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Commuter exposure to inhalable, thoracic and alveolic particles in various transportation modes in Delhi

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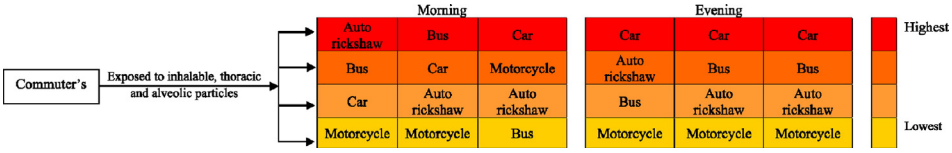
HIGHLIGHTS

- Commuters personal exposure to particles is compared in various transport modes
- Particles exposure decreases notably from morning to evening in different modes
- Car commuters exposure depends on further accumulation of particles in car interior
- Motorcycle commuters are exposed to lower levels in comparison to inside vehicles
- Transport micro-environment appears heavily affected by local emissions

GRAPHICAL ABSTRACT



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ABSTRACT

A public health concern is to understand the linkages between specific pollution sources and adverse health impacts. Commuting can be viewed as one of the significant-exposure activity in high-vehicle density areas. This paper investigates the commuter exposure to inhalable, thoracic and alveolic particles in various transportation modes in Delhi, India. Air pollution levels are significantly contributed by automobile exhaust and also in-vehicle exposure can be higher sometime than ambient levels. Motorcycle, auto rickshaw, car and bus were selected to study particles concentration along two routes in Delhi between Kashmere Gate and Dwarka. The bus and auto rickshaw were running on compressed natural gas (CNG) while the car and motorcycle were operated on gasoline fuel. Aerosol spectrometer was employed to measure inhalable, thoracic and alveolic particles during morning and evening rush hours for five weekdays. From the study, we observed that the concentration levels of these particles were greatly influenced by transportation modes. Concentrations of inhalable particles were found higher during morning in auto rickshaw (332.81 ± 90.97 μg/m^3) while the commuter of bus exhibited higher exposure of thoracic particles (292.23 ± 110.45 μg/m^3) and car commuters were exposed to maximum concentrations of alveolic particles (222.37 ± 26.56 μg/m^3). We observed that in evening car commuters experienced maximum concentrations of all sizes of particles among the four commuting modes. Interestingly, motorcycle commuters were exposed to lower levels of inhalable and thoracic particles during morning and evening hours as compared to other modes of transport. The mean values were found greater than the median values for all the modes of transport suggesting that positive skewed distributions are characteristics of naturally occurring phenomenon.

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1. Introduction

In many cities throughout the world air pollution has reached alarming levels (Wallace et al., 2009). Road transport is important and considered as predominant mode of movement of people and goods in India. Citizens in Delhi depend on public and other types of transport for their daily commutes. The exposure to traffic-related air pollutant concentrations is experienced by large urban population in India. In the past two decades, particulates pollution has become a severe problem because of fast industrialization and urbanization in India (Khare and Baruah, 2010). In Indian cities, urban air pollution originates mainly from anthropogenic sources comprising automobiles, domestic fuel use and industries (Bhaskar and Mehta, 2010; Deshmukh et al., 2013; Bhaskar et al., 2008). Recent studies have suggested that combustion originated particles, including traffic-related exhaust, pose a significant health risk as they can penetrate the respiratory tract deeper despite various defense mechanisms including deposition, clearance, retention, and absorption (Plumlee et al., 2006; Plumlee and Ziegler, 2003; Lippmann, 2005; Lindh, 2005a; Lindh, 2005b) and deposition of particulate is a function of its size. Particles in the range (10 to 100) μm are "inhalable fraction", whereas particles in the range (4 μm to 10) μm are "thoracic sub fraction" and particles less than 4 μm are "alveolic fraction" (B.S. EN 481, 1993). Most of the spatial variation in particulate air pollution (<10 mm) in urban areas has been associated with traffic (Nasir and Colbeck, 2009). Several studies have observed that there is an association between the rate of mortality in human populations with particulate pollution (Bascom et al., 1996; Schwartz, 1991, 1993; Schwartz and Dockery, 1992; Schwartz et al., 1996) and the link between human health and high particles concentration in ambient air has been well-established (Bascom et al., 1996; Pozzi et al., 2003). Both respiratory and cardiovascular morbidity and mortality, considered to be results of air pollution and inhaled air pollutants doses, are also influenced by commuting mode and exposure time (Kumar and Gupta, 2013).

