Emissions from India's transport sector: Statewise synthesis

T.V. Ramachandra [a,b,][*], Shwetmala [a]

[a] Energy Research Group (CES), Centre for Ecological Sciences, Indian Institute of Science, Bangalore, Karnataka 560 012, India
[b] Centre for Infrastructure, Transport and Urban Planning (CiSTUP), Indian Institute of Science, Bangalore 560 012, India

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ABSTRACT

A decentralized emission inventories are prepared for road transport sector of India in order to design and implement suitable technologies and policies for appropriate mitigation measures. Globalization and liberalization policies of the government in 90's have increased the number of road vehicles nearly 92.6% from 1980–1981 to 2003–2004. These vehicles mainly consume non-renewable fossil fuels, and are a major contributor of green house gases, particularly CO_2 emission. This paper focuses on the statewise road transport emissions (CO_2, CH_4, CO, NO_x, N_2O, SO_2, PM and HC), using region specific mass emission factors for each type of vehicles. The country level emissions (CO_2, CH_4, CO, NO_x, N_2O, SO_2 and NMVOC) are calculated for railways, shipping and airway, based on fuel types. In India, transport sector emits an estimated 258.10 Tg of CO_2, of which 94.5% was contributed by road transport (2003–2004). Among all the states and Union Territories, Maharashtra's contribution is the largest, 28.85 Tg (11.8%) of CO_2, followed by Tamil Nadu 26.41 Tg (10.8%), Gujarat 23.31 Tg (9.6%), Uttar Pradesh 17.42 Tg (7.1%), Rajasthan 15.17 Tg (6.22%) and, Karnataka 15.09 Tg (6.19%). These six states account for 51.8% of the CO_2 emissions from road transport.

1. Introduction

Transport heralds the development of a region. The demand for infrastructure augmentation increases with the region's pursuit of development goals. The basic infrastructures required for the region's economic growth are roads, railways, water and air connectivity. With the increase in economic activities, the dependence of fossil fuel based energy sources and consequent green house gas (GHG) emissions have increased rapidly in recent times. The transport sector in India consumes about 16.9% (36.5 mtoe: million tonnes of oil equivalent) of total energy (217 mtoe in 2005–2006). Various energy sources used in this sector are coal, diesel, petroleum (gasoline) and electricity. Road, rail and air are responsible for emission of 80%, 13% and 6% respectively (TEDDY, 2006). Vehicular emissions account for about 60% of the GHG's from various activities in India (Patankar, 1991).

Globalization and liberalization policies of the government has spurted the economic activities. Consequent to this policy change are increase in urbanization and concentrated economic activities in certain load centers resulting in higher mobility. This fuelled the rapid increase in number of vehicles and traveling distance resulting in the higher consumption of energy with an average annual rate of 2.9%. During the last two decades, number of registered motor vehicles has increased dramatically from 5.4 million in 1980–1981 to 72.7 million in 2003–2004 (TEDDY, 2006). Energy consumption also varies with the modes of transport and public transport system has least average energy consumption per passenger kilometer (Singh, 2006). The urban population of India, which constitutes 28% of the total, is predominantly dependent on road transport. Around 80% of passenger and 60% of freight movement depend on road transport (MoF, 2000). Traffic composition of six mega cities of India (Delhi, Mumbai, Bangalore, Hyderabad, Chennai and Kolkata) shows that there is significant shift from the share of slow moving vehicles to fast moving vehicles and public transport to private transport (Jalihal et al., 2005). Among different type of motor vehicles, percentage of two wheelers has shown rapid growth (doubling in every 5 years) and it constitutes 70% of total motor vehicles of India (MoSRTH, 2004). Total number of road vehicles in India as per the latest available statistics (March 2004) were 72.7 million (MoSRTH, 2007a).

Indian railways has important role for long journey movement of both people and freight. In last ten years, there is a sharp increase in number of passenger and goods movement and consequent fuel consumption. Current energy consumption in railways is around

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* Corresponding author. Energy Research Group (CES), Centre for Ecological Sciences, Indian Institute of Science, Bangalore, Karnataka 560 012, India. Tel.: +91 80 23600985/22932506/22933099; fax: +91 80 23601428/23600085/23600683 [CES-TVR].
E-mail addresses: cestvr@ces.iisc.ernet.in, energy@ces.iisc.ernet.in (T.V. Ramachandra), shwetmala@ces.iisc.ernet.in (Shwetmala).
URL: http://ces.iisc.ernet.in/energy

5.1% of total transport energy with about 77.5% from diesel and balance is through electricity (TEDDY, 2007). During 2004–2005 Indian civil aviation accounted for more than 24% increase in the number of international and domestic flights, with consequent increase of aviation fuel from 0.98 million tonnes (mt) (1976–1977) to 6.2 mt in 2005–2006. Shipping sector has aided in the movement of about 18 mt of cargo (TEDDY, 2007).

The focus of this work is to develop the statewise inventory of GHG's from Indian transport sector. Fig. 1 depicts India with cities that are important in terms of industrial and economic activities. Emissions from shipping, railways and aviation sectors were computed using the country level data. However, data is available at disaggregated levels for the road sector.

2. Methods

Emissions from the transport sector depend mainly on type of transport and fuel apart from type of combustion engine, emission mitigation techniques, maintenance procedures and vehicle age. The major pollutant emitted from transport are Carbon dioxide (CO_2), Methane (CH_4), Carbon monoxide (CO), Nitrogen oxides (NO_x), Nitrous oxide (N_2O), Sulphur dioxide (SO_2), Non-methane volatile organic compounds (NMVOC), Particulate matter (PM) and Hydrocarbon (HC). Diesel is used in public passenger and cargo vehicles, while private two wheelers, light motor vehicles (passenger), car and jeeps use gasoline. In the National capital, Delhi, most of the buses and omni buses and 5% of total cars and jeeps use Compressed Natural Gas (Das and Parikh, 2004).

