Health Impacts of Air Pollution

The Indian Perspective

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India faces the dual problem of air pollution at rural & urban fronts

- **Millions affected**
  - Urban & rural

- **Health risk**
  - Fairly Established
  - High risk group
    - Children
    - Elderly (> 65 yr)
    - Persons with RI & heart problems
    - Diabetics

- **Prevention**
  - At an early stage

- **Dimension**
  - Practically unexplored

Although vehicular & industrial pollution are much emphasized, biomass emission affecting a greater populace has received very little attention.
Our Urban Scenario

In all major cities of India pollutant levels over the last 10 years were far above NAAQS

Mean annual conc. of PM$_{10}$ in Indian cities $>150 \mu g/m^3$, 2.5-times NAAQS

Vehicular emission contribute

50-70\% of urban pollution load - aggravated by

- sharp rise in no. of vehicles
- old & ill-maintained vehicles
- low traffic speed & jams
- poor fuel quality
- adulterated fuel
Annual average PM10 conc. during (2003-2005)

DELHI

CPCB
1. Ashok Vihar
2. Shahzada Bagh
3. Shahadra
4. Janakpuri
5. ITO
6. Nizamuddin
7. Siri Fort

NEERI
8. Chandni Chowk
9. Mayapuri Ind. Area
10. Sarojini Nagar
11. Moti Bagh

KOLKATA

WBPCB
1. Ultadanga
2. Shyambazar
3. Minto Park
4. Moulali
5. Raj Bhavan
6. Picnic Garden
7. Beliaghata
8. Mominpur
9. Behala
10. Hyde Road
11. Gariahat
12. Tollygunge
13. Baishnabghata
14. Topsia
15. Parivesh Bhawan
16. Park Circus

PM 10

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<tr>
<th>PM 10</th>
<th>130 - 137</th>
<th>137 - 144</th>
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PM 10

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<th>90 - 100</th>
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The Rural Front

Biomass fuel used by 578 million (78%) people – 23% of total & 80% domestic energy consumption

Wood (302 m ton/yr)  Crop residues (115 m ton/yr)  Dung (121 m ton/yr)

estimated use: 1.2-2.1 kg/capita/day

Energy efficiency & capital cost: wood > crop residue > dung

Scarcity of wood causes switch to inferior fuel
Behind the smoke

Emission conc. 10-100 times NAAQS; localized

Exposure- Very high for short duration (2-3h/dy)

Vulnerable group - Over 400 million women & children in poor household

![Graph showing PM concentrations for non-cooking and cooking activities. The graph indicates higher PM concentrations during cooking, particularly for PM10 and PM2.5.]
Air pollution is associated with similar pattern of disease in the rural and urban population but the impact is more in the biomass users due to higher exposure & greater number of people affected.
Overall similar pollutant mixtures in rural & urban emission

Gases, VOCs, PAH, Metals, Particulates & Secondary pollutants

**Particulate Matter** - the single best indicator of potential harm
A complex mixture of variable size (0.01-100µm), composition (Metals, nitrates, sulfate, PAH, VOC etc.), & concentration

**Particle toxicity** ~ Decreasing size, solubility, presence of transition metals & free radicals

Health effects are the impact of this complex mixture rather than a particular pollutant
Deposition

Breathing patterns, particle size & airway geometry

Daily loading*
Assuming Annual $PM_{10}$ mean = $162 \, \mu g/m^3$
$404 \, \mu g$ of particles are deposited in the lung each day \{(Conc. x Vol. inhaled per hr. x time) x deposition efficiency\}

Particle clearance
- Depends on its size & solubility
- Half time of clearance by cells – 300 days - yrs
- Particle retention time- determinant of adverse health effects

*(Calculated by the LUDEP computer programme of IRCP66 lung model)
Response to air pollution across population differs due to

- extent & nature of exposure
- co-exposure of different pollutant mixtures
- population structure
- nutritional & socio economic status
- susceptibility factors
Our Research Goals

Research has been directed to pin down the impact to target interventions effectively.

