Outline

1. Background: health effects of air pollution
2. Clean air action in PRC: an quasi-experimental health intervention
3. Health impact assessment: enlarged benefits & lowered inequality
4. Air quality challenges in Asia: Climate-related & anthropogenic pollution
Background: health effects of air pollution
The lifelong course effects of air pollution

Major outcomes

- Stroke
- Ischemic Heart Disease (2013)
- Lung cancer, COPD
- Low respiratory infection (2017)
- Type-2 diabetes (2018)

+++ Adverse birth outcomes (2020)

Global burden of air pollution

- High systolic blood pressure
- Tobacco
- Dietary risks
- Air pollution
- High fasting plasma glucose
- High body-mass index
- High LDL
- Kidney dysfunction
- Malnutrition
- Alcohol use

The 4th leading risk factor


Global Statement of Air 2020; Every breath we take: the lifelong impact of air pollution, 2016
Unequal toxicities of atmospheric pollutants

PM$_{2.5}$ is a chemical mixture

Differential effects for PM$_{2.5}$ components

Sources underlying burden of PM$_{2.5}$-associated diseases

Leading source underlying PM$_{2.5}$-related child mortality

Xue et al. Faraday Dis. 2021

Li et al Environ Int 2023
J Hazard Mater 2023
Ecotoxicol Environ Saf 2023
Individuals vulnerable to air pollution

**Air pollution vulnerability**

- **Vulnerable individual**
  - Exposure level: Vulnerability: same exposure, more adverse outcome

- **Non-vulnerable individual**

**US EPA statements on PM$_{2.5}$ vulnerability**

<table>
<thead>
<tr>
<th>Vulnerable Group</th>
<th>Evidence Classification</th>
<th>Factors Evaluated</th>
<th>Population/Exposure</th>
<th>Potentially at Increased Risk</th>
<th>Factor-Specific Evidence</th>
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</thead>
<tbody>
<tr>
<td>Child</td>
<td>Adequate</td>
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<td>Non-white</td>
<td>Suggestive</td>
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<tr>
<td>Cardiovascular</td>
<td>Adequate</td>
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<td>Respiratory</td>
<td>Suggestive</td>
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<td>Obesity</td>
<td>Inadequate</td>
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<td>Genetic mutation</td>
<td>Inadequate</td>
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<td>Low socioeconomic status</td>
<td>Inadequate</td>
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<td>Current smoking</td>
<td>Inadequate</td>
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<tr>
<td>Diabetes</td>
<td>Inadequate</td>
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<td>The elderly</td>
<td>Inadequate</td>
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<tr>
<td>Male</td>
<td>Inadequate</td>
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<td>Urban</td>
<td>Inadequate</td>
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<tr>
<td>Unhealthy diet</td>
<td>Inadequate</td>
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</tbody>
</table>

**Evidence-based findings & health effects**

- Limited evidence: insufficient data or studies demonstrating increased risk or associations between PM$_{2.5}$ exposure and adverse health outcomes.

**Evidence-based findings & health effects**

- Inadequate: Evidence is limited due to gaps in research, inconsistent findings, or insufficient data.

**Evidence-based findings & health effects**

- Suggestive: Evidence is suggestive but not conclusive due to limitations in study design, quality, or scope.

**Evidence-based findings & health effects**

- Adequate: Evidence is robust, consistent, and well-supported by multiple studies.

**Evidence-based findings & health effects**

- Inadequate: Evidence is insufficient or inconsistent, requiring further research to establish a clear association.

**Evidence-based findings & health effects**

- Suggestive: Evidence is suggestive but not conclusive due to limitations in study design, quality, or scope.
Clean air action in PRC: an quasi-experimental health intervention
Clean air actions in PRC: 2013 to now

Air pollution is a common issue

- London, UK
- Los Angeles, US
- Beijing, PRC
- New Delhi, India

Rapidly reduced PM$_{2.5}$ pollution

- Stage 1: Air Pollution Prevention & Control Action Plan
  - PRC’s new PM$_{2.5}$ standard
  - WHO air quality guideline

- Stage 2: Blue Sky Action
  - China Reduced Air Pollution in 7 Years as Much as US Did in Three Decades
    - Poor air quality reduces life expectancy more than smoking
    - Bangladesh, India among world’s most polluted countries

Source: tapdata.org.cn
Emission-control policies & trends in major air pollutants

Emission controls

Trends, 2013-2020

PM$_{2.5}$

O$_3$

Zhang et al. PNAS 2019

CCAPP report, 2023
Observed health benefits from clean air intervention

**Quasi-experiment**
Groups by PM$_{2.5}$ reduction target or real-world PM$_{2.5}$ reductions:

Control $\leq$ 5% vs Treat $>$ 5%

**Statistical model to show policy effect**

e.g., DID model: Between-group difference reveals policy effect

MMSE change from pre- to post-intervention

Improved cognitive function

Yao et al. Lancet Healthy Longev 2022
Clean air actions improved health in multiple dimensions

- Improved cognitive function
- Reduced depressive risk
  (Lancet Healthy Longev 2022; Lancet Reg Health West Pac 2021; Nat Commun, 2019)
- Improved lung function
  (Ann Am Thorac Soc 2021)
- Improved physical mobility
  (J Gerontol A 2021)
- Improved lipid profiles
  (Environ Int 2021)
- Improved kidney filtration
  (Health Data Sci 2022)

The saved household medical expenditure due to clean air action: 1% GDP

Household medical expenditure (RMB per capita)
Health impact assessment: enlarged benefits & lowered inequality
Exposure and health impact assessments

Health impact assessment model

Exposure response function

Population-weighted average

Average or by subpopulations

By sex, age and urban/rural residence

Xue et al. Natl Sci Rev 2023
Gain of life expectancy due to clean air actions

**Tempera trend**

Temporal trend in gain of life expectancy, determined by changes in loss of life expectancy attributable to PM$_{2.5}$ and O$_3$ exposure caused by Clean Air Actions in China, 2013-2022.

