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Estimation of high resolution emissions from road transport sector in a megacity Delhi

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ABSTRACT

Estimation of spatially resolved traffic related emissions is important for exposure and health impact studies. However, this task is difficult for the megacities where detailed traffic related information is not available. In this work, we estimate the exhaust emissions of particular matter (PM), carbon monoxide (CO) and oxides of nitrogen (NOx) at a very high resolution of 100 sq.m from the road transport sector over a developing megacity Delhi for the year 2010. A total annual emission of PM, CO and NOx have been estimated to be equal to 4.5 Gg/year, 114 Gg/year and 51.5 Gg/year respectively. These estimates are relatively lower than earlier reported emission estimates. The highest emission per unit area is estimated in New Delhi district followed by East, North and Central districts. Major roads are estimated to be main source contributing more than 50% of the total emissions. HCVs contribute the most to the total emission of PM followed by LCVs and 2 Ws. Despite the large in number, cars contribute only 8% to the total PM due to the small emission factors. The biggest contributors to CO are cars and 2 Ws. Buses are the largest contributors of NOx followed by HCVs.

1. Introduction

In recent years urban air is getting polluted heavily due to the increased amount of anthropogenic activities especially in the megacities of the world (Gurjar et al., 2008; Mage et al., 1996). Air pollution is a matter of concern because of its direct link to climate, air quality (Jacob and Winner, 2009), and human health (Pope and Dockery, 2006; Kampa and Castanas, 2008; Grahame and Schlesinger, 2010; Gurjar et al., 2010; Rohr and Wyzga, 2012). The anthropogenic sources of pollution are emissions from various sources such as industries, power plants, vehicular traffic, biomass burning, etc. On road vehicular exhaust is one of the main contributors (Gurjar et al., 2016; Guttikunda and Calori, 2013) to the total emissions from the transport sector especially near the roads (Singh et al., 2014). Vehicular exhaust also plays an important role in the formation of photochemical smog which affects visibility during the daytime (Dimitriades, 1972). The vehicular emissions include carbon monoxide, oxides of nitrogen and sulphur, hydrocarbons and particulate matter. The emission of pollutants varies according to the type of the vehicle, fuel used, engine capacity, emission standard, driving conditions and speed of the vehicles (Franco et al., 2013). Vehicle types include scooters, motorbikes, auto rickshaws, cars, taxis, buses, small and large goods vehicles including multi-axle trucks with different engine type and capacity. Vehicles primarily use petrol/gasoline, diesel, compressed natural gas (CNG) as a fuel. The new generation vehicles also use the hybrid concept to reduce the emissions. Over 90% of vehicles on the road use gasoline and diesel fuels. Each kind of fuel has its merits and demerits in terms of driving and emissions. Diesel vehicles make a considerable contribution to both gaseous and

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particulate air pollutants in the urban atmosphere as compared to other fuels. CNG vehicles have less particulate emissions but produce more NOx (Ravindra et al., 2006).

Estimation of traffic emissions is a complex task which requires detailed traffic information (D'Angiola et al., 2010). However, in the absence of the detailed information, traffic emissions need be estimated with limited data available for a city. In this study, we have taken Delhi as a case study to estimate high-resolution emissions from traffic exhaust. Delhi is one of the largest megacities in the world having a population of 16.8 million (Census Of India, 2011) is one of the polluted cities in the world (WHO, 2012). During 2001–2011, the urban areas in Delhi have increased from 924 sq.km to 1113 sq.km (Statistical Abstract of Delhi, 2014). This increase of 20% is an indication of rapid urbanization and growth. The population of national capital territory (NCT) of Delhi (NCTD) has also increased from 13.8 million in 2001 to 16.8 million in 2011 with an increase of almost 22% making population density higher. Increase in the population, and economic growth of NCT Delhi directly affects the number of on-road vehicles. The total number of registered vehicles has grown rapidly in the past decade. In 2011–2012 the number of registered vehicles was 7.4 million (Statistical Abstract of Delhi, 2014), which is highest among the other main cities in India. Due to traffic congestion and increase in demand, road length in Delhi also increased significantly in the past decade allowing more vehicles on the road leading to more emissions. The distribution of personal vehicles having 31% of cars/jeep and 62% of motorcycles/scooters (Statistical Abstract of Delhi, 2014) in 2011–2012 indicates the type of vehicles dominating the roads in NCT Delhi. Higher emissions along with favorable meteorological conditions result in elevated levels of pollution (Guttikunda and Gurjar, 2012) in Delhi.

