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RESEARCH ARTICLE

INVENTORIZATION OF DIRECT AND EMBODIED EMISSIONS OF TRACE GASES AND AIR POLLUTANTS FROM DIFFERENT SECTORS IN INDIAN MEGA-CITY: DELHI

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ABSTRACT

Indian mega city, Delhi has witnessed a rapid growth in population and urbanization during last few decades. The quality of air has affected due to rapid urbanization. As a step in this direction, efforts have been initiated to develop emission inventories of direct and embodied emission of pollutants from different sectors in Delhi. This paper presents the emission estimates of direct and embodied emission of pollutants like CO_2, CO, CH_4, HC and NOx for Delhi. Sector wise emission inventory of pollutant due to the consumption of energy products (viz. Gasoline, Diesel and Coal), traditional biomass, enteric fermentation, paddy fields and waste sector have been estimated from the year 1990 to 2005 in Delhi. The present study indicate that both direct and embodied emission are responsible for the air quality degradation. The increasing embodied emissions with time from energy sector and industrial sector indicate, rapid urbanization and development.

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INTRODUCTION

The high population densities and high material demands are the characteristic features of mega cities. In addition, the demand of urbanization for land and resources has numerous environmental concerns, including the deterioration of city's ambient air quality. The cities having 10 million or more inhabitants are generally categorized as 'mega cities' (WHO, 1992). Delhi is a mega city having 13.8 million inhabitants in an area spread over 1483 Km^2 (DSH, 2006). According to a World Bank and Asian Development Bank joint study of air pollution for 20 major Asian cities between 2000 and 2003, Delhi has been reported to be one of the most polluted cities of the Asia. (http://cities.expressindia.com/). Delhi is a sprawling metropolis regarded by most as the 'city of migrants' as peoples from neighboring states come here for better employment and livelihood opportunities. The rapid urbanization of city has resulted in a sharp increase in population even though the geographical area of Delhi remained same. The population density in Delhi has been increasing quite significantly. During the last century, it was 274 persons/ Km^2 in 1901,which increased to 1176 persons/ Km^2 in 1951 and 9294 persons/ Km^2 in 2001 (http://delhiplanning.nic).

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The average population density at all-India level has been reported to be 324 persons/ Km^2 in 2001. During 1991 to 2001, the population in Delhi has increased from 9.4 million to 13.8 million. The proportion of urban population in Delhi over the last century has also increased very significantly. While the urban population in Delhi was 52.76% in 1901 and has increased to 93.01% by 2001. This is the highest urban population percentage in India (Census, 2001), because of the unique nature of Delhi which is not only a city but also a state of India. This shows that now entire Delhi area is almost completely urbanized. However, there are intra-regional differences in the dynamics of population pattern within the city. For example, the population density change indicates that it has increased phenomenally in the central & north eastern parts of Delhi compare to south and western parts during the period 1991 & 2001. This indicates the preferred locations for settlement of migratory populations due to reasons like affordability and available opportunities.

At city level, green house gas emission inventories for some cities have been prepared but most of these have so far been limited to direct emissions. Gurjar (2004) have reported sectoral emission inventory for Delhi for the period 1990-2000, mainly focusing on direct emissions from different sectors. Sharma (2002a) estimated greenhouse gas emission inventory for transport sector for Delhi & Kolkata based on consumption of gasoline and diesel in the transport sector.

Sharma (2002b) estimated greenhouse gases emission inventory for energy sector for Delhi & Kolkata, Most of the available emission inventories have been estimated for direct emissions (Chakraborty *et al.,* 2008; Garg *et al.,* 2001; Garg *et al.,* 2002; Garg & Shukla 2002; Kumar *et al.,* 2004; Mitra, 1992, 1998, 2002, 2008; Reddy and Venkataraman, 2002a, 2002b; Sharma 2002a, 2002b, 2002c; Singh 1996)**.** This paper presents the comprehensive assessment and estimation of direct and indirect (embodied) emissions of Trace Gases and Air Pollutants namely Carbon dioxide (CO_2), Carbon monoxide (CO), Sulpher dioxide (SO_2), Methane (CH_4), Hydrocarbons (HC), Carbon soot (Cs), Organic carbon (OC), Black carbon (BC), Volatile organic carbon (VOC), Non-methane volatile organic carbon (NMVOC), suspended particulate matter (SPM), Nitrogen oxides (NOx and N_2O), and other oxides of nitrogen from different sectors in the city for the period 1990–2005.

MATERIALS AND METHODS

Emission of the above mentioned air pollutants & trace atmospheric gases from different direct and embodied sources for Delhi have been estimated. The direct sources includes transport sector, waste sector, agriculture sector etc and the embodied sources includes materials which are purchased elsewhere but consumed in the city. These things should be included in the city's emission inventory as they are also responsible for the emission of the pollutants. It include the emission from animal providing milk to city population, Cement and steel imported within the city for construction. The city level activity data has been collected from the government sources (DSH 2006) and other reliable sources. For the emission estimation from transport sector, there are two approaches provided by IPCC, Top-down & Bottom-up. In Top-down approach, emission from total consumption of fuel like gasoline & diesel in transport sector is estimated while in bottom-up approach, emissions are estimated categories wise. For the estimation of CO, HC, PM, NOx emissions from diesel & gasoline, the country specific emission factors (Mitra *et al*., 1998) have been used. We have also calculated emissions of black carbon (BC) and organic carbon (OC) from petroleum product consumption using the available emission factors (Mitra *et al*., 1998).To estimate the emissions, in most of the cases IPCC methodologies (IPCC 1996) have been followed using default emission factor or country specific emission factors, depending upon their availability.

