Air Pollution and Child Health
I shall first describe various adverse effects on child health from exposure to air pollution, and the level of evidence for each health outcome.

I shall next examine the evidence of the link between air pollution and ill-health derived from local studies.

I shall then examine the possible ways to reduce exposure to air pollution in children, and discuss the effectiveness of these strategies in the improvement of children’s health.
Background

- The evidence of adverse effects on child health from exposure to air pollution is strong, even at levels experienced in developed countries in Europe and North America.

- Epidemiological evidence is rapidly growing in developing countries in Asia, including China.
Why are children more susceptible to air pollution?

SMALLER AIRWAYS MORE VULNERABLE

Diagram of the Effect of Edema on the Cross-Sectional Airway Diameter

(R = radius)

**Adult Airway**

\[ \text{Area} = \pi \cdot R^2 = \pi \cdot 10^2 = 100 \pi \text{ mm}^2 \text{ (Normal)} \]

If have 1 mm Edema  \[ \text{Area} = \pi \cdot 9^2 = 81 \pi \text{ mm}^2 \]

or 81% of normal

**Full Term Newborn**

\[ \text{Area} = \pi \cdot R^2 = \pi \cdot 3^2 = 9 \pi \text{ mm}^2 \text{ (Normal)} \]

If have 1 mm Edema  \[ \text{Area} = \pi \cdot 2^2 = 4 \pi \text{ mm}^2 \]

or 44% of normal
# DEPOSITION OF POLLUTANTS IN THE RESPIRATORY TRACT

<table>
<thead>
<tr>
<th>Water solubility</th>
<th>Initial level of impact</th>
<th>Air pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Eyes, nose, pharynx, larynx</td>
<td>HCHO, NH₃, Cl₂, SO₂</td>
</tr>
<tr>
<td>Medium</td>
<td>Trachea, bronchi</td>
<td>O₃</td>
</tr>
<tr>
<td>Low</td>
<td>Bronchioles, alveoli</td>
<td>NO₂</td>
</tr>
</tbody>
</table>
Coarse particles (2.5–10μm) are deposited in the upper respiratory tract and large airways.

Fine particles (< 2.5μm) may reach terminal bronchioles and alveoli.

Particle size is the most important factor in determining where particles are deposited in the lung. Compared with large particles, fine particles can remain suspended in the atmosphere for longer periods and be transported over longer distances. Some studies suggest that fine particles have stronger respiratory effects in children than large particles. This diagram shows that particles greater than 10μm rarely make it past the upper airways, whereas fine particles smaller than 2μm can make it as far as the alveoli.
The respiratory system continues to grow and develop through linear growth.

At birth, a baby has about 10 million alveoli, but at age 8 years, the lungs have grown and the number of alveoli has reached 300 million.

Exposures to air pollutants during this growth period are known to have adverse consequences on both structure (growth of the lungs) and function.
# Why are children more susceptible to air pollution?

<table>
<thead>
<tr>
<th>Lung growth and development</th>
<th>Vulnerability of developing and growing airways and alveoli; Immature host defence mechanisms;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-activity patterns</td>
<td>More time spent outdoors; Increased ventilation with play and exercise;</td>
</tr>
<tr>
<td>Prevalence of chronic disease</td>
<td>High prevalence of asthma; Rising prevalence of cystic fibrosis (better survival);</td>
</tr>
<tr>
<td>Incidence of acute disease</td>
<td>High incidence of acute respiratory infections</td>
</tr>
</tbody>
</table>

*Source: Effects of air pollution on children’s health and development: A review of the evidence. WHO Special Programme on Health and Development, European Centre for Environment and Health, Bonn Office 2005*
## Diseases / conditions associated with air pollution

