Introductory Comments: Methodology for Producing Inventory of GHGs and Other Pollutants

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1. Introduction

Delhi and Calcutta are the two important mega-cities in India with different techno-socio-economic parameters. The total population of the cities together was about 20 millions in 1990 but has increased to about 29 millions in 2000 as a result of rapid urbanization. Keeping this in mind, the present program supported by the APN/IGES on mega-cities included these two Indian cities. This is not to undermine the role of other mega-cities in India namely Mumbai and Chennai and fast upcoming cities like Bangalore, Hyderabad and Ahmedabad but to develop and try the concepts first in these target cities to be expended to rest of the cities. At present as per 2001 Indian census, there are more than thirty million plus cities in India with rapid developmental and industrial activities and seven cities including four metro cities (Delhi, Calcutta, Mumbai, Chennai) have been chosen stringent regulations of emissions from automobiles. Figure-1 shows the location of the seven Indian mega-cities with their population and suspended particulate matter (SPM) concentrations. The high SPM concentrations have been responsible for the implementation of stricter emission control measures especially from transport sector.

In addition in a recent meeting of SASCOM (South Asian START Committee) at Kathmandu, it was decided to enlarge the studies to two other South Asian Mega-cities namely Dhaka and Karachi for which efforts have been initiated and as reference cities, Chandigarh and Islamabad have also been proposed. These reference cities came into existence at the time of independence. In addition, Metro Manila provides another socio-economic and developmental setting.

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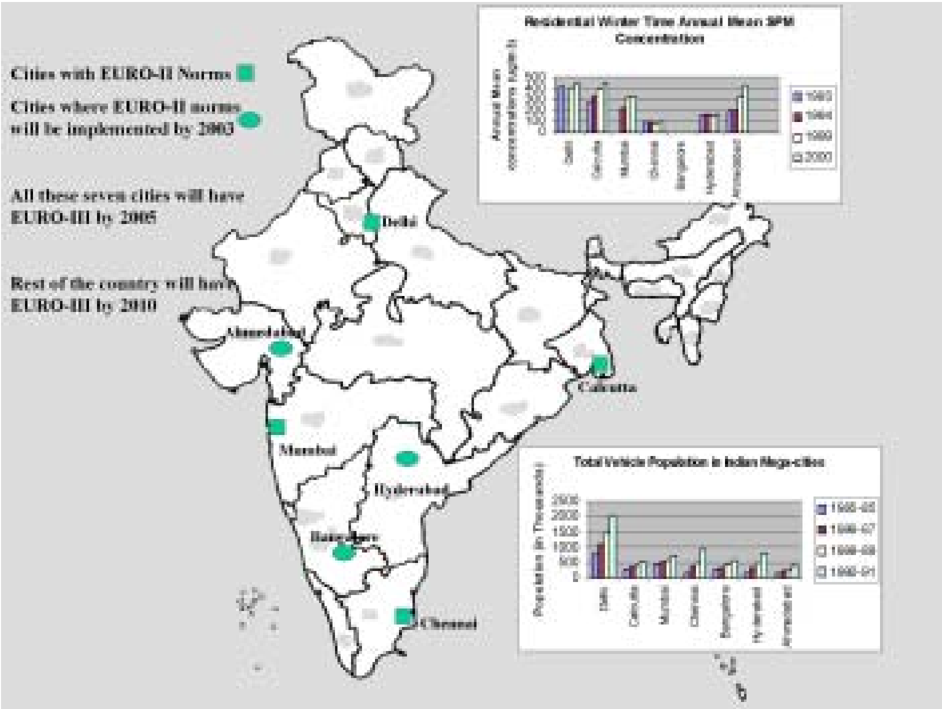
Figure - 1: Seven mega-cities of India targeted for stricter transport emission norms with their respective population and ambient SPM concentrations



In the urban areas in India, one of the worst parameter in ambient air quality is the presence of high concentrations of suspended particulate matter (SPM). As per Central Pollution Control Board (CPCB) of India, more than 20 cities have reported higher levels of SPM above than the prescribed limits for residential areas in 1996. This trend has extended to other upcoming cities in India also. This is one of the reasons for adverse health effects on human population living in these areas. Although, under increased public awareness and the intervention of judiciary, corrective measure are being taken up and environmental friendly policies are being framed up. An example of it is the recent cabinet decision on a road map for the implementation of emission norms in India. As per this decision, Euro II norms for vehicles, which are now enforced in four Indian mega-cities namely Delhi, Calcutta, Mumbai and Chennai, will be extended to three more cities namely Bangalore, Hyderabad and Ahmedabad by the year 2003. As a next step, all these seven cities will have Euro-III complied vehicles by 2005 and the entire country will have Euro-III complied vehicles by the year 2010.

