Health impact assessment of particulate matter exposure in Pearl River Delta (PRD), China

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Outline

- Human health effects of PM pollution
- PM pollution level in PRD in 2006
- Risk assessment methods
- Results and discussion
- Conclusions
Potential general pathophysiological pathways linking PM exposure with cardiopulmonary morbidity and mortality.

Pope and Dockery, J. Air & Waste Manage. Assoc. 56: 709-742, 2006
Exposure-response coefficients of PM in China

Percentage increase per 10 μg/m³ increase of PM (%)

Health outcomes

<table>
<thead>
<tr>
<th>TM</th>
<th>RM</th>
<th>CM</th>
<th>RHA</th>
<th>CHA</th>
<th>RO</th>
<th>CO</th>
<th>CA</th>
<th>CB</th>
</tr>
</thead>
</table>
| PM₁₀| PM₂₅| 95% Confidence Intervals

**Legend:**
- **PM₁₀** - Total mortality
- **PM₂₅** - Respiratory mortality
- **CM** - Cardiovascular mortality
- **RHA** - Respiratory hospital admissions
- **CHA** - Cardiovascular hospital admissions
- **RO** - Respiratory outpatients
- **CO** - Cardiovascular outpatients
- **CA** - Children asthma
- **CB** - Children bronchitis
## Areas and Number of Sites

<table>
<thead>
<tr>
<th>Areas</th>
<th>Number of sites</th>
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<tr>
<td>Guangzhou</td>
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<tr>
<td>Shenzhen</td>
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<td>Zhuhai</td>
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<tr>
<td>Huizhou</td>
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<td>Jiangmen</td>
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<tr>
<td>Dongguan</td>
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<tr>
<td>Zhongshan</td>
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<tr>
<td>Foshan</td>
<td>2</td>
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<tr>
<td>Zhaoqing</td>
<td>1</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>3</td>
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</tbody>
</table>
Zhaoqing

Huizhou

Zhongshan

Hongkong

Concentration (µg/m$^3$)

PM10

WHO 24-hour average Guideline  50µg/m$^3$
Guangzhou

Hongkong

WHO 24-hour average Guideline 25μg/m³
GZ-Guangzhou  SZ-Shenzhen  ZH-Zhuhai  FS-Foshan  JM-Jiangmen
ZQ-Zhaoqing  HZ-Huizhou  ZS-Zhongshan  DG-Dongguan  HK-Hongkong

Except for Guangzhou and Hongkong, the concentrations of PM2.5 were converted from PM10. The conversion factor 0.7 was used.
Risk assessment method

Short-term effects
- Poisson model — number of attributable deaths

Long-term effects
- Poisson model — number of attributable deaths
- Life-table — gain in life expectancy
short-term effects

$$\Delta E = \sum_{i=1}^{365} (p \times \beta \times (C_i - C_0) \times E_0)$$

$$= \sum_{i=1}^{365} (p \times \beta \times \Delta C \times E_0)$$

β - exposure-response coefficient
Cᵢ - ambient PM daily concentrations
C₀ - reference PM 24-hour concentrations (here WHO Guideline values were used)
ΔC - difference between Cᵢ and C₀ (ΔC=0 if Cᵢ below C₀)
p - amount of population
E and E₀ - the health effects at Cᵢ and C₀
ΔE - the health damage caused by increased pollution
Long-term effects

\[ \Delta E = p \times ((1 + \beta \times (C - C_0)) \times E_0 - E_0) \]
\[ = p \times \beta \times \Delta C \times E_0 \]

\( \beta \) - exposure-response coefficient
\( C \) - ambient PM annual concentrations
\( C_0 \) - reference PM annual concentrations (here WHO guideline values were used)
\( \Delta C \) - difference between \( C \) and \( C_0 \)
\( p \) - amount of population
\( E \) and \( E_0 \) - the health effects at \( C_i \) and \( C_0 \)
\( \Delta E \) - the health damage caused by increased pollution
## Long-term exposure

Life expectancy of residents in PRD in 2006

<table>
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<th>Age group</th>
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<th>FS</th>
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<td>5.8</td>
<td>6.4</td>
<td>5.4</td>
<td>5.9</td>
<td>9.5</td>
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</tbody>
</table>
Short-term effects

Avoidable deaths attributable to PM pollution in PRD in 2006

2700 (95% CI, 2200-3400) premature deaths would be prevented annually for PM$_{10}$
Long-term effects

Avoidable deaths attributable to PM pollution in PRD in 2006

43000 premature deaths would be prevented annually for PM$_{10}$ and 40000 premature deaths for PM$_{2.5}$
Long-term effects

PM$_{10}$

PM$_{2.5}$

Age groups

Life extending/year

GZ-Guangzhou
SZ-Shenzhen
ZH-Zhuhai
FS-Foshan
JM-Jiangmen
ZQ-Zhaoqing
HZ-Huizhou
ZS-Zhongshan
DG-Dongguan
HK-Hongkong
Long-term effects

Life expectancy attributable to PM pollution in PRD

GZ-Guangzhou
SZ-Shenzhen
ZH-Zhuhai
FS-Foshan
JM-Jiangmen
ZQ-Zhaoqing
HZ-Huizhou
ZS-Zhongshan
DG-Dongguan
HK-Hongkong
Long-term effects

Average lifetime of residents in PRD would prolong 2.57 years for PM$_{10}$ and 2.38 years for PM$_{2.5}$ from PM reductions.
Discussion

PM exposure level

Exposure-response functions

Co-pollutants
A relative stable PM pollution level in PRD especially from 2004
Exposure-response Functions

