Achieving Clean Air:
The Experience of the US Clean Air Act

Dan Greenbaum, President
Health Effects Institute

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Addressing Air Pollution and Public Health
The US Clean Air Act

• Setting Ambient Air Quality Standards
• Taking Actions to meet Standards
• Measuring Progress
• India’s National Clean Air Programme
  • Are there useful ideas from the US Experience?
Where we were before the Clean Air Act:
Key Air Pollution Crises of the Mid-20th Century

Fog Disaster in the Meuse Valley, Belgium, 1930

The London Fog Incident, 1952

Donora, Pennsylvania, 1948

London daytime December 1952
Where we were before the Clean Air Act?
Substantial Premature Mortality During the London Fog

Source: Bell and Davis EHP 2001

~10,000 premature deaths

Date December 1952

Source: Bell and Davis EHP 2001
The Basics of Air Quality Management
(U.S. National Academy of Sciences Report)

Assessing Status
Measuring Progress
-AQ Monitoring
-Health Effects

Setting Standards and Objectives
-Ambient AQ Standards
-Critical Ecosystem Loads

Designing and Implementing Control Strategies
-Identifying key sources
-Controlling Emissions
-Anticipating Growth

Air Quality Management in the United States
http://books.nap.edu/catalog/10728.html
1) Setting Standards and Objectives
- Emissions standards
- Ambient air quality standards
- Reducing acid deposition
- Reducing regional pollution
- Protecting visibility

2) Designing and Implementing Control Strategies
- Source control technology requirements
- Emissions caps and trading
- Voluntary or incentive-based programs
- Energy efficiency
- Pollution prevention (e.g., product substitution and process alteration)
- Compliance assurance

3) Assessing Status and Measuring Progress
- Emissions trends
- Air quality trends
- Health effects trends
- Ecosystem trends
- Institutional accountability

Monitoring:
- Emissions
- Ambient air quality
- Health and exposure
- Ecosystems
- Meteorology

Analysis:
- Models (e.g., air quality, emissions)
- Economics
- Health and ecological risk assessment

Research:
- Public health and ecosystems studies
- Laboratory studies (e.g., air chemistry, toxicology)

Development:
- Source control technology
- Monitoring technology

Scientific and Technical Foundation

High Quality Atmospheric, Health Science to Inform Standards
Reviewed and Distilled By Expert Advisory Panels
(The Act establishes the Clean Air Act Scientific Advisory Committee – CASAC)
US, WHO, India, and Much of the Rest of the World, has set PM and Ozone Ambient Air Quality Standards (in µg/m³)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>WHO AQG (Interim Targets)</th>
<th>US EPA</th>
<th>EU*</th>
<th>China Newly Revised** (adopted by 2016)</th>
<th>India (Revised 2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM10 Annual</td>
<td>20 (70-50-30)</td>
<td>---</td>
<td>40</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>PM10 Daily</td>
<td>50 (150-100-75)</td>
<td>150</td>
<td>50</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>PM2.5 Annual</td>
<td>10 (35-25-15)</td>
<td>12</td>
<td>25</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>PM2.5 Daily</td>
<td>25 (75-50-37.5)</td>
<td>35</td>
<td>---</td>
<td>75</td>
<td>60</td>
</tr>
<tr>
<td>Ozone 8-hour</td>
<td>100 (70ppb)</td>
<td>~140</td>
<td>100***</td>
<td>160</td>
<td>100</td>
</tr>
</tbody>
</table>

***target value, not limit value
# The Indian NAAQS

## TABLE 2: NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Pollutants</th>
<th>Time Weighted Average</th>
<th>Concentration in Ambient Air</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Industrial, Residential, Rural, and Other Areas</td>
</tr>
<tr>
<td>1</td>
<td>Sulphur dioxide (SO$_2$), µg/m$^3$</td>
<td>Annual*</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>Nitrogen dioxide (NO$_2$), µg/m$^3$</td>
<td>Annual*</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>Particulate matter (Size &lt;10 µm) or PM$_{10}$, µg/m$^3$</td>
<td>Annual*</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>Particulate matter (Size &lt;2.5 µm) or PM$_{2.5}$, µg/m$^3$</td>
<td>Annual*</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>Ozone (O$_3$), µg/m$^3$</td>
<td>8 hours**</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 hour**</td>
<td>180</td>
</tr>
<tr>
<td>6</td>
<td>Lead (Pb), µg/m$^3$</td>
<td>Annual*</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>1.0</td>
</tr>
<tr>
<td>7</td>
<td>Carbon monoxide (CO), mg/m$^3$</td>
<td>8 hours**</td>
<td>02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 hour**</td>
<td>04</td>
</tr>
<tr>
<td>8</td>
<td>Ammonia (NH$_3$), µg/m$^3$</td>
<td>Annual*</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>400</td>
</tr>
<tr>
<td>9</td>
<td>Benzene (C6 H6), µg/m$^3$</td>
<td>Annual*</td>
<td>05</td>
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<tr>
<td>10</td>
<td>Benzo(a) pyrene (BaP)-particulate phase only, ng/m$^3$</td>
<td>Annual*</td>
<td>01</td>
</tr>
<tr>
<td>11</td>
<td>Arsenic (As), ng/m$^3$</td>
<td>Annual*</td>
<td>06</td>
</tr>
<tr>
<td>12</td>
<td>Nickel (Ni), ng/m$^3$</td>
<td>Annual*</td>
<td>20</td>
</tr>
</tbody>
</table>