<table>
<thead>
<tr>
<th>Diseases / conditions</th>
<th>Study design</th>
<th>Observations</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premature deaths</td>
<td>time series studies*, cohort studies</td>
<td>+ve association with air pollutants (NO₂, PM, SO₂)</td>
<td><strong>sufficient</strong></td>
</tr>
<tr>
<td>Respiratory symptoms and diseases</td>
<td>Cross-sectional studies, time series</td>
<td>Respiratory symptoms &amp; diseases: +ve association with air pollutants (NO₂, PM, SO₂); No evidence of ↑ asthma incidence and prevalence, but ↑ prevalence of asthma attacks with air pollutants</td>
<td><strong>sufficient</strong> for causal inference for bronchitis, cough and hospital admissions suggestive of causal association for asthma attacks;</td>
</tr>
</tbody>
</table>


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</table>
| Lung growth and lung function         | Cross-sectional studies*, cohort studies (long-term effect); time series studies and panel studies (short-term changes) | +ve association with air pollutants:  
- $O_3$: short-term $\downarrow$ lung function,  
- $PM_{10}$: short-term exposure $\downarrow$ PEF; long-term exposure to $PM_{10}$ and $PM_{2.5}$ $\downarrow$ lung growth;  
- $\uparrow$ traffic density $\downarrow$ lung function; living in polluted district $\downarrow$ lung growth; relocation to a cleaner district $\uparrow$ lung function;  
- Effects are modest: a few % $\downarrow$ in lung function, but effects may be cumulative, irreversible, and $\uparrow\uparrow$ % of children with low lung function; | Sufficient to infer causality  |

*He et al, 2010; Yu et al, 2001, 2004

Air pollution and premature deaths

- Wong CM, Ma S, Hedley AJ, Lam TH. Effect of air pollution on daily mortality in Hong Kong. *Environmental Health Perspectives* 2001; 109:335-40. [NO₂, O₃ and SO₂ were associated with all non-accident cause, cardiovascular and respiratory mortalities in cool seasons (except SO2 and respiratory deaths), with a *positive exposure-response* relationship.]

- Wong TW, Tam WS, Yu TS, Wong AHS. Associations between daily mortalities from respiratory and cardiovascular diseases and air pollution in Hong Kong, China. *Occupational and Environmental Medicine* 2002; 59:30-35. [Significant positive associations between NO₂, O₃, PM₁₀ and SO₂ and all respiratory and IHD deaths. Mortality risks were detected at current ambient concentrations of air pollutants. An *exposure-response effect* was evident for all air pollutants. Findings were consistent with many reported in temperate countries.]
Air pollution and premature deaths

- Hedley AJ, Wong CM, Thach TQ, Ma S, Lam TH, Anderson HR. Cardiorespiratory and all-cause mortality after restrictions on sulphur content of fuel in Hong Kong: an intervention study. *Lancet* 2002; 360:1646-52. [Pollution resulting from sulphur-rich fuels has an effect on death rates, especially respiratory and cardiovascular deaths. The outcome of the Hong Kong intervention provides direct evidence that control of SO$_2$ has immediate and long-term health benefits.]

- Wong CM, Ou CQ, Lee NW, Chan KP, Thach TQ, Chau YK, Ho SY, Hedley AJ, Lam TH. Short-term effects of particulate air pollution on male smokers and never-smokers. *Epidemiology* 2007;18: 593–598. [Ambient particulate air pollution is associated with greater excess mortality in male smokers compared with never-smokers.]

- Wong CM, Ou CQ, Thach TQ, Chau YK, Chan KP, Ho SY, Chung RY, Lam TH, Hedley AJ. Does regular exercise protect against air pollution-associated mortality? *Preventive Medicine* 2007; 44:386–92. [Habitual exercise may prevent premature death attributable to air pollution.]
Air pollution and premature deaths


- Wong CM, Vichit-Vadakan N, Kan H, Qian Z, and the PAPA Project Teams. Public Health and Air Pollution in Asia (PAPA): A Multi-city Study of Short-term Effects of Air Pollution on Mortality. *Environmental Health Perspectives* 2008; 116(9):1195-1202. [The first Asia-based multi-centre time series study in Bangkok, Thailand, and in three cities in China: Hong Kong, Shanghai, and Wuhan on air pollution and health. In individual cities, associations were detected between most of the pollutants (NO$_2$, PM$_{10}$, SO$_2$, O$_3$) most health outcomes under study (i.e., all natural-cause, cardiovascular, and respiratory mortality). The city-combined effects of the four pollutants tended to be equal or greater than those identified in studies conducted in Western industrial nations. In addition, residents of Asian cities are likely to have higher exposures to air pollution than those in Western industrial nations because they spend more time outdoors and less time in air conditioning.]
Air pollution and respiratory illnesses:

