Atmospheric Pollution Research 6 (2015) 21-28

Atmospheric Pollution Research

www.atmospolres.com

Statistical approach for determining the effects of microclimatic parameters on household spray products aerosol deposition

Jamiu Adetayo Adeniran [1], Jacob Ademola Sonibare [2], Lukuman Adekilekun Jimoda [1]

[1] *Environmental Engineering Research Laboratory, Department of Chemical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria*
[2] *Environmental Engineering Research Laboratory, Department of Chemical Engineering, Obafemi Awolowo University, Ile–Ife, Nigeria*

ABSTRACT

The understanding of aerosol deposition in the indoor environment is relevant for assessing the exposure of occupants. This study investigates the effects of microclimatic parameters on the deposition rates of aerosols emanating from the use of household spray products in indoor environment. A three–factor factorial design was used to study the effects of interactions of air temperature, relative humidity and Air Exchange Rate (AER) on the deposition rate of particulate matter (PM). The highest deposition rate of 0.3 µm particles (PM$_{0.3}$) was 627.8 h^{-1} when the relative humidity, temperature and AER were 40%, 40 °C, and 12 h^{-1}, respectively while the highest deposition rate of 5.0 µm particles (PM$_{5.0}$) was 709.20 h^{-1} when the relative humidity, temperature and AER were 70%, 25 °C, and 12 h^{-1}, respectively. Regression analysis showed that air temperature and air exchange rate had significant effects on the deposition of PM$_{0.3}$, while relative humidity and air exchange rate had significant effects on the deposition of PM$_{5.0}$ at $p<0.05$. The experimental values were very close to the predicted values and were not statistically different at 95% confidence level.

Keywords: *Aerosol, deposition, indoor environment, particulate matter, microclimatic parameter*

Corresponding Author:
Jamiu Adetayo Adeniran
☎ : *+234-803-366-0981*
✉ : *adeniranadetayo@yahoo.com*

Article History:
Received: 25 February 2014
Revised: 01 July 2014
Accepted: 01 July 2014

doi: 10.5094/APR.2015.003

1. Introduction

Studies and policies on air quality in terms of its potential impacts on health and environment have focused more on the outdoor air than indoor. This gap has shifted the concern of air quality experts on indoor air, in recent years (Weber, 2006; Liu et al., 2010; Weschler and Nazaroff, 2010; Ocak et al., 2012). Studies have attributed indoor aerosol concentration levels to sources from outdoor (Milner et al., 2004; Massey et al., 2009) and those from indoor related activities like washing, cleaning and cooking (Estokova et al., 2010; Diapouli et al., 2011; Pervez et al., 2012), while cooking (Abdullahi et al., 2013), tobacco smoking (He et al., 2005; Protano et al., 2014) and biomass burning (He et al., 2010) have been rated as significant sources of particulate matter in the indoor environment. Recent studies have identified household spray products as potential sources of aerosols indoor because their uses increase the concentration of gaseous and particulate species (Hagendorfer et al., 2010; Lorenz et al., 2011). The understanding of aerosol deposition from the use of spray products in indoor environment can improve our knowledge on exposure assessment.

World Health Organization estimated that 86% of global exposure to particulate matter takes place in indoor environments (WHO, 2005). Prompt response is needed to prevent short and long term health outcomes from indoor air quality problems because people spend majority of their time in the indoor environment (EC, 1991; WHO, 2006; WHO, 2007; Simoni et al., 2010; Alves et al., 2013). People spend up to 90% of their time indoors especially at home and office environments (Langer et al., 2008). Adults are exposed to pollutants in the work places while children are mostly exposed in schools environment (Schweizer et al., 2007; Protano et al., 2012). The concentration of pollutants in homes are usually significantly different from other indoor environments because buildings are built to be air tight so as to conserve energy (Wang, 2011); inadequate removal and dilution due to reliance on mechanical ventilation systems; and the use of synthetic building and furniture materials (Schripp et al., 2012). The risk of exposure to aerosol fractions from the use of household products is higher in homes where they are often used.

Concentration of particulates in the indoor environments are influenced by indoor microclimatic factors such as temperature, relative humidity and air exchange rate (Weschler and Shields, 2003; Pudpong et al., 2011). Various studies have established the dependency of particulate formation on temperature (Takekawa et al., 2003; Vutukuru et al., 2006; Lane and Pandis, 2007; Qi et al., 2010). Relative humidity affects the formation, size and deposition of aerosols (Wolkoff and Kjaergaard, 2007). The absorption of water by aerosols affects their physicochemical properties such as size (Na et al., 2006), phase (Morawska, 2005), deposition (Chan et al., 2002), atmospheric life time and chemical reactivity (Varutbangkul et al., 2006). The hygroscopicity of aerosols depends on their chemical compositions (Varutbangkul et al., 2006). Na et al. (2006) established that the presence of water vapor inhibit the formation of particulates especially the secondary organic aerosols.

Factorial Design is used to understand the effect of independent variables (factors) upon selected dependent variables

© Author(s) 2015. This work is distributed under the Creative Commons Attribution 3.0 License.

(responses). Various indoor air quality studies that made use of factorial design to study and predict the effect of few factors such as particle type, flooring type and contact time, on particle–to–surface adhesion, O_3, NO_2 concentrations and relative humidity on the behavior of particulate matter in the indoor environment (Pommer, 2003; Gadgil et al., 2008; Hu et al., 2008). The present study thus investigates the usefulness of factorial design in determining microclimatic parameters influence on aerosol dynamics in indoor environment.

