CATALOGUE
OF INDIAN EMISSION INVENTORY REPORTS

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CATALOGUE

OF INDIAN EMISSION INVENTORY REPORTS

Message

Dr Vibha Dhawan

Director General,
The Energy and Resources Institute

The air pollution conundrum has now touched every aspect of our lives. Apart from direct health impacts, air pollution has added a cost burden on the economy, productivity, our cognitive ability and overall well-being. While we collectively look for myriad solutions to make the air we breathe less poisonous, the scientific community agrees that pollution has to be reduced from the source itself. Therefore, identifying the emission sources is the first step towards winning this battle.

Identification and quantification of emission rates from various sources has been practiced for some time now. However, today with mandates from the Central Pollution Control Board, National Green Tribunal, MoEFCC and the National Clean Air Programme, many more cities are preparing emission inventories. The importance of robust emission inventory data has increased since the advancement in air quality monitoring and modelling techniques. Today there is a greater emphasis on accurate and reliable emission data for all pollutants and all sources.

*The report **Catalogue of Indian Emission Inventory Reports** is our endeavour to bring to the forefront all the air pollutant emission inventories that have been carried out for India across the transport, industrial, power plants, agricultural, residential, and all other sectors. The report highlights the good practices of using indigenous emission factors and the importance of using primary data and activity surveys for ground-truthing. The reports attempts to briefly outline the uncertainties associated with emission inventories.*

This seminal work is expected to greatly help scientists and policy makers alike. We hope it will serve a guidebook for all to refer to, and also gain insights on the tremendous strides that India has made towards mapping air pollution. Further, we hope through this report, we will be able to push for revising our existing inventories every year and also expand them into previously less studied sources and geographies.

I would like to congratulate the team for the robust analysis and thank Environmental Defense Fund for their partnership on this very relevant report.

Vibha Dhawan.

Dr Vibha Dhawan
New Delhi, January 2022

Message

Hisham Mundol

Chief Advisor, India,
Environmental Defense Fund

Robust emission inventories are the foundation towards understanding the primary sources of pollution and formulating targeted mitigation strategies. All non-attainment cities under the National Clean Air Programme are now working towards developing emission inventory studies. It is however worthwhile to highlight the tremendous work that has already been done by the scientific community towards the same.

***Catalogue of Indian Emission Inventory Reports** brings together all air pollution emission inventory data that is available for Indian cities. This comprehensive database, painstakingly put together by our researchers, brings together an updated database of emission inventory studies from diverse sectors like transport, industry, power-plants, residential, domestic and agriculture. Through this report, we were able to pin-point the geographic disparity in creation of emission inventories. Predictably, Delhi and NCR have had multiple EI reports by various researchers, albeit using different methodologies and emission factors. Most of these are standalone reports, and efforts need to be made to revise the emission loads every few years. This will especially be useful to understand the evolving nature of our polluting sources, and also test the efficacy of mitigation interventions. Comparing inventories every few years can tell us which actions have worked and needs to be scaled up. EI reports for north-eastern states need to be developed, along with regional inventories, especially when conversation on fighting the air pollution problem through an airshed approach has gained prominence.*

CPCB has set guidelines for development of EI studies, but while cataloguing the team found that use of foreign emission factor was common. This calls for oversight on how EI studies are carried out, as robust inventories will help informed decision making towards strategizing mitigation actions. Further, primary surveys in the zone of influence around monitoring sites is paramount for ground truthing of secondary data. Currently, most primary surveys are done only for road transport. Within the transport sector, we have to now develop inventories of freight, both maritime and on-road. The report also covers less studied sectors like road dust, construction activities, restaurants and bakeries along with total inventory studies. These studies are important as it shows the tremendous progress made towards developing emission factors within each sector, but also highlights sectors which require additional attention.

This report could be used by policy makers and scientists as a handbook of existing EI reports, but can also initiate dialogue on the potential that EIs have towards expanding our existing standards. For example, we do not yet have emission standards for crematoriums. Further, there are no standards for toxic heavy metals like mercury. In both these cases, if emission inventories are able to identify these as either contributing sources, or mercury continues to pervade in the ambient; authorities will be forced to take notice and start monitoring them closely and identify threshold values. Further, for sectors like road dust, which is still largely dependent on USEPA emission factors, India can lead way in developing region specific emission factors, given our diverse terrain, weather and soil conditions.

Environmental Defense Fund would like to express gratitude to Dr B Sengupta, former Member Secretary, CPCB, EMTRC Consultants Pvt. Ltd., and The Energy and Resources Institute (TERI) for their support and partnership for this very pertinent report. We at EDF are delighted to launch our first major study on such a relevant subject matter. We shall continue our endeavours to work closely with scientists and policy makers towards similar research based activities in the realms of air pollution in India in the coming days.

Hisham Mundol

New Delhi, January 2022

Message

Dr B Sengupta
Ex-Member Secretary,
Central Pollution Control Board
Ministry of Environment,
Forest and Climate Change

The Air (Prevention and Control of Pollution) Act, 1981 gives responsibility to CPCB under Section 16(2)(b) to plan and cause to be executed a nation-wide programme for the prevention, control or abatement of air pollution. Similarly under Section 17(a) of the Air Act gives responsibility to SPCB/PCC to plan a comprehensive programme for the prevention, control or abatement of air pollution and to secure the execution thereof. Similar responsibilities under EP Act, 1986 given to Central Government (MoEF&CC).

It is evident from Air Act, 1981 and EP Act,1986 that to prepare a comprehensive plan to control and prevent air pollution following actions are necessary:

- *Preparation of emission inventory (EI) of air pollution (point, line and other sources)*
- *Development of emission factor for industries, vehicles and other air polluting sources*
- *Operation and maintenance of air quality monitoring network.*
- *Development of National Air Quality Standards considering ill effects of air pollution on human health, vegetation and property.*
- *Development of emission standards for point (industries) sources, line (vehicular) sources and other non-point/ fugitive emission sources and enforcement of these standards by SPCB/PCC in polluting industries.*
- *Conducting sources apportionment studies in non-attainment cities and critically polluted areas following Standard Operating Procedures of CPCB and*
- *Preparation of action plan and implementation of the same to achieve national air quality standards in all non-attainment cities and critically polluted areas.*

So far in India CPCB, NEERI and IITs have prepared emission inventory (EI) and developed emission factor based on extensive source emission monitoring of air polluting sources.

The report ***Catalogue of Indian Emission Inventory Report*** *was conceived with the overarching goal of creating of repository of all exiting emission inventory reports. Developing an emission inventory is a complex process, and requires extensive study of industrial process, source (stack) emission monitoring, material and fuel balance, using emission factors and high resolution grid based activity surveys for ground truthing. The guidelines set forth by CPCB prescribed these steps and the studies that have followed this methodology have been highlighted in this report. EDF initially engaged Dr J K Moitra , MD of EMTRC for this work and Dr Moitra and his team has done extensive literature survey work and interviewed large no of stake holder to prepare the initial report. Subsequently EDF associated with TERI to further update the report.*

This comprehensive database includes emission inventory references, along with details on emission factors, grid size, pollutants, location of study and methodology used for data collection. This analysis will be particularly useful for the scientific community to refer studies at a quick glance itself, and also serve as a baseline for future emission inventories for cities.

I would like to congratulate the Air Quality group of EDF, Dr J K Moitra and TERI for their commendable efforts towards bringing this report. This report will serve both scientists and policy makers of CPCB/SPCBs /PCC who are looking for a quick referral on EI reports in cities and industrial clusters and help them to prepare a science based action plan to meet ambient air quality standards.

B. Sengupta

Dr B Sengupta
New Delhi, January 2022

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Design

Subhashish Roy

Contents

Abbreviations

ARAI	Automotive Research Association of India
AP 42	USEPA's Compilation of Air Emission Factors
BARC	Bhabha Atomic Research Agency
BC	Black Carbon
BS	Bharat Stage
CAGR	Compound Annual Growth Rate
CEEW	Council of Energy, Environment & Water
CH_4	Methane
CII	Confederation of Indian Industry
CMRI	Central Mining Research Institute
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
EC	Elemental Carbon
EF	Emission Factor
EI	Emission Inventory
EMTRC	Environment Monitoring Training & Research Institute
ENVIS	Environmental Information System
EPTRI	Environment Protection Training & Research Centre
GERI	Gujarat Ecological Research Institute
GHG	GreenHouse Gas
GIS	Geographic Information System
HC	Hydrocarbon
ICMR	Indian Council of Medical Research
IIPH	Indian Institute of Public Health
IIT	Indian Institute of Technology
IITM	Indian Institute of Tropical Meteorology
IMD	India Meteorological Department
IOCL	Indian Oil Corporation Limited
IPCC	Intergovernmental Panel on Climate Change
ISM	Indian School of Mines
LPG	Liquefied Petroleum Gas
MoEFCC	Ministry of Environment Forests and Climate Change
NO_2	Nitrogen Dioxide
N_2O	Nitrous Oxide
NCL	National Chemical Laboratory
NCR	National Capital Region
NEERI	National Environmental Engineering Research institute
NH_3	Ammonia
NIScPR	National Institute of Science Communication & Policy Research
NMVOC	Non Methane Volatile Organic Compound
NOx	Nitrogen oxides
NPL	National Physical Laboratory

NRDC	Natural Resource Defence Fund
NTPC	National Thermal Power Corporation
O_3	Ozone
OC	Organic Carbon
ONGC	Oil and Natural Gas Corporation
PAH	Polycyclic Aromatic Hydrocarbon
PM	Particulate Matter
PM_{10}	Particulate Matter with diameter less than 10 micro meter
$PM_{2.5}$	Particulate Matter with diameter less than 2.5 micro meter
SO_2	Sulphur Dioxide
SOx	Sulphur oxides
SPA	School of Planning and Architecture
SPCB	State Pollution Control Board
TERI	The Energy Research Institute
TSP	Total Suspended Matter
USEPA	United States Environmental Protection Agency
VKT	Vehicle Kilometre Travelled
VOC	Volatile Organic Compound
WHO	World Health Organization

List of Tables

Executive Summary

A detailed air emission inventory (EI) with a comprehensive list of pollutants within a pre-defined geographical area is beneficial for developing clean air action plans. It can also be used to test the effectiveness of pilot interventions towards air quality abatement. Emission inventories have been prepared for several Indian cities and states, however several of these EI reports have not been given due attention. This report presents a database of all publicly available EI reports and several previously un-referred studies for India to help policymakers and scientists with reckoner of all the work done in the area.

EI studies have been tabulated as per the source contribution (total emissions, transport, residential, industrial, power plants, agriculture, waste and others) along with details such as geography, grid size, emission factors used, and type of data collected (primary surveys or secondary literature). Each sector list also consists of the pollutants studied and highlights those reports that have adhered closely to the existing CPCB guidelines.

During the course of collating all EI reports, it was found that several researchers continue to rely solely on secondary data sets and use only foreign emission factors. Such inconsistencies in the existing body of literature show the need for developing and implementing systematic approaches towards data collection and reporting. They will ensure that the EI reports are accurate and enable better source apportionment studies. There have been a few reports at the pan-India level studies as well. However, there are considerable lacunae on the geographical spread of EI reports. Predictably, Delhi NCR and states in the Indo-Gangetic Plain have several EI reports. However, EI reports are sparse in the southern and north-eastern states. We hope this will change as now all 132 non-attainment cities under the National Clean Air Programme (NCAP) are developing their emission inventories and conducting source apportionment studies.

As per various operating sections of the Air Act 1981, air pollution monitoring, calculation of pollution load, preparation of emission inventory, preparation of action plan for air pollution control should be done as per SOP issued by CPCB from time to time. Therefore, emission inventory prepared by agencies and experts using other methodology may not be tenable per Air Act 1981. In its order for Critically Polluted Areas and Non-Attainment Cities, the National Green Tribunal mentioned that methodologies recommended by CPCB should be followed for such studies.

In recent years the nature of pollution sources has evolved significantly. Identifying them is crucial for prioritizing actions to mitigate air pollution. Further, several sources are not considered big emitters. For instance, emissions from restaurants and bakeries are significantly less than emission load from the transport sector. However, cumulatively these sources (including but not limited to construction and demolition waste, paved road dust, crematoria, bakeries and restaurants, diesel gen-sets) add up to a significant number. These sources are usually only accounted for total emission inventory studies, but we now need a more substantial push to develop individual EI reports for such less studied sectors.

About 200 EI reports have been collated and made available with hyperlinks for researchers and policymakers to use. They have also been sectorally classified for ease. Cities are now implementing clean air action plans, and NCAP funding is tied to performance. Therefore, periodically revised emission inventories could help check the efficacy of actions in each sector. Finally, regional emission inventories need to be prioritised as currently, the airshed approach has gained prominence in the battle against air pollution.

1 INTRODUCTION

Air pollutant Emission Inventory (EI) is the foundation for conducting source apportionment studies and formulating mitigation and control strategies. An emission inventory lists the emission contribution of individual pollutant species from different sources within a defined geographic boundary. Sources may be defined as broad categories such as industrial and transport sectors or respective sub-categories such as various industries, power plants and brick kilns. Apart from formulating action plans, air emission inventories may be developed for a single source or for a very small area for testing the efficacy of pilot experiments or recently deployed control techniques.[1]

In India, EI data generation began at a regional level in 1979-80. Scientists of the Central Pollution Control Board (CPCB) surveyed and identified the air pollution sources in Agra and Firozabad and calculated the sulfur dioxide (SO_2) emission load from each source. The EI data were used for modelling, and the results were used to ascertain source contribution in the area. This study's results culminated in forming the historic **Taj Trapezium Eco-Sensitive Zone**. As a result, many activities were either restricted or regulated within the Taj Trapezium, which helped prevent the marble of the iconic Taj Mahal from undergoing rapid discolouration.

Between 1980 and 1995, agencies engaged by CPCB for preparing the Comprehensive Industries Documents Series (COINDS)[2,3] estimated individual plant level emission load. The documents were used for formulating Minimal National Standards for various industrial sectors. In addition, the Intergovernmental Panel on Climate Change published the IPCC Guidelines for National GHG Inventories in 1996, specifically for estimating and reporting the GHG emissions at the national level. However, these were mainly from a climate change perspective.

Few carrying capacity studies were conducted between 1995 – 2007 by the National Environmental Engineering Research Institute (NEERI), TERI, ISM, CMRI, EPTRI and EMTRC, where plant level emission inventory data were used to estimate the pollution load. Carrying capacity studies were completed for Delhi-NCR, Doon Valley, Damodar River Basin, Greater Kochi, Panipat, Pune and Korba, Thane-Belapur, Goa, Neyveli, Paradip, Angul-Talcher, Visakhapatnam and Raigarh. These reports were submitted to the sponsoring agencies and are not available publicly.

1 Eastern Research Group, Inc., Steering Committee Emission Inventory Improvement Program, (1997), *Introduction to The Emission Inventory Improvement Program*

2 Central Pollution Control Board, *Comprehensive Industry Document Series (COINDS)*

3 Central Pollution Control Board, Ministry of Environment & Forest, (2010), *Comprehensive Industry Document on Electric Arc & Induction Furnaces*

Methods for Carrying Out Emission Inventory Studies

While there is no definition of what constitutes a "good" emission inventory, some practices are followed worldwide while developing emission inventory reports. The critical steps[4] while developing an emission inventory include:

1. listing of all sources in the study area;
2. listing of the type of air pollutants emitted by each source;
3. determination of available emission factor (EF) for the activities;
4. mathematical calculations using emission factor, activity rate and emission reduction technologies for each source;
5. compute the total emissions and sum up the similar emissions for the entire area.

Some of the most common EI manuals include the joint European Monitoring and Evaluation Programme/European Environment Agency (EMEP/CORINAIR) Atmospheric Emission Inventory Guidebook, the IPCC Guidelines, the UNDP manual, The Global Atmospheric Pollution Forum Air Pollutant Emissions Inventory Manual.[5]

An emission inventory should have a detailed analysis for the specific source sector, including emission maps wherever applicable, and the results should be available for dispersion modelling for source apportionment studies.

Emission Factors

An Emissions Factor (EF) **is a computed value that links the quantity of a pollutant emitted to a specific activity[6] associated with the release of that pollutant**. Mathematically, these emission factors are expressed as the numerical ratio of the mass of pollutant and the unit of polluting activity (for example, weight, volume, distance, or time duration). The general formula for emission estimation is

$$E = A \times EF \times (1 - ER/100)$$

Where: E = emissions   A = activity rate
EF = emission factor   ER = overall emission reduction efficiency[7]

Emissions factors are primary values used towards developing emission inventories at the national, regional, city scales. Ideally, each country must have its EFs for each sector, tailored to local conditions. Further, a nation must have EFs developed for all economic activities that may be a source of emissions. However, this is not the case. In practice, while Indian EFs remain the EF of choice, most scientists developing emission inventories have to rely on those developed by IPCC and USEPA for most sectors. The mathematical value of any EF will change with the slightest change in conditions. For example, EF for de-sulphurised coal will differ from EF for regular coal. In addition, EF will need to be revised with each generation of car makes, mass emission standards, etc. Hence, localised and updated emission factors are paramount to developing robust emission inventory reports.

4 H. Q. Bang, V. H. N. Khue, Air Pollution - Monitoring, Quantification and Removal of Gases and Particles, Air Emission Inventory, IntechOpen, (2019), DOI: 10.5772/intechopen.79928

5 Ministry of the Environment of Japan, Prime Station Corp, (2007), *What is an Emission Inventory?*

6 United States Environment Protection Agency (USEPA), *Basic Information of Air Emissions Factors and Quantification, USEPA*.

7 United States Environment Protection Agency (USEPA), *Basic Information of Air Emissions Factors and Quantification, USEPA*.

CPCB and the Automotive Research Association of India (ARAI) developed Emission Factors (EF) for in-use vehicles. After extensive field investigations and laboratory studies, the ARAI developed emission factors for various Indian Automobiles (BS-I to BS-VI, under Indian driving conditions). During the literature review, it was found that organisations such as CPCB, NEERI and TERI have been using emission factors derived by ARAI to prepare emission inventory for in-use vehicles.

CPCB has also developed EF for several other sectors, including but not limited to cement plants, thermal power plants, oil refineries and petrochemical industries. CPCB had used the Emission Factors given in AP42 documents published by the USEPA[8] for sources like paved roads, construction dust, construction of roads and flyovers, glass manufacturing, cast iron furnaces and boilers using wood chips; all within a 2×2 km^2 grid.[9] In addition, the industry-specific COINDS published by CPCB contains emission characteristics data of that specific industry. This information, covering all major industry types is valuable for the preparation of an accurate emission inventory.

CPCB Guidelines

CPCB prepared the Conceptual Guidelines and Common Methodology for Air Quality Monitoring, Emission Inventory & Source Apportionment Studies for Indian Cities in 2010.[10] According to these guidelines, a few critical steps towards developing an EI include:

1. Identify the broad sources of emissions under point, area and line sources
2. Collect secondary data on industrial, domestic, commercial, vehicular and other sectoral emissions from their respective authorized agencies. In addition, there needs to be primary data collection for vehicular emissions on parameters such as different types of vehicles; the average distance travelled by each type of vehicle, their inspection & maintenance schedule, type of fuel used and age of vehicles.
3. To validate and crosscheck the secondary data collected, all the state agencies should be approached to collect data on production capacity, raw materials used, manufacturing process, fuel consumption, and a primary survey. The studies analysed in this chapter have either used secondary datasets or done primary data collection; very few validated the collected data with primary surveys and questionnaires.
4. Primary data collection on various industrial, commercial and domestic sources through questionnaires, wherever necessary, specifically in the zone of influence (2×2 Km^2) around each monitoring location).
5. In cases wherein secondary data is used, the collected data must be analysed for data limitations and constraints while preparing the EI, using appropriate methodologies as used by reputed bodies such as USEPA.
6. For emission load and emission rate calculations, specific cross-checks should be built-in to quantify activity levels in addition to a rigorous QA/QC before any data is incorporated into the study.
7. The emission factors developed by the Automotive Research Association of India (ARAI), Pune, should be used for vehicular emissions load.

CPCB developed the above standard methodology for preparing emission inventory considering the available infrastructure, resources, technical expertise and time frame. CPCB applied the methodology for estimating emission inventory and carrying out the source apportionment studies of six metro cities in India (Delhi, Mumbai, Pune, Kanpur, Chennai, and Bangalore). CPCB published the documents in 2010. The European Environment Agency published the Atmospheric Emission Inventory Guidebook in 2007. Under the Malé Declaration, the Global Atmospheric Pollution Forum published the Air Pollutant Emission Inventory Manual, Version 5, in November 2012.

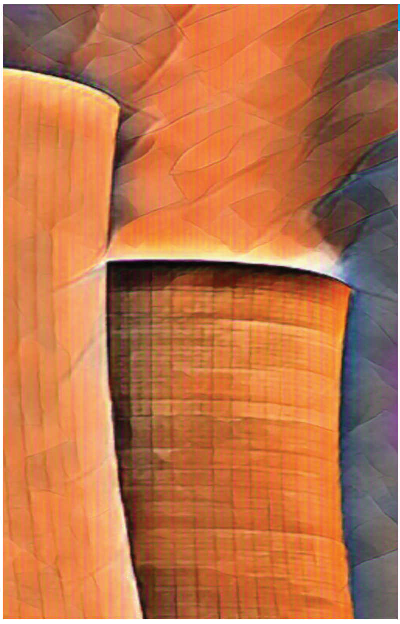
Between 2012-2019, NEERI and a few other private organizations like EMTRC and TERI carried out emission inventory using the CPCB guidelines, which were used for source apportionment studies and preparing issue-based action plans for controlling air pollution. These reports and other standalone emission inventory reports have been collated for this study.

8 United States Environment Protection Agency (USEPA), (1995), *COMPILATION OF AIR POLLUTANT EMISSION FACTORS VOLUME I: STATIONARY POINT AND AREA SOURCES*

9 The Energy and Research Institute, Central Pollution Control Board, (2010), *Air quality assessment, emission inventory and source apportionment study for Bangalore city*

10 Aggarwal, A. L., Gargava, P., & Pathak, A. (2010). *Conceptual Guidelines and Common Methodology for Air Quality Monitoring, Emission Inventory & Source Apportionment Studies for Indian Cities*.

2 ABOUT THE REPORT



Objective

The overarching goal of this report is to catalogue the available emission inventory (EI) reports into a single repository for easy retrieval and referral. EI reports for different cities and states are scattered, and there is not a single comprehensive database.

This report will provide researchers, policymakers, pollution control boards and state governments with a ready reckoner of all available emission inventories till 2021, along with quick pointers on pollutants, type of activity data used, type of emission factor used and geographical spread.

The National Clean Air Programme (NCAP) mandates all 132 non-attainment cities to develop source apportionment studies. Failure to do so will result in a loss of funding to implement clean air action plans. To comply with the mandate, most cities are now developing EIs. The first step for a source apportionment study is an EI and is mandatory before any corrective actions are implemented. Additionally, EI studies are less cost-intensive to be executed. This report will help in giving quick access to all already available EI reports until 2021 in an easily digestible format. Typically, emission inventory studies are used by policymakers to plan mitigation strategies. This report will help identify all the EI reports available along with information on methodology, pollutants covered and how closely the studies adhere to the guidelines set forth by CPCB.

Methodology

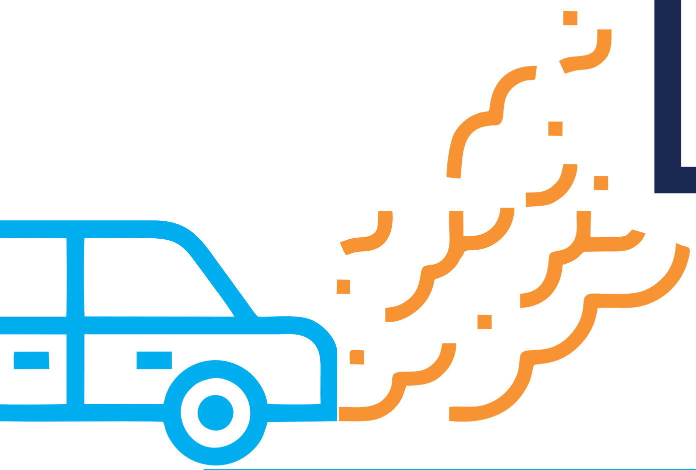
An exhaustive **literature search was carried out through internet searches and visits to websites** of CPCB, all SPCBs, MOEF&CC and its affiliated institutions, NEERI, all IITs and RECs, NIScPR, NAI, BARC, NRSA, IMD, IITM, TERI, ARAI, NPL, NCL, CSE, ENVIS Centres, EPTRI, NIO, ISM, NPC, CII, ISWBM, GERI, SPA, NTPC, IOCL, ONGC, and other organizations for emission inventory data.

The team collated emission inventories available for India. **In case the information was not available online, physical copies were collected from relevant offices**.

The **information was then catalogued in a simplified table and segregated based on sectors**. The studies had to have EI data using methods similar to those mentioned by CPCB were highlighted. The reports that simply mentioned "emission inventory" but did not include actual emission data were not included in the final analysis.

All reports were **segregated into Total Emissions, Transport Emissions, Industrial and Power Plant Emissions, Residential Emissions and Miscellaneous Emissions (waste, agriculture and other niche sectors)**.

Each EI report was **assessed for the location, year, types of pollutants covered, data collection methods (primary vs secondary), and type of emission factor used**.



This report is divided into chapters based on specific sectors, and EI studies have been tabulated lucidly for each sector. All the studies encompass air pollutant emission inventory. Studies that have adhered closely to the CPCB methodology have been highlighted with their respective website links for easy retrieval. If an EI report covered multiple sectors such as residential, transport and agriculture, it has been catalogued repeatedly under each subhead.

3

TOTAL EMISSIONS INVENTORY

Introduction

Vehicular emissions, crop burning, dust generation, mainly from construction sites, industrial and power plant emissions all contribute to declining air quality. A recent study by The Lancet stated that 1.67 million deaths were attributed to air pollution in India in the year 2019. The same study estimated that the damage cost of air pollution in India was about 1.36% of the country's GDP, with Delhi having the highest per-capita economic loss due to air pollution.[11]

The air pollution problem becomes complex due to the multiplicity and complexity of air-polluting sources (e.g., industries, automobiles, generator sets, domestic fuel burning, roadside dust, construction activities, etc.). According to the National Clean Air Programme (NCAP)[12], a cost-effective approach for improving air quality in polluted areas involves;

1. Identification of emission sources
2. Estimating the contribution from these sources
3. Prioritizing source mitigation efforts
4. Exploring options on mitigation considering the feasibility and economic viability
5. Forming the most appropriate action plan

The NCAP mandates the states to conduct source apportionment studies in all the identified non-attainment cities in India. In addition, to achieve that, the first step is to make a robust emission inventory of the study domain. This chapter has reviewed all the research papers, reports, conference papers, and articles, which have estimated emissions for India or Indian cities and states since inception. In addition, the chapter includes studies, which have tried to include emissions from all sources in their respective study domain. Major sectors are listed below, and they have been dealt with individually in different chapters of the report.

11 Pandey, A., Brauer, M., Cropper, M. L., Balakrishnan, K., Mathur, P., Dey, S., & Dandona, L. (2021). Health and economic impact of air pollution in the states of India: The Global Burden of Disease Study 2019. *The Lancet Planetary Health, 5*(1), p25-p38.

12 Ministry of Environment, Forest and Climate Change (MoEFCC), (2019), *National Clean Air Programme*

Common Emission Sources

Residential – Emissions from cooking activities, including burning fuel wood, crop residue, dung cake, and lighting activity, including using kerosene or any other fuel. Fuelwood is also used in the residential sector for water heating, space heating during the winter season and for preparing animal fodder in several parts of India

Transport – Emissions from vehicle exhaust (tailpipe) have been estimated. Transport emissions depend on the type of vehicle, age of the vehicle, fuel used, road conditions and mileage covered by the vehicle Industry - Air pollutant emissions from industries result from different categories of manufacturing activities (combustion process emissions, non-combustion process emissions, and fugitive emissions during manufacturing process) using varied fuel types.

Thermal Power Plants – In thermal power plants (TPP), coal is the primary fuel used in addition to natural gas. Emissions from power plants are a function of the quality of fuel (ash and sulphur content of coal), the type of boilers, and the types of air pollution control devices used and their efficacy.

Brick Kilns - Brick kilns are one of India's largest coal consumers. The brick manufacturing sector is unorganized, using old technologies with low combustion efficiencies and limited emissions control. Traditional brick kilns are slowly being phased out, favouring induced draft "zig-zag" kilns, and some use biomass and cop residue as fuel. However, the rapid increase in brick production due to infrastructure growth has led to the rise in fuel consumption and subsequent emissions of pollutants.

Construction - Emissions of the construction sector depend heavily on the area of construction activity. This sector has one of the most unreliable secondary datasets due to the sheer amount of small, medium, and large construction going on in the country at all times

Road Dust – Resuspension of road dust due to vehicle movement contributes to PM_{10} and $PM_{2.5}$ concentrations in the atmosphere. They only contribute to primary PM but can be a significant source in areas with poor road conditions and plying of heavy-duty vehicles.

Agriculture Burning – Emissions from burning of crop residue after harvesting season is over. Emissions depend on total crop production in an area, type of crop, fraction of residual generated of a particular crop, dry matter in the crop residue and combustion efficiency of crop residue.

