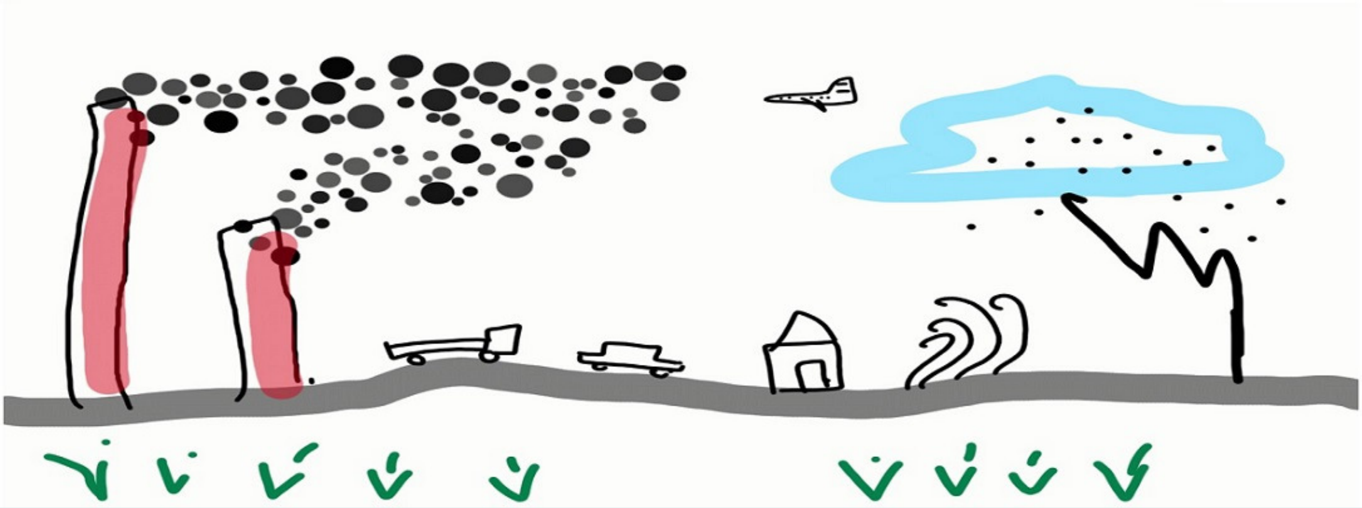
APnA city program



Air Pollution knowledge assessments for Indian cities

Summary report, July 2019

The APnA city programme, designed and implemented by Urban Emissions (India) and facilitated by Shakti Sustainable Energy Foundation (New Delhi, India), seeks to create a comprehensive, city-specific information pool by pulling together data from disparate sources, surveys, reports, maps, and atmospheric modeling.

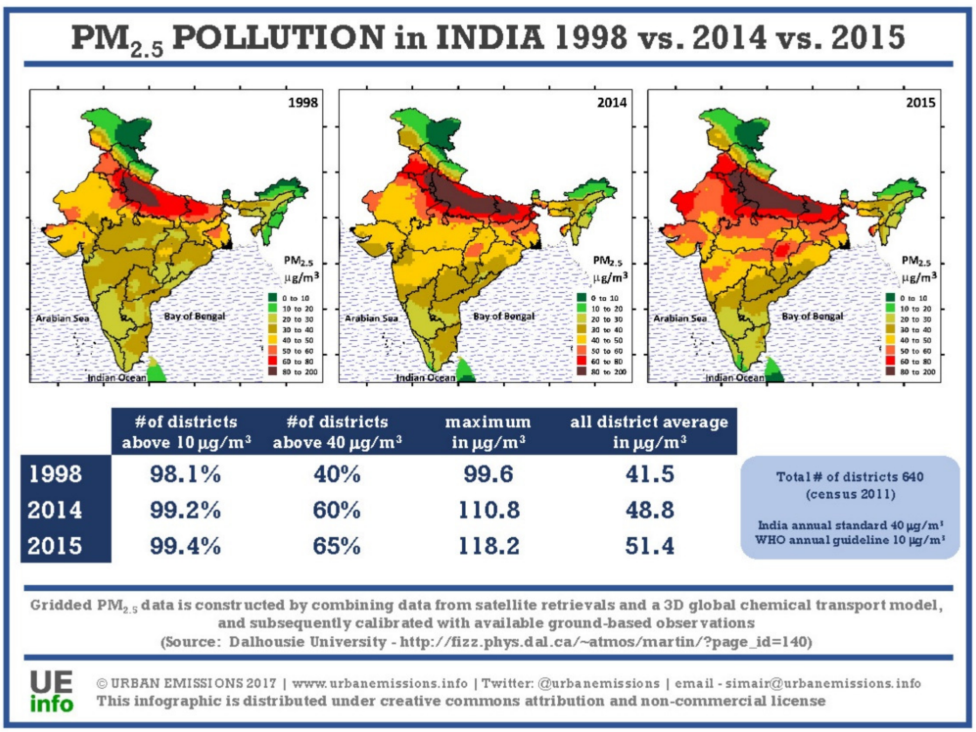
Report written and edited by staff @ Urban Emissions (India)

This report is distributed for free. Send your questions, comments, and suggestions on the methodology and data resources to simair@urbanemissions.info

Founded in 2007, Urban Emissions is an independent research group, with the vision to bridge the knowledge gap between science and policy related to air pollution, through information, research, and analysis.

