Atmospheric Environment 47 (2012) 381–388

Contents lists available at SciVerse ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

A standard reference for chamber testing of material VOC emissions: Design principle and performance

Wenjuan Wei [a], Yinping Zhang [a,*], Jianyin Xiong [b], Mu Li [a]

[a] Department of Building Science, Tsinghua University, Beijing 100084, China
[b] School of Mechanical and Vehicular Engineering, Beijing Institute of Technology, Beijing 100081, China

ARTICLE INFO

Article history:
Received 2 August 2011
Received in revised form
20 October 2011
Accepted 24 October 2011

Keywords:
VOC emission
Standard reference
Chamber
Furniture
Indoor air quality (IAQ)

ABSTRACT

Environmental chambers are widely used to test formaldehyde and other volatile organic compound (VOC) emissions from indoor materials and furniture. However, there is a lack of a proven method to assess the precision of the test results of the chamber system. In this paper, we describe a new standard reference, LIFE (liquid-inner tube diffusion-film-emission), to address this problem. This reference has the following salient features: (1) Constant emission rate, with less than 3.0% change with an ambient airflow speed (>0.014 m/s) at furniture emission range (0.1–1.0 mg/m^3 in a 30 m^3 chamber with air change rate of 1/h) under standard chamber test conditions as specified by ISO 16000-9 (23 °C, 50% RH); (2) Long duration of emissions, on the order of 1000 h; (3) Easy to store, apply and maintain. The design principle and criteria of the LIFE reference are presented. An analytical model and dimensionless analysis were applied to optimize the factors influencing the emission rate, and experiments were conducted to validate the analytical results. In addition, the equivalent emission parameters of the reference, i.e., the initial emittable concentration, the diffusion coefficient and the partition coefficient, were determined through a three-parameter optimizing regression. This can then be used to check the reliability of a chamber method for testing these three parameters. The developed standard reference should prove useful for calibrating chamber systems for indoor material/furniture VOC emissions tests.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

In order to evaluate the emission level of formaldehyde and other volatile organic compounds (VOCs) from indoor furniture, environmental chamber testing systems have been widely used to directly measure the formaldehyde and VOC emission characteristics. However, variations in test results among laboratories can be significant: previous inter-laboratory studies for product emission tests (ECA, 1993; De Bortoli et al., 1999; BAM, 2009; Horn et al., 2010; Howard-Reed and Nabinger, 2006; Howard-Reed et al., 2011) showed a significant variation among laboratories from less than 10% to as high as 240%. The World Calibration Centre for volatile organic compounds (WCC-VOC) coordinated a comparison (Rappengluck et al., 2006) of nine laboratories from seven countries to evaluate the accuracy of the instrumentation employing gas chromatography (GC) for VOC measurement. Standard gas canisters containing 73 VOCs from C_2 to C_{11} with a carrier gas of nitrogen were used as the VOC sources. Comparison results showed that only 18 compounds (propane, isoprene, benzene, ethylene, propylene etc.) were accurately determined by at least 50% of the laboratories. The accuracy of a chamber system for emissions tests is influenced by some factors, such as chamber performance, detection equipment uncertainties, operation misses, etc., and a reference is generally needed to calibrate the chamber system before real emission tests are performed. Both the BIFMA (2009) and the ASTM D6670-01 (2001) standards specify a convenient method of using a petri-dish containing pure VOC liquid as a reference sample (Zhang et al., 1999). A balance is put into the chamber together with the reference sample where real time weighing is performed to determine the emission rate. The emission rate of the reference sample calculated by the chamber test is then compared with the balance value to determine any differences. However, the ambient airflow often influences the emission process, making the emission rate unstable.

Cox et al. (2008, 2010) loaded toluene into a polymethylpentene (PMP) film and tested the toluene emission profile of the film. An inter-lab chamber comparison for small scale chambers was done by using the PMP sample to study the inter-lab emission profile differences as well as the differences compared with the emission model (Howard-Reed et al., 2011). For this particular sample, there

* Corresponding author. Tel.: +86 10 62772518; fax: +86 10 62773461.
E-mail address: zhangyp@tsinghua.edu.cn (Y. Zhang).

1352-2310/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.atmosenv.2011.10.051

are three key emission parameters, i.e., the initial emittable concentration (C_0), the diffusion coefficient of the target VOC in material (D_m), and the material/air partition coefficient (K), which are generally used to predict material emissions by virtue of physical models (Little et al., 1994; Haghighat and Zhang, 1999; Guo, 2002; Xu and Zhang, 2003; Deng and Kim, 2004; Lee et al., 2005; Xiong et al., 2011). Therefore, the emission profile of this sample is similar to that of a real building material. However, the original model (Little et al., 1994) makes an assumption that the convective mass transfer coefficient in the chamber air can be ignored. This assumption may result in higher emission rates or chamber concentrations in the initial period of the emission process compared with the later improved models (Xu and Zhang, 2003; Deng and Kim, 2004). Therefore, for a PMP sample, the theoretical instantaneous emission rate deviation is influenced by modeling deviation and testing deviations of the three key emission parameters of the sample. Meanwhile, several technical steps are needed to deal with the toluene loading process and real chamber test operation to extend the PMP film tests from small scale chambers to full-scale chambers. In addition to the chamber system performance studies, traditional permeation tubes provide another means of chamber emission calibration. In these applications, the tube is placed outside the chamber system with its own heating and air supply system, so that some important chamber properties such as chamber temperature and relative humidity do not influence the emission rate of the tube. However, for real material and furniture tests, all test conditions are controlled by the chamber system. So, laboratories which have similar permeation tube testing results may have different furniture testing results in their chambers.

