Air Pollution and Health

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Approaches to study health effects

- Toxicologic
- Controlled human exposure studies
- Epidemiological studies
Toxicological studies

**Live Animal studies**
- Quick
- Dose response relations can be studied
- Single pollutant can be studied
- Observed effects may not always be relevant to humans
- Only short-term effects can be studied

**In Vitro studies**
- Mechanisms of toxicity can be studied
- Effects of drugs can be studied
- Expensive
- Only short-term effects can be studied
Controlled human exposure studies

**Advantages**
- Single pollutant affects can be studied
- Dose-response relationships can be studied

**Disadvantages**
- Only short-term effects can be studied
- Chronic or Irreversible effects cannot be studied
- Ethical constraints
### Epidemiological studies

#### Advantages

- Studies performed in natural environments
- Acute/chronic effects can be studied
- Risk factors can be identified

#### Disadvantages

- Single pollutant effects cannot be studied
- Confounding factors not easy to control
- Time-consuming
- Causation not established
- Methodology and analysis require careful considerations
Adverse Effects of Air Pollution

- Excessive cardiorespiratory mortality
- Increased health-care utilization
  - Hospitalizations
  - Emergency room visits
- Asthma exacerbations
  - Increased physician visits
  - Decreased peak flow readings
Adverse Effects of Air Pollution

- Increased respiratory illness
  - Increased physician visits
  - Greater respiratory symptoms
- Impaired lung function
  - Poorer spirometry
  - Lower peak flow readings
- Increased airway reactivity
Adverse Effects of Air Pollution

- Increased lung inflammation
- Cardiovascular effects
  - Promotion of thrombosis in vessels
  - Promotion of atherosclerosis (cause of angina, heart attack)
  - Heart rhythm irregularities: potentially fatal
- Altered host defenses
  - Altered immune response (reduced defense against infection)
  - Altered mucociliary function of lungs
## Hospitalization rates and air pollution: AIIMS Study Pande et al

<table>
<thead>
<tr>
<th>Disease</th>
<th>Observed</th>
<th>Expected</th>
<th>Extra</th>
<th>%Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma</td>
<td>7.23±7.82</td>
<td>5.96±4.55</td>
<td>1.27±4.93</td>
<td>21.3</td>
</tr>
<tr>
<td>COPD</td>
<td>4.37±4.97</td>
<td>3.50±2.48</td>
<td>0.87±3.34</td>
<td>24.9</td>
</tr>
<tr>
<td>Ac Coronary</td>
<td>10.09±7.09</td>
<td>8.11±3.07</td>
<td>1.97±5.70</td>
<td>24.3</td>
</tr>
<tr>
<td>Total</td>
<td>21.65±17.7</td>
<td>17.44±9.54</td>
<td>4.20±11.4</td>
<td>24.1</td>
</tr>
</tbody>
</table>
Ambient air pollution and chronic respiratory morbidity in Delhi

Chhabra et al Arch Environ Health 2001; 56:58-64

- Residential areas within 1 Km of permanent monitoring stations were sampled
- Three colonies around each station (lower, middle and higher income groups)
- Inclusion criteria: Age > 18 yrs and residence in area for > 10 years
- n = 4141
Methodology

- Standardized Respiratory Symptoms Questionnaire
- History and examination by chest physicians
- Lung function tests (Spirometry/Peak flow recordings)

Outcome measures

- Chronic respiratory symptoms
- Lung function in asymptomatic nonsmokers
Definitions

- **Chronic cough**: Cough on most days for 3 consecutive months or more for at least last 2 years
- **Chronic phlegm**: Sputum on most days for 3 consecutive months or more for at least last 2 years
- **Dyspnoea**: Breathlessness on walking, requiring the subject to stop or slow down for breath
- **Wheezeing**: Whistling sound in breathing associated with breathlessness
Definitions

