Building and Environment 60 (2013) 272–279

Contents lists available at SciVerse ScienceDirect

Building and Environment

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

A simple and efficient method for evaluating air-cleaning performance against airborne allergen particles

Hak-Joon Kim [a], Bangwoo Han [a], Yong-Jin Kim [a,*], Choon-Soo Jeong [b], Sung-Hwa Lee [c]

[a] Environmental and Energy Systems Research Division, Korea Institute of Machinery and Materials, 156 Gajeongbuk-Ro, Yuseong-Gu, Daejeon 305-343, Republic of Korea
[b] School of Biological Science, University of Ulsan, Ulsan 389-749, Republic of Korea
[c] Digital Appliance Company Research Laboratory, LG Electronics, Seoul 153-802, Republic of Korea

ARTICLE INFO

Article history:
Received 20 July 2012
Received in revised form
29 October 2012
Accepted 1 November 2012

Keywords:
Allergen
Airborne particles
ELISA
Optical particle counter
Clean-air delivery rate
Removal efficiency

ABSTRACT

Size- and time-dependent aerodynamic behaviors of airborne allergen particles were evaluated in a 30-m^3 chamber, both with and without the operation of air-cleaning devices: a dehumidifier and an air conditioner. In-situ real-time measurements were taken using an optical particle counter. Removal efficiencies obtained from the counter, based on particle number and volumetric concentrations, were compared to values from the conventional ELISA method, which is time-consuming and requires off-line measurements. The log of clean-air delivery rates (CADR) was linearly proportional to the log of particle size. When a dehumidifier and an air conditioner were used, CADRs against airborne allergen particles increased by 4 and 7 times, respectively, compared with conditions without air-cleaning devices. The settlement of the particles smaller than 1 μm was hardly affected by gravity, but concentrations of these particles decreased to nearly 50 and 30% of the initial concentrations with the operation of a dehumidifier and of an air conditioner, respectively. Moreover, the concentration of particles with a peak size of about 5.7-μm decreased to 9 and 0.3% of the initial value after only 30 min of operation of a dehumidifier and of an air conditioner, respectively. Comparing removal performance results between analyses that used a particle counter and the ELISA method, our new simple test method, which used an optical counter and was based on total volume concentrations, could easily predict the removal efficiency of airborne allergen particles, and the results were consistent with those obtained using the ELISA method.

1. Introduction

Indoor air quality has received increasing attention in recent years with the global increase in allergic diseases. Exposure to indoor allergens is probably more important than exposure to outdoor allergens because we spend most of our time indoors. Indoor exposure is also perennial and often involves high concentrations, and the level of exposure increases with modernization in housing design [1]. In particular, exposure to allergens derived from house dust mites (HDM) causes bronchoconstriction in asthma patients and induces an inflammatory response in the lungs due to the release of cytokines, chemokines, and additional mediators [2]. Also, HDM allergens, including Der P 1, a major group 1 allergen, are the most common cause of allergic diseases worldwide [3,4]. Exposures to dog and cat allergens are also believed to play important roles in the etiology of asthma. Almost 40% of children with asthma are sensitive to cat allergens, and these allergens are a significant risk factor for acute asthma in patients seeking treatment in emergency rooms; even slight exposure to cats can precipitate severe asthma symptoms in susceptible individuals [5,6]. The single major cat allergen (Fel d 1) is responsible for a large proportion of cat-specific IgE in patients who are allergic to cats [7].

Different allergens are carried by particles with a range of shapes and sizes, which affects their behavior when they are disturbed and airborne. Using an aerosol sampler that collected airborne particles larger than 5 μm and an optical microscope, De Lucaa et al. [8] investigated the physical characteristics of Der P 1 in a house and found that 80% of detectable Der P 1 aerosols were associated with particles larger than 10 μm and that a small portion was associated with particles smaller than 5 μm. However, particles with aerodynamic diameters less than 10 μm increased the likelihood of lung deposition. Custovic et al. [6] also investigated the size distribution of airborne Fel d 1 particles using an aerosol sampler and the ELISA method based on allergen mass and found that 49% of the total allergens were larger than 9 μm, and almost 23% of the airborne Fel d 1 was carried on small particles (<4.7 μm) that could

* Corresponding author. Tel.: +82 42 868 7475; fax: +82 42 868 7284.
E-mail address: yjkim@kimm.re.kr (Y.-J. Kim).

0360-1323/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.buildenv.2012.11.002

remain airborne for several days. However, these studies were only conducted using sampled allergen particles and were only based on allergen mass.

The use of electrical devices, such as air-cleaning devices, to reduce airborne house dust mite and cat allergens indoors may be of clinical benefit for allergen-sensitized respiratory patients [9–12]. Several researchers have studied the effects of filtration devices on the removal of allergen particles indoors [13–16]. However, most of these studies were conducted using only measurements based on the time-consuming ELISA (two-site enzyme-linked immunosorbent assay) method, which cannot analyze the real-time size-dependent aerodynamic properties of removal devices.