Refuse Burning – Burning scrap materials, garbage, biomass materials, etc., those that are burnt anthropogenically in the open area is considered as refuse. The amount of waste generation depends on the population and livelihood of residents in a particular place

Emission Calculation

The basic equation is followed to estimate emission from any sector[13]:

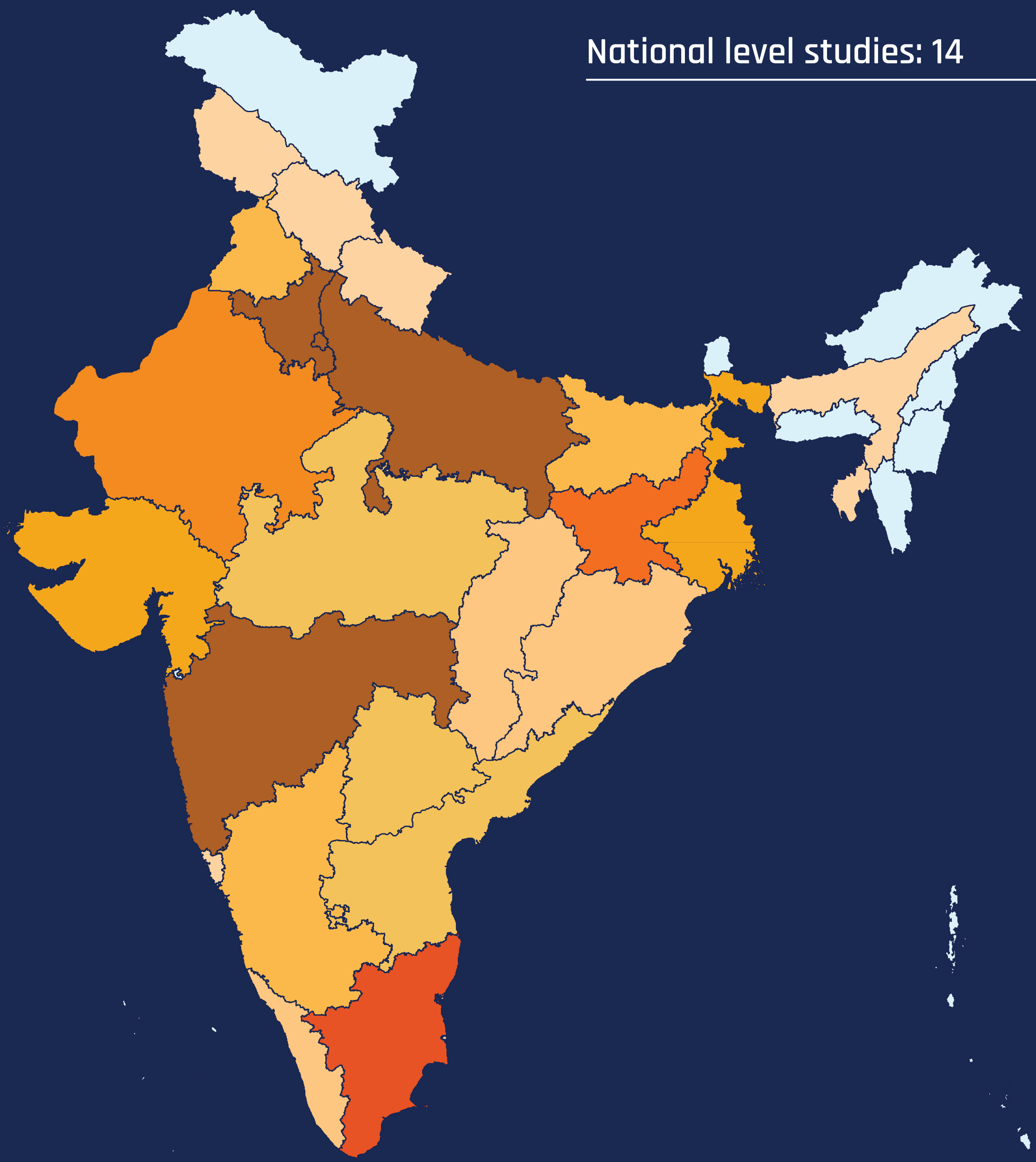
$$\mathbf{Ep = \Sigma_R\, \Sigma_S\, \Sigma_F\, A_{R,S,F} \times EF_{R,S,F} \times (1 - \alpha_{R,S,F}) \times X_{p,R,S,F}}$$

where, Ep is the annual emission of a pollutant (p) (kT); R is the region/state; S is the sector; F is the type of fuel; A is the activity data (fuel consumption or other emission-related data); EF is the emission factor (kT per unit of fuel use) of the pollutant (p); α is the removal efficiency (%) of pollutant (p) with the installed pollution control technology and X is the actual application rate of the control technology.

13 Z. Klimont, J. Cofala, I. Bertok, M. Amann, C. Heyes, F. Gyarfas, IASA, Laxenburg, Austria: IR-02-076, (2002), *Modelling particulate emissions in Europe. A Framework to Estimate Reduction Potential and Control Costs*

MAP 1

GEOGRAPHICAL DISTRIBUTION OF TOTAL EMISSIONS INVENTORY REPORTS IN INDIA



National level studies: 14

No. of studies

0
1
2
3
4
5
6
7
8
>10

Out of the 107 emission estimates studied in this chapter (See table 2), only 14 studies have been conducted at the national level. The remaining 92, were done at city and district levels. Total emissions for Uttar Pradesh, Haryana and Delhi, have been inventoried the most, with 21, 15 and 13 reports each. However, most reports for Uttar Pradesh and Haryana were part of studies estimating emissions for Delhi and NCR. Therefore, Noida, Ghaziabad in Uttar Pradesh and Gurgaon, Faridabad in Haryana have been studied multiple times. Outside of NCR in Uttar Pradesh, Kanpur has been reviewed four times. In the North of India, due to Delhi-NCR, the number of studies have increased, but their spatial coverage is limited to the Indo Gangetic Plain region only. There are a limited number of EI reports for South India. Tamil Nadu had maximum studies (8), but 4 out of 8 were focused on Chennai. Telangana has been studied three times, but all estimates have been made for Hyderabad only. Two out of three studies in Andhra Pradesh were focused on Vishakhapatnam. North Eastern has been largely ignored, except for a few reports for Assam and Tripura.

Due to multiple sources in the total emissions, the studies used a mix of primary and secondary data. For some city-level study domains, authors conducted a preliminary survey for industry, transport, domestic, waste burning sectors, but sectors like power plants, residue burning, construction etc., have been estimated using a secondary dataset. As India does not have EF for all fuel types or activity and sector-specific EF, authors have used GAINS, USEPA, and IPCC EFs for sectors with no Indian data available.

Overview

Implementing the same interventions in two cities with different meteorology, topography, and different types of emission is likely to give varied results. Therefore, the choice of interventions to control urban air pollution has to be city-specific, drawn based on a scientific study with an adequate & representative set of quality data. Therefore, CPCB funded six source apportionment studies conducted between 2007-2010 for Bangalore, Chennai, Delhi, Kanpur, Mumbai and Pune, for which they published conceptual guidelines and a common methodology for estimating emissions for Indian cities.[14]

They have allowed the use of a secondary dataset for estimating EI but urged to validate the dataset with a primary survey of a small area to confirm the secondary dataset reliability. Further, they have mandated the use of different EFs and activity data depending on the source:

Table 1
Emission Inventory Guidelines Laid Down by Central Pollution Control Board for Line, Point and Area Source

Source	Guideline	Activity Data	EF
Line	To conduct road survey of vehicle count, parking lot survey to identify age, technology, engine capacity, VKT and type of fuel use. EF to be used developed by ARAI	Primary	Indian
Point and Area	To get data using secondary sources and crosscheck and validate it through primary surveys. Indian EF to be used given by PCBs and other Indian literature, and for a large industry with no data, use USEPA, WHO, EU EFs and to normalize them for Indian condition	Secondary and Primary	Indian and Foreign

The studies we analysed in this chapter have used different methods to estimate emissions. Some have used primary datasets and foreign EFs[15] as they were trying to find toxicity levels of PM species emissions. Some used only satellite data to estimate total NOx emissions[16] in India for 2005. And a majority of the city and district level studies have followed a similar methodology to estimate emissions from different sectors. Most of the studies which are highlighted in Table 2 have carried out primary surveys for transport sector only, which encompasses traffic count and parking lot surveys.

14 Aggarwal, A. L., Gargava, P., & Pathak, A. (2010). Conceptual Guidelines and Common Methodology for Air Quality Monitoring, Emission Inventory & Source Apportionment Studies for Indian Cities. *Central Pollution Control Board*.

15 12. "A framework for PM2.5 constituents-based (including PAHs) emission inventory and source toxicity for priority controls: A case study of Delhi, India," A. K. Pathak, M. Sharma, P. K. Nagar, *Chemosphere*, 255, 126971 (2020)

16 "Satellite constraints of nitrogen oxide (NOx) emissions from India based on OMI observations and WRF-Chem simulations," S. D. Ghude, G. G. Pfister, C. Jena, P. J. van der A, L. K. Emmons, R. Kumar, *Geophysical Research Letters* 40, 2, 423-428 (2013)

Table 2
List of Studies for Total Emission Inventory

Note:
Studies highlighted in green adhere closely to CPCB guidelines

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
1.	Agra-Mathura region	1981	–	Primary	Indian	SO_2	Central Board for The Prevention And Control Of Water Pollution New Delhi, Central Board For The Prevention And Control Of Water Pollution New Delhi, Inventory and Assessment of Pollution Emission in and around Agra-Mathura Region (Abridged), Control of Urban Pollution Series CUPS/7/1981-82 Available at: http://cpcbenvis.nic.in/scanned%20reports/Inventory%20and%20assessment%20of%20pollution%20emission%20in%20and%20around%20Agra-Mathura%20region%20(Abridged).pdf
2.	India	2000	–	Secondary	Indian, USEPA	$PM_{2.5}$	"Atmospheric optical and radiative effects of anthropogenic aerosol constituents from India," M. S. Reddy, C. Venkataraman, Atmospheric Environment 34, 26, 4511-4523 (2000) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231000001059
3.	Dhanbad	2001	–	Primary	Indian	SOx, NOx, SPM, CO, HC	J. K. Upadhyay, Jawaharlal Nehru University, (2001), Modelling of dispersion of pollutants from various sources using Advanced Gaussian Plume Model in convective boundary layer in Dhanbad region, (Emission Inventory of the Region, Chapter 3). Available at: https://shodhganga.inflibnet.ac.in/bitstream/10603/19236/10/10_chapter%203.pdf
4.	India	2001	District level	Secondary	IPCC	SO_2, NOx	"Sub-region (District) and sector level SO_2 and NOx emissions for India: Assessment of Inventories and mitigation flexibility," A. Garg, P. R. Shukla, S. Bhattacharya, V. K. Dhadwal, Atmospheric Environment 35, 4, 703-713 (2001) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231000003162
5.	India	2003	–	Secondary	Foreign Literature	BC	"Large historical changes of fossil-fuel black carbon aerosols," T. Novakov, V. Ramanathan, J. E. Hansen, T. W. Krichstetter, M. Sato, J. E. Sinton, J. A. Sathaye, Geophysical Research Letters 30, 6 (2003) Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2002GL016345
6.	Delhi	2004	–	Secondary	Indian	CH_4, CO, CO_2, N_2O, NH_3, NMVOC, NOx, SO_2, TSP	"Emission estimates and trends (1990–2000) for megacity Delhi and implications," B. R. Gurjar, J. A. van Aardenne, J. Lelieveld, M. Mohan, Atmospheric Environment 38, 33, 5663-5681 (2004) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231004005394

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
7.	Mumbai	2005	–	Secondary	Indian, USEPA	SO_2, PM, Toxic Metals	"Inventory of SO_2, PM and toxic metals emissions from industrial sources in Greater Mumbai, India," A. D. Bhanarkar, P. S. Rao, D. G. Gajghate, P. Nema, Atmospheric Environment 39, 21, 3841-3864 (2005) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231005002773
8.	Jamshedpur	2005	1×1	Secondary	Indian	SO_2, NO_2	"Assessment of contribution of SO_2 and NO_2, from different sources in Jamshedpur region, India," A. Bhanarkar, S. K. Goyal, R. Sivacoumar, C.V. Chalapati Rao, Atmospheric Environment 39, 40, 7745-7760 (2005) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231005006515
9.	Pune	2007	2×2	–	–	PM_{10}	"Coupling of the Weather Research and Forecasting Model with AERMOD for pollutant dispersion modeling. A case study for PM_{10} dispersion over Pune, India," A. P. Kesarkar, M. Dalvi, A. Kaginalkar, A. Ojha, Atmospheric Environment 41, 9, 1976-1988 (2007) Available at: https://ui.adsabs.harvard.edu/abs/2007AtmEn..41.1976K/abstract_
10.	Hyderabad	2008	–	Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NOx, CO_2	S. Guttikunda, Integrated Environmental Strategies Program Washington DC, USA, (2008), Co-Benefits Analysis of Air Pollution and GHG Emissions for Hyderabad, India Available at: http://environmentportal.in/files/2008-03-IES-Co-Benefits-Hyderabad.pdf
11.	India	2008	100×100	Secondary	Indian, Foreign literature	BC	S. K. Sahu, G. Beig, C. Sharma, Geophysical Research Letters, (2008), Decadal growth of black carbon emissions in India Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2007GL032333
12.	Delhi, Mumbai, Chennai, Kolkata	2010	–	Secondary	Indian and USEPA	VOC	"Emission inventory of evaporative emissions of VOCs in four metro cities in India," A. Srivastava, D. Majumdar, Environmental Monitoring and Assessment 260, 215 (2010) Available at: https://link.springer.com/article/10.1007/s10661-008-0697-4
13.	Delhi, Gurgaon, Faridabad, Rohtak, Jhajjar, Noida, Ghaziabad	2011	1.67×1.67	Primary and Secondary	Indian	$PM_{2.5}$, PM_{10}	"Emissions inventory of anthropogenic $PM_{2.5}$ and PM_{10} in Delhi during Commonwealth Games 2010," S. K. Sahu, G. Beig, N. Parkhi, Atmospheric Environment 45, 34, 6180-6190 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S135223101100834X

S. No.	Location	Year of publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
14.	Delhi, Bangalore, Pune, Mumbai, Chennai, Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}, NOx, SO_2	Central Pollution Control Board, Central Pollution Control Board, (2011), Air quality monitoring, emission inventory and source apportionment study for Indian cities, National Summary Report Available at: https://www.cpcb.nic.in/displaypdf.php?id=RmluYWxOYXRpb25hbFN1bW1hcnkucGRm
15.	Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}	"GIS-Based Emission Inventory, Dispersion Modeling, and Assessment for Source Contributions of Particulate Matter in an Urban Environment" Sailesh N. Behera, Mukesh Sharma, Onkar Dikshit, S. P. Shukla. Water, Air and Soil Pollution. 218, 423-436 (2011) Available at: https://link.springer.com/article/10.1007/s11270-010-0656-x
16.	Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}	S. N. Behera, M. Sharma, O. Dikshit, S. P. Shukla, Advanced Air Pollution, (2011), Development of GIS-aided Emission Inventory of Air Pollutants for an Urban Environment Available at: https://www.intechopen.com/chapters/17388
17.	Jamshedpur	2011	1×1	Primary	Indian	NOx	"Air pollution modeling for an industrial complex and model performance evaluation," R. Sivacoumar, A. D. Bhanarkar, S. K. Goyal, S. K. Gadkari, A. L. Aggarwal, Environmental Pollution 111, 3, 471-477 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S026974910000083X
18.	India	2012	100×100	Secondary	Indian	NOx	"Emerging pattern of anthropogenic NOx emission over Indian subcontinent during 1990s and 2000s," S. K. Sahu, G. Beig, N. S. Parkhi, Atmospheric Pollution Research 3, 3, 262-269 (2012) Available at: https://www.sciencedirect.com/science/article/pii/S1309104215304268
19.	Angul	2012	2×2	Primary	Indian	PM_{10}, SO_2, NOx, CO	Provided by EMTRC Available at: https://indair-neeri.res.in/repository/view/3086%5C
20.	Korba	2013	2×2	Primary	Indian	PM_{10}, NO_2, , SO_2, CO	Provided by EMTRC Available at: https://indair-neeri.res.in/repository/view/3087
21.	Auraiya	2013	2×2	Primary	Indian	PM_{10}, NO_2, , SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3088
22.	Anta	2013	2×2	Primary	Indian	PM_{10}, NO_2, , SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3089

S. No.	Location	Year of publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
23.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian, Foreign Literature	PM, SO_2, NOx, CO, VOC	"A GIS based emissions inventory at 1 km × 1 km spatial resolution for air pollution analysis in Delhi, India," S. K. Guttikunda, G. Calori, Atmospheric Environment 67, 101-111 (2013). Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231012010229
24.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, NOx, CO, VOC	"Health impacts of particulate pollution in a megacity—Delhi, India," S. K. Guttikunda, R. Goel, Environmental Department 6, 8-20 (2013) Available at: https://www.sciencedirect.com/science/article/abs/pii/S2211464512001492?via%3Dihub
25.	India	2013	50×50	Satellite	Satellite	NOx	"Satellite constraints of nitrogen oxide (NOx) emissions from India based on OMI observations and WRF-Chem simulations," S. D. Ghude, G. G. Pfister, C. Jena, R. J. van der A, A. L. K. Emmons, R. Sharma, Geophysical Research Letters, 40, 2, 423-428 (2013) Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/grl.50065
26.	Kanpur	2013	2×2	Primary and Secondary	Indian, USEPA	PM, SO_2, NOx	"Respiratory Disease in Relation to Outdoor Air Pollution in Kanpur, India." H-Y Liu, A. Bartonova, M. Schindler, M. Sharma, S. N. Behera, K. Katiyar, O. Dikshit, Arch Environ Occup Health 68, 4, 204-217 (2013) Available at: https://pubmed.ncbi.nlm.nih.gov/23697693/
27.	Hyderabad	2014	–	Primary	Indian, USEPA, GAINS	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC, CO_2	"Source emissions and health impacts of urban air pollution in Hyderabad, India," S. K. Guttikunda, R. V. Kopakka, Air Qual Atmos Health 7, 195-207 (2014) Available at: https://link.springer.com/article/10.1007/s11869-013-0221-z
28.	Delhi	2014	–	Primary and Secondary	Indian, Foreign Literature	PM_{10}	"Speciated PM_{10} Emission Inventory for Delhi, India," P. Gargava, J. C. Chow, J. G. Watson, D. H. Lowenthal, Aerosol and Air Quality Research 14, 5, 1515-1526 (2014) Available at: https://aaqr.org/articles/aaqr-13-02-oa-0047
29.	Patna	2014	1×1	Secondary	Indian, USEPA	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC, CO_2	S. K. Guttikunda, P. Jawahar, UrbanEmissions.Info., (2014), Characterizing Patna's Ambient Air Quality and Assessing Opportunities for Policy Intervention Available at: https://shaktifoundation.in/report/characterising-patnas-ambient-air-quality-assessing-opportunities-policy-intervention/
30.	Amritsar	2015	For individual industry	Primary	Indian	PM_{10}, SO_2, NOx	"Assessment of Urban Air Quality around a Heritage Site Using AERMOD: A Case Study of Amritsar City, India," S. Gulia, A. Shrivastva, A. K. Nema, M. Khare, Environ Model Assess 20, 6, 599-608 (2015) Available at: https://link.springer.com/article/10.1007/s10666-015-9446-6

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
31.	Delhi	2015	2×2	Primary and Secondary	Indian	CO, NOx, SO_2, PM_{10}	"Anthropogenic Emission Inventory of Criteria Air Pollutants of an Urban Agglomeration - National Capital Region (NCR), Delhi," R. Sindhwani, P. Goyal, S. Kumar, A. Kumar, Aerosol and Air Quality Research 15, 1681-1697 (2015) Available at: https://aaqr.org/articles/aaqr-14-11-oa-0271
32.	Chennai, Vishakapatnam	2015	1×1	Primary and Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NO_2	"Particulate and gaseous emissions in two coastal cities—Chennai and Visakhapatnam, India," S. K. Guttikunda, R. Goel, D. Mohan, G. Tiwari, Air Quality, Atmosphere & Health 8, 6, 559-572 (2015) Available at: https://link.springer.com/article/10.1007/s11869-014-0303-6
33.	Delhi	2015	1.67×.67	Primary and Secondary	Indian, USEPA	NOx, CO	"High Resolution Emission Inventory of NOx and CO for Mega City Delhi, India," S. K. Sahu, G. Beig, N. Parkhi, Aerosol and Air Quality Research 15, 3, 1137-1144 (2015) Available at: https://aaqr.org/articles/aaqr-14-07-tn-0132
34.	Delhi	2016	2×2	Primary and Secondary	Indian	PM_{10}, $PM_{2.5}$, NOx, CO	M. Sharma, O. Dikshit, Department of Environment Government of National Capital Territory of Delhi, Delhi Pollution Control Committee, (2016), Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi (Final Report: Air Pollution component) Available at: https://cerca.iitd.ac.in/uploads/Reports/1576211826iitk.pdf
35.	India	2016	40×40	Secondary	Indian, Foreign Literature	BC	"Monthly and Spatially Resolved Black Carbon Emission Inventory of India: Uncertainty Analyses," U. Paliwal, M. Sharma, J. F. Burkhart, Atmos. Chem. Phys. 16, 12457-12476 (2016) Available at: https://acp.copernicus.org/articles/16/12457/2016/acp-16-12457-2016.pdf
36.	India	2016	36×36	Secondary	Indian, GAINS, USEPA	NOx, NMVOC, CO	"Sensitivity analysis of ground level ozone in India using WRF-CMAQ models," S. Sharma, S. Chatani, R. Mahatta, A. Goel, A. Kumar, Atmospheric Environment 131, 29-40 (2016) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231016300504
37.	Ahmedabad	2017	1.67×1.67	Primary and Secondary	Indian	NOx, CO, BC, OC, $PM_{2.5}$, PM_{10}, SO_2, VOC	G. Beig, N. S. Parkhi, Earth System Science Organization, Ministry of Earth sciences, Govt. of India, Indian Institute of Tropical Meteorology, Pune, (2017), Development of High-Resolution Emission Inventory for Ahmedabad Metropolitan Region (AMR) System of Air Quality and weather Forecasting and Research (SAFAR)- Ahmedabad. Available at: http://assets.nrdc.org/sites/default/files/media-uploads/safar-ahmedabad-ei-2017-full_report.pdf

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
38.	Manali (TN)	2017	0.5×0.5	Primary and Secondary	Indian	NO_2, , SO_2, PM_{10}	"Assimilative capacity–based emission load management in a critically polluted industrial cluster," S. Panda, S. M. S. Nagendra, Journal of the Air & Waste Management Association 67, 12, 1353-1363 (2017) Available at: http://assets.nrdc.org/sites/default/files/media-uploads/safar-ahmedabad-ei-2017-full_report.pdf
39.	Agra	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Agra, India Available at: https://urbanemissions.info/india-apna/agra-india/
40.	Amritsar	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Amritsar, India Available at: https://urbanemissions.info/india-apna/amritsar-india/
41.	Bengaluru	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bengaluru, India Available at: https://urbanemissions.info/india-apna/bengaluru-india/
42.	Bhopal	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bhopal, India Available at: https://urbanemissions.info/india-apna/bhopal-india/
43.	Bhubaneswar	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bhubaneswar, India Available at: https://urbanemissions.info/india-apna/bhubaneswar-india/
44.	Chandigarh	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Chandigarh, India Available at: https://urbanemissions.info/india-apna/chandigarh-india/
45.	Chennai	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Chennai, India Available at: https://urbanemissions.info/india-apna/chennai-india/

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
46.	Coimbatore	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Coimbatore, India Available at: https://urbanemissions.info/india-apna/coimbatore-india/
47.	Dehradun	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Dehradun, India Available at: https://urbanemissions.info/india-apna/dehradun-india/
48.	Indore	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Indore, India Available at: https://urbanemissions.info/india-apna/indore-india/
49.	Jaipur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Jaipur, India Available at: https://urbanemissions.info/india-apna/jaipur-india/
50.	Kanpur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Kanpur, India Available at: https://urbanemissions.info/india-apna/kanpur-india/
51.	Kochi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Kochi, India Available at: https://urbanemissions.info/india-apna/kochi-india/
52.	Ludhiana	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Ludhiana, India Available at: https://urbanemissions.info/india-apna/ludhiana-india/
53.	Nagpur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Nagpur, India Available at: https://urbanemissions.info/india-apna/nagpur-india/
54.	Patna	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Patna, India Available at: https://urbanemissions.info/india-apna/patna-india/

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
55.	Pune	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Pune, India Available at: https://urbanemissions.info/india-apna/pune-india/
56.	Ranchi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Ranchi, India Available at: https://urbanemissions.info/india-apna/ranchi-india/
57.	Raipur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Raipur, India Available at: https://urbanemissions.info/india-apna/raipur-india/
58.	Varanasi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Shakti Sustainable Emission Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Varanasi, India Available at: https://urbanemissions.info/india-apna/varanasi-india/
59.	Panipat, Sonipat, Rohtak, Jhajjar, Rewari, Alwar, Gurgaon, Fardabad, Noida, Ghaziabad, Bulandshar, Meerut, Baghpat	2017	4×4	Primary and Secondary	Indian, GAINS	NOx, NMVOC, CO	"Simulating ozone concentrations using precursor emission inventories in Delhi – National Capital Region of India," S. Sharma, M. Khare, Atmospheric Environment 151, 117-132 (2017) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231016309682
60.	Delhi, NCR	2018	4×4	Primary	Indian	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC	Automotive Research Association of India, The Energy and Resources Institute, Department of Heavy Industry Ministry of Heavy Industries and Public Enterprises, New Delhi, (2018), Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources Available at: https://www.teriin.org/sites/default/files/2018-08/Exec-summary_0.pdf
61.	India	2018	10×10	Secondary	Indian, GAINS	$PM_{2.5}$, BC, OC, SO_2, NOx, NMVOC	"Source influence on emission pathways and ambient $PM_{2.5}$ $PM_{2.5}$ pollution over India (2015–2050)," C. Venkataraman, M. Brauer, K. Tibrewal, P. Sadavarte, Q. Ma, A. Cohen, S. Chaliyakunnel, J. Frostad, Z. Klimont, R. V. Martin, D. B. Millet, S. Philip, K.Walker, S. Wang, Atmos. Chem. Phys. 18, 8017–8039 (2018) Available at: https://acp.copernicus.org/articles/18/8017/2018/

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
62.	India	2018	10×10	Secondary	EDGAR	CO, NOx, SO_2, NMVOC, $PM_{2.5}$, PM_{10}, EC, OC	The Air-Weather-Climate (AWC) Research group, Department of Civil and Environmental Engineering, (2018), Source apportionment, health effects and potential reduction of fine particulate matter ($PM_{2.5}$ $PM_{2.5}$) in India Available at: http://www.indiaenvironmentportal.org.in/files/file/Source-apportionment-india.pdf
63.	India	2018	12×12	Secondary	GAINS	NOx, SO_2, $PM_{2.5}$	"Urban versus rural health impacts attributable to $PM_{2.5}$ and O_3 in northern India," A. Karambelas, T. Holloway, P. L. Kinney, A. M. Fiore, R. DeFries, G. Kiesewettwer, C. Heyes, Environmental Research Letters 13,6, 064010 (2018) Available at: https://iopscience.iop.org/article/10.1088/1748-9326/aac24d/meta
64.	Patna	2019	1×1	Primary and Secondary	Indian, USEPA	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC, CO_2	Center for Study of Science, Technology and Policy, Center for Environment, Energy and Climate Change, Asian Development Research Institute, Urban Emissions, Bihar State Control Board, (2019), Comprehensive Clean Air Action Plan for the City of Patna. Available at: https://shaktifoundation.in/report/comprehensive-clean-air-action-plan-for-the-city-of-patna/?psec=NQ==#MTE5Mzc=
65.	Bangalore	2019	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC	"Air quality, emissions, and source contributions analysis for the Greater Bengaluru region of India," S. K. Guttikunda, Nishad. K A, S. Gota, P. Singh, Atmospheric Pollution Research 10, 3, 941-953 (2019) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1309104218304835
66.	Amravati	2019	–	Primary and Secondary	Indian, Foreign Literature	$PM_{2.5}$	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), ACTION PLAN FOR CONTROL OF AIR POLLUTION IN NON-ATTAINMENT CITIES OF MAHARASHTRA AMARAVATI Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Amravati_Action_Plan07112019.pdf
67.	Chandrapur	2019	1×1	Primary	Indian	PM, CO, HC, NOx	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), Action Plan Of Control Of Air Pollution In Non-Attainment Cities Of Maharashtra Chandrapur Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Chandrapur_Action_Plan07112019.pdf
68.	Agartala	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Agartala (Tripura, India) Available at: https://urbanemissions.info/india-apna/agartala-india/

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
69.	Ahmedabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Ahmedabad (Gujarat, India) Available at: https://urbanemissions.info/india-apna/ahmedabad-india/
70.	Allahabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Prayagraj (Allahabad) (Uttar Pradesh, India) Available at: https://urbanemissions.info/india-apna/allahabad-india/
71.	Asansol	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Asansol (West Bengal, India) Available at: https://urbanemissions.info/india-apna/asansol-india/
72.	Aurangabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Aurungabad (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/aurungabad-india/
73.	Dharwad-Hubli	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Dharwad-Hubli (Karnataka, India) Available at: https://urbanemissions.info/india-apna/dharwad-india/
74.	Dhanbad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Dhanbad (Jharkhand, India) Available at: https://urbanemissions.info/india-apna/dhanbad-india/
75.	Gaya	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Gaya (Bihar, India) Available at: https://urbanemissions.info/india-apna/gaya-india/
76.	Guwahati	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Guwahati (Assam, India) Available at: https://urbanemissions.info/india-apna/guwahati-india/

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
77.	Gwalior	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Gwalior (Madhya Pradesh, India) Available at: https://urbanemissions.info/india-apna/gwalior-india/
78.	Greater Mumbai	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Mumbai (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/mumbai-india/
79.	Greater Kolkata	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Kolkata (West Bengal, India) Available at: https://urbanemissions.info/india-apna/kolkata-india/
80.	Hyderabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Hydrabad, (Telengana, India) Available at: https://urbanemissions.info/india-apna/hyderabad-india/
81.	Jamshedpur	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Jamshedpur (Jharkhand, India) Available at: https://urbanemissions.info/india-apna/jamshedpur-india/
82.	Jodhpur	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Jodhpur (Rajasthan, India) Available at: https://urbanemissions.info/india-apna/jodhpur-india/
83.	Kota	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Kota (Rajasthan, India) Available at: https://urbanemissions.info/india-apna/kota-india/
84.	Lucknow	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Lucknow (Uttar Pradesh, India) Available at: https://urbanemissions.info/india-apna/lucknow-india/
85.	Madurai	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Madurai (Tamil Nadu, India) Available at: https://urbanemissions.info/india-apna/madurai-india/

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
86.	Nashik	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Nashik (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/nashik-india/
87.	Panjim-Vasco-Margao	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Panjim (Goa, India) Available at: https://urbanemissions.info/india-apna/panjim-india/
88.	Puducherry	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Puducherry (Puducherry, India) Available at: https://urbanemissions.info/india-apna/puducherry-india/
89.	Rajkot	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Rajkot (Gujarat, India) Available at: https://urbanemissions.info/india-apna/rajkot-india/
90.	Shimla	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Shimla (Himachal Pradesh, India) Available at: https://urbanemissions.info/india-apna/shimla-india/
91.	Srinagar	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Srinagar (Jammu and Kashmir, India) Available at: https://urbanemissions.info/india-apna/srinagar-india/
92.	Surat	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Surat (Gujarat, India) Available at: https://urbanemissions.info/india-apna/surat-india/
93.	Thiruvananth-puram	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Thiruvananthapuram (Kerela, India) Available at: https://urbanemissions.info/india-apna/thiruvananthapuram-india/
94.	Tiruchupalli	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Tiruchirapalli (Tamil Nadu, India) Available at: https://urbanemissions.info/india-apna/tiruchirapalli-india/

S. No.	Location	Year of publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
95.	Vadodara	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vadodara (Gujarat, India) Available at: https://urbanemissions.info/india-apna/vadodara-india/
96.	Vijaywada	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vijayawada (Andhra Pradesh, India) Available at: https://urbanemissions.info/india-apna/vijayawada-india/
97.	Vishakapatnam	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vishakhapatnam (Andhra Pradesh, India) Available at: https://urbanemissions.info/india-apna/visakhapatnam-india/
98.	Kolkata, Howrah	2019	–	Primary	Indian, USEPA, WHO	PM_{10}, $PM_{2.5}$	West Bengal Pollution Control Board and CSIR-National Environmental Engineering Research Institute, PM_{10} and $PM_{2.5}$ Source Apportionment Study and Development of Emission Inventory of Twin Cities Kolkata and Howrah of West Bengal Available at: https://www.wbpcb.gov.in/writereaddata/files/SA_Kol-How_Final%20Report.pdf
99.	Kolkata	2020	–	Primary and Secondary	Indian, USEPA, GAINS	PM_{10}, $PM_{2.5}$, BC, OC, SO_2, NOx, CO, VOC, NH_3	"Managing future air quality in megacities: Emission inventory and scenario analysis for the Kolkata Metropolitan City, India," D. Majumdar, P. Purohit, A. D. Bhanarkar, P. S. Rao, P. Rafaj, M. Amann, R. Sander, A. Pakrashi, A. Srivastava, Atmospheric Environment 222, 117135 (2020) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231019307745
100.	Jaipur	2020	2×2	Primary and Secondary	Indian, USEPA	PM_{10}, $PM_{2.5}$, NOx, SO_2, CO	M. Sharma, Rajasthan State Pollution Control Board, Jaipur, (2020), Air Quality Assessment, Trend Analysis, Emission Inventory and Source Apportionment Study in Jaipur City (Final Report) Available at: https://environment.rajasthan.gov.in/content/dam/environment/RPCB/EnvironmentalReport/Final-Report-Source-Apportionmnent-Study-Jaipur-IITKanpur.pdf
101.	Delhi	2020	2×2	Primary	Indian, USEPA	$PM_{2.5}$ and its species	"A framework for $PM_{2.5}$ constituents-based (including PAHs) emission inventory and source toxicity for priority controls: A case study of Delhi, India," A. K. Pathak, M. Sharma, P. K. Nagar, Chemosphere 255, 126971 (2020) Available at: https://www.sciencedirect.com/science/article/abs/pii/S0045653520311644

S. No.	Location	Year of publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ Other)	Pollutants	Reference
102.	Ludhiana	2020	2×2	Primary and Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO	Punjab State Council for Science & Technology, Chandigarh, The Energy & Resources Institute, New Delhi, Punjab Pollution Control Board, (2020), Source Apportionment Study to Prepare Action Plan to improve Air Quality of Ludhiana City Available at: https://ppcb.punjab.gov.in/sites/default/files/documents/N_8278_1625047519404.pdf
103.	Dhanbad	2021	2×2	Primary	Indian	PM_{10}	"Emission inventory of PM_{10} in Dhanbad/Jharia coalfield (JCF), India: an intricate coal mining sector," D. Roy, G. Singh, S. Sinha, J. Park, Y-C Seo, Environment, Development and Sustainability 23, 3048-3061 (2021) Available at: https://link.springer.com/article/10.1007/s10668-020-00702-4
104.	India	2021	10×10	Primary and Secondary	Indian	$PM_{2.5}$	"Establishing a link between fine particulate matter ($PM_{2.5}$) zones and COVID -19 over India based on anthropogenic emission sources and air quality data," S. K. Sahu, P. Mangaraj, G. Beig, B. Tyagi, S. Tikle, V. Vinoj, Urban Climate 38, 100883 (2021) Available at: https://www.sciencedirect.com/science/article/pii/S2212095521001139
105.	India	2021	36×36	Primary and Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, VOC, NH_3	The Energy and Resources Institute, The Energy and Resources Institute, Development of Spatially Resolved Air Pollution Emission Inventory of India Available at: https://www.teriin.org/sites/default/files/2021-05/Exxon-Report.pdf
106.	India	2021	36×36	Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, NMVOC	"Air Pollution Over India: Causal Factors for the High Pollution with Implications for Mitigation," N. Singh, S. Agarwal, S. Sharma, S. Chatani, V. Ramanathan, ACS Earth Space Chem. 5, 12, 3297-3312 (2021) Available at: https://pubs.acs.org/doi/10.1021/acsearthspacechem.1c00170
107.	Delhi	2021	2×2	Secondary	Indian, GAINS, USEPA	$PM_{2.5}$, NOx, SO_2	Dr. A. Goel, The Energy and Resources Institute, (2021), Cost-effectiveness Analysis of Control Options for Managing Air Quality in Delhi Available at: https://www.teriin.org/sites/default/files/2021-12/Cost-effectiveness-of%20-interventions-for-control-of%20-air-pollution-in-Delhi.pdf

4

INVENTORY OF INDUSTRIAL AND POWER PLANT EMISSIONS

Introduction

The industrial sector is one of the most significant contributors of PM_{10}, $PM_{2.5}$, NOx, SO_2, along with precursors of secondary $PM_{2.5}$ like SO_4 and NO_3. Coal-based thermal power plants (TPP) fulfil 50% of electricity demand in India, leading to high emissions of these pollutants. Secondary $PM_{2.5}$ comprises more than 60% of total $PM_{2.5}$ concentrations in India. The industrial sector contributes around 16% and power plants around 10% annually[17] to secondary $PM_{2.5}$. Hence these sectors remain a crucial focus of pollution control boards towards air pollution mitigation.