The objectives of this paper are: (1) to describe the design of a liquid-inner tube diffusion-film-emission (LIFE) standard reference with a constant emission rate that is not influenced by ambient airflow under standard temperature and relative humidity conditions; and, (2) to study the equivalent emission parameters of the LIFE reference, which can then be used as reference parameters to determine whether a chamber testing method for measuring C_0, D_m and K is reliable.

2. Design principle and criteria of the LIFE reference

2.1. Properties and structure

Generally, the following properties are required for the reference: (1) the emission rate of the reference remains constant under standard temperature and relative humidity conditions; (2) the emission rate of the reference should be appropriate to simulate actual building material or furniture emission levels; (3) the reference can be directly used in the chamber without any other heating or gas supply system such that the actual emission behavior of the reference is only influenced by the chamber system conditions; (4) the emission rate of the reference is not significantly influenced by the chamber airflow rate.

The designed LIFE reference has the above-mentioned properties and is shown in Fig. 1. The reference is comprised of a cylinder with a diameter of 40 mm and a length of 40 mm to hold a single, purified VOC in liquid state as the emission source, a thin diffusion film to cover the opening of the cylinder to control the emission rate, and fastening pieces to hold the cylinder and film in place. Based on the configuration of the reference, we refer to it as a liquid-inner tube diffusion-film-emission (LIFE) sample. The cylinder and fastening pieces are made of Teflon. Therefore, VOC diffusion through the relatively thick wall of the tube is ignored compared with that through the diffusion film at standard temperature (23 °C).

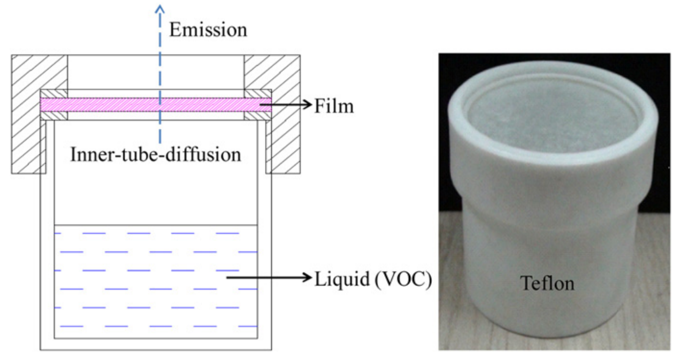

Fig. 1. Schematic of a LIFE reference.

2.2. Model development and dimensionless analysis

A steady state VOC mass transfer process can be broken down into three steps: (1) VOC diffusion through the inner-tube air layer, with a diffusion resistance of $R_{ab} = \delta/(D_{ab}A)$. D_{ab} is the diffusion coefficient of VOC in the inner-tube air, m^2/s; A is the surface area of the film, m^2; δ is the distance between the surface of the VOC liquid and the film, m. (2) VOC diffusion through the diffusion film, with a diffusion resistance of $R_m = L/(D_m A)$. L is the thickness of the film, m; D_m is the diffusion coefficient of VOC in the film, m^2/s. (3) VOC convection to the ambient air, with a convective mass transfer resistance of $R_{conv} = 1/(h_m A)$. h_m is the convective mass transfer coefficient, m/s. The emission model for the reference in a chamber is shown in Fig. 2.

The mass transfer equation within the film is written as:

$$\frac{\partial C}{\partial t} = D_m \frac{\partial^2 C}{\partial x^2} \tag{1}$$

The chamber air is assumed to be well-mixed, i.e., the VOC concentration in the chamber is uniform. The mass conservation equation of the chamber VOC is written as:

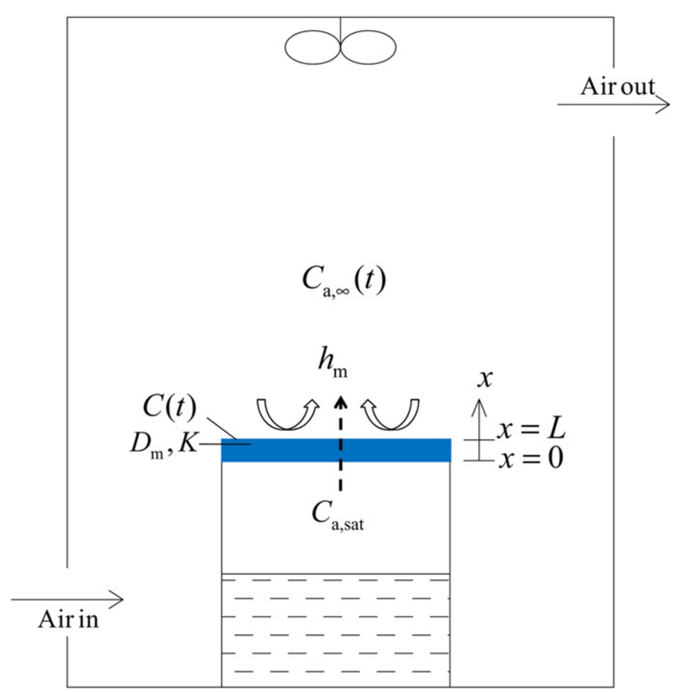

Fig. 2. Emission model of LIFE reference in a chamber.

Download English Version:

https://daneshyari.com/en/article/4439027

Download Persian Version:

https://daneshyari.com/article/4439027

Daneshyari.com