The size- and time-dependent aerodynamic behaviors of airborne influenza particles were evaluated with various kinds of air cleaners in a closed chamber using in-situ optical particle sizers, while using NaCl particles, not real airborne influenza particles [17].

In this study, the size- and time-dependent aerodynamic behaviors of airborne allergen particles in a 30-m^3 chamber, both with and without the operation of air-cleaning devices, were evaluated by taking in-situ real-time measurements using an optical particle counter. We also compared the particle counter results to those from the ELISA method and suggested a new simple method that can predict air-cleaning performance against airborne allergen particles.

2. Experiments

2.1. Preparation and physical characteristics of test powders

Fig. 1 shows photographs of the test powders that were used in this study. To prepare test powders that contained house dust mite and cat allergens, 30 g of culture medium containing house dust mite allergen (Der P 1) and cat allergen (Fel d 1) was cultured at a temperature of 25 ± 3 °C and a relative humidity of 75 ± 2%. The culture medium was then dried for 24 h in an electric dryer. The cultured medium was carefully ground with a stirred ball mill for 10 min, and the mass concentration of the allergen proteins in the ground powder was 10% of the total mass.

Fig. 1. Photograph of test powder containing house dust mite and cat allergens at a concentration of 10% of the total mass.

Fig. 2 shows the size distribution of the test powers based on numeric and volumetric concentrations when 0.2–0.25 g of powder was pulverized in a closed chamber. Based on the volume of airborne particles, the peak concentration of particles with diameters of 3.7–6.7 μm was continuously observed. There were no significant differences in the size distribution of airborne allergen particles during five repeated measurements.

2.2. Experimental methods

The experimental setup for measurements of CADR (clean-air delivery rate) and the removal efficiency of air-cleaning devices for airborne allergen particles are shown in Fig. 3. A dehumidifier and an air conditioner with a pre-filter, as air-cleaning devices, were tested in a closed test chamber with the room temperature and relative humidity of 23 ± 5 °C and 55 ± 15% respectively, and the other functions of the devices to remove water vapor and to reduce temperature in a test chamber were not operated during tests for allergen removal performance because the functions could affect the test conditions of the chamber. The specifications of the test equipment, which were commercially available in Korea, are summarized in Table 1.

A closed stainless steel chamber (4 × 3 × 2.5 m^3) was used in this study. Particle leakage of the test chamber was negligible during the test. When we checked the natural decay after one hour

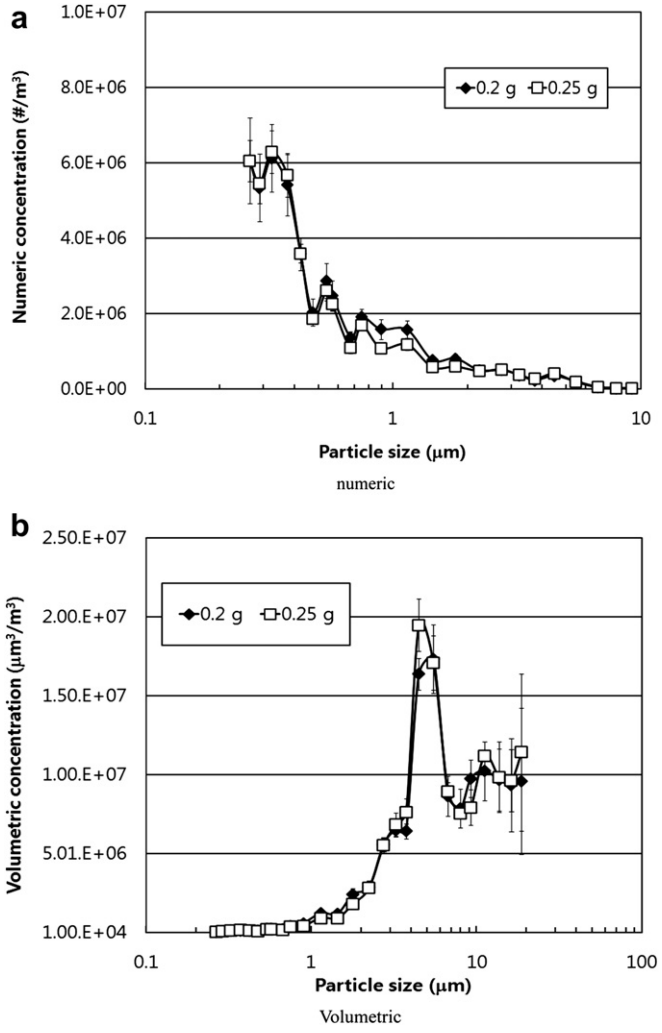

Fig. 2. Size distributions of airborne allergen powders based on numeric and volumetric concentrations in a 30-m^3 closed test chamber: (a) numeric and (b) volumetric.