2.1. Quantification of emission factors

Region specific emission factors of road transport, based on the type of vehicle compiled from various literatures including regulatory agencies (Mittal and Sharma, 2003; EEA, 2001; CPCB, 2007; Kandlikar and Ramachandran, 2000; UNEP, 1999) are listed in Table 1. It is assumed that, diesel is used as fuel in buses, omni buses, taxi, trucks, lorries, light motor vehicles (goods), trailers and tractors, while two wheelers, light motor vehicles (passenger), car and jeeps use gasoline. In Delhi, most of the buses and omni buses and 5% of total cars and jeeps also use Compressed Natural Gas (Das and Parikh, 2004). CO, HC, NO_x and PM emissions from CNG based buses were 1.77, 0.88, 2.81 and 0.032 g km^{-1} and for cars and jeeps were 0.78, 1.55, 0.92 and 0.02 g km^{-1}, respectively (CPCB, 2007). The region specific emission coefficients for emission estimates and
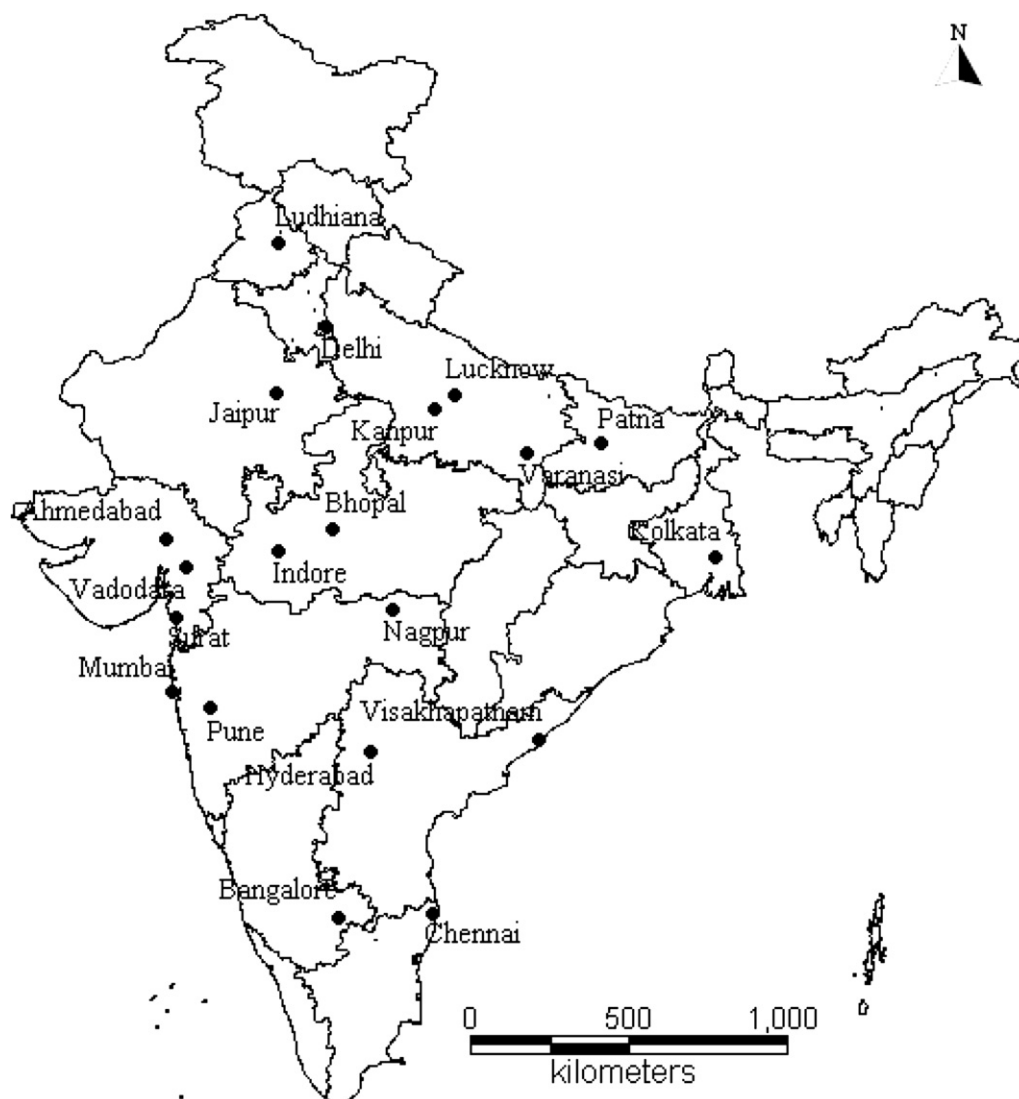

Fig. 1. India with metropolitan cities.

Table 1
Emission factors for road vehicles (g km^{-1}).