To calculate the embodied emissions from livestock population, we have used the import quantity of milk in Delhi. by subtracting the production of milk within the city from total consumption of milk then multiplied by milk production in Kg/dairy animal /day (buffalo =450 Kg/annum and cow = 157 kg/annum, average = 303.5 Kg/ dairy animal/annum) to find out the number of dairy animals used average value (303.5Kg/dairy animal/annum) of dairy cattle to produce import milk in the city. To calculate indirect emission by dairy cattle annually, average dairy cattle have been multiplied the emission factor (IPCC-1996). The waste generation in Mega cities is becoming a matter of consideration, In Delhi, 0.4 Kg/capita per day waste is generated (http://www.dsiidc.org/). To calculate the total amount of daily-generated waste, population is extrapolated and then multiplied by waste generation per day .we have assumed 0.4 Kg/ capita per day is generated as it is difficult to get the exact waste generation per day.

RESULTS

The emission inventories developed for both direct and embodied sources are discussed under different sectors as below.

Energy Sector

Consumption of petroleum products

Energy sector plays key role in the economic development as well as it also contributes to the emission of green house gases in to the environment. Energy related activities are the major sources of GHGs in India; at the national level more then 61% of the total CO_2 equivalent emissions have been estimated to be coming out of the energy related activities (NATCOM 2004). Energy consumption in mega cities by consuming fossil fuels like coal, petroleum, diesel in addition to biofuels. The consumption of fossil fuel contributes to increase in emission of various pollutants like suspended particulate matter (SPM), carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x) & other hydrocarbon (HC). Figure 1 shows the consumption of petroleum products (High speed Diesel Oil (HSDO), Light Diesel Oil (LDO), Liquefied Petroleum Gas (LPG), Compressed Petroleum Gas (CNG) and others which includes aviation turbine fuel, lubricant/grease etc. in Delhi during 1980-81 to 2004-2005 periods. Figure 1 revels that the consumption of diesel is quite higher as compare to gasoline. The consumption of petrol has increased four times from 344 MT in 1990-91 to 639 MT in 2004-05, High Speed Diesel Oil (HSDO) has increased from 732 MT in 1990-91 to 1214 MT in 2004-05, Light Diesel Oil (LDO) has increased from 66 MT to 58 MT from year 1990-91 to 2004-05, and LPG has increased from 205 to576 MT from the period 1980-81 to 1999-00, it is nine times to the 1990-91 value. After the implementation of CNG in the transport sector in Delhi, the CNG consumption is also increasing in Delhi. In 1999-00 it was 3.03 MT which has increased up to 277MT in 2003-04.

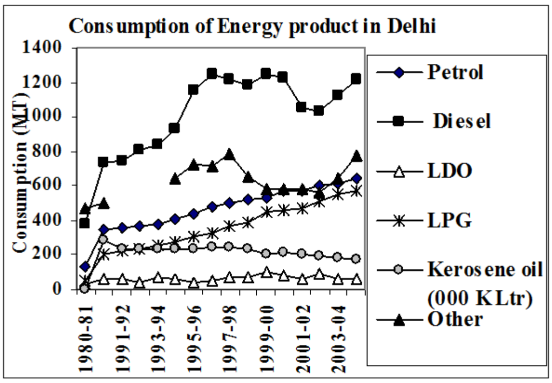

Fig. 1. Consumption of Energy products in Delhi

Electricity Generation

Thermal power plants are major contributors to air pollution. Consumption of coal to generate electricity in Delhi is the direct source of GHGs emissions while electricity purchased from national grid has been used to calculate indirect or embodied GHG emissions. Thermal power plants are the major contributor of CO_2 emission after transport sector in Delhi (DPCC 2001), The CO_2 emission has been estimated to have changed from 57.3Gg to 122.5Gg, NO from 18 Gg to 39Gg, SO_2 from 14.5Gg to 31Gg, PM from 5.2Gg to 11Gg and soot carbon (Cs) from 0.14Gg to 0.3 Gg from the period 1990-91 to 2004-05 (Figure 2). The consumption of electricity is increasing with the time so to fulfill the electricity demand of the city, the additional electricity is purchased from the national grids, which has been considered as an indirect (embodied) of emission in the present calculations. The CO_2 emission has been estimated to have increased from this embodied source from 73330 MT to 153900 MT, NO emission from 54000 MT to 95000 MT, SO_2 emission from 46000 MT to 97000 MT, PM emission from 16000 MT to 34000 MT and Cs from 440 MT to 930 MT from the period 1990-91 to 2004-05. (Figure 3)