2. Methodology

There are two special aspects of these mega-city emission studies:

1. The inclusion of short-lived gases (CO, NO_x, SO_2 etc.) and particulate matter in addition to the usually chosen greenhouse gases (GHGs: CO_2, CH_4 and N_2O)
2. Introduction of the concept of embodied emissions

For the first time, in this project, we have attempted to calculate embodied emissions in the material and energy that flow in the mega-cities. The calculations, currently only preliminary because of uncertainties and complexities, nevertheless give some idea of the magnitude of emissions associated with the development and maintenance of mega-cities. Table-1 shows the kind of input data being collected to develop the inventory of greenhouse and other urban gases from mega-cities. It may be noted here that a whole variety of data ranging from geographic, demographic, and climatic to specific sector data is being collected. Some of these sectors like steel, cement, power, agriculture etc. have major contributions in the embodied emissions from the mega-cities as reflected in the schematic figure-2.

Table-1: INPUTS

1. **Years** ***1970, 1980, 1990, 1995, 2000***

2. **Background Data**
§ ***Geographical areas, built-up areas, Population, Climate conditions, GRP, Land use patterns, Basic Environmental Parameters***

3. **Aggregate Energy Data**
· **Energy Balance, Energy Sources, Sectors (Industry, Construction, Transportation, Residential, Commercial)**

4. **Specific Sector Data**

4.1 Households
· ***Size, Urban vs. Rural, Income groups, Expenditures, Home appliances***

4.2 Commercial and Industrial Establishment, Service Establishment

4.3 Transportation
· ***Vehicles (population, category, vintage), Emission factors, Fuel consumption, Road (structure, length)***

4.4 Energy embodied in materials
· ***Steel, cement, bricks, food, water***

4.5 Infrastructures
4.6 Waste
· ***Municipal solid waste (landfill, incineration), Domestic and commercial waste water***
4.7 Agriculture
· ***Paddy fields, Agriculture soils***

Figure-2: Significance of specific sectors in the emissions from mega-cities

	CO_2	CH_4	N_2O	NO_x	CO	SO_2	Particulates
Energy & Transformation Industries	X			X	X	X	X
Transportation	X			X			
Biomass Burning	X	X	X	X	X		X
Industrial Processes							
Cement	[X]						
Steel	[X]						
Agriculture							
Enteric Fragmentation		[X]					
Rice Cultivation		[X]					
Agricultural Soils			X				
Agricultural residues burning		X	X	X	X		X
Landuse and Forestry	X						
Waste		X					

[X] Deemed

For the calculation of inventory values, in most of the cases IPCC-1996 methodologies have been followed. However, wherever country specific values of emission factors are available, the same has been utilized.

3. Salient features of the studies carried in Delhi, Calcutta and Manila

There are several points of interest in the results obtained so far:

