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Review of Outdoor Air Pollution and Child Health in Hong Kong

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Abstract Our Air Quality Objectives (AQO) for seven air pollutants were established in 1987 under the Air Pollution Control Ordinance but have not been revised. Air pollution in Hong Kong has been continuously worsening and remains incompatible with acceptable standards of health protection for children. Although the government initiated a consultancy for AQO in 2007, revisions to the AQO will not be implemented for at least two more years, in 2014. Furthermore, the government does not accept that Hong Kong's AQO should follow the World Health Organization guidelines set in 2006, despite the high level of local and international evidence that poor quality air is detrimental to individual and population health and that the proposed new AQO will fail to provide adequate protection. We present a synopsis of the susceptibility of children to environmental pollution, international and local evidence of adverse health effects on children and call for support from paediatricians in urging the government to take actionable steps for the achievement of cleaner air to protect our child health.

Key words Child health; Hong Kong; Outdoor air pollution

Introduction

Outdoor air pollution in Hong Kong has been a major environmental problem for more than two decades and remains incompatible with acceptable standards of health protection for children. Our Air Quality Objectives (AQO) for seven air pollutants were established in 1987 under the Air Pollution Control Ordinance but were not revised. The government consultancy which began in 2007, following the World Health Organization (WHO) 2006 recommendations, has been criticised as a delaying tactic. However, any revision to the AQO will not be implemented by government for at least two more years, in 2014. The government does not accept that Hong Kong's AQO should follow those advised by WHO in 2006, despite the high level of evidence both locally and internationally showing that poor quality air is detrimental to individual and population health and that the proposed new AQO will not provide adequate protection.[1] What should be the roles of clinicians, in particular both paediatricians and public health practitioners, in this debate, since children are particularly vulnerable to environmental air pollution and the resulting harm can run a life-time course affecting susceptibility to illness, quality of life and life expectancy? In this report we provide a synopsis of updated evidence of the health impacts on child health attributable to outdoor air pollution and call for both paediatricans and public health experts to

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support and clearly state to the new Government of the HKSAR the mandatory and urgent steps required for cleaner air in Hong Kong. We earnestly urge the new government to take decisive actions in addressing and reversing, on the shortest possible time scale, the severe problem of poor air quality and its serious impact on the current and future health of children in Hong Kong.

Why Are Children More Vulnerable to Environmental Pollution?

Children are not miniature adults. Compared with adults, children have a particular vulnerability to environmental pollution (Table 1).[2,3] First, exposure to air pollutants occurs at a critical window period from foetal to adolescent stage when tissues and organs are rapidly growing, developing and differentiating until maturity. The resultant health effects on those exposed can be life-long. Next, a child's detoxification system is immature and less efficient in handling these toxic air pollutants. The incomplete development of the lung epithelium and frequent upper respiratory tract infection in childhood create increased permeability of the epithelial layer of the respiratory tract, resulting in increased damage for a given exposure.[4] Molecular mechanism studies also suggest that the development of the immune system will skew towards the T-helper 2 phenotype, increasing proneness to the development of allergy in response to environmental exposure. Minute ventilation adjusted for body mass is greater in infancy (400 ml/min/kg) than adult (150 ml/min/kg) and children have greater activity levels than adults, so the resultant exposure of the lungs to air pollutants will be greater. The smaller peripheral airways in infants are also