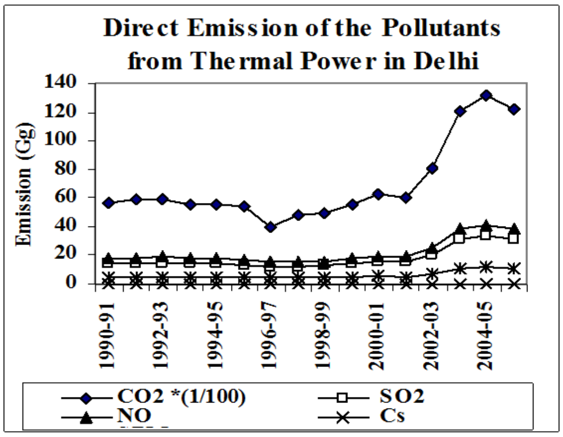

Fig. 2. Direct emission of pollutants from Thermal Power plant

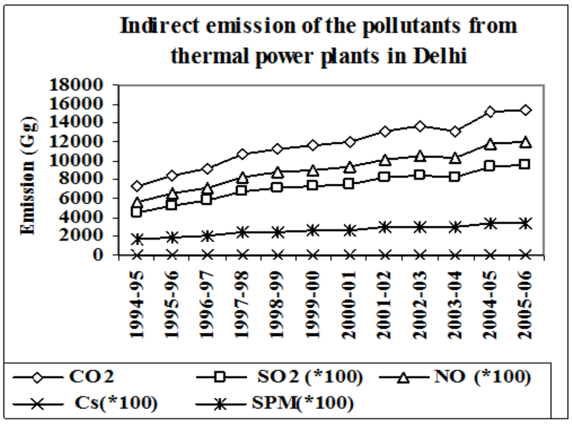

Fig. 3. Indirect emission of pollutants from Thermal power plant

Transport Sector

Delhi is predominantly dependent on road transport for mobility. There has been an increase of about 90 % in overall growth of registered motor vehicles during 1991-2001 at an average compound annual growth rate of about 6.7% in Delhi. As of March 2001, 3.4 million motor vehicles were registered in Delhi. The Census 2001 reported Delhi's population as 13.8 million. This reveals that there are 251 vehicles per 1000 population as of 2001 which are quite higher compared to the availability 192 vehicles per 1000 population in 1991. The percentage distribution of different categories of motor vehicles in Delhi shows that there has been a rapid proliferation in the number of cars/jeeps from 21.9% in 1991 to 26.6% of the total vehicles in 2001, while there has been a decline in the relative share of motorcycle & scooters, auto rickshaws, taxies and goods vehicles during this period. For the top-down approach we have assumed a fraction of 72 % consumption of gasoline by two wheeler and 28 % by four wheeler and 75 % consumption of diesel by LCV vehicles and 25 % consumption of diesel by HCV vehicles based on the population of vehicles.

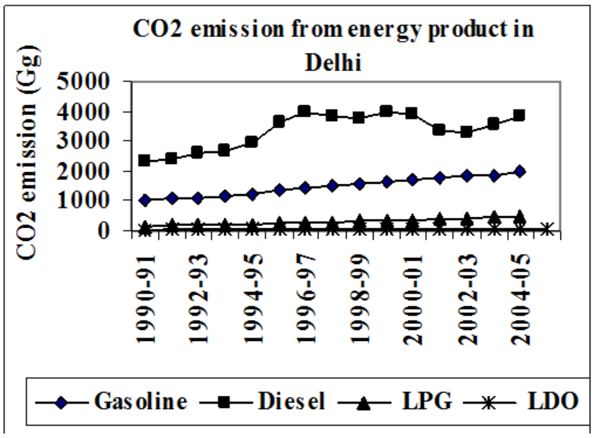

Fig. 4. CO2 emission from Energy product in Delhi

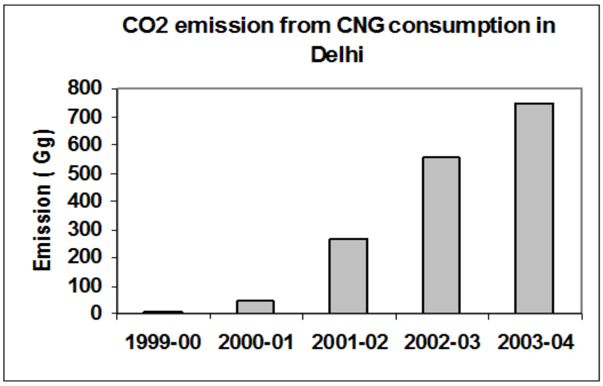

Fig. 5. CO2 emission from CNG Consumption

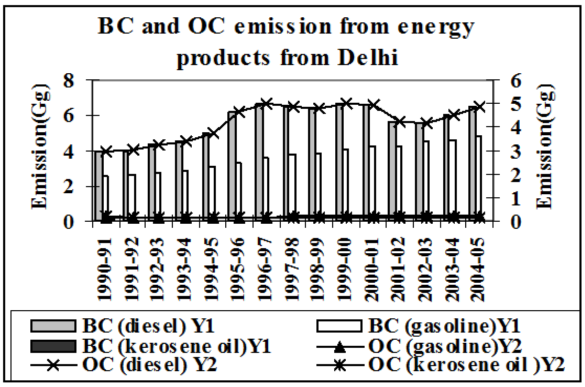

Fig. 6. BCand OC emission from Energy product

Using the top down approach it has been estimated that the CO_2 emission from gasoline consumption in transport sector has increased from 1057 Gg in 1990-91 to 1965 Gg in 2004-05. While CO_2 emission from diesel consumption has increased from 2326Gg in 1990-91 to 3857Gg in 2004-05, CO_2 emission from LPG consumption has increased from 166Gg in 1990-91 to 466 Gg in 2004-05 (Fig. 4). The CO_2 emission from CNG consumption has increased from 8.14 Gg to 746 Gg from year 1999-00 to 2003-04 period (Figure 5).

