HEALTH EFFECTS OF AIR POLLUTION

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Kolkata
AIR POLLUTION

Outdoor
- Vehicular
  - NOx, SOx, CO, PM, VOCs, PAHs, trace metals
- Industrial Thermal power Stations
  - CO, SOx, NOx, PM, trace metals
- Biomass burning
  - NOx, SOx, CO, PM, VOCs, PAHs, trace metals

Indoor
- Pesticides
  - OC, OP, C
Health effects of air pollution

Excess morbidity and mortality from:

- Respiratory diseases
  - URS, LRS, COPD, asthma, reduced lung function, TB, ALRI

- Hematological changes and immune suppression

- Neurological and behavioral problems

- Reproductive toxicity

- Metabolic disorder

- Eye irritation and cataract

Cardiovascular disease
- Hypertension, atherosclerosis, MI

Malignant tumors
Particulate Matter (PM)
the prime concerned pollutant

$PM_{10}$ : diameter < 10 microns
$PM_{2.5}$ : diameter < 2.5 microns
Ultra Fine Particles (UFPs) : diameter < 0.1 microns

Smaller the size, greater the health risk
PM deposition in lungs and the airways

Naso-oropharangeal region
Large and water-soluble PMs are removed

Tracheo-bronchial region
Smaller percentages of PM$_{10}$ and PM$_{2.5}$ are deposited

Alveolar region
PM$_{10}$, PM$_{2.5}$ and UFPs are deposited; a fraction of UFPs migrate to circulation
Alveolar macrophage biomarker of pollution exposure
Alveolar macrophages (AM) engulf inhaled pollutants
Alveolar macrophage: the biomarker of air pollution

Sputum cytology of a 14-year old girl, showing abundance of particle laden AM
Alveolar Macrophage Response
Nuclear heterogeneity of AM
PM$_{10}$ and AM count

AM count correlated positively with PM$_{10}$ level (rho=0.581, p<0.001)
PM$_{10}$ and respiratory symptoms
Prevalence of bronchial asthma

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Delhi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>2.1</td>
<td>3.5</td>
</tr>
<tr>
<td>Women</td>
<td>2.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Total</td>
<td>2.1</td>
<td>3.6</td>
</tr>
</tbody>
</table>
Lower Respiratory Symptoms

Seasonal distribution of respiratory symptoms:
- **Winter:**
  - Dry cough: 6% of children
  - Cough with phlegm: 9% of children
  - PM10: 12 microgram/m³
- **Summer:**
  - Dry cough: 6% of children
  - Cough with phlegm: 9% of children
  - PM10: 8 microgram/m³
- **Monsoon:**
  - Dry cough: 6% of children
  - Cough with phlegm: 9% of children
  - PM10: 6 microgram/m³

Inverse relation with SES:

<table>
<thead>
<tr>
<th>SES</th>
<th>Dry cough</th>
<th>Wet cough</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Medium</td>
<td>2.31*</td>
<td>1.72*</td>
</tr>
<tr>
<td></td>
<td>(1.96-2.73)</td>
<td>(1.48-2.01)</td>
</tr>
<tr>
<td>Low</td>
<td>3.34*</td>
<td>2.20*</td>
</tr>
<tr>
<td></td>
<td>(2.83-3.95)</td>
<td>(1.89-2.57)</td>
</tr>
</tbody>
</table>
## Strong positive association between PM$_{10}$ level and prevalence of LRS

<table>
<thead>
<tr>
<th>PM$_{10}$ (µg/m$^3$)</th>
<th>Dry cough</th>
<th>Wet cough</th>
<th>Wheeze</th>
<th>Breathlessness</th>
<th>Chest discomfort</th>
<th>Disturbed Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>76-100</td>
<td>1.22*</td>
<td>1.06</td>
<td>0.97</td>
<td>1.12*</td>
<td>1.13*</td>
<td>1.26*</td>
</tr>
<tr>
<td></td>
<td>(1.04-1.47)</td>
<td>(0.84-1.29)</td>
<td>(0.76-1.14)</td>
<td>(1.02-1.44)</td>
<td>(1.02-1.34)</td>
<td>(1.10-1.48)</td>
</tr>
<tr>
<td>101-125</td>
<td>1.86*</td>
<td>1.29*</td>
<td>1.04</td>
<td>1.34*</td>
<td>1.66*</td>
<td>1.64*</td>
</tr>
<tr>
<td></td>
<td>(1.54-2.24)</td>
<td>(1.06-1.57)</td>
<td>(0.72-1.38)</td>
<td>(1.14-1.83)</td>
<td>(1.27-2.14)</td>
<td>(1.25-2.13)</td>
</tr>
<tr>
<td>126-150</td>
<td>2.20*</td>
<td>1.30*</td>
<td>1.43*</td>
<td>1.51*</td>
<td>1.94*</td>
<td>1.78*</td>
</tr>
<tr>
<td></td>
<td>(1.81-2.68)</td>
<td>(1.09-1.56)</td>
<td>(1.12-1.77)</td>
<td>(1.22-1.78)</td>
<td>(1.53-2.44)</td>
<td>(1.33-2.27)</td>
</tr>
<tr>
<td>&gt;150</td>
<td>3.12*</td>
<td>3.03*</td>
<td>1.67*</td>
<td>2.84*</td>
<td>2.65*</td>
<td>2.73*</td>
</tr>
<tr>
<td></td>
<td>(2.36-3.75)</td>
<td>(2.53-3.62)</td>
<td>(1.19-2.36)</td>
<td>(2.31-3.47)</td>
<td>(2.09-3.37)</td>
<td>(1.89-4.32)</td>
</tr>
</tbody>
</table>

