チャンバ容積は直接的な因子ではなかった。なお，FA 放散特性は材料の履歴により変化し，また，温度及び湿度により変化すると考えられた。*D* 値と西ドイツの ETB 基準で測定される FA 気中濃度（*C* 値）との間に次式，$C=0.158\,D+0.017$ の関係が得られた。また，FA 気中濃度に影響する諸因子を考慮して，*D* 値より種々の条件の FA 気中濃度を予測するための換算式を提案した。

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