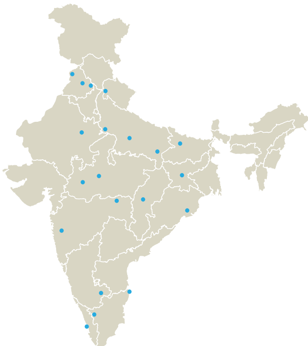
APnA CITY PROGRAM

Clearing the air with data

The Air Pollution Knowledge Assessment (APnA) City Program



APnA Cities (2017)
Agra, Amritsar, Bengaluru, Bhopal, Bhubaneswar, Chandigarh, Chennai, Coimbatore, Dehradun, Indore, Jaipur, Kanpur, Kochi, Ludhiana, Nagpur, Patna, Pune, Raipur, Ranchi, and Varanasi

The Air Pollution Knowledge Assessment (APnA) City Program

That air pollution is a serious environmental health issue in India is not under debate. What is unclear however is the extent of the problem in India. With urbanisation, domestic migration is not only increasing population in the major metropolitan cities, but also in tier-2 cities that are adjusting their infrastructure needs, such as transport and waste management, in response to the increase in population.

To take the policy debate further, we need to move beyond anecdotal evidence and quantify and spatially map out emissions, and assess the pollution impact of sources. Major metropolitan cities like Delhi, Chennai, and Mumbai have some studies that quantified the select sources and these have been instrumental in seeking policy measures. Most other cities have very little data that is available to stakeholders and citizens. We believe that a baseline or quantifying the extent of the problem is a starting point for change.

Designing an effective air quality management plan for a city, requires robust data on the sources of air pollution. The APnA city program is an attempt to fill the vacuum of information, so that policy makers and citizens can begin working towards improving the quality of air in these cities.

Methodology

APnA City Program aims at creating a baseline of air pollution related information for Indian cities, which can lead to an estimate of pollution source contributions – a necessary starting point for the policy makers to chart out strategies for better air quality. One of the main challenges is that data in an easy to use format is hard to come by and most of the estimates and information that we have compiled under this program are the only available information (especially in the case of tier-2 cities).

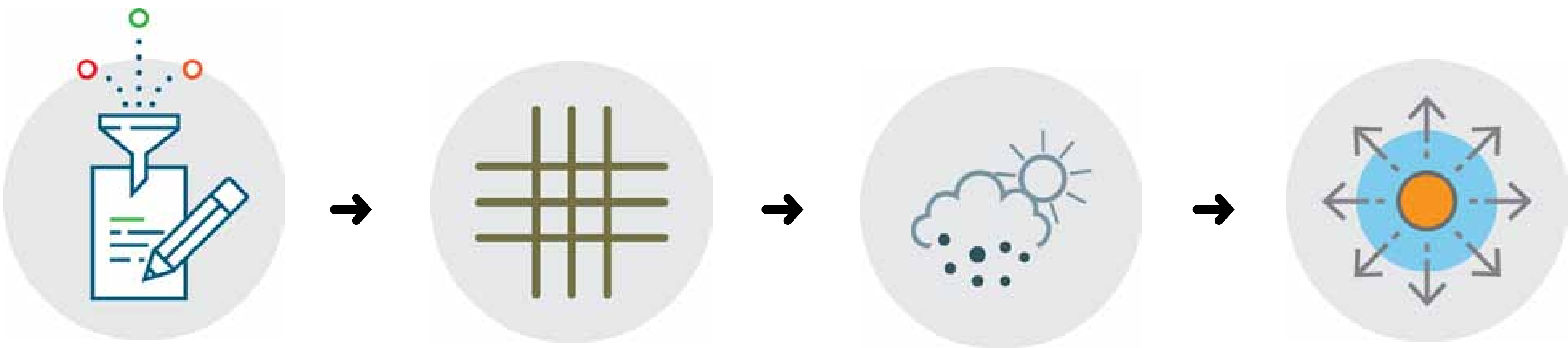
We developed an emissions inventory for the following pollutants – sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), and carbon dioxide (CO2); and particulate matter (PM) in four bins (a) coarse PM with size fraction between 2.5 and 10 μm (b) fine PM with size fraction less than 2.5 ×μm (c) black carbon (BC) and (d) organic carbon (OC), for year 2015 and projected these numbers to year 2030 under pre-defined scenarios.