	Bus	Omni buses	Two wheelers	Light motor vehicles (passenger)	Cars and jeeps	Taxi	Trucks and lorries	Light motor vehicles (goods)	Trailers and tractors	Others[a]	Reference
CO_2	515.2	515.2	26.6	60.3	223.6	208.3	515.2	515.2	515.2	343.87	Mittal and Sharma, 2003
CO	3.6	3.6	2.2	5.1	1.98	0.9	3.6	5.1	5.1	3.86	CPCB, 2007
NO_x	12	12	0.19	1.28	0.2	0.5	6.3	1.28	1.28	3.89	CPCB, 2007
CH_4	0.09	0.09	0.18	0.18	0.17	0.01	0.09	0.09	0.09	0.11	EEA, 2001
SO_2	1.42	1.42	0.013	0.029	0.053[b]	10.3[c]	1.42	1.42	1.42	1.94	Kandlikar and Ramachandran, 2000
PM	0.56	0.56	0.05	0.2	0.03	0.07	0.28	0.2	0.2	0.24	CPCB, 2007
HC	0.87	0.87	1.42	0.14	0.25	0.13	0.87	0.14	0.14	0.54	CPCB, 2007

[a] Average of above value are used for others.
[b] Indian Institute of Petroleum (IIP), Automotive Research Association of India (ARAI) used in UNEP, 1999.
[c] Mittal and Sharma, 2003.

net calorific values (NCV) of different type of fuels (ALGAS, 1998; IPCC, 1996; Singh et al., 2008) are listed in Table 2. Thermal power plant emission factors were used to compute CO and NO_x emissions from coal used in railways (Chakraborty et al., 2008).

2.2. Quantification of emission

Emissions from road were quantified based on the number of vehicles and distance travelled in a year per different vehicle type, which is given by

$$E_i = \sum (Veh_j \times D_j) \times E_{i,j,km} \quad (1)$$

Where, E_i = emission of compound (i); Veh_j = number of vehicles per type (j); D_j = distance travelled in a year per different vehicle type (j); $E_{i,j,km}$ = emission of compound (i) from vehicle type (j) per driven kilometer.

Bottom–up approach (Gurjar et al., 2004) was adopted for estimation of gaseous and particulate emission based on annual average utilization for different vehicle category, number of registered vehicles and the corresponding emission factors. Annual utilization of buses, omni buses, two wheelers, light motor vehicles (passenger), cars and jeeps, and taxi were assumed to be 100 000, 100 000, 6300, 33 500, 12 600 and 12 600 km, respectively (buses, two wheelers, car and auto rickshaw as per Singh, 2006). Similarly for trucks and lorries, light motor vehicles (goods), and trailers and tractors were assumed as 25 000–90 000, 63 000 and 21 000 km yr^{-1} respectively (MoSRTH, 2007b). These values were assumed based on five year planning reports of India. For other section of vehicles, annual utilization was calculated based on average of all above values.

Statewise data is not available for railways, shipping and aviation, so emission was calculated based on the different type of fuel consumption (MoPNG, 2002a,b; CMIE, 2007). The CO_2 emission in railways, water and air transport (Garg et al., 2001) was estimated based on the consumption of fuel (MoPNG, 2002a,b; CMIE, 2007) and emission factor and is given by:

$$E_i = \sum Fuel_{j,k} \times EF_{i,j} \quad (2)$$

Where, E_i = emission of compound (i); $Fuel_{j,k}$ = consumption of fuel (j) for transport type (k); $EF_{i,j}$ = emission factor for compound (i) emitted from fuel(j).

Emissions of CH_4, CO, NO_x, N_2O and NMVOC were estimated (IPCC, 1996) using:

$$\text{Emissions (kt)} = \text{Fuel consumption (kt)} \times \text{NCV}\left(TJ\,kt^{-1}\right)$$
$$\times \text{Gas specific emission coefficients}\left(kg\,TJ^{-1}\right) \quad (3)$$

2.3. Computation of GHG emission per unit area in metropolitan cities

Emission loads per unit area were computed to understand the level of emission with increased urbanization, and is given by:

$$\text{Metropolitan city emission/unit area} = \frac{\left(\sum \text{Emission}_{i,j}\right)}{(A_i)} \quad (4)$$

Where A_i = geographical area of ith city, and jth type of vehicle. Total number of vehicles (MoSRTH, 2007a) and area (Census of India, 2001) of major metropolitan cities were used in this regard.

3. Results and discussion

Measurement and quantifications of GHG's from transport sector is essential for a very fast developing economy like India, in order to design and implement suitable technologies and policies with the appropriate mitigation measures.

3.1. Estimates of transport emission

State and sectorwise inventory of number of vehicles, type and amount of fuel used, age of vehicle is important to develop strategies at regional levels for GHG reduction. Hence an attempt is made to compile these information from various government agencies for GHG emission inventory estimates. However, for

Table 2
Net calorific values and emission coefficients used for different fuel types.

	NCV (TJ/10^3 tonnes)	CO_2 (ton ton^{-1})	CH_4 (kg TJ^{-1})	CO (kg TJ^{-1})	NO_x (kg TJ^{-1})	NMVOC (kg TJ^{-1})	N_2O (kg TJ^{-1})
High speed diesel	43.33	3.18	5	1000	800	200	0.6
Light diesel oil	43.33	3.18	5	1000	800	200	0.6
Fuel oil	40.19	3.13	5	1000	800	200	0.6
Coal	–	1.76	–	5.51 g kg^{-1}	4.02 g kg^{-1}	–	–
Aviation turbine fuel		2.94	2.64 g kg^{-1}	1034 g kg^{-1}	3.52 g kg^{-1}	–	–

Source: ALGAS, 1998; IPCC, 1996; Chakraborty et al., 2008; Singh et al., 2008.

railways and aviation sectors, only fuel consumption is available at the National level, which has been used to quantify emissions.

