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AIR POLLUTION and PUBLIC HEALTH

The current avoidable burden of health problems, community costs and harm to future generations

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Executive Summary

- There is incontrovertible evidence that pollution levels currently experienced throughout the year in Hong Kong are causing an epidemic of health problems arising from damage to lungs, heart and blood vessels. Hong Kong's pollution is a significant cause of premature death from cardiopulmonary disorders.

- Present levels of pollution cause injury to the immature developing lungs of children and adolescents. This damage will lead to life-long health problems in many and a reduction in life-expectancy.

- There is no convincing evidence from analyses of trends in pollutants that pollution mitigation measures in recent years have reduced ambient pollutant concentrations in a way which will benefit public health. There are clear indications that for some pollutants the problem is worsening. Extrapolation of any potential downward trends suggest it will be at least several decades before we achieve safer air quality.

- The government has not given the necessary priority to the protection of public health and there is as yet no strategy in place which will predictably lead to a rapid resolution of regional pollution and the public health threat in the HKSAR.

- The government's review of the "Air Quality Objectives" apparently lacks both transparency and an evidence-based approach as indicated by the adoption of the lowest level WHO Interim Target-1. There is no evidence that it will lead to any reduction in particulate pollution or public health benefit.

- The proposed use of Interim Target-1 should be abandoned because it will delay effective protection of public health. The HKSAR should adopt and use the World Health Organisation *Air Quality Guidelines* as a basis for rapidly developing enforceable *air quality standards* and *caps on maximum permissible levels*. At the same time it is essential that a programme of *Emission Reduction Targets (ERT)* are implemented in a mandatory fail-safe approach to health protection.

- Hong Kong needs an effective system of audit and accountability to address the current crisis in air quality management. A new environmental index developed from research on air pollution and health in The University of Hong Kong and the Chinese University of Hong Kong, and presented and promoted by Civic Exchange demonstrates on an hourly basis the burden of disease and external costs to the whole community incurred from the harm caused by pollution.

- Air pollution is Hong Kong's biggest cause of social and environmental injustice. It harms not only citizens today but, because of its transgenerational effects on the unborn and youngest members of the community, it will project its ill health effects well into the later years of this century unless a radically different approach is taken to air quality management

1.0 Air pollution: a global problem

1.1 A brief history of air pollution

Human activities have created forms of air pollution for millennia and the inhalation of products of combustion, as particles and gases from fuels, has long been recognized as a cause of ill health and premature death.

In modern history several dramatic pollution incidents led to public health action to protect populations against uncontrolled combustion and emissions from fossil fuels and other chemical sources.

1.1.2 The Meuse Valley fog

In December 1930 a dense fog affected the Meuse Valley in Belgium. Beginning on December 3 the fog intensified over three days and was associated with laryngeal symptoms, chest pain, coughing and breathlessness. Some patients showed signs of pulmonary oedema. Overall 60 deaths were attributed to the episode. After a long investigation the cause was considered to be emissions from high sulphur fuels, including sulphur dioxide and sulphuric acid.

1.1.3 The Donora, Pennsylvania, poisonous cloud

In October 1948 in the town of Donora, Pennsylvania, USA an air inversion layer trapped emissions from steel and zinc works. The levels of pollution plunged the town into darkness. The health impacts were considered to include 20 deaths in the first three days; another 50 deaths after the inversion lifted and several hundred with long term respiratory and cardiovascular damage. The Donora Smog Museum holds archives of the event and describes the actions taken to improve air quality, leading to the *Air Pollution Control Act (1955) and the Clean Air Act (1963).*

1.1.4 The Great London Smog

In 1952 the best known and most catastrophic air pollution episode occurred in the city of London UK between 5 to 9 December. A cold winter spell associated with fog led to a marked increase in domestic consumption of coal. The coal sold for domestic use had a high sulphur content. The loss of visibility extended down to only a few metres so that it was not possible to navigate streets either on foot or in vehicles. It is estimated that about 4,000 deaths were caused in five days by high levels of particulates and SO_2 with concentrations estimated at thousands of micrograms per cubic metre (Figure 1). Most of the deaths were in middle life or the elderly, with infants and children also affected. There is evidence to suggest that the distribution of deaths continued to be relatively high for several more months after the pollution episode with possibly an additional 8,000 deaths. The principal causes of death were lung infections and heart disease. The

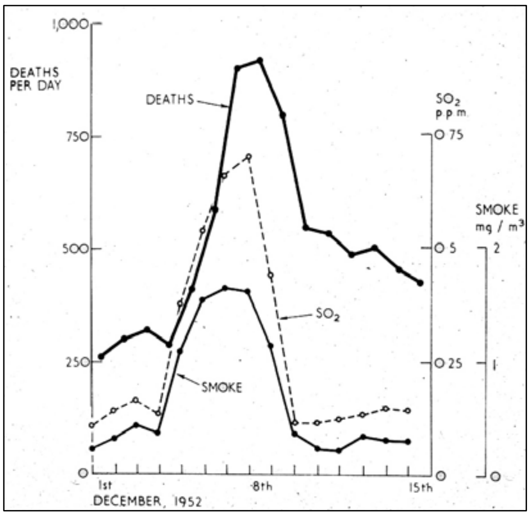


Figure 1: The epidemic of deaths from heart and lung disease began when the levels of particulates and SO_2 rose sharply

victims died quickly so that the impact was mostly recognised by funeral directors, coffin manufacturers and florists rather than general practitioners and hospitals.

1.2 Recent history of air pollution epidemiology and public health analysis

1.2.1 ***New research and understanding:*** In the late 1980s research on the health effects of air pollution underwent a transformation. Greater insights into the biological action of pollutants on animal and human cells, together with clinical and population studies of health outcomes and new methods for statistical analysis led to a marked increase in the quality and quantity of reports about the influence of air pollutants on health, health care utilization and premature deaths.

1.2.2 ***What is the current threat to health?:*** The mitigation of air pollution following the introduction of clean air legislation has been followed by a period of unprecedented economic development creating new forms of pollution from the combustion of fossil fuels. The reduced levels of air pollution achieved in the 1970s and early 1980s was originally thought to be an unlikely cause of heart and lung disease. However public health and environmental science has since demonstrated that the present mix of particulate and gaseous pollutants is in fact highly toxic. There are probably several reasons for this. For example, in contrast to the relatively large tar laden particulates from burning dirty coal which caused episodes like the London Smog, traffic pollution now generates fine particles with a different size and composition, and gases such as NO_2 which may cause injury to the respiratory system and amplify the effects of other pollutants such as particulates and drive the formation of the secondary pollutant ozone.

2.0 Which air pollutants are a threat to public health?

2.1 ***The criteria pollutants:*** The World Health Organisation identifies five pollutants, particulates (PM_{10}), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3) and carbon monoxide, as important ("criteria") pollutants relevant to health protection. Although carbon monoxide at present urban levels is a potentially important cause of health problems such as cardiovascular disease, the current research focus is mainly on the other four pollutants PM_{10} (also referred to as Respirable Suspended Particulates (RSP)), NO_2, SO_2 and O_3.

2.2 ***Particulates:*** Particulates which are involved in causing health effects are sized in millionths of a metre (microns). The diameter of a human hair is approximately 70 microns while particulate matter of prime environmental interest is estimated to be 10 microns or less (PM_{10}). Fine (2.5 microns) or ultra-fine (0.1 microns) particulates are probably the most hazardous because of their ability to penetrate the airways of the lung and gain access to other body tissues. Ultra fine particles, which are approaching the size of viruses, have very low mass but are present in very large numbers. Their large surface area may be the most significant factor in their ability to deliver toxic chemicals to respiratory and circulatory systems. They remain suspended in the air for long periods prolonging the period of exposure to anyone breathing polluted air. However all fractions of PM_{10} should be regarded as hazardous and there is substantial evidence that $PM_{2.5}$ – PM_{10} (the so-called "coarse fraction") causes inflammatory changes in body tissues.

2.3 ***Volatile Organic Compounds:*** Urban pollutant emissions from road vehicles and industrial processes include volatile organic compounds (VOCs) such as benzene, 1:3 butadiene and benzo(a)pyrene and many others, which are implicated in the causation of cancers including leukaemia, and damage to embryos in the uterus of a pregnant mother.

2.4 ***Gases:*** Primary combustion sources such as power generation, manufacturing, traffic, marine and port activities are responsible for emissions of particulates, NO_2 and SO_2, while ozone is formed from a complex series of reactions involving NO_2 and VOCs under the action of ultra violet light. There is a strong interaction between ozone and oxides of nitrogen. Nitric oxide which is a principal emission from traffic exhausts scavenges ozone, reducing its ambient levels. One possible implication of this is that initial reductions in traffic emissions may lead to higher street levels of ozone in a relatively high overall pollution environment.

Gases are important pollutants because they may cause injury to sensitive tissues and also generate secondary particles, typically in the ultra fine range. In studies of air pollution health effects in Hong Kong and mainland China gases consistently show strong effects on bad health outcomes.

2.5 ***Seasonal and annual risks:*** Pollutants follow a strong seasonal pattern in Hong Kong with peaks in the distribution of PM_{10}, NO_2 and ozone occurring in the cool season (approximately October to March) and a smaller peak for SO_2 in the warm season.

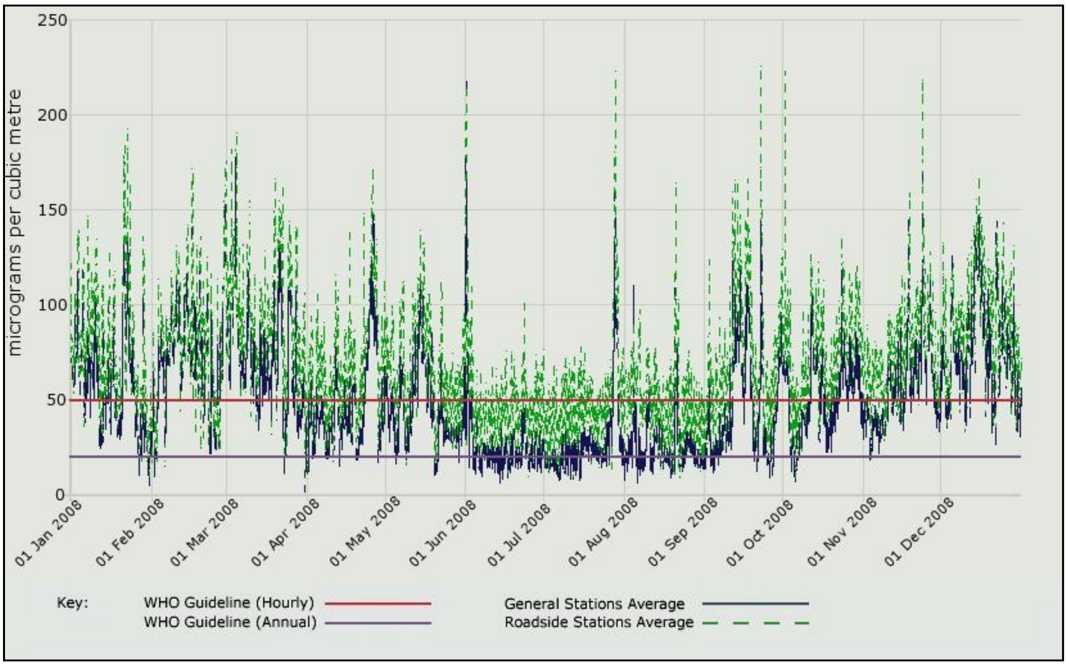


Figure 2: Seasonal patterns of pollutants in Hong Kong showing that even the lowest warm season levels are well above the WHO guidelines (downloaded from EPD and the Hedley Index http://147.8.71.207/pollution/home.php#s)

The months of July and August represent the lowest average pollutant levels in Hong Kong but these are currently still high in terms of harm to public health, as indicated by the WHO Air Quality Guidelines.

