where do we start planning for better air quality in Indian cities?

Dr. Sarath Guttikunda

URBANEMISSIONS.info
our answer....

start with disseminating information on
• how much is the pollution
• where is the pollution
• when is the pollution
• what are the sources

how do we address the problem?
at least not with this...
GOOD NEWS, CONSUMERS! There's NO NEED to CHANGE your HABITS or MODIFY your LIFESTYLE - thanks to my new SUCKER-MATIC SUPER-HOOVER!

It SUCKS IN all the FOUL AIR and FILTERS OUT the DUST and the POLLUTION and the CO₂, before PUMPING it back OUT, smelling like a SUMMER MEADOW!

Neat, huh?

So...YOU can all just GET ON with your BUSY, BUSY LIVES...

While I SAVE the WORLD.

I MIGHT need a BIGGER Hoover
Giant vacuum cleaner?

(2.5 crore) equivalent of at least two continuous monitoring stations
Discontinuous Real-time Monitors
so, where do we start?

people cover their unwillingness to act under the guise of unending inquiry… we can't do anything because, we don't yet know everything…

Jon Stewart, The Daily Show (final episode, 2015)
Particulate Matter (PM)

- PM\textsubscript{10}
- PM\textsubscript{2.5}
- SO\textsubscript{2}
- NO\textsubscript{2}
- Ozone
- CO

Image courtesy of EPA, Office of Research and Development
Source Contributions

- Industries
- Power plants
- Road dust
- Domestic fuels
- Vehicle exhaust
- Construction
- Garbage burning
Air Pollution in Indian Cities

GBD 2010 (Lancet, 2012)

~627,000 premature deaths
~100,000 from household pollution to outdoor
Data from the Manual Stations

Ambient Annual Average SO₂ Concentrations
National annual standard = 50 μg/m³

SO₂
Data from the Manual Stations

Ambient Annual Average PM$_{10}$ Concentrations
National annual standard = 60 μg/m$^3$
Data from the Manual Stations

Ambient Annual Average NO₂ Concentrations
National annual standard = 40 μg/m³
Where is the data?

- All manual stations
- 30-40% collection
- Limited CAMS
- Limited PM$_{2.5}$
- Limited access

Stations under the national ambient monitoring program (NAMP)
Discontinuous Real-time Monitors
Discontinuous Real-time Monitors

Anand Vihar, Delhi AQI: Anand Vihar, Delhi Real-time Air Quality

482 Hazardous
Updated on Tuesday 15:00
Primary pollutant pm10

<table>
<thead>
<tr>
<th>Current Last 2 days</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2.5 AQI</td>
<td>152</td>
<td></td>
</tr>
<tr>
<td>PM10 AQI</td>
<td>482</td>
<td></td>
</tr>
<tr>
<td>O3 AQI</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>NO2 AQI</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>SO2 AQI</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>CO AQI</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Temp</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td>1006</td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Custom power intelligence
All your power news on pennwellhub. Create your free account today!
Question

Do we want discontinuous information for ten pollutants

Or

Do we want continuous information for one critical pollutant at ten locations
What will it take to make our cities environment-smart?

PM Modi’s vision of smart cities will remain unrealised till we have environmentally-smart urban centres, equipped to mitigate the severe chronic air pollution levels. But what will it entail? Sarath Guttikunda analyses.

- **7500 crores** for up to 30 CAMS per city, in 50 cities, for 10 years of operations
- **500 crores** for up to 50 BAMS (PM2.5 only) per city, in 50 cities, for 10 years of operations
- **75 crores** for up to 100 low cost PM2.5 monitors per city, in 50 cities, for 10 years of operations
Alternatives

- Handheld monitors like Dust-Traks for PM or BAMS
- Low-cost monitors
PM2.5 Real-time Monitors

New Delhi US Embassy AQI: New Delhi US Embassy Real-time

312 Hazardous
Updated on Friday 7:00
Temp: 6°C

Mumbai US Consulate
160 Unhealthy
Updated on Friday 7:00

Hyderabad US Consulate
154 Unhealthy
Updated on Friday 7:00

R.K. Puram, Delhi Air
no data
Updated on Thursday 18:00

Kolkata US Consulate
no data
Updated on Thursday 18:00

Chennai US Consulate
197 Unhealthy
Updated on Friday 7:00

Mandir Marg, Delhi Air
no data
Updated on Thursday 18:00

PM2.5 AQI
Temp
Pressure
Humidity
Wind
Rain

Last 2 days
Thu 06
Fri 05
PM2.5
6
3
16
985
981
985
79
68
88
1
1
4
0
0
0
#Indiaspend

IndiaSpend  #breathe

Click on a location to display its Air Quality Data
surveys and modelling
to support urban environments
odd/even rule in Delhi....