Sources of Emission from the Industrial Sector Emission

The emissions from the industrial sector result from different categories of manufacturing activities. Broadly three types of emissions can be categorized as industrial sector emissions.[18]

1. Combustion related emissions like the burning of fuels like coal, petcoke, biomass, furnace oil, diesel, and natural gas in boilers and furnaces
2. Non-Combustion related emissions – Naphtha and natural gas as use of feedstocks for petrochemical products and blendstocks for gasoline
3. Fugitive emissions from the manufacturing process, storage, and handling of materials during the industrial process

Sources of Emissions from Thermal Power Plants

Coal-fired thermal power plants continue to be the significant chunk of installed capacity for electricity generation in India. Large quantities of coal are consumed annually in the TPPs, leading to fly ash and bottom ash production. Particulate matter emissions from coal-based TPPs are linked to high ash content (between 20% and 40%) in Indian coal. Sulphur content in Indian coal (generally < 0.6%) leads to increased emission of SO_2 from these sectors.[19]

17 "Air Pollution Over India: Causal Factors for the High Pollution with Implications for Mitigation," N. Singh, S. Agarwal, S. Sharma, S. Chatani, V. Ramanathan, *ACS Earth Space Chem*. 5, 12, 3297-3312 (2021)

18 Development of Spatially Resolved air pollution emission inventory of India. TERI. 2021. *https://www.teriin.org/sites/default/files/2021-05/Exxon-Report.pdf.*

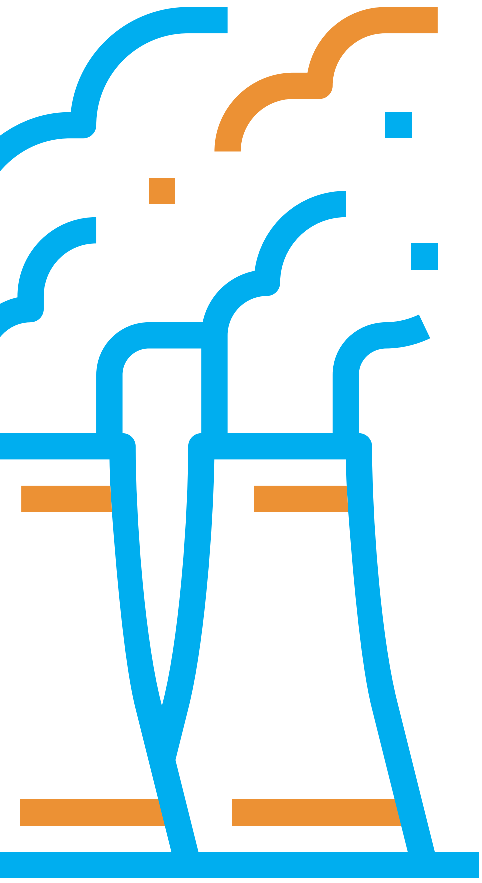
19 Development of Spatially Resolved Air Pollution Emission Inventory of India. TERI. 2021. *https://www.teriin.org/sites/default/files/2021-05/Exxon-Report.pdf.*

Emissions from the power plants sector are a function of the quality of fuel, the type of boilers, the types of air pollution control devices used, and their efficiency. In addition to coal, natural gas is also used in power plants in India.

Air-borne inorganic particles such as fly ash, carbonaceous material (soot), suspended particulate matter (SPM), and other trace gas species are also emitted from power plants. Additionally, the fugitive emissions from ash pond also contribute significantly to the ambient pollutant concentrations.

The emissions from these two sectors have been well studied. Over 122 studies were analysed which estimated the emissions of local air pollutants like $PM_{2.5}$, PM_{10}, NOx, SO_2, VOCs, etc., from industrial and power plant sectors. Most of the studies have considered industry a point source; only a few considered it an area source. All power plants were considered as point sources only. Studies on emissions from diesel generator (DG) sets have been included in this chapter.

Activity data collection in industrial sectoral emission estimation varied with the domain size of the study. The activity data were collected using secondary sources for most pan India studies. Using Google Earth and similar GIS tools, the industrial clusters were marked. The activity data were collected from studies with domain sizes spanning a few districts from the respective pollution control boards. The activity data was sourced using primary data collection only for inventories about an individual industrial cluster. The activity data of power plants have been from state pollution control boards and publicly available reports published by the Central Electricity Authority of India (CEA). As most power plants are significant point sources, they are known, and CEA publishes the coal consumption data.[20]



Formula Used to Calculate the Industrial Emissions:

E = Industrial fuel consumption × EF × Efficiency of control

(For Medium and Small Industries)

E = Industrial production × EF × Efficiency of control

(For Major Industries)

Formula Used to Calculate the Power Plant Emissions:

E = Fuel consumption × EF x Efficiency of control

Emissions are estimated using the actual ash content of the fuel.

Geographical Distribution of Industrial and Power Plant Emission studies in India

Metropolitan cities have been the focus of researchers while carrying out emission inventories, even though rural India is exposed to air pollution equally. Amongst the rural states, industrial pockets of Dhanbad and Jamshedpur in Jharkhand have been well studied.[21,22] Uttar Pradesh, Haryana and Delhi were the top 3 states with 21, 15, and 15 studies, respectively. Though Haryana has 15 studies, all of those were part of NCR based studies. Industrial areas and power plants outside NCR in Haryana have not been studied yet. Karnataka has 4 studies, out of which 3 were carried out in the Bengaluru region.

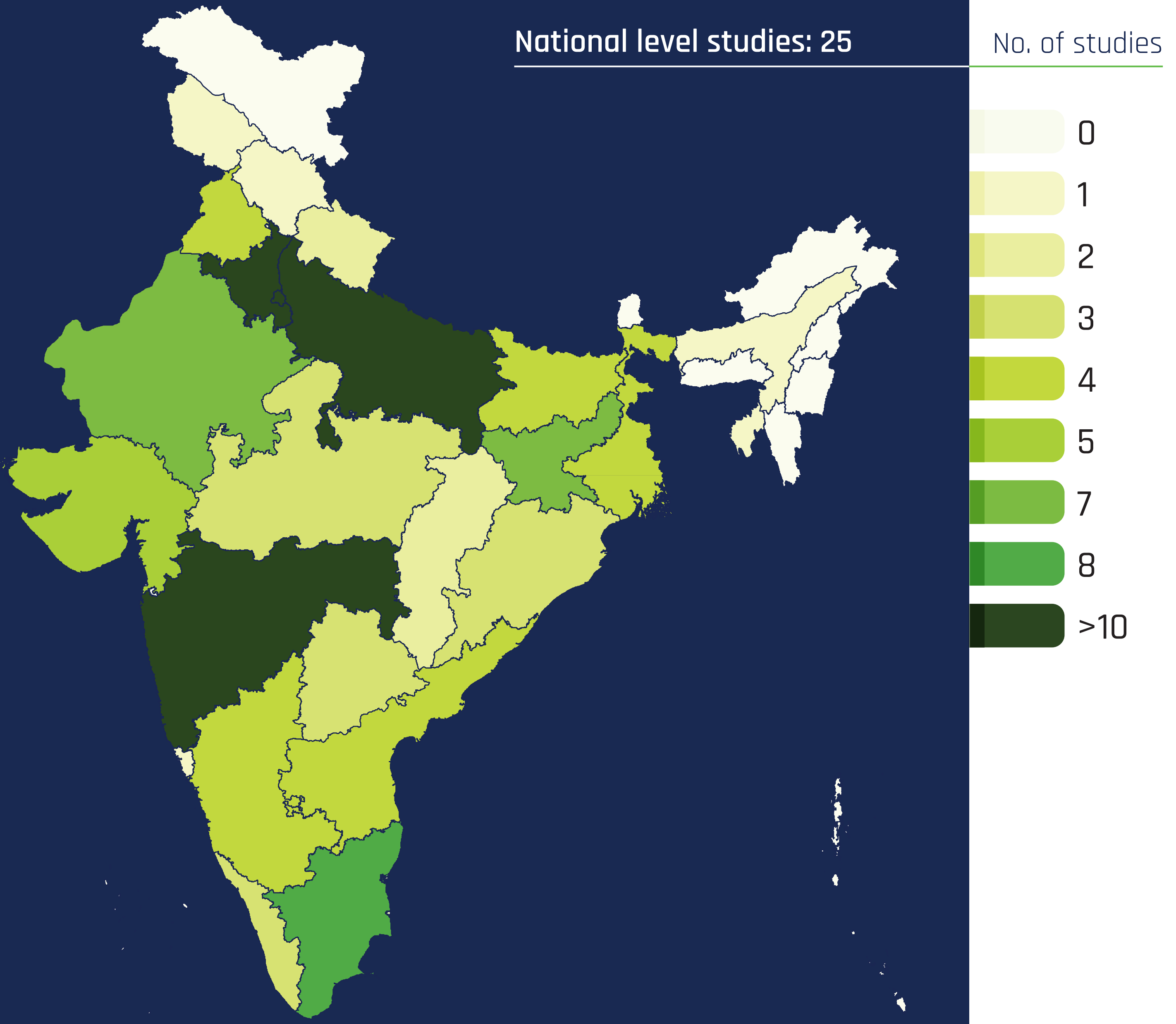
20 Central Authority of India. Ministry of Power, Government of India, *All India Electricity Statistics*

21 "Emission inventory of PM10 in Dhanbad/Jharia coalfield (JCF), India: an intricate coal mining sector," D. Roy, G. Singh, S. Singh, J. Park, Y-C Seo, *Environment, Development and Sustainability* 23, 3048-2061 (2021)

22 "Assessment of contribution of SO2 and NO2 from different sources in Jamshedpur region, India," A. D. Bhanarkar, S. K. Goyal, R. Sivacoumar, C. V. Chalapati Rao, *Atmospheric Environment*, 39, 40, 7745-7760 (2005)

MAP 2

STATE-WISE NUMBER OF INDUSTRIAL AND POWER PLANT EMISSION STUDIES



There are no EI reports for the North of Karnataka, the Bellary – Gulbarga belt, an iron and steel industrial belt. In North-East India, except Assam and Tripura, where there is one study each, north-eastern states do not have any emission inventory for these sectors. The geographical distribution seems skewed towards a few states. The rest of India and major rural industrial areas and power plant concentrated in states like West Bengal, Gujarat, Chhattisgarh are left behind by researchers. Ten states and U.T.'s have zero industrial emission estimation. Twenty five studies have calculated Industrial EI at the pan-India level. All these studies have used secondary data sets and both the Indian as well as foreign EFs for calculation. The latest pan-India level EI available is for 2019[23,24,24] and the oldest was made for the year 1999 [26] for significant point sources in India.

From Table 3, it may be inferred that since the launch of the National Clean Air Program in 2019, there are very few updated industrial emission inventories for the years 2020 and 2021, though most states and city governments have now commissioned source apportionment and emission inventory studies, as envisaged in the NCAP. In addition, many studies have been published to estimate emissions for 2025, 2030 and 2050. Still, they are projected based on the decadal economic growth of the country.

Overview

The most recent EI reports for these sectors were published in 2019. A study done for the Jamshedpur Industrial area has used both the primary and secondary data set (for industries where the primary data was unavailable). An interesting study done for the region of Delhi[27] highlights different types of interlinkages an EI report. The authors mention the interlinking of mass-based EI with $PM_{2.5}$ constituents and source toxicity. This is especially true given the toxicity of industrial pollution on human health. Captive power plants that provide localised energy sources to users also emit pollutants in large numbers. However, the number of studies on captive power plants is less than on thermal power stations. Their information is also not readily available regarding exact locations, fuel type used, and electricity production capacity.

Most studies have used Indian emission factors (EF), but they were not specific for a particular industry or power plant. Instead, they are based on fuel type, control technologies, and other factors. It would be interesting to develop emission inventories using EF for particular industry and compare the results. The remaining authors have used USEPA EFs to estimate emissions. All the studies done at industrial cluster levels have calculated their EFs using primary surveys to estimate the amount of fuel used and by monitoring of the flue gases emissions. For city-level EI reports, Indian EF has been collated from literature. Due to the unavailability of EFs at district and cluster level, authors conducting large scale studies often resort to using EFs from secondary sources, which are not specific to fuel type, process technology and control technology being used in particular industrial areas.

Similarly, for power plants, usually EF for Indian specific coal is used. In studies where the EF or activity data of the type of coal used was not available, EFs provided by CPCB or USEPA has been used. This leads to a margin of errors between actual and estimated emissions. Therefore, efforts need to be made towards developing emission factors for all indigenous coal varieties.

23 *Development of Spatially Resolved Air Pollution Emission Inventory of India*. TERI. 2021.

24 International Institute for Energy Conservation (IIEC), Climate & Clean Air Coalition, (2020), *Reducing air pollution in India's industrial clusters through smart energy management*

25 "Establishing a link between fine particulate matter ($PM_{2.5}$) zones and COVID -19 over India based on anthropogenic emission sources and air quality data," S. K. Shau, P. Mangaraj, G. Beig, B. Tyagi, S. Tikle, V. Vinoj, Urban Climate 38, 100883 (2021)

26 "Emission Inventory for an Industrial Area of India," P. Gargava, A. L. Aggarwal, *Environmental Monitoring and Assessment* 55, 299-304 (1999)

27 "A framework for $PM_{2.5}$ constituents-based (including PAHs) emission inventory and source toxicity for priority controls: A case study of Delhi, India," A. K. Pathak, M. Sharma, P. K. Nagar, Chemosphere, 255, 126971 (2020)

Table 3

List of Studies for Industrial and Power Plants Emission Inventory

Note:
Studies highlighted in green adhere closely to CPCB guidelines

S. No	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
1.	Agra-Mathura region	1981	–	Primary	Indian	SO_2	Central Board for The Prevention and Control Of Water Pollution New Delhi, Central Board For The Prevention And Control Of Water Pollution New Delhi, Inventory and Assessment of Pollution Emission in and around Agra-Mathura Region (Abridged), Control of Urban Pollution Series CUPS/7/1981-82 Available at: http://cpcbenvis.nic.in/scanned%20reports/Inventory%20and%20assessment%20of%20pollution%20emission%20in%20and%20around%20Agra-Mathura%20region%20(Abridged).pdf
2.	Cochin	1999	For individual industry	Primary	Indian	PM, HC, NOx, SOx, CO, NH_3, HCl+CL_2, Acid Mist, H_2S, F	"Emission Inventory for an Industrial area of India," P. Gargava, A. I. Aggarwal, Environmental Monitoring Assessment 55, 299-304 (1999) Available at: https://link.springer.com/article/10.1023/A:1005947026732
3.	India	2000	–	Secondary	Indian, USEPA	$PM_{2.5}$	"Atmospheric optical and radiative effects of anthropogenic aerosol constituents from India," M. S. Reddy, C. Venkataraman, Atmospheric Environment 34, 26, 4511-4523 (2000) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231000001059
4.	Dhanbad	2001	For individual industry cluster	Primary	Indian	SOx, NOx, SPM, CO, HC	J. K. Upadhyay, Jawaharlal Nehru University, (2001), Modelling of dispersion of pollutants from various sources using Advanced Gaussian Plume Model in convective boundary layer in Dhanbad region, (Emission Inventory of the Region, Chapter 3) Available at: https://shodhganga.inflibnet.ac.in/handle/10603/19236
5.	India	2001	District level	Secondary	IPCC	SO_2, NOx	"Sub-region (district) and sector level $SO_2$and NOx emissions for India: assessment of inventories and mitigation flexibility," A. Garg, P. R. Shukla, S. Bhattacharya, V. K. Dhadwal, Atmospheric Environment 35, 4, 703-713 (2001) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231000003162
6.	India	2002	Individual LPS	Secondary	Indian, Foreign Literature	CO_2, SO_2, NOx, CH_4, N_2O	"Large point source (LPS) emissions from India: regional and sectoral analysis," A. Garg, M. Kapshe, P. R. Shukla, D. Ghosh, Atmospheric Environment 36, 2, 213-224 (2002) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231001004393

S. No	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
7.	India	2002	25×25	Secondary	Indian, USEPA	SO_2, PM, BC, OC	"Inventory of aerosol and sulphur dioxide emissions from India: I-Fossil fuel combustion," M. S. Reddy, C. Venkataraman, Atmospheric Environment I36, 4, 677-697 (2002) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231001004630
8.	India	2003	–	Secondary	Foreign Literature	BC	"Large historical changes of fossil-fuel black carbon aerosols," T. Novakov, V. Ramanathan, J. E. Hansen, T. W. Krichstetter, M. Sato, J. E. Sinton, J. A. Sathaye, Geophysical Research Letters 30, 6 (2003) Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2002GL016345
9.	Delhi	2004	–	Secondary	Indian	CH_4, CO, CO_2, N_2O, NH_3, NMVOC, NOx, SO_2, TSP	"Emission estimates and trends (1990–2000) for megacity Delhi and implications," B. R. Gurjar, J. A. van Aardenne, J. Lelieveld, M. Mohan, Atmospheric Environment 38, 33, 5663-5681 (2004) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231004005394
10.	Mumbai	2005	Individual Industrial clusters	Secondary	Indian, USEPA	SO_2, PM, Toxic Metals	"Inventory of SO_2, PM and toxic metals emissions from industrial sources in Greater Mumbai, India," A. D. Bhanarkar, P. S. Rao, D. G. Gajghate, P. Nema, Atmospheric Environment 39, 21, 3841-3864 (2005) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231005002773
11.	Jamshedpur	2005	1×1	Primary and Secondary	Indian	SO_2NO_2	"Assessment of contribution of $SO_2$and NO_2 from different sources in Jamshedpur region, India," A. Bhanarkar, S. K. Goyal, R. Sivacoumar, C.V. Chalapati Rao, Atmospheric Environment 39, 40, 7745-7760 (2005) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231005006515
12.	Pune	2007	2×2	–	–	PM_{10}	"Coupling of the Weather Research and Forecasting Model with AERMOD for pollutant dispersion modeling. A case study for PM_{10} dispersion over Pune, India," A. P. Kesarkar, M. Dalvi, A. Kaginalkar, A. Ojha, Atmospheric Environment 41, 9, 1976-1988 (2007) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231006010570
13.	Hyderabad	2008	For individual industry	Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NOx, CO_2	S. Guttikunda, Integrated Environmental Strategies Program Washington DC, USA, (2008), Co-Benefits Analysis of Air Pollution and GHG Emissions for Hyderabad, India Available at: https://urbanemissions.info/wp-content/uploads/docs/SIM-09-2008.pdf

S. No	Location	Year of Publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
14.	India	2008	100×100	Secondary	Indian, Foreign literature	BC	S. K. Sahu, G. Beig, C. Sharma, Geophysical Research Letters, (2008), Decadal growth of black carbon emissions in India Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2007GL032333
15.	Delhi, Mumbai, Chennai, Kolkata	2010	–	Secondary	Indian, USEPA	VOC	"Emission inventory of evaporative emissions of VOCs in four metro cities in India," A. Srivastava, D. Majumdar, Environmental Monitoring and Assessment 260, 215 (2010) Available at: https://pubmed.ncbi.nlm.nih.gov/19093218/
16.	Delhi	2011	For individual industry cluster	Primary	Indian	TSP, SO_2, NO_2	"Air quality modelling study to analyse the impact of the world Bank emission guidelines for the thermal power plants in Delhi," A. Kansal, M. Khare, C. S. Sharma, Atmospheric Pollution Research 2, 1, 99-105 (2011) Available at: https://www.sciencedirect.com/science/article/pii/S1309104215305213
17.	Nagpur	2011	–	Secondary	Indian, USEPA, IPCC	CO_2, CH_4, N_2O, SO_2	"Sectoral CO_2, CH_4, N_2O and SO_2emissions from fossil fuel consumption in Nagpur City of Central India," D. Majumdar, D. G. Gajghate, Atmospheric Environment 45, 25, 4170-4179 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231011005024
18.	Delhi, Gurgaon, Faridabad, Rohtak, Jhajjar, Noida, Ghaziabad	2011	1.67×1.67	Primary and Secondary	Indian	$PM_{2.5}$, PM_{10}	"Emissions inventory of anthropogenic $PM_{2.5}$ and PM_{10} in Delhi during Commonwealth Games 2010," S. K. Sahu, G. Beig, N. Parkhi, Atmospheric Environment 45, 34, 6180-6190 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S135223101100834X
19.	Delhi, Bangalore, Pune, Mumbai, Chennai, Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}, NOx, SO_2	Central Pollution Control Board, Central Pollution Control Board, (2011), Air quality monitoring, emission inventory and source apportionment study for Indian cities, National Summary Report Available at: https://cpcb.nic.in/displaypdf.php?id=RmluYWxOYXRpb25hbFN1bW1hcnkucGRm
20.	Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}	S. N. Behera, M. Sharma, O. Dikshit, S. P. Shukla, Advanced Air Pollution, (2011), Development of GIS-aided Emission Inventory of Air Pollutants for an Urban Environment Available at: https://www.intechopen.com/chapters/17388
21.	Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}	"GIS-Based Emission Inventory, Dispersion Modeling, and Assessment for Source Contributions of Particulate Matter in an Urban Environment," S. N. Behera, M. Sharma, O. Dikshit, S. P. Shukla, Water, Air and Soil Pollution, 218, 423-436 (2011) Available at: https://link.springer.com/article/10.1007/s11270-010-0656-x

S. No	Location	Year of Publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
22.	Pantnagar	2011	2×2	Primary	Indian	NO_2	"Application of air pollution dispersion modeling for source-contribution assessment and model performance evaluation at integrated industrial estate-Pantnagar," T. Banerjee, S. C. Barman, R. K. Srivastava, Environ Pollut 159, 4, 865-875 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S0269749110005920
23.	Jamshedpur	2011	1×1	Primary	Indian	NOx	"Air pollution modeling for an industrial complex and model performance evaluation," R. Sivacoumar, A. D. Bhanarkar, S. K. Goyal, S. K. Gadkari, A. L. Aggarwal, Environmental Pollution 111, 3, 471-477 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S026974910000083X
24.	Angul	2012	2×2	Primary	Indian	PM_{10}, SO_2, NOx, CO	Provided by EMTRC Available at: https://indair-neeri.res.in/repository/view/3086%5C
25.	India	2012	100×100	Secondary	Indian	NOx	"Emerging pattern of anthropogenic NOx emission over Indian subcontinent during 1990s and 2000s," S. K. Sahu, G. Beig, N. S. Parkhi, Atmospheric Pollution Research 3, 3, 262-269 (2012) Available at: https://doi.org/10.5094/APR.2012.021
26.	India	2012	Individual TPP	Secondary	Indian	CO_2, NO_2, NO	M. L. Mittal, C. Sharma, R. Singh, International emission inventory conference, (2012), Estimates of Emissions from Coal Fired Thermal Power Plants in India Available at: https://www3.epa.gov/ttnchie1/conference/ei20/session5/mmittal.pdf
27.	India	2012	25×25	Secondary	Indian, IEA	NOx	"Increase in NOx Emissions from Indian Thermal Power Plants during 1996–2010: Unit-Based Inventories and Multisatellite Observations," Z. Lu, D. G. Streets, Environ. Sci. Technol. 46, 14, 7463-7470 (2012) Available at: https://pubs.acs.org/doi/abs/10.1021/es300831w
28.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian, Foreign Literature	PM, SO_2, NOx, CO, VOC	"A GIS based emissions inventory at 1 km x 1 km spatial resolution for air pollution analysis in Delhi, India," S. K. Guttikunda, G. Calori, Atmospheric Environment 67, 101-111 (2013) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231012010229
29.	Korba	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3087
30.	Auraiya	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3088

S. No	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
31.	Anta	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3089
32.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, NOx, CO, VOC	"Health impacts of particulate pollution in a megacity—Delhi, India," S. K. Guttikunda, R. Goel, Environmental Department 6, 8-20 (2013) Available at: https://www.sciencedirect.com/science/article/abs/pii/S2211464512001492
33.	India	2013	25×25	Secondary	Indian, IEA	SO_2	"Ozone Monitoring Instrument Observations of Interannual Increases in SO_2Emissions from Indian Coal-Fired Power Plants during 2005–2012," Z. Lu, D. G. Streets, B. de Foy, N. A. Krotkov, 47, 24, 13993-4000 (2013) Available at: https://pubs.acs.org/doi/10.1021/es4039648
34.	Kanpur	2013	2×2	Primary and Secondary	Indian, USEPA	PM, SO_2, NOx	"Respiratory Disease in Relation to Outdoor Air Pollution in Kanpur, India." H-Y Liu, A. Bartonova, M. Schindler, M. Sharma, S. N. Behera, K. Katiyar, O. Dikshit, Arch Environ Occup Health 68, 4, 204-217 (2013) Available at: https://pubmed.ncbi.nlm.nih.gov/23697693/
35.	Hyderabad	2014	For individual industry	Primary	Indian, USEPA, GAINS	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC, CO_2	"Source emissions and health impacts of urban air pollution in Hyderabad, India," S. K. Guttikunda, R. V. Kopakka, Air Qual Atmos Health 7, 195-207 (2014) Available at: https://link.springer.com/article/10.1007/s11869-013-0221-z
36.	Delhi	2014	–	Primary and Secondary	Indian, Foreign Literature	PM_{10}	"Speciated PM_{10} Emission Inventory for Delhi, India," P. Gargava, J. C. Chow, J. G. Watson, D. H. Lowenthal, Aerosol and Air Quality Research 14, 5, 1515-1526 (2014) Available at: https://aaqr.org/articles/aaqr-13-02-oa-0047
37.	Patna	2014	1×1	Secondary	Indian, USEPA	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC, CO_2	S. K. Guttikunda, P. Jawahar, UrbanEmissions.Info., (2014), Characterizing Patna's Ambient Air Quality and Assessing Opportunities for Policy Intervention Available at: https://shaktifoundation.in/wp-content/uploads/2017/06/Urban-Emissions-2014-AQM-in-Patna-Final-Report.pdf
38.	India	2014	25×25	Secondary	Indian, USEPA	$PM_{2.5}$, BC, OC, CO, NOx, NMVOC, CH_4	"Trends in multi-pollutant emissions from a technology-linked inventory for India: I. Industry and transport sectors," P. Sadavarte, C. Venkataraman, Atmospheric Environment 99, 353-364 (2014) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231014007754