Table 1 Vulnerability of children to environmental pollution

Factors	Resultant effects
Biological	
Foetal to adolescent stage is a critical window for growth	Resultant effect due to exposure to air pollutants can be life-long
Immature detoxification system in foetus and young child	Inefficient in handling toxic air pollutants
Lung development has not completed	Increased permeability of epithelia layer of respiratory tract and
Frequent upper respiratory tract in childhood	increased damage per a given exposure
Maturing immune system	May skew towards T-helper 2 phenotype in response to environmental exposure to air pollutants
Physiological	
Minute ventilation adjusted for body mass greater in infancy	Exposure of lungs to air pollutants greater
Children have greater activity levels	
Smaller peripheral airways	More susceptible to airway obstruction
Proneness to mouth breathing due to enlarged adenoid and tonsils or allergic rhinitis	Loss of nasal filtering and greater deposition of air pollutants to lower airway
Genetic	
Genetic susceptibility to air pollution induced lung injury and repair	More prone to develop symptoms with exposure to air pollutants
Behavioural	
Spend more time in outdoor activities than adults	More likely to be exposed to air pollutants and develop more
Less likely to pay heed of warnings of poor air quality	severe symptoms
Less likely to stop activities when symptoms develop due to exposure to air pollution	
Child Protection	
No choice on where to live or attend school	Passive to exposure to air pollutants

more susceptible to airway obstruction by inflammatory secretion and bronchospasm.[5] Children, who are prone to mouth breathing due to enlarged adenoids and tonsils or allergic rhinitis, experience a loss of nasal filtering and greater deposition of air pollutants in the lower respiratory tract.[6] There is also evidence of genetic susceptibility to air pollutant-induced lung injury and repair. Glutathione-S-transferases (GST) catalyse the conjugation of glutathione to secondary oxidation products produced by exposure of lipids to environmental oxidants such as ozone. Asthmatic children with GST M1 null and GST P1 valine/valine genotypes appear more susceptible to developing respiratory symptoms related to ozone exposure.[7,8] Polymorphism in the genotype of tumour necrosis factor (TNF), an inflammatory cytokine, also influences the lung function response to ozone. Those with TNF-308 GG genotype had a significantly reduced risk of bronchitic symptoms with low-ozone exposure.[9] Children's behaviour also increases their personal exposure to air pollutants as they spend more time in outdoor activities than adults. These risks to health are especially marked in the cooler months of the year when ozone, particulates and nitrogen dioxide levels are highest and there is an important interaction between seasonal and air pollutant health effects. Most importantly, children usually have no choice where they live or attend school and there is no good evidence that restricting activity on selected days in a generally high pollution environment confers any overall health protection.

Current Evidence for Adverse Health Effects of Poor Quality Air on Children

There have been abundant time series studies that captured relationships between air pollution and more severe health impacts such as hospital admissions or mortality. They have provided strong evidence to support the significant association of ambient air pollutants with hospital admission for asthma, especially in children.[10,11] Patterns of O_3 and fine particles ($PM_{2.5}$) in particular were associated with severe asthma attacks requiring admission for general or intensive care in children aged 6-18 years.[12] Longitudinal studies are scarce as they are more resource demanding but they can also explore the less severe but important health impacts of air pollution that have often been overlooked. A recent longitudinal study carried out in California showed that wheeze was significantly associated with short-term exposures to NO_2 and the coarse particulate fraction of $PM_{10-2.5}$ in children aged 6-11 years, especially those who were sensitised to cat or common fungi, and in boys with mild intermittent asthma.[13] Modest but consistent associations were also found between NO_2, $PM_{2.5}$ and wood-smoke and otitis media in a large birth cohort exposed to relatively low levels of ambient air pollution.[14] In recent years, there has been increasing concern about the effect of traffic-related air pollution. There is consistent evidence that living near traffic sources is associated with asthma incidence and exacerbations.[15] Even in areas with good regional air quality, a cross-sectional study showed associations between current asthma in children in grade 3 to 5 and residential proximity to traffic, with highest risk for those living within 75 metres of freeways/highways.[16] A hospital based longitudinal study showed that exposure to traffic-related air pollution within 300 metres of residence increased asthma severity and hospital utilisation in children younger than 18 years.[17] In Hong Kong, exposure to traffic emissions is generally unavoidable in children living in urban areas.

