Study on the Distribution Characteristics and Purification Effect of Formaldehyde in Decorated Indoors under Different Ventilation Methods

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Abstract. This paper analyzes the improvement of formaldehyde concentration in residential decoration after one month and ten months by testing, and uses simulation software to numerically simulate the distribution of formaldehyde in the closed, natural ventilation and mechanical ventilation conditions of the decorated house. The results indicate that, the concentration of formaldehyde is 0.10 mg/m³ after one month of decoration, 25% above standard; reduced to 0.08mg/m³ after ten months, reaching the standard. In closed conditions, the concentration of formaldehyde near the sofa and bed is the highest at 0.08mg/m³, while the concentration in the kitchen and bathroom is slightly lower, around 0.07mg/m³. Compared with closed conditions, the concentration of formaldehyde in the living room, master bedroom, secondary bedroom, and kitchen is reduced by 40%, 35%, 10%, and 25% respectively when the natural ventilation wind speed is 0.2m/s; reduced by 80%, 80%, 50%, and 70% respectively when the natural ventilation wind speed is 2m/s; reduced by 40%, 55%, 55%, and 25% respectively when the mechanical ventilation wind speed is 2m/s.

1. Introduction
Nowadays, more and more new building materials are used in the decoration of houses and become the source of many indoor pollutants. Among them, the most harmful to the human body and one of the pollutants with a very long sustained release period is formaldehyde. The concentration of formaldehyde in the range of 0.05mg/m³~0.06mg/m³ will affect the human brain waves; in the range of 0.06mg/m³~0.07mg/m³, infants will have mild asthma[1]. Ventilation is an effective measure to treat indoor formaldehyde. Natural ventilation is economical and energy-saving but uncontrolled, it will increase the cooling and heating load. Mechanical ventilation can solve the problem of insufficient fresh air flow caused by closing windows when the outdoor climate is bad. Peng Yudan of Tianjin University[2] simulated a certain residence, obtained the diffusion law of formaldehyde, and carried out a quantitative evaluation. Wang Jingwen [3] analyzed the influence of outdoor wind speed and different intake and exhaust areas on the effect of natural ventilation.

2. Test research
2.1. Test contents
A typical newly decorated house in Shenyang is selected as the research object. Test the indoor formaldehyde concentration after one month and ten months of decoration, and explore the change rule of whether the window is opened or not within 40 minutes after 12 hours of airtight.
2.2. Test results

As shown in Figure 1, one month after residential decoration, the indoor formaldehyde concentration reached a maximum of 0.10mg/m³. During the test, the testers initially smelled a peculiar smell, and ten minutes later they felt dizzy and uncomfortable in their nose. Open the window after 15 minutes, the formaldehyde concentration decreased steadily after five minutes of ventilation. After 10 minutes of ventilation, the formaldehyde concentration stabilized within the range of 0.06mg/m³~0.07mg/m³.

As shown in Figure 2, ten months after the residential decoration, the highest formaldehyde concentration was 0.08mg/m³, and the testers did not feel discomfort. After 5 minutes of opening the window, the concentration of formaldehyde began to decrease and gradually stabilized, stabilizing within the range of 0.05mg/m³~0.06mg/m³. Residents can move in at ease but good indoor ventilation is required.

3. Numerical simulation research

3.1. Simulation of formaldehyde diffusion under closed conditions

3.1.1. Model establishment.
Use Geometry to build a geometric model, Mesh to divide the grid, and Fluent for numerical simulation. The house plan is shown in Figure 3.

3.1.2. Boundary conditions.
The bedroom floor, coffee table, dining table and sofa are the sources of pollution. The release rate of sofa (cloth) is $7.2\times10^{-11}$kg/s[4], and the release rate of wood furniture is $1.2\times10^{-8}$kg/s[5]. The initial concentration is set to 0.08mg/m³.
3.1.3. Simulation results.