S. No	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
39.	India	2014	25×25	Secondary	Indian, USEPA	$PM_{2.5}$, BC, OC, CO, NOx, NMVOC, CH_4	"Trends in multi-pollutant emissions from a technology-linked inventory for India: II. Residential, agricultural and informal industry sectors," A. Pandey, P. Sadavarte, A. B. Rao, C. Venkataraman, Atmospheric Environment 99, 341-352 (2014) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231014007742
40.	India	2014	25×25	Secondary	Indian, GAINS	$PM_{2.5}$, PM_{10}, SO_2, NOx, CO, VOC, CO_2	"Atmospheric emissions and pollution from the coal-fired thermal power plants in India," S. K. Guttikunda, P. Jawahar, Atmospheric Environment 92, 449-460 (2014) Available at: https://www.sciencedirect.com/science/article/abs/pii/S135223101400329X
41.	India	2014	Individual TPP	Secondary	Indian	CO_2, NO_2, NO	"Decadal emission estimates of carbon dioxide, sulfur dioxide, and nitric oxide emissions from coal burning in electric power generation plants in India," M. L. Mittal, C. Sharma, R. Singh, Environmental Monitoring Assessment 186, 6857-6866 (2014) Available at: https://link.springer.com/article/10.1007/s10661-014-3894-3
42.	Kadapa	2014	–	Primary	Indian	SPM, SOx, NOx, CO	"Emission Inventory for Criteria Pollutants of a Thermal Power Plant," S. A. K. Varma, Journal Civil & Environmental Engineering 04, 01 (2014) Available at: https://www.hilarispublisher.com/open-access/emission-inventory-for-criteria-pollutants-of-a-thermal-power-plant-2165-784X.1000135.pdf
43.	Amritsar	2015	For individual industry	Primary	Indian	PM_{10}, SO_2, NOx	"Assessment of Urban Air Quality around a Heritage Site Using AERMOD: A Case Study of Amritsar City, India," S. Gulia, A. Shrivastva, A. K. Nema, M. Khare, Environ Model Assess 20, 6, 599-608 (2015) Available at: https://link.springer.com/article/10.1007/s10666-015-9446-6
44.	India	2015	36×36	Secondary	USEPA, GAINS, CITEPA	NMVOC	"Emission inventory of non-methane volatile organic compounds from anthropogenic sources in India," S. Sharma, A. Goel, D. Gupta, A. Kumar, A. Mishra, S. Kundu, S. Chatani, Z. Klimont, Atmospheric Environment 102, 209-219 (2015) Available at: https://doi.org/10.1016/j.atmosenv.2014.11.070
45.	Delhi	2015	2×2	Secondary	Indian	CO, NOx, SO_2, PM_{10}	"Anthropogenic Emission Inventory of Criteria Air Pollutants of an Urban Agglomeration - National Capital Region (NCR), Delhi," R. Sindhwani, P. Goyal, S. Kumar, A. Kumar, Aerosol and Air Quality Research 15, 1681-1697 (2015) Available at: https://aaqr.org/articles/aaqr-14-11-oa-0271

S. No	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
46.	Chennai, Vishakapatnam	2015	1×1	Primary and Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NO_2	"Particulate and gaseous emissions in two coastal cities—Chennai and Visakhapatnam, India," S. K. Guttikunda, R. Goel, D. Mohan, G. Tiwari, Air Quality, Atmosphere & Health 8, 6, 559-572 (2015) Available at: https://link.springer.com/article/10.1007/s11869-014-0303-6
47.	India	2015	25×25	Primary	Indian, Foreign Literature	PM, NOx, SOx, CO, CO_2	"Rising critical emission of air pollutants from renewable biomass based cogeneration from the sugar industry in India," S. K. Sahu, T. Ohara, G. Beig, J. Kurokawa, T. Nagashima, Environmental Research Letters 10, 9 095002 (2015) Available at: https://iopscience.iop.org/article/10.1088/1748-9326/10/9/095002
48.	Delhi	2015	1.67×.67	Primary and Secondary	Indian, USEPA	NOx, CO	"High Resolution Emission Inventory of NOx and CO for Mega City Delhi, India," S. K. Sahu, G. Beig, N. Parkhi, Aerosol and Air Quality Research 15, 3, 1137-1144 (2015) Available at: https://aaqr.org/articles/aaqr-14-07-tn-0132
49.	Delhi	2016	2×2	Primary and Secondary	Indian	PM_{10}, $PM_{2.5}$, NOx, CO	M. Sharma, O. Dikshit, Department of Environment Government of National Capital Territory of Delhi, Delhi Pollution Control Committee, (2016), Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi (Final Report: Air Pollution component) Available at: https://cerca.iitd.ac.in/uploads/Reports/1576211826iitk.pdf
50.	India	2016	40×40	Secondary	Indian, Foreign Literature	BC	"Monthly and Spatially Resolved Black Carbon Emission Inventory of India: Uncertainty Analyses," U. Paliwal, M. Sharma, J. F. Burkhart, Atmos. Chem. Phys. 16, 12457-12476 (2016) Available at: https://acp.copernicus.org/articles/16/12457/2016/acp-16-12457-2016.html
51.	India	2016	36×36	Secondary	Indian, GAINS, USEPA	NOx, NMVOC. CO	"Sensitivity analysis of ground level ozone in India using WRF-CMAQ models," S. Sharma, S. Chatani, R. Mahatta, A. Goel, A. Kumar, Atmospheric Environment 131, 29-40 (2016) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231016300504
52.	Panipat, Sonipat, Rohtak, Jhajjar, Rewari, Alwar, Gurgaon, Fardabad, Noida, Ghaziabad, Bulandshar, Meerut, Baghpat	2017	4×4	Primary and Secondary	Indian, GAINS	NOx, NMVOC, CO,	"Simulating ozone concentrations using precursor emission inventories in Delhi – National Capital Region of India," S. Sharma, M. Khare, Atmospheric Environment 151 (2017) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231016309682

S. No	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
53.	Ahmedabad	2017	1.67×1.67	Primary and Secondary	Indian	NOx, CO, BC, OC, $PM_{2.5}$, PM_{10}, SO_2, VOC	G. Beig, N. S. Parkhi, Earth System Science Organization, Ministry of Earth sciences, Govt. of India, Indian Institute of Tropical Meteorology, Pune, (2017), Development of High-Resolution Emission Inventory for Ahmedabad Metropolitan Region (AMR) System of Air Quality and weather Forecasting and Research (SAFAR)- Ahmedabad Available at: http://assets.nrdc.org/sites/default/files/media-uploads/safar-ahmedabad-ei-2017-full_report.pdf
54.	Manali (TN)	2017	0.5×0.5	Secondary	Indian	NO_2, SO_2, PM_{10}	"Assimilative capacity–based emission load management in a critically polluted industrial cluster," S. Panda, S. M. S. Nagendra, Journal of the Air & Waste Management Association 67, 12, 1353-1363 (2017) Available at: https://www.tandfonline.com/doi/full/10.1080/10962247.2017.1372319
55.	Agra	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Agra, India Available at: https://urbanemissions.info/india-apna/agra-india/
56.	Amritsar	2017	1×1	Secondary	Indian , USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Amritsar, India Available at: https://urbanemissions.info/india-apna/amritsar-india/
57.	Bengaluru	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bengaluru, India Available at: https://urbanemissions.info/india-apna/bengaluru-india/
58.	Bhopal	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bhopal, India Available at: https://urbanemissions.info/india-apna/bhopal-india/
59.	Bhubhneshwar	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bhubaneswar, India Available at: https://urbanemissions.info/india-apna/bhubaneswar-india/

S. No	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
60.	Chandigarh	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Chandigarh, India Available at: https://urbanemissions.info/india-apna/chandigarh-india/
61.	Chennai	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Chennai, India Available at: https://urbanemissions.info/india-apna/chennai-india/
62.	Coimbatore	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Coimbatore, India Available at: https://urbanemissions.info/india-apna/coimbatore-india/
63.	Dehradun	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Dehradun, India Available at: https://urbanemissions.info/india-apna/dehradun-india/
64.	Indore	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Indore, India Available at: https://urbanemissions.info/india-apna/indore-india/
65.	Jaipur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Jaipur, India Available at: https://urbanemissions.info/india-apna/jaipur-india/
66.	Kanpur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Kanpur, India Available at: https://urbanemissions.info/india-apna/kanpur-india/
67.	Kochi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Kochi, India Available at: https://urbanemissions.info/india-apna/kochi-india/

S. No	Location	Year of Publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
68.	Ludhiana	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Ludhiana, India Available at: https://urbanemissions.info/india-apna/ludhiana-india/
69.	Nagpur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Nagpur, India Available at: https://urbanemissions.info/india-apna/nagpur-india/
70.	Patna	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Patna, India Available at: https://urbanemissions.info/india-apna/patna-india/
71.	Pune	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Pune, India Available at: https://urbanemissions.info/india-apna/pune-india/
72.	Ranchi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Ranchi, India Available at: https://urbanemissions.info/india-apna/pune-india/
73.	Raipur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Raipur, India Available at: https://urbanemissions.info/india-apna/raipur-india/
74.	Varanasi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Varanasi, India Available at: https://urbanemissions.info/india-apna/varanasi-india/
75.	Delhi, NCR	2018	4×4	Primary	Indian	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC	Automotive Research Association of India, The Energy and Resources Institute, Department of Heavy Industry Ministry of Heavy Industries and Public Enterprises, New Delhi, (2018), Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources Available at: https://www.teriin.org/sites/default/files/2018-08/Exec-summary_0.pdf

S. No	Location	Year of Publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
76.	India	2018	10×10	Secondary	Indian, GAINS	$PM_{2.5}$, BC, OC, SO_2, NOx, NMVOC	"Source influence on emission pathways and ambient $PM_{2.5}$ pollution over India (2015–2050)," C. Venkataraman, M. Brauer, K. Tibrewal, P. Sadavarte, Q. Ma, A. Cohen, S. Chaliyakunnel, J. Frostad, Z. Klimont, R. V. Martin, D. B. Millet, S. Philip, K.Walker, S. Wang, Atmos. Chem. Phys. 18, 8017–8039 (2018) Available at: https://acp.copernicus.org/articles/18/8017/2018/acp-18-8017-2018.html
77.	India	2018	10×10	Secondary	EDGAR	CO, NOx, SO_2, NMVOC, $PM_{2.5}$, PM_{10}, EC, OC	The Air-Weather-Climate (AWC) Research group, Department of Civil and Environmental Engineering, (2018), Source apportionment, health effects and potential reduction of fine particulate matter ($PM_{2.5}$) in India Available at: http://www.indiaenvironmentportal.org.in/files/file/Source-apportionment-india.pdf
78.	India	2018	25×25	Secondary	Indian, GAINS	$PM_{2.5}$, PM_{10}, SO_2, NOx, CO, VOC, CO_2	"Evaluation of Particulate Pollution and Health Impacts from Planned Expansion of Coal-Fired Thermal Power Plants in India Using WRF-CAMx Modeling System," S. K. Guttikunda, P. Jawahar, Aerosol Air Qual. Res. 18, 3187-3202 (2018) Available at: https://aaqr.org/articles/aaqr-18-04-oa-0134
79.	India	2018	12×12	Secondary	GAINS	NOx, SO_2, $PM_{2.5}$	"Urban versus rural health impacts attributable to $PM_{2.5}$ and O_3 in northern India," A. Karambelas, T. Holloway, P. L. Kinney, A. M. Fiore, R. DeFries, G. Kiesewettwer, C. Heyes, Environmental Research Letters 13,6, 064010 (2018) Available at: https://iopscience.iop.org/article/10.1088/1748-9326/aac24d
80.	Jaipur	2018	Point locations	Primary	Indian	NOx, PM_{10}, CO, HC, SOx	"Emission Inventory of Air Pollutants from Diesel Generator Used At Selected Locations In Jaipur City, India," G. Suthar, R. K. Malik, N. K. Sumit, International Journal of Technical in Modern Engineering & Science (IJTIMES) 4, 12 (2018) Available at: https://www.researchgate.net/profile/Gourav-Suthar/publication/330005887_EMISSION_INVENTORY_OF_AIR_POLLUTANTS_FROM_DIESEL_GENERATOR_USED_AT_SELECTED_LOCATIONS_IN_JAIPUR_CITY_INDIA/links/6094f81a92851c490fbfffb0/EMISSION-INVENTORY-OF-AIR-POLLUTANTS-FROM-DIESEL-GENERATOR-USED-AT-SELECTED-LOCATIONS-IN-JAIPUR-CITY-INDIA.pdf
81.	Patna	2019	1×1	Primary and Secondary	Indian, USEPA	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC, CO_2	Center for Study of Science, Technology and Policy, Center for Environment, Energy and Climate Change, Asian Development Research Institute, Urban Emissions, Bihar State Control Board, (2019), Comprehensive Clean Air Action Plan for the City of Patna Available at: https://shaktifoundation.in/wp-content/uploads/2019/12/PCAAP_Report_Final-3-1.pdf

S. No	Location	Year of Publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
82.	Bangalore	2019	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC	"Air quality, emissions, and source contributions analysis for the Greater Bengaluru region of India," S. K. Guttikunda, Nishad. K A, S. Gota, P. Singh, Atmospheric Pollution Research 10, 3, 941-953 (2019) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1309104218304835
83.	Amravati	2019	–	Primary and Secondary	Indian, Foreign Literature	$PM_{2.5}$	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), Action Plan for Control Of Air Pollution In Non-Attainment Cities Of Maharashtra Amaravati Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Amravati_Action_Plan07112019.pdf
84.	Chandrapur	2019	1×1	Primary	Indian	PM, CO, HC, NOx	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), Action Plan Of Control Of Air Pollution In Non-Attainment Cities Of Maharashtra Chandrapur Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Chandrapur_Action_Plan07112019.pdf
85.	Agartala	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Agartala (Tripura, India) Available at: https://urbanemissions.info/india-apna/agartala-india/
86.	Ahmedabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Ahmedabad (Gujarat, India) Available at: https://urbanemissions.info/india-apna/ahmedabad-india/
87.	Allahabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Prayagraj (Allahabad) (Uttar Pradesh, India) Available at: https://urbanemissions.info/india-apna/allahabad-india/
88.	Asansol	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Asansol (West Bengal, India) Available at: https://urbanemissions.info/india-apna/asansol-india/
89.	Aurangabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Aurungabad (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/aurungabad-india/

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90.	Dharwad-Hubli	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Dharwad-Hubli (Karnataka, India) Available at: https://urbanemissions.info/india-apna/dharwad-india/
91.	Dhanbad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Dhanbad (Jharkhand, India) Available at: https://urbanemissions.info/india-apna/dhanbad-india/
92.	Gaya	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Gaya (Bihar, India) Available at: https://urbanemissions.info/india-apna/gaya-india/
93.	Guwahati	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Guwahati (Assam, India) Available at: https://urbanemissions.info/india-apna/guwahati-india/
94.	Gwalior	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Gwalior (Madhya Pradesh, India) Available at: https://urbanemissions.info/india-apna/gwalior-india/
95.	Greater Mumbai	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Mumbai (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/mumbai-india/
96.	Greater Kolkata	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Kolkata (West Bengal, India) Available at: https://urbanemissions.info/india-apna/kolkata-india/
97.	Hyderabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NO_x, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Hyderabad, (Telengana, India) Available at: https://urbanemissions.info/india-apna/hyderabad-india/

S. No	Location	Year of Publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
98.	Jamshedpur	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Jamshedpur (Jharkhand, India) Available at: https://urbanemissions.info/india-apna/jamshedpur-india/
99.	Jodhpur	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Jodhpur (Rajasthan, India) Available at: https://urbanemissions.info/india-apna/jodhpur-india/
100.	Kota	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Kota (Rajasthan, India) Available at: https://urbanemissions.info/india-apna/kota-india/
101.	Lucknow	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Lucknow (Uttar Pradesh, India) Available at: https://urbanemissions.info/india-apna/lucknow-india/
102.	Madurai	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Madurai (Tamil Nadu, India) Available at: https://urbanemissions.info/india-apna/madurai-india/
103.	Nashik	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Nashik (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/nashik-india/
104.	Panjim-Vasco-Margao	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Panjim (Goa, India) Available at: https://urbanemissions.info/india-apna/panjim-india/
105.	Puducherry	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Puducherry (Puducherry, India) Available at: https://urbanemissions.info/india-apna/puducherry-india/
106.	Rajkot	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Rajkot (Gujarat, India) Available at: https://urbanemissions.info/india-apna/rajkot-india/

S. No	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
107.	Shimla	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Shimla (Himachal Pradesh, India) Available at: https://urbanemissions.info/india-apna/shimla-india/
108.	Srinagar	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Srinagar (Jammu and Kashmir, India) Available at: https://urbanemissions.info/india-apna/srinagar-india/
109.	Surat	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Surat (Gujarat, India) Available at: https://urbanemissions.info/india-apna/surat-india/
110.	Thiruvananth-puram	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Thiruvananthapuram (Kerela, India) Available at: https://urbanemissions.info/india-apna/thiruvananthapuram-india/
111.	Tiruchupalli	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Tiruchirapalli (Tamil Nadu, India) Available at: https://urbanemissions.info/india-apna/tiruchirapalli-india/
112.	Vadodara	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vadodara (Gujarat, India) Available at: https://urbanemissions.info/india-apna/vadodara-india/
113.	Vijayawada	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vijayawada (Andhra Pradesh, India) Available at: https://urbanemissions.info/india-apna/vijayawada-india/
114.	Vishakapatnam	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vishakhapatnam (Andhra Pradesh, India) Available at: https://urbanemissions.info/india-apna/visakhapatnam-india/

S. No	Location	Year of Publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
115.	Kolkata	2020	–	Primary and Secondary	Indian, USEPA, GAINS	PM_{10}, $PM_{2.5}$, BC, OC, SO_2, NOx, CO, VOC, NH_3	"Managing future air quality in megacities: Emission inventory and scenario analysis for the Kolkata Metropolitan City, India," D. Majumdar, P. Purohit, A. D. Bhanarkar, P. S. Rao, P. Rafaj, M. Amann, R. Sander, A. Pakrashi, A. Srivastava, Atmospheric Environment 222, 117135 (2020) Available at: http://pure.iiasa.ac.at/id/eprint/16221/
116.	Jharsugda	2020	For individual industry cluster	Primary and Secondary	Indian	PM_{10}, NOx, SO_2,	International Institute for Energy Conservation. 2020. "Reducing Air Pollution in India's Industrial Cluster through Smart Energy Management" Available at: https://www.ccacoalition.org/en/file/7741/download?token=WiV_hbKs
117.	Jaipur	2020	2×2	Primary and Secondary	Indian, USEPA	PM_{10}, $PM_{2.5}$, NOx, SO_2, CO	M. Sharma, Rajasthan State Pollution Control Board, Jaipur, (2020), Air Quality Assessment, Trend Analysis, Emission Inventory and Source Apportionment Study in Jaipur City (Final Report) Available at: https://environment.rajasthan.gov.in/content/dam/environment/RPCB/EnvironmentalReport/Final-Report-Source-Apportionmnent-Study-Jaipur-IITKanpur.pdf
118.	Delhi	2020	2×2	Primary	Indian, USEPA	$PM_{2.5}$ and its species	"A framework for $PM_{2.5}$ constituents-based (including PAHs) emission inventory and source toxicity for priority controls: A case study of Delhi, India," A. K. Pathak, M. Sharma, P. K. Nagar, Chemosphere 255, 126971 (2020) Available at: https://www.sciencedirect.com/science/article/abs/pii/S0045653520311644
119.	Ludhiana	2020	2×2	Primary and Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO	Punjab State Council for Science & Technology, Chandigarh, The Energy & Resources Institute, New Delhi, Punjab Pollution Control Board, (2020), Source Apportionment Study to Prepare Action Plan to improve Air Quality of Ludhiana City Available at: https://ppcb.punjab.gov.in/sites/default/files/documents/N_8278_1625047519404.pdf
120.	Dhanbad	2021	2×2	Primary	Indian	PM_{10}	"Emission inventory of PM_{10} in Dhanbad/Jharia coalfield (JCF), India: an intricate coal mining sector," D. Roy, G. Singh, S. Sinha, J. Park, Y-C Seo, Environment, Development and Sustainability 23, 3048-3061 (2021) Available at: https://link.springer.com/article/10.1007/s10668-020-00702-4

S. No	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
121.	India	2021	10×10	Secondary	Indian	$PM_{2.5}$	"Establishing a link between fine particulate matter ($PM_{2.5}$) zones and COVID -19 over India based on anthropogenic emission sources and air quality data," S. K. Sahu, P. Mangaraj, G. Beig, B. Tyagi, S. Tikle, V. Vinoj, Urban Climate 38, 100883 (2021) Available at: https://www.sciencedirect.com/science/article/pii/S2212095521001139
122.	India	2021	36×36	Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, VOC, NH_3	The Energy and Resources Institute, The Energy And Resources Institute, Development Of Spatially Resolved Air Pollution Emission Inventory Of India Available at: https://www.teriin.org/sites/default/files/2021-05/Exxon-Report.pdf
123.	India	2021	36×36	Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, NMVOC	"Air Pollution Over India: Causal Factors for the High Pollution with Implications for Mitigation," N. Singh, S. Agarwal, S. Sharma, S. Chatani, V. Ramanathan, ACS Earth Space Chem. 5, 12, 3297-3312 (2021) Available at: https://pubs.acs.org/doi/10.1021/acsearthspacechem.1c00170
124.	Delhi	2021	2×2	Secondary	Indian, GAINS, USEPA	$PM_{2.5}$, NOx, SO_2,	Dr. A. Goel, The Energy and Resources Institute, The Energy and Resources Institute, (2021), Cost-effectiveness Analysis of Control Options for Managing Air Quality in Delhi Available at: https://www.teriin.org/sites/default/files/2021-12/Cost-effectiveness-of%20-interventions-for-control-of%20-air-pollution-in-Delhi.pdf

5

INVENTORY OF TRANSPORT EMISSIONS

Introduction

The number of registered motor vehicles in Indian cities has been steadily increasing. The 2020-21 annual report of the Ministry of Road Transport and Highways states a significant increase in the total number of registered motor vehicles in India from 67,007 in 2003 to 2,95,772 in 2019 with a CAGR of 9.91%.[28] In recent years, the number of automobiles has consistently increased. About 3.49 million passenger and commercial vehicles units were sold in 2020, which made India the fifth-largest auto market globally, stepping up from the seventh position in 2019.[29] A young population and an expanding middle class have facilitated the two-wheeler category to dominate the automobile market by volume. The sector is a primary emitter of carbon dioxide (CO_2); Hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), and particulates (PM). The central government announced regulations labelled **India 2000** in 2000, in line with worldwide norms to reduce vehicular pollution, and later upgraded guidelines known as Bharat Stage emission limits.[30] These regulations are comparable to the strict European emission norms and have been gradually phased in.[31] The most stringent version, Bharat Stage IV (BS-IV), was introduced first in 13 cities in April 2010—Delhi (NCR), Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Lucknow, Solapur, and Agra—and then across the rest of the country in April 2017. In 2019, India's federal government announced that India would leapfrog to the cleaner BS-VI mass emission standards (comparable to Euro VI). BS-VI norms kicked in on April 1, 2020, as mandated by the Supreme Court Order of 2018.[32]

28 Government of India, Ministry of Road Transport & Highways, New Delhi, (2021). Annual Report 2020-21, *https://morth.nic.in/sites/default/files/Annual%20Report%20%202021%20(English)_compressed.pdf*. Last accessed 16th December, 2021.

29 Automobile Industry in India, (2021), *https://www.ibef.org/industry/india-automobiles.aspx*.

30 Elavarasan, G., Kannan, M., and Karthikeyan, D., (2019). History of Emission standards in India – A Critical review, International Journal of Research and Analytical Reviews (IJRAR), 6 (2), 28-34.

31 ICCT Policy Update, (2016), India Bharat Stage VI Emission Standards, *https://theicct.org/sites/default/files/publications/India%20BS%20VI%20Policy%20Update%20vF.pdf*

32 Supreme Court of India, (2018), MC Mehta vs, Union of India, Judgement on Writ Petition (Civil) No. 13029 of 1985

Despite the implementation of cleaner emission standards, emissions from motorised transport have continued to impact the city's air quality profoundly. The sector has been well studied, and there are multiple emission inventory reports. The quality and quantity of emissions largely depend on fuel types and other factors like age and condition of vehicles, road conditions, etc.   Usually, gasoline and diesel usage data are gathered to calculate total emissions from automotive sources. Estimates of total emissions from automotive sources are made using the fuel consumption data and the emission factors. The data on emission factors for certain vehicle types, the distance travelled by a specific vehicle type, and the number of cars and their distribution in the type of fuel used are all needed to calculate vehicle emissions.

The following formula is used to determine vehicle emissions[33]

$$E_i = \Sigma\ (Veh_j \times D_j)\ X\ E_{i;\,j;\,km}$$

where E_i denotes emission of the compound. Veh_j: number of vehicles per type (j); D_j: distance travelled in a year per different vehicle type (j); and $E_{i;j;km}$: emission of compound (i), vehicle type (j) per driven kilometre.

Emission factor may be for specific fuel type, and is given by:

$$E_i = \Sigma\ Fuel_{j,k} \times EF_{i,j}$$

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

Geographical Distribution

The transport sector is one of India's most studied sectors for developing the emission inventory. EI on transport has been distributed along with different cities and states in India. The geographical distribution of EI studies on transport in India is shown in Map 3. Delhi, Uttar Pradesh, Maharashtra, Haryana and Tamil Nadu are the states where most EIs for the transport sector are being developed. Delhi, Chennai, Ahmedabad, Jamshedpur, Mumbai, and the cities within Delhi NCR were the most documented in the EIs on road transport. For Delhi and NCR, most emission inventories are standalone reports. It may be worthwhile to update these existing inventories periodically, with recent EFs and revised data, rather than adding to the existing list of reports.

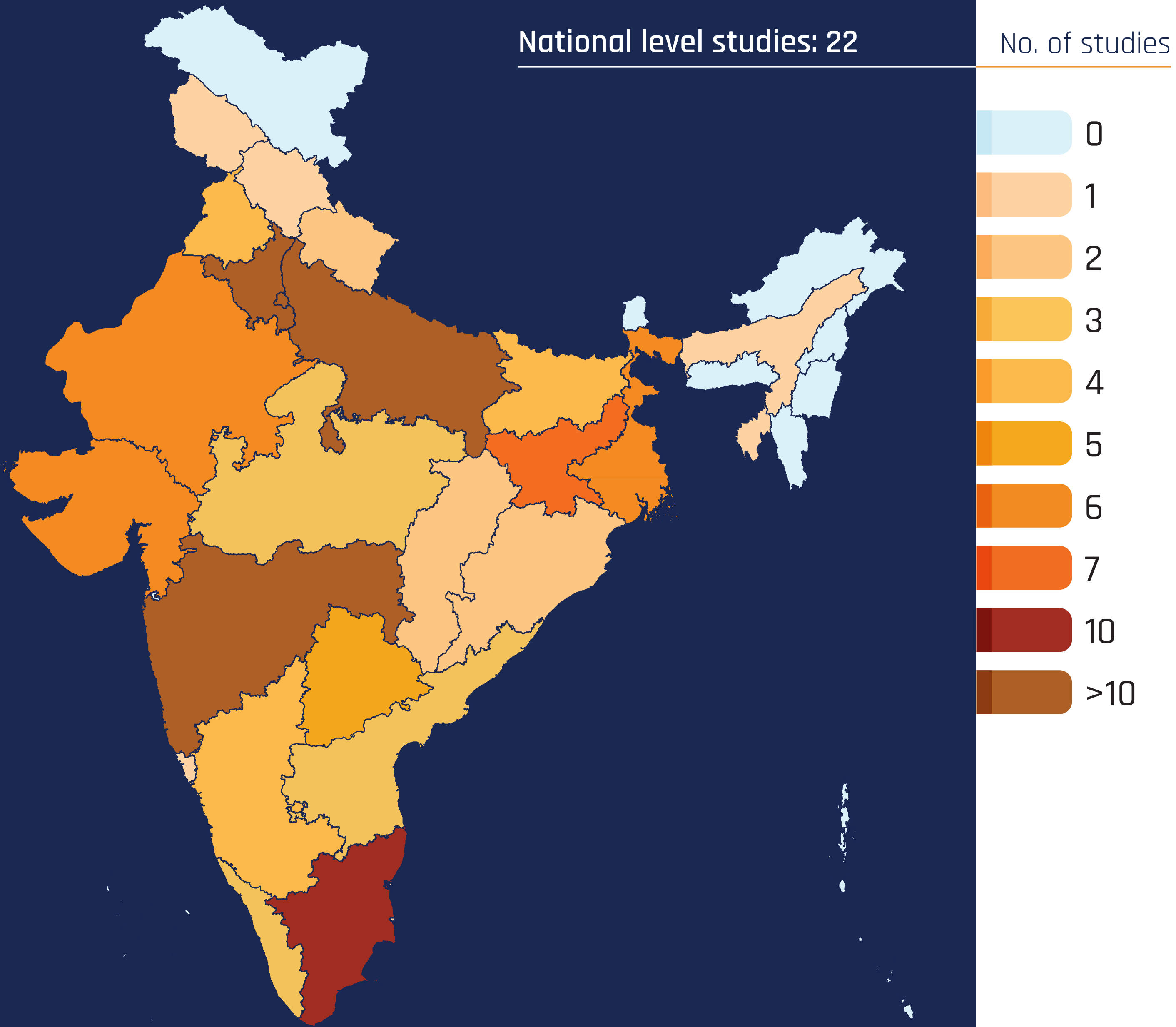
Overview

Overall, out of the 132 EI reports (See table 4) for the transport sector in India that were considered for this document, it was found that most relied on secondary data sets and used a combination of both Indian emission factors and the USEPA emission factors recommended by the IPCC. Automotive Research Association of India (ARAI) has created new emissions factors for various new types of vehicles introduced after 2008.[34] However, emission factors for recent vehicle models are still not developed. The unavailability of emission factors for all kinds of Indian vehicles restrains the researchers from using emission factors suitable for the Indian scenario. Usage of EF of other countries leads to uncertainty in the EI studies.

33 Ramchandra and Shwetmala, (2009). Emissions from India's transport sector: Statewise synthesis, Atmospheric Environment, xxx, 1–8.

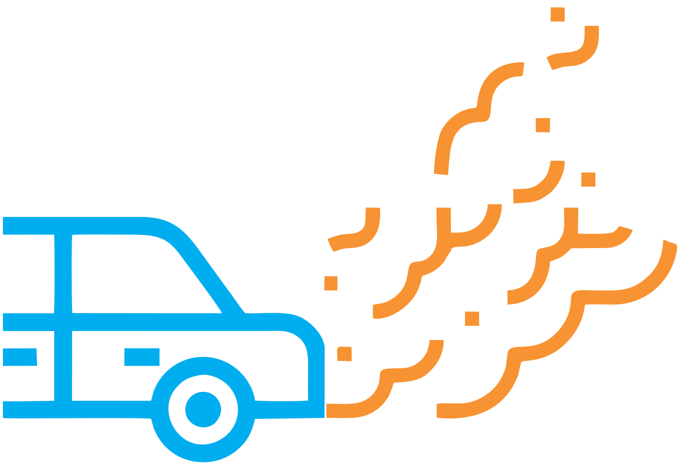
34 ARAI (Automotive Research Association of India), (2007). Emission factor development for Indian vehicles. Project Report No, AEF/2006-07/IOCL/Emission Factor Project. Pune, India. *http://cpcb.nic.in/Emission_Factors_Vehicles.pdf.*

MAP 3
GEOGRAPHICAL DISTRIBUTION OF TRANSPORT EMISSION INVENTORY STUDIES



Most EI reports on the transport sector have been built for PM ($PM_{2.5}$, PM_{10}), GHG (CO_2, CH_4), carbonaceous aerosols like BC, OC, and other gases like SO_2, and Non-Methane Volatile Organic Compounds (NMVOCs). The geographical distribution of the available EI reports for the transport sector elaborates the location disparity. Only a few cities have dedicated EI studies for the transport sector. Delhi and NCR region has been documented with 21 EI studies. On the other hand, some states like Manipur, Meghalaya, Mizoram and Nagaland in the North-eastern part of India have a sparse number of EI reports.