The emissions estimated in and around Delhi area by different studies vary considerably but transport remains the main source. Gurjar et al. (2004) found that more than 80% of NOx, CO, NMVOCs from transport sector contribute towards total emission in Delhi in 2000. Kansal et al. (2011) found vehicular emission as a major source of NOx, Total Suspended Particulate matter (TSP), SO_2 in Delhi which contribute 90%, 54%, 33% respectively at selected receptor locations in Delhi. The emissions estimated by Mohan et al. (2012) for the period of 2000–2008 showed that transport sector contributed about 60% to NOx emissions. Nagpure et al. (2013) using the traffic of megacity Delhi (2000–2005) concluded that level of NOx and TSP did not show an appreciable increase which might be due to CNG influence. Sindhwani and Goyal (2014) made a study of vehicular emission load over a period (2000 − 2010) and concluded that diesel vehicles are a major contributor towards PM_{10} emission. Goyal et al. (2013) developed a gridded map of an area of 780 sq.km of the year 2008 and conclude that CO and NOx emissions due to passenger cars were found to be about 34% and 50% respectively. According to a report (Sharma and Dikshit, 2016), transport sector contributes 20% and 36% to the total $PM_{2.5}$ and NOx emissions respectively in Delhi. Sahu et al. (2011, 2015) developed emission inventory of Delhi during commonwealth games 2010 concluded that transport sector contributes 45%, 63% and 60% to $PM_{2.5}$, NOx and CO emissions respectively. Guttikunda and Calori (2013) estimated 17%, 53% and 18% contributions from transport sector to total $PM_{2.5}$, NOx, and CO respectively.

Different authors have adopted different methodologies, approach and assumptions to estimate vehicular exhaust emissions; the most common approach used by several authors (Gurjar et al., 2004; Mohan et al., 2012; Nagpure et al., 2013) is by taking the number of the registered vehicles, vehicle kilometers traveled and multiplied it by their respective emission factors. This approach can somehow predict the total emission over Delhi but cannot spatially resolve the emissions across Delhi. Sindhwani et al. (2015); Sahu et al. (2011); Guttikunda and Calori (2013) estimated the emissions at 2 sq.km, 1.67 sq.km, and 1 sq.km resolution respectively but did not include traffic at residential and minor roads in their study. Delhi has the highest number of cars and two-wheelers (Statistical Abstract of Delhi, 2014) which are the main source of emissions at the residential and minor roads, therefore, it is important to consider residential road network to estimate the exposure.

This study adopted a slightly different approach to estimate the emissions from the road network of a total length of over 25,000 km across NCT of Delhi including residential roads which was not done earlier. First, the number of vehicular traffic is assigned for each type and area of Delhi by several assumptions and earlier reported data discussed in the methodology. The emissions per road link are estimated according to the vehicular count, vehicle type, fuel type and age of the vehicle and then gridded at 1 sq.km and 100 sq.m resolution using a Geographic Information System (GIS) software. Details about study area, data, traffic counts, emission factors and methodology have been discussed in Section 2. The novelty of this work is to include the entire road network of Delhi to the emissions at a 100 sq.m resolution. As per authors knowledge, this approach is utilized for the first time. High resolution gridded emission inventory can help us to identify the hot spot areas having higher emission and detect the pollution episodes (Singh, 2016) to take necessary control measures (Khaiwal et al., 2016). The emission estimates are shown in Section 3 and summary has been discussed in Section 4.

2. Study area, data, and methodology

2.1. The study domain and road network

The domain for this study includes the NCT of Delhi with an area of 1483 sq.km is situated in the north of India located at around 28°34′N and 77°12′E and has an elevation of 216 m (709 ft) above mean sea level. Delhi is surrounded by Haryana except to the east, across the river Yamuna by Uttar Pradesh. Delhi has a population of 16.8 million as per census, 2011. The NCT of Delhi is divided into 9 revenue districts viz. North Delhi, West Delhi, North East Delhi, North West Delhi, South Delhi, South West Delhi, Central Delhi and New Delhi. The North West part covers the highest area of 443 sq.km, while Central Delhi covers the smallest area of 21 sq.km of the total area of 1483 sq.km. Due to larger Area coverage, NW Delhi has the highest population, however, the largest population density is found in NE Delhi district followed by Central Delhi. The New Delhi district has the lowest population as well as population density. The population counts, population density and number of households in each district have been provided in the supplementary material (Table A1).

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