Air Pollution knowledge Assessments (APnA) Program

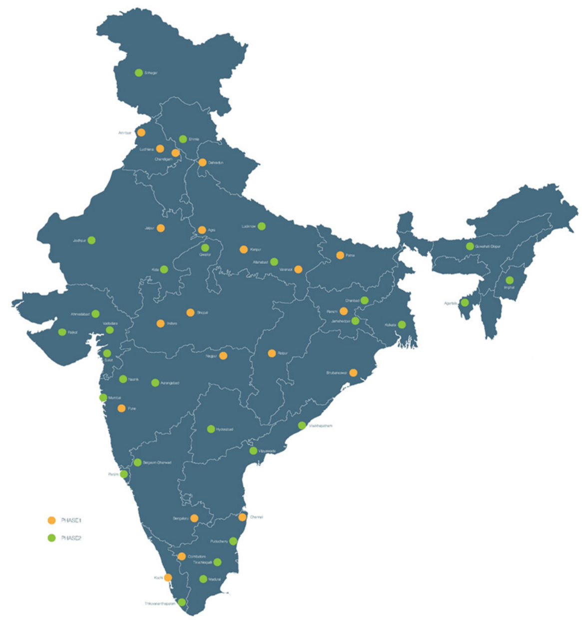
That air pollution is a serious environmental health issue in India is not under debate. The global burden of disease assessments estimated 0.74 million and 1.1 million premature deaths in 1990 and 2016 due to outdoor PM2.5 and ozone pollution and 0.99 million and 0.78 million premature deaths in 1990 and 2016 due to household (indoor) PM2.5 pollution (GBD, 2018). In the monitoring database released by the World Health Organization (WHO) in April 2018 covering 100 countries for the period of 2011 and 2016, India has 14 of the top 15 cities with the worst PM2.5 pollution. Among megacities of the world, Delhi tops the list for PM10 pollution (WHO, 2018).



With an increase in population in major metros as well as medium and small cities, towns are adjusting their infrastructure needs, such as transport and waste management, to accommodate the growing demand. Currently, we have limited idea of the scale of pollution in cities other than Delhi and a few others, where continuous monitoring data is available from more than 1 station. The National Clean Air Program (NCAP) proposed in 2018-19 seeks to address this gap for 102 cities by expanding the monitoring program in the urban areas and in the rural areas, building an emissions inventory, apportioning contribution of various sources to establish an actionable plan to reduce the air pollution levels by 20-30% by 2024.

The Air Pollution knowledge Assessments (APnA) city program seeks to address precisely this shortfall and give policy makers a baseline to work with.

We feel that to take the air pollution policy debate further at the national scale, we need to move beyond anecdotal evidence, quantify and spatially map out pollution, and assess the impact of sources at the local scale (Guttikunda et al., 2014) and for that establishing the baseline or quantifying the extent of the problem in cities other than the metropolitan cities is the starting point for change.



In 2017, under the APnA city program, we released the air pollution assessments for 20 Indian cities (orange dots). In 2019, we added 30 more cities (green dots) to the pool, bringing the total to 50 cities.

As far as we are aware, the APnA city program for 50 cities - with a database of emissions and source contribution assessments by each sector - is the only one of its kind in India and aims at contributing towards the understanding of the issue of urban air pollution in India at greater resolutions.

This report summarizes the new resource material updated since the release of the phase 1 cities and main findings of phase 2 cities. The three primary stages of study included (a) compiling an inventory of sources and data (including meteorology) (b) computation of emissions and their spatial and temporal allocation and (c) mapping pollution and estimating source contributions using a chemical transport model.

