Atmospheric Environment 43 (2009) 5510–5517

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

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

ARTICLE INFO

Article history:
Received 25 October 2008
Received in revised form
26 June 2009
Accepted 6 July 2009

Keywords:
Greenhouse gases
Emission
India
Transport sector
Globalization

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

* 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

1352-2310/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.atmosenv.2009.07.015

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

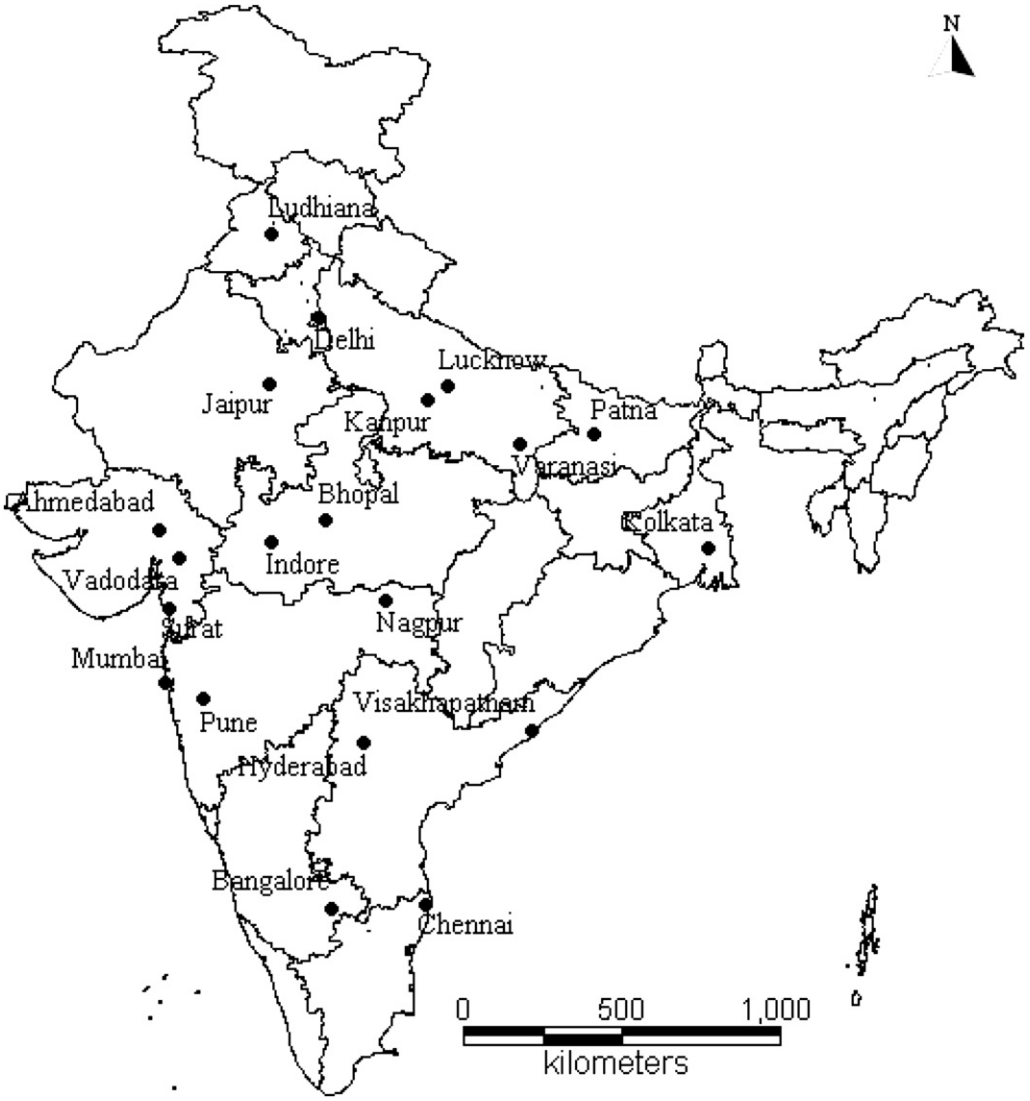

Fig. 1. India with metropolitan cities.