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Passive measurement of NO_2 and application of GIS to generate spatially-distributed air monitoring network in urban environment

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ABSTRACT

Nitrogen dioxide (NO_2) plays an important role in atmospheric chemistry through formation of secondary particulate nitrate that contributes a major portion to the mass of particulate matter (PM) that has several impacts on the environment in the scales of local, regional and global. NO_2 is regulated in most of the countries, because it acts as a precursor for nitrate formation and it shows significant negative effects on human health. The present study was conducted for measurement of NO_2 concentration at 204 and 101 sampling locations in two Indian large cities (population more than 4 million), Delhi and Kanpur, respectively by using passive samplers. From the experimental results, an average concentration of 68.6 ± 20.1 μg/m^3 was observed in Delhi and it was 36.9 ± 12.1 μg/m^3 in Kanpur. The observed data from all sampling sites were utilized on the platform of Geographic Information System (GIS) to generate spatially distributed pollution maps (using Kriging interpolation method) and maps of probability of exceedences of air quality standards. Based on the survey results on emission activities, meteorology and pollution maps, this study proposed locations of air quality sampling sites for a long-term monitoring network in Delhi and Kanpur.

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1. Introduction

A fast growing population coupled with industrialization, urbanization and high levels of energy consumptions is worsening the ambient air quality of urban areas, particularly in developing countries (Bhati, 2000; Lawrence et al., 2007; Sharma et al., 2014). Out of several air pollutants, nitrogen dioxide (NO_2) (representative of nitrogen oxides, (NO_x) = nitric oxide ($NO + NO_2$), is originated from both primary sources and secondary transformation in the atmosphere. NO_2 is regulated in most of the countries and is used as an indicator to assess the status of ambient air quality in the urban environments (Baldasano et al., 2003; Ravindra et al., 2008). NO_x is predominantly present as NO_2 in the ambient air, whereas NO dominates at the emitting sources followed by its oxidation to NO_2 in the ambient air. The important attribute of NO_2 is to act as a precursor in the atmospheric chemistry leading to formation of secondary particulate nitrate, which in turn has major impacts on local, regional and global scales in the environment (Millstein and Harley, 2010; Stock et al., 2013). In the atmospheric system, various NO_2-related complex reactions take place which produce several secondary pollutants that are sometimes more harmful than NO_2 (Vione et al., 2006; Stock et al., 2013). In addition, NO_2 causes several adverse effects on human health, causing pulmonary edema and damages to the central nervous system, tissues etc. (Lal and Patil, 2001; Kampa and Castanas, 2008).

The major sources of NO/NO_2 in urban environments are fuel combustion in motor vehicles, thermal power plants and industrial furnaces (Garg et al., 2006; Klimont et al., 2009; Bootdee et al., 2012). The motor transport system is increasing at an alarming rate in large cities of the world due to rapid growth in urbanization and modernization. For example, from 1981 to 2002, the total number of motorized two-wheelers raised from fewer than 3 million to 42 million in India, with a 14-fold increase (Pucher et al., 2007; Behera et al., 2014). The fast growing transportation system causes rapid increase in levels of ambient NO_2 and other criteria pollutants in the large cities (Cohen et al., 2004; Gokhale and Raokhande, 2008). Therefore, it is pertinent to monitor ambient NO_2 levels on regular basis in the large cities, as a surrogate of other pollutants and to control NO_2 emissions (Janssen et al., 2001; Maruo et al., 2003; Jackson, 2005).

The measurement of NO_2 is normally conducted either through bubbling air in a chemical medium or using real-time online analysers through chemiluminescence technique (Allegrini and Costabile, 2002; Hadad et al., 2005). Both these methods require financial and human resources, however, passive samplers require almost insignificant resources and can be installed at multiple locations simultaneously (Krochmal and Kalina, 1997; Ferm and Svanberg, 1998; Briggs et al., 2000; Varshney and Singh, 2003). Several studies in the past measured NO_2 levels using passive sampling diffusion tubes in different urban environments (e.g., Hansen et al., 2001; Lewne et al., 2004; Lozano et al., 2009; Salem et al., 2009; Ahmad et al., 2011). Most of these studies focused on presentation of results of NO_2 concentrations and their interpretation with respect to spatial distribution and meteorology.

The site selection for air quality monitoring depends largely on data availability on intensity of pollutant concentrations, distribution of emitting sources, meteorology and possible extent of human exposure (Noll et al., 1977; Allegrini and Costabile, 2002). To develop a control strategy for effective reduction of NO_2 pollution, information on spatial distribution of NO_2 levels is necessary. Spatial distribution of NO_2 concentration can be prepared from the measurements taken at several monitoring sites more than 50. The measurements at more sites can conveniently be done through installation of a large number of inexpensive passive samplers (Hadad et al., 2005; Allegrini and Costabile, 2002). Preparation of pollution maps through the techniques of Geographic Information System (GIS) requires a spatial interpolation method that includes statistical or other methods to model the pollution surface. Among relevant interpolation methods (e.g. trend surface analysis, moving window methods, Kriging method, spline interpolation), Kriging method is a linear interpolation procedure which is reliable and provides linear unbiased estimation for quantities at unsampled sites that vary in space (e.g., Oliver and Webster, 1990; Myers, 1994; Briggs et al., 1997). Several studies reported the applications of Kriging method with various applications; e.g., Haas (1992) on design of continental-scale monitoring networks; Schaug et al. (1993) on acid precipitation; Campbell et al. (1994) on national patterns of NO_2 concentrations; Liu et al., 1995 on ozone concentrations. However, it is