



Emissions inventory of vehicles pollutants and their toxicity in National Capital Region towns around Delhi

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Abstract: Estimation of emissions of CO, NO_x, PM, HC from different types of vehicles have been made for the year 1997-98 using emission factors prescribed for pre EURO norms of different kinds of towns in National Capital Region (NCR), Delhi (viz., Alwar, Bulandshar, Faridabad, Ghaziabad, Gurgaon, Meerut, Panipat, Rewari, Rohatak and Sonipat). Meerut and Faridabad has largest number of vehicles as compare to other towns. In order to understand the effect of technological intervention, the same activity data have been subjected to EURO-1 emission norms to estimate the resultant emissions. This provided an insight on the magnitude of reduction occurred in the vehicles emission due to the implementation of EURO-1 vehicle norms in these cities. It has been found that in the EURO-1 technology same vehicles fleet would have been responsible for 70% reduction in CO and 51% reduction in HC+ NO_x from car and jeeps. The toxicity of different type of pollutants have also been calculated and observed that the emission of NO_x is less but its toxicity is higher as compare to other pollutants.

Key words: Emission, EURO-1, Pollutants, Vehicles

Introduction

Due to the immense growth of Delhi providing avenues for jobs and economic growth, a large population is migrating towards Delhi and settling down near by satellite towns thus catalyzing increased urbanization in these satellite towns also. There are ten cities (viz., Alwar, Bulandshar, Faridabad, Ghaziabad, Gurgaon, Meerut, Panipat, Rewari, Rohatak and Sonipat) around Delhi. A large population of these ten cities travel to Delhi their livelihood. In addition, the local pollution generated in these cities also contribute to deteriorate ambient air quality of Delhi. Keeping this in view, we have attempted to prepare inventory of emission of various pollutants from this transport sector in these surrounding townships which is discussed here.

The total area of National Capital Region covers three surrounding states of Delhi is Uttar Pardash, Haryana and Rajasthan. National Capital Region (NCR) is 30242, shared by Delhi (1483 km²), Uttar Pradash (10853 km²) Haryana (13343 km²) and Rajasthan (4563 km²) (Table 1). The share of population (%) in some of these surrounding of different states are contributing to the population of NCR. The shares of these state populations (%) are 28, 15, 24 and 39 from Uttar Pardash, Haryana, Rajasthan and National Capital Territory (NCT) Delhi respectively and percentage contribution of area (km²) is 36, 44, 15 and 5 respectively.

The major pollutants emitted from transport sector are suspended particulate matter (SPM), carbon monoxide (CO) nitrogen oxides (NO_x) and sulphur oxides SO₂ levels and some of them have been observed to be much beyond the permissible levels by the central pollution control board (CPCB) of India. These increasing levels of air pollution are responsible for higher incidence rate of respiratory diseases, cancer, and heart diseases in the urban area (Peters *et al.*, 1997). These gases play important role in the climate changes by acting as precursor gases for ozone formation besides causing adverse effects on human and plants (Streets *et al.*, 1999; Krupnick and Harrington, 2000).

At the national level, under Asian least cost greenhouse gas abatement strategy project (ALGAS, 1998) an inventory of emission

of trace gases including GHGs (Mitra, 1992) had been prepared but in this paper we present emission inventory for NCR towns, which are located around Delhi from transport sector. This paper is the over view study of estimation of pollutants from transport sector in the National Capital Territory Region. At city level inventories for some cities have been prepared (Garg *et al.*, 2002; Garg and Shukla, 2002; Sharma *et al.*, 2002a, b, c; Goyal and Sidharth, 2003) but most of these have so far been limited to mega-cities of the world only and smaller town have not been subjected for such an efforts. However these towns provide maximum opportunity for implementation of mitigation technologies and the emissions from these cities affect the ambient air quality of the region due to emission from transport sector.