* Annual arithmetical mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 08 hourly or 01 hourly monitored values, as applicable shall be complied with 98% of the time in a year. 2% of the time may exceed the limits but not on two consecutive days of monitoring.
The Basics of Air Quality Management (U.S. NAS 2004)

Assessing Status
- Measuring Progress
  - AQ Monitoring
  - Health Effects

Setting Standards and Objectives
- Ambient AQ Standards
- Critical Ecosystem Loads

Designing and Implementing Control Strategies
- Identifying key sources
- Controlling Emissions
- Anticipating Growth
The First Key Step: the Clean Air Act Requires that Areas Not Meeting the Standard ("Nonattainment") must take action to reduce emissions
A Second Key Step: Source Apportionment

• The Challenge of Source Apportionment
  • *High Quality Source Apportionment is not easy*
  • Many different techniques (e.g. PMF, CMB)
  • A large number of cities that need to conduct Source Apportionment
    • Often do not have the expertise and data...

• But without good source knowledge, it is difficult to pinpoint which sources to control
Many Sources of PM in India
A Third Key Step:
Implement Actions to Meet AAQS
A Case Study: US Diesel Fuel and Technology Rules

• US EPA rules to reduce diesel fuel sulfur and engine emissions
  • Fuel sulfur from 500 ppm to 15 ppm in 2006
  • Reduced PM and NOx emissions in 2007, 2010
Cost-Effective Technology Now Exists To Dramatically Clean Up New Vehicles

- Diesel Particulate Filters
- NOx Reduction Technology
- Needs Ultra-low sulfur diesel

Source: Michael Walsh
Improvements in PM and NOx Diesel Emission Standards

EPA Heavy-Duty Engine Emission Standards

- Steady State Test
- Transient Test
- NOx (Unregulated)
- PM (Unregulated)
- NOx + HC

Model Year:
- 1970
- 1975
- 1980
- 1985
- 1990
- 1995
- 2000
- 2005
- 2010
- 2015

Oxides of Nitrogen (g/bhp-hr)

Particulate Matter (g/bhp-hr)
Estimates of benefits
(Source: US EPA RIA, 2000)

Number of Annual Cases for All of US 2030
- Mortality: 8,300
- Hospital Admissions: 5,600
- Emergency Room Visits: 2,100
- Acute respiratory symptoms:
  - New cases of chronic bronchitis: 5,500
  - New cases of bronchitis in children: 17,600
  - Acute asthma attacks: 361,400
  - Acute respiratory symptoms e.g.: new cases of croup, pneumonia: 386,000
- Restricted activity days: 9.5 million
Comparing Costs and Benefits
US Highway Diesel Rule
(Source US EPA RIA 2000)

- Substantial Net Benefits!
Did the Rules Work?

Dramatic Reductions

98% reduction in mass
90% - 99% reduction in Ultrafine Particles

(Source: HEI’s Advanced Collaborative Emissions Study (ACES):
Are the Rules Working?
Effect of Diesel Rules in Southern California

- On-road measurements show diesel rules reducing PM and NO\textsubscript{X} on a truck-dominated freeway near the Ports of Los Angeles and Long Beach
- Continued reductions expected as the Truck and Bus Rule is implemented

Kozawa et al. (2014) Environmental Science & Technology, 48, 1475-1483
India Progress on Diesel

• Leapfrog to Bharat Stage 6/VI by 2020:
  • Fuels with very low sulfur
  • Will enable clean diesel technology for all new vehicles

• However, two significant challenges remain:
  • Compliance: Ensuring that in-use performance matches the rules
    • Beware the VW Experience in US and Europe!
  • Older Existing Diesels: Diesels have long life, and older, dirtier vehicles will continue for many years
    • Will need older vehicle retirement schemes
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The Good News!
Clean Air Act Progress 1980 - 2017:
Economic Activity Up --- Emissions Down

http://www.epa.gov/airtrends/aqtrends.html
Assessing progress after actions to improve Air Quality: Reduction in Sulfate due to SO2 trading