3.0 How do air pollution exposures lead to bad health outcomes?

3.1 ***Inflammation:*** The mechanism by which air pollutants may damage healthy tissues is an extensive, complex and evolving subject. The current laboratory and clinical evidence strongly suggests that exposures to pollution generate inflammation throughout the body and disrupt or destroy many normal physiological processes which are essential for health.

The effects of pollution will therefore to some extent reflect the predisposition (genetic, environmental lifestyle and behavioural factors) to develop these diseases in a population together with the existing prevalence of diseases which may be exacerbated by pollution.

Living in polluted urban environments is associated with increased levels of biological markers of inflammation compared with residence in a clean air environment. A move from a polluted to a cleaner environment is associated with a reduction in inflammatory markers in body tissues.

3.2 ***The pyramid of effects:*** Investigations into the causation of health problems and health care utilisation can be summarized in the form of a pyramid (Figure 3). At the base of the pyramid we can identify the earliest pathological inflammatory changes as biological markers.

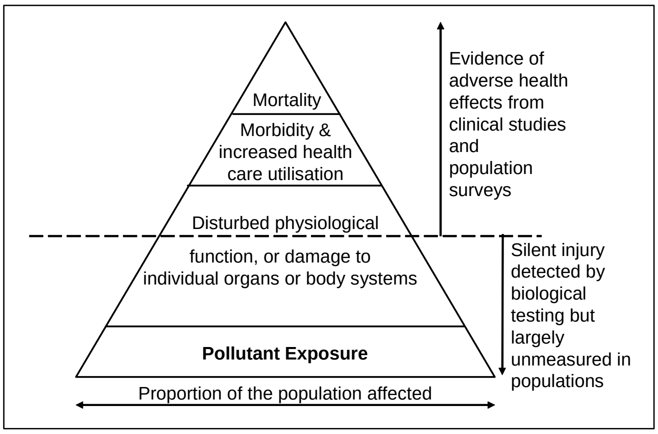


Figure 3: The burden of ill-health and the risks of future illnesses can be represented as a pyramid

At the next level the previously "silent injury" becomes symptomatic. Health care utilization increases Self-medication and use of traditional medicine may precede or take place concurrently with formal Western medicine at the primary care level.

Those with serious disease may require hospitalisation and continuing specialist care.

The tip of the pyramid comprises the premature deaths caused by health problems which are initiated or exacerbated by exposures to air pollutants.

This graphical view of the impact of pollution on health and the health care system can also be viewed as an "iceberg". The bad health outcomes which are most visible are only the tip of the iceberg and much of the burden placed on the future of community health and the economy is hidden.

3.3 ***Making the diagnosis:*** One important difficulty in assessing both the causal relationships between air pollution and health, and the specific health outcomes, is that the air pollution injury is not labelled with a specific medical diagnosis, such as an International Classification of Disease diagnostic rubric. This can be contrasted with infectious diseases such as influenza or severe acute respiratory syndrome

(SARS) caused by specific viruses where the agent causing the disease can be isolated and recovered from body tissues.

The damage caused by air pollution inevitably manifests itself through a variety of common and recognised health problems such as upper respiratory complaints heart and lung disease. Because of this we can use epidemiological and statistical methods as well as clinical studies to detect the "signal" of changes in health problems and increased health care demands in the population caused on a daily basis by air pollution.

It is worth reflecting that if the several thousand serious illnesses and deaths associated with pollution annually in Hong Kong carried a diagnostic label of *Air Pollution* then official recognition of the serious detriment to population health might conceivably be on a different level today.

3.4 ***Which health problems are definitely or probably associated with air pollution exposures?:*** Based on different levels of evidence, the number of reliable studies and biological plausibility the following list provides an indication of the systemic multi-organ involvement in the injuries caused by breathing polluted air.

Cardiovascular disease

Formation of arterial plaques (atherosclerosis)
Coronary artery disease
Heart attacks (myocardial infarction)
Irregular heart rhythm (arrythmias)
Loss of heart rate variability
Stiffening of arterial walls (arteriosclerosis)
High blood pressure (hypertension)
Alteration of clotting factors increasing the coagulability of blood
Stroke (cerebral thrombosis)

Respiratory disease

Inflammation of nasal, sinus, throat and tracheal airways with acute or chronic symptoms
Lower respiratory tract inflammation and infection causing bronchitis and pneumonia
Chronic airways damage causing chronic obstructive pulmonary disease (chronic bronchitis and emphysema of COPD)
Initiation and/or exacerbation of asthma
Reduction lung growth and function in young people

Interactions between inflammation, respiratory and vascular effects from air pollution

Exposure to particulates and other air pollutants causes a specific decline in lung function which can, for example, be measured as a test of the forced expiratory volume of air achieved in one second (FEV_1). There is a strong association between reduced lung function based on this type of measurement and cerebrovascular disease measured as stroke.

The possible mechanism for this association is an active area of research but there are several strong indicators. Following exposure to air pollutants there is an increase in the circulation of biomarkers which signal that inflammation is occurring. These include white cell counts, increases in plasma fibrogen (causing increased viscosity of the blood), other protein markers of inflammation and a group of substances which are called pro-inflammatory mediators.

The relevance of this example is that when inhaled pollutants cause inflammation in the air sacs of the lung this initiates a cascade of inflammatory processes which leads to widespread involvement of blood vessels and organs throughout the body.

Damage to the central nervous system by air pollution

In the days when printing workers handled large quantities of ink containing carbon particles it was shown at autopsy that fine carbon particulates could track along the olfactory nerve sheath from the nose to the brain.

Recently it has been demonstrated that when rats and dogs are exposed to ultra-fine particulates by inhalation this leads to their deposition in the central nervous system and increased brain inflammation. Two studies in humans have tentatively demonstrated effects on mental health and cognitive function in young children but the information is still incomplete.

In another study in adults who lived in high or low areas of air pollution, autopsy examination of the brain showed increased markers of inflammation with residence in higher pollution areas.

The possibility of damage to brain tissue by high levels of pollution should be regarded as a potentially widespread and serious health outcome.

Harm to the unborn foetus from air pollution

There is an accumulating evidence that when pregnant mothers breathe polluted air this affects the health of the baby. Although this research is at an early stage there are strong indications that pollution exposures cause:

- impaired growth of the foetus in the womb with reduced birth weight
- stillbirths
- deaths in newborns from respiratory illness
- birth defects including abnormal heart valves and cleft palate

Reports are available for review from Beijing, Vancouver, Southern California USA, New Jersey USA, Taiwan and Czech Republic,. The pollutants investigated include particulates, oxides of nitrogen and sulphur, carbon monoxide and polycyclic aromatic hydrocarbons (PAHs). The possible mechanisms implicated include

- interaction with DNA
- increased mutations
- disruption of endocrine systems
- decreased exchange of oxygen and nutrients with the foetus

The association with exposure to cancer causing PAH compounds is considered biologically plausible because of the similarity of the pollutant mix and its effects to second hand tobacco smoke (SHS). Studies in Hong Kong based on the Department of Health birth cohort have shown reduced birth weights in babies born to mothers exposed to SHS (Leung et al 2003; Leung et al 2004).

3.5 *Air pollution and life-expectancy*

Determinants of the life-span: The important determinants of an individual's life span comprise a complex interaction between inherited genes, literacy levels and the socioeconomic and physical environment particularly as they affect mothers and infants. For infants and the survivors of early years, gross domestic product per capita is a strong indicator of longer term survival patterns. Additional important influences may arise from war, famine and marked socioeconomic inequalities. In recent years, large scale epidemics caused by infections and chronic toxic exposures have led to erosion of life-expectancy in sub-saharan Africa (HIV and tuberculosis) and the former countries of the USSR (alcohol causing deaths from heart disease).

Air pollution effects: Evidence has been accumulating that pollution causes either a change toward a downward trend in life expectancy or otherwise limits the expected increases in life span. Three large cohort studies with long term follow-up of defined population groups in the United States in the 1970s and 1980s showed that even the much reduced levels of air pollution were apparently associated with shortening of life-spans of one to two years on average. The biggest effects were seen for deaths from heart and lung disease and lung cancer.

The most recent study from the United States, published in the New England Journal of Medicine January 3 2009, indicates that reductions in fine particulates ($PM_{2.5}$) were strongly associated with gains in life years independently of the effects of social and economic development and a decline in the prevalence of smoking.

In the 1990 restriction on the sulphur content of fuel in Hong Kong the annual decline in age-specific mortality rates was estimated to add, on average, 20 to 41 days to the life-span. This intervention only reduced one source of pollutants and it showed that life expectancy is very sensitive to pollutant exposures.

The *average* population gains in life years may appear numerically small but should be interpreted carefully and related to the large minority who for various reasons are more susceptible to pollution. In this group the average gains in life years from pollution abatement will potentially amount to several years.

I previously addressed the issue of life expectancy and pollution in Hong Kong at a Legco Environmental Affairs Panel on 27 November 2006 (Attachment 1) and in the South China Morning Post on 30 November 2006 (Attachment 2). In these submissions I tried to point out that life expectancy is strongly driven by social and economic factors but may be seriously eroded by adverse environmental changes. If the Hong Kong population continues to be exposed to high levels of pollution then gains in life expectancy will predictably be reduced by this counter-trend in our environment. For the survivors there is also the prospect of longer periods of ill-health and incapacity before the point of death. This will tend to negate the current aims of improving the health related lifestyle of the older population and compressing morbidity towards the end of the life-span.

4.0 How are the public health risks of air pollution estimated in Hong Kong?

The work on the population health risks arising from air pollution has been carried out principally by two teams in the Chinese University of Hong Kong (Professor TW Wong) and in The University of Hong Kong (Dr CM Wong).

Hong Kong has some excellent information systems which can be used to support epidemiological and public health research at the population level. These include:

- The Environmental Protection Department air quality monitoring network in 10 districts with 3 additional roadside stations.
- The Census and Statistics Department and the Department of Health register of deaths labeled by WHO (ICD) diagnostic rubrics.
- The Hospital Authority Clinical Medical System which provides discharge diagnoses on all patients admitted to the public hospital system.

Access to information in the private sector is much more limited and this is an important deficiency particularly if we need to study primary medical care where most of the daily medical work occurs in the HKSAR. For this reason special studies have had to be designed and implemented in primary care.

Three reports can be reviewed to illustrate the methodology applied to study pollution and health outcomes.

4.1 Association between air pollution and general practitioner visits for respiratory diseases in Hong Kong (Wong TW et al 2006)

Clinic attendance data from a network of GPs was analyzed to derive the relationship between air pollution and daily doctor visits for respiratory problems. Significant associations were observed for first time attendances and increases in concentrations of $PM_{2.5}$, PM_{10}, NO_2 and O_3. Increased risks were found for both upper respiratory tract infections (URTI) and for other respiratory problems. The highest excess risk per 10 micrograms/cubic metre (m^3) of pollutant (3.0%) was observed for NO_2.

4.2 Effects of air pollution on hospital admissions in Hong Kong and London (Wong CM et al 2002)

This enquiry was conducted using the same standardized methodology and similar data in two populations in Hong Kong and the United Kingdom. We hypothesized that similar results in the two locations would strengthen the evidence for a causal association between air pollution and the need for treatment at a high level of the health care system.

Using data for admissions over a two year period we found similar risks for most pollutants and medical conditions in the two cities despite the considerable differences in ethnicity, social, life-style and environmental conditions.

The associations between cardiac admissions and PM_{10}, NO_2 and SO_2 were similar in Hong Kong and London as were patterns of association specifically for ischaemic heart disease.

The strongest associations were found in the periods of lowest humidity: the cool season for Hong Kong and warm season for London.

The highest excess risks for hospital admission per 10 micrograms/m^3 of pollutant in Hong Kong were for NO_2 and SO_2 for both heart and lung diseases. PM_{10} also exerted a strong effect.

4.3 Effect of air pollution on mortality (Wong CM et al 2001)

In this study the effects of four air pollutants on mortality in both cool and warm seasons were studied. Again the oxidant gases NO_2 and SO_2 showed a strong cool season effect on mortality in addition to the effects of particulates.

