Impact on the Indoor Environment of the Release and Diffusion of TVOC

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Abstract: The release of VOC_s by architectural decorative material, furniture and indoor things for use is considered the main reason for indoor environment pollution. The polypropylene Styene-Butadiene Rubber (abbreviation SBR) is regarded as a TVOC release source. The control function of the mechanism mode is put forward according to the process of the TVOC under dry conditions within the room in this study. The function is made up of three parts: the diffusion transport function of VOC_S in the material and the release transport function in the interface between air and material and the convention diffusion transport function of the TVOC in the air. The ventilation rate of the local research region was determined after analyzing the VOC_S release and diffusion concentrations by using the CFD and VOC_S release rates. The average concentration in the different baking temperature was compared. Effective dilution and ventilation methods should be further developed to shorten VOC_S release time and reduce its indoor concentration.

Key words: TVOC, release and diffusion mechanical mode, bake temperature, local purging flow rate

1. INTRODUCTION

It is researched that the release of VOC_s by architectural decorative material, furniture and indoor things for use is the principal reason of the indoor environment pollution. In recent twenty years, the research of the release character of the formaldehyde and VOC_s has been carrying at home and abroad, the reason of which is that the VOC_s release and diffusion process need to be mastered to appraise and control of the indoor pollution. According to literatures, there are two types: experiment mode and mechanism mode. At present, several tens of mathematics models have been developed to describe the diffusion process of indoor contamination. In the paper, the SBR lying over the floor board is regarded as the TVOC release source and control equations of VOC_s diffusing within the room is given according to the mechanism mode of release and diffusion of building materials contaminations in dry condition advanced by X.Yang[1] . After analyzing the VOC_S release rate and the average concentration in the different baking temperature, the local purging flow rate is obtained by using the CFD technique. Thus, the ventilation rate can be appraised and the effective dilution and ventilation way can be further set for less VOC_s concentration and pollution within the room.

2. THE CONTROL EQUATION OF THE TVOC RELEASE AND DIFFUSENESS MODE

The TVOC release and diffusion process can be expressed a representative indoor compound. In the paper, VOC_s is taken for example.

The release process of indoor VOC_s mainly involves three substance transmission processes [1] (See figure 1), the diffusion transport process of the VOC_S in the material, which represents as molecule diffusion process, the thermodynamics transport process in the interface between air and material, which represents as the distribution process of the adsorption and volatilization of the contamination component between the material and air, and the transport function of the TVOC in the air , which represents as the convention diffusion process. In the three subprocesses, the source inside of the first process and the airflow boundary layer of the third process are crucial. To predigest the transport process of the contamination source item, the following postulations are set:

1) The texture of the material is homogeneous and the contamination initial concentration is the same.

2) The contamination release and giving-off process of the material is physics phenomenon completely and it has no chemical reaction.

3) The contamination diffusion processes of the material do not interfere for each other.

4) The contamination diffusion of the material keeps to Fick Law entirely and the molecule diffusion caused by electric field or magnetic field is ignored.

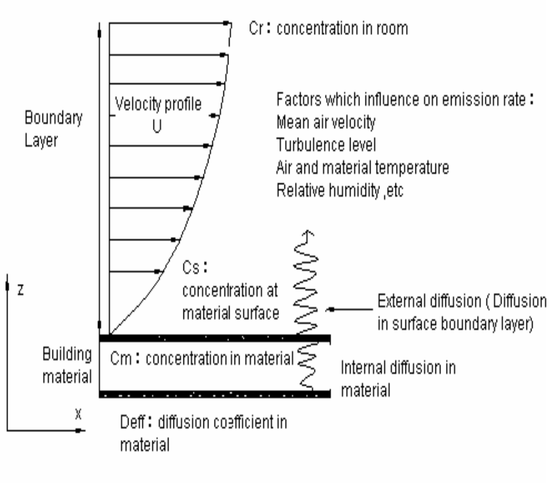

Fig.1 The VOC_S release process of the indoor material

2.1 The Release Mode of the Contamination inside the Material

The release of VOC_s inside the material can be described by the one-dimensional diffusion equation put forward by X.Yang.

$$\frac{\partial C}{\partial t}=\frac{\partial}{\partial z}(D_{eff}\frac{\partial C}{\partial z}) \quad (1)$$

$$C(z,t)=C_0 \quad 0\le z\le h, t=0$$

$$\frac{\partial C(z,t)}{\partial z}=0 \quad z=0, t>0$$

Where: $C(z,t)$ is the equivalence VOC_s concentration of the contamination inside the material in dry condition, mg/m^3. D_{eff} is the efficiency diffusion coefficient of VOC_s inside the material in dry condition, m^2/s. t ——time, s. C_0 ——the initial concentration of VOC_s inside the material in dry condition, mg/m^3.