- **Asthma:** Recurrent episodes of breathlessness associated with wheezing, with or without cough and phlegm
- **Chronic bronchitis:** Cough and phlegm on most days for 3 consecutive months or more for at least last 2 years
- **Chronic Obstructive Pulmonary Disease (COPD):** Symptoms of chronic bronchitis associated with breathlessness on exertion
Results

- Nearly 25% of residents of Delhi have chronic respiratory symptoms.
- Females residing in higher pollution areas had higher prevalence of chronic cough and chronic phlegm.
- Smoking was the major determinant of respiratory morbidity.
- Lower socioeconomic status, older age and male sex were other significant risk factors.
- Area of residence (Lower or higher pollution zone) was not a significant risk factor in MLR.
- Lung function was superior among both males and females in residents of lower pollution areas.
Spirometry (Female subjects)

- FVC
- FEV₁
- F_<sub>25-75</sub>
- PEFR

Higher Pollution Zone
Lower Pollution Zone

Percent of predicted

***
***
**
ns
Spirometry (Male subjects)

- FVC
- FEV₁
- F₂₅-₇₅
- PEFR

Higher pollution zone vs Lower Pollution Zone

Percent of predicted
Increased cardiovascular mortality and morbidity

- London smog episode of December 1952: 4000 excess deaths in 1 week
- *A key finding was that sudden deaths were increased*
- Philadelphia: Comparison of high and low pollution days showed increase in sudden deaths *Schwartz Environ Res 1994;64:26–35*
- Significant increase in risk of ventricular arrhythmias
- Increased hospital admissions for heart failure
- Increased risk of acute myocardial infarction
Risks of death with increase of PM$_{2.5}$

- **Lung Cancer**: 8%
- **Heart Disease**: 6%
- **All Cause**: 4%

Source: C A Pope et al 2002, JAMA, Vol 287, No 9
# AIR POLLUTION AND MORTALITY

## Global Evidence

<table>
<thead>
<tr>
<th>Place</th>
<th>PM$_{10}$</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA (6 cities)</td>
<td>10µg/m$^3$</td>
<td>1%</td>
</tr>
<tr>
<td>Inchon, Korea</td>
<td>10µg/m$^3$</td>
<td>1.2%</td>
</tr>
<tr>
<td>Bangkok, Thailand</td>
<td>10µg/m$^3$</td>
<td>3-6%</td>
</tr>
<tr>
<td>Lyon, France</td>
<td>50µg/m$^3$</td>
<td>4%</td>
</tr>
<tr>
<td>Barcelona, Spain</td>
<td>100µg/m$^3$</td>
<td>10%</td>
</tr>
<tr>
<td>Paris, France</td>
<td>100µg/m$^3$</td>
<td>17%</td>
</tr>
</tbody>
</table>
to identify changes in the daily all-natural-cause mortality rate that could be attributed to changes in air quality

3-year study period included the years 2002 through 2004

Increased concentrations of PM\(_{10}\) and of NO\(_2\) were associated with increased all-natural-cause mortality

10-µg/m\(^3\) change in PM\(_{10}\) was associated with 0.15% increase in total all-natural-cause mortality

Daily all-natural-cause mortality increased 0.84% for every 10-µg/m\(^3\) increase in NO\(_2\)
Health impact of new generation pollutants: Ozone
In India, monitoring of ozone in the ambient air is not done on a regular basis as it is done for particulates, sulphur dioxide and oxides of nitrogen.

Our present concerns about the adverse effects of air pollution have been related to the particulates.

However, the limited data available on levels of ozone in the ambient air in Delhi shows that the concentrations often exceed this limit.
Where does Ozone come from?

- Ozone is a byproduct of the action of sunlight on oxides of nitrogen and VOC that are emitted in vehicular exhaust.

