Characteristics of Formaldehyde Emission from Indoor Crib

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Abstract—Based on characteristics of wood crib releasing formaldehyde (CH₂O), a physical model, which CH₂O releases and diffuses from crib in indoor, is established to simulate the distribution characteristics of CH₂O concentration in confined and ventilated indoor. CH₂O concentration near crib is larger, and then gradually reduced to around. When baby lies down, sits and stands in crib interior, CH₂O concentration decreased with height increasing. Compared CH₂O concentration in confined indoor, CH₂O diffusion is strengthened with indoor ventilation, and CH₂O concentration in crib interior is decreased at different height, especially in the middle part decreases obviously.

Keywords—formaldehyde; crib; indoor pollution; ventilation

I. INTRODUCTION

With the improvement of socio-economic level, for comfortable living environment, furniture aesthetics become increasingly demanding, but the resulting indoor air pollution has become increasingly serious [1]. Seen from related investigations, decoration materials paint, wallpaper, plywood, lots of applications, CH₂O exceeding rate of 60% to 100% in newly renovated public spaces, and CH₂O having 3 to 15 years of long release cycle. This makes CH₂O has become an indication of indoor pollution contaminants [2]. However, the infant indoor CH₂O pollution is particularly prominent. CH₂O have different degrees of stimulation damaging effect respiratory system, nervous system and immune system [2-3]. IARC has confirmed human carcinogen CH₂O, these indoor pollutants associated with 70% of human disease, exceeding 90% of children are contaminated by interior of leukemia gas caused [4-5]. Because infants is sensitive populations, so more vulnerable to air pollutants, meanwhile children most of time is spent indoors. This will resulting increase incidence of various diseases indoor air pollution exposure has long, low-dose characteristics, Research shows that infant respiratory system, heart and lung function, asthma and serious harm to the immune system caused by CH₂O pollution [6].

Currently, parents increasing emphasis crib over issue of CH₂O release, however, about crib release of CH₂O has been reported rarely. By establishing crib CH₂O release model, by analyzing effect of ventilation on reducing CH₂O concentration, thus reducing the harm of CH₂O pollution caused by infants.

II. FORMALDEHYDE INDOOR AIR DIFFUSION THEORY

A. Turbulence Model

Follow through stress modeled Laminar Flow stress, introduced Boussinesq hypothesis, by the turbulence caused stress can be expressed as:

$$-\overline{u_i u_j} = \nu_t \left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i} \right) - \frac{2}{3} \kappa \delta_{ij} \quad (1)$$

Wherein, ν_t is turbulent eddy viscosity coefficient; k is the turbulent kinetic energy per unit mass of the fluid indicates the average kinetic energy of turbulent fluctuations; U_i , u_i , respectively represent the average amount and fluctuating volume velocity.

Three-dimensional unsteady N-S equation can be derived k equation and ε equation modeling after:

$$\begin{cases} \frac{\partial \kappa}{\partial t} + U_j \frac{\partial \kappa}{\partial x_j} = \frac{\partial}{\partial x_j} \left[\left(C_\kappa \frac{\kappa^2}{\varepsilon} + \nu \right) \frac{\partial \kappa}{\partial x_j} \right] - \overline{u_i u_j} \frac{\partial U_i}{\partial x_j} - \varepsilon \\ \frac{\partial \varepsilon}{\partial t} + U_j \frac{\partial \varepsilon}{\partial x_j} = \frac{\partial}{\partial x_j} \left[\left(C_\varepsilon \frac{\kappa^2}{\varepsilon} + \nu \right) \frac{\partial \varepsilon}{\partial x_j} \right] - C_{\varepsilon 1} \frac{\varepsilon}{\kappa} \overline{u_i u_j} \frac{\partial U_i}{\partial x_j} - C_{\varepsilon 2} \frac{\varepsilon^2}{\kappa} \end{cases} \quad (2)$$

When homogenized continuity equation, standard k - ε two sides closed process control equations of the model is composed of N-S equations and modeling of the k equation and eddy viscosity coefficient ε equation.

B. Release of Formaldehyde Diffusion Equation

For crib wooden materials, CH_2O will diffuse into indoor air, CH_2O release strength is $0.01\sim 0.015\text{kmol}/(\text{m}^2\cdot\text{h})$ [7], CH_2O diffusion process can be expressed as:

$$\frac{\partial \rho C}{\partial t} + \frac{\partial \rho C U_j}{\partial x_j} = \frac{\partial}{\partial x_j} \left(\frac{\mu}{\sigma C} \frac{\partial C}{\partial x_j} - \rho u_j C \right) + S_c \quad (3)$$

Where, C is the concentration of formaldehyde, S_c for the source term.

III. CRIB FORMALDEHYDE DIFFUSION MODEL

A. Geometry

A size of $4\text{ m} \times 6\text{ m} \times 3\text{ m}$ inside room (door size of $0.9\text{ m} \times 2.1\text{ m}$, window size of $1.5\text{ m} \times 1\text{ m}$), place the size of $1\text{ m} \times 1.4\text{ m} \times 0.6\text{ m}$ cot (under section four wood leg support, high 0.4 M , wood pitch 3 cm bed four weeks), as shown in FIG. Crib placed in the room shown in Figure 1 (no other furniture indoor).

Figure 1. Crib model

B. Physical Model

① The use of multi-component transport model no chemical reaction to participate, the standard $k-\epsilon$ model and non-equilibrium wall function.

② Boundary conditions: formaldehyde releases from each board of crib.