The CPCB collected data from different stations in India has revealed that the suspended particulate matter (SPM) as well as PM₁₀ levels are relatively high in all Indian metropolitan cities and exceed many times the national ambient air quality standards (NAAQS) of India. The presence of particulate matter in cities environment is not only contributed by vehicular and industrial activities but also significantly because of soil originated particles and re-suspended dust generated by strong winds and construction activities. In fact, some of the Indian cities are considered to be among the most polluted cities in the world in an air quality status point of view (CPCB, 2001b). In the surrounding cities of Delhi also the SPM levels have been found to be more than the prescribed standard values (Table 1). However, the concentrations of NO_x and SO₂ in rest of the stations have been found to be with in the NAQSS ambient air quality standards.

Materials and Methods

For the development of the emission inventories of criteria pollutants from the transport sector in the towns (viz., Alwar, Bulandshar, Faridabad, Ghaziabad, Gurgaon, Meerut, Panipat, Rewari, Rohatak and Sonipat) around Delhi the activity data of vehicular population (Table 2) has been taken from NCR planning board (NCR, 2000) for the year 1997-98. Mashelkar committee report (Mashelkar, 2002) on auto fuel Policy provide

Table - 1: Air quality in towns around NCT Delhi (Pollution Control Board) for the year 1998

Cities	SPM ($\mu\text{g m}^{-3}$)	SO ₂ ($\mu\text{g m}^{-3}$)	NO ($\mu\text{g m}^{-3}$)
Ghaziabad	415	42	51
Gurgaon	NA	NA	NA
Noida	315	28	39
Bahadurgarh	NA	NA	NA
Faridabad	430	65	90

Table - 2: Number of vehicles during 1997-98 in NCR Delhi

Town	Heavy vehicles				Light vehicles	
	Bus	Truck	Car/jeep	Tractor	M. Cycle/Scooter	Other
Faridabad	1105	26309	14039	3899	110254	28701
Gurgaon	NA	NA	2423	9991	36599	2189
Panipat	NA	NA	2348	14115	38160	551
Sonipat	NA	NA	1513	11654	21080	422
Rewari	416	2994	577	7701	8085	3597
Rohatak	908	6791	2199	10370	23396	4339
Alwar	402	5801	3185	18983	71325	5542
Meerut	49995	4425	11580	49995	115181	3517
Ghazabad	68	246	3082	947	13153	1622
Bulandshahr	999	4394	1498	17328	40054	1147

Table - 3: Average traveled distance by different type of vehicles in NCR Delhi

Categories	Mileage (Km/day)
Car and jeeps (4W)	43
Tractor	43
Motorcycle and scooters (2w)	39
Total heavy vehicles	127
Other	69

Reference - Mashelkar committee report 2000 on Auto fuel Policy

Table - 4: Measured mass emission factors (gm/km) for 1996-2000 period

Species	2 Wheeler		3 Wheeler	4 Wheeler		Buses	Truck
	(2S)	(4S)	(2s)	(G)	(D)		
CO	4	2.6	8.6	3.9	1.2	4.5	4.5
NOx	0.06	0.3	0.09	1.1	0.69	16.8	8.4
HC	3.3	0.7	7	0.8	0.37	1.21	1.21
PM	0.1	0.06	0.15	0.05	0.42	1.6	0.8

S=Stoke, D=Diesel, G=Gasoline

Table - 5: Emission factor (EURO-1) for different type of vehicles in NCR Delhi

Categories	Emission factor (gm/km)	
	CO	HC+NOx
Car and jeeps (4W)	2.72	0.97
Tractor	2.72	0.97
Motorcycle and scooters (2w)	2	2
Other	4	2

Table - 6: Toxicity weight factor of different pollutants

Pollutants	Toxicity weighting factor
CO	0.04
NOx	4.5
SOx	1.4
Dust	0.9
PM ₁₀	2.3
Volatile organic compound	1.8
Pb	85

average vehicles mileage (Table 3) for Delhi have been utilized to derive vehicles mileage travel for different kinds of vehicles in NCR township assuming that average mileage given in the report is applicable for the NCR towns, for the emission estimation of CO, NO_x, HC and particulate matter as most of the vehicles registered in NCR are plying in NCT. To calculate the average distance traveled, vehicles population is multiplied by mileage and then multiplied by emission factor.

$$\text{Average distance travel} = \text{vehicular population} * \text{mileage}$$

$$\text{Emissions} = \text{Average distance traveled} * \text{emission factor}$$

In our calculations we use emission factor (Table 4) prescribed by Govt of India. We have used 1997-98 year vehicular population as activity data, depends upon the availability of data. That period of time EURO-1 emission norms was not implemented, prescribed by CPCB (CPCB, 2005) (Transport Fuel Quality-2005).