The particles deposition patterns depend on their diameter and on anatomical and physiological characteristics of the host. Smaller particles are efficiently deposited in successively inner parts of the respiratory tract. Inhaled particles greater than 10 μm are removed by particulate clearance mechanisms while inhaled particles greater than 2.5 μm are mostly removed in the upper respiratory system. The effective exchange of O_2 and CO_2 occurs in the alveoli and particles less than 2.5 μm in diameter have the ability to reach deeper (Plumlee et al., 2006). Inhaled particles settled in the trachea bronchial region are cleared by mucociliary action. For some portion of particles deposited in the respiratory tract the action of clearing mechanisms may be slow than expected (Stahlhofen et al., 1995). Moreover, particulate matters that are

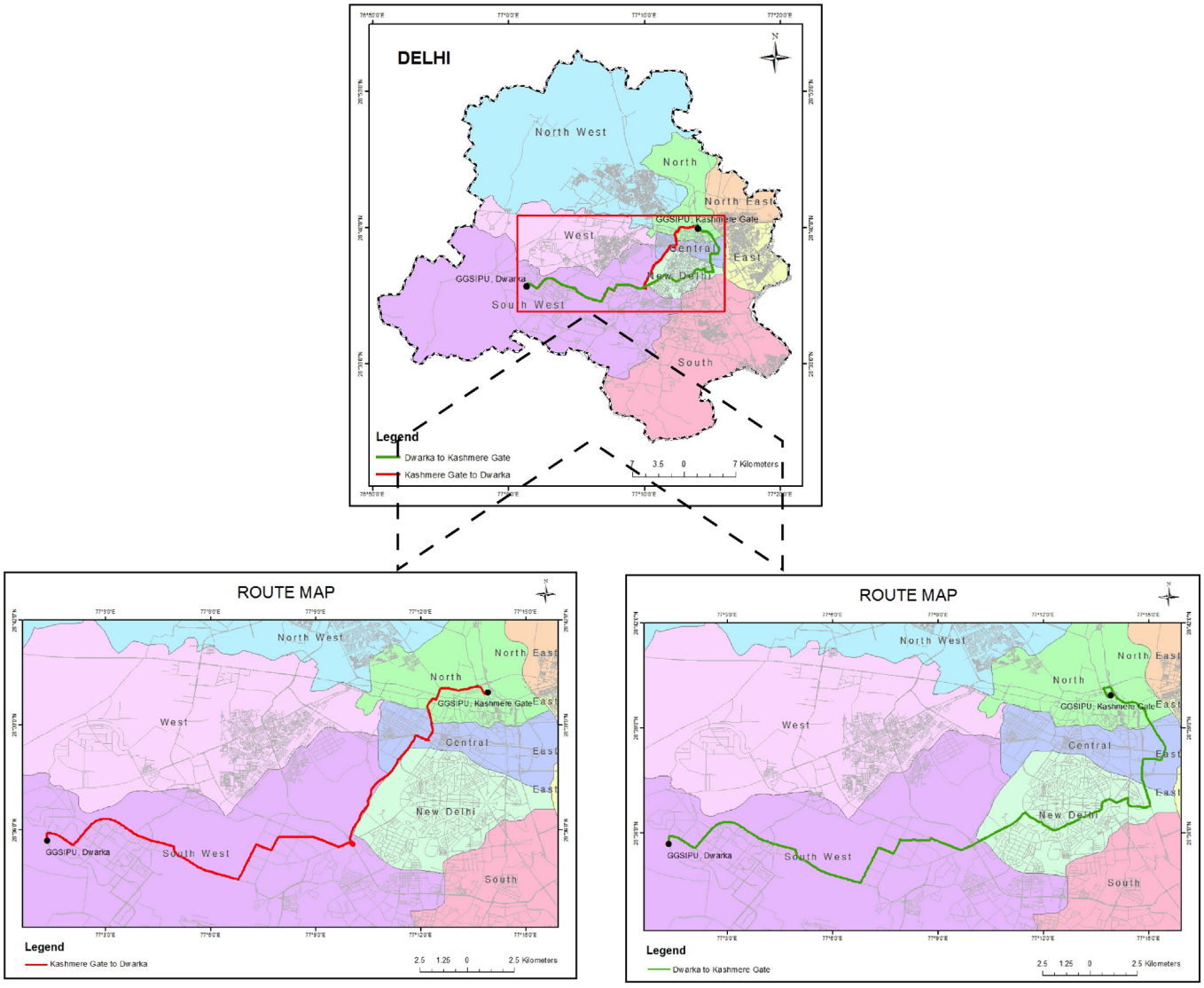

Fig. 1. Description of the sampling route for the commuter exposure study in Delhi, 2012.