(a) Y-axis living room  
(b) Y-axis near the head of the bed  
Figure 4. Closed conditions

3.2. Simulation of indoor formaldehyde diffusion under ventilation

3.2.1. Model establishment.

Figure 5. natural ventilation conditions  
Figure 6. mechanical ventilation conditions

3.2.2. Boundary conditions.

Entrance boundary of natural ventilation conditions: windows 1 and 2 are set as entrances, the speed of the test day 0.2m/s and the weather data speed 2m/s are set as two working conditions. Entrance boundary of mechanical ventilation conditions: the air supply outlets are set as entrances, the wind speed is set to 2m/s.

Exit boundary of natural ventilation conditions: windows 3 and 4 are set as exits. Exit boundary of mechanical ventilation conditions:Figure 6 shows the air outlets.

Other boundary conditions are the same as 3.1.2.

3.2.3. Simulation results.

(a) Y-axis living room  
(b) Y-axis near the head of the bed  
Figure 7. Natural ventilation wind speed of 0.2m/s
4. Conclusion

(1) One month after residential decoration, the indoor formaldehyde concentration exceeds the standard by 25%, which will endanger human health, people will feel uncomfortable indoors. After opening the window for ventilation, it can be reduced to the range of 0.06mg/m^3~0.07mg/m^3. At this time, the concentration is reduced to the standard value, but it is still harmful to human health, so it is not suitable to live in; ten months after decoration, the formaldehyde concentration is obvious decrease, the formaldehyde concentration value is up to the standard but still close to the standard value. Although you can stay at ease, you need to maintain good ventilation.
(2) The simulation results show that after ten months of residential decoration under closed conditions, the diffusion of formaldehyde is dependent on the air. It is not only simple density difference diffusion, but also stratification, but the concentration difference is not obvious, and it is close to uniform distribution in the room. The concentration of formaldehyde is the highest near the sofa and bed, which is 0.08mg/m³. If the room is not ventilated for a long time, people will be greatly polluted by formaldehyde during rest. The concentration value in the kitchen and bathroom is slightly lower, around 0.07mg/m³.

(3) Ten months after renovation, under the condition of natural ventilation of 0.2m/s, a large area of formaldehyde vortex area appears near the sofa and bed. Formaldehyde mainly gathers in the second bedroom, kitchen and the vicinity of the pollutant release source. Compared with airtight conditions, the formaldehyde concentration values of the living room, master bedroom, secondary bedroom, and kitchen have been respectively reduced by 40%, 35%, 10%, and 25%, and the ventilation effect of the secondary bedroom and kitchen is poor; under the condition of natural ventilation of 2m/s, the indoor formaldehyde vortex area is greatly reduced. The average indoor formaldehyde concentration level does not exceed 0.04mg/m³. After the ventilation reaches a stable state, the air quality in the living room and the master bedroom is the best. The concentration of formaldehyde near the head of the master bedroom is about 0.03mg/m³, and the concentration of formaldehyde near the head of the second bedroom is relatively high, about 0.05mg/m³. The concentration of formaldehyde in the four rooms has been reduced by 80%, 80%, 50%, and 70% respectively compared with airtight conditions, and the ventilation effect of each room is good.

(4) Under the working condition of mechanical ventilation of 2m/s, the concentration of formaldehyde in the four rooms was reduced by 40%, 55%, 55%, and 25% respectively. The formaldehyde concentration values of the master bedroom and the second bedroom are very low, the average value does not exceed 0.4mg/m³, the formaldehyde concentration near the sofa in the living room is slightly lower, in the range of 0.03mg/m³~0.063mg/m³; The concentration of formaldehyde in the kitchen and bathroom is relatively high but not exceeding the standard. It is a reasonable and effective way of ventilation when outdoor weather conditions are poor or there is no wind.

Acknowledgments
This work is supported by the National Natural Science Foundation of China(52078308): A Study on HAM Coupling Migration Discontinuous Model and Dynamic Performance of Porous Crack Enclosure Structure. 2021-01-01 to 2024-12-31.

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