Indian road transport contributes a significant quantities of 243.82 Tg CO_2 (94.5%) and smaller quantities of CO, CH_4, NO_x, SO_2, HC and PM. CO_2 emission in the road sector, quantified based on 2003–2004 data, is given in Fig. 2a. This illustrates that industrially and economically advanced states (Maharashtra, Gujarat, Tamil Nadu) contribute maximum compared to other states and average emission for the country is 6.97 Tg. Among the states and UT, Maharashtra's contribution is the largest, 28.85 Tg (11.8%) of CO_2, followed by Tamil Nadu 26.41 Tg (10.8%), Gujarat 23.31 Tg (9.6%), Uttar Pradesh 17.42 Tg (7.1%), Rajasthan 15.17 Tg (6.22%) and Karnataka 15.09 Tg (6.19%). The total of these six states accounts for 51.8% of the CO_2 emissions from road transport. Total CO_2 emission from road transport in year 2003–2004 is approximately 2.3 times more than in comparison to year 2000 emission. CO, CH_4, NO_x, SO_2, HC emissions and PM is given in Fig. 2b–g. This shows average statewise emission of CO, CH_4, NO_x, SO_2, HC and PM are 3.62, 63.25, 20.26, 20.67 and 4.37 Gg, respectively. The result further confirms that Gujarat, Maharashtra and Tamil Nadu have higher proportion of emissions of CO, CH_4, NO_x, SO_2, HC and PM.

In Maharashtra, there is significant increase in state GDP from 2478 to 4380 billion Rs. during 1999 and 2005 (CMIE, 2008). This has also contributed to higher number of private vehicles resulting in higher emissions. With the increase in city size, the traveling distance has become longer; the relative importance of walking and cycling has come down significantly.

The emissions calculated for different type of road transport vehicles are summarized in Table 3. Among different type of vehicles, trucks and lorries contribute 28.8% CO_2 (70.29 Tg), 39% NO_x (0.86 Tg), 27.3% SO_2 (0.19 Tg), and 25% PM (0.03 Tg), which constitute 25% of the total vehicular emission of India. Similarly two wheelers are major source of CO (0.72 Tg; 23.7%), CH_4 (0.06 Tg; 46.4%), and HC (0.46 Tg; 64.2%) and buses are emitting NO_x (0.68 Tg; 30.7%) and PM (0.03 Tg; 20.5%).