It is noteworthy that air pollution does not just cause acute health effects but can induce long term pathophysiological damage to the developing lung in children and adolescents.[18] Residential traffic-related air pollution exposure is associated with reduced lung function in schoolchildren.[19,20] Longitudinal studies indicate that traffic exhaust contributes to the development of respiratory illness in childhood. There is substantial evidence for the development of asthma,[21-23] in addition to the aggravation of symptoms in those with asthma, and many studies have shown that early life exposure to traffic-related air pollutants is associated with new onset childhood asthma. The associations between traffic-related pollution with other allergic diseases such as allergic rhinitis and eczema were initially inconsistent but were strengthened with the findings in more recent studies.[24,25] In addition, there is a growing body of evidence indicating the adjuvant effect of traffic-related air pollutants, including diesel exhaust particles and NO_2, in promoting allergic sensitisation to inhaled allergens.[26-31] There are increasing numbers of observational studies which suggest an association between traffic-related air pollution and children's cognitive function[32,33] and neurobehaviuoral function[34,35] although the underlying mechanisms await further elucidation. Traffic is also a source of toxic environmental exposures, including benzene, which may be associated with childhood leukemia. A national case-control study in France showed that acute leukaemia in children was significantly associated with higher estimates of traffic NO_2 concentrations at the place of residence (>27.7 $\mu g/m^3$ versus <21.9 $\mu g/m^3$) and with the presence of a heavy-traffic road within 500 metres. There was also a significant association between acute leukaemia and a high density of heavy-traffic roads within 500 metres, with a significant positive linear trend in the association of acute leukaemia with the total length of heavy-traffic road within 500 metres.[36]

Evidence for the adverse health effects of chronic exposure in pregnant women and young infants is accumulating. Babies born to mothers who were exposed to high levels of ambient air pollutants showed increased evidence of intrauterine growth retardation, low birth weight and preterm delivery.[3,37-39] Increased micronuclei and bulky DNA adducts in cord blood after maternal exposures to traffic-related air pollution have been found, demonstrating that these transplacental environmental exposures induce DNA damage in newborns.[40] Meta-analysis showed an association between ambient air pollution and congenital anomalies, notably congenital heart disease, including NO_2 and SO_2 exposures with coarctation of the aorta and Tetralogy of Fallot, and PM_{10} exposure with atrial septal defects.[41] Two studies showed an association with omphalocoele and PM_{10} exposure[42] and unspecified nervous system anomalies with black smoke.[43] A Korean birth cohort study demonstrated a relationship between gestational exposures to particulate matter and infant mortality for all-causes and respiratory mortality in normal birth weight infants.[44]

There are numerous good quality local studies to show the adverse population health effects of air pollution, some of which are particularly related to child health. There is evidence of reduced oxygen uptake during exercise in children living in Kwun Tong and Shatin that led to impairment of physical performance during sports activities.[45] Air pollution (NO_2, PM_{10}, $PM_{2.5}$ and O_3) in Hong Kong increases paediatric asthma admissions to hospital. This is also the first study to show the association between fine particles $PM_{2.5}$ with increased asthma admissions to hospital.[11]