2.2 The VOCs Transport Process in the Interface between Air and Material

In the interface of the material, according to the law of conservation of mass, the diffusion rate of the contamination inside the material is equal to the release rate of the contamination in the interface of the material.

$$D_{eff}\left.\frac{\partial C}{\partial z}\right|_{w,s+}=D_a\left.\frac{\partial C}{\partial z}\right|_{w.s-} \quad (2)$$

Where: C is the equivalence VOC_s concentration of the air in the material side and air side in the dry condition, mg/m^3. D_a is the diffusion coefficient of the molecule in the air, m^2/s. $w,s+$ and $w,s-$ are corresponding to the wall of the material side and the air side respectively.

2.3 The Convection Transport Process of the VOCs within the room

The VOC_s indoors is transported by the indoor airflow, influenced by the air molecule diffusion rate D_a and the air turbulent flow diffusion rate ν_t and finally is discharged by the indoor exhaust opening.

$$\frac{\partial C}{\partial t}+\frac{\partial(u_i C)}{\partial x_j}=\frac{\partial}{\partial x_j}[(D_a+\nu_t)\frac{\partial C}{\partial x_j}] \quad (3)$$

Where: $C(x,z,t)$ is the VOC_s concentration of the indoor air, mg/m^3. $u(x,z,t)$ is the indoor air speed, m/s. ν_t is the turbulent vortex viscosity coefficient, m^2/s.

The formula (1) (2) and (3) form the control equation of the release and diffusion mechanics of the indoor sheet material TVOC, which describes the three chief subprocesses of the VOC_S from the material to the indoor air.

3. NUMERICAL SIMULATION AND

RESULTS ANALYSIS

Using the character of the chemical matter of the decorating material easily volatilizable in the high temperature, the baking method can accelerate the dis -charge time of the venomousness or nocuousness gas. Comparing to the photochemical catalysis me-thod and the adsorption method, the baking method has the advantages of simpleness, high efficiency of elimination and disrepetition of pollution, so baking method has been thought one of the main methods of eliminating the indoor chemical contamination. In the paper, it has been carried out the release rate and the average concentration distribution of the board VOC_s in different baking temperature.

3.1 The Computing Model

The model is two-dimensional. The size of the room is 4.500×3.000m (length×highness) and the room has no person or no furniture. The room has uniformity temperature and no heat transfer. The wall and the ceiling have no adsorption function. The grou -nd is covered the SBR, of which the nature parame-ters are given. The transport equation inside the SBR is added to the ground and the pollution source is re-garded that homogeneously distributes in the whole ground. The supply-air outlet of the room is located in the left upper and its width is 0.06m. The supply air speed is determined by the ventilation frequency. The exhaust airway is located in the right upper and its width is equal to that of the supply-air outlet (see figure 2).

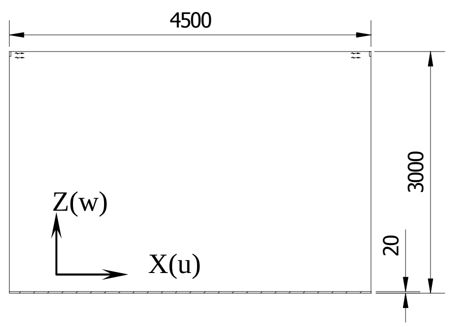

Fig.2 The calculate model

The material temperature range is 20 ~45 by the temperature corrected formula in the literature 2.It is showed in figure 3 the change of the effective diffu -sion coefficient D_{eff} and the indoor airflow molecule diffusion coefficient D_a with the baking

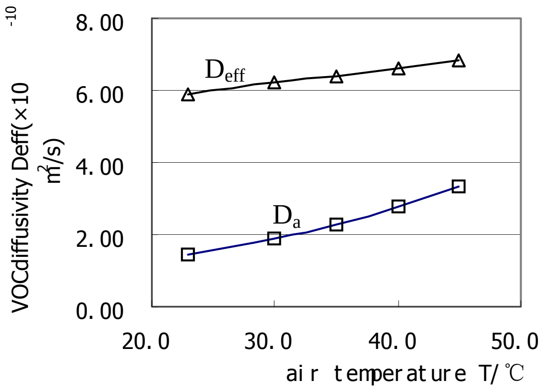

Fig.3 The effective diffuseness coefficient of VOC_S in the sheet material

3.2 The VOC_S Release Concentration inside the Sheet Material

The equation (1) is resolved with regarded the equation (2) as a boundary condition of the equation (1). The equation is belonging to the one-dimensional unsteady state problem in the limited zone, the ana-lytic solution of concentration of the VOC_S in the material can be obtained by method of variables separation[3].There are four different baking tempera -ture: 23 , 30 , 35 and 40 .Figure 4 show the VOC_S release concentration in the different tempera -ture.