Social awareness
Health awareness
What else?
Delhi On-road Exposures

55% of the day time population exposed to air pollution (HEI)
In-vehicle PM$_{2.5}$ exposure

**Bus Stops**
- Walk
- Cycle
- 2-Wheelers
- Auto Rickshaw
- Car OW (Open-window)
- Bus OW
- Bus AC
- Car AC
- Metro Platform
- Metro

Goel et al., 2015

PM2.5 Monitor
GPS
Relative Humidity
Sample Data Collection Run

28 February, 2014
9:40 AM – 11:00 AM

Goel et al., 2015
Urban Sprawl between 1990 and 2013
Air Pollution Modeling in Delhi

Results from 3D Eulerian Chemical Transport Modeling @ 1km grid resolution over a 80 x 80 km² domain

http://delhiairquality.info
In Delhi, 20 min of idling for cars = Rs. 1 crores in fuel losses (~$150,000) per day

Goel & Guttikunda, 2014
“Pollution Under Check” (PUC) Data Analysis

- Mandatory to get PUC certificate every 3 months
- No. of PUC certificates issued every month (to pvt vehicles): 4 lakh
- No. of challans issued by transport dept between April 1, 2010, and Feb 1, 2012: 87,561
- Percentage of compliance in private vehicles: less than 30%
- Cost of PUC check: Rs 80 for CNG/petrol four-wheelers; Rs 150 for others
- Challan of Rs 1,000 on first violation; subsequent violations attract fine of Rs 2,000
- PUC certificate must have a security hologram
- PUC centre must be air-conditioned: located within petrol pump/workshop premises

**Motorcycle**

**Petrol Car**

<table>
<thead>
<tr>
<th>Model Year</th>
<th>CO (%) in MTWs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>0.00</td>
</tr>
<tr>
<td>2011</td>
<td>0.00</td>
</tr>
<tr>
<td>2012</td>
<td>0.00</td>
</tr>
<tr>
<td>2013</td>
<td>0.00</td>
</tr>
</tbody>
</table>

- 95% Confidence Interval
- Mean
Fuel Station Surveys

<table>
<thead>
<tr>
<th>Vehicular Fuel Efficiency Survey in Delhi</th>
</tr>
</thead>
<tbody>
<tr>
<td>by</td>
</tr>
<tr>
<td>INDIAN INSTITUTE OF TECHNOLOGY</td>
</tr>
<tr>
<td>DELHI</td>
</tr>
</tbody>
</table>

**Type of Vehicle:**  
- ☐ Car  ☐ SUV  ☐ Auto  ☐ MC  ☐ Other

**Type of Fuel:**  
- ☐ Petrol  ☐ Diesel  ☐ CNG  ☐ LPG

**Make/Model/Year:**

**Mileage:**

**Odometer Reading:**

---

2-3 minutes per response

age mix

vehicle usage by age

fuel efficiency

Goel et al., 2014
Delhi On-road Emissions

modeled road transport emissions for the Greater Delhi region
including Delhi metropolitan area and its satellite cities covering an area of 80 km x 80 km

Source: Goel and Guttikunda, 2015, Atmospheric Environment
National Transport Emissions 2030

Planning Commissions NDTPC report; Guttikunda and Mohan, 2013
More @http://www.urbanemissions.info
information to policy support
Coal-fired thermal power plants

COAL KILLS
An Assessment of Death and Disease caused by India’s Dirtiest Energy Source