Data are in kilograms per hectare. Source: EPA 2003m.
Los Angeles Then and Now

Source: New York Times
Association of Improved Air Quality with Lung Development in Children

W. James Gauderman, Ph.D., Robert Urman, M.S., Edward Avol, M.S., Edward Rappaport, M.S., Roger Chang, Ph.D., Fred Lurmann, M

An HEI “Accountability” Study: AQ and Health in LA Gauderman et al March 5, 2015

Air Quality Improved (though not Ozone)

Figure 1. Levels of Four Air Pollutants from 1994 to 2011 in Five Southern California Communities. Colored bands represent the relevant 4-year averaging period for the analysis of lung-function growth in each of the three cohorts, C, D, and E. PM$_{2.5}$ denotes particulate matter with an aerodynamic diameter of less than 2.5 μm, and PM$_{10}$ particulate matter with an aerodynamic diameter of less than 10 μm.
Cleaner Air and Improved Lung Health

• Tracked growth in Lung Function in 3 “cohorts” (2,100 children total) in Southern California 1994 – 2011

• Saw notable improvement in lung function in the most recent cohort (who grew up 2007 – 2011 in cleaner air)
The **Continuing** Challenges of Air Quality Management

**Assessing Status**
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- Health Effects

**Setting Standards and Objectives**
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- Critical Ecosystem Loads

**Designing and Implementing Control Strategies**
- Identifying key sources
- Controlling Emissions
- Anticipating Growth
With experience and new science:
Standards and Control Actions Continue to be Reviewed, Implemented...

• In the US we have been working on this for nearly 50 years; Air Quality Management is not static:
  • Not everything we have tried has worked the first time!
  • New studies identify continuing air pollution problems
  • Clean technologies become more effective at lower cost
  • As rules are tightened, compliance and enforcement become more important

• AQM needs continuous improvement
  • Fortunately, India can take advantage of significant technologies already available
  • ....And move faster than the US!
What Might The US Experience Suggest for India?
Air Pollution a Significant Health Burden in India

Source: India: State of the Nation’s States ICMR/PHFI/IHME 2017
An Important First Step
Three Key Elements

NATIONAL CLEAN AIR ACTION PLAN

- Knowledge and Database Augmentation
- Institutional Strengthening
- Mitigation Actions
Building the Base of Facts

Knowledge & Database Augmentation

- Knowledge and Database Augmentation
- Institutional Strengthening
- Mitigation Actions
Building the Knowledge Base

- Progress in India:
  - An expanding air quality monitoring network
  - Initial investments in source apportionment and health science
    - MOES, DST, and MoEFCC

- Based on the US experience what else might be needed?
  - A *substantial investment* in science
    - Atmospheric chemistry
    - Source apportionment
    - Health and specific pollutants
  - Establishment of High Quality Science Advisory Committees to review, distill the science (e.g. the US Clean Air Scientific Advisory Committee – CASAC)
  - Applying consistent Source Apportionment
    - Training across all states and cities on the best approaches
  - Continue efforts, through monitoring and further studies, to *track progress and see where more work is needed*
Taking Action

MITIGATION ACTIONS

- Knowledge and Database Augmentation
- Institutional Strengthening
- Mitigation Actions
Mitigation Actions

• Progress:
  • A number of actions taken:
    • Leapfrog to BS 6/VI
    • New Thermal Power Plant rules
    • Ujjwala Yojana LPG Program (Household Air Pollution is a significant contributor to outdoor air quality in India)

• Based on the US experience what else might be needed?
  • Actions to deal with existing sources:
    • Power Plants, older diesel vehicles, factories
  • Strong attention to compliance and enforcement
  • A mechanism for continually revisiting rules to strengthen/upgrade them as technologies improve.
Important: Strengthening the Institutions
Institutional Strengthening

• Progress:
  • NCAP an important first step

• Based on the US experience what might be needed?
  • Air pollution does not stop at state or city boundaries
  • A strong role for the Centre will be important
    • To take nationwide actions that are more cost-effective (e.g. vehicles and fuels)
    • To work to have upwind states take action to protect downwind states
    • To ensure there is a level playing field, where some states do not try to weaken rules to compete for industry (Yes, this has happened in the US!)

• In the US, the National Academy of Sciences estimated that over 80% of the reductions in air pollution came from federal Government action, not from states and cities.
Concluding Thoughts...

- India faces significant air quality challenges
- But India is not the first to face it..
- The Good News...
  - There are management systems and technologies for improving air quality
  - They can be implemented along with a strong economy, and
  - India has already taken the first important steps...
Thank You!

dgreenbaum@healtheffects.org