- To prepare a database on air pollution related respiratory & systemic alterations
- To Understand the mechanism of air pollutant induced health effects
- To develop simple, cost effective biomarkers for biomonitoring air pollution effects
- To establish the effectiveness of interventions
Study Approach

- **Target Population:**
  - *Urban residents of Kolkata & Delhi of different age, sex, occupation & socio-economic status (n= 8,200)*
  - *Rural women exposed to biomass fuel emission (n=850 )*
  - *Children urban & rural (n=42,600)*

- **Questionnaires**
- **Clinical examination**
- **Lung function test**
- **Sampling & lab investigation:**
  - *Sputum - cytology*
  - *Buccal mucosa - genotoxicity*
  - *Blood – hematology, immunology biochemistry, enzymology*
  - *Urine – t,t-MA*

- **Statistical Analysis:**
  - *Epi Info6, SYSTAT 9.0 Software system (SPSS INC. Chicago, USA)*
**Children - the ‘soft’ target**

Children are most vulnerable group

- Lower breathing zone
- Greater oxygen consumption
- More susceptible target organs
- Immunity not fully operational

Air pollution related respiratory symptoms have been assessed through specially designed questionnaires & lung function tests

*Rural & suburban areas of West Bengal – 31,000*

*Kolkata - 3,800*

*Delhi – 11,628*  
*Age groups - 8-16 years*

*Study period – 2000 - 2006*
Respiratory health in children of West Bengal

Ambient PM10
- Industrial (>200)
- Urban (>150)
- Suburban (<150)
- Rural (<80)

Asthma
- Industrial (>200)
- Urban (>150)
- Suburban (<150)
- Rural (<80)

Eye Irritation
- Industrial
- Urban
- Suburban
- Rural

Impaired lung function (incl. Mild & Moderate type)
- Industrial
- Urban
- Suburban
- Rural

Sampling Sites
(n=31,000; Age 6-17 yrs)
PM10 concentration and respiratory symptoms in children of Delhi

CPCB
1. Ashok Vihar
2. Shahzada Bagh
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Age 6-17 yrs n-11,628 (2003-2005)
Pulmonary responses to vehicular and biomass emission

RSC (past 1 week)

Lung Function
(inclusive of mild-moderate type)

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<tr>
<th>Normal</th>
<th>Restrictive</th>
<th>Obstructive</th>
<th>Combined</th>
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</table>

Control (Rural)

Vehicular- Urban

Biomass user

Urban (Kolkata & Delhi) – Vehicular emission exposed (Traffic police, hawker, driver)
Rural (West Bengal) – Biomass emission exposed women
PM10 concentration and pulmonary responses in adults of Delhi

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PM10 (Past 1 week)
- 130 - 137
- 137 - 144
- 144 - 151
- 151 - 158

- 158 - 165
- 165 - 172
- 172 - 179
- 179 - 186

- MONITORING SITES
- CAMP SITES

RSC (Past 1 week)
- 1-2
- 2-3
- 3-4
- 4-5
- 5-6
- 6-7
- 7-8
- 8-9

Lung Function Impairment (incl. Mild – Moderate type)
- 20 – 26
- 26 – 32
- 32 – 38
- 38 - 44
- 44 – 50
- 50 – 56
- 56 – 62
- 62 - 66

n-6005 (2003-2005)
Lung responses - the gender bias

RSC (past 1 week)

LF impairment (inclusive of mild-moderate types)

Urban
Female
Male

Urban (BF)

Rural (BF)

Urban male (n = 2900), female (n = 3006)
Rural male (n = 220), female (n = 450)
Lung responses
socio-economic status (Urban)

LF impairment
(including mild-moderate types)

RSC (past 1 week)

% of individuals

PM10 Conc.