Typically the short term excess risks for air pollution effects on morbidity and mortality range from 0.5% to 3.0% for each pollutant. When applied to the whole population these additional risks lead to large cumulative number of avoidable illnesses and deaths.

4.4 Effects of air pollution on mortality in socially deprived urban areas

(Wong CM et al 2008)

We examined the interaction between social deprivation (including unemployment; household income; schooling; one-person household; marital status) on information derived from a six year period in 209 Tertiary Planning Units. We found significant associations between NO_2, SO_2, PM_{10} and ozone with all non-trauma and cardiovascular deaths in areas of middle or high deprivation.

In areas categorized as high deprivation, cardiovascular and respiratory mortality was strongly associated with NO_2 and SO_2 compared with other less deprived areas.

We have been able to consistently demonstrate the risks to health from air pollution, at different times, in different population samples and at different levels of the health care system. The risk estimates are a reliable and important tool in the estimation of the avoidable health problems caused by pollution.

5.0 What is the best evidence that pollution abatement protects health?

This question concerns the level of evidence and its interpretation. The majority of studies rely on observations of daily changes in health outcomes with daily variations in ambient pollution (time series studies) and cohort follow-up studies which identify gradients in health experience with different exposures over varying periods of time from days to years. While true experiments in the allocation of different groups to high or low pollution are neither feasible nor desirable, several *interventions* which can be regarded as natural experiments can now be analyzed.

The following five interventions could be said to have created a defining moment from which the impact on both air quality and health outcomes could be analyzed.

5.1 The Utah Valley steel mill (CA Pope III 1989)

From August 1986 to September 1987 a worker's strike closed a Utah steel mill which was known to generate large amounts of particulate pollution. The periods before, during and after closure of the mill provided a series of baseline and intervention data on both air quality and the impact on child health. During closure of the mill the investigators found benefits to child and adult health in terms of reductions in:

- Elementary school absences
- Abnormalities of lung function
- Hospital admissions for bronchitis and asthma for pre-school children
- Hospital admissions for pneumonia, pleurisy, bronchitis and asthma
- Daily mortality
- Age adjusted deaths for malignant and non-malignant respiratory disease
- Pre-term births

The chemistry of the emissions from the mill includes the presence of the metals Iron, Copper, Zinc, Lead and Nickel.

During the mill closure there were no further exceedances of the then 24 hour PM_{10} standard of 150 µg/m^3 and child hospital admissions were about 3 times lower than the period before closure.

5.2 **Coal sale bans in Dublin** (Clancy L et al 2002)

On September 1st 1990 the Irish government banned the marketing, sale and distribution of soft coal in Dublin city. An analysis of ambient air pollution and death rates showed that particulates ("black smoke") fell by about 66% and SO_2 by 33%. In a comparison of trends in death rates before and after the coal ban they found an overall 6% decrease in all non-trauma deaths, with a 10% to 16% reduction in fatal heart and lung diseases.

5.3 **Fuel sulphur restriction in Hong Kong** (Hedley AJ et al 2002)

On July 1st 1990 all power plants and road vehicles were restricted to the use of fuel oil with not more than 0.5% sulphur by weight. This relatively small restriction led to an immediate and large reduction in ambient SO_2, 45% on average and up to 80% in high pollution areas (Figure 4), and reductions in two metals Nickel and Vanadium (Figure 5).

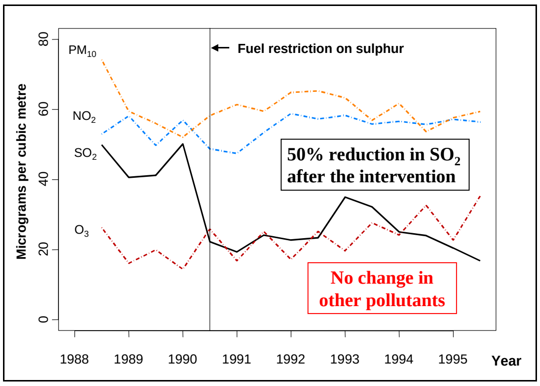


Figure 4: Air pollutant concentrations in Hong Kong 1988-95: half yearly mean levels showing effect of fuel sulphur restriction

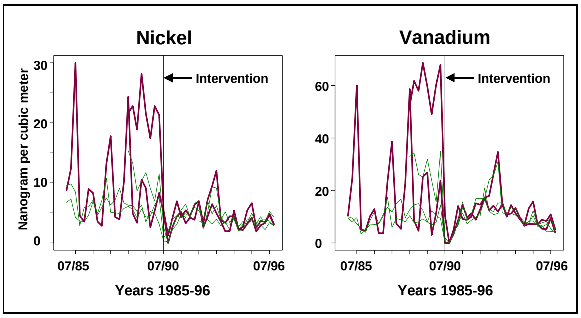


Figure 5: Effects of conversion to low sulphur fuel (0.5%) on transition metal concentrations in Hong Kong

In the two years following the intervention we found several health benefits including significant reductions in:

- chronic bronchitic symptoms
- bronchial hyper-responsiveness

in primary school children aged mainly 8 to 10 years, and also in bronchitic symptoms in their mothers.

In a separate analysis we found a significant decline (2.1%) in the average annual trend in deaths from all non-trauma causes with greater declines for respiratory deaths (3.9%) and in the elderly from cardiopulmonary causes (>4.0%).

There was no sustained downward change in particulates, NO_2 or O_3, so this analysis provides evidence that emissions from sulphur rich fuels (including SO_2, Nickel and Vanadium) are the probable cause of respiratory disease in children and cardiopulmonary deaths in adults. This modest restriction of sulphur emissions reduced bronchitic problems in thousands of children, and cardiopulmonary deaths by 600 annually in people aged 46 and older.

It is notable that the Hong Kong 1990 fuel sulphur intervention stands as one of the definitive pieces of evidence which guided decisions on the World Health Organisation Air Quality Guidelines.

5.4 California Children's Health Study (CHS) (Avol et al 2001)
The CHS provides us with an interesting and important set of observations on the effect of changing exposures in a vulnerable group. The main study is a large scale long term analysis of chronic air pollution exposures on child health. In one sub-study they followed 110 children who moved residence to lower or higher levels of pollution. Those who moved to lower PM_{10} pollution showed improved lung growth and development while the converse applied to those moving to higher PM_{10} areas.

5.5 Traffic pollution during the Atlanta Olympics 1996 (Friedman et al 2001)
During the 17 days of the 1996 Olympics, traffic patterns were changed leading to reductions in exposures from mobile emissions. Across the four weeks before and after the games ozone, PM_{10} and carbon monoxide levels declined. Hospital admissions for childhood asthma declined by about 40% during the games while there was no change in other illness patterns.

These five examples clearly demonstrate, in a way which satisfies the criteria for establishing causality, how appropriate, practicable and economically viable interventions can quickly yield very large health gains among those most vulnerable to environmental pollution.

6.0 Who are most vulnerable to air pollution?

6.1 ***High risk groups:*** Air pollution potentially affects everyone but on different time scales, and some are much more vulnerable than others. As with any health problem arising from environmental or behavioural risks there may be important interactions with an individual's genetic make-up or previous and current medical problems.

Those most sensitive to air pollution health effects include

- the very young
- the elderly
- those with either asymptomatic or established morbidity
- those with lifestyle risk factors for chronic disease including
    - * sedentary life-style
    - * active or passive smoking
    - * poor nutrition, especially a lack of anti-oxidant rich foods

Particular disease groups or health states have been identified as especially at-risk from chronic air pollution exposures; they include

- heart and blood vessel disease
- lung disease and those with other exposures which may cause or aggravate lung disease
- diabetes
- other inflammatory conditions such as rheumatoid arthritis
- overweight/obesity

Air pollution may initiate a disease process or independently aggravate it in a way which causes a serious illness. An example would be the development of atherosclerosis. The formation of atherosclerotic plaques through the deposition of lipids in the arterial wall is promoted by the action of pollutants on the endothelial or lining cells of the arterial wall. In an episode of inflammation caused by pollution the plaque may rupture causing blood clots to form and resulting in a heart attack or stroke.

6.2 ***Social inequity; the poor and disadvantaged:*** Evidence is emerging from studies in different countries that the impact of pollution on those who are most disadvantaged in the community may be very marked.

In Hong Kong we have shown that those with lower socio-economic status or living in more deprived areas have higher pollution related mortality risks than those who are better off and living in better conditions (Ou CQ et al 2008; Wong CM et al 2008).

Air pollution exposures are likely to be higher in more deprived areas and those who reside there are more susceptible to health problems and less able to maintain good health. The underlying causes of this source of social inequity may include lifestyle (housing, nutrition, smoking, recreational exercise) and access to and affordability of medical care.

7.0 How preventable is harm to health from air pollution?

7.1 ***Protection is difficult to achieve:*** It is very difficult to envisage any form of individual protection from ambient air pollution. Outdoors the exposure of the population to pollutants approximates to 100%. The wearing of ordinary surgical masks will make no difference to inhalation of gases or fine particles. The use of carbon filter masks and other new biotechnology masks could offer some degree of protection. Those at high risk, for example with asthma, may possibly achieve protection for several hours a day especially in highly polluted environments. There is some evidence however that many people would find the wearing of close fitting masks unacceptable. It should also be stressed that there is as yet no formal evidence of overall health benefit in the context of normal activities of daily living.

7.2 ***Lifestyle:*** Lifestyle including nutrition are potentially important factors determining either susceptibility to or protection from pollution. There is evidence, of varying strengths, that the following would offer benefit:

- ***Nutrition:*** a diet rich in antioxidant foods (Because of the strong accumulating evidence on the neutral or even harmful effects of vitamin supplements we emphasise the need to base protection on diet and not medication).
- ***Smoking:*** smoking cessation and protection from second-hand smoke inhalation will make an important contribution to protection from ambient pollutant exposures. Active and passive smoking cause severe inflammatory changes in the lung.
- ***Physical fitness:*** good physical fitness, for example maintained by walking or other light to moderate exercise may protect against cardiopulmonary effects of pollutants and higher mortality risks (Wong CM et al 2007). More vigorous and prolonged exercise is likely to be associated with higher exposures and the risk of health problems. Training for competitive endurance events may be a particular hazard. There are many uncertainties associated with striking a balance between the health benefits of exercise and the risks of pollution exposures.
- ***Hot spots:*** avoidance of intense pollution exposures, for example at street level, would be advisable especially in children and those at-risk from heart and lung disease. However the average daily exposures in high pollution environments will be the main determinant of risk.

7.3 ***Indoor environments:*** Indoor pollution levels are usually largely determined by outdoor concentrations of pollutants. Some mitigation can be expected by adsorption of pollutants onto furniture and fittings, however in relative terms the difference in overall daily exposure indoors may be small. Fresh air intakes on air conditioners will inevitably add outdoor pollution to the indoor environment and in residences close to busy roads this will make a significant contribution to exposures, as will open windows.

Air filters within the indoor air space can reduce gases and particulates in a way which may benefit health. However they are costly in terms of average incomes and for that reason would not be available to a majority of the population. While there are sound reasons for trying to reduce exposure by any means available, and that would be particularly true for those most susceptible, there is as yet no formal scientific evidence that using air filters in the home prevents the cardiopulmonary problems which characterize populations living in a high pollution environment. Given the serious risks for health associated with indoor pollutants there should be the highest possible legal protection for indoor air quality, especially in terms of smoke free policies (Hedley et al 2006) The combination of outdoor pollution and indoor tobacco smoke has led to intense contamination of hospitality venues exempted from the Smoking (Public Health) (Amendment) Ordinance 2006.

7.4 ***High pollution alerts:*** The concept of an early warning system, based on a prediction of high air pollution levels, has been popular and is still being advocated. There are many fallacies associated with this and we have written an extensive critique of the proposal for a "High Air Pollution (HAP) Day" alert (attachment 3). In summary our reasons for rejecting this approach include the following:

- the lack of any threshold level for pollutant-health effects means that any advisory to the public would be associated with a very high level of uncertainty.