The transportation industry encompasses a variety of forms of transportation, including air, sea, rail, and road. However, the EI reports on the transport sector largely dealt with motorized road transport. Similarly, there are limited EI reports dedicated to freight vehicles. However, emission estimates from freights like trucks, lorries, light motor vehicles (goods), trailers and tractors are considered along with other vehicle types in the studies.



In most of the reports assessed for this study, transport data consisted of tourist vehicles in tourist destinations, automobiles in shopping malls, commercial taxis, petrol outlets, bus terminals, taxi stops, and parking lots. Data related to vehicle types, the distance travelled by a specific vehicle type, and the number of cars and their distribution in the type of fuel used was collected from different secondary sources while developing an EI. Primary surveys were also done in many cases for generating data required to calculate the emissions from transport.

The emission estimates in most EIs were made using a Vehicular Kilometre Travelled (VKT) technique for various vehicle types. In the VKT approach, the annual average value of kilometres travelled by vehicle and emission factors for different vehicle types are considered for estimating pollutant emissions.[35] While the VKT approach is widely used to calculate emissions for transport, this technique has its own limitations. For instance, yearly VKTs are not available for a city or state. Researchers use the same VKT values for all the years during their study period. Besides using foreign emission factors, another set of discrepancies might arise in the EI due to the quality of the activity data used. On some occasions, there are variations in EI reported by different groups for a particular city due to the different methodologies adopted. The variations arise primarily due to the interpretation of the counting methods and consequently reported number of survey stations, traffic estimation methods, vehicle fleet composition, fuel consumption patterns, and emission factors.

Further, different research groups' primary and secondary data sources for developing the EI of a city also varied. Most reports used secondary data sets. Outdated and faulty secondary data sets from unknown sources can lower the accuracy of an EI. Therefore, researchers should try to incorporate real-time data generated through primary data surveys in the EIs wherever feasible to boost the quality of the report. Only a few reports used primary data sets via methods like parking lot surveys, questionnaires, interacting with other personnel, and road monitoring using click counter.

35 Singh, R., Sharma, C., and Agrawal, M., (2017). Emission inventory of trace gases from road transport in India, *Transportation Research* Part D, 52, 64–72.

Table 4
List of Studies for Transport Sector Emission Inventory

Note:
Studies highlighted in green adhere closely to CPCB guidelines

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
1.	Agra-Mathura region	1981	–	Primary	Indian	SO_2	Central Board For The Prevention And Control Of Water Pollution New Delhi, Inventory and Assessment of Pollution Emission in and around Agra-Mathura Region (Abridged), Control of Urban Pollution Series CUPS/7/1981-82 Available at: http://cpcbenvis.nic.in/scanned%20reports/Inventory%20and%20assessment%20of%20pollution%20emission%20in%20and%20around%20Agra-Mathura%20region%20(Abridged).pdf
2.	Cochin	1999	–	Primary	Indian	PM, HC, NOx, SOx, CO, CO_2, HCl+CL_2, Acid Mist, H_2S, F	"Emission Inventory or an Industrial area of India," P. Gargava, A. I. Aggarwal, Environmental Monitoring Assessment 55, 299-304 (1999) Available at: https://link.springer.com/article/10.1023/A:1005947026732
3.	Dhanbad	2001	–	Primary	Indian	SOx, NOx, SPM, CO, HC	J. K. Upadhyay, Jawaharlal Nehru University, (2001), Modelling of dispersion of pollutants from various sources using Advanced Gaussian Plume Model in convective boundary layer in Dhanbad region, (Emission Inventory of the Region, Chapter 3) Available at: https://shodhganga.inflibnet.ac.in/handle/10603/19236
4.	India	2002	25×25	Secondary	Indian, USEPA	SO_2, PM, BC, OC	"Inventory of aerosol and sulphur dioxide emissions from India: I-Fossil fuel combustion," M. S. Reddy, C. Venkataraman, Atmospheric Environment I36, 4, 677-697 (2002) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231001004630
5.	India	2003	–	Secondary	Foreign Literature	BC	"Large historical changes of fossil-fuel black carbon aerosols," T. Novakov, V. Ramanathan, J. E. Hansen, T. W. Krichstetter, M. Sato, J. E. Sinton, J. A. Sathaye, Geophysical Research Letters 30, 6 (2003) Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2002GL016345
6.	Delhi	2004	–	Secondary	Indian	CH_4, CO, CO_2, N_2O, CO_2, NMVOC, NOx, SO_2, TSP	"Emission estimates and trends (1990–2000) for megacity Delhi and implications," B. R. Gurjar, J. A. van Aardenne, J. Lelieveld, M. Mohan, Atmospheric Environment 38, 33, 5663-5681 (2004) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231004005394

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
7.	Jamshedpur	2005	1×1	Primary and Secondary	Indian	SO_2, NO_2	"Assessment of contribution of SO_2 and NO_2 from different sources in Jamshedpur region, India," A. Bhanarkar, S. K. Goyal, R. Sivacoumar, C.V. Chalapati Rao, Atmospheric Environment 39, 40, 7745-7760 (2005) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231005006515
8.	Greater Mumbai	2005	2×2	Primary	USEPA	VOC, NOx	"Fuel Based Emission Inventory for Planning Gasoline Quality Modifications in Indian Mega City,"R. Biniwale, R. Kumar, SAE Technical Paper 2005-26-016 (2005) Available at: https://www.sae.org/publications/technical-papers/content/2005-26-016/
9.	Pune	2007	2×2	–	–	PM_{10}	"Coupling of the Weather Research and Forecasting Model with AERMOD for pollutant dispersion modeling. A case study for PM_{10} dispersion over Pune, India," A. P. Kesarkar, M. Dalvi, A. Kaginalkar, A. Ojha, Atmospheric Environment 41, 9, 1976-1988 (2007) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231006010570
10.	Hyderabad	2008	–	Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NOx, CO_2	S. Guttikunda, Integrated Environmental Strategies Program Washington DC, USA, (2008), Co-Benefits Analysis of Air Pollution and GHG Emissions for Hyderabad, India Available at: https://urbanemissions.info/wp-content/uploads/docs/SIM-09-2008.pdf
11.	India	2008	100×100	Secondary	Indian, Foreign literature	BC	S. K. Sahu, G. Beig, C. Sharma, Geophysical Research Letters, (2008), Decadal growth of black carbon emissions in India Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2007GL032333
12.	Delhi	2008	–	Secondary	USEPA	CO_2, CO, NOx, VOC	"Inventory Of Greenhouse Gases and Other Pollutants from The Transport Sector: Delhi," C. Sharma, R. Pundir, Journal Of Environmental Health Science & Engineering 5, 2, 117-124 (2008) Available at: https://ijehse.tums.ac.ir/index.php/jehse/article/view/158
13.	Madurai	2008	1×1	Primary	–	PM_{10}	"Measurement and modeling of respirable particulate (PM_{10}) and lead pollution over Madurai, India," B. V. Bhaskar, R. V. J. Rajasekhar, P. Muthusubramanian, A. P. Kesarkar, Air, Quality, Atmosphere & Health 1, 45-55 (2008) Available at: https://link.springer.com/article/10.1007/s11869-008-0004-0

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
14.	India	2009	–	Secondary	Indian	CO_2, CH_4, CO, NOx, N_2O, SO_2, PM, HC, NMVOC	"Emissions from India's transport sector: Statewise synthesis," T. V. Ramachandra, Shwetmala, Atmospheric Environment 43, 34, 1-8 (2009) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231009005871
15.	New Delhi, Mumbai, Chennai, Kolkata, Bangalore, Hyderabad, Ahmedabad	2009	–	Secondary	Indian, USEPA	CO_2, CH_4, CO, NMVOC, NOx, SO_2, primary PM, PM1, BC and OC	"Atmospheric emissions from road transportation in India," S. Baidya, J. Borken-Kleefeld, Energy Policy 37, 10, 3812-3822 (2009) Available at: https://www.sciencedirect.com/science/article/abs/pii/S0301421509005230
16.	Delhi, Mumbai, Chennai, Kolkata	2010	–	Secondary	Indian, USEPA	VOC	"Emission inventory of evaporative emissions of VOCs in four metro cities in India," A. Srivastava, D. Majumdar, Environmental Monitoring and Assessment 260, 215 (2010) Available at: https://pubmed.ncbi.nlm.nih.gov/19093218/
17.	Chennai	2010	–	Primary and Secondary	–	CO, VOC, NOx, PM, CO_2, CH_4, N_2O	"Estimation of automobile emissions and control strategies in India," K. S. Nesamani, Science of the Total Environment 408, 8, 1800-1811 (2010) Available at: https://www.sciencedirect.com/science/article/abs/pii/S0048969710000513
18.	Kolkata	2010	–	Secondary	Indian, USEPA	CO_2, CO, NOx, SPM, SO_2, VOCs	"Pollutant Emissions from Road Vehicles in Mega-City Kolkata," B. R. Gurjar, A. Nagpure, P. Kumar, N. Sahni, Indian Journal of Air Pollution Control 18-30 (2010) Available at: https://www.semanticscholar.org/paper/Pollutant-Emissions-from-Road-Vehicles-in-Mega-City-Gurjar-Nagpure/a2bd4c0ee3de805ba2e0946180376aae796ae268
19.	Delhi, Gurgaon, Faridabad, Rohtak, Jhajjar, Noida, Ghaziabad	2011	1.67×1.67	Primary and Secondary	Indian	$PM_{2.5}$, PM_{10}	"Emissions inventory of anthropogenic PM 2.5 and PM 10 in Delhi during Commonwealth Games 2010," S. K. Sahu, G. Beig, N. Parkhi, Atmospheric Environment 45, 34, 6180-6190 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S135223101100834X
20.	Delhi	2011	–	Primary	Indian	TSP, SO_2, NO_2	"Air quality modelling study to analyse the impact of the world Bank emission guidelines for the thermal power plants in Delhi," A. Kansal, M. Khare, C. S. Sharma, Atmospheric Pollution Research 2, 1, 99-105 (2011) Available at: https://www.sciencedirect.com/science/article/pii/S1309104215305213

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
21.	Nagpur	2011	–	Secondary	Indian, USEPA, IPCC	CO_2, CH_4, N_2O, SO_2	"Sectoral CO_2, CH_4, N_2O and SO_2 emissions from fossil fuel consumption in Nagpur City of Central India," D. Majumdar, D. G. Gajghate, Atmospheric Environment 45, 25, 4170-4179 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231011005024
22.	Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}	"GIS-Based Emission Inventory, Dispersion Modeling, and Assessment for Source Contributions of Particulate Matter in an Urban Environment," S. N. Behera, M. Sharma, O. Dikshit, S. P. Shukla, Water, Air and Soil Pollution, 218, 423-436 (2011) Available at: https://link.springer.com/article/10.1007/s11270-010-0656-x
23.	Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}	S. N. Behera, M. Sharma, O. Dikshit, S. P. Shukla, Advanced Air Pollution, (2011), Development of GIS-aided Emission Inventory of Air Pollutants for an Urban Environment Available at: https://www.intechopen.com/chapters/17388
24.	Pantnagar	2011	2×2	Primary	Indian	NO_2	"Application of air pollution dispersion modeling for source-contribution assessment and model performance evaluation at integrated industrial estate-Pantnagar," T. Banerjee, S. C. Barman, R. K. Srivastava, Environ Pollut 159, 4, 865-875 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S0269749110005920
25.	Jamshedpur	2011	1×1	Primary	Indian	NOx	"Air pollution modeling for an industrial complex and model performance evaluation," R. Sivacoumar, A. D. Bhanarkar, S. K. Goyal, S. K. Gadkari, A. L. Aggarwal, Environmental Pollution 111, 3, 471-477 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S026974910000083X
26.	Delhi	2011	–	Secondary	USEPA	CO_2, CH_4, CO, NOx, N_2O, NMVOC	R. Singh, C. Sharma, Journal of Scientific & Industrial Research, (2011), Assessment of emissions from transport sector in Delhi Available at: http://nopr.niscair.res.in/handle/123456789/13494
27.	Delhi	2012	–	Secondary	Indian, USEPA	CH_4, CO, CO_2, N_2O, CO_2, NMVOC, NOx, SO_2, TSP	M. Mohan, S. Bhati, P. Gunwani, P. Marappu, InTech, (2012), Emission Inventory of Air Pollutants and Trend Analysis Based on Various Regulatory Measures Over Megacity Delhi Available at: https://www.intechopen.com/chapters/37983
28.	India	2012	100×100	Secondary	Indian	NOx	"Emerging pattern of anthropogenic NOx emission over Indian subcontinent during 1990s and 2000s," S. K. Sahu, G. Beig, N. S. Parkhi, Atmospheric Pollution Research 3, 3, 262-269 (2012) Available at: https://doi.org/10.5094/APR.2012.021

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
29.	India	2012	–	Secondary	Indian, USEPA	CO_2, PM, NOx, CO, Benzene, 1-3 Butadiene, Formaldehyde, Acetaldehyde, Aldehyde, Total PAH	"Development and evaluation of Vehicular Air Pollution Inventory model," A. S. Nagpure, B. R. Gurjar, Atmospheric Environment 59, 160-169 (2012) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231012003743
30.	Angul	2012	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3086%5C
31.	Korba	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3087
32.	Auraiya	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3088
33.	Anta	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3089
34.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian, Foreign literature	PM, SO_2, NOx, CO, VOC	"A GIS based emissions inventory at 1 km x 1 km spatial resolution for air pollution analysis in Delhi, India," S. K. Guttikunda, G. Calori, Atmospheric Environment 67, 101-111 (2013). Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231012010229
35.	Delhi	2013		Primary and Secondary	Indian, USEPA	CO, NOx, PM	"Vehicular emission inventory of criteria pollutants in Delhi," P. Goyal, D. MIshra, A. Kumar, SpringerPlus 2, 2016 (2013) Available at: https://springerplus.springeropen.com/articles/10.1186/2193-1801-2-216
36.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, NOx, CO, VOC	"Health impacts of particulate pollution in a megacity—Delhi, India," S. K. Guttikunda, R. Goel, Environmental Department 6, 8-20 (2013) Available at: https://www.sciencedirect.com/science/article/abs/pii/S2211464512001492
37.	Delhi	2013	–	Secondary	USEPA	CO_2, CO, HC, NOx, TSP, SO_2, Pb, VOC	"Traffic induced emission estimates and trends (2000–2005) in megacity Delhi," A. S. Nagpure, K. Sharma, B. R. Gurjar, Urban Climate 4, 61-73 (2013) Available at: https://www.sciencedirect.com/science/article/abs/pii/S2212095513000114
38.	Kanpur	2013	2×2	Primary and Secondary	Indian, USEPA	PM, SO_2, NOx	"Respiratory Disease in Relation to Outdoor Air Pollution in Kanpur, India." H-Y Liu, A. Bartonova, M. Schindler, M. Sharma, S. N. Behera, K. Katiyar, O. Dikshit, Arch Environ Occup Health 68, 4, 204-217 (2013) Available at: https://pubmed.ncbi.nlm.nih.gov/23697693/

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
39.	Patna	2014	1×1	Secondary	Indian, USEPA	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC, CO_2	S. K. Guttikunda, P. Jawahar, UrbanEmissions.Info., (2014), Characterizing Patna's Ambient Air Quality and Assessing Opportunities for Policy Intervention Available at: https://shaktifoundation.in/wp-content/uploads/2017/06/Urban-Emissions-2014-AQM-in-Patna-Final-Report.pdf
40.	Delhi	2014	–	Primary and Secondary	Indian, Foreign literature	PM_{10}	"Speciated PM_{10} Emission Inventory for Delhi, India," P. Gargava, J. C. Chow, J. G. Watson, D. H. Lowenthal, Aerosol and Air Quality Research 14, 5, 1515-1526 (2014) Available at: https://aaqr.org/articles/aaqr-13-02-oa-0047
41.	Hyderabad	2014	–	Primary	Indian, USEPA, GAINS	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC, CO_2	"Source emissions and health impacts of urban air pollution in Hyderabad, India," S. K. Guttikunda, R. V. Kopakka, Air Qual Atmos Health 7, 195-207 (2014) Available at: https://link.springer.com/article/10.1007/s11869-013-0221-z
42.	Delhi	2014	–	Secondary	Indian, USEPA	PM_{10}, BC, OC, SO_2, NOx, CO, VOC, Pb, CH_4, HC	"Assessment of traffic-generated gaseous and particulate matter emissions and trends over Delhi (2000–2010)," R. Sindhwani, P. Goyal, Atmospheric Pollution Research 5, 3, 438-446 (2014) Available at: https://www.sciencedirect.com/science/article/pii/S1309104215303007
43.	Delhi	2014	–	Secondary	Indian	CO, NOx, PM_{10}	"Estimation of vehicular emissions using dynamic emission factors: A case study of Delhi, India," D. Mishra, P. Goyal, Atmospheric Environment 98, 1-7 (2014) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231014006499
44.	India	2014	25×25	Secondary	Indian, USEPA	$PM_{2.5}$, BC, OC, CO, NOx, NMVOC, CH_4	"Trends in multi-pollutant emissions from a technology-linked inventory for India: II. Residential, agricultural and informal industry sectors," A. Pandey, P. Sadavarte, A. B. Rao, C. Venkataraman, Atmospheric Environment 99, 341-352 (2014) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231014007742
45.	India	2014	–	Primary and Secondary	Indian	NOx, CO, PM, VOC	"Critical Emissions from the Largest On-Road Transport Network in South Asia," S. K. Sahu, G. Beig, N. Parkhi, Aerosol and Air Quality Research 14, 1, 135-144 (2014) Available at: https://aaqr.org/articles/aaqr-13-04-oa-0137

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
46.	India	2014	–	Secondary	Indian, USEPA	$PM_{2.5}$, BC, OC	"Estimating emissions from the Indian transport sector with on-road fleet composition and traffic volume," A. Pandey, C, Venkataraman, Atmospheric Environment 98, 123-133 (2014) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231014006414
47.	Chennai, Vishakhapatnam	2015	1×1	Primary and Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NO_2	"Particulate and gaseous emissions in two coastal cities—Chennai and Visakhapatnam, India," S. K. Guttikunda, R. Goel, D. Mohan, G. Tiwari, Air Quality, Atmosphere & Health 8, 6, 559-572 (2015) Available at: https://link.springer.com/article/10.1007/s11869-014-0303-6
48.	Delhi	2015	2×2	Primary and Secondary	Indian	CO, NOx, SO_2, PM_{10}	"Anthropogenic Emission Inventory of Criteria Air Pollutants of an Urban Agglomeration - National Capital Region (NCR), Delhi," R. Sindhwani, P. Goyal, S. Kumar, A. Kumar, Aerosol and Air Quality Research 15, 1681-1697 (2015) Available at: https://aaqr.org/articles/aaqr-14-11-oa-0271
49.	India	2015	36×36	Secondary	USEPA, GAINS, CITEPA	NMVOC	"Emission inventory of non-methane volatile organic compounds from anthropogenic sources in India," S. Sharma, A. Goel, D. Gupta, A. Kumar, A. Mishra, S. Kundu, S. Chatani, Z. Klimont, Atmospheric Environment 102, 209-219 (2015) Available at: https://doi.org/10.1016/j.atmosenv.2014.11.070
50.	Amritsar	2015	–	Primary	Indian	PM_{10}, SO_2, NOx	"Assessment of Urban Air Quality around a Heritage Site Using AERMOD: A Case Study of Amritsar City, India," S. Gulia, A. Shrivastva, A. K. Nema, M. Khare, Environ Model Assess 20, 6, 599-608 (2015) Available at: https://link.springer.com/article/10.1007/s10666-015-9446-6
51.	Delhi	2015	1.67×.67	Primary and Secondary	Indian, USEPA	NOx, CO	"High Resolution Emission Inventory of NOx and CO for Mega City Delhi, India," S. K. Sahu, G. Beig, N. Parkhi, Aerosol and Air Quality Research 15, 3, 1137-1144 (2015) Available at: https://aaqr.org/articles/aaqr-14-07-tn-0132
52.	Delhi	2016	2×2	Primary and Secondary	Indian	PM_{10}, $PM_{2.5}$, NOx, CO	M. Sharma, O. Dikshit, Department of Environment Government of National Capital Territory of Delhi, Delhi Pollution Control Committee, (2016), Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi (Final Report: Air Pollution component) Available at: https://cerca.iitd.ac.in/uploads/Reports/1576211826iitk.pdf
53.	Madurai	2016	–	Primary and secondary	Indian	CO, HC, $C0_2$, NOx, PM	"Emission inventory- a preliminary approach to primary pollutants," S. Venkitasamy, B. V. Bhaskar, Current Science 111, 11, 1831-1835 (2016) Available at: https://www.jstor.org/stable/24911545

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54.	India	2016	40×40	Secondary	Indian, Foreign literature	BC	"Monthly and Spatially Resolved Black Carbon Emission Inventory of India: Uncertainty Analyses," U. Paliwal, M. Sharma, J. F. Burkhart, Atmos. Chem. Phys. 16, 12457-12476 (2016) Available at: https://acp.copernicus.org/articles/16/12457/2016/acp-16-12457-2016.html
55.	Lucknow	2016	–	Primary and Secondary	Indian, Foreign literature	SO_2, NOx, CO, PM, PAH	"GIS-Based On-Road Vehicular Emission Inventory for Lucknow, India," D. Singh, S. P. Shukla, M. Sharma, S. N. Behera, D. Mohan, N. B. Singh, G. Pandey, Journal of Hazardous, Toxic, and Radioactive Waste 20, 4 (2016) Available at: https://ascelibrary.org/doi/abs/10.1061/(ASCE)HZ.2153-5515.0000244
56.	India	2016	36×36	Secondary	Indian, GAINS, USEPA	NOx, NMVOC, CO	"Sensitivity analysis of ground level ozone in India using WRF-CMAQ models," S. Sharma, S. Chatani, R. Mahatta, A. Goel, A. Kumar, Atmospheric Environment 131, 29-40 (2016) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231016300504
57.	Delhi	2016	–	Secondary	USEPA	CO_2, HC, PM_{10}, CO, NOx, MSATs	"Estimation of exhaust and non-exhaust gaseous, particulate matter and air toxics emissions from on-road vehicles in Delhi," A. Nagpure, B. R. Gurjar, V. Kumar, P. Kumar, Atmospheric Environment 127, 118-124 (2016) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231015305951
58.	Ahmedabad	2017	1.67×1.67	Primary and Secondary	Indian	NOx, CO, BC, OC, $PM_{2.5}$, PM_{10}, SO_2, VOC	G. Beig, N. S. Parkhi, Earth System Science Organization, Ministry of Earth sciences, Govt. of India, Indian Institute of Tropical Meteorology, Pune, (2017), Development of High-Resolution Emission Inventory for Ahmedabad Metropolitan Region (AMR) System of Air Quality and weather Forecasting and Research (SAFAR)- Ahmedabad Available at: http://assets.nrdc.org/sites/default/files/media-uploads/safar-ahmedabad-ei-2017-full_report.pdf
59.	Agra	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC,OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Agra, India Available at: https://urbanemissions.info/india-apna/agra-india/
60.	Amritsar	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Amritsar, India Available at: https://urbanemissions.info/india-apna/amritsar-india/

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61.	Bengaluru	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bengaluru, India Available at: https://urbanemissions.info/india-apna/bengaluru-india/
62.	Bhopal	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bhopal, India Available at: https://urbanemissions.info/india-apna/bhopal-india/
63.	Bhubhneshwar	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bhubaneswar, India Available at: https://urbanemissions.info/india-apna/bhubaneswar-india/
64.	Chandigarh	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Chandigarh, India Available at: https://urbanemissions.info/india-apna/chandigarh-india/
65.	Chennai	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Chennai, India Available at: https://urbanemissions.info/india-apna/chennai-india/
66.	Coimbatore	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Coimbatore, India Available at: https://urbanemissions.info/india-apna/coimbatore-india/
67.	Dehradun	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Dehradun, India Available at: https://urbanemissions.info/india-apna/dehradun-india/
68.	Indore	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Indore, India Available at: https://urbanemissions.info/india-apna/indore-india/

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69.	Jaipur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Jaipur, India Available at: https://urbanemissions.info/india-apna/jaipur-india/
70.	Kanpur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Kanpur, India Available at: https://urbanemissions.info/india-apna/kanpur-india/
71.	Kochi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Kochi, India Available at: https://urbanemissions.info/india-apna/kochi-india/
72.	Ludhiana	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Ludhiana, India Available at: https://urbanemissions.info/india-apna/ludhiana-india/
73.	Nagpur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Nagpur, India Available at: https://urbanemissions.info/india-apna/nagpur-india/
74.	Patna	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Patna, India Available at: https://urbanemissions.info/india-apna/patna-india/
75.	Pune	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Pune, India Available at: https://urbanemissions.info/india-apna/pune-india/
76.	Ranchi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Ranchi, India Available at: https://urbanemissions.info/india-apna/ranchi-india/
77.	Raipur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Raipur, India Available at: https://urbanemissions.info/india-apna/raipur-india/

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78.	Varanasi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Varanasi, India Available at: https://urbanemissions.info/india-apna/varanasi-india/
79.	Panipat, Sonipat, Rohtak, Jhajjar, Rewari, Alwar, Gurgaon, Fardabad, Noida, Ghaziabad, Bulandshar, Meerut, Baghpat	2017	4×4	Primary and Secondary	Indian, GAINS	NOx, NMVOC, CO	"Simulating ozone concentrations using precursor emission inventories in Delhi – National Capital Region of India," S. Sharma, M. Khare, Atmospheric Environment 151 (2017) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231016309682
80.	India	2017	–	Secondary	Indian, USEPA	CO_2, CH_4, CO, NOx, N_2O, SO_2, PM, HC	"Emission inventory of trace gases from road transport in India," R. Singh, C. Sharma, M. Agarwal, Transportation Research Part D: Transport and Environment 52, A, 64-72 (2017) Available at: https://doi.org/10.1016/j.trd.2017.02.011
81.	Delhi, NCR	2018	4×4	Primary	Indian	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC	Automotive Research Association of India, The Energy and Resources Institute, Department of Heavy Industry Ministry of Heavy Industries and Public Enterprises, New Delhi, (2018), Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources Available at: https://www.teriin.org/sites/default/files/2018-08/Exec-summary_0.pdf
82.	India	2018	10×10	Secondary	Indian, GAINS	$PM_{2.5}$, BC, OC, SO_2, NOx, NMVOC	"Source influence on emission pathways and ambient $PM_{2.5}$ pollution over India (2015–2050)," C. Venkataraman, M. Brauer, K. Tibrewal, P. Sadavarte, Q. Ma, A. Cohen, S. Chaliyakunnel, J. Frostad, Z. Klimont, R. V. Martin, D. B. Millet, S. Philip, K.Walker, S. Wang, Atmos. Chem. Phys. 18, 8017–8039 (2018) Available at: https://acp.copernicus.org/articles/18/8017/2018/acp-18-8017-2018.html
83.	India	2018	–	Secondary	Indian	CO, CO_2, NO_x	"A technology-based mass emission factors of gases and aerosol precursor and spatial distribution of emissions from on-road transport sector in India," J. Prakash, G. Habib, Atmospheric Environment 180, 192-205 (2018) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231018301389
84.	India	2018	12×12	Secondary	GAINS	NOx, SO_2, $PM_{2.5}$	"Urban versus rural health impacts attributable to $PM_{2.5}$ and O_3 in northern India," A. Karambelas, T. Holloway, P. L. Kinney, A. M. Fiore, R. DeFries, G. Kiesewettwer, C. Heyes, Environmental Research Letters 13,6, 064010 (2018) Available at: https://iopscience.iop.org/article/10.1088/1748-9326/aac24d

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85.	Bangalore	2019	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC	"Air quality, emissions, and source contributions analysis for the Greater Bengaluru region of India," S. K. Guttikunda, Nishad. K A, S. Gota, P. Singh, Atmospheric Pollution Research 10, 3, 941-953 (2019) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1309104218304835
86.	Patna	2019	1×1	Primary and Secondary	Indian, USEPA	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC, CO_2	Center for Study of Science, Technology and Policy, Center for Environment, Energy and Climate Change, Asian Development Research Institute, Urban Emissions, Bihar State Control Board, (2019), Comprehensive Clean Air Action Plan for the City of Patna Available at: https://shaktifoundation.in/report/comprehensive-clean-air-action-plan-for-the-city-of-patna/?psec=NQ==#MTE5Mzc=
87.	Amravati	2019	–	Primary and Secondary	Indian, Foreign Literature	$PM_{2.5}$	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), Action Plan for Control Of Air Pollution In Non-Attainment Cities Of Maharashtra Amaravati Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Amravati_Action_Plan07112019.pdf
88.	Chandrapur	2019	1×1	Primary	Indian	PM, CO, HC, NOx	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), Action Plan Of Control Of Air Pollution In Non-Attainment Cities Of Maharashtra Chandrapur Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Chandrapur_Action_Plan07112019.pdf
89.	Agartala	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Agartala (Tripura, India) Available at: https://urbanemissions.info/india-apna/agartala-india/
90.	Ahmedabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Ahmedabad (Gujarat, India) Available at: https://urbanemissions.info/india-apna/ahmedabad-india/
91.	Allahabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Prayagraj (Allahabad) (Uttar Pradesh, India) Available at: https://urbanemissions.info/india-apna/allahabad-india/

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92.	Asansol	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Asansol (West Bengal, India) Available at: https://urbanemissions.info/india-apna/asansol-india/
93.	Aurangabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Aurungabad (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/aurungabad-india/
94.	Dharwad-Hubli	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Dharwad-Hubli (Karnataka, India) Available at: https://urbanemissions.info/india-apna/dharwad-india/
95.	Dhanbad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Dhanbad (Jharkhand, India) Available at: https://urbanemissions.info/india-apna/dhanbad-india/
96.	Gaya	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Gaya (Bihar, India) Available at: https://urbanemissions.info/india-apna/gaya-india/
97.	Guwahati	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Guwahati (Assam, India) Available at: https://urbanemissions.info/india-apna/guwahati-india/
98.	Gwalior	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Gwalior (Madhya Pradesh, India) Available at: https://urbanemissions.info/india-apna/gwalior-india/
99.	Greater Mumbai	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Mumbai (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/mumbai-india/

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
100.	Greater Kolkata	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Kolkata (West Bengal, India) Available at: https://urbanemissions.info/india-apna/kolkata-india/
101.	Hyderabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Hyderabad, (Telengana, India) Available at: https://urbanemissions.info/india-apna/hyderabad-india/
102.	Jamshedpur	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Jamshedpur (Jharkhand, India) Available at: https://urbanemissions.info/india-apna/jamshedpur-india/
103.	Jodhpur	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Jodhpur (Rajasthan, India) Available at: https://urbanemissions.info/india-apna/jodhpur-india/
104.	Kota	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Kota (Rajasthan, India) Available at: https://urbanemissions.info/india-apna/kota-india/
105.	Lucknow	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Lucknow (Uttar Pradesh, India) Available at: https://urbanemissions.info/india-apna/lucknow-india/
106.	Madurai	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Madurai (Tamil Nadu, India) Available at: https://urbanemissions.info/india-apna/madurai-india/
107.	Nashik	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Nashik (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/nashik-india/
108.	Panjim-Vasco-Margao	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Panjim (Goa, India) Available at: https://urbanemissions.info/india-apna/panjim-india/