The emission is also calculated by using Euro-1 emission factors prescribed by Govt of India to find out the effect of policies and technological changes in transport sector. For analyzing the effect of policies on emissions from transport sector, we used the sum of HC and NOx (HC+NOx) emission. As for the year 1997 the emission factors for HC and NOx was separately notified (Table 7) and in EURO-1 emission norms (Table 5) (Saxana *et al.*, 2002) the HC and NOx emission factor is provided as HC+NOx. Toxicity of different pollutants (Table 6) has also been calculated in this paper using the toxicity index for CO, NOx, HC, PM reported by world development report (WDR, 2000).

Result and Discussion

The results of the emission estimates of CO, NOx, HC, particulate matter emitted from different type of vehicles in the NCR towns are discussed below in four separate sections respectively, in addition to toxicity index of these cities (*viz.*, Alwar, Bulandshar, Faridabad, Ghaziabad, Gurgaon, Meerut, Panipat, Rewari, Rohatak and Sonipat), For the estimation of emission of pollutants like CO, NO_x, HC and particulate matter from two wheelers the emission factors have also been used accordingly. We have assumed that in these towns 80% are 2 stroke and 20% are 4 stroke. Estimates of reduction of these pollutants have also been made using on hypothetical assumption that all the vehicles in these types are converted in to EURO-1 in order to assess the impacts of policy or policies interventions in transport sector.

CO is produced as a result of incomplete combustion of fuel, Fig. 2 shows the emission estimates of CO from different types of vehicles in NCR towns, it is evident that large CO emission occurs in Meerut where busses contribute more than 2/3 of total CO emission. This has been followed by second largest CO emitter city, which is Faridabad where trucks seems to contribute to largest emitter in the total CO emission. The other largest emitter town for the emission of CO seems to be Rewari, Rohatak, Alwar and Bulandshar. The total CO emission from different kinds of road transport vehicles from Alwar, Bulandshar, Faridabad, Ghaziabad, Gurgaon, Meerut, Panipat, Rewari, Rohatak and Sonipat, have been estimated to be 1997, 1578, 7391, 314, 397, 13108, 429, 983, 2048 and 326 tones respectively, the contribution of Meerut in CO emission is about half of the total CO emission from transport sector in target year, the major

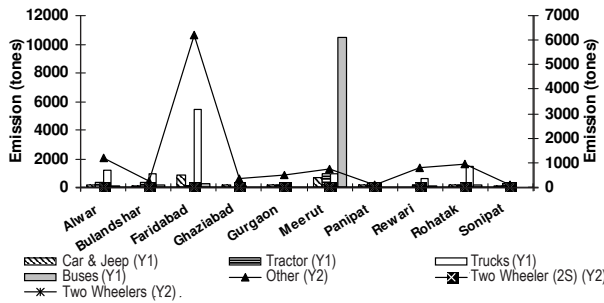


Fig. 1: Total CO emission estimation from different type of vehicles in NCR Delhi

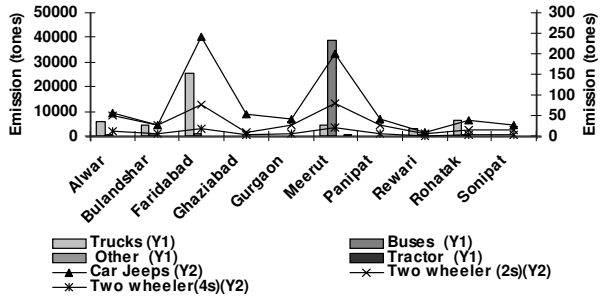


Fig. 2: Total NOx emission estimation from different type of vehicles in NCR Delhi