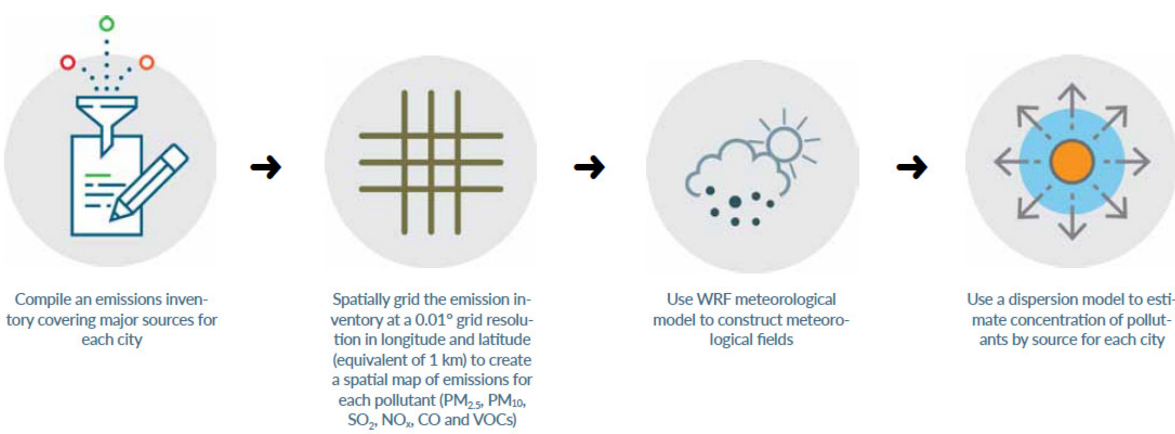


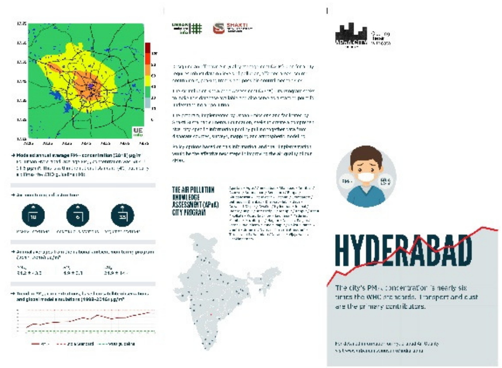
Table 1: APnA Indian cities

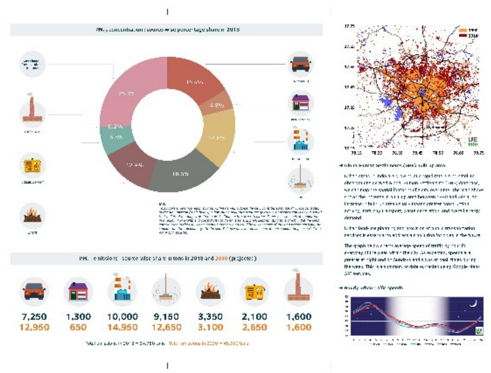
	State/Union Territory	City (from Phase 1)	City (from Phase 2)	Total cities
1	Andhra Pradesh		Vijayawada, Visakhapatnam	2
2	Arunachal Pradesh			-
3	Assam		Dispur-Guwahati	1
4	Bihar	Patna	Gaya	2
5	Chhattisgarh	Raipur		1
6	Goa		Panjim-Vasco-Margao	1
7	Gujarat		Ahmedabad, Surat, Rajkot, Vadodara	4
8	Haryana			-
9	Himachal Pradesh		Shimla	1
10	Jammu & Kashmir		Srinagar	1
11	Jharkhand	Ranchi	Jamshedpur, Dhanbad-Bokaro	3
12	Karnataka	Bengaluru	Dharwad-Hubli	2
13	Kerala	Kochi	Thiruvananthapuram	2
14	Madhya Pradesh	Indore, Bhopal	Gwalior	3
15	Maharashtra	Nagpur, Pune	Mumbai, Nashik, Aurangabad	5
16	Manipur			-
17	Meghalaya			-
18	Mizoram			-
19	Nagaland			-
20	Orissa	Bhubaneswar		1
21	Punjab	Amritsar, Ludhiana		2
22	Rajasthan	Jaipur	Kota, Jodhpur	3
23	Sikkim			-
24	Tamil Nadu	Chennai, Coimbatore	Madurai, Tiruchirapalli	4
25	Telangana		Hyderabad	1
26	Tripura		Agartala	1
27	Uttarakhand	Dehra Dun		1
28	Uttar Pradesh	Kanpur, Varanasi, Agra	Lucknow, Allahabad	5
29	West Bengal		Asansol-Durgapur, Kolkata	2
30	Andaman & Nicobar			-
31	Chandigarh	Chandigarh		1
32	Dadra & Nagar Haveli			-
33	Daman and Diu			-
34	Delhi			-
35	Lakshadweep			-
36	Puducherry		Puducherry	1

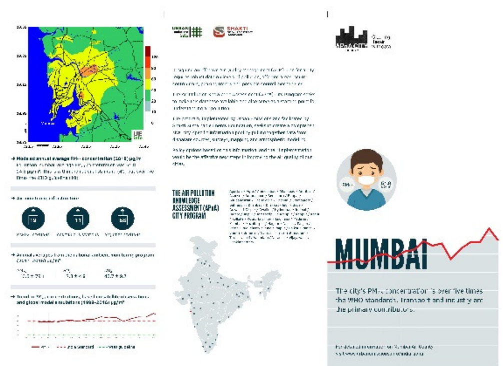
Individual city reports for all 50 cities are available on the program website which present the following in detail

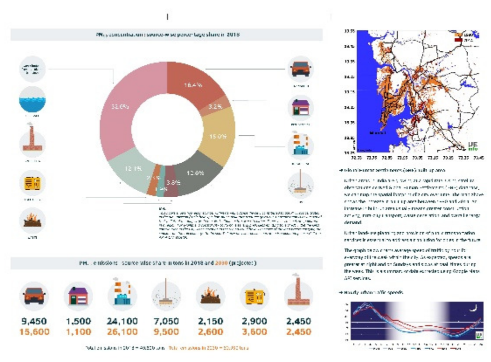
- An overview of the urban airshed of the city, which covers the city and the surroundings with any influential sources
- An overview of the annual meteorological fields over the airshed, which determine the seasonal pollution intensities
- A snapshot of major point sources in the airshed
- A spatial and temporal summary of the traffic speeds in the airshed
- An emissions heat map for PM2.5 for the base year and projected year (2030)
- A time series of emissions between base year and projected year by sector
- A pollution heat map for PM2.5 for the base year, along with an estimate for annual contributions of sources inside and outside the airshed
- Modelled monthly average air pollution maps
- A summary of all the available monitoring data for key pollutants

The city reports also includes a quick look leaflet summarizing some of these results. Link to resource material used for this analysis and methodologies are documented separately on the program website.









City Emissions

We built an emissions inventory for each of the cities for year 2018 for the following pollutants – particulate matter (PM) in four classes (a) PM10 (b) PM2.5 (c) black carbon (BC) and (d) organic carbon (OC), sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs).

We also projected the emission loads to year 2030 under a business as usual scenario after accounting for policy interventions already under implementation (e.g. accelerated introduction of liquified petroleum gas (LPG) for cooking).

Sources of pollution include anthropogenic sources, such as transport (road, rail, ship, and aviation), large scale power generation (from coal, diesel, and gas power plants), small scale power generation (from diesel generator sets for household use, commercial use, and agricultural water pumping), small and medium scale industries, dust (road resuspension and construction), domestic (cooking, heating, and lighting), open waste burning, seasonal open fires, and non-anthropogenic sources, such as (where relevant) sea salt, dust storms, biogenic, and lightning.

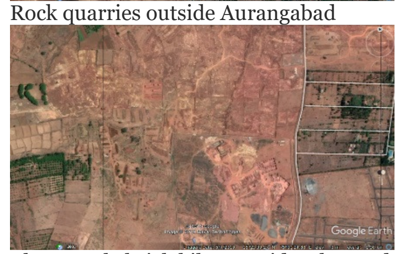

Thermal power plant in Gandhi Nagar


IISCO steel plant in Asansol


Rock quarries outside Aurangabad


Coal mining around Dhanbad


Bokaro steel plant


Clamp style brick kilns outside Dharwad


Refinery in Guwahati


Fixed chimney brick kilns in Gwalior


Freight hub in Kolkata

Emission inventories is a function of fuel burnt which is then converted to emission loads using relevant emission factors. The main challenge is that useful and formatted data necessary to build an emissions inventory is hard to come by. We thus accessed data from a wide array of sources for each sector. For this purpose, we documented and digitized information available from the annual reports, maps, and databases such as census and ambient measurements.

To build the emissions inventory, we used layers of information from a range of sources in order to get a detailed picture of the state of air pollution in that city. Accordingly, the data to build the emissions inventory includes;

- **Static Data** - CPCB, state PCBs, Census Bureau, Niti Aayog, National Sample Survey Office (NSSO), Ministry of Road Transport and Highways (MoRTH), Society of Indian Automobiles Manufacturers (SIAM), Directorate general of Civil Aviation (DGCA), Ministry of Petroleum and Natural Gas (MoPNG), Ministry of Statistics and Program Implementation, Annual Survey of Industries (ASI), Central Electrical Authority (CEA), National Power Program (NPP), Cement Manufacturers Association (CMA), and Municipalities.