1. The per-capita electricity consumption is almost three times higher in Delhi and Calcutta compared to average national per-capita consumption (Figure-3).
2. The total share of carbon dioxide emissions from Delhi and Calcutta together to the national total has been worked out to be about 5% (population 2.4%) in 1990 and 5.2% (population 2.7%) in 1995, two times the national per capita rate for CO_2. The share of two cities together in the national emission of methane is 2.7 % (Figure-4). For the seven cities selected for EuroII/III implementation, the share in national CO_2 emissions comes to be 8.8%. For Metro Manila, CO_2 emissions (from electricity consumption and transport) comes out to be 11Tg CO_2/year in 1990 and 21 Tg in 2000, as much as 27% of the national emission in 1990 and 31% in 2000.
3. Consumption of coal for electricity supplied to Delhi tops the emission and contributes about 54% while in Calcutta it contributes about 62%. The direct CO_2 emissions from consumption of energy products in Delhi are higher (about 27%) compared to Calcutta where it is about 9% only. However, embodied emissions associated with steel and cement consumption show higher values for Calcutta than Delhi (Figure-5).
4. For methane emissions, we find that the waste sector is the major source contributing about 42% in both the cities. The share of methane emission embodied in rice (40% for Calcutta and 42% for Delhi) and milk (8% and 9% for Calcutta and Delhi respectively) consumed are almost equal. But the methane emission from bio-fuel, which is insignificant in Delhi, is contributing about 10% in the total methane emission in Calcutta. He total methane emission from Delhi and Calcutta to the national total methane emission is about 2.7% (Figure-6).
5. The high consumption of bio fuel in Calcutta is also one of the major reasons for high indoor polluted related health effects in Calcutta. Better technologies can reduce the emissions very significantly and enhance the air quality. For example, the emission of black carbon from coal consumed for electricity would be reduced to about half with a technology used in developed countries as emission factors for developing countries are almost twice of that for developed country.
6. In addition, amongst the short-lived gases, CO amounts to about 8% against the national from petrol and diesel consumption.
7. For particulate matter, the contribution from Delhi and Calcutta is 5.4% in transport sector emissions.

Figure-3:PER CAPITA ELECTRICITY CONSUMPTION IN DELHI AND CALCUTTA

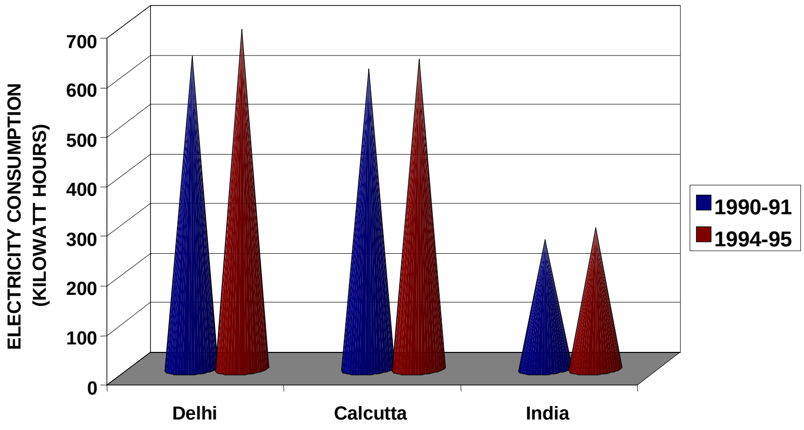


Figure-4: Comparison of CO_2 emissions from Delhi & Calcutta with the National CO_2 Emission(1990)

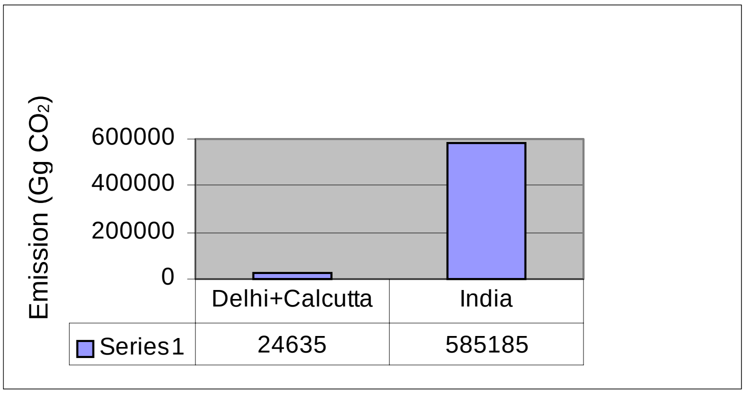


Figure-5: CO_2 EMISSIONS IN DELHI AND CALCUTTA (Gg CO_2)