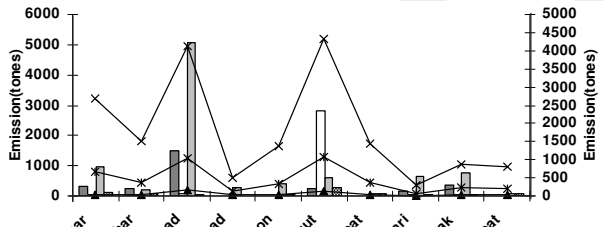


Fig. 3: Total HC emission estimation from different type of vehicles in NCR Delhi

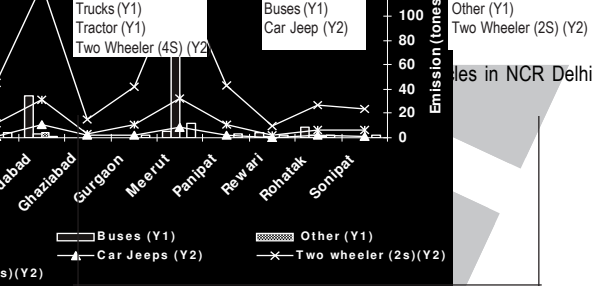


Fig. 4: Particulate matter emission from different type of vehicles

emitter are buses, trucks tractor and car / jeep, emit 10428, 923, 941, 708 tones respectively from Meerut. Truck, buses and car and jeeps play vital role in CO emission in Faridabad, emit 5487, 230, 859 tones respectively. Other surrounding towns like Bulandshahr, Rewari, Rohatak and Alwar are also following Meerut and Faridabad in CO emission. The trucks emit 916, 624, 1416, 1210 tones respectively buses emit 208, 86, 189 and 83 tones respectively. The CO emission from other mode of transport like car and jeeps, tractor, two wheeler (2s), two wheeler (4s) is very less.

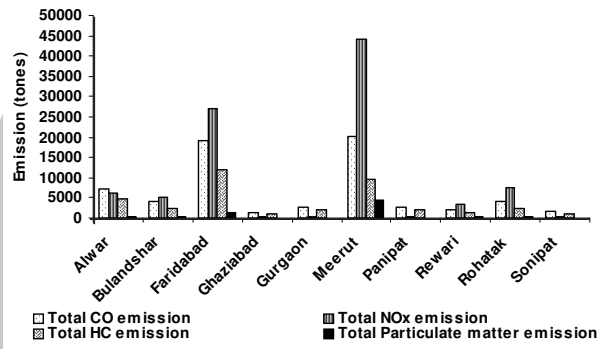


Fig. 5: Total emission of different type of pollutants from towns around Delhi

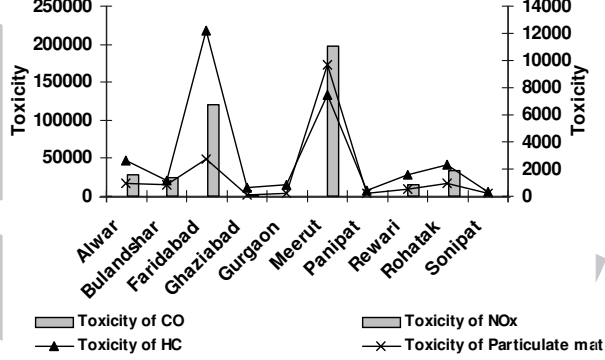


Fig. 6: Toxicity of different pollutant in National Capital Territory Region

Figure 3 shows that the emission estimates of NOx from different type of vehicles from surrounding towns of Delhi, Meerut and Faridabad emit larger amount of NOx in comparison of other towns, it is evident that large NOx emission occurs in Meerut where busses contribute to more than 2/3 of total NOx emission. The total NOx emission from Alwar, Bulandshahr, Faridabad, Ghaziabad, Gurgaon, Meerut, Panipat, Rewari, Rohatak, Sonipat have been estimated to be 6233, 5271, 26821, 359, 155, 43991, 194, 3340, 7478 and 153 tones respectively. Buses emit 38934, 860 tones and trucks emit 4307, 25610 tones from Meerut and Faridabad respectively. The other emitter towns for NOx seem to be Rewari, Rohatak, Alwar, and Bulandshahr. Has the largest buses and truck fleet among all these towns. In these towns C O emitted by buses as 323, 707, 313, 777 tones while the trucks emit 2914, 6610, 5647 and 4277 tones respectively from these towns.