- Ong SG, Liu J, Wong CM, Lam TH, Tam AYC, Daniel L, Hedley AJ. Studies on the respiratory health of primary school children in urban communities of Hong Kong. The Science of the Total Environment 1991; 106:121-35. [A cross-sectional study that demonstrated a higher prevalence of respiratory symptoms in school children in the more polluted Kwai-Ching District than the cleaner South District, after adjusting for confounding factors.]

- Tam AYC, Wong CM, Lam TH, Ong SG, Peters J, Hedley AJ. Bronchial responsiveness in children exposed to atmospheric pollution in Hong Kong. Chest 1994; 106:1056-60. [A subset of the above study showing a district difference in the prevalence of bronchial hyper-reactivity to histamine challenge among children in the 2 districts.]
Air pollution and respiratory illnesses

- Wong TW, Tam W, Yu TS, Wun YT, Wong AHS, Wong CM. Air pollution and general practice consultations for respiratory illnesses. *Journal of Epidemiology and Community Health* 2002;56:949–50. [The first local report of a positive association between PM$_{10}$ and URTI using prospectively collected data. PM had a significant impact on respiratory morbidity in GP.]

- Wong TW, Tam W, Yu ITS, Wun YT, Wong AHS, Wong CM. Association between Air Pollution and General Practitioner Visits for Respiratory Diseases in Hong Kong. *Thorax* 2006; 61:585-591. [Significant associations were observed between first visits for URTI and concentrations of NO$_2$, O$_3$, PM$_{10}$ and PM$_{2.5}$. The risk was highest for NO$_2$ (3.0%), followed by O$_3$ (2.5%), PM$_{2.5}$ (2.1%) and PM$_{10}$ (2.0%). Similar associations with these air pollutants were found for non-URTI respiratory diseases.]
Air pollution and respiratory illnesses

- Tam WWS, Wong TW, Ng L, Wong SYS, Wong AHS. Association between air pollution and general outpatient clinic consultations for upper respiratory tract infection in Hong Kong. PLOS ONE 2014; 9(1) e86913:1-6. [Time series study based on data from Hospital Authority general outpatient clinics. Significant associations were found between the daily number of consultations due to URTIs in GOPCs and the concentrations of NO₂, SO₂, O₃ and PM₁₀.]
Air pollution and respiratory illnesses

- Yu TS, Wong TW, Wang XR, Song H, Wong SL, Tang JL. Adverse effects of low-level air pollution on respiratory health of school children in Hong Kong. Journal of Occupational and Environmental Medicine 2001; 43:310-16. [A cross-sectional study showing the lung functions of children in a more polluted district were significantly poorer than those in less polluted districts, after adjusting for confounding factors. The differences among girls were more marked.]

- Yu TS, Wong TW, Liu HJ. Impact of air pollution on cardiopulmonary fitness in schoolchildren. Journal of Occupational and Environmental Medicine 2004; 46:946-52. [Habitual physical exercise was associated with a higher VO$_{2\text{max}}$ in the low-pollution district but not in the high-pollution district. Air pollution adversely affected the VO$_{2\text{max}}$ in children, and physical exercise in a polluted environment might not have beneficial effect on cardiopulmonary fitness.]
Air pollution and respiratory illnesses


- Gao Y, Chan EYY, Zhu Y, Wong TW. Adverse effect of outdoor air pollution on cardiorespiratory fitness in Chinese children. *Atmospheric Environment* 2013; 64:10-17. [A cross-sectional study on children’s predicted VO$_{2max}$ and air pollution. The results showed that children in high-pollution district had significantly lower predicted VO$_{2max}$ compared to those in low- and moderate-pollution districts.]