Coal Kills
Health Impacts of Air Pollution from India’s Coal Power Expansion

2013

2014
## Coal-fired thermal power plants

<table>
<thead>
<tr>
<th>Country</th>
<th>PM</th>
<th>SO₂</th>
<th>NO₂</th>
<th>Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>India a</td>
<td>350mg/Nm³ for &lt;210MW 150mg/Nm³ for &gt;210MW</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>China b</td>
<td>30mg/Nm³ (proposed all) 20mg/Nm³ for key regions 50mg/Nm³ for key regions</td>
<td>100mg/Nm³ for new 200mg/Nm³ for old</td>
<td>100mg/Nm³</td>
<td>None</td>
</tr>
<tr>
<td>Australia c</td>
<td>100mg/Nm³ for 1997-2005 50mg/Nm³ after 2005 standards</td>
<td>None</td>
<td>800mg/Nm³ for 1997-2005 500mg/Nm³ after 2005</td>
<td>In discussion based on USA</td>
</tr>
<tr>
<td>European Union c</td>
<td>Pre-2003 100mg/Nm³ for &lt;500MW 50mg/Nm³ for &gt;500MW Post 2003 50mg/Nm³ for &lt;100MW 30mg/Nm³ for &gt;100MW</td>
<td>Pre-2003 Scaled for &lt;500MW 400mg/Nm³ for &gt;500MW Post 2003 850mg/Nm³ for &lt;100MW 200mg/Nm³ for &gt;100MW</td>
<td>Pre-2003 600mg/Nm³ for &lt;500MW 500mg/Nm³ for &gt;500MW Post 2003 400mg/Nm³ for &lt;100MW 200mg/Nm³ for &gt;100MW</td>
<td>In discussion</td>
</tr>
<tr>
<td>USA a d</td>
<td>37 mg/Nm³ for <strong>old</strong> 6 mg/Nm³ for <strong>new</strong></td>
<td>245 mg/Nm³ for <strong>old</strong> 50 mg/Nm³ for <strong>new</strong></td>
<td>61 mg/Nm³ for <strong>old</strong> 42 mg/Nm³ for <strong>new</strong></td>
<td></td>
</tr>
</tbody>
</table>

Atmospheric Environment (2014)
### Coal-fired thermal power plants

**Draft standards proposed in April, 2015**

**Amended in December, 2015**

<table>
<thead>
<tr>
<th>Country</th>
<th>PM</th>
<th>SO₂</th>
<th>NO₂</th>
<th>Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>350 mg/Nm³ for &lt;210MW</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>150 mg/Nm³ for &gt;210MW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>30 mg/Nm³ (proposed all)</td>
<td>100 mg/Nm³ for &lt;200 MW</td>
<td>100 mg/Nm³ for new</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>20 mg/Nm³ for key regions</td>
<td>200 mg/Nm³ for key regions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>1997-2005</td>
<td>800 mg/Nm³ for old</td>
<td>100 mg/Nm³ for old</td>
<td>In base</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>500 mg/Nm³ for new</td>
<td>100 mg/Nm³ for new</td>
<td></td>
</tr>
<tr>
<td>European Union</td>
<td>Pre-2003</td>
<td>Pre-2003</td>
<td>Pre-2003</td>
<td>In discussion</td>
</tr>
<tr>
<td></td>
<td>100 mg/Nm³ for &lt;500MW</td>
<td>Scaled for &lt;500MW</td>
<td>600 mg/Nm³ for &lt;500MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 mg/Nm³ for &gt;500MW</td>
<td>Post 2003</td>
<td>500 mg/Nm³ for &gt;500MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post 2003</td>
<td></td>
<td>850 mg/Nm³ for &lt;100 MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 mg/Nm³ for &lt;100 MW</td>
<td></td>
<td>400 mg/Nm³ for &lt;100 MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 mg/Nm³ for &gt;100 MW</td>
<td></td>
<td>200 mg/Nm³ for &gt;100 MW</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>37 mg/Nm³ for old</td>
<td>245 mg/Nm³ for old</td>
<td>61 mg/Nm³ for old</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 mg/Nm³ for new</td>
<td>50 mg/Nm³ for new</td>
<td>42 mg/Nm³ for new</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Atmospheric Environment (2014)*
open and untapped information
Household energy consumption (HEC) emissions were calculated in four classes - cooking (CK), lighting (LG), space heating (SH), and water heating (WH). Bottom-up emissions for the four classes are available at 0.25 degree spatial resolution, and further aggregated to district and state level. A sub-classification is available by fuel - biomass, coal, kerosene, liquified petroleum gas (LPG), and others.