- The current advisories associated with the Environment Protection Department's API levels are arguably totally meaningless and misleading because they are scaled using outdated information and air quality objectives which cannot protect health.

- While the adoption of the World Health Organisation guidelines for safer air quality would provide a more valid indicator of risk, Hong Kong's daily pollutant levels are so high that offering any advice on gradation or restriction of activities on a particular day is likely to be either invalid or, if precautionary, would probably have to be offered on more than 300 days of the year. That would certainly be the case through the cool season from October to March. This would understandably be unacceptable and unaffordable. People have to be able to get on with their lives and earning a living almost whatever the detriment to their health.

- Given Hong Kong's present very high ambient levels of pollution a system of HAP day alerts would create economic losses comparable to a very long series of typhoon signals across the year costing billions of dollars but without health benefits.

- Even if restriction of activities for some is feasible, it is unlikely that pollutant levels can be predicted reliably and in a way which will prevent involuntary exposures. Sudden and large shifts in pollutants occur frequently in Hong Kong and would negate any possibility that people could plan their day to minimize exposures.

- It is important that those responsible for dealing with air quality management or proposing community wide interventions to reduce exposures, fully understand the relationship between air pollutant concentrations, exposures and health risks. Again, it need to be emphasised that Hong Kong's average levels of pollution and not simply exceptionally high days are the main drivers of morbidity and mortality. We should be cautious about recommending actions which carry the implied promise of benefit, when the evidence for benefit is uncertain.

- *Given the public desire for advice we can continue to examine possible approaches to daily air pollution advisories which might be helpful to individual decision making, providing the limitations are understood.*

8.0 Monitoring pollution levels, assessing the risks and counting the costs: the need for accountability

8.1 ***The Hedley Environmental Index (HEI) (http://147.8.71.207/pollution/home.php#s):*** We have worked to bring together a comprehensive picture of air pollution as it affects Hong Kong on an hourly basis.

The HEI was developed by the air pollution research group at the Department of Community Medicine, School of Public Health, University of Hong Kong with funding, design and presentation support by Civic Exchange (www.civic-exchange.org) in collaboration with Fu Tak Iam Foundation and ADM Capital Foundation. The Index site uses the daily air monitoring data provided by the EPD and the Hong Kong Observatory webcam to provide an indication of current visibility in relation to air pollution levels.

The real-time pollution surveillance system implemented and maintained by the Environmental Protection Department, using 10 general and 3 roadside monitors, is a valuable asset which has been adapted to provide the basis of an accountability system.

8.2 ***What does the HEI provide?:***

- *Pollutants:* The hourly, daily and annual levels of pollutants can be viewed continuously in a *Pollution Tracker* scaled in relation to the World Health Organisation Air Quality Guidelines providing an immediate and continuous picture of the exceedances of the WHO indicators of *safer* air quality. The evidence from studies in Hong Kong and mainland China is that each pollutant has the potential to harm health. The new HEI allows the pattern of each of the four common pollutants and its potential health risks to be interpreted individually.

- *Total Excess Risks:* The total concentrations of pollutants are continuously translated into excess risks using data from the studies on primary care utilisation, hospital admissions and deaths reported by the University of Hong Kong and Chinese University of Hong Kong research groups (see section 4.0).

- *Burden of illness:* Application of these excess risks allows us to derive estimates of the *avoidable burden of health problems* if pollution levels were reduced from those being observed to the levels of the WHO guidelines.

- *Cumulative displays:* We have proposed a method for combining the risks of the four pollutants and this is used to calculate the *rate* at which health care utilisation, premature deaths and costs are being incurred. These health events and dollar values are continuously displayed on digital clocks together with historical data and cumulative figures for any defined period of time (Figures 6 and 7).

- *Dollar costs:* The index shows the *direct* health care costs; the *indirect* costs of lost productivity. We also present the *intangible* costs derived from the population's *willingness to pay* to avoid a day of symptoms, an admission to hospital and a premature death which gives us a *value of the lives lost* due to pollution.

- *A focus for accountability:* We believe the index and its future development will help to provide a new focus for discussions and effective decision making on Hong Kong's major threat to environmental health and the costs which are being paid by the whole community, including government, public and private sector services, employers and each individual.

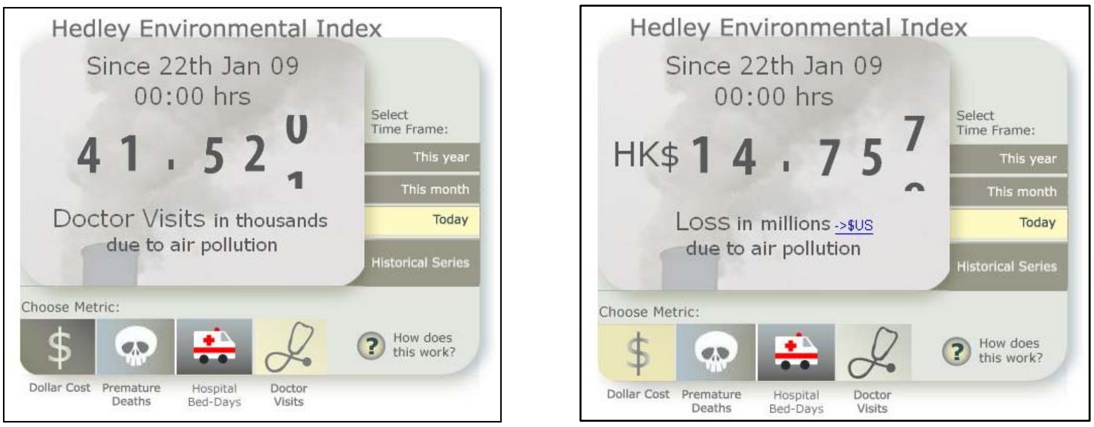


Figure 6: The clock displays in this example are counting from 00:00 on 22 Jan to 23:50 on 22 Jan and show that at the time viewed (evening) the estimated number of doctor visits and the costs on that day

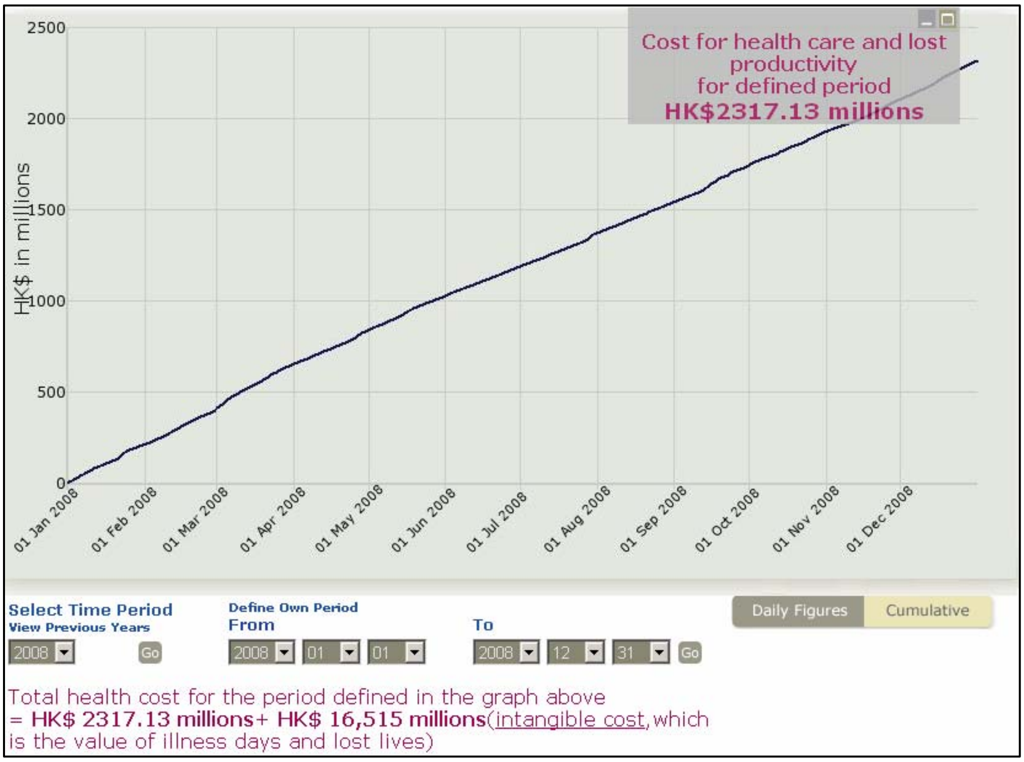


Figure 7: In 2008 the cumulative cost of air pollution was estimated at $2,317 billion for health care and lost productivity and $16.5 billion for pain and suffering and the value of lives lost

8.3 ***Visibility and the avoidable events caused by pollution, including doctor visits, hospital bed-days, deaths and dollar values:*** The HEI presents a cumulative record of the daily burden of disease and costs due to pollution. Reducing Hong Kong's average annual levels of pollution to the WHO guideline level would avoid about 7 million doctor visits, 64,000 – 80,000 hospital bed-days for cardiopulmonary disease and 1,300 – 1,600 deaths each year. The direct and indirect costs of health care and lost productivity amount to about $2 billion and the intangible costs range from $16 to $19 billion. A typical year's burden (for 2004) is shown in Figure 8.

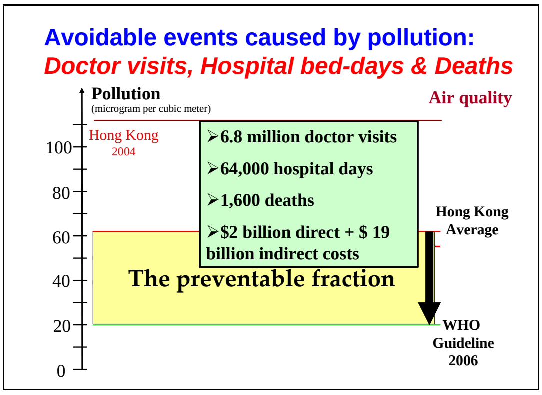


Figure 8: A typical pollution year burden of potentially avoidable illness, deaths and costs

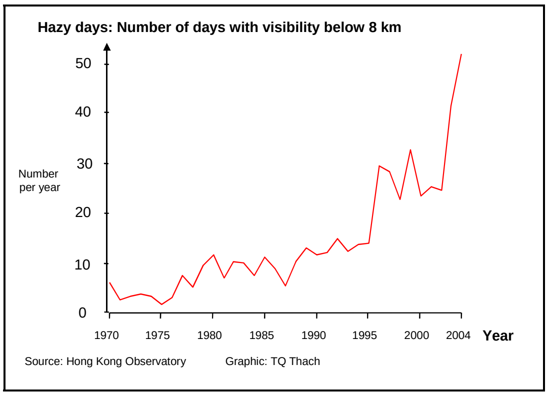


Figure 9: Loss of visibility is a strong indicator of the daily risk of health problems

In Hong Kong daily visibility is a strong predictor of health outcomes (Figure 9). It is possible to look out of the window and rate the environment for its health risks on any given day. Our poor visibility and loss of horizon closely reflects the health impacts from pollution across the population. Improvement in visibility from *poor* to *good* is strongly associated with lower ambient pollutant levels. Calculations of health costs based on this visible measure of environmental degradation yield very similar results to those obtained by simply using the mass concentrations of pollutants (Hedley et al 2008; attachment 4).

8.4 ***How valid are the estimates of disease burden and community costs generated by the Hedley Index?:*** The answer to this question lies in the estimation of the excess health risks and the methods used to combine them. All of the information used in constructing the index has been published through independent international peer review in scientific journals. The important issues involved in the construction of the Index are presented in section 4.0 and also discussed in two additional reports (Hedley et al 2008; Hedley et al 2006).

While there is inevitably uncertainty associated with this type of work we believe that the outputs of the index are strongly indicative of the burden of disease and the costs to the whole community.

The Index is conservative and there are two major reasons why the Index may currently under-estimate the risks and costs:

- *First the methodology used to generate the long term risk estimates* ***from cohort follow-up studies*** *are much greater than the short term risks estimated from the* ***time series studies*** *described in section 4.0. This is amply demonstrated by the data published in January 2009 from the American Cancer Society cohort* (Pope et al 2009).