- Gao Y, Chan EYY, Li PL, He QQ, Wong TW. Chronic effects of ambient air pollution on lung function of Chinese children. *Archives of Disease in Childhood* 2013; 98:128-135. [Children living in districts of poor air quality had lower lung functions than those in districts of better air quality.]
Measuring children’s lung functions in schools
Air pollution and hospital admissions for respiratory and cardiovascular / circulatory diseases

- Wong TW, Lau TS, Yu TS, Neller A, Wong SL, Tam W, Pang SW. Air pollution and hospital admissions for respiratory and cardiovascular diseases in Hong Kong. *Occupational and Environmental Medicine* 1999; 56:679-683. [The first local comprehensive time series study on air pollution and health showing significant positive associations between daily hospital admissions for all respiratory diseases, all cardiovascular diseases, COPD and heart failure and daily concentrations of NO₂, PM₁₀, O₃ and SO₂; and between asthma, pneumonia and influenza except SO₂.]

- Ko FWS, Tam WS, Wong TW, Lai CKW, Wong GWK, Leung TF, Ng S, Hui DSC. Effects of air pollution on asthma hospitalization rates in different age groups in Hong Kong. *Clinical and Experimental Allergy* 2007; 37:1312-1319. [Significant associations were found between hospital admissions for asthma and levels of NO₂, O₃, PM₁₀ and PM₂.₅.]
Air pollution and hospital admissions for respiratory and cardiovascular / circulatory diseases


- Pun VC, Yu ITS, Qiu H, Ho KF, Sun Z, Louie PKK, Wong TW, Tian L. Short-Term Associations of Cause-Specific Emergency Hospitalizations and Particulate Matter Chemical Components in Hong Kong. *American Journal of Epidemiology* 2014/3/18. [Focus on the health impact of specific components of PM]
Air pollution and hospital admissions for respiratory and cardiovascular / circulatory diseases

- Qiu H, Tian LW, Pun VC, Ho KF, Wong TW, Yu ITS. Coarse particulate matter associated with increased risk of emergency hospital admissions for pneumonia in Hong Kong. *Thorax* 2014 (Accepted 7 August 2014). [Focus on coarse particulates]

The most convincing evidence: Intervention Studies


The most convincing evidence: Intervention Studies

- Wong CM, Lam TH, Peters J, Hedley AJ, Ong SG, Tam AYC, Liu J, Spiegelhalter DJ. Comparison between two districts of the effects of an air pollution intervention on bronchial responsiveness in primary school children in Hong Kong. *Journal of Epidemiology and Community Health* 1998; 52:571-78. [A cross-sectional study conducted after the mandatory restriction of sulphur content in diesel fuel in Hong Kong in 1990 that showed a steeper decline in bronchial responsiveness among children in the more polluted district than the less polluted district.]
# Non-pulmonary diseases / conditions associated with air pollution

<table>
<thead>
<tr>
<th>Diseases / conditions</th>
<th>Study design</th>
<th>Observations</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Childhood leukaemia</td>
<td>Spatial studies, case control and cohort studies</td>
<td>No ↑ risk in childhood cancer with traffic-related air pollution</td>
<td>Insufficient</td>
</tr>
<tr>
<td>Low birth weight, preterm births, intrauterine growth retardation and birth defects</td>
<td>Time series studies, birth cohorts, comparative spatial studies</td>
<td>Evidence of SO$<em>2$, CO and PM$</em>{10}$ with premature birth; Evidence of SO$<em>2$ and CO with low birth weight, and PM$</em>{10}$ with IUGR</td>
<td>Suggestive but inconsistent for LBW, preterm births and IUGR; Limited evidence for birth defects</td>
</tr>
<tr>
<td>Neurobehavioral deficit</td>
<td>Cross-sectional and cohort studies</td>
<td>Pb, Hg, Mn well-documented, PCB and other persistent organic pollutants – some evidence of neurobehavioral deficit</td>
<td>Mainly through ingestion, but air pollution also contributes to indirect exposure</td>
</tr>
</tbody>
</table>

