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An experimental study of relative humidity effect on VOCs' effective diffusion coefficient and partition coefficient in a porous medium

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ABSTRACT

Most building materials are porous media. As a critical environmental factor, the influence of relative humidity on VOCs diffusion is still not well understood. In this study, VOC transport and sorption in a porous medium in the building materials (calcium silicate) were measured under three levels of relative humidity (25%, 50% and 80%) by using a dynamic dual chamber method. Tests were conducted for water-soluble compound (formaldehyde) and non-soluble compound (toluene). In addition, the transport of acetaldehyde, hexanal, benzaldehyde, butanol and decane through the calcium silicate were also tested at 50%RH to study the relationship between the effective diffusion coefficient (D_e), partition coefficient (K_{ma}) and the VOCs' physical properties (molecular weight, vapor pressure and Henry's law constant). Experimental results showed that: relative humidity in the 80%RH led to a higher partition coefficient for formaldehyde compared to 50%RH. However, between 25% and 50%RH, there was no significant difference in partition coefficient. Partition coefficient of toluene decreased with the increase of humidity due to competition of water molecules for pore surface area and the non-solubility nature of toluene. Relative humidity had no significant influence on the effective diffusion coefficient on both formaldehyde and toluene for the range of moisture conditions tested. The solubility of VOCs was found to correlate with the partition coefficient of VOCs. The partition coefficient of VOCs was not simply inversely proportional to the vapor pressure of the compound, but also increased with the increase of Henry's law constant.

1. Introduction

Relative humidity can affect the emission rate depending on the type of the emission materials and type of volatile organic compounds (VOCs) emitted. Wolkoff [1] tested five common building products under 0% and 50%RH. The materials studied were nylon carpet with latex backing, PVC flooring, floor varnish on pretreated beechwood parquet, sealant and waterborne wall paint on gypsum board. The increase from 0% to 50%RH led to the higher concentration of 2-ethylhexanol from carpet during the first week and obvious concentration elevation of 1, 2-propandiol from wall paint in the whole test period of 25 days. The concentration of dimethyloctanols from sealant was higher at 50% than 0% during the first couple of days, but the trend reversed later.

Fang et al. [2] measured the chemical emissions from five building materials (carpet, polyvinyl chloride (PVC) flooring, sealant, floor varnish and wall paint) in the relative humidity range of 30%–70% in modified CLIMPAQ chamber. For floor varnish and wall paint, the measured TVOC increased very significantly when humidity increased from 30% to 70%; however, for carpet, PVC flooring and sealant, the influence of relative humidity was not obvious. Relative humidity affected only the waterborne materials-floor varnish and wall paint.

Zhang et al. [3] tested the sorption characteristics at 25%, 50% and 80%RH, respectively. The tested VOCs included ethylbenzene, benzaldehyde, decane, 1, 4-dichlorobenzene, undecane and dodecane. For painted drywall, the increase of RH from 25% to 80% significantly increased the amount of decane, 1, 4-diclorobenzene, undecane and dodecane. For ceiling tile, the sink effect of benzaldehyde was increased when RH increased from 50% to 80%, but the amount of dodecane adsorbed decreased with the increase of relative humidity. The results did not show obvious influence for the other compounds. For carpet, only the amount of 1, 4-dichlorobenzene increased slightly with the increase of relative humidity.

The above results indicate that a higher humidity may lead to increase in some VOC emissions from some materials, but the mechanism for the humidity effects is not clear. Broadly speaking, possible causes of enhanced emission at a higher humidity may

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