Percent increase in mortality per 10µg/m³ increase of PM concentrations

<table>
<thead>
<tr>
<th>Pollutans</th>
<th>Subjects</th>
<th>Exposure-response coefficients</th>
<th>mean (β)</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term exposure</td>
<td>PM$_{2.5}$</td>
<td>all population</td>
<td>0.42</td>
<td>(0.03, 0.81)</td>
</tr>
<tr>
<td></td>
<td>PM$_{10}$</td>
<td>all population</td>
<td>0.33</td>
<td>(0.24, 0.43)</td>
</tr>
<tr>
<td>Long-term exposure</td>
<td>PM$_{2.5}$</td>
<td>≥30 years</td>
<td>7.6</td>
<td>(3.6, 11.6)</td>
</tr>
<tr>
<td></td>
<td>PM$_{10}$</td>
<td>≥30 years</td>
<td>5.4</td>
<td>(2.8, 7.8)</td>
</tr>
</tbody>
</table>
Exposure-response functions

PM$_{10}$

Percent increase in mortality
per 10µg/m$^3$ increase of PM

China, Europe, USA

PM$_{2.5}$

Percent increase in mortality
per 10µg/m$^3$ increase of PM

China, Europe, USA, Canada

China: our study result
Europe: Anderson et al. 2004
USA: Daniels et al. 2000
Canada: Burnett et al. 2000

China: our study result
Europe: Peters et al. 2002, Neuberger et al., 2007
USA: Zanobetti et al. 2009
Canada: Burnett et al. 2000
Co-pollutants

Annual average daily concentration /µg/m³

NO₂: 37-79 µg/m³
SO₂: 20-110 µg/m³
O₃: 30-60 µg/m³

GZ-Guangzhou
SZ-Shenzhen
ZH-Zhuhai
FS-Foshan
JM-Jiangmen
ZQ-Zhaoqing
HZ-Huizhou
ZS-Zhongshan
DG-Dongguan
HK-Hongkong
<table>
<thead>
<tr>
<th>Areas</th>
<th>Pollutants</th>
<th>SO₂</th>
<th>NO₂</th>
<th>O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangzhou</td>
<td>PM₁₀</td>
<td>0.739(***)</td>
<td>0.840(***)</td>
<td>0.418(***)</td>
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<tr>
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<td>SO₂</td>
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<td>0.805(***)</td>
<td>0.233(***)</td>
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<tr>
<td></td>
<td>NO₂</td>
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<td>0.267(***)</td>
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<tr>
<td>Shenzhen</td>
<td>PM₁₀</td>
<td>0.551(***)</td>
<td>0.498(***)</td>
<td>0.507(***)</td>
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<tr>
<td></td>
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<td>0.265(***)</td>
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<tr>
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<td>NO₂</td>
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<td>0.260(***)</td>
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<tr>
<td>Zhuhai</td>
<td>PM₁₀</td>
<td>0.483(***)</td>
<td>0.490(***)</td>
<td>0.196(***)</td>
</tr>
</tbody>
</table>
|              | SO₂        | 1     | 0.817(***)| -0.007(***)|\
|              | NO₂        | 1     |       | -0.088(***)|
| Foshan       | PM₁₀       | 0.881(***)| 0.795(***)| 0.142(***)|
|              | SO₂        | 1     | 0.800(***)| -0.044   |\
|              | NO₂        | 1     |       | 0.237(***)|
| Jiangmen     | PM₁₀       | 0.739(***)| 0.403(***)| 0.244(***)|
|              | SO₂        | 1     | 0.687(***)| -0.062(***)|\
|              | NO₂        | 1     |       | -0.154(*) |\
| Zhaoqing     | PM₁₀       | 0.635(***)| 0.775(***)| 0.319(***)|
|              | SO₂        | 1     | 0.740(***)| 0.219(***)|\
|              | NO₂        | 1     |       | 0.128(*)  |\
| Zhongshan    | PM₁₀       | 0.805(***)| 0.713(***)| 0.321(***)|
|              | SO₂        | 1     | 0.733(***)| 0.044(***)|\
|              | NO₂        | 1     |       | 0.072(*)  |\
| Hong Kong    | PM₁₀       | 0.413(***)| 0.593(***)| 0.659(***)|
|              | SO₂        | 1     | 0.456(***)| 0.248(***)|\
|              | NO₂        | 1     |       | 0.372(***)|

** Correlation is significant at the 0.01 level (2-tailed)
Conclusions

1. Annual mean concentrations of PM$_{10}$ and PM$_{2.5}$ were found to reach 72µg/m$^3$ and 51µg/m$^3$ respectively in PRD, in 2006. Foshan, Huizhou And Dongguan had more severe PM pollution. Zhongshan and Zhuhai had a little slighter PM pollution.

2. In term of avoidable deaths, 2700(95% CI, 2200-3400) premature deaths for PM$_{10}$ could be prevented annually if the PM 24-hour concentrations were reduced to below WHO 24-hour guideline value. Much larger benefits would be gained for long-term exposure. For PM$_{10}$, 42000(95% CI, 28000-55000) premature deaths would be prevented annually and the number of deaths avoidable became 40000(95% CI, 23000-54000), for PM$_{2.5}$.

3. The expected gain in person-years of adults would be 68000000 and the average lifetime would prolong 2.57 years for PM$_{10}$. And for PM$_{2.5}$, the expected gain in person-years would turn to 63000000 and the average lifetime would prolong 2.38 years if the annual concentrations in PRD reduced to below WHO guideline values.

4. The potential benefits of reducing PM levels varied in different prefectures. Different manage strategies should be carried out in different types of prefectures in PRD to improve the air quality.
Thank you for your attentions!