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Study of the resistances to transfer of gaseous pollutant between material and indoor air

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ABSTRACT

The main parameters which control the emission of volatile organic compounds between wall materials and indoor air were examined. A physically based model considers that the global emission phenomenon results from three elementary physical phenomena: diffusion through the boundary layer separating the wall from environment, diffusion within the porous network of the materials, and sorption of the gas molecules on the active sites of the materials. The pollutant transfer between porous material and air is therefore subjected to two complementary resistances and we identify first the resistance which controls the transfer. Then, we predict the global emission time constant from the mass transfer coefficient of convection and the thickness of the material. Experimental results from a small scale chamber are compared to predicted values in the case of acetone emission from chipboard in humid air and for high initial acetone concentration. Good agreement is obtained at the beginning of emission but an acetone retention effect by chipboard is observed, showing that it will be necessary to take into account the interactions of water vapor with materials and the pollutants to achieve accurate modeling of the material VOC emission process.

1. Introduction

The furnishing or building materials contain many pollutants [1,2] making indoor air quality as a major stake. A particular interest relates to the volatile organic compounds, like those emitted by constituting materials of the walls of a room. Among the effective solutions to improve indoor air quality, ventilation consists of eliminating the pollutant as soon as it is emitted. Then, recent works have shown that sorption of VOCs on material surface should be considered in ventilation strategy [3,4]. Also it has been reported that increasing air velocity at the material surfaces can increase the VOCs initial emission rate [5,6].

Therefore, the period during which a material emits a pollutant must be known if one wants to adjust ventilation and to reduce energy over consumptions. Defining the appropriated ventilation requires to better understand how a pollutant is accumulated/emitted and transported. It also requires to characterize the main phenomenon which controls the process [7].

That's why several mass transfer models have been developed to predict the time variation of the indoor VOC concentration [4,8–10]. A review of existing macroscopic models and elemental model has been already presented [10]. The authors concluded that elemental models coupling local equilibrium sorption models and diffusion equations are more realistic. According to Li and Niu [4], the single-layer, double layer and multi-layer continuum models are suitable for environment chamber study. The authors developed a multi-phase emission/sorption model able to simulate multiple-material components and varying ventilations. They observed that pre-occupancy flush-out, lead time ventilation or similar measures have substantial impact on indoor air VOC concentration. A three-dimensional mass transfer modeling of VOCs from wet painting was also developed [8]. It takes into account the convective mass transfer between the fresh paint and air, the diffusion in the paint film and diffusion in the substrate. Evaporation from paint dominated first. Then, the substrate acts as a sink and VOCs emission is controlled by diffusion, showing that the relative magnitude of the resistances of surface convection and material diffusion varies with time.

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