The BC emission from gasoline consumption has increased from 20 MT to 50 MT from the year 1990-91 to 2004-05, the BC emission from diesel consumption has increased from 3900 MT to 6500 MT during the same period while the emissions from kerosene consumption has decreased from 50 MT to 30 MT from the year 1990-91 to 2004-05 (Figure. 6). The OC emission from gasoline consumption has increased from 130 MT to 230 MT from the year 1990-91 to 2004-05, the emission from diesel consumption has increased from 2900 MT to 4900 MT during the same period while the OC emission from kerosene consumption has decreased from 0.2MT to 0.1 MT from the year 1990-91 to 2004-05 (Fig. 6).

For the bottom up approach the CO_2, CO, NO_X, VOC have been estimated both for gasoline driven (Motorcycle and car) and diesel driven (LCV and HCV) vehicles for the period of 1990-91 to 2004-05 for Delhi.

Gasoline driven vehicles

The CO_2 emissions from motorcycles /scooters have been estimated to be 759MT in 1990-91which have increased to 1419 MT in 2004-05, from cars it has been estimated to be 297MT in 1990-91 and 543 MT in 2004-05 (Fig. 7). The NOx emission from motorcycle /scooter was 0.55 MT in 1990-91 to 1.03 MT in 2004-05 and from cars it has been estimated to be 0.9 MT in 1990-91 and 3.5 MT in 2004-05 (Figure. 8), The CO emission from motorcycle /scooter have been estimated to be 146 MT in 1990-91 and increased up to 274 MT in 2004-05 from car it has been estimated to be 17 MT in 1990-91 to 31 MT in 2004-05 (Figure 9). The VOC emission from motorcycles / scooters have been estimated to be 73MT in 1990-91 which increased up to 136 MT in 2004-05. From car it has been estimated 3.3 MT to be in 1990-91 which increased to 6.0 MT in 2004-05 (Figure 10).