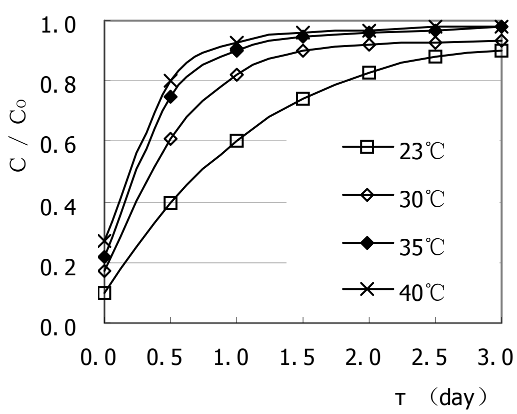

Fig.4 The release concentration of VOC_S inside the material

The higher the baking temperature, the faster the release speed. When the temperature becomes higher from 23 to 40 , the release concentration is two times in the foremost half day. It suggests that the release speed of the contamination is very fast. With the time going on, the release speed of the contamination has been reduced. Therefore, it is feasible in theory that the baking method can accelerate the release of the organic contamination in the room.

3.3 The Concentration Distribution of the Contamination within Room

The calculation of the indoor flow field is calculated by adoption the standard $k-\varepsilon$ mode. The concentration distribution of the VOC_s in different baking temperature is obtained by resolving the concentration distribution of the whole flow field .And the release concentration of the VOC_S inside the material is treated as the boundary condition of flow field. Figure 5 shows the VOC_S concentration distribution under baking temperature of at 23 for whole day. The concentration distribution at other temperature are similar to that at 23 and omitted.

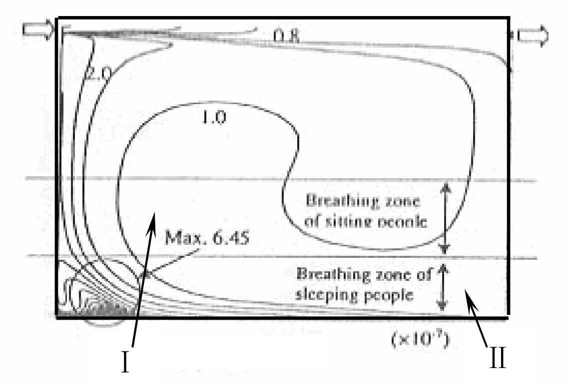

Fig.5 The distribution of the VOC_S consistency at 23

Figure 6 describes the time-varying change of the average concentration of the indoor VOC_S at different temperature.

3.4 The Indoor Ventilation Efficiency Evaluation

In order to further forecast the distribution of indoor contamination, local purging flow rate (abbreviation L-PFR) [4] is used to evaluate the indoor ventilation efficiency. L-PFR is defined as the necessary effective air circulation rate, which describes the capability of wiping off the contamination from a certain

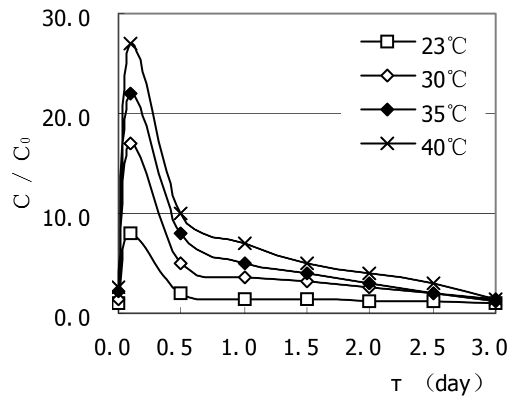

Fig.6 The attenuation change of VOC_S concentration with time

research zone. It is the ventilation efficiency index in the local research zone. Its expression is:

$$L-PFR=\frac{C_p}{C_{domain}} \qquad (4)$$

Where: C_p is the average concentration of the contamination in the local research zone, mg/m^3.

C_{domain} is the average concentration of the contamination in the calculate zone, mg/m^3.

In the paper, breath zone when sitting quietly and breath zone when sleeping are regarded as the local research zone (see figure 5, and zone). L-PFR of and zone can be figured out according to the result of figure 4 and figure 5.The calculation shows when room temperature is 23 ,the L-PFR of and zone is 0.63 and 0.56 respectively, which means that the efficiency ventilation rate in the breath zone is 63% when sitting at room-temperature and 56% when lying. In other words, 37% and 44% of the total ventilation quantity is not used to dilute VOC_s. Especially in zone, nearly half ventilation quantity is exhausted from the exhaust airway directly instead of using to diluting VOC_s. Therefore, it is a problem to be discussed further on how to set the ventilation measure properly at this place to achieve more efficiency ventilation rate.

4. CONCLUTSIONS

The following conclusions can be gained:

1) The control equation serials of the model is set up according to the release and diffusion mechanics model of indoor contamination, which describes the whole process of the release, transportation and diffusion of the indoor contamination.

2) The release speed of VOC_S in the sheet material has close correlation to the material temperature. The increasing of the baking temperature can accelerate the release and volatilization of the organic contami -nation in the sheet material, so the baking method can be used to shorten the time of VOC_S emitting indoors.

3) The diffusion speed of the VOC_S concentration is very fast during the foremost day and the peak value is mainly centralized within 1m on the source. In the zone, the local purging flow rate is 56% when the baking temperature is 23 .Thus, the more effective measure of dilution and ventilation should be taken to efficiently discharge contamination.

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