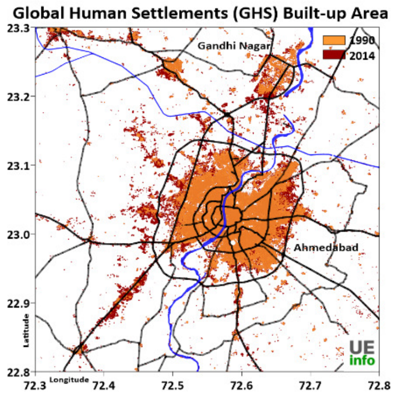
- **Dynamic inputs** - NASA satellite feeds on open fires, dust events, and lightning, 3D meteorological feeds processed through Weather Research and Forecasting (WRF) model, traffic speed maps (a paid service from google), weekday and weekend profiles for transport sector (pre-decided based on speed profiles), power demand and consumption rates from the load dispatch centers, and annual/seasonal reports from various sectors listed above.

- **Monitoring data** - monitoring data from official and unofficial networks to evaluate model performance.

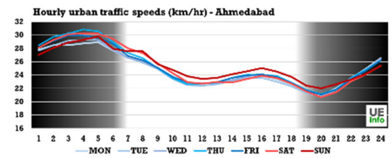
- **Google** - We used a paid API service from Google to map various establishments in the city – hotels, hospitals, restaurants, bus stops, train stops, traffic lights, fuel stations, cinema halls, residential complexes, institutions, banks, bars, cafes, worship places, funeral homes, markets, and parks. We also collected speed and traffic information for 2 weeks to make a congestion map and plot hourly vehicle speed.

- **Global Human Settlement Database** - For each airshed, we extracted built up area from Pesaresi et al. (2016) for 1990 and 2014. This data gives us the extent of the spatial footprint of the city and allows us to estimate growth in cities for our future scenario runs.

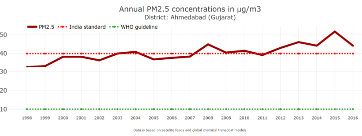
Examples from three cities is presented here



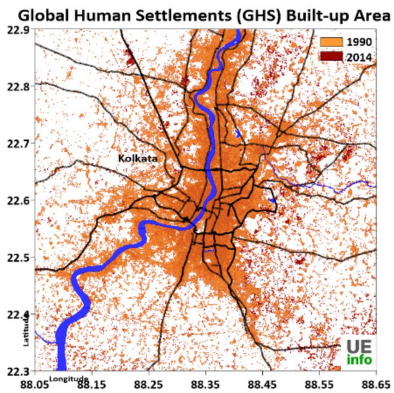
Ahmedabad



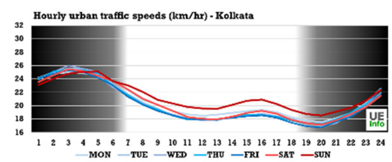
This is a summary of speed data extracted from Google Maps API service for the entire airshed for a minimum of 2 weeks. More details are online.

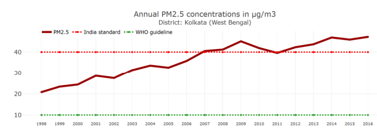


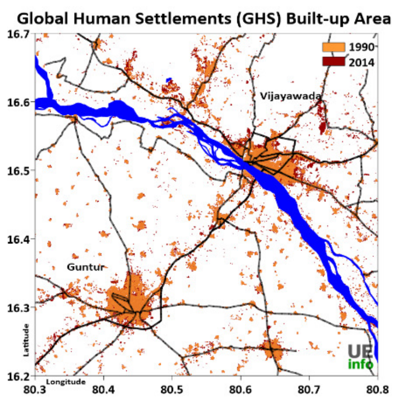
This is a summary of annual average PM2.5 concentrations based on satellite observations and global chemical transport modeling. More details are online.



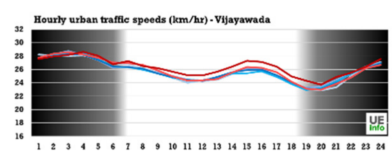
Kolkata

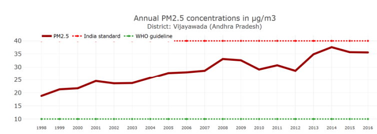






Vijayawada





We used similar methodologies for 10 Indian cities – Pune, Chennai, Ahmedabad, Indore, Surat, Rajkot, Hyderabad, Chennai, Vishakhapatnam, and Delhi (Guttikunda and Jawahar, 2012; Guttikunda and Calori, 2013; Guttikunda and Kopakka, 2014; Guttikunda et al., 2014); national transport sector (Guttikunda and Mohan, 2014); national power plant sector (Guttikunda and Jawahar, 2014); and Delhi transport sector (Goel and Guttikunda, 2015).

We used multiple sources to collate a library of emission factors for transport, industrial, and domestic sectors (CPCB, 2011; Pandey et al., 2014; Sadavarte and Venkataraman, 2014; IIASA, 2015; Goel and Guttikunda, 2015; Sakar et al., 2016).