Vehicular emissions vary with type, efficiency and type of fuel used. Emission analysis based on the vehicle type reveal that bus and omni buses contribute higher CO_2 (CO_2: 96.5%, NO_x: 2.28%) compared to two wheelers (CO_2: 86.8%, CO: 7.18%, HC: 4.6%), passenger light motor vehicles (CO_2: 86.8%, CO: 7.6%, NO_x: 1.9%), cars and jeeps (CO_2: 98.8%), taxi (CO_2: 94.6%, SO_2: 4.68%), trucks and lorries (CO_2: 97.6%, NO_x: 1.2%), goods light
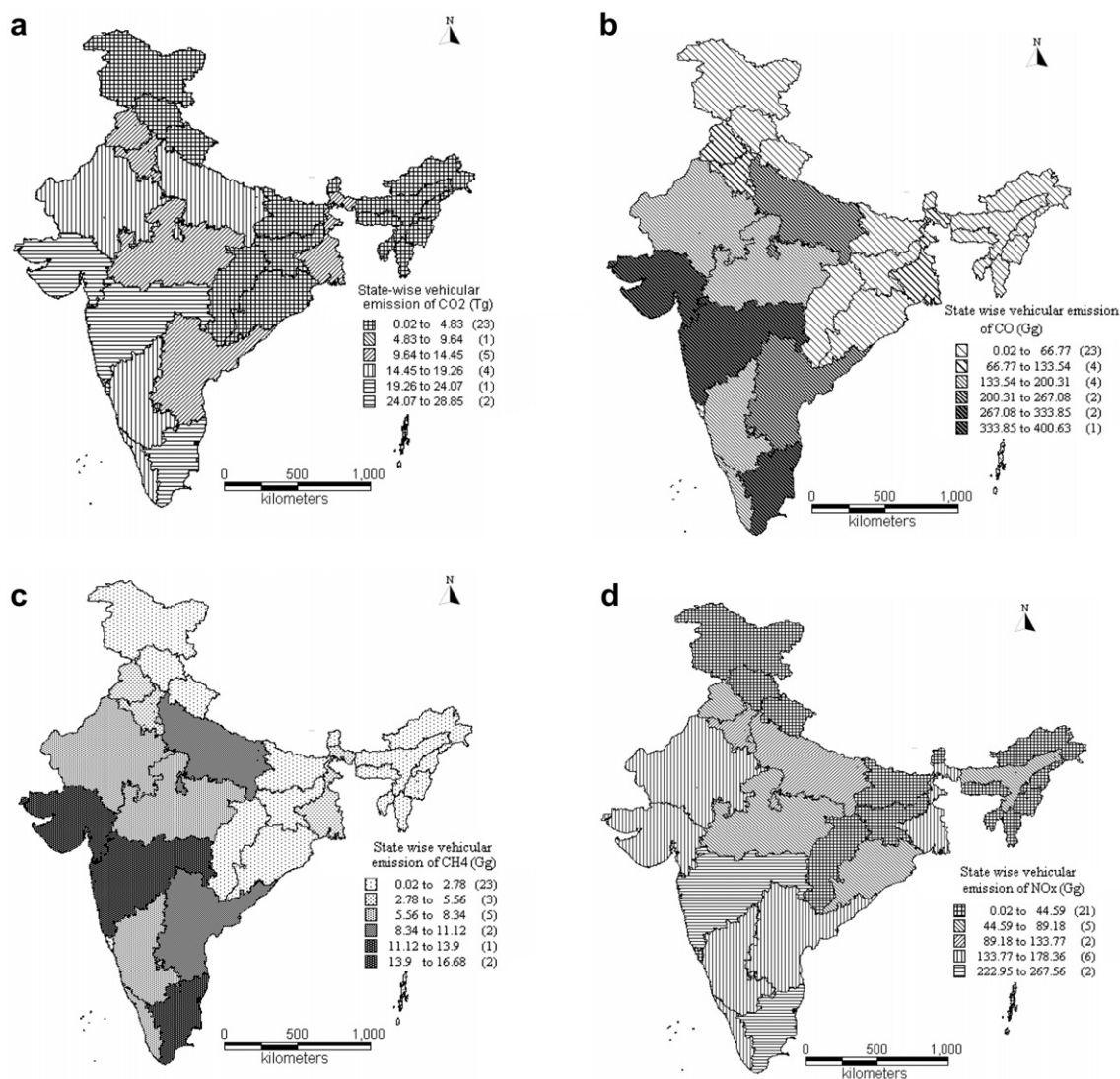
Fig. 2. a. CO_2 emission from road transport. b. CO emission from road transport. c. CH_4 emission from road transport. d. NO_x emission from road transport. e. SO_2 emission from road transport. f. HC emission from road transport. g. PM emission from road transport.
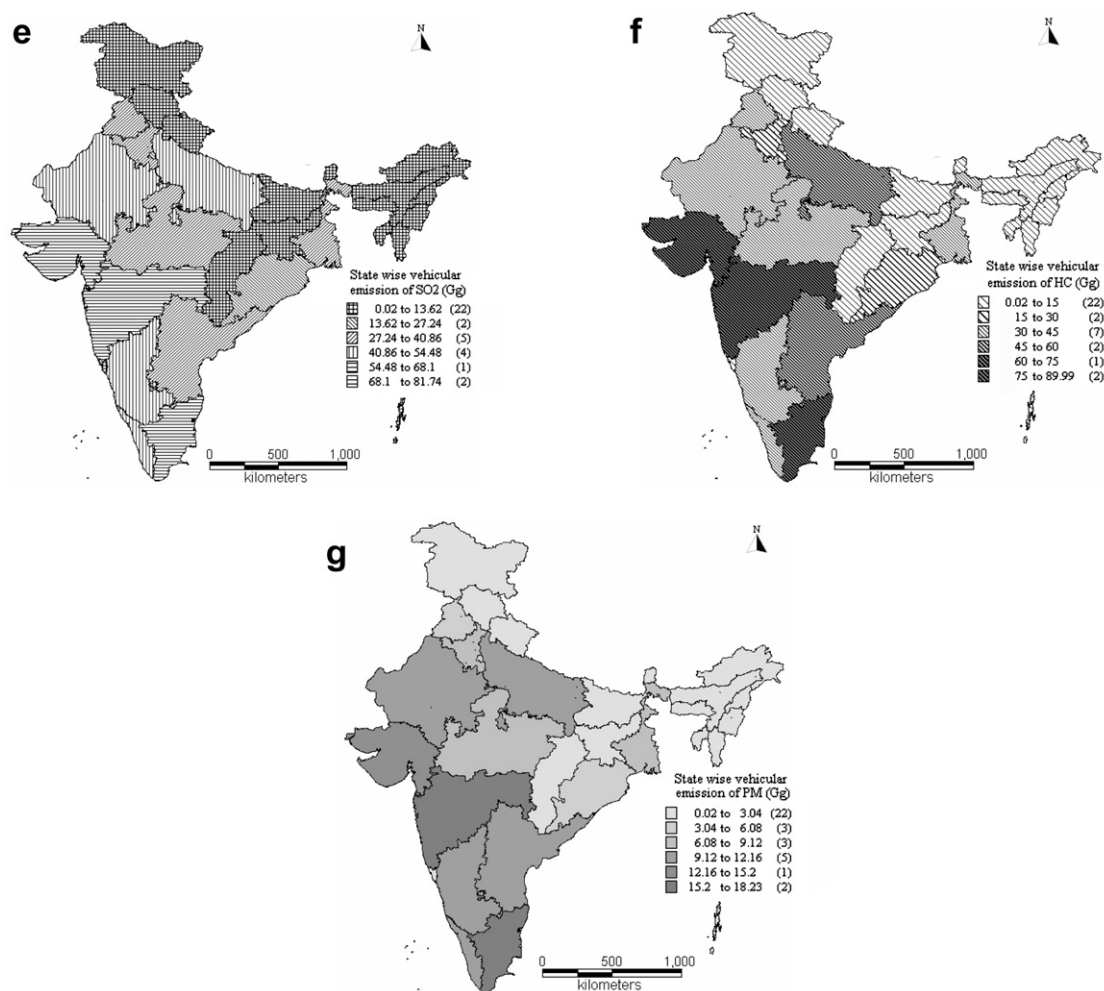
Fig. 2. (*continued*).

motor vehicles (CO_2: 98.4%), and trailers and tractors (CO_2: 98.4%) are different.

