EXECUTIVE SUMMARY

Broadly, air pollution includes the introduction of gases or particles to the ambient atmosphere that can have negative impacts on humans and/or the environment. Here, the ambient atmosphere is defined as the portion of the troposphere within 100 m of ground level. Important air pollutants include primary particulate matter (PM), both below 2.5 microns in diameter ($PM_{2.5}$) and below 10 microns in diameter (PM_{10}), and gaseous pollutants, such as carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2), volatile organic compounds (VOCs), and ammonia (NH_3). These pollutants are a major concern, particularly in a country with growing economies such as India (which has improved its global economic ranking from 10th to 6th between 2012 and 2016) because of its impacts on human health, agriculture, and economic growth. Delhi, the capital city of the country, is the focus of discussion around the world because ambient PM_{10} and $PM_{2.5}$ concentrations are significantly higher than most of the cities in the world (WHO, 2019). Apart from the capital city, several other cities in the country also violate the national ambient air quality standards (NAAQS) of PM_{10} and $PM_{2.5}$ concentrations almost throughout the year. Considering the dynamically changing energy landscape that reflects the economic growth of the country as well as recent interventions taken on reducing air pollution, there is a need to update the existing Indian emissions inventory.

In order to address air pollution issues, it is important to understand primary sources of major ambient air pollutants (e.g., PM_{10}, $PM_{2.5}$, CO, NO_x, SO_x, VOCs, NH_3) in the country. These sources range from those that arise due to fuel use (i.e., energy use sectors) to sectors from which pollution is emitted by other means (i.e., no energy use sectors). Here "energy use" sectors include the residential, power, industry, and transport sectors; "no energy use" sectors include open agricultural burning, refuse burning, crematoria, construction sector, and mining. For example, in the residential sector, poverty-driven issues related to energy access lead to the use of biomass-based fuels for cooking purposes. In the transportation sector, limitations in public transport and economic growth have led to unprecedented increase in the number of vehicles in the cities. Growing power demands and the dependence on coal also contribute significantly to emissions along with industrial pollution. Improper management of municipal and agricultural waste is also another key issue which eventually leads to emissions of pollutants, as significant quantities of these wastes are combusted for volume reduction and heating purposes.

To accurately reflect emissions for India, it is important to have indigenous source specific emission factors of different pollutants while estimating the emissions from the respective sources. Additionally, the emission inventory for pollutants such as ammonia (NH_3), which plays important role in secondary particulate formation is not yet established in India. TERI had undertaken this study to develop India-specific emission factors for agriculture residue burning, refuse burning and road dust resuspension in different categories of Indian roads vis-à-vis to develop an updated air pollutants emission inventory of different sectors in the country for the year 2016.

Importantly, when primary air pollutants are released into the ambient air they can transform through chemical reactions to form secondary air pollutants (e.g., gaseous SO_2 and NO_x can transform to ammonium sulphate and ammonium nitrate particles, respectively, by reacting with ammonia). Thus, while an emission inventory provides the amount of primary pollutants emitted, it is necessary to use a chemical transport model that takes into account atmospheric, meteorological and thermodynamic conditions to fully assess ambient concentrations of air pollutants. Both primary and secondary atmospheric pollutants together determine the ambient air quality of a region. This study also simulated the ambient concentrations of particulate matters (PM_{10} and $PM_{2.5}$) at 36 km × 36 km scale by integrating the meteorological variables based on the estimated emission inventory described in this report (of $PM_{2.5}$, PM_{10}, SO_x, NO_x, CO, NMVOC, and NH_3) and chemical reactions in the atmosphere. WRF-CMAQ simulation platform was used in the study to simulate the ambient concentrations of $PM_{2.5}$ at 36 km × 36 km scale using the gridded emissions inventory, meteorological parameters and the global air quality products of the National Centre for Atmospheric Research (NCAR), USA.

Considering emissions from different fuels, results (Table S1) of the emission inventory study show that PM_{10} and $PM_{2.5}$ emissions were higher from coal, CO emission was higher from the burning of fuelwood, while NO_x emission was higher from diesel. Sector-specific inventory of different pollutants are summarized in Table S2.