The SIM-air family of tools were customized to fit the base information collated from several sources including; the Central Pollution Control Board, the State Pollution Control Board, Census Bureau, Niti Aayog, National Sample Survey Office, Ministry of Road Transport and Highways, Ministry of Statistics and Program Implementation, Annual Survey of Industries, Central Electrical Authority, municipal waste management, satellite observations of landuse, fires, dust storms, and lightnings, and meteorology. Note that there are many factors that influence the changes in a city's social, economic, landuse, urban, and industrial layout and hence the growth rates assumed should be considered as an estimate only.

The air quality status in a city is reflected in the monitoring data. We used these estimates to evaluate the likely trend in city's total emissions, their likely impact on the ambient particulate matter (PM) concentrations calculated using the Comprehensive Air Quality Model with Extensions (CAMx) coupled with the Weather Research Forecast (WRF) model for meteorology at a spatial resolution 1km for of the APnA cities.

A brief description of the methods we have used to estimate the emissions and concentrations by source for each of these cities is given below.

It involves creating city-specific information pool, by pulling together data from disparate sources, surveys, mapping and atmospheric modeling.



Compile an emissions inventory covering major sources for each city

Spatially grid the emission inventory at a 0.01° grid resolution in longitude and latitude (equivalent of 1 km) to create a spatial map of emissions for each pollutant ($PM_{2.5}$, PM_{10}, SO_2, NO_x, CO and VOCs)

Use WRF meteorological model to construct meteorological fields

Use a dispersion model to estimate concentration of pollutants by source for each city

Summary of Total Estimated Emissions by Pollutant for 2015

City	#grids	%urban-area	%urban-pop	$PM_{2.5}$	PM_{10}	BC	OC	NOx	CO	VOC	SO_2	CO_2
Agra	1600	26.3%	90.7%	8,350	15,600	2,100	2,950	10,250	79,250	16,400	950	1.55
Amritsar	1600	27.3%	85.1%	8,600	13,450	2,000	2,600	12,050	72,100	16,500	2,400	2.40
Bengaluru	3600	27.2%	93.0%	31,300	67,100	9,350	8,450	56,900	3,35,550	83,500	5,300	10.42
Bhopal	1600	25.8%	96.6%	5,900	13,650	1,300	1,550	8,950	54,300	15,100	900	1.65
Bhubaneswar	1500	26.7%	88.2%	11,250	22,400	2,700	3,600	22,250	1,29,050	27,350	1,350	2.28
Chandigarh	3600	26.6%	84.6%	18,300	33,600	3,450	4,850	56,300	1,60,350	35,850	3,200	3.91
Chennai	2500	27.0%	92.7%	94,050	1,32,350	14,500	11,250	2,07,400	3,45,550	92,900	26,600	9.76
Coimbatore	2500	19.2%	87.9%	14,100	23,900	3,500	3,050	25,150	1,13,100	28,200	2,650	3.13
Dehradun	800	18.6%	88.4%	4,650	7,500	1,300	1,700	7,200	39,450	8,600	750	1.04
Indore	1600	27.8%	93.0%	11,850	27,600	3,250	3,150	15,200	83,700	22,250	1,400	2.72
Jaipur	1600	27.9%	93.6%	17,200	34,800	4,700	5,250	20,400	1,37,600	31,550	2,650	3.79
Kanpur	1200	26.3%	89.9%	34,550	43,900	5,150	5,550	24,750	1,66,000	34,100	2,450	2.39
Kochi	1600	26.4%	94.4%	9,150	16,400	2,250	2,100	63,900	69,550	14,850	20,900	2.40
Ludhiana	1600	27.6%	86.9%	14,500	24,200	4,550	3,850	31,200	1,28,550	25,900	3,750	3.53
Nagpur	1600	26.6%	95.5%	67,100	86,300	6,900	7,900	1,28,100	1,76,850	52,900	9,600	6.89
Patna	1800	18.9%	84.8%	18,050	29,500	4,800	6,150	18,350	1,71,450	27,650	3,850	2.86
Pune	1600	27.9%	96.7%	17,700	36,900	5,600	4,150	37,000	1,66,050	41,900	3,950	5.81
Raipur	1800	18.7%	86.6%	41,500	59,650	9,150	9,050	60,700	1,63,300	1,18,150	7,600	3.13
Ranchi	1600	21.5%	87.2%	13,150	24,300	3,350	4,550	13,150	1,28,500	25,300	1,950	2.31
Varanasi	1600	15.5%	71.0%	12,100	17,450	3,050	4,850	14,050	1,34,400	21,850	2,300	1.79