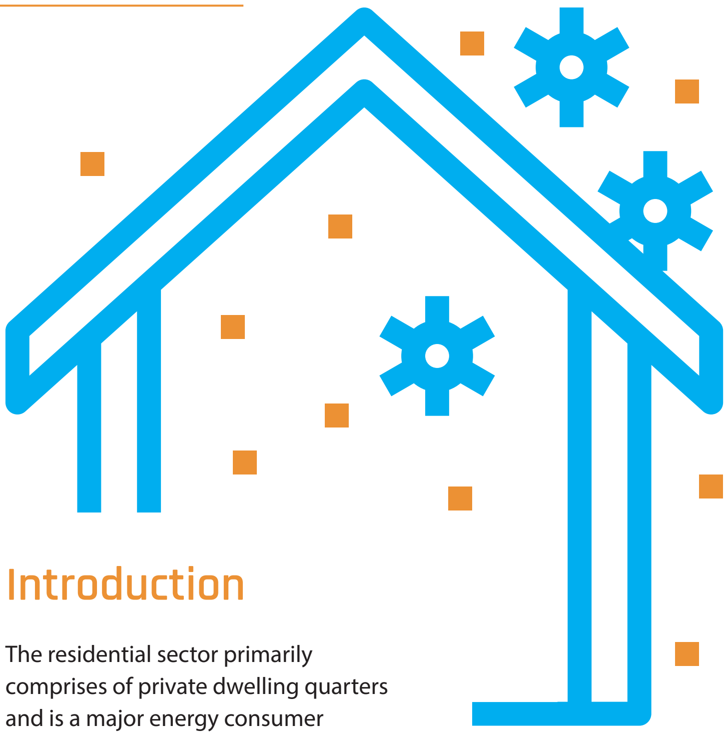
S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
109.	Puducherry	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Puducherry (Puducherry, India) Available at: https://urbanemissions.info/india-apna/puducherry-india/
110.	Rajkot	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Rajkot (Gujarat, India) Available at: https://urbanemissions.info/india-apna/rajkot-india/
111.	Shimla	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Shimla (Himachal Pradesh, India) Available at: https://urbanemissions.info/india-apna/shimla-india/
112.	Srinagar	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Srinagar (Jammu and Kashmir, India) Available at: https://urbanemissions.info/india-apna/srinagar-india/
113.	Surat	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Surat (Gujarat, India) Available at: https://urbanemissions.info/india-apna/surat-india/
114.	Thiruvananth-puram	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Thiruvananthapuram (Kerela, India) Available at: https://urbanemissions.info/india-apna/thiruvananthapuram-india/
115.	Tiruchupalli	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Tiruchirapalli (Tamil Nadu, India) Available at: https://urbanemissions.info/india-apna/tiruchirapalli-india/
116.	Vadodara	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vadodara (Gujarat, India) Available at: https://urbanemissions.info/india-apna/vadodara-india/

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
117.	Vijayawada	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vijayawada (Andhra Pradesh, India) Available at: https://urbanemissions.info/india-apna/vijayawada-india/
118.	Vishakapatnam	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vishakhapatnam (Andhra Pradesh, India) Available at: https://urbanemissions.info/india-apna/visakhapatnam-india/
119.	Hyderabad	2019	–	Primary and Secondary	Indian, USEPA	CO, HC, NOx,	"Emission modelling of light-duty vehicles in India using the revamped VSP-based MOVES model: The case study of Hyderabad," H. Perugu, Transportation Research Part D: Transport and Environment 68, 150-163 (2019) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1361920917301104
120.	Kolkata	2020	–	Primary and Secondary	Indian, USEPA, GAINS	PM_{10}, $PM_{2.5}$, BC, OC, SO_2, NOx, CO, VOC, CO_2	"Managing future air quality in megacities: Emission inventory and scenario analysis for the Kolkata Metropolitan City, India," D. Majumdar, P. Purohit, A. D. Bhanarkar, P. S. Rao, P. Rafaj, M. Amann, R. Sander, A. Pakrashi, A. Srivastava, Atmospheric Environment 222, 117135 (2020) Available at: http://pure.iiasa.ac.at/id/eprint/16221/
121.	Delhi	2020	2×2	Primary	Indian, USEPA	$PM_{2.5}$ and its species	"A framework for $PM_{2.5}$ constituents-based (including PAHs) emission inventory and source toxicity for priority controls: A case study of Delhi, India," A. K. Pathak, M. Sharma, P. K. Nagar, Chemosphere 255, 126971 (2020) Available at: https://www.sciencedirect.com/science/article/abs/pii/S0045653520311644
122.	India	2020	27.75	Secondary	Indian	BC, OC, $PM_{2.5}$	"New Emission Inventory of Carbonaceous Aerosols from the On-road Transport Sector in India and its Implications for Direct Radiative Forcing over the Region," J. Prakash, P. Vats, A. K. Sharma, D. Ganguly, G. Habib, Aerosol and Air Quality Research, 20, 741–761 (2020) Available at: https://aaqr.org/articles/aaqr-19-08-oa-0393
123.	Ludhiana	2020	2×2	Primary and Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO	Punjab State Council for Science & Technology, Chandigarh, The Energy & Resources Institute, New Delhi, Punjab Pollution Control Board, (2020), Source Apportionment Study to Prepare Action Plan to improve Air Quality of Ludhiana City Available at: https://ppcb.punjab.gov.in/sites/default/files/documents/N_8278_1625047519404.pdf

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
124.	Jaipur	2020	2	Primary and Secondary	Indian	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO	M. Sharma, Rajasthan State Pollution Control Board, Jaipur, (2020), Air Quality Assessment, Trend Analysis, Emission Inventory and Source Apportionment Study in Jaipur City (Final Report) Available at: https://environment.rajasthan.gov.in/content/dam/environment/RPCB/EnvironmentalReport/Final-Report-Source-Apportionmnent-Study-Jaipur-IITKanpur.pdf
125.	India	2021	36×36	Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, NMVOC	"Air Pollution Over India: Causal Factors for the High Pollution with Implications for Mitigation," N. Singh, S. Agarwal, S. Sharma, S. Chatani, V. Ramanathan, ACS Earth Space Chem. 5, 12, 3297-3312 (2021) Available at: https://pubs.acs.org/doi/10.1021/acsearthspacechem.1c00170
126.	Lucknow	2021	–	Secondary	–	CO, NOX, HC, $PM_{2.5}$, SO_2, CO_2	T. Alam, A. K. Shukla, Advances in Civil Engineering and Infrastructural Development, (2021), Vehicular Emission Inventory of Lucknow Available at: https://link.springer.com/chapter/10.1007%2F978-981-15-6463-5_44
127.	Dhanbad	2021	2×2	Primary	Indian	PM_{10}	"Emission inventory of PM_{10} in Dhanbad/Jharia coalfield (JCF), India: an intricate coal mining sector," D. Roy, G. Singh, S. Sinha, J. Park, Y-C Seo, Environment, Development and Sustainability 23, 3048-3061 (2021) Available at: https://link.springer.com/article/10.1007/s10668-020-00702-4
128.	India	2021	–	Secondary	USEPA	NMVOCs, CO, NOx, CO_2, CH_4, CO_2, $PM_{2.5}$	"RTEII: A new high-resolution (0.1° × 0.1°) road transport emission inventory for India of 74 speciated NMVOCs, CO, NOx, CO_2, CH_4, CO_2, $PM_{2.5}$ reveals massive overestimation of NOx and CO and missing nitromethane emissions by existing inventories," H. Hakkim, A. Kumar, S. Annadate, B. Sinha, V. Sinha, Atmospheric Environment: X 11, 100118 (2021) Available at: https://www.sciencedirect.com/science/article/pii/S2590162121000186
129.	India	2021	10×10	Secondary	Indian	$PM_{2.5}$	"Establishing a link between fine particulate matter ($PM_{2.5}$) zones and COVID -19 over India based on anthropogenic emission sources and air quality data," S. K. Sahu, P. Mangaraj, G. Beig, B. Tyagi, S. Tikle, V. Vinoj, Urban Climate 38, 100883 (2021) Available at: https://www.sciencedirect.com/science/article/pii/S2212095521001139

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/Other)	Pollutants	Reference
130.	India	2021	–	Primary and Secondary	Indian, USEPA	CO_2, CO, PM, NOx	N. Singh, T. Mishra, R. Banerjee, Research Square, (2021), Emissions inventory for road transport in India in 2020: Framework and post facto policy impact assessment Available at: https://link.springer.com/article/10.1007/s11356-021-17238-3
131.	India	2021	36×36	Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, VOC, CO_2	The Energy and Resources Institute, The Energy And Resources Institute, Development Of Spatially Resolved Air Pollution Emission Inventory Of India Available at: https://www.teriin.org/sites/default/files/2021-05/Exxon-Report.pdf
132.	Faridabad, Gurugram	2021	–	Secondary	Indian	NOx	"Coupled WRF-AERMOD modeling system by using Dispersion of Air Pollutant and Generation of Gridded Emission Inventory of NOx over Faridabad and Gurugram," N. Sharma, R. Singh, Y. K. Rojoria, P. Rajendra, R. Boadh, International Journal of Scientific Research in Mathematical and Statistical Sciences 8, 1, 01-12 (2021) Available at: https://www.researchgate.net/profile/Yogendra-Rajoria/publication/354177173_Coupled_WRF-AERMOD_modeling_system_by_using_Dispersion_of_Air_Pollutant_and_Generation_of_Gridded_Emission_Inventory_of_NOX_over_Faridabad_and_Gurugram/links/6129d57a38818c2eaf64a985/Coupled-WRF-AERMOD-modeling-system-by-using-Dispersion-of-Air-Pollutant-and-Generation-of-Gridded-Emission-Inventory-of-NOX-over-Faridabad-and-Gurugram.pdf

6 INVENTORY OF EMISSIONS FROM THE RESIDENTIAL SECTOR



Introduction

The residential sector primarily comprises of private dwelling quarters and is a major energy consumer through lighting, air conditioning, cooking, refrigeration, and water heating. The sector is a major emitter of air pollutants and also greenhouse gases (GHGs).[36]

Researchers from many countries investigated household energy usage trends and GHG emissions to encourage low-carbon lifestyles. Domestic fuel burning is often a significant source of Non-Methane Volatile Organic Compound (NMVOC) emissions due to the inefficiency of the cooking equipment; hence, estimating fuel use in this sector is more challenging. Besides the most commonly used LPG, different solid fuels like wood, agricultural residues, dung cake are used in Indian households, especially in rural pockets. All of them are rich sources of emissions. These have disproportionate impacts on the health of women and young children. Only 9% of households use LPG in rural areas, compared to 62% in metropolitan areas until 2015. With the inception of Pradhan Mantri Ujjwala Yojana (PMUY), LPG penetration has increased to 89,133,764 connections as of 14th December 2021[37] across various states, and there is now a significant drop in usage in solid fuel. However, with one cylinder and stove being available for a family of three or more, fuel stacking continues to plague rural households. Further, though LPG penetration has increased many folds in India, high costs of refilling, along with cultural barriers, has led to continued usage of firewood *chulhas* wherein firewood is easily available. Therefore, any emission inventory for the residential sector in India needs to encompass these complex energy use patterns.

36 INCCA Indian Network for Climate Change Assessment, 2010. India: Greenhouse Gas Emissions 2007. Ministry of Environment and Forests, Government of India.

37 Pradhan Mantri Ujjwala Yojana 2.0, (2021), *https://www.pmuy.gov.in/.*

The domestic sector uses lighting, air conditioning, cooking, refrigeration, and water heating energy. However, residential cooking emissions have been the main focus in the EIs developed for the residential sector. The following equation is generally used to compute emissions from fossil fuel combustion in residential stoves.[38]

$$E_i = \Sigma\,(Fuel_j \times EF_{i;j})$$

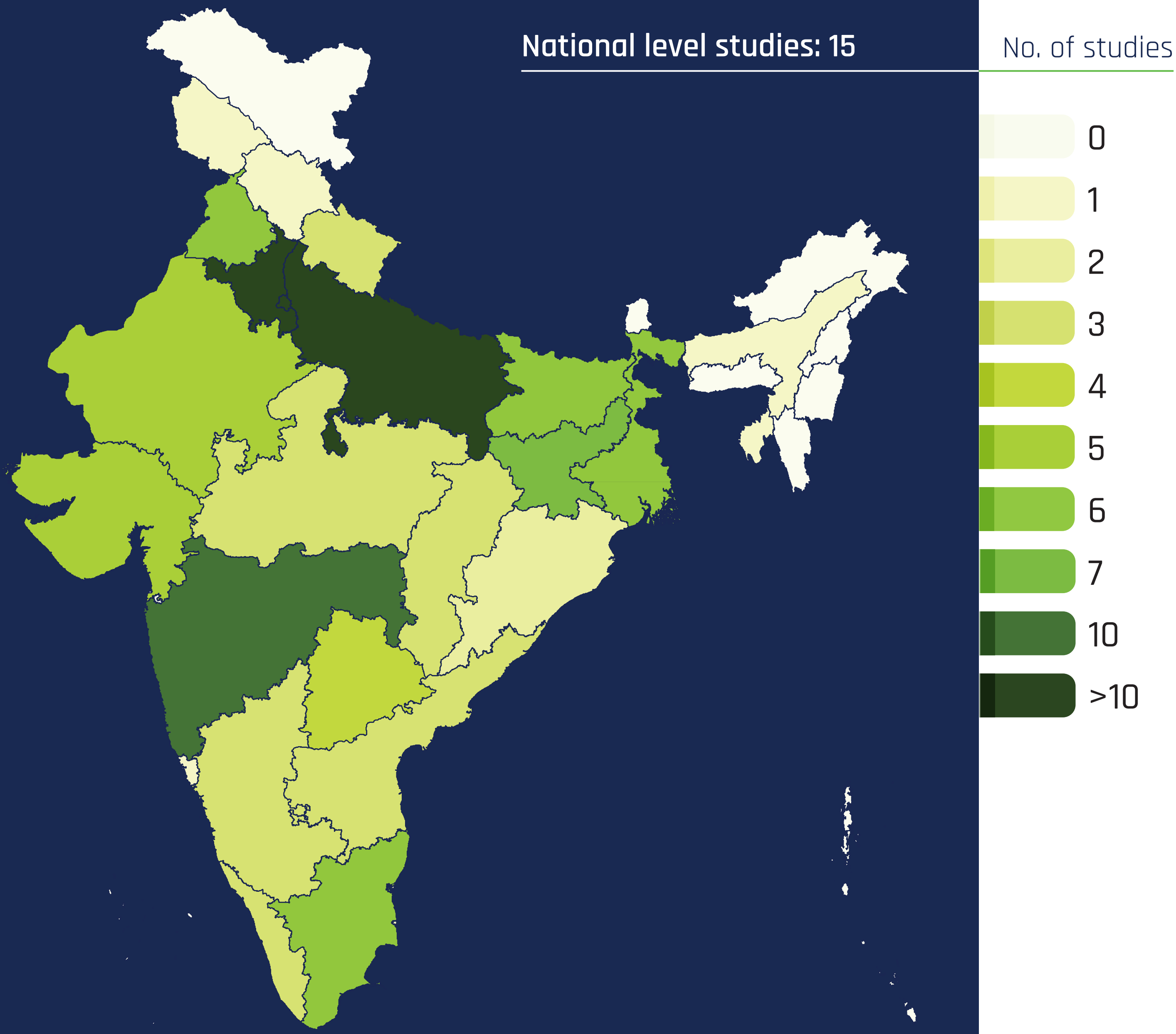
Where, E_i is the emission per compound (i)
$Fuel_j$ is the amount of fuel consumed by each type of fuel (j)
$EF_{i,\,j}$ is emissions of compound (i) per unit of energy (j).

Geographical Distribution

Many groups in India have developed EI for the domestic sector that has been distributed along with different cities and states. A total of 112 EI reports (See table 5) on the residential sector have been documented on a national and city-scale in India to date. The geographical distribution of EI studies on the household sector in India is shown in Map 4. Most EIs of the residential sector have been prepared for Delhi, Uttar Pradesh, and Maharashtra.

38 Gurjara, B. R., van Aardennea, J. A., Lelievelda, J., and Mohan, M. Emission estimates and trends (1990–2000) for megacity Delhi and implications. *Atmospheric Environment*, 38, 5663–5681.

MAP 4
GEOGRAPHICAL DISTRIBUTION OF RESIDENTIAL SECTOR EMISSION INVENTORY STUDIES



Overview

Most EI in the domestic sector has been built for PM ($PM_{2.5}$, PM_{10}), GHG (CO_2, CH_4), carbonaceous aerosols like BC, OC, and other gases like SO_2, NMVOCs. The geographical distribution of EI made for the domestic sector reflects the disparity in spatial representation. Only a few cities like Delhi, Chennai, Hyderabad, Ahmedabad, Kolkata, Mumbai, Bengaluru, Jamshedpur and cities in the Delhi-NCR area were frequently documented for the EI studies.

Some states like Meghalaya, Manipur, Mizoram and Nagaland in the North-eastern part of India have very sparse EI reports. Predictably, Delhi NCR has several EI reports for the domestic sector. About 15 national inventories have been developed on emissions from the residential sector. All the EIs for the residential sector at the national scale were mainly developed using secondary data, while EIs developed at the city scale used primary and secondary data. City-based EI has finer spatial resolution than the national inventories with coarse resolution. The grid size for city-based EI generally varies from 1 to 4 km^2, whereas nationwide inventory varies from 10 to 40 km^2. The coarse-resolution grid-scale tends to average the emission peaks on a sub-grid scale leading to spatial homogenization of emissions and might consequently result in lower emissions in some instances.[39,40] The city-scale finer resolution EIs provides more detailed emission features, which raises the accuracy of the input data for model simulation.

Emission factors used in the studies were both Indian and USEPA factors recommended by IPCC. Usage of EF of other countries that do not truly represent the Indian scenario might lead to uncertainty in the EI. To calculate the emissions from the residential sector, data such as the population, type of fuel used, the amount of fuel consumed, the time spent cooking, or heating, the type of stove used needs to be gathered from primary survey or secondary sources while preparing the EIs. Certain biomass fuels like wood, charcoal and coal in places of easy availability may also be used in rural households and are supplied by the small-time local vendors. Usage data for such fuels is not available. Hence, there might be an underestimation of the residential sector's overall emissions.

Primary data on household fuel consumption should ideally be collected during the two critical seasons, summer and winter, as fuel usage tend to increase significantly in winter. Further, due to unfavourable meteorological conditions, pollutant concentrations are much higher in the winter than in the summer. Reduced wind speed and lowered boundary layer height during winter limit the dispersion of pollutants in the atmosphere, resulting in increased surface pollutant concentrations. All these minor details are often missing, hence lowering the quality of EI reports.

About nine EI reports for cities including Delhi, Dhanbad, Jamshedpur, Madurai, Raipur, Palwal were solely developed from primary data sources.[41,42] Some of the EIs were based on both primary surveys and secondary sources. However, most of the EIs for the residential sector is based on secondary data sources.

There is an urgent need to bolster the availability of robust data, quantify the uncertainties, adopt standard methodologies and create fine spatial resolution inventories for the residential sector. Standard methodologies include comprehensive survey and primary data collection on domestic sources by questionnaire in the zone of influence (2×2 km^2) around each monitoring point and secondary data collection on domestic emissions through authorized organizations. The primary and secondary data must be analysed through appropriate techniques. Using GIS techniques, different types of pollution sources relevant to the location should be identified and mapped. To measure fuel consumption in the residential sector, data should be obtained from a sample of representative localities from various socioeconomic levels to assess differences between urban and suburban areas. The proposed data collection should cover the number of households, including the family members and the type, source, quantity, and fuel cost. Fuel supplying agencies will also be contacted for data on gross fuel use. Various fuels' daily per capita use will be approximated based on the data mentioned above.

39 Balasubramanian, S., McFarland, D. M., Koloutsou-Vakakis, S., Fu, K., Menon, R., Lehmann, C., and Rood, M. J., (2020). Effect of grid resolution and spatial representation of NH_3 emissions from fertilizer application on predictions of NH_3 and $PM_{2.5}$ concentrations in the United States Corn Belt, Environ. Res. Commun. 2, 025001.

40 Tan, J., Zhang, Y., Ma, W., Yu, Q., Wang, J., Chen, L., (2015). Impact of spatial resolution on air quality simulation: A case study in a highly industrialized area in Shanghai, China, Atmospheric Pollution Research, 6, 322-333.

41 Roy, D., Singh, G., Sinha, S., Park, J., and Seo, Y. C., (2020). Emission inventory of PM10 in Dhanbad/Jharia coalfield (JCF), India: an intricate coal mining sector, Environment, Development and Sustainability, *https://doi.org/10.1007/s10668-020-00702-4*

42 Pandey, A., Patel, S., Pervez, S., Tiwari, S., Yadama, G., Chow, J. C., Watson, J. G., Biswas, P., and Chakrabarty, R. K., (2017). Aerosol emissions factors from traditional biomass cookstoves in India: insights from field measurements, Atmos. Chem. Phys., 17, 13721–13729.

Table 5
List of Studies for Residential Sector Emission Inventory

Note:
Studies highlighted in green adhere closely to CPCB guidelines

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
1.	Agra-Mathura region	1981	–	Primary	Indian	SO_2	Central Board for The Prevention and Control Of Water Pollution New Delhi, Central Board For The Prevention And Control Of Water Pollution New Delhi, Inventory and Assessment of Pollution Emission in and around Agra-Mathura Region (Abridged), Control of Urban Pollution Series CUPS/7/1981-82 Available at: http://cpcbenvis.nic.in/scanned%20reports/Inventory%20and%20assessment%20of%20pollution%20emission%20in%20and%20around%20Agra-Mathura%20region%20(Abridged).pdf
2.	Cochin	1999	–	Primary	Indian	PM, HC, NOx, SOx, CO, NH_3, HCl+CL_2, Acid Mist, H_2S, F	"Emission Inventory or an Industrial area of India," P. Gargava, A. I. Aggarwal, Environmental Monitoring Assessment 55, 299-304 (1999) Available at: https://link.springer.com/article/10.1023/A:1005947026732
3.	Dhanbad	2001	–	Primary	Indian	SOx, NOx, SPM, CO, HC	J. K. Upadhyay, Jawaharlal Nehru University, (2001), Modelling of dispersion of pollutants from various sources using Advanced Gaussian Plume Model in convective boundary layer in Dhanbad region, (Emission Inventory of the Region, Chapter 3) Available at: https://shodhganga.inflibnet.ac.in/handle/10603/19236
4.	India	2002	25×25	Secondary	Indian, USEPA	SO_2, PM, BC, OM	"Inventory of aerosol and sulphur dioxide emissions from India: I-Fossil fuel combustion," M. S. Reddy, C. Venkataraman, Atmospheric Environment I36, 4, 677-697 (2002) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231001004630
5.	India	2002	25×25	Secondary	Indian, USEPA	SO_2, PM, BC, OM	"Inventory of aerosol and sulphur dioxide emissions from India. Part II—biomass combustion," M. S. Reddy, C. Venkataraman, Atmospheric Environment 36, 4, 699-712 (2002) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231001004642
6.	India	2003	–	Secondary	Foreign Literature	BC	"Large historical changes of fossil-fuel black carbon aerosols," T. Novakov, V. Ramanathan, J. E. Hansen, T. W. Krichstetter, M. Sato, J. E. Sinton, J. A. Sathaye, Geophysical Research Letters 30, 6 (2003) Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2002GL016345

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
7.	Delhi	2004	–	Secondary	Indian	CH_4, CO, CO_2, N_2O, NH_3, TSP, NMVOC, NOx, SO_2	"Emission estimates and trends (1990–2000) for megacity Delhi and implications," B. R. Gurjar, J. A. van Aardenne, J. Lelieveld, M. Mohan, Atmospheric Environment 38, 33, 5663-5681 (2004) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231004005394
8.	India	2004	–	Primary and Secondary	Indian, USEPA	SO_2, BC	"New methodology for estimating biofuel consumption for cooking: Atmospheric emissions of black carbon and sulfur dioxide from India," G. Habib, C. Venkataraman, M. Srivastava, R. Banerjee, J. W. Stehr, R. R. Dickerson, Global Biochemical Cycles 18, 3 (2004) Available at: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2003GB002157
9.	Jamshedpur	2005	1×1	Primary and Secondary	Indian	SO_2, NO_2	"Assessment of contribution of SO_2 and NO_2 from different sources in Jamshedpur region, India," A. Bhanarkar, S. K. Goyal, R. Sivacoumar, C.V. Chalapati Rao, Atmospheric Environment 39, 40, 7745-7760 (2005) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231005006515
10.	Pune	2007	2×2	–	–	PM_{10}	"Coupling of the Weather Research and Forecasting Model with AERMOD for pollutant dispersion modeling. A case study for PM_{10} dispersion over Pune, India," A. P. Kesarkar, M. Dalvi, A. Kaginalkar, A. Ojha, Atmospheric Environment 41, 9, 1976-1988 (2007) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231006010570
11.	Hyderabad	2008	–	Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NOx, CO_2	S. Guttikunda, Integrated Environmental Strategies Program Washington DC, USA, (2008), Co-Benefits Analysis of Air Pollution and GHG Emissions for Hyderabad, India Available at: https://urbanemissions.info/wp-content/uploads/docs/SIM-09-2008.pdf
12.	India	2008	100×100	Secondary	Indian, Foreign literature	BC	S. K. Sahu, G. Beig, C. Sharma, Geophysical Research Letters, (2008), Decadal growth of black carbon emissions in India Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2007GL032333
13.	Madurai	2008	1×1	Primary	–	PM_{10}	"Measurement and modeling of respirable particulate (PM_{10}) and lead pollution over Madurai, India," B. V. Bhaskar, R. V. J. Rajasekhar, P. Muthusubramanian, A. P. Kesarkar, Air, Quality, Atmosphere & Health 1, 45-55 (2008) Available at: https://link.springer.com/article/10.1007/s11869-008-0004-0

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
14.	Delhi, Gurgaon, Faridabad, Rohtak, Jhajjar, Noida, Ghaziabad	2011	1.67×1.67	Primary and Secondary	Indian	$PM_{2.5}$, PM_{10}	"Emissions inventory of anthropogenic PM 2.5 and PM 10 in Delhi during Commonwealth Games 2010," S. K. Sahu, G. Beig, N. Parkhi, Atmospheric Environment 45, 34, 6180-6190 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S135223101100834X
15.	Delhi	2011	–	Primary	Indian	TSP, SO_2, NO_2	"Air quality modelling study to analyse the impact of the world Bank emission guidelines for the thermal power plants in Delhi," A. Kansal, M. Khare, C. S. Sharma, Atmospheric Pollution Research 2, 1, 99-105 (2011) Available at: https://www.sciencedirect.com/science/article/pii/S1309104215305213
16.	Nagpur	2011	–	Secondary	Indian, USEPA, IPCC	CO_2, CH_4, N_2O, SO_2	"Sectoral CO_2, CH_4, N_2O and SO_2 emissions from fossil fuel consumption in Nagpur City of Central India," D. Majumdar, D. G. Gajghate, Atmospheric Environment 45, 25, 4170-4179 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231011005024
17.	Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}	"GIS-Based Emission Inventory, Dispersion Modeling, and Assessment for Source Contributions of Particulate Matter in an Urban Environment," S. N. Behera, M. Sharma, O. Dikshit, S. P. Shukla, Water, Air and Soil Pollution, 218, 423-436 (2011) Available at: https://link.springer.com/article/10.1007/s11270-010-0656-x
18.	Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}	S. N. Behera, M. Sharma, O. Dikshit, S. P. Shukla, Advanced Air Pollution, (2011), Development of GIS-aided Emission Inventory of Air Pollutants for an Urban Environment Available at: https://www.intechopen.com/chapters/17388
19.	Jamshedpur	2011	1×1	Primary	Indian	NOx	"Air pollution modeling for an industrial complex and model performance evaluation," R. Sivacoumar, A. D. Bhanarkar, S. K. Goyal, S. K. Gadkari, A. L. Aggarwal, Environmental Pollution 111, 3, 471-477 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S026974910000083X
20.	Delhi, Uttar Pradesh, Punjab, Haryana, Uttarakhand, Bihar	2011	–	Primary	Indian	PM, SO_2, NO, NO_2	"Emission estimates of particulate matter (PM) and trace gases (SO_2, NO and NO_2) from biomass fuels used in rural sector of Indo-Gangetic Plain, India," T. Saud, R. Gautam, T. K. Mandal, D. P. Singh, S. K. Sharma, M. Saxena, A. Mukherjee, Atmospheric Environment 45, 32, 5913-5923 (2011) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231011006248

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21.	Delhi	2012	–	Secondary	Indian, USEPA	CH_4, CO, CO_2, N_2O, NH_3, MVOC, NOx, SO_2, TSP	M. Mohan, S. Bhati, P. Gunwani, P. Marappu, InTech, (2012), Emission Inventory of Air Pollutants and Trend Analysis Based on Various Regulatory Measures Over Megacity Delhi Available at: https://www.intechopen.com/chapters/37983
22.	Delhi, Punjab, Haryana, Uttar Pradesh, Uttarakhand, Bihar, West Bengal	2012	–	Primary	Indian	EC, OC	"Emission estimates of organic and elemental carbon from household biomass fuel used over the Indo-Gangetic Plain (IGP), India," T. Saud, R. Gautam, T. K. Mandal, D. P. Singh, S. K. Sharma, M. Dahiya, M. Saxena, Atmospheric Environment 61, 212-220 (2012) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231012007029
23.	India	2012	100×100	Secondary	Indian	NOx	"Emerging pattern of anthropogenic NOx emission over Indian subcontinent during 1990s and 2000s," S. K. Sahu, G. Beig, N. S. Parkhi, Atmospheric Pollution Research 3, 3, 262-269 (2012) Available at: https://doi.org/10.5094/APR.2012.021
24.	Angul	2012	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3086%5C
25.	Korba	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3087
26.	Auraiya	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3088
27.	Anta	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3089
28.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian, Foreign literature	PM, SO_2, NOx, CO, VOC	"A GIS based emissions inventory at 1 km x 1 km spatial resolution for air pollution analysis in Delhi, India," S. K. Guttikunda, G. Calori, Atmospheric Environment 67, 101-111 (2013) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231012010229
29.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, NOx, CO, VOC	"Health impacts of particulate pollution in a megacity—Delhi, India," S. K. Guttikunda, R. Goel, Environmental Department 6, 8-20 (2013) Available at: https://www.sciencedirect.com/science/article/abs/pii/S2211464512001492
30.	Kanpur	2013	2×2	Primary and Secondary	Indian, USEPA	PM, SO_2, NOx	"Respiratory Disease in Relation to Outdoor Air Pollution in Kanpur, India." H-Y Liu, A. Bartonova, M. Schindler, M. Sharma, S. N. Behera, K. Katiyar, O. Dikshit, Arch Environ Occup Health 68, 4, 204-217 (2013) Available at: https://pubmed.ncbi.nlm.nih.gov/23697693/