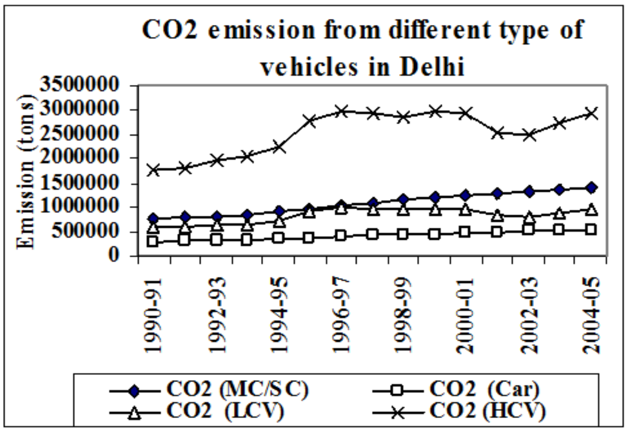

Fig. 7. CO2 emission from different type of vehicles

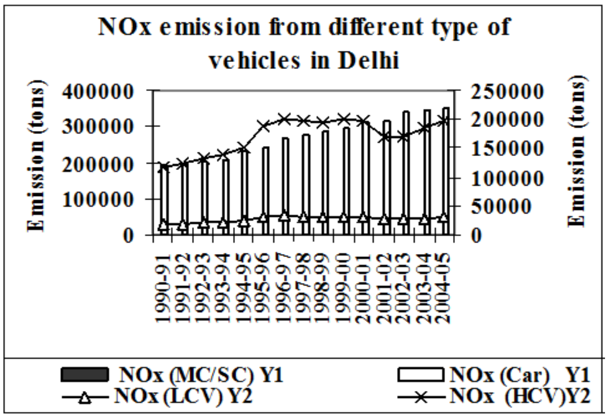

Fig. 8. NOx emission from different type of vehicles

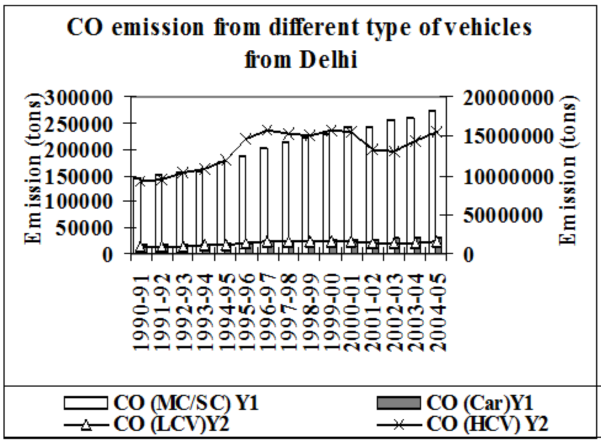

Fig. 9. CO emission from different type of vehicles

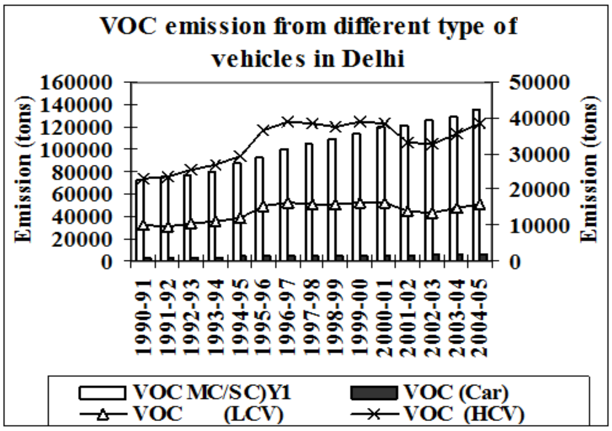

Fig. 10. VOC emission from different type of vehicles

Diesel driven vehicles

The CO_2 emission from diesel driven LCV has increased from 593 to 959 MT from year 1990-91 to 2004-05 and from HCV has increased from 1754 to 2933 MT from year 1990-91 to 2004-05 (Figure 7). The NOx emission from LCV has increased from 19.4 to 31.3MT from year 1990-91 to 2004-05 and from HCV has increased from 119 to 198 MT from year 1990-91 to 2004-05 (Figure. 8). The CO emission from LCV has been to be increase from 9.2 to 15 MT from year 1990-91 to 2004-05 and from HCV has increased from 92 to 154 MT from year 1990-91 to 2004-05 (Figure 9). The VOC emission from LCV have been estimated to be 9.9 in 1990-91 increased up to 16.0 MT in 1999-00 from HCV has been estimated 23 in 1990-91 and increased 38.4 MT in 2004-05 (Figure 10).

Industry Sector

Steel and cement industries are the major source of GHGs emissions (NATCOM 2004). There are no steel and cement industries within the city and therefore all the cement and steel consumed in the city represent embodied source of emissions. The cement consumption in Delhi has increased from 1.76MT in 1993-94 and 2.97 MT in 2002-2003, while the steel consumption has increased from 195 MT in 1994-95 and 440 MT in 2000-01 period. The embodied emissions of CO_2 & SO_2 from cement consumption for the period 1993-94 to 2002-2003 have been estimated to have increased from 877Gg to 1480Gg & 0.53Gg to 0.89Gg respectively (Figure 11). The growth rates of 60 Gg/year and 0.036 Gg/year respectively for the cement consumption in Delhi. It has been estimated that 877Gg CO_2 was emitted in 1993-94 to 1480 Gg in 2000-01 from steel consumption in Delhi, NO_2 emitted from steel consumption was 0.78Gg in 1994-95 to 1.76Gg in 2000-01, NMVOC 0.58Gg in 1994-95 to 1.32Gg in 2000-01, SO_2 from 0.87Gg in 1994-95 to 1.98Gg in 2000-01, CO from 0.019Gg in 1994-95 to 0.044Gg in 2000-01(Figure 12).

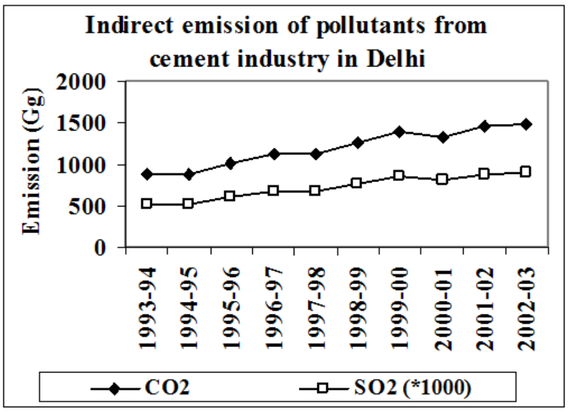

Fig. 11. Indirect emission of pollutants from cement industry

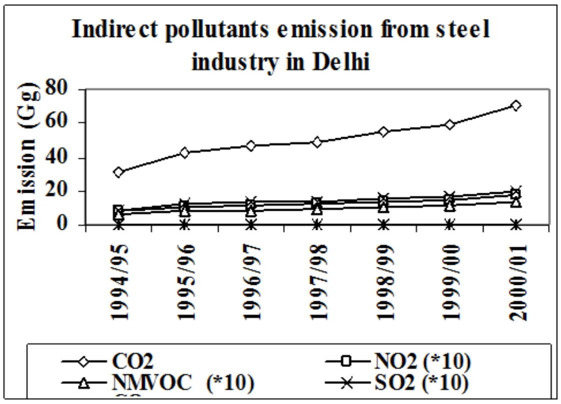

Fig.12. Indirect emission of pollutants from steel industry

Agriculture sector

Agriculture sector is the important sector for methane emissions into the atmosphere. Agricultural activities contribute directly to the emission of GHGs through different process taking place in live stocks, paddy fields, and agriculture soils. At national level about 90% of CH_4 has been estimated emitted from livestock due to enteric fermentation (Garg *et al.,* 2001). Ruminant animals (viz cattle, buffalo, sheep and goat) contribute the CH_4 emissions. Anaerobic decomposition in flooded rice fields produces methane, which escapes to the atmosphere. The fertilizer used in agriculture sector is the source of N_2O emissions from agriculture soil. According to the livestock population census, the total number of livestock in Delhi was 326492 in 1987, 368121 in 1997 and 374778 in 2007.