  There are no general population cohort studies in Hong Kong and while this would be possible, given appropriate funding and other resources, the ubiquitous high levels of pollution in the HKSAR would now make it difficult to identify groups with contrasting exposures.

- *The second major reason why detriment to health is likely to be under-estimated concerns the incompleteness of studies on health outcomes in Hong Kong. Several should be mentioned to illustrate this point:*

  - *Intra-uterine growth retardation in the foetus*
  - *Psychomotor development in infants and children*
  - *The future long term effect on health related quality of life in children whose lung function is being damaged by pollution*
  - *The additional impairment of health and health care costs in patients with chronic disease including for example:*
    - *diabetes*
    - *coronary heart disease*
    - *asthma and chronic obstructive pulmonary disease*

We should take special note of the study of 10 to 18 year old adolescents in southern California reported in 2004 (Gauderman et al 2004). Over an 8 year period of follow-up they found that exposures to NO_2 *and* $PM_{2.5}$ *were strongly associated with deficits in lung function by age 18. This impairment of lung growth and development at entry to adulthood will predictably be a cause of poorer health related quality of life and reduced life expectancy. The average levels of* NO_2 *experienced by this cohort of children were much lower than current* average annual levels in Hong Kong.

9.0 Is air quality in Hong Kong improving?

Our emphatic response to this question, from a public health viewpoint, is *no*.

In a report published in the South China Morning Post on January 3, 2009 it is stated that an Environmental Protection Department spokeswoman said *"concentrations of individual pollutants were a better means than the API to assess long term air quality trend and had been decreasing over the past 10 years."*

While the first part of the statement is unquestionably true, the second part is open to serious doubt in terms of trends, their magnitude and relevance to health protection.

It is important that appropriate statistical methodology is used to estimate and represent trends in pollutants, especially over the relatively short periods such as a few years. There is clearly considerable random variation in the data available and it would, for example, be extremely misleading to pick two points at the beginning or end of an arbitrary period of time and use the simple arithmetic difference in the data to infer that a significant trend had occurred.

We would wish to emphasise the importance and public health impact of high roadside levels of pollution. Conservatively about 50% of the population live and/or work close to heavy traffic movements. In practice it is likely that a majority of the population is exposed to roadside pollution on most days of the week.

A second important issue relates to the marked seasonal variation in pollutant levels. We should be cautious in using average annual levels of pollutants as the only indicator of exposure. Cool season pollutants are extremely high in Hong Kong and there are important seasonal and pollutant interactions which give rise to the excess risks for health problems in Hong Kong.

The following preliminary analysis for data from 1997-2008 and 2003-2008 provides strong indications of current trends and their implications for public health.*

9.1 *Respirable Suspended Particulates (PM_{10})*

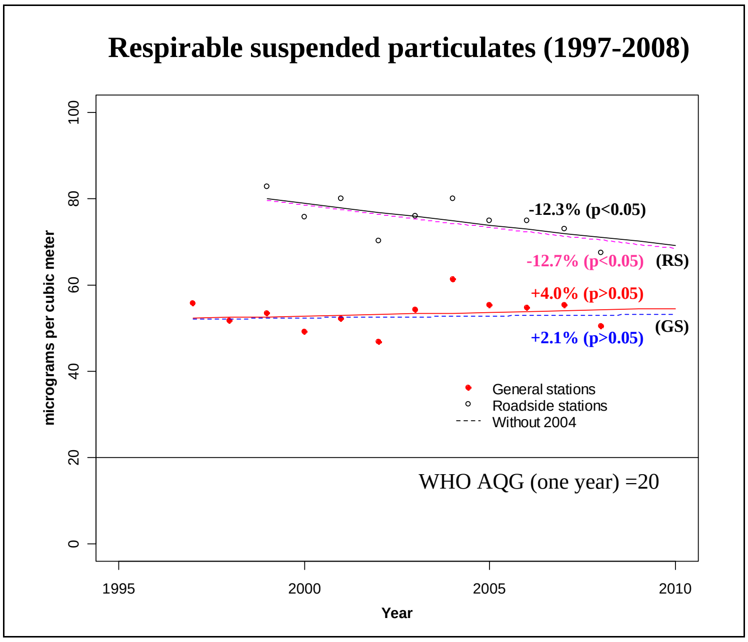
1997-2008: RSP levels showed marked differences between general and roadside stations. In the period 1997-2008 the roadside levels, based on annual means, show an estimated 12% decline but this shallow slope if extrapolated will not approach the annual WHO guideline for several decades. At general stations the trend is stable or upwards (+4.0%) (Figure 9). An extrapolation of the past 10 years annual means for RSP indicates they would not reach WHO AQG until around year 2120.

1997-2008 cool season: An examination of the 1997-2008 cool season trends show an 84.5% increase at roadside stations and a stable or non-significant 15.4% increase at general stations (Figure 10).

2003-2008: In the period 2003-08 roadside quarterly means show a steep upward slope (33%) which is slightly accentuated (37%) when data for year 2004 (a particularly high pollution period) is omitted. At the general stations the levels are stable with the slope at present (–1.8% to –6.6%) and not significantly different from zero (Figure 11).

There is clearly no indication that either curve would begin to approach the WHO guideline within the foreseeable future.

Figure 9: Trends for RSP in 1997-2008 show little change of public health relevance



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* Technical note: We fitted a log-linear model on the quarterly mean pollutant data against the time trend from year 2003 to 2008. We obtained the expected values of the model and predicted up to the end of year 2012 to obtain the estimated slope.

We also estimated the percentage change during the period, by the difference in the expected values between the last quarter of 2008 and the first quarter of 2003.

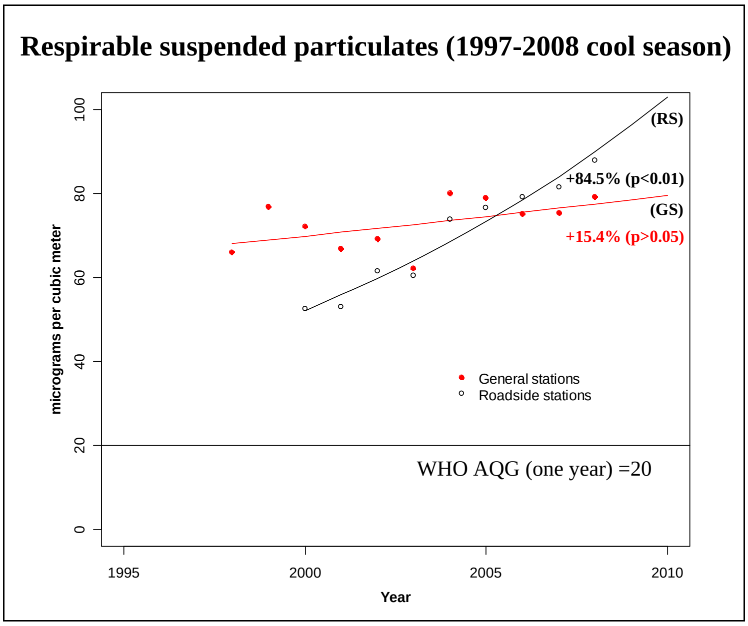


Figure 10: Cool season RSP trends show a marked upward trend at roadside stations

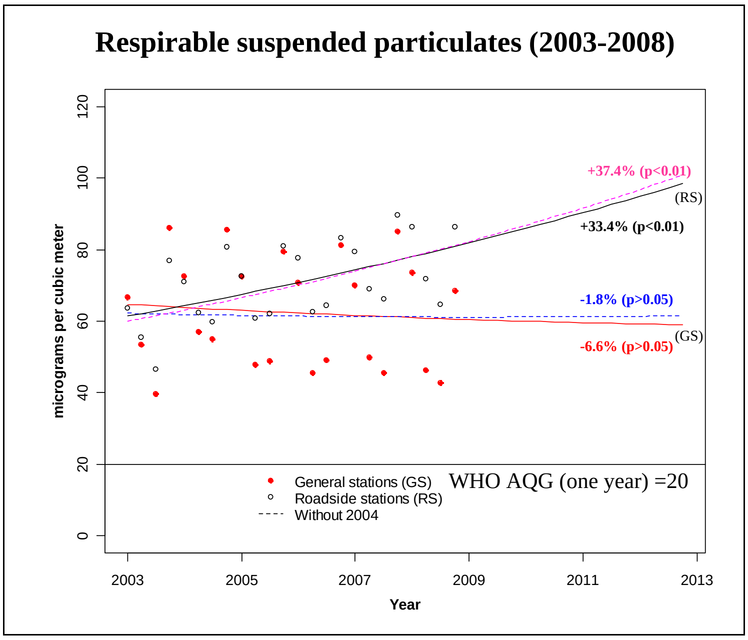


Figure 11: Recent years show a clear upward trend for RSP at roadside stations

9.2 *Nitrogen dioxide*

1997-2008: Roadside station levels are stable or increasing (5.5%) (not significant); and general stations similarly show an essentially flat curve with a non-significant downward slope of –4.5% (Figure 12).

1997-2008: Cool season NO_2 is very high and stable at both roadside and general stations. The slope at general stations (–7.5%) is not significant (Figure 13).

Extrapolation of the cool season slope indicates that the WHO guideline would probably only be achieved sometime beyond year 2080.

2003-2008: The pattern is essentially the same over this shorter period with no significant change in high roadside levels. The estimate of –1.5% is modified to +2.2% with omission of year 2004. The apparent downward trend at general stations is markedly attenuated from –10.1% to –5.8% if the year 2004 is omitted (Figure 14).

Figure 12: The curves for NO are statistically flat and show no trend likely to benefit public health

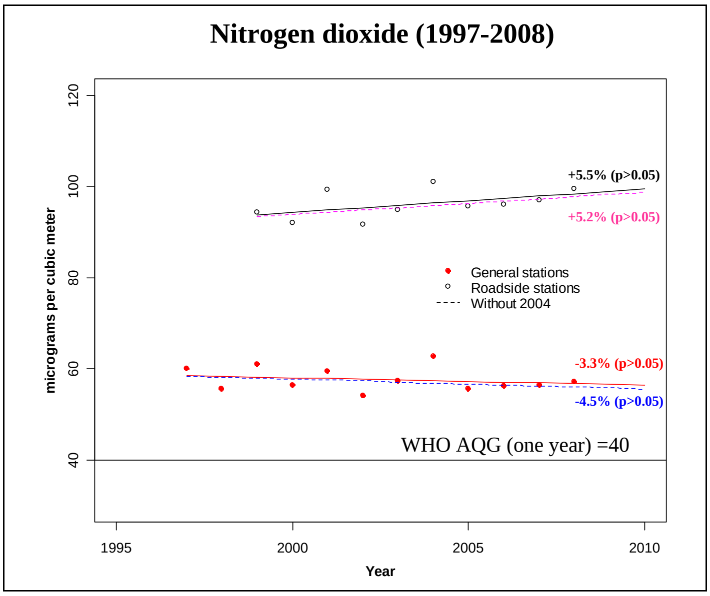


Figure 13: Annual cool season NO_2 levels are very high and show no significant change over the last ten years