- **2013**: "Air Pollution Prevention and Control Action Plan"
- **2017**: "Three-year plan on defending the blue sky"
- **2020**:

**Spatial distribution**

<table>
<thead>
<tr>
<th>Stage 1: Air Pollution Prevention &amp; Control Action Plan</th>
<th>Stage 2: Blue Sky Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Stage 2</td>
</tr>
<tr>
<td>Overall</td>
<td>Overall</td>
</tr>
</tbody>
</table>

Xue et al. Natl Sci Rev 2023
Health inequality and progress in PRC’s clean air actions

Distribution of gain of life expectancy

- Blue Sky Action, Gini index = 0.18
- Air Pollution Prevention & Control Action Plan, Gini index = 0.32

Efficacy and Equality

- Health benefits from the rapid reduction in ambient exposure to air pollutants after China’s clean air actions: progress in efficacy and geographic equality.

- 1/3 Pop
- 1/4 Pop
- 1/2 Health benefit

Health Benefits of Air Quality Improvement in PR China
Air quality challenges in Asia: Climate-related & anthropogenic pollution
Air pollution source profile, and disease profile in Asia

Sources underlying PM$_{2.5}$ deaths

Both anthropogenic and climate-related sources contribute to air pollution in Asia

East Asia

Central Asia

South Asia

Southeast Asia

McDuffie et al. Nat Commun 2021

Profile of diseases in Asia

Asia is rich of environment-sensitive diseases, particularly for the vulnerable children and the elderly.

https://vizhub.healthdata.org/gbd-compare/
Burden of diseases attributable to early-life PM$_{2.5}$ exposure

**PM$_{2.5}$–related stillbirths**

0.83 (0.54, 1.08) million  
Xue et al. Nat Commun 2023

**O$_3$–related child mortality**

0.15 (0.02, 0.28) million  
Xue et al. Lancet Planet Health 2023

**Wildfire–related stillbirths**

50,000 (4,000–93,000)  
Xue et al. Environ Pollut 2023

**Dust–related child mortality**

1.26 (0.26, 2.07) million  
Wang et al. In preparation
## Atlas for Burden of Climate-related Diseases due to Early-life Environmental Exposures (ABCDE³)

<table>
<thead>
<tr>
<th>Environmental Exposure</th>
<th>Stillbirth</th>
<th>Neonatal death or its mediators</th>
<th>Child death or its mediators</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Neonatal deaths</td>
<td>Birthweight</td>
<td>Child deaths</td>
</tr>
<tr>
<td></td>
<td>Tong: Reduced birthweight of 41g (2015)</td>
<td>Xue: 2600 deaths/yr (2015)</td>
<td></td>
</tr>
<tr>
<td>O₃</td>
<td>Xue: 20595 deaths/yr (2015)</td>
<td>Li: Reduced birthweight of 14 g, Mediated 841 deaths/yr (2000-14)</td>
<td></td>
</tr>
<tr>
<td>Dust PM₂.₅</td>
<td>Xue: 2795 deaths/yr (2015)</td>
<td>GBD: Reduced birthweight of 22 g, Shortened gestation of 1 week</td>
<td></td>
</tr>
<tr>
<td>Fire PM₂.₅</td>
<td>Xue: 63830 deaths/yr (2015)</td>
<td>GBD: 4564 deaths/yr</td>
<td></td>
</tr>
</tbody>
</table>

### The pilot ABCDE³ project for PR China

**GBD results**

- Reduced birthweight of 22 g, Shortened gestation of 1 week
- 4564 deaths/yr
- 17642 children/yr (2015)

**Our findings**

- Kang: 3613 deaths/yr (SSP245, 2021-30)
- Tong: Reduced birthweight of 41g (2015)
- GBD results
- Reduced birthweight of 22 g, Shortened gestation of 1 week
- 17642 children/yr (2015)
Carbon Neutrality: an opportunity to remove air pollution

- On-time carbon peak can avoid 480,000 premature deaths per year
- Carbon neutrality can further avoid 1,380,000 premature deaths per year
- With carbon neutrality, PM$_{2.5}$ can meet WHO interim target 4

Cheng et al. One-Earth 2023
### Summary

<table>
<thead>
<tr>
<th>Clean air actions in PRC</th>
<th>The clean air actions can be an effective public health intervention with universal coverage, and thus promote health equality.</th>
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<tr>
<td>Air quality challenges in Asia</td>
<td>(1) More anthropogenic emissions, (2) climate change and (3) increased human vulnerability can bring a heavier burden of air pollution. Achieving carbon neutrality is one possible solution.</td>
</tr>
</tbody>
</table>
Thank you for attentions

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