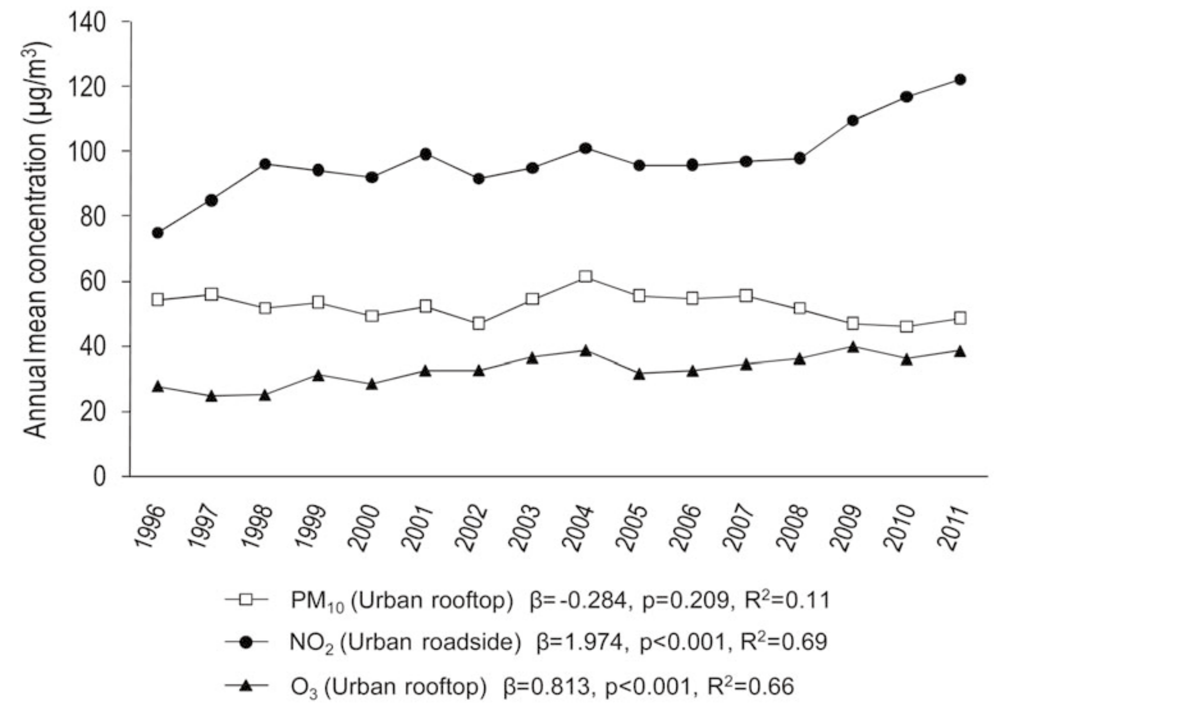
Cross sectional and cohort studies have shown how air quality controls can lead to a reduction in respiratory symptoms and doctor visits. Bronchial hyper-responsiveness provoked by a histamine challenge in primary school children who were not symptomatic at the time of the initial and follow-up examinations, was reduced after air quality improvement. These health gains were more marked in the more polluted areas after implementation of the legislation to restrict fuel sulphur levels in July 1990.[46,47] The legislation also led to a significant reduction in mortality in individuals aged 46 and older especially due to respiratory and cardiovascular causes in the subsequent 5-year period.[48]

High concentrations of air pollutants (NO_2, SO_2, PM_{10}, O_3) are related to higher excess risks of mortality and hospitalisation, mainly from cardiopulmonary disease.[49,50] The damaging effect of Hong Kong's air pollution on environmental justice and health inequity has been convincingly demonstrated by the fact that those in lower socio-economic groups are most affected.[51,52] These are landmark studies and the findings in Hong Kong and mainland China were adopted in the consensus statement which established the WHO 2006 Air Quality Guideline.[53]