Total Indian transport emission of CO_2, CO, NO_x, CH_4, SO_2, PM, HC, N_2O and NMVOC are summarized in Table 4. During 2003–2004, total transport emission of CO_2 was 258.10 Tg CO_2 contribution of road sector, aviation, railways and shipping was 243.82 Tg (94.5%), 7.60 Tg (2.9%), 5.22 Tg (2%) and 1.45 Tg (0.6%), respectively. Road sector and aviation mainly contribute 3.03 Tg (53.3%) and 2.57 Tg (45.1%) of CO. Among all type (road, shipping, railways and aviation) of transport, road and aviation are the major contributor of air pollution. Emissions from shipping and airway generally not

accounted for the National emission inventories, because they occur mostly in international waters and air. Fuel consumption in water and air transport is used to calculate the emission to reflect the respective sectors emission contribution in India. During 2004–2005, aviation sector has become second major source of transport emissions as there is tremendous increase in the number of passenger movement and also international and domestic flights. Estimate of 10 Gg for 1990 based on fuel consumption pertaining to coal-related CO_2 emission from railway transport sector (Garg et al., 2001), is much higher than the value for the emission of CO_2 (5.28 Gg) computed for 2003–2004.

Table 3
Emission from different vehicle types of India (Gg).

Categories	CO_2	CO	NO_x	CH_4	SO_2	PM	HC
Bus	28 748.16	207.26	679.73	5.02	79.24	31.36	51.72
Omni buses	8508.42	60.94	200.53	1.49	23.45	9.28	15.11
Two wheelers	8701.08	719.64	62.15	58.88	4.25	16.36	464.49
Light motor vehicles (passenger)	4378.10	370.29	92.93	13.07	2.11	14.52	10.16
Cars and jeeps	23 901.22	212.30	22.14	18.17	5.67	3.22	28.01
Taxi	2367.08	10.23	5.68	0.11	117.05	0.80	1.48
Trucks and lorries	70 288.92	491.15	859.51	12.28	193.73	38.20	118.69
Light motor vehicles (goods)	44 654.58	442.04	110.94	7.80	123.08	17.33	12.13
Trailers and tractors	46 563.85	460.94	115.69	8.13	128.34	18.08	12.65
Others	5705.22	57.41	64.54	1.83	32.19	3.98	8.96

Table 4
Total emission from Indian transport for 2003/04 (Gg).

	CO_2	CO	NO_x	CH_4	SO_2	PM	HC	N_2O	NMVOC
Shipping									
High speed diesel	782.2800	10.6592	8.5273	0.0533	–	–	–	0.0064	2.1318
Light diesel oil	162.1800	2.2098	1.7679	0.0110	–	–	–	0.0013	0.4420
Fuel oil	510.1900	6.5510	5.2408	0.0328	–	–	–	0.0039	1.3102
Railways									
Coal	5.2800	0.0155	0.0121		0.0421				
Electricity	Not considered								
High speed diesel	5186.5800	70.6712	56.5370	0.3534	–	–	–	0.0424	14.1342
Light diesel oil	6.3600	0.0867	0.0693	0.0004	–	–	–	0.0001	0.0173
Fuel oil	25.0400	0.3215	0.2572	0.0016	–	–	–	0.0002	0.0643
Aviation									
High speed diesel	85.8600	1.1699	0.9359	0.0058	–	–	–	0.0007	0.2340
Light diesel oil	6.3600	0.0867	0.0693	0.0004	–	–	–	0.0001	0.0173
Fuel oil	222.2300	2.8535	2.2828	0.0143	–	–	–	0.0017	0.5707
Aviation turbine fuel	7294.1400	2565.3540	8.7331	6.5498	–	–	–	–	–
Road transport	243 816.6443	3032.1843	2213.8552	126.7809	709.0928	153.1271	723.4093	–	–
Total	258 103.1443	5692.1632	2298.2880	133.8038	709.1348	153.1271	723.4093	0.0568	18.9219

3.2. GHG emission per unit area (for metropolitan cities)

Emission per unit area for metropolitan cities is summarized in Table 5. Chennai, Bangalore, Kolkata, Delhi and Hyderabad are the five major metropolitan cities of India with large number of industries and play a vital role in Indian economy. In the case of Mumbai, GDP has increased from 90.2 to 149.9 billion Rs. during 1997–2005, while human population has increased from 10.8 to 11.9 million (Das and Parikh, 2004). These increases have also increased the total passenger travel demand from 32 to 61 billion passenger km. Similar situation prevails in other major metropolitan cities in India.

With the increase in economic activities number of transport is increasing in restricted area of metropolitan cities. It increases the transport emission load of Indian cities. The introduction of vehicles with stricter emission control may decrease the overall emissions, but the vehicle population growth rate might neutralize that impact in overall emissions (Sharma and Pundir, 2008).

CO_2 emission per unit area in five major metropolitan cities (Chennai, Bangalore, Kolkata, Delhi and Mumbai) of India is depicted in Fig. 3. Similarly, Figs. 4 and 5 depict emissions of CO, CH_4, HC, NO_x, PM and SO_2 per unit area. Number of vehicles in important Indian cities is 20 million, with a share of 28% of total vehicles of India. Chennai, Bangalore, Kolkata, Delhi and Mumbai with 10.2 million vehicles constitute 51.1% of total vehicles of important Indian cities and 14% of total vehicles of India. Total emission per unit area of metropolitan cities is 0.25 Tg km^{-2} of CO_2. Chennai has the largest contribution of 0.034 Tg km^{-2} (13.5%) followed by Bangalore with 0.032 Tg km^{-2} (12.4%), Kolkata with 0.022 Tg km^{-2} (8.7%), Delhi with 0.02 Tg km^{-2} (8%) and Hyderabad with 0.018 Tg km^{-2} (7.1%).