Air pollution and hospital admissions for adverse reproductive outcomes


- Chung MK, Lao TT, Ting YH, Wong TW, Leung TY. Seasonality of Fetal Trisomy 21 - Have Ambient Air Pollutants Played A Role? Journal of maternal-fetal & neonatal medicine, 5/2014. [Seasonal variation in incidence of fetal trisomy 21 was correlated with ambient levels of NO\textsubscript{x} and O\textsubscript{3}. The role of environmental pollutants on fetal aneuploidy warrants further investigation.]
Types of outdoor air pollutants

- **Gases**: Oxides of nitrogen ($\text{NO}_x$), sulphur dioxide ($\text{SO}_2$), ozone ($\text{O}_3$)
- **Particulates (PM)**: $\text{PM}_{10}$, $\text{PM}_{2.5}$, ultrafine particles
- **Toxic air pollutants (TAPs)**: diesel fumes, various volatile organic chemicals (VOCs) - aromatic and aliphatic, heavy metals,
Sources of indoor air pollution in Hong Kong

- Passive tobacco smoking
- Radon
- Formaldehyde (HCHO) and other volatile organic chemicals (VOCs)
- Seepage of outdoor air pollutants
- Cooking-generated air pollutants: NO, NO$_2$, CO, PM$_{2.5}$
- House dust mites, insect parts, animal danders, moulds, ....
How to reduce exposure?

POINTS TO NOTE

- Most adults stay in an indoor environment much longer than outdoors.
- The same is true for infants, toddlers and pre-school children.
- **Older children** spend much more time in an outdoor environment and are physically more active.
My strategies

1. Identify the major sources of exposure: indoor or outdoor?

2. Some indoor sources can be eliminated or minimized: e.g., passive smoking, animal danders, house dust (use vacuum cleaner with HEPA filter), good ventilation of kitchen (general ventilation – extraction fan, local exhaust hoods), avoid deep frying and stir-frying that generate oil fumes (less fried food – a more healthy diet)

3. Is gas cooking a source of air pollution?

- Kitchens using gas stoves produced higher air pollutant concentrations, temperatures and noise levels than those with induction cookers.
- Workers in gas-fuelled kitchens had poorer lung function and a higher prevalence of respiratory symptoms than those in kitchens using electricity.
We conducted a pilot “before-after study” on the air quality inside domestic kitchens that used gas as fuel and later switched to electric induction cooking. In gas cooking, there was a much greater increase in the concentration of PM$_{2.5}$ (from background to cooking) compared to electric induction cooking. Mean NO$_2$ concentrations measured in air bags were also higher in gas cooking compared to electric cooking, and the increase from background level during cooking was much greater for gas cooking compared to electric induction cooking.

In gas cooking, there was a much greater increase in the concentration of CO (from background to cooking) compared to electric induction cooking.
My strategies

4. Are air cleaners useful? [Some are. Some are not!]
5. When and how to reduce outdoor exposure? [time of the day; location]
6. Do children need to wear masks when going outdoors? If so, which type? [particulate filter]
7. Air Quality Health Index: Is it suitable to play or do physical exercise outdoors? [AQHI in your district]
8. Walking / bicycling to school? Which public transport to take, public buses, mini-buses, trams, train, MTR, taxi, private cars? [Do we have sufficient data?]
Concluding Remark

- The strategies to reduce children’s exposure to air pollution depends on the home environment (indoor source), the child’s activity pattern (both outdoor and indoor / micro-environmental sources) and whether the child has pre-existing respiratory diseases e.g., asthma.

- The underlying principle is to reduce exposure – both indoors and outdoors. This is the most effective way to protect our children’s health.

- Can we improve the home environment to reduce the source of indoor air pollution? Yes we can!

- Can we reduce exposure to outdoor air pollution? We need data on children’s daily activities and exposure pattern. More research!

- Source reduction: Government’s role.

- What we can do: join a Non-Governmental Organization; lobby to government, District Board members, LegCo members, …..
We must work out the best solutions for our children.

Thank you!