Current Situation in Hong Kong

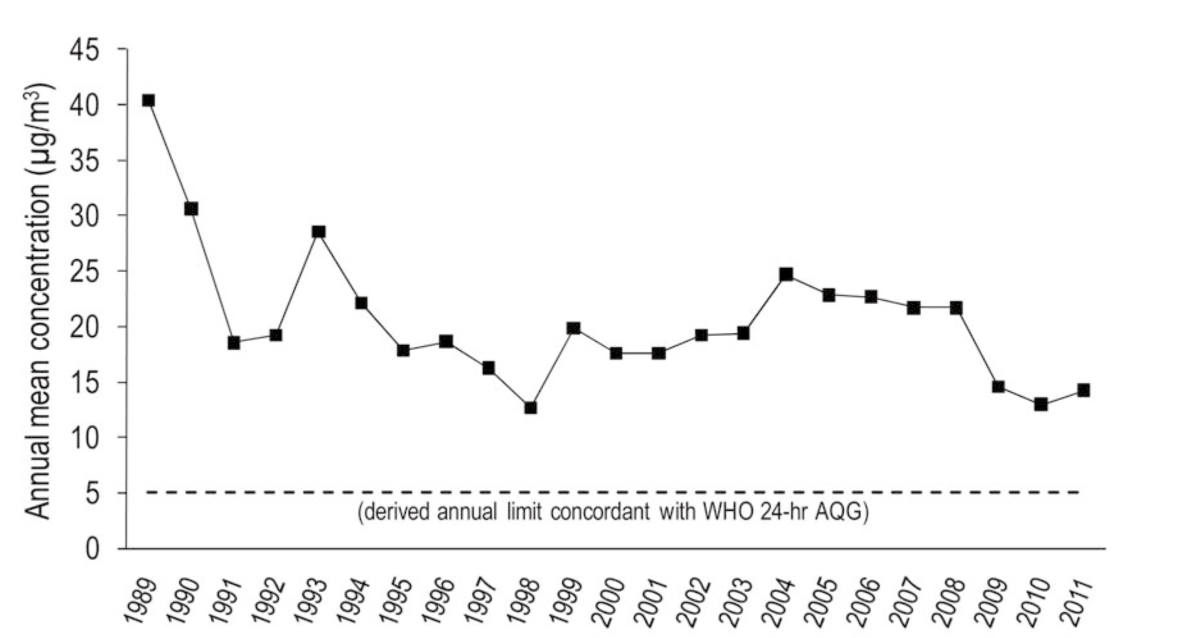
Despite the strong evidence for the adverse health effects related to air pollution provided by both local and international studies, the Government of the HKSAR has failed to take sufficient action over the past two decades to improve air quality. Except for the ambient sulphur dioxide SO_2 level, the levels of other major criteria air pollutants have continuously deteriorated (Figure 1). As a matter of fact, Hong Kong's air quality is regarded as poor by most international standards. Even the successful dramatic reduction of ambient sulphur dioxide SO_2 level due to implementation of legislation to reduce fuel sulphur level in mid 1990 was not sustained with predictable damage to child health. There was a continuous increase in SO_2 levels from the late 1990s followed by a slow decline to a point at least 100% above the WHO limit for safer air quality (Figure 2). The 2011 roof-top SO_2 level was 13.5 $\mu g/m^3$, which is 170% higher than the 5 $\mu g/m^3$ level predicted if we had complied with the WHO 24 hour limit of 20 $\mu g/m^3$. The corresponding roadside figure was 12 $\mu g/m^3$, 140% higher than the predicted level achievable through compliance with the short term limit.

It is recognised that the Hong Kong Air Pollution Index (API), which has been used for the past 20 years, needs revision. Even using this seriously outdated index, the number of days when roadside stations regularly recorded an index of greater than 100 was very high. Due to the 'canyon effect' of buildings, the levels of air pollutants measured at roadside monitoring stations are usually much higher than those measured at general (roof top) stations. Using internationally accepted 2006 WHO guidelines, air pollutants in Hong Kong are continuously above safer levels for PM_{10}, NO_2, and frequently for SO_2 in certain locations, with important consequences for illness, health care and



*linear trends were tested using linear regression

Figure 1 Trends of annual mean concentrations of PM_{10}, NO_2 and O_3 from 1996 to 2011.



*SO_2 concentration data from urban rooftop monitors in Hong Kong. Annual limit at 5 µg/m^3 was derived from WHO 24-hour AQG based on a deterministic model.[1]

Figure 2 Annual mean SO_2 concentration from 1989 to 2011 compared with the annual limit derived from WHO 24-hour Air Quality Guideline (AQG).

community costs as demonstrated on a continuing basis by the Hedley Environmental Index. (http://hedleyindex.sph.hku.hk/pollution/home.php#s).