The numbers of dairy cattle, buffalo were 28796, 218515 in 1987-88, 51272, 203054 in 1997-98 and 47108, 230552 in 2002-03 respectively (DSH 2006). Animal census data for the live stock population of Delhi is available for the years 1987, 1992, 1997 and 2003 which have been used to calculate direct methane emissions from livestock. The Milk production in Delhi has increased from 264.4 MT in 1996-97 to 303 MT in 2004-05 registering a growth of 10.43% during the period of five years in Delhi. The milk imported within the city was 922 MT in 1996-97 that has increased from1104 MT in1999-00 and later decreased to 908.4MT in 2004-05.

The total CH_4 emission from livestock population have been estimated 12.9 Gg in 1987-88 and has increased up to 14.4 Gg in 1992-93 and then decreased to 12.8 Gg in 1999-00 (Figure 13). On the basis of milk imported in Delhi we have calculated number of animals responsible for production of that milk which was used to calculate indirect CH_4 emission from livestock in Delhi. The Indirect emission of CH_4 from livestock population in Delhi have been estimated 15595 Gg for the year 1990-91and 25449 Gg in 1999-00 (Figure 14).

The methane is estimated in terms of CO_2 equivalent for direct live stock population, have been estimated 166.17 Gg in 1987-88 & 185 Gg in 2003. The methane is estimated in terms of CO_2 equivalent for embodied live stock population, have been estimated 1786 Gg in 1997 and 1760 Gg in 2003. CH_4 in terms of CO_2 equivalent from paddy field have been estimated 0.02 Gg in 1990-91 and 0.09Gg in year 2005-06. N_2O from fertilizer consumption in terms of CO_2 equivalent have also been estimated 44 Gg in 1994-95 & 65 Gg in 2004-05.

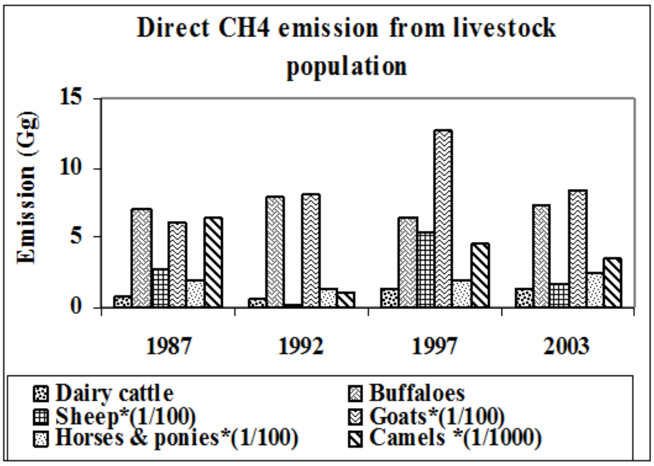

Fig. 13. Direct CH4 emission of from Livestock population

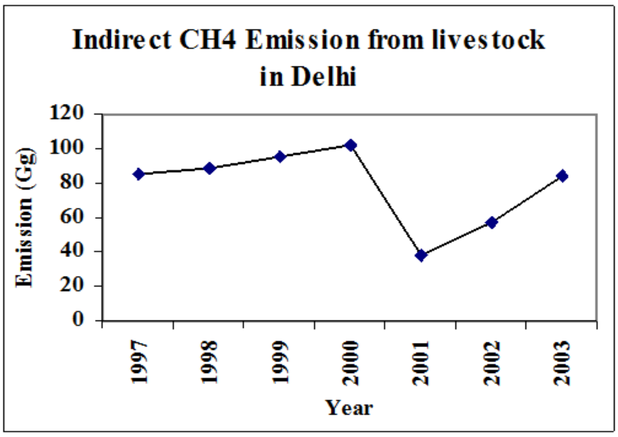

Fig.14. Indirect CH4 emission from Livestock population

The methane emission is estimated by the production of rice is multiplied with the yield (Kg/hectare), to calculate the land utilized for the production then multiplied by the default emission factor (IPCC) for rice-irrigated land. We have estimated the value where no data was available, as we have calculated land on the basis of production, the land is increasing while in real scenario that cannot be possible as land is a limited resource. The CH_4 emission from rice paddy field in Delhi have been estimated to be 0.7MT in 1990-91 and 4.5 MT in 2004-05 (Figure. 15). We have also calculated N_2O from the agriculture soil. To calculate N_2O from agriculture soil, we have taken total nitrogenous fertilizer consumption with in agriculture sector in the city, multiplied by default emission factor (IPCC-1996) for the direct N_2O emission from agriculture soil. The consumption of nitrogenous fertilizer in Delhi was 13039 MT in 1994-95 which has increased up to 2010 MT in 2004-05. The N_2O emissions from agriculture soil in Delhi have been estimated to be 0.15Gg to 0.22 Gg from 1994-95 to 2004-05 period (Figure 15).