Figure 4 shows that emission estimates of HC from different type of vehicles from surrounding towns Delhi .It is apparent that largest HC emission occurs in Faridabad and Meerut while the other town like Rewari, Rohatak, Alwar, emit lesser HC emission. Total HC emission from Alwar, Bulandshahr, Faridabad, Ghaziabad, Gurgaon, Meerut, Panipat, Rewari, Rohatak, Sonipat have been estimated to be 1484, 629, 6810, 349, 479, 4122, 213, 878, 1287 and 163 tones respectively out of which trucks emit 1476, other (3w) emit 5059 and car and jeeps emit 176 tones in Faridabad while in Meerut, buses, trucks, others are the major contributor, emits 2804, 248, 620, 145 tones respectively, the truck emit 325 and 380 tones while other mode of transport emit 977 and 765 tones from Alwar and Rohatak respectively. The contribution of other towns are very less as compare to these NCR towns.

PM emissions from petroleum fuel combustion are mostly in the smaller particle size range, with $PM_{2.1}$ mass accounting over 90% (Cass *et al.*, 1982) qualitatively and quantitatively, it is shown that road dust and vehicular emissions are the main sources for these SPM concentrations with road dust contribution being more than 40% (Kumar *et al.*, 1994, 2001; Patil and Kumar, 1994). Diesel is the main contributor of particulate matter emission in transport sector. Fig. 5 shows that the emission estimates of PM from different type of vehicles from surrounding towns of Delhi, Particulate matter is higher in Meerut and Faridabad in NCR towns. The total particulate matter emission from Alwar, Bulandshar, Faridabad, Ghaziabad, Gurgaon, Meerut, Panipat, Rewari, Rohatak, Sonipat have been estimated to be 393, 356, 1203, 29, 76, 4224, 97, 206, 405 and 79 tones respectively. Trucks and other mode of transport have significant role in particulate matter emission from transport sector in Faridabad emit, 975, 108 tones respectively while other categories vehicle's contribution is very less, In Meerut buses, tractor & trucks are major contributor, emits 3708, 329, 164 tones respectively, followed by Rohatak, Alwar, and Bulandshar in NCR towns. Meerut has the largest buses fleet among all these towns considered here but interestingly Faridabad has the largest fleet of trucks. This is because of low registration taxes in Haryana compared to UP and Rajasthan states where jurisdiction under all these towns.

Toxicity Index in NCR Towns: The transportation sector is largely responsible for the degradation of urban air quality (DPCC, 2001). An attempt has been made to calculate the toxicity index in NCR towns studied here based on the emission inventory generated from transport sector. The toxicity factor for different pollutant is given Table 6 as provided by World Bank -1995. With the emission value of different pollutants their toxicity level is also very important as different pollutants have toxicity factor (Pope and Dockery, 1999). Most of the air quality studies preformed so far is based on measurements of PM_{10} in urban air because of their health impacts, but the other pollutants are also having harmful effect on human health. Fig. 7 shows the toxicity factor of different pollutants. The toxicity index generated for cities Faridabad, Gurgaon, Panipat, Sonipat, Rewari, Rohatak, Alwar, Meerut, Ghaziabad, Bulandshar is given in Fig. 7. It shows that although the emission of CO is higher as compare to other pollutants while the toxicity of CO is lesser than the other pollutants, the emission of NO_x , HC and particulate matter is very high (Fig. 7) so toxicity of the pollutants make the pollutant more harmful.

The Transport sector in India is witnessing a rapid transition phase due to several policies interventions related to emission norms for vehicles and quality fuel supplied, National Capital Territory (NCT) Delhi needs to be planned together with NCR. NCT Delhi cannot sustain itself for long time without depending on National Capital Region as land being limited in administrative boundaries of NCT Delhi at present and near future, it has to co-survive with NCR in terms of population and economic activities, thus policies related to emission norms for vehicles and quality fuel should also be implacable in National Capital Region Delhi. The use of CNG in public transport as well as in private vehicles should be encouraged in NCR Delhi.

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