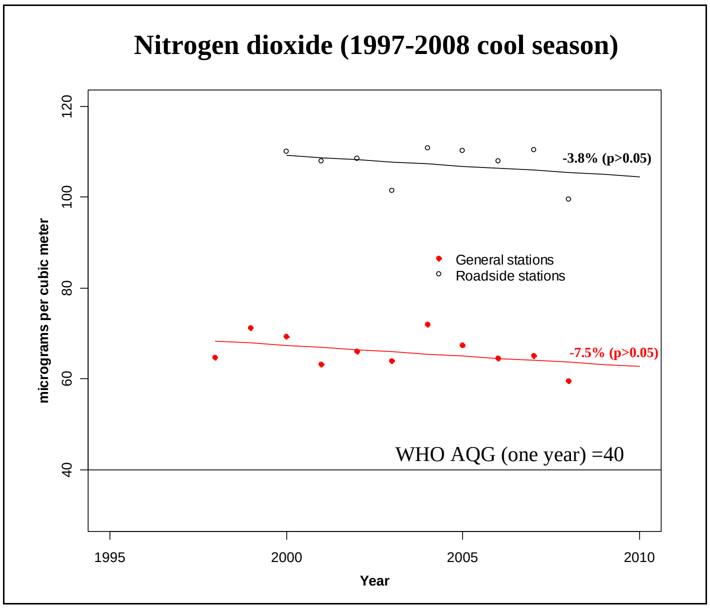
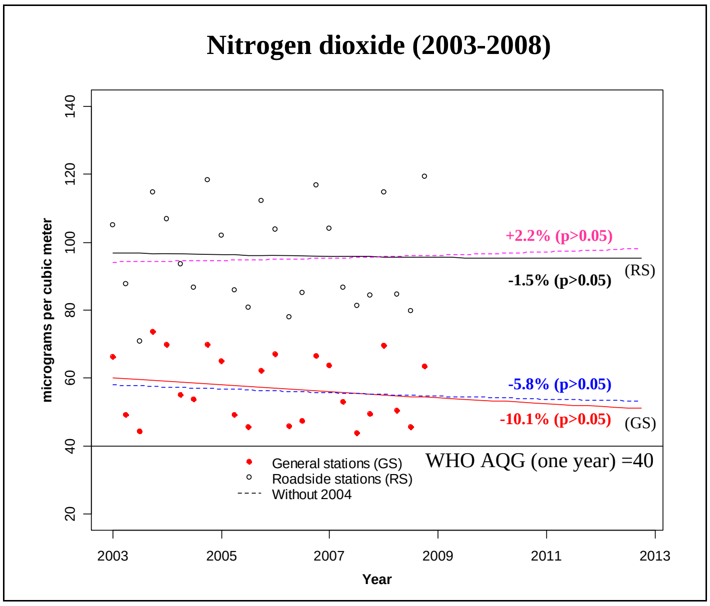


Figure 14: Based on quarterly means high roadside levels show no change over the 5 years period. The apparent downward trend for general stations is unstable and strongly influenced by year on year variations.



9.3 *Sulphur dioxide, nickel and vanadium*

1990-2007: The early years of this period were subject to progressive restrictions on sulphur fuel content in Hong Kong with important reductions in ambient annual means. However around 1998 there is an apparent turning point leading to progressive degradation of air quality in terms of these pollutants which are strongly related to health impacts (Figure 15). *These trends indicate that the benefits gained by the sulphur fuel restrictions in 1990 and beyond are being eroded.*

2003-2008: At the general stations there was considerable variation of SO_2 levels in several years. Estimates of trends are upwards though currently non-significant (Figure 16). However omission of the 2004 data indicates an increasing upward slope of 17.8%.

At the roadside there is a clear significant increasing trend of 22% to 34.8% which is sensitive to the 2004 data.
Overall there is concern that the gains made in abatement of SO_2 and related emissions are being lost. The public health implications should be viewed as serious given the evidence from Hong Kong and elsewhere for its causal relationship with heart and lung disease.

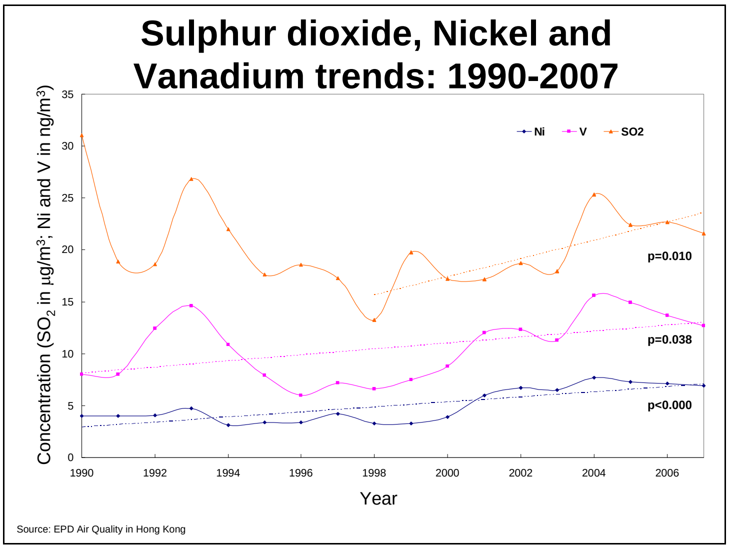


Figure 15: The reduction in emissions from sulphur rich fuels in the early 1990s is now being negated by counter trends for SO_2,Nickel and Vanadium

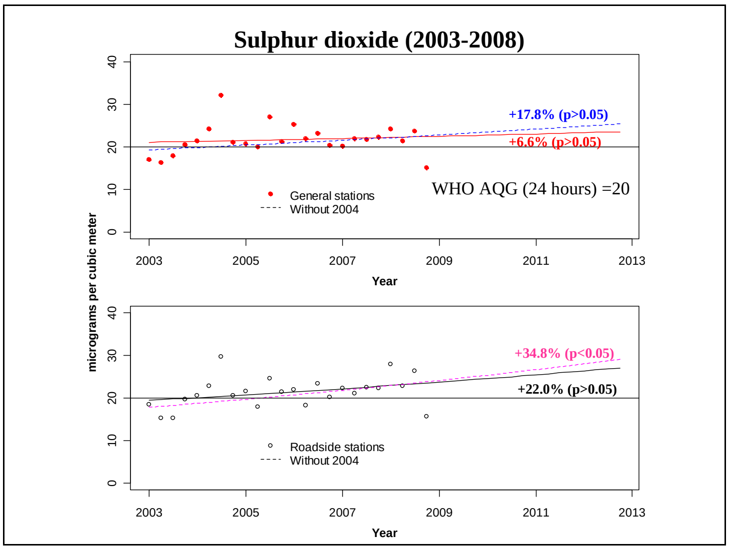


Figure 16: There are strong indications that SO_2 concentrations are rising at both general and roadside stations

10.0 Should Hong Kong adopt the WHO Guidelines as a formal step toward exposure reduction?

10.1 ***Key points in the introduction to WHO AQG:*** The 2005 WHO Guidelines were based on a comprehensive review of the best available evidence on the health effects of the criteria pollutants RSP (PM_{10}), NO_2, SO_2 and O_3.

The Air Quality Guidelines *Global Update 2005* states

> *"The guidelines are written for worldwide use, and are intended to support actions aiming for the* ***optimal*** *(my emphasis) achievable level of air quality in order to protect public health in different contexts"*

This is the first statement in the advice offered on the use of the *"Updated guidelines and air quality management"*.

It goes on to emphasise that

Statement (1) *"Air quality standards are an important instrument of risk management and environmental policy, and should be set by each country to protect the health of its citizens."*

Statement (2) *"The standards set in each country will vary according to specific approaches to balancing risks to health, technological feasibility, economic considerations and other political and social factors."*

Statement (3) *"This variability will depend on the country's level of development, capability in air quality management and other factors."*

10.2 Interpretation of the WHO advisory by HKSAR government

Statement (3) is a classical piece of diplomatic phraseology which is an obligatory part of any report from an agency of the United Nations. However it is susceptible to misappropriation as a justification for inadequate action on air quality management. The inclusion of a phrase on "economic considerations" perhaps makes it particularly prone to misunderstanding or manipulation.

In Hong Kong official statements on air pollution virtually never refer to the *primacy of health protection*.

On the other hand the HKSAR government repeatedly refers to Statement (2) and (3). There is no reference by government to the collective strengths in Hong Kong in environmental science and economics, public health and community based advocacy which could form a powerful advisory body with the capability to help the government initiate and expedite exposure reduction.

The substantial international track record of three universities, NGOs, and some professionals working in EPD, is largely being ignored.

When academics and others with expertise and experience were invited to join an "Advisory Panel" on the current "Review of Air Quality Objectives" they, along with other members, were apparently ignored and by-passed over the decision on adoption of WHO IT-1.

10.3 The HKSAR present position on WHO AQG

The recent adoption of Interim Target-1 (IT-1)
The government has now apparently adopted the low level Interim Target-1 criterion as its main definitive strategy, at least in the short term. Several points should be made:

- the Interim Targets are in the WHO AQG report to provide an entry level approach for countries with a serious lack of resources and expertise. They are not intended as a mechanism for *inaction* in a very high GDP per capita environment with the potential to act quickly and decisively.

- If the IT-1 is applied in Hong Kong it will predictably make no difference to pollutants originating in Hong Kong

The introduction of IT-1 will influence and colour the entire policy, and the audit and evaluation of any interventions. It will likely delay any prospect of achieving the necessary major reductions in pollutants.

The IT-1 is more permissive than the present HKAQO in terms of the annual level (70µg/m^3) and the same as the current mainland lax 24 hour level of 150µg/m^3. If it is implemented, even with our current very high levels of pollution we will achieve about 98% or greater compliance with IT-1, even in the cool season at the roadside, according to the EPD daily RSP readings. In 1997 to 1999 the 99^{th} percentiles of 24 hour cool season roadside RSP were 145, 131 and 144 µg/m^3 respectively, and therefore below the IT-1 24 hour level.

There is therefore apparently no mechanism whereby adoption of IT-1 is going to make any impact on Hong Kong's annual particulate levels of pollution.

10.4 What can we contribute to this argument?

The government's often repeated justification for inaction is that *"no other jurisdiction has so far adopted the AQG"*.

The senior officials in the Environment Bureau refer to pollution mitigation as a *"long term aspirational goal"*. This viewpoint, together with repetition of the diplomatic caveats from the WHO report have led to a spurious line of reasoning which will have serious public health consequences in Hong Kong.

It may be helpful if we can define the principal arguments against the adoption of a low key approach to the obvious and urgent targets for pollution abatement.

As a possible primer, the following points have been made by our Air Quality Objective Concern Group (AQOCG) coordinated by Civic Exchange:

(i) We are talking about the need for public health protection in Hong Kong, not other jurisdictions. We do not know of any similar socially and economically developed region which has the same sustained, widespread and serious degradation of air quality. Other jurisdictions with much lower levels of pollution are not so challenged, but nevertheless are moving towards tighter standards and progressive interventions to reduce exposures. The European Commission is taking legal action against member countries (such as the United Kingdom) with much lower levels of pollution than Hong Kong, for non-compliance with EU standards.

(ii) Other jurisdictions already have in place mechanisms for regular assessments and reviews, as part of an evidence-based regulatory procedure. So we can expect these overseas regulations to move forward along predictable time-lines.

(iii) Hong Kong's air quality objectives have remained unchanged for 21 years. The science base today bears no relation whatever to the situation in the early to mid-1980's when the USEPA formulated the standards on which the HKAQO was eventually based. From this perspective Hong Kong has no valid regulatory framework at present, within which we might be able to work to reduce emissions in a way which reduces pollutant concentrations to safer levels.

(iv) Despite the serious environmental situation, public confidence and health protection would be bolstered by the adoption of an evidence based strategy and a transparent and valid framework for audit and evaluation, with clear evidence for the achievement of benefits.

(v) We need to oppose any argument which involves the *cost of a clean-up*, without reference to both the monetised and non-monetised external costs of the present damage caused by pollution. The United States Environmental Protection Agency has made a statement which makes very clear the health protection imperatives rather than a cost based approach.

(vi) *Senior officials in the Hong Kong Environment Bureau have repeatedly stated that clean air and blue skies will have to be paid for. Our analyses of pollution related costs clearly show that the whole community is now paying a very high price for dirty air.*

11.0 How can risks to population health from air pollution be reduced?

11.1 ***An issue of human rights:*** Clean air must be regarded as a human right along with clean food and water. While public health action on food which is a vector for disease and unfit for consumption has been largely swift and comprehensive, no such imperatives have been accepted for the achievement of clean air.

The demonstration of environmental injustice, with the more disadvantaged sectors of the community bearing a greater burden of the pollution epidemic provides clear grounds for government to accept responsibility and ensure effective action.