Table S1 Fuel-wise emissions (Gg) of different pollutants during 2016

Fuel	PM_{10}	$PM_{2.5}$	SO_x	NO_x	CO	NMVOC	NH_3
Fuelwood	1538	1045	182	386	15,112	3611	0
Crop residue	628	417	51	132	4677	621	0
Dung cake	290	121	17	28	2168	665	0
Coal	5357	2719	6946	2844	5277	253	165
Kerosene	334	334	0	1	143	14	0
Diesel	311	245	741	3058	1736	124	1
Gasoline	11	10	1	285	1387	0	12
CNG	25	25	8	92	90	1	0
LPG	5	5	6	41	28	270	0
Total	8499	4921	7952	6868	30,618	5559	177

Table S2 Sectorial emission inventory of different atmospheric pollutants during 2016

Sector	Emissions (Gg)						
	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	VOCs	NH_3
Energy use sectors							
Residential	2836	1941	331	598	22,421	5233	
Power	574	230	5437	2517	182	80	0.1
Industry	5386	2792	3886	1179	7978	177	165
Transport (Tailpipe)*	192	187	14	2228	2938	1033	14
Road dust*	*1001*	*242*					
Transport total	1193	429	14	2228	2938	1033	14
Diesel generator set	78	66	71	1110	239	91	
No energy use sectors							
Open burning	1325	937	158	527	6501	600	118
Refuse burning	880	655	127	332	2638	370	
Crematoria	47	23	1	6	235	131	
Construction	3291	197					
Mining	163	33	8	3			
Agriculture activities	87	13					5482
Total	15,806	7316	10,033	8500	43,132	7715	5779

** The emissions from transport (tailpipe) and road dust are summed and presented as transport total.*

Based on our WRF-CMAQ modelling results, the simulated ambient concentration of $PM_{2.5}$ remained higher in Gujarat and northeastern region of the Indo-Gangetic plain (IGP) of India (Figure S1) compared to other parts of the country.

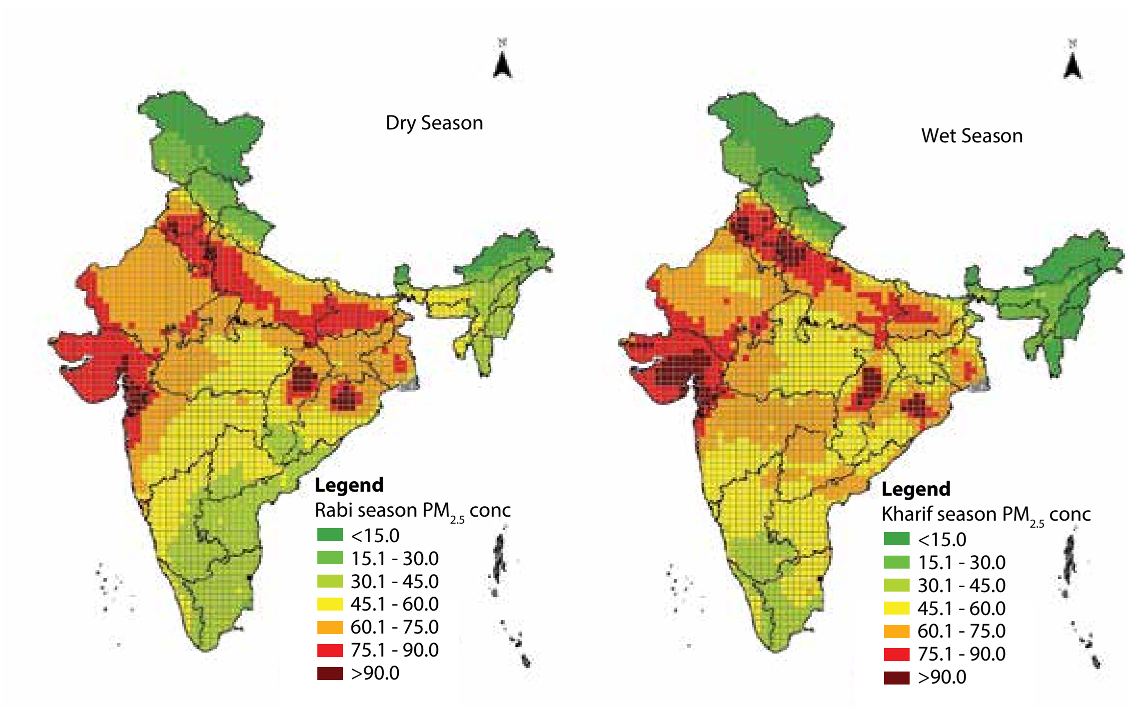

Figure S1 Simulated ambient $PM_{2.5}$ concentration (mg/m³) over India during 2016