#grids = number of grids in the selected urban airshed with a spatial resolution of 0.01° x 0.01° (approximately 1km x 1km); %urban-area = the share of grids designated as urban grids, depending on the built-up area in each of the grids; %urban-pop = the share of total domain population living in the urban grids; emission units – all particulates, SO2, NOx, CO, and VOC are in tons/year and CO2 is in million tons/year; all the emission estimates are from this study, calculations based on collated information for various sectors and using the SIM-air family of tools

Summary of Monitoring and Modeled Air Pollution Data

City	Stations-Manual	Stations-Continuous	Stations-Needed	NAMP PM_{10}	NAMP NO_2	NAMP SO_2	Satellite $PM_{2.5}$ 1998	Satellite $PM_{2.5}$ 2014	% change 1998 - 2014	Modeled $PM_{2.5}$ (2015)	Modeled-%non-urban
Agra	6	1	23	362 ± 193	43.9 ± 22.1	09.3 ± 5.4	82.8	93.6	13.0%	89.0 ± 12.2	36%
Amritsar	3	1	18	195 ± 44.9	38.9 ± 7.6	13.8 ± 2.6	58.6	58.8	0.3%	83.4 ± 8.3	53%
Bengaluru	7	5	41	302 ± 208	69.2 ± 44.0	30.9 ± 23.5	27.2	29.7	9.2%	36.5 ± 9	16%
Bhopal	5	0	18	196 ± 117	23.2 ± 16.9	02.9 ± 2.5	34.5	46.4	34.5%	49.9 ± 6.7	42%
Bhubaneswar	5	0	22	128 ± 102	26.9 ± 17.2	03.0 ± 1.5	34.9	45.6	30.7%	47.7 ± 9.4	32%
Chandigarh	5	1	27	226 ± 103	44.3 ± 32.4	04.0 ± 1.9	53.4	59.1	10.7%	58.1 ± 6.9	51%
Chennai	11	3	38	199 ± 101	65.5 ± 37.1	39.7 ± 31.8	34.7	33.8	-2.6%	57.5 ± 16.8	13%
Coimbatore	3	0	19	062 ± 39.7	26.9 ± 15.3	04.0 ± 1.7	28.5	27.9	-2.1%	19.4 ± 4	33%
Dehradun	3	0	13	170 ± 53.8	26.3 ± 8.0	23.9 ± 7.3	63.2	84.9	34.3%	51.2 ± 9.1	42%
Indore	3	0	20	139 ± 69.8	18.9 ± 3.9	11.3 ± 3.7	33.9	43.7	28.9%	66.3 ± 12.3	28%
Jaipur	6	2	26	313 ± 141	79.8 ± 25.3	14.5 ± 7.5	50	53.8	7.6%	99.6 ± 19.4	30%
Kanpur	8	1	27	421 ± 188	70.7 ± 32.0	14.0 ± 11.7	81.5	85.4	4.8%	114.1 ± 25.6	23%
Kochi	7	0	23	221 ± 167	38.4 ± 30.5	10.7 ± 10.6	25.4	24	-5.5%	29.1 ± 7.6	21%
Ludhiana	4	1	20	335 ± 149	48.0 ± 14.4	18.7 ± 6.0	57.3	63	9.9%	90.2 ± 20.3	41%
Nagpur	7	1	22	192 ± 112	64.7 ± 36.0	20.7 ± 18.8	34.9	45.6	30.7%	84.9 ± 19.1	21%
Patna	2	1	26	162 ± 91.7	33.0 ± 24.3	04.6 ± 5.0	63.2	84.9	34.3%	122.2 ± 23.1	19%
Pune	4	1	30	162 ± 104	82.5 ± 45.0	40.3 ± 20.9	33.3	44.8	34.5%	56.3 ± 12.9	25%
Raipur	2	0	19	275 ± 81.0	35.3 ± 13.3	12.9 ± 5.0	37.9	49.9	31.7%	82.3 ± 21.8	26%
Ranchi	1	0	16	190 ± 52.3	35.1 ± 5.4	18.3 ± 2.0	39.1	49.5	26.6%	73.0 ± 15.4	29%
Varanasi	2	1	23	139 ± 15.9	26.2 ± 6.7	18.4 ± 2.5	66.5	78.3	17.7%	78.4 ± 10.3	31%