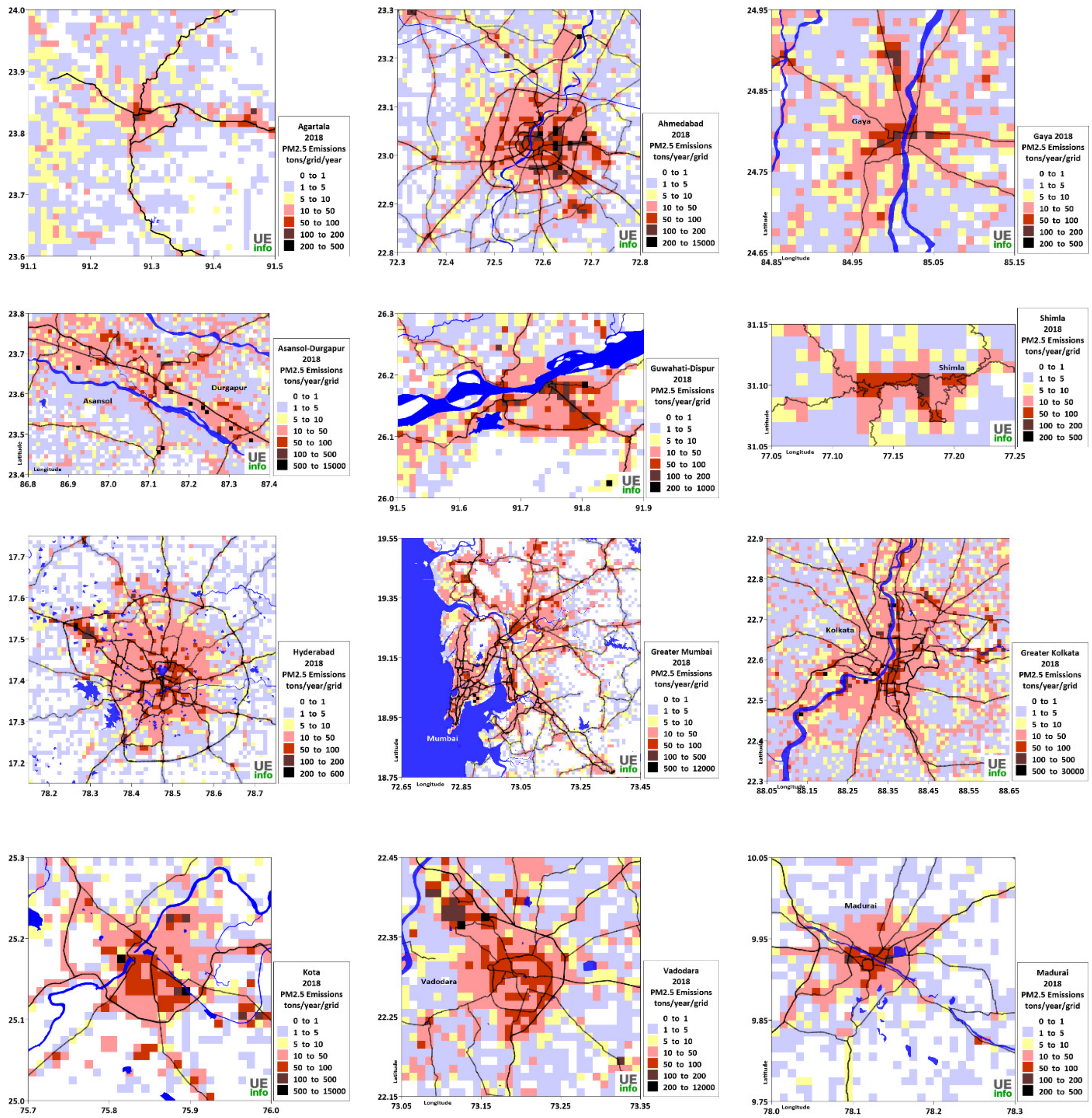
Table 2: Summary of base year (2018) PM2.5 emissions by sector (tons)

	City name	Trans	Resid	Indus	Dust	Waste	DG sets	Bricks	Total
1	Agartala	1,850	2,100	400	2,250	1,450	300	1,150	9,500
2	Ahmedabad	11,800	1,900	44,200	10,350	3,700	3,200	2,200	77,350
3	Allahabad	5,500	1,700	2,600	4,000	950	1,000	4,000	19,750
4	Asansol	7,850	1,250	46,300	9,650	1,650	2,050	5,800	74,550
5	Aurangabad	2,500	300	6,000	3,200	900	750	1,900	15,550
6	Dharwad-Hubli	3,300	100	1,200	2,150	500	150	350	7,750
7	Dhanbad	9,050	650	60,900	11,500	1,050	1,400	1,500	86,050
8	Gaya	5,000	850	200	3,650	500	700	2,150	13,050
9	Guwahati-Dispur	10,450	600	2,850	7,850	850	300	650	23,550
10	Gwalior	2,800	700	5,050	2,450	550	350	600	12,500
11	Hyderabad	12,950	650	14,950	12,650	3,100	2,650	1,600	48,550
12	Jamshedpur	6,750	1,000	29,200	5,050	600	850	1,200	44,650
13	Jodhpur	7,200	700	2,900	8,200	550	500	-	20,050
14	Kolkata	12,050	3,300	50,050	10,700	5,950	6,050	6,900	95,000
15	Kota	4,750	500	20,700	3,350	450	200	450	30,400
16	Lucknow	9,000	5,650	4,350	9,650	2,650	1,700	4,850	37,850
17	Madurai	3,500	50	1,600	2,450	750	250	-	8,600
18	Mumbai	15,600	1,100	26,100	9,500	2,600	3,600	2,450	60,950
19	Nashik	3,500	700	19,200	4,100	950	650	1,050	30,150
20	Panjim	4,300	50	1,700	2,350	500	500	-	9,400
21	Puducherry	3,850	100	5,250	2,800	1,100	1,250	1,000	15,350
22	Rajkot	6,050	400	7,100	4,400	700	450	-	19,100
23	Shimla	1,600	850	-	850	400	50	-	3,750
24	Srinagar	2,200	9,250	150	2,350	800	950	1,950	17,650
25	Surat	12,150	250	40,300	6,900	2,050	1,400	1,250	64,300
26	Thiruvananthapuram	14,900	50	2,200	3,350	800	1,000	-	22,300
27	Tiruchirapalli	3,350	150	4,950	2,600	750	550	-	12,350
28	Vadodara	6,200	450	5,850	5,200	900	1,150	800	20,550
29	Vijayawada	8,600	300	20,650	9,750	1,550	1,550	1,300	43,700
30	Visakhapatnam	10,300	300	39,550	4,150	1,300	50	-	56,150

Note: Trans = Transport emissions from road, rail, aviation, and shipping (for coastal cities); Resid = Residential emissions from cooking, heating, and lighting activities; Indus = Industrial emissions from small, medium, and heavy industries (including power generation); Dust = Dust emissions from road re-suspension and construction activities; Waste = Open waste burning emissions; DG sets = Diesel generator set emissions; Bricks = Brick kiln emissions (not included in the industrial emissions)

We built the emissions inventory at a resolution of 0.01° (approximately 1-km) and the inventory is formatted such that it can be used for urban and regional chemical transport modeling with ease. The methodology to spatially and temporally allocate emissions has been developed using many layers of information listed earlier and documented in detail in Guttikunda et al., 2019.