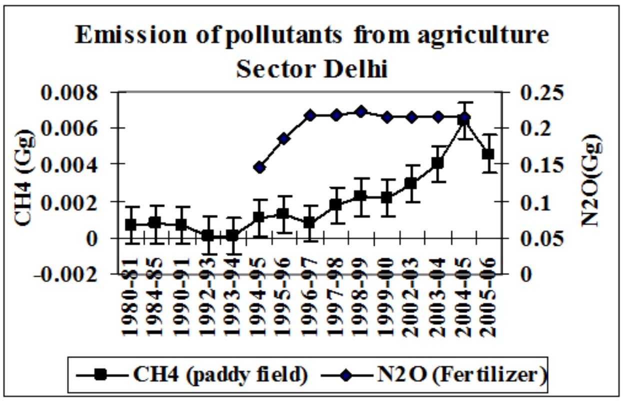

Fig. 15. Direct emission of pollutants from agriculture sector

Forestry Sector

Forestry sector contributes significantly to global carbon budget as it provides significant opportunities for sequestration of CO_2. To maintain the ecological balance and check environmental pollution, the development plans of Delhi have given high priority to afforestation programmes.

The inventory estimation using IPCC methodology revels that there is a net CO_2 removal from the land use and forestry sector in Delhi. The forest cover of Delhi was 1561 hectare in 1990-91 & then decreased up to 1281 in 1999-00 and then become constant in 2004-05. The total CO_2 removal was 21463 Gg in 1990-01 and then decreased in 2004-05 up to 17613 Gg (Figure 16).

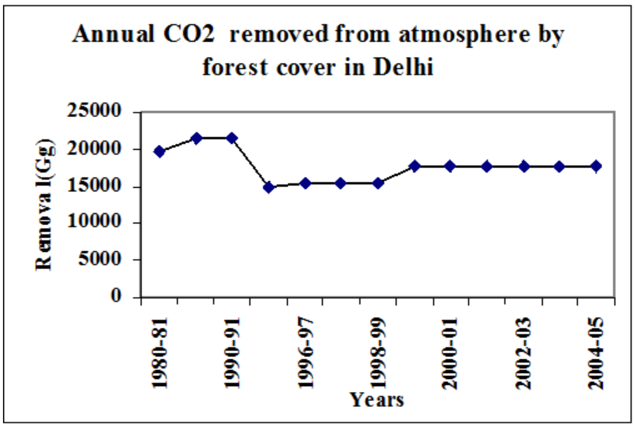

Fig.16. Removal of CO2 through forest cover

Waste sector

The waste dumped in the landfills is potential source of methane emission in to the atmosphere. Over 80% of the total municipal solid waste (MSW) collected from the urban centers of the world is dumped either in the landfills or in open dumps (Flintoff, 1976). However in India, it is estimated that more than 90% of the MSW is disposed off on the land without taking any specific precautions (CPHERI, 1973). The deposited waste is rarely covered & compacted & the depth is generally less than five meters. The organic content & the moisture are higher in Indian MSW as compared to the developed countries and the higher atmospheric temperature result in higher degradation (Bhide, 1998). Therefore, anaerobic conditions develop in the lower layer of landfills in spite of the absence of soil cover & lesser depths. Due to rapid growth of urbanization, there is substantial increase in generation of solid waste in both absolute and per capita terms. The CH4 emission for Delhi have been estimated to be 460 Gg in 1990-91 which has increased to 655 Gg in the year 1999-00.

DISCUSSION

The transport sector has the largest direct source of emissions due to higher consumption of gasoline and diesel as well as growth rate of vehicle population. The implementation of CNG in transport sector is assuming significant importance as a fuel but its contribution in the ambient NOx concentration needs to be investigated. The introduction of vehicles with stricter emission control seems to decrease the overall pollutant's emissions but the growth rate of vehicle population might probably negate that impact in overall emissions. The present study also indicates that pricing of fuel types also has significant bearing on the total emissions from transport sector. It is therefore prudent to consider a suit of parameters like fuel types, available technologies and alternative mode transport for developing and adopting suitable transport sector policies for sustainable environment management. Steel & cement industry are also the major embodied source of emission in industrial sector in Delhi .In our study we find out that the embodied emission from industrial sector is increasing with time . The rapid urbanization of Delhi is responsible for the day by day increasing demand & supply of building construction material. Thermal power plants are the major contributor of CO_2 emission after transport sector in Delhi (DPCC 2001). The consumption of electricity is increasing with the time so to fulfill the electricity demand of the city, the additional electricity is purchased from the national grids, which has been considered as an indirect (embodied) of emission in the present calculations. There has been an increase of about 90 % in overall growth of registered motor vehicles during 1991-2001 at an average compound annual growth rate of about 6.7% in Delhi. Due to rapid growth of urbanization, there is substantial increase in generation of solid waste in both absolute and per capita terms.

Conclusion

In our study we find out that indirect emission source are also the major contributor of air pollution in Delhi as compare to direct sources, it indicates that the air quality is improving after different policies implementation in different sectors in Delhi In year 1993-94 direct sources contributed 47% & indirect emission sources contributed 53% in total emission, In year 1994-95 direct source contributed 40% or indirect sources contributed 60% in total emission, Same as in year 1995-96 direct sources contributed 41% & indirect sources contributed 59% while in year 1996-97 direct sources contributed 39% & indirect sources contributed 61% in total emission in Delhi .It indicates that direct sources emission has decreased from 53% in year 1993-94 to 39% in 1996-97 in Delhi . Steel & cement industry are the major embodied source of emission in industrial sector in Delhi . The emission from steel industry has increase from 0.13% to in 1994-95 to 0.23% in 1999-00 and for cement industry the embodied emission has increased from 3.8% in year 1994-95 to 5.5 %in year 1999-00.The emission contribution from gasoline in transport sector first decreased from 17% in year1990-91 to 7.7% in year 1997-98 and then increase up to 11.5 % in year 1999-00, indicating that the private mode of transport has increased, the emission from diesel contributed 38% in year 1990-91 to 29% in 1999-00 while the emission contribution from Total petroleum product has change from 45% in year 1990-91 to 31% in 1999-00 year. In agriculture & waste sector, the emission contribution from Agriculture sector is negligible in total emission as compare to other sectors in Delhi.