NAMP = National Ambient Monitoring Program running manual and continuous monitoring stations, operated and maintained by the Central Pollution Control Boad (CPCB); the NAMP data (for PM_{10}, NO_2, and SO_2) in the table is a summary of all the data available from the network between 2011 and 2015; number of stations listed is based on published information as of September 2017; #needed = the number of stations needed in each of the cities to represent air pollution spatially and temporally (our calculations based on the population and the urban extent in the city); satellite derived $PM_{2.5}$ (for 1998 and 2014) is the district level average from the global database used for GBD assessments; modeled $PM_{2.5}$ data is from this study for 2015; %non-urban = the percentage of modeled pollution for the city's urban area which is estimated to originate from outside the modeling domain; Modeled concentrations are an output of WRF-CAMx atmospheric dispersion model

How various sources contributed annually to the modeled ambient PM2.5 concentrations in 2015

City	domestic	transport	dust	bricks	indus	waste	dgsets	outside	seasalt
Agra	23.8%	14.0%	10.7%	0.0%	0.3%	12.4%	2.8%	36.0%	
Amritsar	10.7%	10.5%	7.1%	2.2%	7.3%	6.2%	3.2%	52.8%	
Bengaluru	9.9%	26.5%	23.0%	2.6%	2.1%	16.1%	4.0%	15.7%	
Bhopal	10.3%	14.1%	17.1%	0.1%	2.8%	8.8%	5.0%	41.8%	
Bhubaneswar	16.0%	17.1%	20.9%	4.1%	0.6%	5.7%	3.6%	32.1%	
Chandigarh	11.5%	10.6%	12.7%	1.4%	1.4%	9.0%	2.6%	50.9%	
Chennai	3.6%	24.6%	23.5%	3.1%	12.8%	15.6%	1.6%	13.3%	1.8%
Coimbatore	6.5%	18.3%	13.8%	1.1%	11.2%	14.1%	2.5%	32.6%	
Dehradun	14.3%	14.3%	4.4%	0.5%	1.3%	19.6%	3.8%	41.7%	
Indore	8.1%	27.0%	22.7%	2.1%	2.4%	7.9%	2.0%	27.8%	
Jaipur	13.5%	24.1%	17.6%	1.8%	2.4%	8.5%	2.2%	29.9%	
Kanpur	33.9%	13.8%	9.0%	1.2%	6.5%	8.9%	4.1%	22.5%	
Kochi	9.6%	20.2%	16.4%	3.8%	4.1%	3.8%	4.6%	21.0%	16.5%
Ludhiana	7.9%	16.4%	12.3%	2.9%	8.0%	9.2%	2.7%	40.7%	
Nagpur	6.8%	17.2%	11.0%	3.3%	26.7%	11.6%	1.9%	21.5%	
Patna	14.6%	14.8%	12.2%	9.3%	11.3%	13.0%	5.5%	19.3%	
Pune	5.9%	24.1%	23.4%	2.7%	9.8%	6.5%	2.9%	24.8%	
Raipur	11.9%	17.3%	11.6%	1.4%	22.9%	6.3%	2.8%	25.9%	
Ranchi	18.0%	21.2%	14.2%	3.2%	1.2%	12.2%	1.4%	28.5%	
Varanasi	20.9%	13.5%	8.3%	6.2%	0.3%	16.2%	3.4%	31.3%	