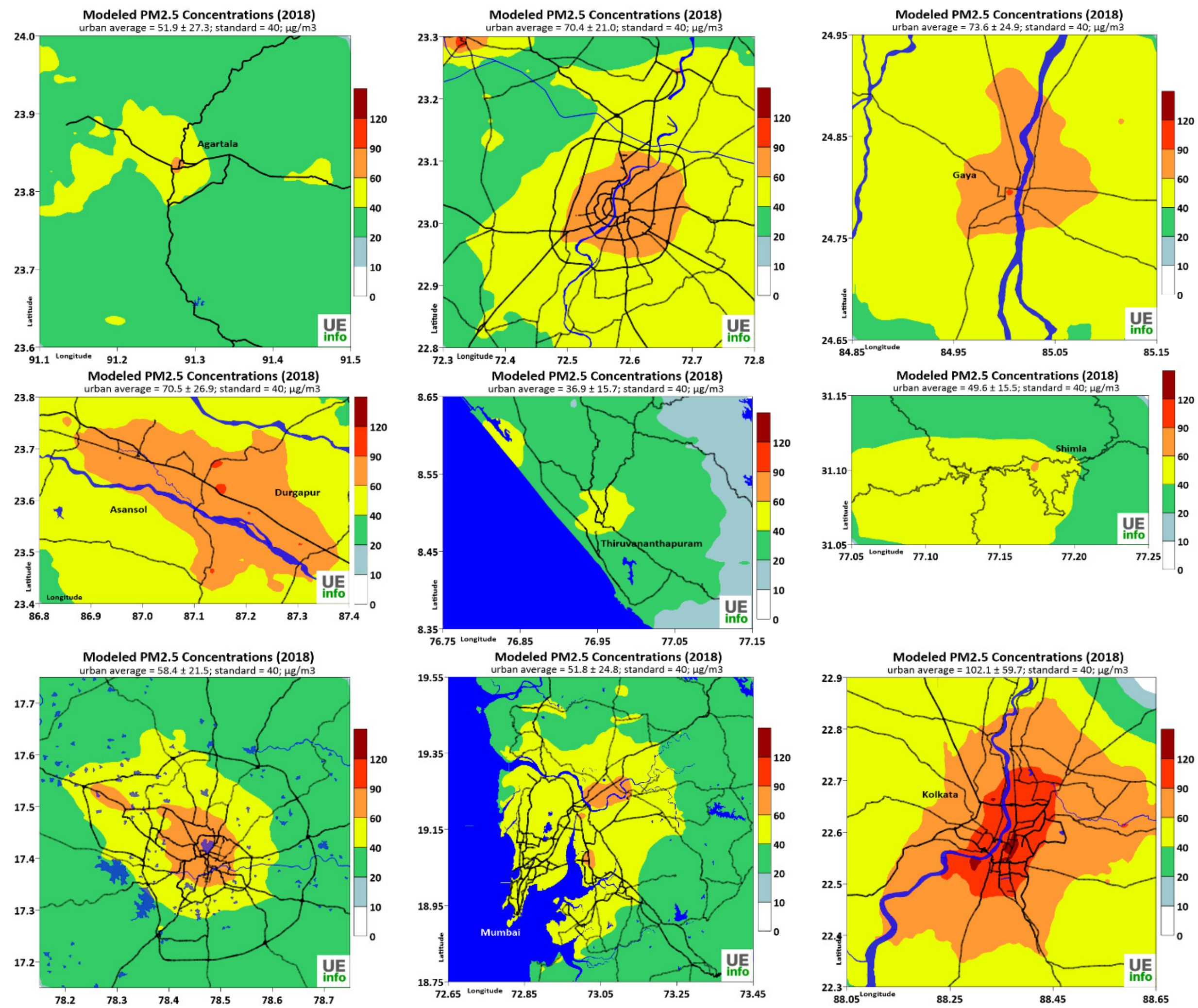
Examples emission heat maps for the cities are presented below.



More details for online for each of these cities.

Pollution Heatmaps & Source Apportionment

The gridded emissions inventory combined with the 3-D meteorological data is processed through Comprehensive Air Quality Model with Extensions (CAMx), a Eulerian photochemical transport model, suitable for integrated assessments of gaseous and particulate air pollution over many scales ranging from sub-urban to continental, to build a pollution heat map for the city. Example annual average modeled PM2.5 concentration maps are presented below.



The model setup also allows to estimate source contributions (annual estimates are summarized in Table 3). Monthly pollution maps and monthly source contribution results are presented online on individual city pages.

Table 3: Summary of base year (2018) modeled annual average PM2.5 concentrations and source contributions to the urban parts of the city