Table 5
Emission from vehicular transport of metropolitan cities.

Metropolitan city	Number of all road vehicles in metropolitan city	Ratio	Geographical area of metropolitan city (km^2)	CO_2 (Mg km^{-2})	CO (Mg km^{-2})	CH_4 (Mg km^{-2})	HC (Mg km^{-2})	NO_x (Mg km^{-2})	PM (Mg km^{-2})	SO_2 (Mg km^{-2})
Hyderabad[a]	1 355 700	0.24	172.70	18 258.86	281.47	13.26	78.05	197.12	13.91	55.94
Visakhapatnam	411 691	0.07	182.70	5034.01	77.60	3.66	21.52	54.35	3.84	15.42
Patna	335 623	0.45	108.34	18 244.82	189.16	5.91	32.91	149.03	10.42	55.60
Delhi[b]	4 236 675	1.00	431.09	20 843.82	284.43	15.56	87.74	129.99	9.13	42.38
Ahmedabad	1 075 213	0.15	281.08	12 438.69	165.52	6.67	35.49	93.20	7.52	32.99
Surat	692 118	0.10	212.52	10 967.65	145.94	5.88	31.30	82.18	6.63	29.09
Vadodara	586 438	0.08	113.87	2481.43	21.33	0.81	5.52	29.16	1.47	8.66
Bangalore	1 890 692	0.48	226.24	32 013.25	405.25	16.14	86.03	323.75	22.18	93.29
Bhopal	391 579	0.10	298.48	3786.22	47.58	1.92	11.60	27.29	2.19	12.26
Indore	644 771	0.17	160.45	11 973.75	150.46	6.06	36.69	86.31	6.92	38.77
Mumbai	1 199 416	0.13	438.00	8562.01	118.91	4.95	24.69	67.80	5.41	23.67
Nagpur	543 322	0.06	217.56	7955.70	110.49	4.60	22.94	63.00	5.03	22.00
Pune	754 902	0.08	430.00	5366.96	74.54	3.10	15.48	42.50	3.39	14.84
Ludhiana	770 784	0.22	159.37	14 847.91	183.90	7.52	43.43	98.33	8.09	38.70
Jaipur	823 715	0.21	484.64	6571.53	72.76	2.83	17.61	65.61	4.13	18.35
Chennai	2 014 776	0.23	174.00	34 903.50	429.13	18.99	118.95	353.67	23.01	108.04
Kanpur	424 652	0.07	266.74	4570.50	59.85	2.56	15.07	32.01	2.65	12.30
Lucknow	614 794	0.10	310.10	5616.32	73.55	3.15	18.52	39.34	3.26	15.12
Varanasi	365 913	0.06	91.90	11 370.76	148.91	6.38	37.49	79.64	6.60	30.61
Kolkata	875 156	0.34	186.23	22 402.15	213.94	9.10	59.66	273.55	14.23	72.07
	20 007 930	0.34	4946.01	258 209.86	3254.71	139.04	800.68	2287.85	160.00	740.09

Source: MoUD, 2008; Census of India, 2001; MoSRTH, 2007a,b.
[a] Area figure covers area falling in Hyderabad Dist. Ratio = proportion of vehicles in metropolitan city (to that of the state).
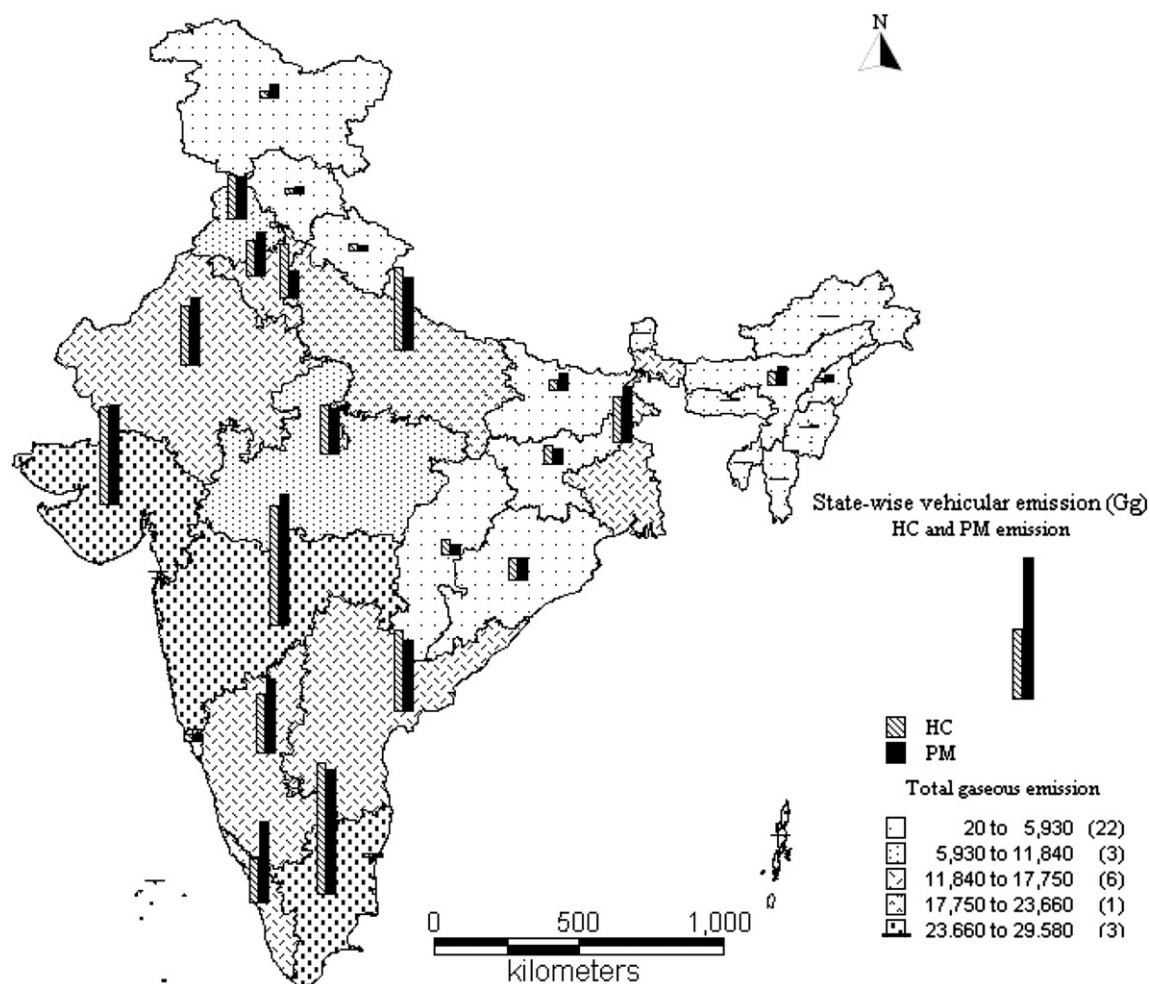[b] Urban area as in 1991.