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31.	Patna	2014	1×1	Secondary	Indian, USEPA	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC, CO_2	S. K. Guttikunda, P. Jawahar, UrbanEmissions.Info., (2014), Characterizing Patna's Ambient Air Quality and Assessing Opportunities for Policy Intervention Available at: https://shaktifoundation.in/wp-content/uploads/2017/06/Urban-Emissions-2014-AQM-in-Patna-Final-Report.pdf
32.	Delhi	2014	–	Primary and Secondary	Indian, Foreign literature	PM_{10}	"Speciated PM_{10} Emission Inventory for Delhi, India," P. Gargava, J. C. Chow, J. G. Watson, D. H. Lowenthal, Aerosol and Air Quality Research 14, 5, 1515-1526 (2014) Available at: https://aaqr.org/articles/aaqr-13-02-oa-0047
33.	Hyderabad	2014	–	Primary	Indian, USEPA, GAINS	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC, CO_2	"Source emissions and health impacts of urban air pollution in Hyderabad, India," S. K. Guttikunda, R. V. Kopakka, Air Qual Atmos Health 7, 195-207 (2014) Available at: https://link.springer.com/article/10.1007/s11869-013-0221-z
34.	India	2014	25×25	Secondary	Indian, USEPA	$PM_{2.5}$, BC, OC, CO, NOx, NMVOC, CH_4	"Trends in multi-pollutant emissions from a technology-linked inventory for India: II. Residential, agricultural and informal industry sectors," A. Pandey, P. Sadavarte, A. B. Rao, C. Venkataraman, Atmospheric Environment 99, 341-352 (2014) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231014007742
35.	Chennai, Vishakapatnam	2015	1×1	Primary and Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NO_2	"Particulate and gaseous emissions in two coastal cities—Chennai and Visakhapatnam, India," S. K. Guttikunda, R. Goel, D. Mohan, G. Tiwari, Air Quality, Atmosphere & Health 8, 6, 559-572 (2015) Available at: https://link.springer.com/article/10.1007/s11869-014-0303-6
36.	Delhi	2015	2×2	Secondary	Indian	CO, NOx, SO_2, PM_{10}	"Anthropogenic Emission Inventory of Criteria Air Pollutants of an Urban Agglomeration - National Capital Region (NCR), Delhi," R. Sindhwani, P. Goyal, S. Kumar, A. Kumar, Aerosol and Air Quality Research 15, 1681-1697 (2015) Available at: https://aaqr.org/articles/aaqr-14-11-oa-0271
37.	India	2015	36×36	Secondary	USEPA, GAINS, CITEPA	NMVOC	"Emission inventory of non-methane volatile organic compounds from anthropogenic sources in India," S. Sharma, A. Goel, D. Gupta, A. Kumar, A. Mishra, S. Kundu, S. Chatani, Z. Klimont, Atmospheric Environment 102, 209-219 (2015) Available at: https://doi.org/10.1016/j.atmosenv.2014.11.070
38.	Delhi	2015	1.67×.67	Primary and Secondary	Indian, USEPA	NOx, CO	"High Resolution Emission Inventory of NOx and CO for Mega City Delhi, India," S. K. Sahu, G. Beig, N. Parkhi, Aerosol and Air Quality Research 15, 3, 1137-1144 (2015) Available at: https://aaqr.org/articles/aaqr-14-07-tn-0132

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39.	Amritsar	2015	–	Primary	Indian	PM_{10}, SO_2, NOx	"Assessment of Urban Air Quality around a Heritage Site Using AERMOD: A Case Study of Amritsar City, India," S. Gulia, A. Shrivastva, A. K. Nema, M. Khare, Environ Model Assess 20, 6, 599-608 (2015) Available at: https://link.springer.com/article/10.1007/s10666-015-9446-6
40.	Delhi	2016	2×2	Primary and Secondary	Indian	PM_{10}, $PM_{2.5}$, NOx, CO	M. Sharma, O. Dikshit, Department of Environment Government of National Capital Territory of Delhi, Delhi Pollution Control Committee, (2016), Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi (Final Report: Air Pollution component) Available at: https://cerca.iitd.ac.in/uploads/Reports/1576211826iitk.pdf
41.	India	2016	40×40	Secondary	Indian, Foreign literature	BC	"Monthly and Spatially Resolved Black Carbon Emission Inventory of India: Uncertainty Analyses," U. Paliwal, M. Sharma, J. F. Burkhart, Atmos. Chem. Phys. 16, 12457-12476 (2016) Available at: https://acp.copernicus.org/articles/16/12457/2016/acp-16-12457-2016.html
42.	India	2016	36×36	Secondary	Indian, GAINS, USEPA	NOx, NMVOC, CO	"Sensitivity analysis of ground level ozone in India using WRF-CMAQ models," S. Sharma, S. Chatani, R. Mahatta, A. Goel, A. Kumar, Atmospheric Environment 131, 29-40 (2016) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231016300504
43.	Ahmedabad	2017	1.67×1.67	Primary and Secondary	Indian	NOx, CO, BC, OC, $PM_{2.5}$, PM_{10}, SO_2, VOC	G. Beig, N. S. Parkhi, Earth System Science Organization, Ministry of Earth sciences, Govt. of India, Indian Institute of Tropical Meteorology, Pune, (2017), Development of High-Resolution Emission Inventory for Ahmedabad Metropolitan Region (AMR) System of Air Quality and weather Forecasting and Research (SAFAR)- Ahmedabad Available at: http://assets.nrdc.org/sites/default/files/media-uploads/safar-ahmedabad-ei-2017-full_report.pdf
44.	Agra	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Agra, India Available at: https://urbanemissions.info/india-apna/agra-india/
45.	Amritsar	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Amritsar, India Available at: https://urbanemissions.info/india-apna/amritsar-india/

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46.	Bengaluru	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bengaluru, India Available at: https://urbanemissions.info/india-apna/bengaluru-india/
47.	Bhopal	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bhopal, India Available at: https://urbanemissions.info/india-apna/bhopal-india/
48.	Bhubhneshwar	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Bhubaneswar, India Available at: https://urbanemissions.info/india-apna/bhubaneswar-india/
49.	Chandigarh	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Chandigarh, India Available at: https://urbanemissions.info/india-apna/chandigarh-india/
50.	Chennai	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Chennai, India Available at: https://urbanemissions.info/india-apna/chennai-india/
51.	Coimbatore	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Coimbatore, India Available at: https://urbanemissions.info/india-apna/coimbatore-india/
52.	Dehradun	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Dehradun, India Available at: https://urbanemissions.info/india-apna/dehradun-india/
53.	Indore	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Indore, India Available at: https://urbanemissions.info/india-apna/indore-india/

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54.	Jaipur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Jaipur, India Available at: https://urbanemissions.info/india-apna/jaipur-india/
55.	Kanpur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Kanpur, India Available at: https://urbanemissions.info/india-apna/kanpur-india/
56.	Kochi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Kochi, India Available at: https://urbanemissions.info/india-apna/kochi-india/
57.	Ludhiana	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Ludhiana, India Available at: https://urbanemissions.info/india-apna/ludhiana-india/
58.	Nagpur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Nagpur, India Available at: https://urbanemissions.info/india-apna/nagpur-india/
59.	Patna	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Patna, India Available at: https://urbanemissions.info/india-apna/patna-india/
60.	Pune	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Pune, India Available at: https://urbanemissions.info/india-apna/pune-india/
61.	Ranchi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Ranchi, India Available at: https://urbanemissions.info/india-apna/pune-india/
62.	Raipur	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Raipur, India Available at: https://urbanemissions.info/india-apna/raipur-india/

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63.	Varanasi	2017	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Varanasi, India Available at: https://urbanemissions.info/india-apna/varanasi-india/
64.	Kolkata, Kharagpur, Delhi, Kanpur, Hyderabad, Pune	2017	–	Secondary	Indian, USEPA	BC	"Estimates of spatially and temporally resolved constrained black carbon emission over the Indian region using a strategic integrated modelling approach," S. Verma, D. M. Reddy, S. Ghosh, D. B. Kumar, A. K. Chowdhury, Atmospheric Environment 195, 9-19 (2017) Available at: https://www.sciencedirect.com/science/article/pii/S0169809517300133
65.	Raipur	2017	–	Primary	Indian	$PM_{2.5}$, OC, EC	"Aerosol emissions factors from traditional biomass cookstoves in India: insights from field measurements," A. Pandey, S. Patel, S. Pervez, S. Tiwari, G. Yadama, J. C. Chow, J. G. Watson, P. Biswas, R. K. Chakrabarty, Atmos. Chem. Phys. 17, 22 (2017) Available at: https://acp.copernicus.org/articles/17/13721/2017/
66.	Delhi, NCR	2018	4×4	Primary	Indian	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC	Automotive Research Association of India, The Energy and Resources Institute, Department of Heavy Industry Ministry of Heavy Industries and Public Enterprises, New Delhi, (2018), Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources Available at: https://www.teriin.org/sites/default/files/2018-08/Exec-summary_0.pdf
67.	India	2018	10×10	Secondary	Indian, GAINS	$PM_{2.5}$, BC, OC, SO_2, NOx, NMVOC	"Source influence on emission pathways and ambient $PM_{2.5}$ pollution over India (2015–2050)," C. Venkataraman, M. Brauer, K. Tibrewal, P. Sadavarte, Q. Ma, A. Cohen, S. Chaliyakunnel, J. Frostad, Z. Klimont, R. V. Martin, D. B. Millet, S. Philip, K.Walker, S. Wang, Atmos. Chem. Phys. 18, 8017–8039 (2018) Available at: https://acp.copernicus.org/articles/18/8017/2018/acp-18-8017-2018.html
68.	India	2018	12×12	Secondary	GAINS	NOx, SO_2, $PM_{2.5}$	"Urban versus rural health impacts attributable to $PM_{2.5}$ and O_3 in northern India," A. Karambelas, T. Holloway, P. L. Kinney, A. M. Fiore, R. DeFries, G. Kiesewettwer, C. Heyes, Environmental Research Letters 13,6, 064010 (2018) Available at: https://iopscience.iop.org/article/10.1088/1748-9326/aac24d
69.	Palwal	2018	–	Primary	Indian	CO, CO_2, VOC, $PM_{2.5}$	"Emissions from village cookstoves in Haryana, India, and their potential impacts on air quality," L. T. Fleming, R. Weltman, A. Yadav, R. D. Edwards, N. K. Arora, A. Pillarisetti, S. Meinardi, K. R. Smith, D. R. Blake, S. A. Nizkorodov, Atmos. Chem. Phys. 18, 20 (2018) Available at: https://acp.copernicus.org/articles/18/15169/2018/

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
70.	Bangalore	2019	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC	"Air quality, emissions, and source contributions analysis for the Greater Bengaluru region of India," S. K. Guttikunda, Nishad. K A, S. Gota, P. Singh, Atmospheric Pollution Research 10, 3, 941-953 (2019) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1309104218304835
71.	Patna	2019	1×1	Primary and Secondary	Indian, USEPA	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC, CO_2	Center for Study of Science, Technology and Policy, Center for Environment, Energy and Climate Change, Asian Development Research Institute, Urban Emissions, Bihar State Control Board, (2019), Comprehensive Clean Air Action Plan for the City of Patna Available at: https://shaktifoundation.in/wp-content/uploads/2019/12/PCAAP_Report_Final-3-1.pdf
72.	Amravati	2019	–	Primary and Secondary	Indian, Foreign literature	$PM_{2.5}$	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), Action Plan for Control Of Air Pollution In Non-Attainment Cities Of Maharashtra Amaravati Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Amravati_Action_Plan07112019.pdf
73.	Chandrapur	2019	1×1	Primary	Indian	PM, CO, HC, NOx	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), Action Plan Of Control Of Air Pollution In Non-Attainment Cities Of Maharashtra Chandrapur Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Chandrapur_Action_Plan07112019.pdf
74.	Agartala	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Agartala (Tripura, India) Available at: https://urbanemissions.info/india-apna/agartala-india/
75.	Ahmedabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Ahmedabad (Gujarat, India) Available at: https://urbanemissions.info/india-apna/ahmedabad-india/
76.	Allahabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Prayagraj (Allahabad) (Uttar Pradesh, India) Available at: https://urbanemissions.info/india-apna/allahabad-india/
77.	Asansol	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Asansol (West Bengal, India) Available at: https://urbanemissions.info/india-apna/asansol-india/

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
78.	Aurangabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Aurungabad (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/aurungabad-india/
79.	Dharwad-Hubli	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Dharwad-Hubli (Karnataka, India) Available at: https://urbanemissions.info/india-apna/dharwad-india/
80.	Dhanbad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Dhanbad (Jharkhand, India) Available at: https://urbanemissions.info/india-apna/dhanbad-india/
81.	Gaya	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Gaya (Bihar, India) Available at: https://urbanemissions.info/india-apna/gaya-india/
82.	Guwahati	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Guwahati (Assam, India) Available at: https://urbanemissions.info/india-apna/guwahati-india/
83.	Gwalior	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Gwalior (Madhya Pradesh, India) Available at: https://urbanemissions.info/india-apna/gwalior-india/
84.	Greater Mumbai	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Mumbai (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/mumbai-india/
85.	Greater Kolkata	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Kolkata (West Bengal, India) Available at: https://urbanemissions.info/india-apna/kolkata-india/

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
86.	Hyderabad	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Hyderabad, (Telengana, India) Available at: https://urbanemissions.info/india-apna/hyderabad-india/
87.	Jamshedpur	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Jamshedpur (Jharkhand, India) Available at: https://urbanemissions.info/india-apna/jamshedpur-india/
88.	Jodhpur	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Jodhpur (Rajasthan, India) Available at: https://urbanemissions.info/india-apna/jodhpur-india/
89.	Kota	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Kota (Rajasthan, India) Available at: https://urbanemissions.info/india-apna/kota-india/
90.	Lucknow	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Lucknow (Uttar Pradesh, India) Available at: https://urbanemissions.info/india-apna/lucknow-india/
91.	Madurai	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Madurai (Tamil Nadu, India) Available at: https://urbanemissions.info/india-apna/madurai-india/
92.	Nashik	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Nashik (Maharashtra, India) Available at: https://urbanemissions.info/india-apna/nashik-india/
93.	Panjim-Vasco-Margao	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Panjim (Goa, India) Available at: https://urbanemissions.info/india-apna/panjim-india/

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94.	Puducherry	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Puducherry (Puducherry, India) Available at: https://urbanemissions.info/india-apna/puducherry-india/
95.	Rajkot	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Rajkot (Gujarat, India) Available at: https://urbanemissions.info/india-apna/rajkot-india/
96.	Shimla	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Shimla (Himachal Pradesh, India) Available at: https://urbanemissions.info/india-apna/shimla-india/
97.	Srinagar	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2017), India – Air Pollution Knowledge Assessment (APnA) city program City – Srinagar (Jammu and Kashmir, India) Available at: https://urbanemissions.info/india-apna/srinagar-india/
98.	Surat	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Surat (Gujarat, India) Available at: https://urbanemissions.info/india-apna/surat-india/
99.	Thiruvananth-puram	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Thiruvananthapuram (Kerela, India) Available at: https://urbanemissions.info/india-apna/thiruvananthapuram-india/
100.	Tiruchupalli	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Tiruchirapalli (Tamil Nadu, India) Available at: https://urbanemissions.info/india-apna/tiruchirapalli-india/
101.	Vadodara	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vadodara (Gujarat, India) Available at: https://urbanemissions.info/india-apna/vadodara-india/

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102.	Vijayawada	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vijayawada (Andhra Pradesh, India) Available at: https://urbanemissions.info/india-apna/vijayawada-india/
103.	Vishakapatnam	2019	1×1	Secondary	Indian, USEPA	SO_2, NOx, CO, NMVOC, CO_2, $PM_{2.5}$, PM_{10}, BC, OC	Shakti Sustainable Energy Foundation, UrbanEmissions.Info., (2019), India – Air Pollution Knowledge Assessment (APnA) city program City – Vishakhapatnam (Andhra Pradesh, India) Available at: https://urbanemissions.info/india-apna/visakhapatnam-india/
104.	Kolkata	2020	–	Primary and Secondary	Indian, USEPA, GAINS	PM_{10}, $PM_{2.5}$, BC, OC, SO_2, NOx, CO, VOC, NH_3	"Managing future air quality in megacities: Emission inventory and scenario analysis for the Kolkata Metropolitan City, India," D. Majumdar, P. Purohit, A. D. Bhanarkar, P. S. Rao, P. Rafaj, M. Amann, R. Sander, A. Pakrashi, A. Srivastava, Atmospheric Environment 222, 117135 (2020) Available at: http://pure.iiasa.ac.at/id/eprint/16221/
105.	Delhi	2020	2×2	Primary	Indian, USEPA	$PM_{2.5}$ and its species	"A framework for $PM_{2.5}$ constituents-based (including PAHs) emission inventory and source toxicity for priority controls: A case study of Delhi, India," A. K. Pathak, M. Sharma, P. K. Nagar, Chemosphere 255, 126971 (2020) Available at: https://www.sciencedirect.com/science/article/abs/pii/S0045653520311644
106.	Ludhiana	2020	2×2	Primary and Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO	Punjab State Council for Science & Technology, Chandigarh, The Energy & Resources Institute, New Delhi, Punjab Pollution Control Board, (2020), Source Apportionment Study to Prepare Action Plan to improve Air Quality of Ludhiana City Available at: https://ppcb.punjab.gov.in/sites/default/files/documents/N_8278_1625047519404.pdf
107.	Jaipur	2020	2×2	Primary and Secondary	Indian, USEPA	PM_{10}, $PM_{2.5}$, NOx, SO_2, CO	M. Sharma, Rajasthan State Pollution Control Board, Jaipur, (2020), Air Quality Assessment, Trend Analysis, Emission Inventory and Source Apportionment Study in Jaipur City (Final Report) Available at: https://environment.rajasthan.gov.in/content/dam/environment/RPCB/EnvironmentalReport/Final-Report-Source-Apportionmnent-Study-Jaipur-IITKanpur.pdf
108.	India	2021	36×36	Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, NMVOC	"Air Pollution Over India: Causal Factors for the High Pollution with Implications for Mitigation," N. Singh, S. Agarwal, S. Sharma, S. Chatani, V. Ramanathan, ACS Earth Space Chem. 5, 12, 3297-3312 (2021) Available at: https://pubs.acs.org/doi/10.1021/acsearthspacechem.1c00170

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
109.	Dhanbad	2021	2×2	Primary	Indian	PM_{10}	"Emission inventory of PM_{10} in Dhanbad/Jharia coalfield (JCF), India: an intricate coal mining sector," D. Roy, G. Singh, S. Sinha, J. Park, Y-C Seo, Environment, Development and Sustainability 23, 3048-3061 (2021) Available at: https://link.springer.com/article/10.1007/s10668-020-00702-4
110.	India	2021	10×10	Secondary	Indian	$PM_{2.5}$	"Establishing a link between fine particulate matter ($PM_{2.5}$) zones and COVID -19 over India based on anthropogenic emission sources and air quality data," S. K. Sahu, P. Mangaraj, G. Beig, B. Tyagi, S. Tikle, V. Vinoj, Urban Climate 38, 100883 (2021) Available at: https://www.sciencedirect.com/science/article/pii/S2212095521001139
111.	India	2021	36×36	Secondary	Indian, GAINS, USEPA	PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, VOC, NH_3	The Energy and Resources Institute, The Energy And Resources Institute, Development Of Spatially Resolved Air Pollution Emission Inventory Of India Available at: https://www.teriin.org/sites/default/files/2021-05/Exxon-Report.pdf
112.	Delhi	2021	2×2	Secondary	Indian, GAINS, USEPA	$PM_{2.5}$, NOx, SO_2	Dr. A. Goel, The Energy and Resources Institute, The Energy and Resources Institute, (2021), Cost-effectiveness Analysis of Control Options for Managing Air Quality in Delhi Available at: https://www.teriin.org/sites/default/files/2021-12/Cost-effectiveness-of%20-interventions-for-control-of%20-air-pollution-in-Delhi.pdf

7

INVENTORY OF EMISSION FROM AGRICULTURE, ROAD DUST AND MISCELLANEOUS SECTORS

Introduction

Emissions from agricultural activities and biomass burning, construction and demolition waste, road dust (paved and unpaved) and burning of municipal solid waste contribute richly to the overall emission load within an area. These sources are often accounted for only while carrying out total emission inventory studies. Some niche sectors cumulatively have a sizable emission load apart from the core sectors. These include brick kilns, generator sets, bio-medical incinerators, crematoria, concrete batching, small restaurants and eateries and emissions from aviation and shipping. EI reports for generator sets have been covered under industrial emissions.

The agriculture sector is considered a rich source of emissions. Most EI reports focus on GHG emissions like CH_4, N_2O and CO_2 from the sector. From an air pollution perspective, burning biomass such as crop residue has garnered much attention in the past decade and most EI reports focus solely on that, mainly paddy stubble burning. However, detailed emission inventories are required for other sources related to agriculture. For instance, emissions from farm vehicles.

Waste burning is one of the primary causes of the release of methane and many other chlorinated pollutants like dioxins and furans, along with regular PM. While methane emissions from landfills are usually covered in GHG inventories, other emissions from waste are not well tallied. Understanding emission load at a local scale will be crucial for planning mitigation strategies. In addition, other under-studied sources of pollutants significantly impact the overall emission load when combined. For example, the restaurant industry has seen tremendous growth in the last two decades but remains largely unorganised. Various fuel is used for cooking, including liquefied petroleum gas (LPG), charcoal, wood and coal. These release pollutants like PM, CO_2, NO_2, SO_2 and NMVOC. This industry is usually overlooked while preparing EI reports as its not considered a significant contributor, like transport or power plants.[43]

India is a developing country, and large scale infrastructure projects are likely to continue. This is certain to increase the amount of construction and demolition (C&D) waste generated. Dust emissions from the C&D sector constitute a significant source of PM. It is estimated that 112 to 700 million tonnes/year of C&D waste is generated in India.[44] Out of this, only about 50% is recycled or re-utilised. The remaining end up in landfills.[45] Since C&D waste primarily comprises concrete, metals and wood, spontaneous combustion in landfills also leads to the release of pollutants in the air, apart from the dust. While road dust re-suspension is well studied for all total emission inventory reports, inventory of emissions solely from C&D waste is limited.

43 Emissions of greenhouse and non-greenhouse air pollutants from fuel combustion in restaurant industry," D. Majumdar, A. Chintada, J. Sahu, C. V. Chalapati Rao, International Journal of Environmental Science and Technology 10, 995-1006 (2013)

44 M. Ramanathan, V. G. Rao, Sustainable Environmental Geotechnics, Proceedings of EGRWSE, (2019), pp. 95-105. 10.1007/978-3-030-51350-4_11

45 "The Impact of C & D Waste on Indian Environment: A Critical Review," S. Gupta, R. K. Malik, *Civil Engineering Research Journal* 5, 2 (2018)

Overview

Most studies that have reported emission inventory of these sectors have used a combination of Indian emission factors and those developed by USEPA. Indian emission factors are available for agricultural biomass burning and burning of MSW. However, for road dust, EF developed by USEPA are usually used.

Common Emission Factors

Road Dust

$$E = \text{Vehicle Kilometres Travelled (VKT)} \times \text{Emission Factor (EF)}$$

$$EF = k\,(SL)0.91 \times (W)1.02 \times (1-P/4N)$$

Based on AP42 methodology,[46] E is Emissions due to resuspension of road dust, SL is silt loading (g/m^2), W is average weight of fleet in tons, P is number of rainy days and N is number of days.

Agricultural Waste Burning[47]

$$E = Pc \times Rc \times fDc \times fBc \times Bf \times EFpol$$

where Rc: fraction of residue generated for the production (Pc),[48] fDc: fraction of dry matter in the residue of the particular crop (c),[49] fBc: combustion efficiency of crop residue that is burnt. Bf: burning fraction of the crop estimated on the basis of MODIS FRP data. EFpol: emission factor of the pollutant (g/kg).

Waste/Refuse Burning[50]

$$E = \text{Population} \times \text{per capita waste generation} \times (1-\text{Collection efficiency}) \times 0.6 \times \text{Emission factor}$$

The factor 0.6 is based on the different studies conducted on the MSW burning, wherein it has been found that about 60% of the uncollected waste is burned. Hence 0.6 has been used as a multiplication factor in the formula.

Brick Kilns

$$E = \text{Brick production} \times \text{Distribution of technology used for production} \times EF$$

(based on technology of brick production)

46 USEPA. 2015. AP-42 emission factor database. Washington, DC: United State Environment Protection Agency. Available at: *www.epa.gov/ttnchie1/ap42/*.

47 Air pollutant emissions scenario for India. TERI. 2016. Accessed from: *https://www.researchgate.net/publication/ 317105835_Air_pollutant_emissions_scenario_for_India*.

48 Jain, N., Bhatia, A., and Pathak, H. Emission of air pollutants from crop residue burning in India. *Aerosol* and *Air Quality Research*. 2014, 14:422–30.

49 Turn, S.Q., Jenkins, B.M., Pritchet, L.C., Campbell, D., Cahill, T., Whalen, S.A. Elemental characterization of particulate matter emitted from biomass burning: Wind tunnel derived source profiles for herbaceous and wood fuels. Journal of Geophysical Research, 1997,102, 3686–3699

50 Singh, N., Agarwal, S., Sharma, S., Chatani, S., & Ramanathan, V. (2021). Air Pollution Over India: Causal Factors for the High Pollution with Implications for Mitigation. *ACS Earth and Space Chemistry*. 5(12), 3297-3312

During the course of the literature search, 56 studies were found, which included these less studied sectors. Studies on agricultural biomass were most common, while most EI reports related to solid waste focused on GHG and methane, though not from an air pollution perspective. Since the sectors were so varied, various pollutants had ben inventoried, including but not limited to $PM_{2.5}$, PM_{10}, SO_2, NOx, CO, VOC, CO_2, NMVOC, EC, OC, PAH and some elemental ions. However, there are no inventory reports of toxins such as dioxins, furans or any heavy metals like mercury(Hg).

Most of the reports for these sectors only focused on a particular city. Funding needs to be allocated to encourage national-level inventories for these sectors that are otherwise ignored. Predictably, emission factors have not been developed for many sources, like road dust and C&D waste and other construction activities. At present, EFs from the USEPA –AP42 document is most commonly used.

Emission inventory of these less-studied sectors provides a unique opportunity to develop standards. For instance, if their EI reports are developed for toxics coming from refuse burning or emissions from electro-plating units, there would be a need to create standards to devise any enforcement-based mitigation strategies. Similarly, emissions from restaurants are not well studied. However, accounting for these would first lead to the complete data for any city, and secondly would be crucial to formulating standards. At present, there is the usual perception that these account for tiny fraction of the emission load and hence do not warrant any standards. Our pollution sources are evolving and expanding. We now have uncommon sources like incinerators, bakeries, stone crushers, and the omnipresent fugitive emissions in industries that need to be accounted for. Therefore, there should be a focus on developing Indian emission factors for these activities and developing emission inventory reports.

Table 6
List of Studies for Agriculture, Road Dust and Miscellaneous Sectors Emission Inventory

Note:
Studies highlighted in green adhere closely to CPCB guidelines

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
1.	Agra-Mathura region	1981	–	Primary	Indian	SO_2	Central Board for The Prevention and Control Of Water Pollution New Delhi, Central Board For The Prevention And Control Of Water Pollution New Delhi, Inventory and Assessment of Pollution Emission in and around Agra-Mathura Region (Abridged), Control of Urban Pollution Series CUPS/7/1981-82 Available at: http://cpcbenvis.nic.in/scanned%20reports/Inventory%20and%20assessment%20of%20pollution%20emission%20in%20and%20around%20Agra-Mathura%20region%20(Abridged).pdf
2.	India	2000	–	Secondary	Indian, USEPA	$PM_{2.5}$	"Atmospheric optical and radiative effects of anthropogenic aerosol constituents from India," M. S. Reddy, C. Venkataraman, Atmospheric Environment 34, 26, 4511-4523 (2000) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231000001059
3.	India	2001	District level	Secondary	IPCC	SO_2, NOx	"Sub-region (district) and sector level SO_2 and NOx emissions for India: assessment of inventories and mitigation flexibility," A. Garg, P. R. Shukla, S. Bhattacharya, V. K. Dhadwal, Atmospheric Environment 35, 4, 703-713 (2001) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231000003162
4.	Delhi	2004	–	Secondary	Indian	CH_4, CO, CO_2, N_2O, NH_3, NMVOC, NOx, SO_2, TSP	"Emission estimates and trends (1990–2000) for megacity Delhi and implications," B. R. Gurjar, J. A. van Aardenne, J. Lelieveld, M. Mohan, Atmospheric Environment 38, 33, 5663-5681 (2004) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231004005394
5.	India	2004	–	Primary and Secondary	Indian, USEPA	BC	"New methodology for estimating biofuel consumption for cooking: Atmospheric emissions of black carbon and sulfur dioxide from India," G. Habib, C. Venkataraman, M. Srivastava, R. Banerjee, J. W. Stehr, R. R. Dickerson, Global Biochemical Cycles 18, 3 (2004) Available at: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2003GB002157

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
6.	India	2006	1×1	Secondary	Others (Published Literature)	BC, OM, $PM_{2.5}$, CO_2, CO, NOx, SO_2, NMVOC, NH_3	"Emissions from open biomass burning in India: Integrating the inventory approach with high-resolution Moderate Resolution Imaging Spectroradiometer (MODIS) active-fire and land cover data," C. Venkataraman, G. Habib, D. Kadamba, M. Srivastava, J.-F. Leon, B. Crouzille, O. Boucher, D. G. Streets, Global Biochemical Cycles 20, 2 (2006) Available at: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2005GB002547
7.	Pune	2007	2×2	–	–	PM_{10}	"Coupling of the Weather Research and Forecasting Model with AERMOD for pollutant dispersion modeling. A case study for PM_{10} dispersion over Pune, India," A. P. Kesarkar, M. Dalvi, A. Kaginalkar, A. Ojha, Atmospheric Environment 41, 9, 1976-1988 (2007) Available at: https://www.infona.pl/resource/bwmeta1.element.elsevier-eff212b0-b96b-318a-b293-2866c46e961f
8.	Hyderabad	2008	–	Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NOx, CO_2	S. Guttikunda, Integrated Environmental Strategies Program Washington DC, USA, (2008), Co-Benefits Analysis of Air Pollution and GHG Emissions for Hyderabad, India Available at: https://urbanemissions.info/wp-content/uploads/docs/SIM-09-2008.pdf
9.	Mumbai	2008	–	Secondary	USEPA	TSP, PM_{10}, NOx, SO_2	"Estimation of air pollutant emission loads from construction and operational activities of a port and harbour in Mumbai, India," J. Joseph, R. S. Patil, S. K. Gupta, Environ Monit Assess 159, 85 (2009) Available at: https://pubmed.ncbi.nlm.nih.gov/19030999/
10.	Eastern Ghats of India	2008	–	Primary and Secondary	–	CO, CO_2, O_3	"Biomass Burning Emission Inventory from Remote Sensing, GIS and Ground Based Measurements - A Case Study from Secondary Mixed Deciduous Forests, India," V. K. Prasad, K. V. S. Badrinath, P. K. Gupta, Geocarto International 17, 2, 13-20 (2008) Available at: https://www.tandfonline.com/doi/abs/10.1080/10106040208542231
11.	Kanpur	2008	–	–	Indian	PM	"Assessment of fugitive road dust emissions in Kanpur, India: A note," V. S. Bhaskar, M. Sharma, Transportation Research Part D: Transport and Environment 13, 6, 400-403 (2008) Available at: https://trid.trb.org/view/874721
12.	Chandrapur	2009	–	Primary	USEPA	TSPM	"Dust dispersion modeling using fugitive dust model at an opencast coal project of Western Coalfields Limited, India," R. Trivedi, M. K. Chakraborty, B. K. Tewary, CSIR, 68, 71-78 (2009) Available at: http://nopr.niscair.res.in/handle/123456789/2794