Acknowledgement

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REFERENCE

Bhide A. D. 1998. `Methane emissions from landfills', In: Global Environment Chemistry, D.C. Parashar, C. Sharma and A.P.Mitra (Eds.) 116-127.

Chakraborty, N., Mukherjee, I., Santra, A., Chowdhury, S., Chakraborty, S., Bhattacharya, S., Mitrad, A., Sharma, C. 2008. Measurement of CO2, CO, SO2, and NO emissions from coal-based thermal power plants in India. Atmospheric Environment., 42 : 1073–1082.

CPHERI ‘Solid waste in India' Final report, 1973.

Delhi Statistical Handbook, 2006. Directorate of Economics & Statistics, Government of National Capital Territory of Delhi, various issues.

DPCC,2001. Towards cleaner air: a case study of Delhi, Delhi pollution Control Board, N. Delhi. (http://envfor.nic.in/)

Flintoff, F. 1976. Management of solid waste in developing countries. WHO regional publication, SEA series I, WHO, New Delhi.

Garg, A., Bhattacharya, S., Shukla, P., Dadhwal, V. 2001. Regional and sectoral assessment of greenhouse gas emissions in India. Atmospheric Environment., 35: 2679–2695.

Garg, A., Kapshe, M., Shukla, P., Ghosh, D. 2002. Large point source (LPS) emissions from India: regional and sectoral analysis. Atmospheric Environment., 36: 213–224.

Garg,A., Shukla, P.R. 2002. Emission inventory of India. New Delhi, India: Tata McGraw-Hill Publishing Company Limited.

Gurjar, B., Aardenne, J., Van, Lelieveld J., Mohan, M. 2004. Emission estimates and trends (1990-2000) for mega-city Delhi and implications. Atmospheric Environment., 38: 5663-5681.

http://delhigovt.nic.in/

http://www.indiaagronet.com/

http://www.who.int/whr/2002/chapter4/en/index7.html

IPCC. 1996. Revised IPCC guidelines for national greenhouse gas inventories: reference manual. Intergovernmental Panel on Climate Change, 3.

Kumar, Mondal, A., Gaikwad, S., Devotta1, S., Singh, R. 2004.Qualitative assessment of methane emission inventory from municipal solid waste disposal sites: A case study. Atmospheric Environment., 38: 4921–4929.

Mitra, A. P., Global change — greenhouse gas emissions in India 1992. update. Scientific report No. 4, August 1992. New Delhi, India: National Physical Laboratory

Mitra, A., Sharma, C. 2008. Measurement of CO2, CO, SO2, and NO emissions from coal-based thermal power plants in India. Atmospheric Environment., 42 : 1073–1082.

Mitra, A.P. 2002. Science & Culture Number 9-12 (68), September-December, 2002, New Delhi, India : National Physical Laboratory; 2002.

Mitra, A.P. Global change — greenhouse gas emissions in India 1998. update. Scientific report No. 11, May 1998. New Delhi, India: National Physical Laboratory.

MoEF, 1997. White Paper on Pollution in Delhi With an Action Plan, Ministry of Environment and Forest, Govt of India, New Delhi.

NATCOM. 2004. Initial National Communication to the united Nations Framework Convention on climate Change, Ministry of Environment and forests govt of India

Reddy, M., Venkataraman, C. 2002b. Inventory of aerosol and sulphur dioxide emissions from India. Part II—biomass combustion. Atmospheric Environment., 36(4): 699-712.

Reddy, M., Venkataraman, C. 2002a. Inventory of aerosol and sulphur dioxide emissions from India: I—Fossil fuel combustion. Atmospheric Environment., 36(4): 677-697.

Sharma, C., Dasgupta, A., Mitra, A. 2002a. Future scenarios of inventories of GHGs and urban pollutants from Delhi and Calcutta. In: Proceedings of Workshops of IGES/APN Mega-city Project. 23–25 January Kitakyushu, Japan.2002.

Sharma, C., Dasgupta, A., Mitra, A. 2002b. Inventory of GHGs and other urban pollutants from transport sector in Delhi and Calcutta. In: Proceedings of Workshop of IGES/APN Mega-city Project. 23–25 January. Kitakyushu, Japan.2002.

Sharma, C., Dasgupta, A., Mitra, A. 2002c. Inventory of GHGs and other urban pollutants from agriculture and waste sectors in Delhi and Calcutta. In: Proceedings of Workshop of IGES/APN Mega-City project. 23–25 January Kitakyushu, Japan.2002.

Singh, A. Road transport and GHG emissions. In: Mitra AP, (1996) editor. Global change — greenhouse gas emissions in India—1996 update. Scientific report no. 11. New Delhi, India: National Physical Laboratory. November 1996.

WHO, World Health Organization, 2002. The world health report 2002. Quantifying Selected Major Risks to Health. (Chapter-4). Accessible at URL:

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