Fig. 3. Total emission from road transport in India.

One of the main contributors of emissions in Indian transport is from the road sector. Encouraging the use of efficient public transport in place of private transport will help to reduce the number of vehicles. Introduction of more efficient vehicles and fuels, such as CNG or battery operated vehicles, will reduce emissions. However, various urban policies such as metro railway, transport management and emission control practices will further curtail transport emissions.

Fig. 4. Vehicular emission in major metropolitan cities of India.

4. Conclusions

In India, number of vehicles and there consequent emissions were different for each of the state or UT. Therefore, a decentralized emission inventories were prepared for road transport sector in order to design and implement suitable technologies and policies for appropriate GHG mitigation measures. First time an attempt has been made to calculate decentralized or statewise road transport emission of India, using number of different categories of vehicles and region specific mass emission factors and a country level emission were calculated for shipping, railways and aviation, using different type of fuel consumption.

The total CO_2 emission for Indian transport was 258.10 Tg in 2003–2004. Among all type of transport, road and aviation were first and second major contributor of air pollution. The road transport sector has contributed 94.5% and 53.3% of total transport emission of CO_2 and CO. Among all the states and UT, Maharashtra's contribution is the largest, 28.85 Tg (11.8%) of CO_2, followed by Tamil Nadu 26.41 Tg (10.8%), Gujarat 23.31 Tg (9.6%), Uttar Pradesh 17.42 Tg (7.1%), Rajasthan 15.17 Tg (6.22%) and, Karnataka 15.09 Tg (6.19%). The total of these six states accounts for 51.8% of the CO_2 emissions from road transport. The aviation has contributed 2.9% and 45.1% of CO_2 and CO of total transport emission. Shipping is most environment friendly mode of transport. It has contributed only 0.6% of CO_2 emission, while railways have contributed 2.0% and 1.2% of CO_2 and CO of total transport emission. For aviation,
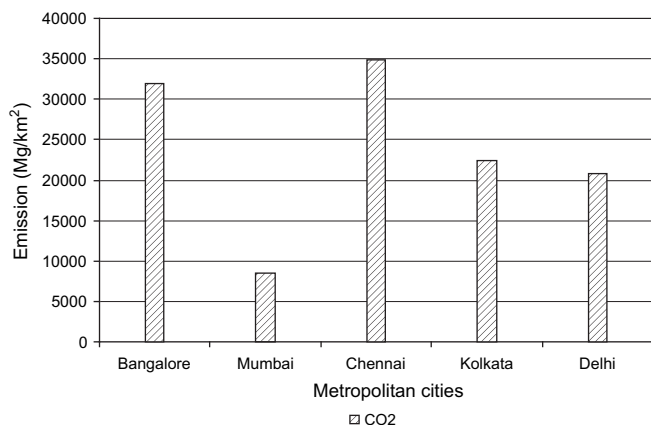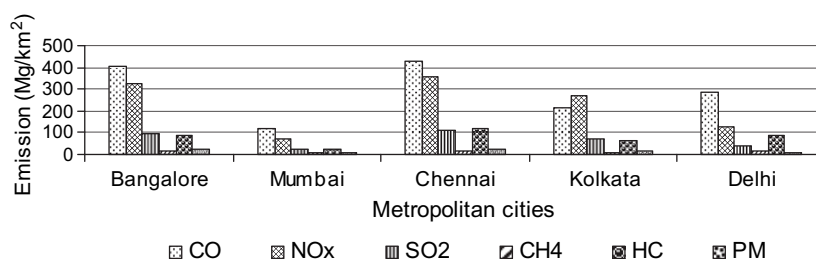
Fig. 5. Vehicular emission in major metropolitan cities of India.

railways and shipping, emissions were also calculated for 2004–2005 and 2005–2006. Total emission of CO_2 from railways, shipping and aviation has increased by 24.2% from 14.29 Tg in 2003–2004 to 17.74 Tg in 2005–2006. Similarly CO and CH_4 emissions have increased from 32.3% to 31.8%, respectively.

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