*The results are expressed as odds ratio with 95% CI in parentheses; *, p<0.05*
Pulmonary function test

Assessed by spirometry using portable spirometer (Spirovit SP1, Schiller, Switzerland)

Parameters assessed: FVC, FEV₁, PEFR, FEF₂₅-₇₅%

Lung function impairment categorized as restrictive, obstructive and combined defects & degree of impairment was ascertained.
Overall prevalence of lung function deficits

Lung function reduction was more prevalent in girls

Lung function reduction was highest (44.9%) in the age group of 15 – 17 years
Reduced lung function

% of children

Winter  Summer  Monsoon

PM$_{10}$ (microgram/m$^3$)

% of children

Mild  Moderate  Severe

PM$_{10}$ (microgram/m$^3$)

% of children

Boys  PM$_{10}$

North  Central  West  East  South

7.3% of children of Delhi had severe lung function deficits

Lung function decrement was highest in North Delhi (48.5%), and lowest in South Delhi (34.3%)
Air pollution and COPD among never-smokers
Adverse cellular lung reactions to chronic air pollution exposures
Changes in airway epithelial cells

Goblet cell hyperplasia. The change indicates hypersecretion of mucous, a defence against pollutants

Aggregates of columnar epithelial cells, suggesting airway injury
Hematological changes
Alteration in immune status
increased susceptibility to disease

suppression of CD4+ Th cells

increase in CD 8+ Tc

CD4:CD8 ratio 2:1 → 1:1

decrease in CD19+ B cells

increase in CD16+56+ NK cells
Liver and kidney function

- 2-fold rise in liver and kidney function impairments
- 4-fold rise in diabetes: 7.4% in Delhi vs. 1.9% in control
Neurobehavioral symptoms

Depression: 2-times more in Delhi
Significant alteration in plasma neurotransmitter level
Marked fall in plasma acetylcholinesterase activity
A positive association between PM$_{10}$ and depression (OR=1.83)
Attention Deficit Hyperactivity Disorder (ADHD)

9% of the boys in Delhi had ADHD against 2% of the girls, giving a male: female ratio of 4.5:1.

Children with ADHD are impulsive, forgetful, restless, prone to fail, unable to follow tasks, unpredictable and moody.
# Hypertension - I

## Hypertension

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>1.2</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Urban</td>
<td>4.8</td>
<td>7.9</td>
<td>6.2</td>
</tr>
</tbody>
</table>

## Pre-hypertension

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>8.6</td>
<td>9.8</td>
<td>9.3</td>
</tr>
<tr>
<td>Urban</td>
<td>31.8</td>
<td>26.4</td>
<td>29.4</td>
</tr>
</tbody>
</table>

- **Control**
- **Delhi**

% of children with hypertension increased progressively with age.
Hypertension - II

Prevalence of hypertension was least (1.8%) in underweight children and highest (16.7%) in obese group.

Children from high SES had highest prevalence of hypertension.
Hematological alterations - I

9.8% of Delhi’s children had abundance of ‘target’ cells in their peripheral blood compared with 4.3% of controls (p<0.001)

Their presence in circulation in excess signifies liver problem
Higher prevalence of circulating immature neutrophil and toxic granulation in neutrophil in Delhi’s school children suggests greater risk of infection and inflammation.
Benzo[a]pyrene: 3.82 ng/m³
Benzene: 21.4 ng/m³
Mean concentrations of

Benzo[a]pyrene and Benzene in Delhi
Metabolically active carcinogens induce DNA damage

Comet assay in PBL & AEC
DSB : $\gamma$H2AX expression
MN (Chromosomal breaks)
Chromosomal damage

MN assay in BEC & AEC
Deficiency in DNA repair

NHEJ, MMR, BER in airway epithelial cells
Up-regulation of Akt
Proliferation advantage
Journey towards cancer

Normal stem cell → Metaplasia → Dysplasia → CIN → Invasive Cancer → Metastasis

Carcinogen [ B(a)P] → Reactive electrophile → DNA adduct → DNA damage → Insufficient repair → Mutation, irreversible DNA damage → Cancer / Cell death

CYP 450
Airway cells following DNA damage, precancerous changes
Metaplasia and dysplasia of airway cells among never-smoking biomass-using women
3.2% of individuals

Kolkata

Metaplasia

% of individuals

15.9

Control

Kolkata
## Cancer incidence in rural and urban Delhi

<table>
<thead>
<tr>
<th>Site of cancer</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male (overall)/100,000</strong></td>
<td>55.2</td>
<td>116.9</td>
</tr>
<tr>
<td>Lung (%)</td>
<td>6.5</td>
<td>13.8</td>
</tr>
<tr>
<td>Oral (%)</td>
<td>8.0</td>
<td>11.4</td>
</tr>
<tr>
<td>Larynx (%)</td>
<td>4.0</td>
<td>7.9</td>
</tr>
<tr>
<td><strong>Female (overall)/ 100,000</strong></td>
<td>47.7</td>
<td>116.7</td>
</tr>
<tr>
<td>Breast (%)</td>
<td>7.8</td>
<td>30.2</td>
</tr>
<tr>
<td>Uterus (%)</td>
<td>10.3</td>
<td>17.5</td>
</tr>
<tr>
<td>Ovary (%)</td>
<td>3.3</td>
<td>8.5</td>
</tr>
<tr>
<td>Gall bladder (%)</td>
<td>3.5</td>
<td>7.4</td>
</tr>
</tbody>
</table>

*Manoharan et al, 2009, 2010*
The Study Team

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THANK YOU