IV. NUMERICAL ANALYSIS OF FORMALDEHYDE RELEASE OF CRIB INDOOR

This paper considers crib in closed and open doors and windows ventilation of indoor formaldehyde release under conditions. CH_2O release in early crib, take this article formaldehyde emission intensity of $0.012\text{ mmol}/(\text{m}^2\cdot\text{h})$, set the door when ventilation air inlet velocity, wind speed 1 m/s .

A. Formaldehyde Concentration Distribution Indoor

(a) Enclosed rooms

(b) Ventilate rooms

Figure 2. Formaldehyde concentration distribution indoor

From Fig.2 it can be seen, because of crib surface is the release source of CH_2O , so that the CH_2O concentration was highest of bed surface. enclosed room, the CH_2O concentration gradually decreases from bed to surrounding, like the dome cover layer overlying crib around. When the air came from door, CH_2O spread to window, resulting in the CH_2O concentration reduced around the crib.

B. Formaldehyde Concentration Distribution in Horizontal Plane

Consider position height when baby lying (Facial height was 10 cm), sitting (Facial height was 38 cm) and standing (Facial height was 55.5 cm) in crib, In model were $z=0.56\text{ m}$, $z=0.86\text{ m}$ and $z=0.995\text{ m}$. Analysis of these three positions at height of CH_2O concentration contours Distribution, as shown in Fig.3.

It can be seen from fig.3, The higher region about CH_2O concentration was near crib, and as position height increases when baby lying down, sitting and standing, CH_2O concentration decreases. In closed room, CH_2O diffusion capacity is weak, and therefore CH_2O gathered around the crib, and CH_2O concentrations is higher in inside space of bed.

Figure 3. Formaldehyde concentration distribution at different height

When indoor ventilation, CH₂O diffusion with romantic, thus the CH₂O concentration increases in the downwind until

spread to the entire interior, However, because of crib is the source of release of CH_2O , CH_2O concentration in the vicinity is still high, especially in the inner side crib.

C. Formaldehyde Concentration Distribution in Door Facade

(a) Enclosed

(b) Ventilation

Figure 4. Formaldehyde concentration distribution in the cross-section $y=0\text{m}$

(a) Enclosed

(b) Ventilation

Figure 5. Formaldehyde concentration distribution in the cross-section $x=0\text{m}$

Fig.4 and Fig.5 are vertical plane CH_2O concentration contours when longitudinal and transverse interception cot body, from figure we can see, CH_2O concentration in the inside and bottom of bed are higher. In closed indoor, the concentration outwardly from crib gradually reduced, but diffusion distance of CH_2O is short. When indoor ventilation, CH_2O diffusion strengthened, but CH_2O concentration becomes smaller in inlet area, and downwind area becomes larger.

D. Comparison of Formaldehyde Concentration in Different Heights Inside Crib

(a) Enclosed

(b) Ventilation

Figure 6. Inside crib formaldehyde concentration at different heights

Inside crib, along the longitudinal direction, examine distribution of CH_2O concentration at different heights, obtained concentration of CH_2O by numerical calculation in Figure 6. As can be seen from Fig.6, As the baby lying down, sitting and standing, the position height is increased, the concentration of CH_2O has been reduced, but still has high concentration, Such as $z=0.56\text{m}$, $z=0.86\text{m}$ and $z=0.995\text{m}$, the CH_2O concentrations in center were 0.03568 mmol/m^3 , 0.03789 mmol/m^3 and 0.03919 mmol/m^3 , it is the standard 0.10mg/m^3 of Ministry of Public Health 10.7, 11.3, 11.7 times. When indoor ventilation, CH_2O concentrations inside of the crib will be reduced, such as $z=0.56\text{m}$, $z=0.86\text{m}$ and $z=0.995\text{m}$, the minimum of CH_2O were 0.03431 mmol/m^3 , 0.03703 mmol/m^3 and 0.03907 mmol/m^3 , it is the standard 0.10mg/m^3 of Ministry of Public Health 10.3, 11.1, 11.7 times.

(a) Enclosed

(b) Ventilation

Figure 7. Formaldehyde concentration inside crib as the room enclosed and ventilation.

Fig.7 reflects the change about concentration of CH_2O in the inside of crib at different heights when the room was enclosed and ventilation. As can be seen from Fig.9, in ventilation, inside crib at different heights CH_2O concentrations were reduced, and the below part of

concentration of CH_2O in cribs reduce is the most obvious. However, from the concentration changes of CH_2O , we can find that the ventilation can reduce the concentration of CH_2O close to crib. If prolonged ventilation time, the release of CH_2O strength will be weakened, and then strengthen the ventilation speed, will also reduce the CH_2O concentration near crib.

V. CONCLUSION

This article by establishing CH_2O release model of Crib, at room enclosed and ventilation conditions, numerical simulation of distribution about concentration of CH_2O close to crib, calculations proves that Crib CH_2O concentration gradually decreases from bed to surrounding, and with increasing the height of baby lying down, sitting and standing position, the CH_2O concentration decreases. In ventilation, the inside of crib at different heights for CH_2O concentrations were reduced, and the below part of concentration of CH_2O in cribs reduce is the most obvious. Ventilation enhanced diffusion of CH_2O , and the CH_2O concentration becomes smaller in inlet area, and the downwind area becomes larger, but the inside of crib still has a high concentration of CH_2O concentration. Compared CH_2O concentration indoor confined conditions, CH_2O diffusion is strengthened with indoor ventilation, and CH_2O concentration in the crib interior is decreased at different height, If prolonged ventilation time, the release of CH_2O strength will be weakened, and then strengthen the ventilation speed, will also reduce the CH_2O concentration near crib. This study reveals theoretically indoor CH_2O concentration distribution near crib, which has important practical significance to raise awareness of CH_2O pollution and take some protective measures, in order to reduce harm caused by CH_2O for infants.

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