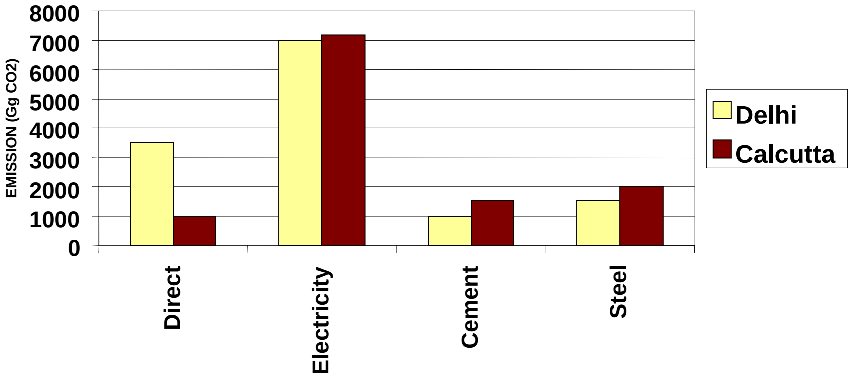


Figure-6: Comparison of CH_4 Emissions from Delhi & Calcutta with the National CH_4 Emissions(1990)

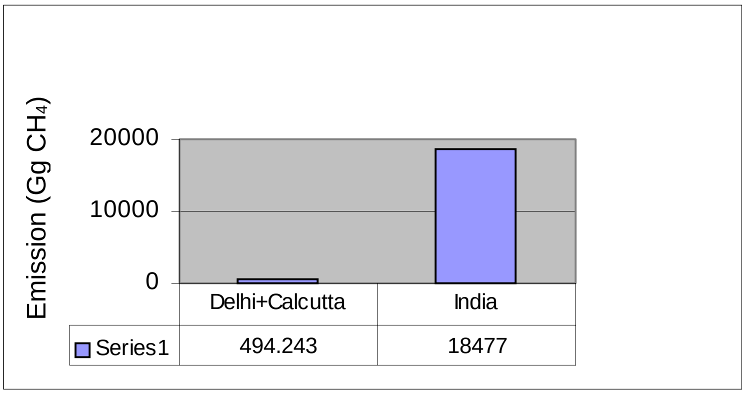
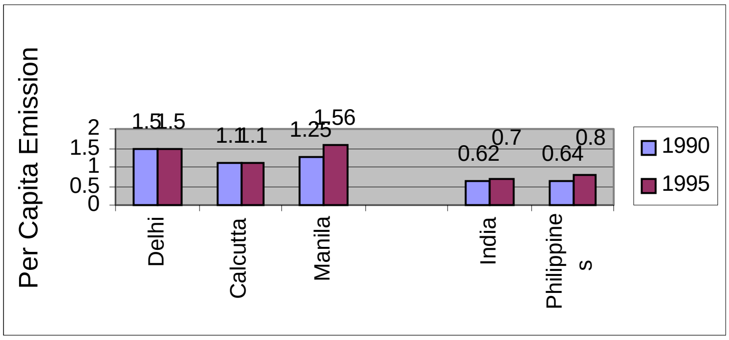


Figure-7: Per Capta CO_2 Emissions from Delhi, Calcutta and Manila



The per-capita CO_2 emissions from Delhi, Calcutta and manila are given in Figure-7 against the respective national per-capita emissions, and a comparison of CO_2 emissions, population and per-capita CO_2 emissions are given in Table-2.

Table-2: Comparison of CO_2 emissions of cities with national emissions

		Delhi	Calcutta	Manila	India	Philipinnes
1990	Emission	13 Tg	13 Tg	11 Tg	536Tg	40 Tg
	Population	8.8 m	11.8 m	8.5 m	855 m	62.4 m
	Per-capita	1.5	1.1	1.25	0.62	0.64
Delhi+Calcutta = 5% emissions ; 2.4% population						
1995	Emission	16.6 Tg	15.2 Tg	15.6 Tg	608Tg	54 Tg
	Population	11m	13.8 m	10 m	930 m	70 m
	Per-capita	1.5	1.1	1.56	0.7	0.8
Delhi+Calcutta = 5.2% emissions ; 2.7% population						
2000	Emission	19.8 Tg	17.27	21Tg	780 Tg	67Tg
	Population	13.2	15.7	11.8m	1000m	72 m
	Per-capita	1.5	1.1	1.8	0.78	0.9

One of the remarkable feature of this comparison is the large contribution in CO_2 emissions from Manila to the total Philippines emission of CO_2 compared to Delhi and Calcutta which contributed about 5% to the national total CO_2 emissions for 1990. Nevertheless, these findings show that mega-cities can be potential targets for reductions of greenhouse and urban gases.