2. Materials and Methods

The study was conducted in a designated empty room (2.72 × 2.82 × 2.00) m^3 in the Environmental Engineering Research Laboratory of the Department of Chemical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. The room was chosen as the experimental room because it has no major indoor and outdoor particle generating sources except the aerosols being released from the selected household spray products. The room is equipped with a ceiling fan and an air conditioning unit. The room was cleaned before each experimental run. The fan was switched on for 30 minutes to increase the deposition velocity of the particulates and then switched off for 1 hour to allow for the rapid deposition of the residual airborne particles. Afterwards, residual particulate number concentrations were measured. The initial residual PM concentrations were subtracted from the number concentrations measured after spray application to obtain the actual concentration of PM released from spray products. The experimental set up is as shown in Figure 1. Propellants (butane and propane) based spray products (air fresheners) were sprayed at the centre of the room at the height of 2 m above the ground and the samplers were placed at 1.5 m above the ground.

Control experiments were performed without the application of the spray products under the microlimatic parameters range being investigated. MetOne Particle Counter (Model GT– 321) was used to measure Particulate Matter (PM) number concentration of size range of 0.3–5.0 µm. The particle counter measures five number ranges of suspended particles: $PM_{0.3}$, $PM_{0.5}$, PM_1, PM_2, and $PM_{5.0}$. $PM_{0.3}$ was chosen as a representative of the submicron particles while $PM_{5.0}$ was chosen as a representative of the coarse particles. Air infiltration rate (Equation 1) was calculated using the mathematical relation proposed by the American Society of Heating, Refrigerating and Air–Conditioning Engineers (ASHRAE), (ASHRAE, 2011).

$$Q = A\,[a\Delta T + b(W_v)^2]^{\frac{1}{2}} \tag{1}$$

where, Q is the air infiltration rate ($m^3\ h^{-1}$), A is the total effective leakage area of the building (cm^2); a is the stack coefficient ($m^6\ h^{-2}\ cm^{-4}\ K^{-1}$); b is the wind coefficient ($m^4\ s^2\ h^{-2}\ cm^{-4}$); ΔT is the average inside–outside temperature difference (K), and W_V is the outdoor mean wind velocity ($m\ s^{-1}$). The coefficients, a=0.00188 and b=0.00413 (ASHRAE, 2011; Loupa, 2013).

Air exchange rate based on ventilation rate method (ASHRAE, 2003) is as given in Equation (2).

$$\alpha = \frac{A\,[a\Delta T + b(W_v)^2]^{\frac{1}{2}} \times 60}{R_v} \tag{2}$$

where, α is the air change per hour, and R_v is the room volume.

2.1. Estimation of particle deposition rates

It was assumed that the principal factors governing the levels of airborne particles indoors are the contributions from indoor and outdoor sources, the deposition rate of particles on indoor surfaces, and the air exchange rate as suggested by Thatcher and Layton (1995) and Thatcher et al. (2003). Taking these factors into consideration and assuming well–mixed conditions, indoor particle concentration levels can be expressed as (Koutrakis et al., 1992; Chen et al., 2000; He et al., 2005):

$$\frac{dC_{in}}{dt} = P\alpha C_{out} + \frac{Q_s}{R_V} - (\alpha + \kappa)C_{in} \tag{3}$$

where, C_{in} and C_{out} are the indoor and outdoor particle concentrations, respectively; P is the penetration efficiency; α is the air exchange rate; K is the deposition rate; Q_s is the indoor particle generation rate; t is time; and R_V is the efficient volume of the environmental room. All the factors in this equation, with the exception of the efficient volume of the room (R_V), are functions of some other factors. In the absence of indoor particle sources, Equation (3) can be written as:

$$\frac{dC_{in}}{dt} = P\alpha C_{out} - (\alpha + \kappa)C_{in} \tag{4}$$

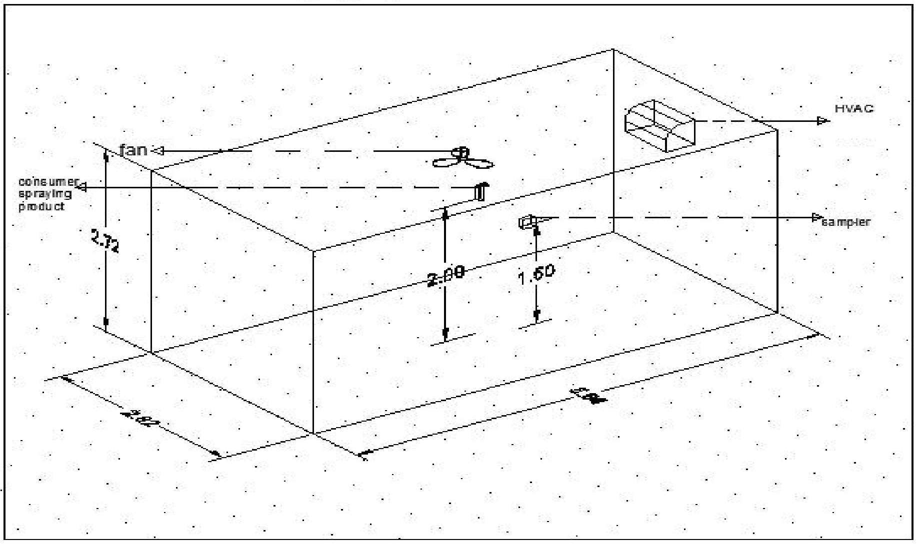

Figure 1. *Description of the sampling set up in the experimental room.*

Download English Version:

https://daneshyari.com/en/article/4434540

Download Persian Version:

https://daneshyari.com/article/4434540

Daneshyari.com