High (n= 430) Medium (n=445) Low (n= 495)
Inside the alveolus

Reflection in sputum
Alveolar macrophage - the big eater
- a biomarker of pollution exposure

- AM is the first line of defense in the lung & interact directly with toxic particles and gases.
- Phagocytosis, migration & secretion of AM is pivotal in pathogenesis of lung diseases.
- AM response varies with the level of pollutants (Lahiri et al., 2000)
- Easily accessible by noninvasive procedure.
**Alveolar Macrophage (AM) Response**

- Increase in number & enlargement
- Particle overload
- Disintegration & release of particles
  *initiation of lung injury*

**Graph**
- AM / hpf
- Ambient PM10 (µg/m³)
- Urban (Kolkata & Delhi)
  - 1714
- Rural (BF)
  - 850

$n= Control 300,$
$Urban (Kolkata & Delhi) 1714,$
$Rural (BF) 850$
Functional Alteration of AM - 1

High acid phosphatase activity – activation of AM

Release of elastase by AM – degradation of elastin - emphysema

Heavy Iron deposition in AM – covert pulmonary hemorrhage?
Sputum Cytology Alterations

- Eosinophilia
  - allergy
  - bronchitis
  - asthma

- Neutrophilia
  - airway obstruction & Inflammation

- Lymphocytosis
  - viral infection

Charts showing the percentage of individuals with different cytology alterations in different settings:

- Urban Control
- Rural (BF)
The Carcinogenic Assault

Metaplasia with atypia
carcinogen
Insult & faulty repair-risk for COPD & lung cancer

Koilocyte (with perinuclear halo)
HPV infection – Cervical cancer?
Systemic effects

Fine particulates can reach deep into blood stream & cause

- hematological alterations
- Inflammatory reactions
- immune alteration
- metabolic disorders
- Cardiovascular effects

Particles (ultra fine) transitional metals

Particles (ultra fine)

transitional metals

Particles (ultra fine) transitional metals

LDL

ox

Liver

Coagulation factor

Thrombosis

Myocardial Infarction

Plaque formation

Rupture

Systemic effects

Particles (ultra fine) transitional metals

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The common blood response

- Suppressive effect on Hb & RBC values
- Elevated no. of target cells
- Increase in WBC (N & E)
- Increased no. of immature neutrophils
- Toxic granulation
- Increase in platelet count & p-selectin expression

Anemia
Altered liver function
Inflammatory response
Coagulation defect

Anisocytosis & target cell
Increased Neutrophils
Toxic granulation in PMN & band cell
Increased oxidative stress through free radicals–oxidant–antioxidant imbalance

Alteration in immune status—increased susceptibility to disease

↓ suppression of CD4+ Th cells
↑ increase in CD8+ Tc
CD4:CD8 ratio 2:1 → 1:1
↓ decrease in CD19+ B cells
↑ increase in CD16+56+ NK cells
The hit inside

Micronucleus – biomarker of genotoxicity

Micronucleus

Broken egg

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Findings Summarised

Both vehicular & biomass emission cause marked increase in

- Respiratory Symptoms
- Lung Function Impairment
- Numerical, Structural & Functional alteration of AM
- Systemic alterations
  - Genotoxicity
  - Hematological & Metabolic alterations
  - Immune alterations (vulnerable to infections)

Effects more marked in biomass exposure

Some of these alterations are reversible & proper intervention measures can prevent the development of irreversible diseases like COPD & cancer
Research needs

- Epidemiological studies on the link between air pollution and cancer, cardiovascular disease, tuberculosis, adverse pregnancy outcomes & mental health problems
- Identification of susceptible groups through biomarkers
- Medical intervention strategies
- Emphasis on research for less polluting technologies to reduce outdoor & indoor air pollution
We advocate…

**Drastic reduction of vehicular pollution by**
- lowering emissions
- changing fuel composition
- cleaner energy options &
- alternative fuels (CNG)

**Immediate interventions for reducing indoor air pollution exposure by**
- improved cooking devices
- improved housing & ventilation / chimneys
- cleaner energy options e.g., biogas
- awareness campaigns on health & behavioral changes
Appropriate & immediate measures need to be taken by all concerned to abate the alarmingly high pollution exposure in urban & rural India to protect our future generation.