City name	PM2.5 (μg/m³)	Trans	Resid	Indus	Dust	Waste	DG sets	Bricks	Seasalt	Outside
Agartala	51.9 ± 27.3	17.5%	14.9%	4.3%	15.3%	8.3%	2.7%	2.1%		34.9%
Ahmedabad	70.4 ± 21.0	14.9%	6.6%	12.4%	17.7%	8.4%	6.5%	0.7%		32.8%
Allahabad	79.4 ± 26.2	18.6%	12.5%	6.2%	14.9%	4.0%	4.1%	3.2%		36.6%
Asansol	70.5 ± 26.9	12.5%	7.1%	8.5%	16.2%	4.9%	4.2%	13.9%		32.7%
Aurangabad	47.7 ± 18.4	10.8%	4.3%	18.7%	10.7%	12.0%	6.7%	1.9%		34.9%
Dharwad-Hubli	28.0 ± 13.4	21.6%	5.6%	9.2%	14.7%	8.5%	1.7%	0.7%		38.0%
Dhanbad	74.5 ± 24.4	12.2%	4.1%	12.5%	29.2%	2.6%	3.0%	4.3%		32.2%
Gaya	73.6 ± 24.9	23.1%	10.0%	0.9%	17.3%	3.6%	4.4%	4.7%		36.1%
Guwahati-Dispur	85.1 ± 30.4	36.5%	6.8%	5.2%	27.0%	6.8%	1.7%	0.8%		15.1%
Gwalior	75.6 ± 18.1	12.7%	9.3%	12.2%	12.9%	4.8%	2.5%	4.2%		41.4%
Hyderabad	58.4 ± 21.5	16.5%	4.8%	14.8%	18.6%	12.9%	6.8%	0.2%		25.3%
Jamshedpur	96.4 ± 32.2	19.5%	6.6%	25.8%	15.0%	3.0%	3.7%	2.2%		24.1%
Jodhpur	88.3 ± 17.4	19.9%	6.1%	6.6%	25.5%	3.8%	2.1%	0.0%		36.0%
Kolkata	102.1 ± 59.7	13.5%	8.6%	17.6%	12.5%	12.8%	9.4%	6.7%		19.0%
Kota	80.7 ± 19.7	16.7%	8.0%	19.5%	12.5%	4.7%	1.4%	0.5%		36.6%
Lucknow	94.5 ± 43.8	13.0%	24.3%	4.3%	13.9%	7.5%	3.3%	3.5%		30.1%
Madurai	31.7 ± 10.8	23.4%	3.5%	13.6%	19.0%	15.0%	3.6%	0.0%		22.0%
Mumbai	51.8 ± 24.8	16.4%	3.2%	15.0%	12.6%	3.8%	1.9%	2.3%	12.1%	32.6%
Nashik	46.0 ± 18.6	12.1%	6.6%	15.8%	13.2%	8.7%	3.6%	0.9%		39.1%
Panjim	28.3 ± 10.7	22.6%	0.6%	4.5%	12.6%	2.8%	2.6%	0.0%	17.0%	37.3%
Puducherry	36.4 ± 13.6	9.7%	1.2%	27.8%	6.7%	8.9%	7.8%	0.6%	7.3%	30.0%
Rajkot	71.6 ± 27.9	19.0%	5.1%	20.9%	16.4%	6.9%	2.2%	0.0%		29.6%
Shimla	49.6 ± 15.5	17.4%	11.8%	0.2%	11.8%	5.5%	1.0%	0.0%		52.2%
Srinagar	61.8 ± 16.8	9.8%	41.3%	0.8%	8.2%	6.4%	7.4%	1.8%		24.4%
Surat	88.5 ± 27.5	16.4%	1.7%	31.4%	10.3%	9.8%	3.3%	0.3%	5.6%	21.2%
Thiruvananthapuram	36.9 ± 15.7	37.0%	5.5%	9.4%	17.4%	6.6%	5.4%	0.0%	3.2%	15.4%
Tiruchirapalli	38.8 ± 15.3	19.0%	3.9%	28.2%	16.2%	7.9%	4.4%	0.0%		20.5%
Vadodara	69.7 ± 25.4	20.8%	4.7%	8.0%	17.2%	7.6%	5.8%	0.6%		35.4%
Vijayawada	51.6 ± 16.1	22.7%	3.5%	11.7%	19.7%	9.3%	5.9%	1.4%		25.8%
Visakhapatnam	51.8 ± 13.3	19.3%	3.3%	23.5%	10.9%	8.1%	2.3%	0.0%	4.8%	27.8%

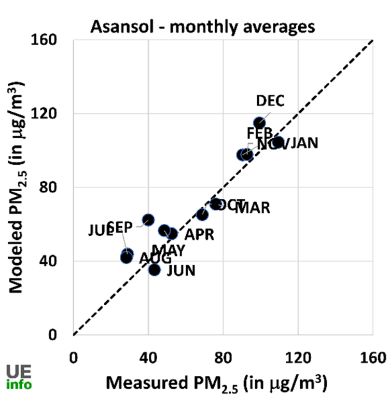
Note: PM2.5 = concentration presented as average +/- standard deviation of all the grids in the designated urban area (annual standard is 40 μg/m3 and WHO guideline is 10 μg/m3); Trans = Transport emissions from road, rail, aviation, and shipping (for coastal cities); Resid = Residential emissions from cooking, heating, and lighting activities; Indus = Industrial emissions from small, medium, and heavy industries (including power generation); Dust = Dust emissions from road re-suspension and construction activities; Waste = Open waste burning emissions; DG sets = Diesel generator set emissions; Bricks = Brick kiln emissions (not included in the industrial emissions); Seasalt is a natural source applicable only for sea facing cities; Outside = contribution of pollution originating outside the designated city airshed

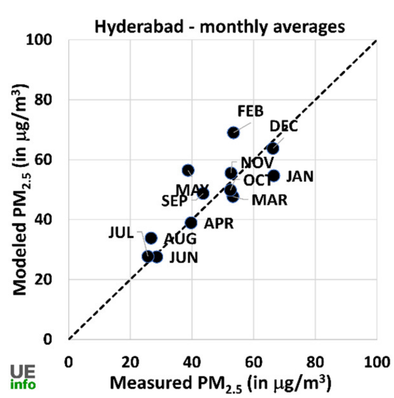
Air Quality Monitoring

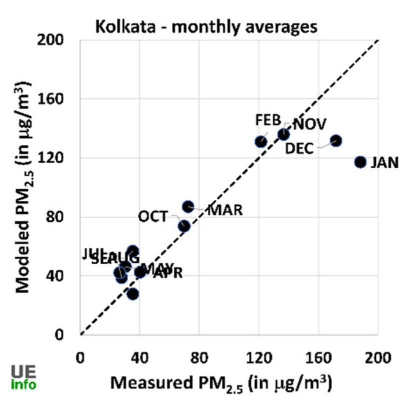
The Central and the State Pollution Control Boards (CPCB and SPCBs) maintain and operate the national ambient monitoring programme (NAMP). This is the only official ambient monitoring database available in India since 1990. The monitoring network is slowly expanding. In 2015, there were 206 manual monitoring stations in 46 cities. As of June 2019, there are 770 manual stations and 188 continuous stations (37 stations are operating in Delhi). In September 2017, there were 74 continuous stations in operation – a 150% increase over 18 months. The continuous ambient monitoring stations report pollution levels for all the criteria pollutants every 15 min. This data is available in real time on CPCB's website.

The current monitoring capacity in the cities is limited even after combining the manual and continuous monitoring setup. For all India, our estimate is 4,000 continuous monitors to spatially and temporally represent the air quality levels experienced in the city. For each of the cities in the APnA program, we have estimated what is the minimum number of stations required to represent the pollution trends better. This information is available on the city summary leaflets and on the individual city pages online.