A high API has resulted in advice to restrict outdoor sport and leisure activities, especially for vulnerable groups, for example children with pre-existing respiratory and cardiac diseases, but these advisories come from the Environmental Protection Department with no specialist public health or medical input. They are meaningless in terms of public health protection. The Child Health Survey 2005 to 2006 suggested that only around 15% of children aged 6-14 years in Hong Kong had moderate to severe vigorous activities each day, in contrast to nearly 60% who spent at least two hours in screen time at home.[54] If air pollution contributes to the adoption of an even more sedentary lifestyle in our local children population, then it may also contribute to the emerging epidemic of childhood obesity in addition to the many other associated medical problems. The loss of daily visibility, landscapes and horizons degrades a child's natural environment but its impact on health related quality of life has not yet been assessed. In Hong Kong, myopia was the commonest chronic health problem reported in the Child Health Survey 2005 to 2006.[54] There is concern that the deterioration in visibility due to air pollution over the past 40 years,[55] with less exposure to greater depth of field and less usage blur than with higher outdoor light intensities, may be an additional contributing factor in the genesis of myopia in this region.

While exposure to air pollutants in residential areas is a major concern for child health, another priority area is the location of most of the schools in Hong Kong. There are a total of around 650 primary schools in Hong Kong of which 20% are situated close to a main road, as defined by the Transport Department, at a mean distance of 20.5 with standard deviation of 24.7 metres[56] and traffic related air pollution must therefore be regarded as a major health threat to school children. It is clear that the current neglect of air quality in Hong Kong and acceptance of the status quo will have a significant impact on quality of life, life expectancy and community costs of health care for our children. The Government of the HKSAR has made considerable efforts in the past to improve our child health through many interventions, for example the establishment of the Maternal and Child Health Service and Student Health Service, and provision of universal immunisation. However the question remains as to whether there is the political will, organisation and expertise to accept primacy of the need to improve air quality for protection of the health of our children, and indeed of the whole population, now and in the future. The government consultancy for new air quality objectives which began in 2007 has resulted in an extremely lax limit for pollutants which does not conform to the evidence guidelines of WHO. These proposed new AQO will not be effective instruments to support air quality regulation and improvement. We can show that their adoption will likely lead to predictable and measurable continuing adverse health effects in children.[1] Hong Kong should adopt the full WHO 2006 Air Quality Guidelines as the basis for risk assessment and risk communication. It should be recognised that there is no discernible threshold for the health effects of air pollutants. While it may be argued that the creation of intermediate compromised standards could possibly lead to some mitigation of the threat to child health, given Hong Kong's extremely high levels of pollution, the impact on avoidable morbidity and morbidity will be relatively small and unacceptable as a public health approach to the problem.

We have suggested mandatory actionable steps for the Government of the HKSAR, local authorities and other organisations to clean the air of Hong Kong. The government should acknowledge that air quality is an urgent public health problem with serious implications for the current and future child health in the community. Most importantly the government has a clear duty to adopt immediate legislative and administrative measures to reduce the impact of our current urban environment and transport policies on air quality, and develop evidence-based strategies for rapid improvements. These can include adopting advanced technology to reduce emissions from power plants, traffic and marine sources, clean transportation options and modern vehicle fleets, infrastructure planning including establishing low emission zones in urban areas,[57] protecting kindergartens, schools and sports facilities from intense pollutant sources, planting vegetation in street canyons[58] and promoting building designs like urban wide conversion of black roof to green roof.[59] Local councils should press the government for immediate effective action to protect children in inner conurbations, consistent with the Department of Health's promotion of the WHO Healthy City concept to District Councils. The government should fund scientific-based population health research on the long term implications of toxic air on child health, to support policies for heath protection. Food and Health Bureau should take the lead in monitoring the health impact of air pollution and use information from expert groups in Hong Kong and overseas, including paediatric and public health expertise, to provide evidence-based advice to relevant sectors of our government to strengthen policy decisions.

Conclusion

Children need our continuing commitment to their future health and wellbeing. Good health care in a nurturing environment, with safe water, food and air are all important for our children now and in the future. The Government of the HKSAR is a signatory to the Convention of Rights of the Child adopted by the United Nations. We urge all paediatricians to join to press the government to support these principles by taking effective and immediate action, on the shortest possible timescale, to minimise environmental pollution, and prevent further serious harm to Hong Kong's young people. Failure to take a comprehensive, effective and precautionary approach will result in large scale detriment to health related quality of life among our children for decades to come.

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