The primacy of child health protection should at the very least be regarded as immutable by government.

The evidence provided by the EPD high quality monitoring network clearly shows (through diurnal, seasonal and other spatial variations) the avoidable fraction of air pollution (which will reflect individual exposures) which results from emissions in Hong Kong. In addition a detailed analysis of pollution sources by Dr Alexis Lau of the University of Science and Technology demonstrated that about 53% of the annual time-related exposure was dominated by pollutants originating in Hong Kong (*Relative Significance of Local vs. Regional Sources: Hong Kong's Air Pollution* www.civic-exchange.org). This is an important finding for public health because it points to important cost-effective solutions to avoidable morbidity and mortality within the HKSAR.

Hong Kong needs to devise and implement a series of effective multisector interventions on a much shorter timescale than is apparently currently envisaged to avoid or at least lessen the creation of a large long term epidemic of pollution induced ill-health in young people.

Hong Kong needs a rational radical evidence-based strategy which will address the large and growing threat to public health as a matter of urgency.

11.2 ***Exposure reduction must become an urgent and achievable goal:*** While we strongly support the adoption of the WHO Guidelines as a basis for formulating air quality standards and creating "caps", these single limit values should not be misinterpreted or misused. Lessons must be learned from the disastrous application of the Hong Kong Air Quality Objectives under the Environment Impact Assessment Ordinance. The HKAQOs became an instrument whereby pollution in a given location, from a new development, could legally be increased. That remains the situation today and it is inevitable that this mechanism has contributed to the population burden of ill-health caused by pollution.

It bears repeating that current scientific studies suggest there is no threshold for health effects from a pollutant such as $PM_{2.5}$. The European Commission has proposed the concept of Exposure Reduction Targets (ERT). The introduction of ERT would be the principal strategy for protecting public health in that it would require that pollutant concentrations are reduced even in relatively clean areas.

If limit values are the sole instrument for pollution abatement then as air quality improves smaller proportions will be affected by exceedances. However these individuals are likely to be the most vulnerable and therefore achievement of the public health objectives will be compromised.

Emission Reduction Targets should be focussed on areas of greatest need in a fail-safe strategy to protect health and not simply, as previously stated by the Environment Bureau, "on a best endeavour basis".

Limit values should be rigorous to ensure that any individual's risk is minimized while coverage of the whole population, in terms of exposure reduction, ensures that opportunities to maximize the avoidable fraction are achieved.

In the process of air quality management in Hong Kong there should be greater emphasis on the ambient pollutant concentrations as a proxy for exposures. Repetitious statements about emission reductions may reflect *attempts* to mitigate pollution but they have little public health relevance if they do not lead to improvements in air quality measured as concentrations per cubic metre of air.

Finally we need a better translation of public health research, on air pollution effects, into policy, practice and enforcement.

11.3 ***The public health viewpoint:*** The lack of any formal authority or responsibility for air pollution related environmental health problems among the public sector health authorities, including public health physicians and other disciplines, should be remedied without further delay. At the present time the only public health research and advocacy on air pollution takes place among non-governmental organisations.

We need better data on lifetime exposures and their relationship to health experience and given the magnitude and seriousness of the problem there should be substantive additional resource allocation for high quality multisectoral work on the impact of pollution on population health and the economy.

The World Health Organisation Air Quality Guidelines should be adopted without further delay. At the same time the purpose of the guidelines should not be misinterpreted.

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Legco 27 November 2006 Environmental Affairs Panel

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1. I understand that the Chief Executive has said that because Hong Kong life expectancy is one of the highest in the world, Hong Kong is therefore the most environmentally friendly place for executives. As a public health physician I am totally dismayed to hear such a naïve, misleading and fallacious statement from our Chief Executive. It is clear that the CE has been very badly advised on our current population health issues. It appears to show a serious misunderstanding of the complex determinants of health and survival.

2. First it is important to realise that overall population high life expectancy is driven by employment, and income and reflected in high GDP per capita, whereas poverty would have a negative effect. Whereas air pollution would be unlikely to reverse our overall life expectancy it would certainly slow the progression of gains in longevity. For a reversal of life expectancy trends there would have to be a complete breakdown of social structures, or war, famine and widespread fatal infectious disease; examples would include the turmoil and massive increase in alcohol consumption which followed the breakup of the Soviet Union, or the HIV/AIDS epidemic in Africa.

3. Our high life expectancy in Hong Kong is also attributable to

   - Our very low infant mortality rate (a tribute to the reproductive performance of Chinese mothers)
   - High quality maternal and child health services
   - The healthy migrant effect given the high proportion of older people who were mainland migrants. Migrants are fitter and generally better survivors.

   The Chief Executive should not confuse contemporary effects with cohort effects.

4. Hong Kong has the best data worldwide on the impact of pollution on survival and there is no question that air pollution causes premature deaths and shortens the lives of hundreds if not thousands in Hong Kong. The 1990 sulphur restriction in fuel was a very modest single intervention; we have demonstrated for the Government's benefit that it reduced age specific mortality rates, mainly from lung and heart diseases.

   But beneath the tip of the iceberg of deaths is a huge burden of ill health. In polluted environments many more people become sick for longer periods before the point at which they die. The Chief Executive should be aware that delays in cleaning up the air will cause large scale impairment to health-related quality of life, including illness days, hospital admissions and time off school and work. Pollution damages people with existing disease such as heart and lung problems and diabetes, and also otherwise healthy individuals both now and in their future health experience.

5. Merrill Lynch did not put a sell notice on property investment just because of reduction in life expectancy; I believe they were concerned about healthy life expectancy.

   The executives which the Chief Executive refers to will only be as good as their work force and the next generation of workers in Hong Kong. One of the questions Mr Tsang should be asking is “What will be the impact on young people of growing up in dirty air?”. The answer to that is unfortunately for many of them their lungs will fail to mature properly by the time they are about 18 years old. Poor lung growth in childhood is a major predictor of shortened life expectancy.

Attachment 2

South China Morning Post

南華早報 PUBLISHED SINCE 1903 HONG KONG: $7.00

THURSDAY, NOVEMBER 30, 2006

DONALD TSANG ON AIR QUALITY *Anthony Hedley*

Polluted by misinformation

The chief executive said this week that, because Hong Kong's life expectancy is one of the highest in the world, the city is therefore the most environmentally friendly place for executives. From a public-health viewpoint, I am totally dismayed to hear such a naive, misleading and fallacious statement.

It is clear that Donald Tsang Yam-kuen is seriously out of his depth on this public-health issue, and has been very badly advised about our population's health-protection needs. His claims reveal a serious misunderstanding of the complex determinants of health and survival, and the calculation of life expectancy.

High life expectancy is mainly driven by employment and income, and usually reflects a relatively high gross domestic product per capita. Air pollution here would be unlikely to reverse our overall life expectancy trends in the short term, but it would certainly slow the progression of gains in longevity, as acknowledged by Edgar Cheng Wai-kin, former head of the Central Policy Unit, after Mr Tsang's speech.

A reversal of life expectancy trends requires large numbers of deaths associated with a catastrophic breakdown of social structures or war, famine or widespread fatal infectious disease.

Our high life expectancy in Hong Kong is also attributable to our very low infant-mortality rate; high-quality maternal and child-health services; and the so-called "healthy-migrant" effect – given the high proportion of older people who moved here from the mainland. Migrants are fitter, and generally better survivors, than average.

The chief executive should not confuse contemporary effects with cohort effects. He could benefit from expert advice from public-health specialists; it is free of charge from our Air Quality Objectives Concern Group, unlike the costly and unnecessary consultancy on air quality which the government now intends to pay for.

Hong Kong has some of the best data worldwide on the impact of pollution on survival: there is no question that air pollution here causes premature deaths and shortens the lives of hundreds, if not thousands. The 1990 sulfur restriction in fuel was a very modest, single, air-quality intervention – but it has been demonstrated for the government's benefit that it markedly reduced age-specific mortality rates, mainly from lung and heart diseases.

Beneath the tip of the iceberg of deaths is a huge burden of ill health. In polluted environments, many more people become sick for longer periods before they die.

Mr Tsang should be aware that delays in cleaning up the air will cause large-scale impairment to health-related quality of life, including illness days, hospital admissions and time off school and work.

Pollution damages people with existing diseases – such as heart and lung problems and diabetes – as well as otherwise healthy individuals. The Merrill Lynch financial firm did not put a "sell" notice on Hong Kong property investment recently just because of fears of a reduction in life expectancy: I believe it was deeply concerned about the health-related quality of life and healthy life expectancy.

Everyone is at risk. But we are not so much concerned with relatively well-protected executives and foreign businesses, as with the harm being caused to children and adolescents at the most formative stage of their lives. The executives to whom Mr Tsang refers will only be as good as their workforce and the next generation of workers in Hong Kong.

One question Mr Tsang should be asking is: "What will be the impact on young people of growing up in dirty air?" The answer is that, unfortunately for many of them, their lungs will fail to mature properly by the time they are about 18 years old. Poor lung growth in childhood is a major predictor of shortened life expectancy.

Anthony Hedley is Chair Professor in Community Medicine at the University of Hong Kong's School Of Public Health

Attachment 3

Amended version: 15 October 2007

The Sustainable Development Council Invitation and Response Document: Clean Air-Clear Choices

Will High Air Pollution Alert Days provide an efficient path to health protection?

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The Air Quality Objective Concern Group
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October 2007

Background

The Air Quality Objective Concern Group has submitted separately a comprehensive set of comments on the Council for Sustainable Development's (CSD) three proposals. Here we address in more detail the proposal for High Air Pollution alert days (HAP alerts) made by the CSD in its public consultation.

Any appraisal of this proposal needs to focus on its *validity* and *utility* and these concepts need to be disclosed and explained to potential respondents before any informed forced choices or comparisons can be made, or would have any value for decision makers. The fundamental problem is that the definition of the HAP needs to be based on *health outcomes* which in turn requires the adoption of evidence-based criteria for harm reduction which can be derived from the best science currently available. The government asserts that we are not yet in a position to adopt current science based air standards in Hong Kong and this will remain a major rate limiting factor in air quality control for at least two more years.

The proposal to create an alert system for high air pollution days (HAPs) is based on the assumption that exposures to air pollutants can be significantly reduced and bad health outcomes avoided. There is no strong empirical evidence available from any studies to show that modification of usual activities of daily living (ADL) will make a major difference to the harm caused to population health by air pollution at the uniformly high levels generally experienced in Hong Kong.

The loss of visibility and our horizon over 20 years is the most visible evidence of our poor air quality. This trend (Figure 1) is also the curve for an epidemic of heart and lung disease in the HKSAR. It is a reminder than a large proportion of the complex gases and chemical particulates (comprising highly penetrating nano-sized material which does not settle, creates a pollutant "blanket" which simply cannot be avoided if the air is breathed.

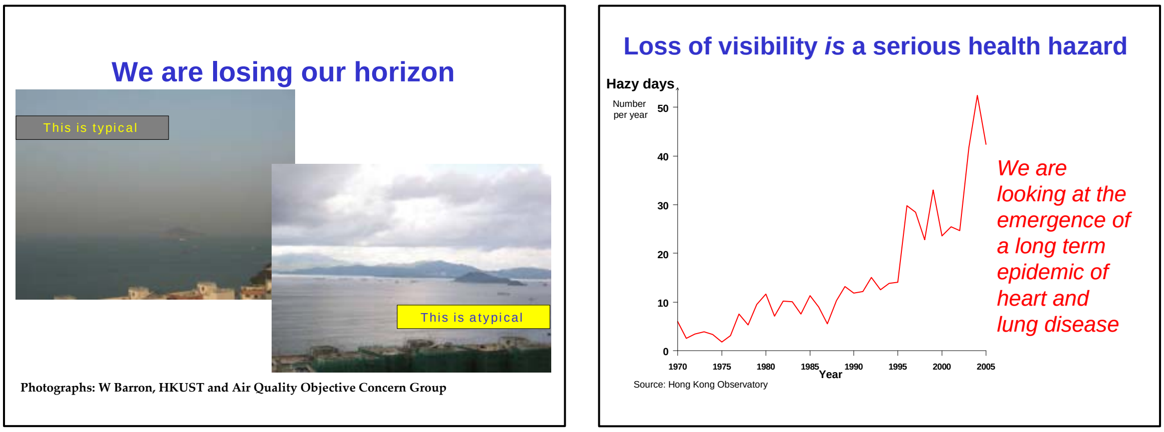


Figure 1: Poor visibility in Hong Kong is directly related to trends and episodes in air pollution. Loss of visibility is also a direct measure of illness and deaths caused by air pollution

What is the possible significance of HAP alert days?