**District Emissions**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>11%</td>
</tr>
<tr>
<td>WH</td>
<td>15%</td>
</tr>
<tr>
<td>LG</td>
<td>3%</td>
</tr>
<tr>
<td>SH</td>
<td>71%</td>
</tr>
</tbody>
</table>

**National Emissions**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>55%</td>
</tr>
<tr>
<td>WH</td>
<td>18%</td>
</tr>
<tr>
<td>SH</td>
<td>22%</td>
</tr>
<tr>
<td>LG</td>
<td>5%</td>
</tr>
</tbody>
</table>

**% Contribution of HEC emissions to modeled ambient PM$_{2.5}$ concentrations**

- National: 29.6%
- District: 29.0%

The health impacts of outdoor air pollution as ischemic heart diseases (which can lead to heart attacks), cerebrovascular disease (which can lead to strokes), chronic obstructive pulmonary diseases, lower respiratory infections, and cancers (in trachea, lungs, and bronchitis) were estimated using the age-dependent relative risk functions detailed in the Global Burden of Disease study (2013) and dispersion modeling results from this study. The final calculations were conducted at the district level using the population distribution by age presented in the study.

**Estimated premature mortality of outdoor air pollution per year - apportioned to HEC emissions**

- National: 59,000 - 72,000
- District: 168 - 198

Emission and dispersion modeling results, pollution animations, and summary sheets by district and state are hosted at http://www.urbanemissions.info. Send your comments and questions to sim-air@urbanemissions.info.
Household energy consumption (HEC) emissions were calculated in four classes - cooking (CK), lighting (LG), space heating (SH), and water heating (WH). Bottom-up emissions for the four classes are available at 0.25 degree spatial resolution, and further aggregated to district and state level. A sub-classification is available by fuel - biomass, coal, kerosene, liquified petroleum gas (LPG), and others.

**Households Primary Cooking Fuel**
- **gas+elec**: 78.8%
- **others**: 21.2%

**Estimated district annual HEC emissions**
- Particulates (2.5µm): 500 tons
- Sulfur dioxide: 80 tons
- Nitrogen oxides: 20 tons
- Carbon monoxide: 6,400 tons
- Hydrocarbons: 1,560 tons
- Black carbon (BC): 100 tons
- Organic carbon: 220 tons
- Carbon dioxide (CO2): 0.19 mil tons

**Estimated PM$_{2.5}$ emissions @ 0.25 degree resolution**
- Modeled share of HEC emissions to ambient PM$_{2.5}$

**National Emissions**
- PM$_{2.5}$: National 29.6%, District 32.7%
- CO$_2$: National 59,000 - 72,000, District 10 - 13

The health impacts of outdoor air pollution as ischemic heart diseases (which can lead to heart attacks), cerebrovascular disease (which can lead to strokes), chronic obstructive pulmonary diseases, lower respiratory infections, and cancers (in trachea, lungs, and bronchus) were estimated using the age-dependent relative risk functions detailed in the Global Burden of Disease study (2013) and dispersion modeling results from this study. The final calculations were conducted at the district level using the population distribution by age presented in.

**Estimated premature mortality of outdoor air pollution per year - apportioned to HEC emissions**
- National 59,000 - 72,000
- District 10 - 13

Emission and dispersion modeling results, pollution animations, and summary sheets by district and state are hosted at [http://www.urbanemissions.info](http://www.urbanemissions.info)
Send your comments and questions to sim-air@urbanemissions.info
Household energy consumption (HEC) emissions were calculated in four classes - cooking (CK), lighting (LG), space heating (SH), and water heating (WH). Bottom-up emissions for the four classes are available at 0.25 degree spatial resolution, and further aggregated to district and state level. A sub-classification is available by fuel - biomass, coal, kerosene, liquified petroleum gas (LPG), and others.