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
13.	Maharashtra, Madhya Pradesh	2010	–	Satellite	Satellite	NOx	"Rain-Induced Soil NOx Emission from India During the Onset of the Summer Monsoon: A Satellite Perspective," S. D. Ghude, D. M. Lal, G. Beig, R. van der A, Dipali Sable, Journal of Geophysical Research: Atmospheres 115, D16 (2010) Available at: https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/924192
14.	Bangalore, Chennai, Delhi, Kanpur, Mumbai, Pune	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}, NOx, SO_2,	Central Pollution Control Board, Central Pollution Control Board, (2010), Air quality monitoring, emission inventory and source apportionment study for Indian cities Available at: http://cpcb.nic.in/displaypdf.php?id=RmluYWxOYXRpb25hbFN1bW1hcnkucGRm
15.	Kanpur	2011	2×2	Primary and Secondary	Indian, USEPA	PM_{10}	S. N. Behera, M. Sharma, O. Dikshit, S. P. Shukla, Advanced Air Pollution, (2011), Development of GIS-aided Emission Inventory of Air Pollutants for an Urban Environment Available at: https://www.intechopen.com/chapters/17388
16.	Indo-Gangetic Plain	2011	_	Primary and Secondary	Indian	PM, SO_2, NO and NO_2	"Emission estimates of particulate matter (PM) and trace gases (SO_2, NO and NO_2) from biomass fuels used in rural sector of Indo-Gangetic Plain, India," T. Saud, T. K. Mandal, R. Gadi, D. P. Singh, S. K. Sharma, M. Saxena, A. Mukherjee, Atmospheric Environment 45, 32, 5913-5923 (2011) Available at: https://www.sciencedirect.com/science/article/pii/S1352231011006248
17.	India	2011	For individual farm patches	Secondary	IPCC	CH_4, CO, N_2O, NOx	"Assessment of trace gases, carbon and nitrogen emissions from field burning of agricultural residues in India," S. Sahai, C. Sharma, S. K. Singh, P. K. Gupta, Nutrient Cycling in Agroecosystems 89, 143-157 (2011) Available at: https://link.springer.com/article/10.1007/s10705-010-9384-2
18.	Nagpur, Raipur	2012	–	Primary	Indian, IPCC, USEPA	NMHC, CO, TSP, SO_2, NOx, BC	"Emissions of greenhouse and non-greenhouse air pollutants from fuel combustion in restaurant industry," D. Majumdar, A. Chintada, J. Sahu, & C.C. Rao. International Journal of Environmental Science and Technology, 10(5), 995-1006 (2013). Available at: https://link.springer.com/article/10.1007/s13762-013-0247-7
19.	India	2012	–	Secondary	Indian, USEPA, Others	NH_3, N_2O	"Reactive nitrogen emissions from crop and livestock farming in India," V. P. Aneja, W. H. Schlesinger, J. W. Erisman, S. N. Behera, M. Sharma, W. Battey, Atmospheric Environment 42, 92-103 (2012) Available at: https://airqualityresearch.wordpress.ncsu.edu/files/2018/11/151.pdf

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
20.	Hyderabad	2013	1×1	Secondary	Indian, Foreign Literature	$PM_{2.5}$, PM_{10}, SO_2, NOx, CO, VOC, CO_2	"Source emissions and health impacts of urban air pollution in Hyderabad, India," S. K. Guttikunda, R. V. Kopakka, Air Qual Atmos Health 7, 195-207 (2014) Available at: https://theasthmafiles.org/sites/default/files/artifacts/media/pdf/guttikundakopakka_hyderabadairemissionshealthimpacts_2014.pdf
21.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian, Foreign Literature	PM, SO_2, NOx, CO, VOC	"A GIS based emissions inventory at 1 km x 1 km spatial resolution for air pollution analysis in Delhi, India," S. K. Guttikunda, G. Calori, Atmospheric Environment 67, 101-111 (2013) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231012010229
22.	Delhi, Gurgaon, Noida, Faridabad, Ghaziabad	2013	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, NOx, CO, VOC	"Health impacts of particulate pollution in a megacity—Delhi, India," S. K. Guttikunda, R. Goel, Environmental Department 6, 8-20 (2013) Available at: https://www.sciencedirect.com/science/article/abs/pii/S2211464512001492
23.	India	2013	25×25	Satellite	Satellite	NOx	"Application of satellite observations for identifying regions of dominant sources of nitrogen oxides over the Indian Subcontinent," S. D. Ghude, S. H. Kulkarni, C. Jena, G. G. Pfister, G. Beig, S. Fadnavis, R. J. van der A, Journal of Geophysical Research: Atmospheres 118, 2, 1075-1089 (2013) Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2012JD017811
24.	Auraiya	2013	2×2	Primary	Indian	PM_{10}, NO_2, SO_2, CO	Provided by EMTRC. Available at: https://indair-neeri.res.in/repository/view/3088
25.	Delhi	2014	–	Primary and Secondary	Indian, Foreign Literature	PM_{10}	"Speciated PM_{10} Emission Inventory for Delhi, India," P. Gargava, J. C. Chow, J. G. Watson, D. H. Lowenthal, Aerosol and Air Quality Research 14, 5, 1515-1526 (2014) Available at: https://aaqr.org/articles/aaqr-13-02-oa-0047
26.	Patna	2014	1×1	Secondary	Indian, USEPA	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC, CO_2	S. K. Guttikunda, P. Jawahar, UrbanEmissions.Info., (2014), Characterizing Patna's Ambient Air Quality and Assessing Opportunities for Policy Intervention Available at: https://shaktifoundation.in/wp-content/uploads/2017/06/Urban-Emissions-2014-AQM-in-Patna-Final-Report.pdf
27.	India	2014	25×25	Secondary	Indian, USEPA	$PM_{2.5}$, BC, OC, CO, NOx, NMVOC, CH_4	"Trends in multi-pollutant emissions from a technology-linked inventory for India: I. Industry and transport sectors," P. Sadavarte, C. Venkataraman, Atmospheric Environment 99, 353-364 (2014) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1352231014007754

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
28.	India	2014	NA	Secondary	IPCC	CO_2, CO, SOx, NOx, NH_3, $PM_{2.5}$, BC, PAH, NMVOC and NMHC	"Emission of air Pollutants from Crop Residue Burning in India," N. Jain, A. Bhatia, H. Pathak, Aerosol and Air Qual. Res. 14,1, 422-430 (2013) Available at: https://aaqr.org/articles/aaqr-13-01-oa-0031
29.	Amritsar	2015	–	Primary	Indian	PM_{10}, SO_2, NOx	"Assessment of Urban Air Quality around a Heritage Site Using AERMOD: A Case Study of Amritsar City, India," S. Gulia, A. Shrivastva, A. K. Nema, M. Khare, Environ Model Assess 20, 6, 599-608 (2015) Available at: https://link.springer.com/article/10.1007/s10666-015-9446-6
30.	Delhi	2015	2×2	Secondary	Indian	CO, NOx, SO_2, PM_{10}	"Anthropogenic Emission Inventory of Criteria Air Pollutants of an Urban Agglomeration - National Capital Region (NCR), Delhi," R. Sindhwani, P. Goyal, S. Kumar, A. Kumar, Aerosol and Air Quality Research 15, 1681-1697 (2015) Available at: https://aaqr.org/articles/aaqr-14-11-oa-0271
31.	Chennai, Vishakapatnam	2015	1×1	Primary and Secondary	Indian, USEPA, GAINS	PM_{10}, SO_2, NO_2	"Particulate and gaseous emissions in two coastal cities—Chennai and Visakhapatnam, India," S. K. Guttikunda, R. Goel, D. Mohan, G. Tiwari, Air Quality, Atmosphere & Health 8, 6, 559-572 (2015) Available at: https://link.springer.com/article/10.1007/s11869-014-0303-6
32.	India	2015	25×25	Primary	Indian, Foreign Literature	PM, NOx, SOx, CO, CO_2	"Rising critical emission of air pollutants from renewable biomass based cogeneration from the sugar industry in India," S. K. Sahu, T. Ohara, G. Beig, J. Kurokawa, T. Nagashima, Environmental Research Letters 10, 9 095002 (2015) Available at: https://iopscience.iop.org/article/ 10.1088/1748-9326/10/9/095002
33.	Delhi	2015	–	Secondary	Combination of Indian and IPCC	CH_4, N_2O, NH_3, NO, NO_2 and CO_2	"Gaseous Emissions from Agricultural Activities and Wetlands in National Capital Territory of Delhi," B. R. Gurjar, A. Nagpure, P. Kumar, Ecological Engineering 75, 123-127 (2015) Available at: https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/2848916
34.	Delhi	2016	2×2	Primary and Secondary	Indian	PM_{10}, $PM_{2.5}$, NOx, CO	M. Sharma, O. Dikshit, Department of Environment Government of National Capital Territory of Delhi, Delhi Pollution Control Committee, (2016), Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi (Final Report: Air Pollution component) Available at: https://cerca.iitd.ac.in/uploads/Reports/1576211826iitk.pdf

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
35.	India	2016	–	Primary and Secondary	USEPA	$PM_{2.5}$, NOx	Z. Shao, The International Council on Clean Transportation, (2016), An emissions inventory for agricultural tractors and construction equipment in India Available at: http://www.theicct.org/publications/emissions-inventory-agricultural-tractors-and-construction-equipment-india
36.	India	2016	–	Primary and Secondary	Indian, GAINS, USEPA	NOx, NMVOC, CO	"Sensitivity analysis of ground level ozone in India using WRF-CMAQ models," S. Sharma, S. Chattani, R. Mahatta, A. Goel, A. Kumar, Atmospheric Environment 131, 29-40 (2016) Available at: https://www.sciencedirect.com/science/article/pii/S1352231016300504
37.	Baddi-Nalagarh	2016	1	Primary and Secondary	Indian	PM_{10}	"Synergy of receptor and dispersion modelling: Quantification of PM_{10} emissions from road and soil dust not included in the inventory," S. PriyaDarshini, M. Sharma, D. Singh, Atmospheric Pollution Research 7, 3, 403-411 (2016) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1309104215000720
38.	Ahmedabad	2017	1.67×1.67	Primary and Secondary	Indian	NOx, CO, BC, OC, $PM_{2.5}$, PM_{10}, SO_2, VOC	G. Beig, N. S. Parkhi, Earth System Science Organization, Ministry of Earth sciences, Govt. of India, Indian Institute of Tropical Meteorology, Pune, (2017), Development of High-Resolution Emission Inventory for Ahmedabad Metropolitan Region (AMR) System of Air Quality and weather Forecasting and Research (SAFAR)- Ahmedabad Available at: http://assets.nrdc.org/sites/default/files/media-uploads/safar-ahmedabad-ei-2017-full_report.pdf
39.	Delhi, NCR	2018	4×4	Primary	Indian	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC	Automotive Research Association of India, The Energy and Resources Institute, Department of Heavy Industry Ministry of Heavy Industries and Public Enterprises, New Delhi, (2018), Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources Available at: https://www.teriin.org/sites/default/files/2018-08/Exec-summary_0.pdf
40.	India	2018	10×10	Secondary	EDGAR	CO, NOx, SO_2, NMVOC, $PM_{2.5}$, PM_{10}, EC, OC	The Air-Weather-Climate (AWC) Research group, Department of Civil and Environmental Engineering, (2018), Source apportionment, health effects and potential reduction of fine particulate matter ($PM_{2.5}$) in India Available at: http://www.indiaenvironmentportal.org.in/files/file/Source-apportionment-india.pdf

S. No.	Location	Year of Publication	Resolution (km²)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
41.	Delhi	2018	–	Secondary	–	$PM_{2.5}$	"Quantifying the influence of agricultural fires in northwest India on urban air pollution in Delhi, India," D. H. Cusworth, L. J. Mickley, M. P. Sulprizio, T. Liu, M. E. Marlier, R. S. DeFries, S. K. Guttikunda, P. Gupta, Environmental Research Letters 13, 4, 044018 (2018) Available at: https://iopscience.iop.org/article/10.1088/1748-9326/aab303/meta
42.	India	2018	10×10	Primary and Secondary	Indian	CO, NOx, SO_2, CO_2, NH_3, CH_4, $PM_{2.5}$, PM_{10}, BC and NMVOCs	"Missing Waste and Open Burning - an Activity and Consumption Based Emission Inventory for CO, NOx, SO_2, CO_2, NH_3, CH_4, $PM_{2.5}$, PM_{10}, BC and NMVOCs Emissions from Domestic Waste Burning in India," G. Sharma, P. Pallavi, P. Chandra, A. K. Sharma, H. Hakim, B. Sinha, AGU Fall Meeting Abstracts A33K-3302 (2018) Available at: https://pubs.acs.org/doi/abs/10.1021/acs.est.8b07076
43.	Madurai	2018	–	Primary and Secondary	Indian	BC	"An Emission Inventory Based Study on Black Carbon Aerosols Produced During Biomass Burning," B. V. Bhaskar, R. M. Rajeshkumar, K. Mthuchelian, Aerosol Science and Engineering 2, 3, 141-152 (2018) Available at: https://link.springer.com/article/10.1007/s41810-018-0031-7
44.	Patna	2019	1×1	Primary and Secondary	Indian, USEPA	PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, NMVOC, CO_2	Center for Study of Science, Technology and Policy, Center for Environment, Energy and Climate Change, Asian Development Research Institute, Urban Emissions, Bihar State Control Board, (2019), Comprehensive Clean Air Action Plan for the City of Patna Available at: https://shaktifoundation.in/wp-content/uploads/2019/12/PCAAP_Report_Final-3-1.pdf
45.	Bangalore	2019	1×1	Secondary	Indian	$PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NMVOC	"Air quality, emissions, and source contributions analysis for the Greater Bengaluru region of India," S. K. Guttikunda, Nishad. K A, S. Gota, P. Singh, Atmospheric Pollution Research 10, 3, 941-953 (2019) Available at: https://www.sciencedirect.com/science/article/abs/pii/S1309104218304835
46.	Amravati	2019	–	Primary and Secondary	Indian, Foreign Literature	$PM_{2.5}$	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), Action Plan for Control Of Air Pollution In Non-Attainment Cities Of Maharashtra Amaravati Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Amravati_Action_Plan07112019.pdf
47.	Chandrapur	2019	1×1	Primary	Indian	PM, CO, HC, NOx	Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, (2019), Action Plan Of Control Of Air Pollution In Non-Attainment Cities Of Maharashtra Chandrapur Available at: https://www.mpcb.gov.in/sites/default/files/pollution-index/severly-report/Chandrapur_Action_Plan07112019.pdf

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
48.	India	2019	10×10	Primary and Secondary	Indian	CO, NOx, SO_2, CO_2, NH_3, HCl, CH_4, PM_{10}, $PM_{2.5}$, BC, NMVOC	"Gridded Emissions of CO, NOx, SO_2, CO_2, NH_3, HCl, CH_4, $PM_{2.5}$, PM_{10}, BC, and NMVOC from Open Municipal Waste Burning in India," G. Sharma, B. Sinha, Pallavi, H. Hakkim, B. P. Chandra, A. Kumar, V. Sinha, Environ. Sci, Tenchnol. 53, 9, 4765-4774 (2019) Available at: https://pubs.acs.org/doi/abs/10.1021/acs.est.8b07076
49.	Delhi	2020	1×1	Primary and Secondary	FINNv1.5 EI	$PM_{2.5}$	"How Much Does Large-Scale Crop Residue Burning Affect the Air Quality in Delhi?" S. H. Kulkarni, S. D. Ghude, C. Jena, R. K. Karumuri, B. Sinha, V. Sinha, R. Kumar, V. K. Soni, M. Khare, Environ. Sci. Technol. 54, 8, 4790-4799 (2020) Available at: https://pubs.acs.org/doi/10.1021/acs.est.0c00329
50.	Indo-Gangetic Plain	2020	1×1	Secondary	IPCC	$PM_{2.5}$, PM_{10}, CO, CO_2, SO_2, NOx, N_2O, NH_3, CH_4, NMVOC, EC, OC, PAH	"A high-resolution emission inventory of air pollutants from primary crop residue burning over Northern India based on VIIRS thermal anomalies," T. Singh, A. Biswal, S. Mor, K. Ravindra, V. Singh, S. Mor, Environmental Pollution 266, 1, 115132 (2020) Available at: https://www.sciencedirect.com/science/article/abs/pii/S0269749120334485
51.	Jaipur	2020	2×2	Primary and Secondary	Indian, USEPA	PM_{10}, $PM_{2.5}$, NOx, SO_2, CO	M. Sharma, Rajasthan State Pollution Control Board, Jaipur, (2020), Air Quality Assessment, Trend Analysis, Emission Inventory and Source Apportionment Study in Jaipur City (Final Report) Available at: https://environment.rajasthan.gov.in/content/dam/environment/RPCB/EnvironmentalReport/Final-Report-Source-Apportionmnent-Study-Jaipur-IITKanpur.pdf
52.	Dhanbad	2021	2×2	Primary	Indian	PM_{10}	"Emission inventory of PM_{10} in Dhanbad/Jharia coalfield (JCF), India: an intricate coal mining sector," D. Roy, G. Singh, S. Sinha, J. Park, Y-C Seo, Environment, Development and Sustainability 23, 3048-3061 (2021) Available at: https://link.springer.com/article/10.1007/s10668-020-00702-4
53.	Delhi	2020	50×50	Primary and Secondary	Indian	$PM_{2.5}$	"Objective evaluation of stubble emission of North India and quantifying its impact on air quality of Delhi," G. Beig, S. K. Sahu, V. Singh, S. Tikle, S. B. Sobhana, P. Gargeva, K. Ramakrishna, A. Rathod, B. S. Murthy, Sci. Total Environ. 709, 136126 (2020) Available at: https://www.sciencedirect.com/science/article/pii/S0048969719361224
54.	India	2020	25×25	Satellite	Satellite	BC, OC	K. Venkataraman, V. Bhaskar, A. Kesarkar, Research Square, (2020), An Inventory on Black carbon and Organic Carbon Emission by the Different Vegetative Ecosystem Over India Available at: https://assets.researchsquare.com/files/rs-124451/v1/5f9cdb93-4e2f-4796-922b-a2f82ed513f9.pdf?c=1631867424

S. No.	Location	Year of Publication	Resolution (km^2)	Primary surveys/ Secondary data	EF used (Indian/ IPCC/ USEPA/ other)	Pollutants	Reference
55.	North-west India	2021	1×1	Primary	Indian, Other	VOCs	"Gridded 1 km × 1 km emission inventory for paddy stubble burning emissions over north-west India constrained by measured emission factors of 77 VOCs and district-wise crop yield data," A. Kumar, H. Hakkim, B. Sinha, V. Sinha, Sci. Total Environ. 789, 148064 (2021) Available at: https://www.sciencedirect.com/science/article/pii/S0048969721031351
56.	India	2021	10×10	Primary	Indian, Other	PM_{10}, $PM_{2.5}$, Benzene, VOCs	"Underreporting and open burning – the two largest challenges for sustainable waste management in India," P. Chaudhury, S. Garg, T. George, M. Shabin, S. Saha, S. Subodh, B. Sinha, Resources, Conservation and Recycling 175, 105865 (2021) Available at: https://www.sciencedirect.com/science/article/pii/S0921344921004742

8 CONCLUSION AND RECOMMENDATIONS

Non-attainment cities under the NCAP have now been mandated to carry out emission inventory and source apportionment studies. This is an excellent opportunity to create EI reports for smaller cities otherwise ignored. The existing multi-sectoral emission inventories need to be updated for cities with emission inventories. Most rural areas are left unattended when it comes to EI studies. The focus of past studies has been metros, but it is essential to cover the rural area in an airshed. Funding support must be provided to bridge those gaps. Further, EI must be repeated for cities periodically after a few years to test the efficacy of interventions.

Methodological Challenges

It would be helpful if special care is taken to use as much primary data as possible to make the inventory more reliable and generate robust datasets for recent years. Since new studies being conducted for NCAP cities have small domain sizes, they can estimate activity data using primary surveys and calculate. This will create a wealth of primary data for 132 cities, which can further be used for national-level studies, and source apportionment results will become more reliable. Spatial grid resolution used in the EI models also impacts the outputs as coarse-scale tends to average the emission peaks resulting in underestimated emissions.

Many studies still rely on foreign EF (USEPA) because EF is unavailable on specific industry types, fuel types, control technologies, and process technologies. This leads to several challenges. First, using secondary data sets from unrecognized sources results in inaccurate emission estimates. In the absence of Indian emission factors for different pollutant sources, researchers tend to use foreign emission factors which might not reflect the regional scenario. This leads to uncertainty in the EIs. To rule away from the uncertainties in the EIs, it is of utmost necessity that researchers strictly comply with Central Pollution Control Board guidelines, consider the primary data surveys and use Indian emission factors in the methodology while developing an EI.

Maximum Coverage of Pollution Sources

Further, pollution sources are evolving and expanding. We now have uncommon sources like incinerators, bakeries, stone crushers, and the omnipresent fugitive emissions in industries that need to be accounted for. Focus on developing Indian emission factors for these activities and developing emission inventory reports. Besides the niche sectors mentioned in the report, city-specific unique sources need urgent attention. For instance, a thriving dry cleaning industry spread across major cities. These units use residual waste solvents from chemical industries, leading to a higher VOC emissions load. These are not counted in any inventory. These VOCs react with NOx emitted from vehicles in the presence of sunlight to form photochemical smog (secondary particles). Several legal and illegal goldsmith shops operate in almost all big and small towns in India, which use Aqua Regia (a mixture of three parts concentrated hydrochloric acid and one part concentrated nitric acid) in their operations resulting in NOx emissions and Acid Mist. These are a few examples of the evolving and expanding nature of sources.

Abundant source emission data is now available in India for various types of industries (Thermal Power Plants, Cement Plants, Aluminium Smelters, Integrated Iron and Steel Plants, Furnaces, Oil Refineries, Sponge Iron Plants, Brick Kilns, Lime Kilns, Stone Crushers, Boilers, Lead, Copper and Zinc Smelters, Mines). Therefore, India needs to develop Indian emission factors for each industry. Emission Factors of these industries would benefit CPCB and MoEFCC for estimating rapid emission inventory.

Moreover, India still has various cultural practices that differ from the West regarding the fuel used and regionally. For example, street-side tea sellers may use anything from an electric stove to kerosene, coal or dung cakes. Brick kiln technology may vary with different regions of India and hence a region specific emission inventory dedicated to brick kilns is needed. Additionally, adulterants such as kerosene are added to vehicle fuel to reduce running costs for commercial vehicles in tier II and tier III cities. Most cities use region-specific biomass in their crematoriums. Inventorying emissions from those would be helpful. Therefore, regional EI based on the primary dataset can help in providing more robust data for source apportionment studies.

Emission inventory for ammonia (NH_3), which plays a vital role in secondary particulate formation, is not yet established in India.[51] Further, numerous studies have highlighted the abundance of secondary air pollutants in India and their importance to mitigate it.[52] Hence, estimation of NH_3 emissions is crucial for correct mitigation strategies for the Indian air pollution scenario.

An Opportunity to Develop Standards

Emission inventory of less studied sectors also provides essential information to develop standards. At present, there is the usual perception that these sources account for a tiny fraction of the emission load and hence do not warrant any measures. For instance, if EI reports are developed for toxics coming from refuse burning or emissions from electro-plating units, there would be a need to create standards to devise any enforcement-based mitigation strategies. Similarly, emissions from restaurants are not well studied. However, accounting for these would first lead to the complete data for any city, and secondly would be crucial to formulating standards. There is no standard; there is no measurement and thus no monitoring. If seen from a larger perspective, every emission inventory with primary data collection provides us with the opportunity to strengthen our measures to control air pollution.

The papers that matched closely with the CPCB have been highlighted in the sector lists. Most premium institutions like NEERI, TERI, ARAI, EMTRC, IITs have followed the CPCB methodology to prepare the Emission Inventory. In addition, as EI reports have gained momentum, several new organisations have begun carrying out EIs. However, the study by other agencies revealed methodological deficiencies.

51 *Development of Spatially Resolved Air Pollution Emission Inventory of India*. TERI. 2021.

52 "Air Pollution Over India: Causal Factors for the High Pollution with Implications for Mitigation," N. Singh, S. Agarwal, S. Sharma, S. Chatani, V. Ramanathan, *ACS Earth Space Chem*. 5, 12, 3297-3312 (2021)

The landmark reports that have been considered for taking policy level decisions by Government of India are described below:

S. No.	Name of the Report	Publisher and Year	Name of Policy Decision taken by Government of India
1.	Inventory and Assessment of Pollution Emission in and around Agra · Mathura Region	Central Pollution Control Board, 1981	Formation of Taj Trapezium and Constitution of Authority for Regulation of Industrial Activity inside the Trapezium for preservation of Taj Mahal.
2.	Air Quality Monitoring, Emission Inventory and Source Apportionment Study for Six Indian Cities	Central Pollution Control Board, 2010	Development of SOP and Guidelines for Emission Inventory Studies Preparation of City Action Plan for improvement of Air Quality by CPCB under the supervision of Hon'ble Supreme Court.
3.	Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi	IIT Kanpur, Delhi Pollution Control Committee & Department of Environment, Delhi, 2015	The concept of the Graded Response Action Plan was formulated by the Environment Pollution (Prevention & Control) Authority for improving the air quality of Delhi and the National Capital Region.
4.	Carrying Capacity Study for Environmentally Sustainable Iron & Manganese Ore Mining in Keonjhar, Sundergarh and Mayurbhanj District in Odisha	CSIR-NEERI Nagpur, 2018	Recommendations given for sustainable mining of Iron ore and Manganese in Odisha State. The Odisha Government constituted a Committee to oversee the implementation of recommendations
5.	Breathing clean air, ten scalable solutions for Indian Cities	The Energy and Resources Institute (TERI), 2016	First report which recommended a national level interventions in the form of programs like NCAP
6.	Source apportionment of PM10 and PM2.5 of Delhi NCR for identification of major sources	The Energy and Resources Institute (TERI) and The Automotive Research Association of India (ARAI), 2018	NCAP refers to this report for city and regional level mitigation strategies.
7.	Air quality assessment, emissions inventory and source apportionment study for Bangalore city	The Energy and Resources Institute (TERI), 2010	Recommendations suggested in this report led to strengthening of city level air quality management plan
8.*	PM_{10} and $PM_{2.5}$ Source Apportionment Study and Development of Emission Inventory of Twin Cities Kolkata and Howrah of West Bengal	West Bengal Pollution Control Board and CSIR-National Environmental Engineering Research Institute, 2019	Recommendations suggested in this report led to strengthening of city level air quality management plan

* This report contains total emissions inventory. Available at: *https://www.wbpcb.gov.in/writereaddata/files/SA_Kol-How_Final%20Report.pdf*

ANNEXURE – REPORT OF THE CONSULTATION MEETING

Compilation of Emission Inventory Data of India: Presentation of Draft Report

A meeting was organised on the **2nd October 2020 (11 AM to 1 PM) at Hotel Crowne Plaza, Mayur Vihar, Phase-I Extension, Delhi**, to present the draft report before a panel of experts and discuss the methodology and findings. Following experts attended the meeting:

	Name	Organization	Designation	Expertise
1.	Dr. A.L. Agarwal	Retired from National Environmental Engineering Research Institute, CSIR- NEERI Nagpur	Deputy Director	He played the key role in the project: Source Apportionment Study of Six Indian Cities, evolving common methodology for doing Emission Inventory, Air Quality Measurement and Dispersion Modelling
2.	Dr. J.S. Sharma	Retired from ONGC Presently he is an Expert Appraisal Committee Member in the Ministry of Environment, Forests & Climate Change	President, Indian Association Air Pollution Control Formerly Group General Manager (Chem.), Head Environment, ONGC	He is the Air Quality Expert, appointed by Govt of India for appraisal and recommending Environmental Clearance of Industrial Projects
3.	Dr. S.D. Attri	India Meteorological Department	Additional Director General	He is an expert in meteorology, air pollution dispersion modelling and air quality forecasting
4.	Dr. Abhijit Pathak	Central Pollution Control Board, Govt of India	Additional Director	He is the author of CPCB Document "Conceptual Guidelines and Common Methodology for Air Quality Monitoring, Emission Inventory & Source Apportionment Studies for India Cities"

Mr Parthaa Bosu from EDF was also present during the meeting.

Dr B. Sengupta and Dr J. K. Moitra presented the draft report to the experts.

The following points emerged out of the discussions.

1. Emission Inventory (EI) is the Emission Factor (EF) and Activity product. Identifying all activities contributing to air pollution inside a defined area is very important. Every activity must be identified through a physical survey using the SOP developed by CPCB. During the field survey, such activities must be collected in a structured questionnaire and appropriately documented. The field survey should be done for an extended period to normalise the EI.

2. In India, Emission Factor has been extensively developed and published by the Automotive Research Association of India (ARAI) for all types and categories of in-use vehicles. Therefore, it is possible to generate accurate EI of vehicles. But the classification of vehicles is based on type (Bus/ Truck/Dumper/Car/SUV/2-wheelers/3-wheelers) and category (BS-II, BS-III, BS-IV and BS-VI) is a must for calculation of EI.

3. Central Pollution Control Board has published Comprehensive Industrial Document Series (COINDS)[53,54] for 76 categories of industries. EF for most of these 76 industrial sectors are not developed in India. Relying on AP42 EF derived by USEPA could probably lead to underestimation. Therefore, India specific Emission Factor should be developed for all industrial sectors.

4. Emission factors for fugitive emissions from various types of mining activities, roads (unpaved and paved), raw material handling, biomass burning in landfill sites and other open areas, wood-fired crematoriums, use of coal and biomass in domestic stoves, use of LPG and PNG in gas stoves, etc. are not developed in India. Therefore, relying on the AP42 Emission Factor derived by USEPA could probably be underestimated. Consequently, it is high time that India specific Emission Factor should be developed for all types of fugitive emissions.

5. Emission Inventory must include all location-specific activities; missing one leads to underestimation. Even though emission generating activities in India are common, uncommon emissions from practices are at times witnessed. For instance, the burning of dry hides as fuel in Kanpur, use of coal to burn dead bodies in Kaniha (Odisha) and use of biomass (dried cow-dung) to burn dead bodies in Korba (Chhattisgarh) should not be missed as an activity while calculating the Emission Inventory.

6. IPCC Guidelines for National GHG Inventories by Intergovernmental Panel on Climate Change, 1996, are based on certain hypotheses and are suited for preparing National level Emission Inventory. Therefore, it is impossible to scale down these guidelines and prepare the Emission Inventory at the local level.

7. Air Pollutant Emission Inventory Manual by Global Atmospheric Pollution Forum (Male Declaration), November 2012, revised in 2019. The revised version includes satisfactory Emission Factors for activities commonly seen in India and other South-East Asian countries. In addition, the Conceptual Guidelines and Common Methodology for Air Quality Monitoring, Emission Inventory & Source Apportionment Studies for Indian Cities by CPCB, 2007 need to be revised, keeping in view the latest developments.

53 Central Pollution Control Board, *Comprehensive Industry Document Series (COINDS)*

54 Central Pollution Control Board, Ministry of Environment & Forest, (2010), *Comprehensive Industry Document on Electric Arc & Induction Furnaces*

CATALOGUE OF INDIAN EMISSION INVENTORY REPORTS

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