The contributions are modeled using the CAMx atmospheric dispersion model, the city specific emissions inventory from this study, the meteorological fields at 0.01° x 0.01° (approximately 1km x 1km) processed through WRF, and then averaged for the urban parts of the modeling domain

General Findings and Recommendations

Air monitoring capacity and data fall very short of expectations, in all the APnA program cities. Chennai, Bengaluru, Kanpur, Agra and Nagpur monitor at 25-30% of the recommended capacity. From the national ambient monitoring program

- All cities, except for Coimbatore, exceeds the PM10 annual standard of 100 μg/m3. Five out of 20 cities record more than three-times the annual standard. Major sources include everything that burns like coal, kerosene, petrol, diesel, biomass, cow dung, and waste and non-combustion sources like dust.
- All cities, comply with the SO2 annual standard of 50 μg/m3, with Chennai and Pune recording the highest concentrations. Major sources include combustion of coal and diesel.
- Nine of the 20 cities exceed the NO2 annual standard of 40 μg/m3, with Bengaluru, Chennai, Jaipur, Nagpur, Kanpur and Pune recording the highest concentrations. Major sources include combustion of petrol, diesel, and gas (i.e., transport related emissions) and large industries.

For $PM_{2.5}$, the modeled source contributions for 2015, highlight transport (including on-road dust), industries (including the coal-fired power plants and brick kilns, where operational), open waste burning, residential and commercial cooking and heating, diesel generator sets, as the key air pollution sources in urban areas.

Two of the 20 cities lie on the coast – Kochi and Chennai. Both of these show the influence of land-sea breeze on dispersing emissions, thus resulting in overall lower ambient annual average concentrations. These two cities host large commercial ports, with significant contributions to $PM_{2.5}$ and SO2 pollution from freight movement (ships and on roads heavy duty trucks). This sector can benefit from a freight management program (for example, movement of freight on rail, restrictions on vehicle types entering the port area, restrictions on the fuel quality used by ships anchored at the ports).

All the cities 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 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 with an increasing share of LPG and electrification, in the urban and rural areas.

None of the cities have a comprehensive waste management system. 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 urbanised.

Upgrading the brick kiln technology from the current fixed-chimney and clamp-style baking to (for example) zig-zag for the approximately 4,000 brick kilns mapped in the urban 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 close proximity that strongly influences each other's ambient air quality. For example, these cities on average experi-

ence in excess of 25% of ambient $PM_{2.5}$ 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) dispersion 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 catchup 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 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.

The program, implemented by Urban Emissions and facilitated by Shakti Sustainable Energy Foundation, seeks to create a comprehensive, city-specific information pool by pulling together data from disparate sources, surveys, mapping and atmospheric modeling.

Policy options based on this information, and their implementation, would be the effective next steps in improving the air quality of our cities.

Send your questions, comments, and suggestions on the methodology and data resources to the program coordinators – Email: simair@urbanemissions.info

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