**District Emissions**

- **PM$_{2.5}$**
  - WH: 12%
  - SH: 42%
  - CK: 42%
  - LG: 6%
- **CO$_2$**
  - WH: 15%
  - SH: 17%
  - CK: 66%
  - LG: 2%
- **BC**
  - WH: 9%
  - SH: 35%
  - CK: 29%
  - LG: 27%

**National Emissions**

- **PM$_{2.5}$**
  - WH: 18%
  - SH: 22%
  - CK: 55%
  - LG: 5%
- **CO$_2$**
  - WH: 19%
  - SH: 16%
  - CK: 62%
  - LG: 3%
- **BC**
  - WH: 14%
  - SH: 43%
  - CK: 20%
  - LG: 23%

**% contribution of HEC emissions to modeled ambient PM$_{2.5}$ concentrations**

- **National**: 29.6%
- **District**: 36.8%

The health impacts of outdoor air pollution as ischemic heart disease (which can lead to heart attacks), cerebrovascular disease (which can lead to strokes), chronic obstructive pulmonary diseases, lower respiratory infections, and cancers (in trachea, lungs, and bronchitis) were estimated using the age-dependent relative risk functions detailed in the Global Burden of Disease study (2013) and dispersion modeling results from this study. The final calculations were conducted at the district level using the population distribution by age presented in.

**Estimated premature mortality of outdoor air pollution per year - apportioned to HEC emissions**

- **National**: 59,000 - 72,000
- **District**: 274,000 - 343,000

Emission and dispersion modeling results, pollution animations, and summary sheets by district and state are hosted @ http://www.urbanemissions.info

Send your comments and questions to sim-air@urbanemissions.info
Household energy consumption (HEC) emissions were calculated in four classes - cooking (CK), lighting (LG), space heating (SH), and water heating (WH). Bottom-up emissions for the four classes are available @ 0.25 degree spatial resolution, and further aggregated to district and state level. A sub-classification is available by fuel - biomass, coal, kerosene, liquified petroleum gas (LPG), and others.

<table>
<thead>
<tr>
<th>% Households Primary Cooking Fuel</th>
<th>gas+elec</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.6%</td>
<td>83.4%</td>
<td></td>
</tr>
</tbody>
</table>

Estimated district annual HEC emissions:
- Paticulates (2.5µm): 4,700 tons
- Sulfur dioxide: 910 tons
- Nitrogen oxides: 60 tons
- Carbon monoxide: 84,900 tons
- Hydrocarbons: 7,460 tons
- Black carbon (BC): 1,170 tons
- Organic carbon: 1,940 tons
- Carbon dioxide (CO2): 0.34 mil tons

Estimated PM$_{2.5}$ emissions @ 0.25 degree resolution: 12%
Modeled share of HEC emissions to ambient PM$_{2.5}$: 5% CO$_2$, 62% PM$_{2.5}$, 16% BC

% contribution of HEC emissions to ambient PM$_{2.5}$ concentrations:
- National: 29.6%
- District: 16.2%

The health impacts of outdoor air pollution as ischemic heart diseases (which can lead to heart attacks), cerebrovascular disease (which can lead to strokes), chronic obstructive pulmonary diseases, lower respiratory infections, and cancers (in trachea, lungs, and bronchitis) were estimated using the age-dependent relative risk functions detailed in the Global Burden of Disease study (2013) and dispersion modeling results from this study. The final calculations were conducted at the district level using the population distribution by age presented in

Estimated premature mortality of outdoor air pollution per year - apportioned to HEC emissions:
- National: 59,000 - 72,000
- District: 28 - 31

Emission and dispersion modeling results, pollution animations, and summary sheets by district and state are hosted @ http://www.urbanemissions.info

Send your comments and questions to sim-air@urbanemissions.info
Share of HH fuel consumption to outdoor PM2.5 pollution
improving economic measures
Pollution tax for diesel vehicles
Or
DPF’s for diesel vehicles
People cover their unwillingness to act under the guise of unending inquiry - we can't do anything because we don't yet know everything

Jon Stewart, The Daily Show (final episode, 2015)
Thank you

More @ URBANEMISSIONS.info