Building and Environment 46 (2011) 1699–1708

Contents lists available at ScienceDirect

Building and Environment

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

Removal of submicron particles using a carbon fiber ionizer-assisted medium air filter in a heating, ventilation, and air-conditioning (HVAC) system

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ARTICLE INFO

Article history:
Received 4 November 2010
Received in revised form
14 February 2011
Accepted 15 February 2011

Keywords:
HVAC system
Air cleaning
Ventilation
Medium air filter
Carbon fiber ionizer
Submicron aerosol particles

ABSTRACT

Laboratory tests of particle removal were performed with a pair of carbon fiber ionizers installed upstream of a glass fiber air filter. For air flow face velocities of 0.4, 0.6, and 0.8 m/s, the overall particle removal efficiencies of the filter for all submicron particles were 17%, 16%, and 14%, respectively, when the ionizers were not turned on. These values increased to 27%, 23%, and 19%, respectively, when the ionizers were used to generate ions of 6.0×10^9 ions/cm^3 in concentration. The carbon fiber ionizers were then installed in front of a glass fiber air filter located in a heating, ventilation, and air-conditioning (HVAC) system. Field tests were performed in a test office room with a total indoor particle concentration of 2.2×10^4 particles/cm^3. When the flow rate was 75 cubic meters per hour (CMH), the steady-state values of the total indoor particle concentrations using the glass fiber air filter with and without ionizers decreased to 0.87×10^4 particles/cm^3 and 1.15×10^4 particles/cm^3, respectively, resulting in a 25% decrease of the ionizer effect. When the operation flow rate was increased to 115 and 150 CMH, the effect of the ionizer decreased to 19% and 17%, respectively. These experimental data match the results calculated using a mass-balance model whose parameters were determined from laboratory tests.

1. Introduction

Increasing public concern regarding air quality in residential and non-residential buildings has necessitated the development of efficient indoor aerosol filtration techniques. Higher exposure to fine particles has been related to higher death rates due to lung cancer and cardiopulmonary illness. When humans inhale, particles in the air enter the body. Micron-sized particles are intercepted by the hairs of the nostril, but submicron-sized particles can reach the lungs and become deposited in the alveoli [1,2].

An understanding of indoor particle sources is important to enable exposure control and reduction. Morawska et al. [3] examined fine particle numbers and mass concentrations in residential houses. Cooking [4–6] and tobacco smoking [3,7,8] are important indoor sources of fine aerosol particles. Several studies have reported that laser printers can be a source of ultrafine particles (<0.1 μm) [9–11].

Heating, ventilation, and air-conditioning (HVAC) systems with air cleaning systems have been the main tool for controlling indoor aerosols. HVAC systems can be equipped with air filters and electrostatic precipitator (ESP) for air cleaning. Commercially available air filters for HVAC systems consist of fibrous materials and represent a wide range of collection efficiencies for submicron particles. Jamriska et al. [12] investigated an HVAC system in an office building consisting of a medium filter and an air-conditioning unit in which submicron particle concentration levels were reduced by 34%. Rudnick [13] designed a high-efficiency particulate air (HEPA) filter for removal of submicron-sized indoor particles. The collection efficiency of a HEPA filter used to remove nano-sized aerosols was studied by Steffens and Coury [14]. However, most efficient filters with high packing densities often cause a higher initial pressure drop that can increase over time due to additional loading [13,15].

ESPs are commonly used for particle removal. They can handle large gas volumes and collect a wide range of particle sizes without draft loss [16]. Howard-Reed et al. [17] measured the deposition of several kinds of particles of different sizes, ranging from 0.3 to 10 μm, with a central HVAC fan on or off and with the ESP on or off. Wallace et al. [18] conducted a study that compared ventilation systems using ESP and fibrous mechanical filters. Fisk et al. [15] predicted attainable reductions in the indoor mass concentrations of particles by using ESP and filters in building supply airstreams. Despite their effectiveness, ESPs have limitations including high

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doi:10.1016/j.buildenv.2011.02.010