Building and Environment 46 (2011) 2303–2313

Contents lists available at ScienceDirect

Building and Environment

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

Particle concentrations and effectiveness of free-standing air filters in bedrooms of children with asthma in Detroit, Michigan

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ARTICLE INFO

Article history:
Received 24 November 2010
Received in revised form
22 March 2011
Accepted 13 May 2011

Keywords:
Indoor environment
Free-standing HEPA air filters
Asthmatic children
Particulate matter
Exposures

ABSTRACT

Asthma can be exacerbated by environmental factors including airborne particulate matter (PM) and environmental tobacco smoke (ETS). We report on a study designed to characterize PM levels and the effectiveness of filters on pollutant exposures of children with asthma. 126 households with an asthmatic child in Detroit, Michigan, were recruited and randomized into control or treatment groups. Both groups received asthma education; the latter also received a free-standing high efficiency air filter placed in the child's bedroom. Information regarding the home, emission sources, and occupant activities was obtained using surveys administered to the child's caregiver and a household inspection. Over a one week period, we measured PM, carbon dioxide (CO_2), environmental tobacco smoke (ETS) tracers, and air exchange rates (AERs). Filters were installed at midweek. Before filter installation, PM concentrations averaged 28 μg m^{-3}, number concentrations averaged 70,777 and 1471 L^{-1} in 0.3–1.0 and 1–5 μm size ranges, respectively, and the median CO_2 concentration was 1018 ppm. ETS tracers were detected in 23 of 38 homes where smoking was unrestricted and occupants included smokers and, when detected, PM concentrations were elevated by an average of 15 μg m^{-3}. Filter use reduced PM concentrations by an average of 69–80%. Simulation models representing location conditions show that filter air flow, room volume and AERs are the key parameters affecting PM removal, however, filters can achieve substantial removal in even "worst" case applications. While PM levels in homes with asthmatic children can be high, levels can be dramatically reduced using filters.

1. Introduction

Airborne particulate matter (PM) is an environmental trigger of asthma [1–3] and has been linked to adverse health impacts including aggravation of respiratory conditions and premature death [4,5]. Often, attention focuses on the PM fraction that is small enough to enter deep into the respiratory tract, e.g., $PM_{2.5}$ consisting of particles smaller than 2.5 μm dia [6,7]. Exposure to environmental tobacco smoke (ETS), to which a large fraction (60%) of asthmatic children in the U.S. is exposed [8], is associated with increased frequency and severity of asthma attacks, prolonged duration of symptoms, and decreased lung function [9,10]. Children in urban areas are especially exposed to elevated levels of allergens and indoor air pollutants, including $PM_{2.5}$ [7].

Indoor environments dominate exposures of many pollutants, including PM, because most people spend the bulk of their time indoors, e.g., U.S. adults and children respectively are indoors 87 and 85% of the time [11]. Indoor PM concentrations are determined by both indoor emission sources, e.g., tobacco smoke, gas stoves, cooking, vacuuming, and outdoor (ambient) sources, e.g., suspended soils, pollen and traffic exhaust [12–14]. Ambient $PM_{2.5}$ can easily penetrate building envelopes [7,18–20] and it represents an important component of indoor exposure [15]. ETS is an important source of PM as well as gaseous pollutants [9,16]. In addition to the types and strengths of indoor and outdoor sources [14,17], indoor concentrations are affected by building characteristics [17,18], air exchange rates (AER) [19], air mixing characteristics [20,21], heating/cooling system type [22], and the presence, if any, of PM filters [19,23–25].

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doi:10.1016/j.buildenv.2011.05.012