Where available, monitoring data was used for validating the modeling results. A comparison is presented below for the cities of Asansol (1 station), Hyderabad (10 stations), and Kolkata (6 stations). Similar assessments are posted online for Ahmedabad, Aurangabad, Dhanbad, Gaya, Jodhpur, Kolkata, Lucknow, Mumbai, Nashik, Panjim, Thiruvananthapuram, Vijayawada, and Visakhapatnam. We were able to replicate the qualitative and quantitative variations and trends in the PM2.5 concentrations.







More details are presented on the respective city pages.

Conclusions

For most the APnA cities, this is the first time an emissions inventory and source-based apportionment was conducted at this spatial and temporal scales. The overall comparisons with limited monitoring data provide the much-needed confidence in taking this forward for (a) to further explore the possibilities of bettering the analysis with some customized local inputs and (b) using the results for formulating some long-term policy measures.

The analysis of the sectors that contribute to air pollution in the 30 cities (and the 20 cities from the previous phase) gives us some direction on what we need to focus on when formulating pollution control policy. A general set of recommendations that can apply to all the cities are as under:

- Cities in India need to aggressively promote public- and para- transportation systems, in order to reduce the use of millions of passenger vehicles and their respective emissions. By 2030, the vehicle exhaust emissions are expected to increase on average 30% under business as usual scenario and at least remain constant, if and only if, Bharat 6 fuel standards are introduced nationally in 2020, as recommended by the Auto Fuel Policy. A sustainable transport policy must also promote non-motorized transport (walking and cycling) infrastructure, to not only reduce the contribution of vehicle exhaust emissions but also to reduce on-road dust re-suspension.
- By 2030, the share of emissions from residential cooking and lighting is expected to decrease significantly with an increasing share of LPG and electrification in both urban and rural areas.
- Few of the cities have started to develop a comprehensive waste management system, but not enough to tackle the current load of waste generation in the urban and the rural parts. The practice of open waste burning is hard to regulate and monitor and contributes significantly to air pollution. Municipalities will have to address this important source as cities become more urbanized.
- Upgrading the brick kiln technology from the current fixed-chimney and clamp-style baking to (for example) zig-zag and regulating standards for the clamp style brick kilns in the city airsheds will improve their overall energy efficiency and reduce emission loads.
- Coal-fired power plants and large industries with captive power plants need to enforce stricter environmental standards for all the criteria pollutants to reduce their share of influence on urban air quality.
- The densely populated Indo-Gangetic plain has cities and rural areas in proximity that strongly influences each other’s ambient air quality. For example, these cities

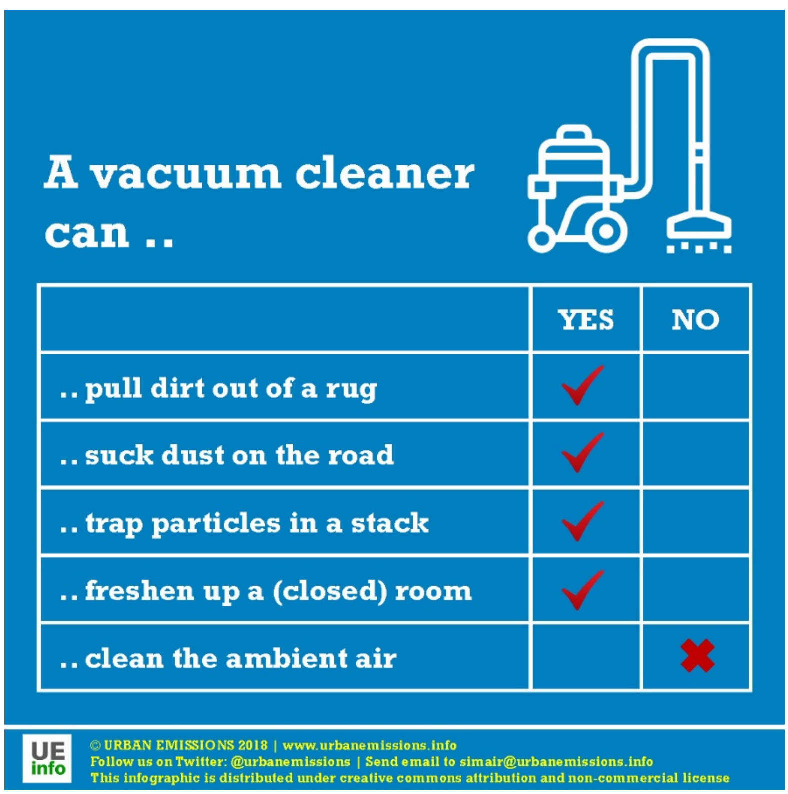
on average experience in excess of 30% of ambient PM2.5 pollution originating from sources outside the city limits. A regional air quality management, spanning multiple states, districts, and stakeholders is necessary to reduce the pollution loads for all the cities.

- Seasonal contributions from open fires and dust storms are intermittently significant. These are included in the urban dispersion modeling exercise as boundaries conditions, extracted from the national (all India) atmospheric model. The "outside" contributions for the cities include these sources.

Air pollution in Indian cities is a symptom of inadequate urban planning and a byproduct of industrial activity. Unless there is a sustained effort to address the causes of air pollution at its source, the problem will only exacerbate over time.

Many of these cities have grown rapidly and the infrastructure and systems are yet to catch-up with growing urban population, more waste generation (per capita and totals), greater share of motorized transport for individual and commercial purposes, an increase in industrial and manufacturing activity, and a growing demand for clean fuels for cooking and heating.

With the lack of systems, cities resort to ad hoc methods (like air purifiers at road intersections) to deal with increased pressure on existing infrastructure. Hence cities need to start planning by anticipating the challenges they will face as they grow and be proactive about solutions to reduce air pollution.



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Resources and methodologies utilized for this analysis are described in detail
@ http://www.urbanemissions.info/india-apna
More relevant references are documented in a journal article
@ https://doi.org/10.1016/j.uclim.2018.11.005
Developments in air pollution research are also documented
@ http://www.urbanemissions.info/publications

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