- With the ever-increasing number of vehicles, ozone air pollution already constitutes a major problem in India as well and is going to increase in the future.
Good Ozone & Bad Ozone

**Good Ozone**
- The ozone layer 10 - 30 miles above the earth protects life on earth from the sun's harmful ultraviolet rays

**Bad Ozone**
- Closer to earth, ozone is an air pollutant that can be harmful. It is created and hangs around in the layer of air near the ground
Harmful effects: Acute

Irritates the Respiratory System

- Coughing
- Throat irritation
- Uncomfortable sensation in the chest

*These symptoms can last for a few hours after exposure to ozone and may even become painful*
Harmful effects: Acute

- Reduces “Lung Function”
  - volume of air that we draw in when we take a full breath and (restrictive)
  - speed at which we are able to blow it out (obstructive)

- Difficulty to breathe deeply and vigorously
- Uncomfortable breathing - dyspnoea
- More rapid and shallow breaths than normal during an exercise
Harmful effects: Acute

Aggravates Asthma

- Increased frequency and severity of symptoms
- Increased use of medication
- Worsening of lung function
- Increases sensitivity to allergens
Harmful effects: Acute

- **Proximal:** Inflames and damages the epithelial lining of the Lung

- **Distal:** Damages the cells that line the air spaces in the lung
Harmful effects

Healthy Airways  Airways exposed to Ozone
Harmful effects: Chronic

- Long-term effects are less well-established

- Airway injury, inflammation, and repair continue to occur during repeated short-term exposure and may permanently injure the lung

- Repeated ozone impacts on the developing lungs of children may lead to reduced lung function as adults

- Induction of new asthma: some evidence of increased allergies
Effect of Ozone exposure on development of asthma in experimental model

Objectives

- To study the effects of exposure to ambient concentrations of ozone on induction of asthma in guinea pigs
- To study the oxidant-antioxidant balance in allergen-induced asthma and the effect of exposure to ozone on it
- To evaluate the protective effect of dietary supplementation with antioxidant vitamins - alpha-tocopherol and ascorbic acid on the Ozone-Allergen interaction
Material and Methods

- Study approved by Institutional Animal Ethics Committee
- Male guinea pigs (250-350g)
- Baseline bronchial reactivity to histamine measured
- Animals were sensitized with ovalbumin and divided into three groups, and one control was taken:
  - **Group A (Nonsensitized)**. Control group without any intervention
  - **Group B (Sensitized)**. Animals sensitized to ovalbumin
  - **Group C (Sensitized + Ozone)**. Animals sensitized to ovalbumin and also received daily inhalation of ozone, 0.12 ppm for 2 hours
  - **Group D (Sensitized + Ozone + Diet)**. Animals with intervention as in Group C. Also received a diet supplemented with vitamin C (2mg/Kg body wt) and E (7 IU/Kg Body wt)
- The study parameters were evaluated at 4 weeks
Effect of Ozone on Physiological Response to Allergen

In sensitized animals exposed to ozone, there was:

- a greater increase in bronchial reactivity
- enhanced effect of allergen inhalation producing a greater early bronchospasm
- A more sustained late bronchospastic response

These observations suggest that sensitized animals had a more intense response to allergen challenge after ozone inhalation
Effect of addition of vitamins E and C on ozone-exposed animals

- Prevented post-sensitization increase in bronchial reactivity
- Reduced early bronchospastic response after ovalbumin challenge
- Reduced late bronchospastic response after ovalbumin challenge
- These results show that Vitamin E and C largely countered the physiological effects of ozone
Effect of addition of vitamins E and C on ozone-exposed animals

- Less disturbance in oxidant-antioxidant balance
- Lesser lipid peroxidation than non-diet supplemented animals
- Lipid peroxidation similar to sensitized animals
- Lack of decrease in Superoxide dismutase as compared to non-diet supplemented animals
- Less intense inflammatory response to allergen challenge
- These results show that Vitamin E and C largely countered the biochemical effects of ozone
Conclusions of Ozone Study

- Current levels of ambient ozone are likely to aggravate the response of allergic bronchial asthma patients to allergen inhalation
- Likely mechanism is a potentiation of oxidative stress
- Dietary supplementation with vitamin E and C may have a protective role against the allergen-ozone interaction
What are the harmful levels?

- The lowest concentration at which effects are observed depends upon:
  - the level of activity
  - the duration of exposure
  - the sensitivity of each individual to ozone

- Thus, effects can occur at 40, 80 or 120 ppb.
- National Ambient Air Quality Standards 2009:
  - 8 hrs, 100 ug/m³ (50 ppb)
  - 1 hr, 180 ug/m³ (90 ppb)
**CENTRAL POLLUTION CONTROL BOARD**

**CONTINUOUS AMBIENT AIR QUALITY**

**Date:** Monday, November 07, 2011  
**Time:** 2:40:57 PM

**Air Quality Monitoring Station:** Delhi College of Engineering  
**Type of Area:** Residential  
**Current Air Pollution Levels**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Date</th>
<th>Time</th>
<th>Concentration</th>
<th>Concentration (previous 24 Hours)/Prescribed Standard</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| Sulfur Dioxide        | 27/10/2011 | 11:45:00   | NA            | -36.0 µg/m³  
Prescribed Standard: 80.0 µg/m³                       |                          |
| Nitric Oxide          | 27/10/2011 | 11:45:00   | 2.0 µg/m³     | 5.0 µg/m³                                            |                          |
| Nitrogen Dioxide      | 27/10/2011 | 11:45:00   | NA            | -6.0 µg/m³  
Prescribed Standard: 80.0 µg/m³                        |                          |
| Oxides of Nitrogen    | 27/10/2011 | 11:45:00   | NA            | 0.0 ppb                                              |                          |
| Carbon Monoxide       | 27/10/2011 | 11:45:00   | 664.0 µg/m³   | 643.0 µg/m³  
* Prescribed Standard: 4,000.0 µg/m³                    |                          |
| Ozone                 | 27/10/2011 | 11:45:00   | 472.0 µg/m³   | 286.0 µg/m³                                          |                          |

* Prescribed Standard for CO is one hourly Average
### Air Quality Monitoring Station: ITO

#### Type of Area: Kerbside

#### Current Air Pollution Levels

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Date</th>
<th>Time</th>
<th>Concentration</th>
<th>Concentration (previous 24 Hours) / Prescribed Standard</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Sulfur Dioxide</td>
<td>27/10/2011</td>
<td>11:45:00</td>
<td>8.0 µg/m³</td>
<td>6.0 µg/m³</td>
<td>Prescribed Standard: 80.0 µg/m³</td>
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<tr>
<td>Nitric Oxide</td>
<td>27/10/2011</td>
<td>11:45:00</td>
<td>9.0 µg/m³</td>
<td>4.0 µg/m³</td>
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<tr>
<td>Nitrogen Dioxide</td>
<td>27/10/2011</td>
<td>11:45:00</td>
<td>63.0 µg/m³</td>
<td>78.0 µg/m³</td>
<td>Prescribed Standard: 80.0 µg/m³</td>
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<tr>
<td>Oxides of Nitrogen</td>
<td>27/10/2011</td>
<td>11:45:00</td>
<td>41.0 ppb</td>
<td>45.0 ppb</td>
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<tr>
<td>Carbon Monoxide</td>
<td>27/10/2011</td>
<td>11:45:00</td>
<td>943.0 µg/m³</td>
<td>767.0 µg/m³</td>
<td>* Prescribed Standard: 4,000.0 µg/m³</td>
</tr>
<tr>
<td>Ozone</td>
<td>27/10/2011</td>
<td>11:45:00</td>
<td>200.0 µg/m³</td>
<td>105.0 µg/m³</td>
<td></td>
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</tbody>
</table>

* Prescribed Standard for CO is one hourly Average
Adverse health effects of air pollution: Beyond The Lungs

- Cardiovascular system
- Systemic inflammation
- Pro-inflammatory
- Prothrombotic
- Pro-atherosclerosis
- Arrhythmogenic
Thank You

Questions?