The primary objective of a strategy and special interventions to improve air quality should be health protection, and all sectors of the community will expect any approach to be demonstrably evidence-based and cost-effective. Although it is mainly the current trends in loss of visibility which have driven arguments for urgent pollution abatement measures, we need to remember that it is the unseen and silent injuries caused by the *average* annual levels of pollutants which are responsible for most of the burden of pollution related illness and deaths in the HKSAR. The very high pollution days will certainly make an additional contribution to the illness experience of many people, but they will be a relative minority of all days which are hazardous for health. Furthermore we cannot assume that we can do much to avoid the risks of the very high pollutant days.

It is important to remember that apart from the acute health effects which lead to increased daily doctor visits, hospital admissions and premature deaths, we should be deeply concerned about the long term impact on the growth and development of children's lungs. This is the site of a potentially irreversible injury at the most formative stage of a young person's development. It would not be prevented by calling occasional HAP alert days.[1]

Figure 2: Children are among the groups most sensitive to air pollutions. Damage to young growing lungs may be permanent and have lifelong effects on respiratory health and life expectancy.

One recent newspaper headline about the Council's public consultation told us that *"Now, it's up to you"*.[2] At this stage we would like to pose the question as to why it should be up to the general public to determine and decide how and when a major epidemic of disease (affecting heart, lungs and blood vessels and the lifelong health experience of children) should be prevented? We believe that the solutions are manifestly obvious and need to be applied through coordinated government action at the highest level and on an intersectoral basis.

There are important social and ethical issues to be considered here because the HAP alert proposal carries with it the implied promise of benefit and is likely to raise expectations that personal commitment, lifestyle change and probably inconvenience and privation will be rewarded with better health protection. This may not be true.

We need timely and effective interventions

There is no question that the only real hope for a *timely* and *effective* improvement in regional air quality will come from legislation and mandatory comprehensive interventions on *emissions* in all sectors, in a way which actually reduces the pollutant *concentrations* of the air we breathe. The first place this must happen for protection of the Hong Kong population is within the boundaries of the HKSAR.

From a public health viewpoint we suggest that the battle against pollution is currently being lost in terms of the daily threat to health and longer term environmental degradation. We have previously pointed to the avoidable community costs of pollution resulting from direct costs of health care needs and lost productivity. There needs to be clear recognition of the external costs of air pollution and a focus on approaches which will *reduce* it, rather than additional costly actions which will not do so.

Air quality standards are key to all interventions

The daily and annual average levels of all pollutants in Hong Kong are well above the guidelines agreed by the World Health Organization in 2005 and promulgated in a global promotion in 2006. A member of the HKSAR government Environmental Protection Department attended and contributed to the final WHO review meeting in Bonn in October 2005, so the government would have been well acquainted with the detailed evidence considered by the WHO Working Group on Air Quality Guidelines. The review was steered by experts in epidemiology, toxicology, air quality exposure assessment, air quality management and public policy. It is unquestionably a high quality state-of-the-art review.

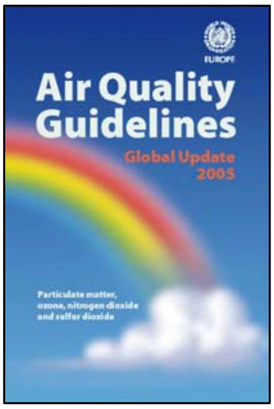


Figure 3: The World Health Organization Air Quality Guidelines (AQG) provide the best interpretation and synthesis of the current global evidence on health effects of air pollution. The guidelines are based on a precautionary approach to health protection.

Nevertheless the Hong Kong government believes it does not have sufficient evidence or guidance to implement new air quality standards or comprehensive strategies with explicit timelines to achieve abatement of the current high levels of pollution. The government's own review did not begin until mid 2007 and will not report until end 2008. Any meaningful action beyond that point will take a further indeterminate period. This delay needs to be viewed in terms of the unaddressed avoidable short term effects on illness and premature deaths, huge external costs to all sectors of the community and permanent long term damage to generations of young children and adolescents. The adoption and use of meaningful criteria for air quality would be central to the establishment of any HAP alert system.

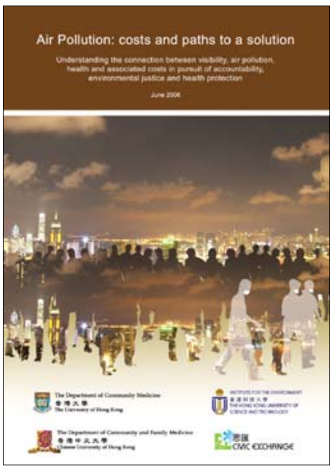
The community burden of the costs of air pollution

We need to continue to translate the excess risks of breathing dirty air into monetary values and measures of quality of life in an attempt to drive policies on the environment. It is now clear that simply calculating the large burden of disease – for example in terms of chest symptoms, hospital admissions and deaths – has not made any material difference to the government's approach.

Figure 4: The current position of both government and vested interests in the business sector is to ignore the external costs of pollution including the burden of illness across the whole community. We need to move to an evidence-based assessment of the impact of pollution on health which includes measures of quality of life impacts on the Hong Kong population.

We need to be able to translate excess risks of air pollution and effects of mitigation measures into monetary values and measures of utility in an attempt to drive policy

June 2006



We introduced the issue of external costs together with clear options for urgent action in our June 2006 report from the Air Quality Objective Concern Group.[3,4] The *preventable fraction* of the illnesses and premature deaths which could be achieved by reducing Hong Kong's air pollution is very large indeed. For example a reduction of our average annual pollutant levels, as measured at general monitoring stations, down to the levels of the WHO guidelines, would avoid nearly 7 million doctor visits, over 60,000 hospital bed-days and up to 1600 deaths each year. The attributable *direct* cost of health care and lost productivity is about $2 billion per annum. About 50% of the population live within 100 metres of busy roadways. If we rate the health impact and costs using road-side pollution the benefits of mitigation are much greater. A question relevant to the HAP alert proposal is therefore, what difference will HAP alerts make to the community burden of disease and costs.

The CSD has claimed that we do not know what the public responses are to questions about *willingness to pay* for cleaner air, to prevent illness or deaths attributable to pollution. We would argue that this not true. There are now several sources of data which indicate the general scale of values which the public places on their preferences related to health protection from pollution. We have specifically reported on the intangible costs of pollution from our surveys on willingness-to-pay, to avoid a day of respiratory symptoms such as cough, a hospital admission for heart or lung problems and a premature death, all caused by breathing pollutants. The value of this is around $20 billion each year. The government's response to our report was muted or frankly negative and dismissive. The then acting director of the Environmental Protection Department, referring to our estimate of the overall economic burden of pollution *"…noted that the health care expenditure attributable to air pollution was indirect…"*.[5] Again this isn't true, but it also shows how both government and vested interests may place a very different value on the health threat caused by pollution compared with the lay public. Whether HAP alerts would work for health benefit or not we can expect that there will be many different viewpoints on their value.

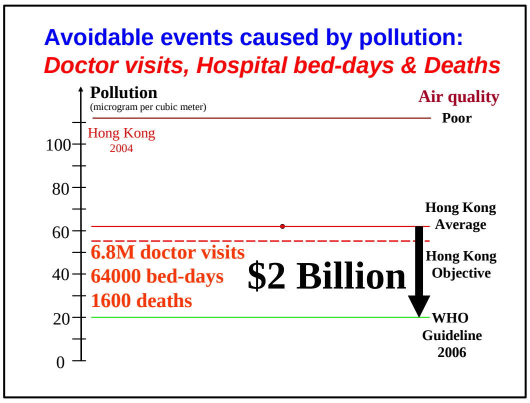


Figure 5: The reduction in doctor visits for health problems caused by pollution, hospital admissions for serious acute and chronic disease. The estimates for reduction in morbidity and mortality through air quality improvement do not yet include many bad health outcomes, such as the effects on the unborn foetus and long term effects on child health. The estimates are also conservative in that they are based on general monitoring station levels. It is possible that the health impacts are greater on those who live and work near busy roadways, estimated to be about 50% of the population. There is no evidence of a safe threshold for air pollutants and the upper limits of the WHO guidelines should not be regarded as safe.

The preventable fraction of illness and death is not simply a medical statistic but an issue of social justice and inequity for Hong Kong.

What is the value of the questions posed by the SDC questionnaire?

We would certainly agree that there is scope for further good quality surveys of public perceptions of the risks of air pollution and the monetary value of the penalties we pay. However we are disappointed with the structure and content of the SDC questionnaire. The questions posed in the survey are leading and tendentious. We do not think that they will give any indication of the uncertainty associated with a respondent's understanding of the issues or their choice of response. This is important because many questions, which are represented simplistically, are highly technical in nature or associated with other complex issues to such an extent that they either cannot be answered or are implausible as potential solutions to the hazard of air pollution.

Two key examples of poorly thought out questions would be:

Q8 *"How long before a high air pollution alert day should a notice be issued?*
Q12 *"Should we require employers to allow staff … with respiratory or heart disease to work from home?"*

We discuss these issues in later sections of this paper.

Our June 2006 report was a very conservative estimate of the burden of disease and costs, based on the best available local scientific evidence. The question therefore arises as to what the government will do with any pleas from the public for immediate and radical action to mitigate daily pollutant exposures which are likely to arise in this consultation – and have already been expressed for several years. Government reactions to public views submitted in other public health consultations have been the subject of concern and criticism. A clearer exposition of how responses from the public will be handled would create greater transparency and clarify the potential usefulness of the whole exercise.

Principles of efficient health care programmes

So bearing in mind that the principal force of morbidity and mortality is probably the *average* annual exposure to air pollution, what impact would HAP alert days make on the burden of disease and community costs?

Ideally in an *efficient* preventive health strategy, for example a screening test, we need to be able to identify the *maximum amount of risk* in the *smallest number of people*.

If we relate this to air pollution alerts we need to try and *maximize population health gains* by intervening *in the smallest number of days* each year.

There are two main problems here. First Hong Kong's levels of pollution for most of the year are generally uniformly high in terms of health risks throughout the year. It follows that any reduction in harm and benefit to health achieved by any single alert will be very low, in comparison to the overall risk. In order to have a chance of making a large difference we would have to call multiple HAP alerts across the year. We also need to remember that the pollutant threshold level for health protection (for example as indicated by WHO guidelines) is very low compared with Hong Kong's average levels.

We need cost-effectiveness affordability curves to assess the proposed HAP alert system. Put simply, we are talking about the three 'A's:

- Achievability
- Acceptability
- Affordability

Can we reliably predict HAP days?

The CSDC questionnaire asks the question
"How long before a high air pollution alert day should a notice be issued?"

This is a potentially unanswerable question in the sense that the prediction and timing of an alert will be driven by factors which are outside of anyone's control. Further discussion on this issue from environmental scientists would be useful.

Even assuming that possible benefit will result from a HAP alert, we need to recognize that the public, not least the business sector, will want reasonable precision in the announcement of an alert. Patterns of pollutant concentrations on very high pollution days show sharp divergent trends with the slope of the trend changing rapidly within an hour or two, often in the middle of the working day. These patterns are often complex. For example on September 15th – 16th 2007 there were about 7 different phases in a 24 hours period (Figure 6). On the day of the marathon, 4 March 2007, a major change in the level of pollutant concentrations actually occurred during the running events.

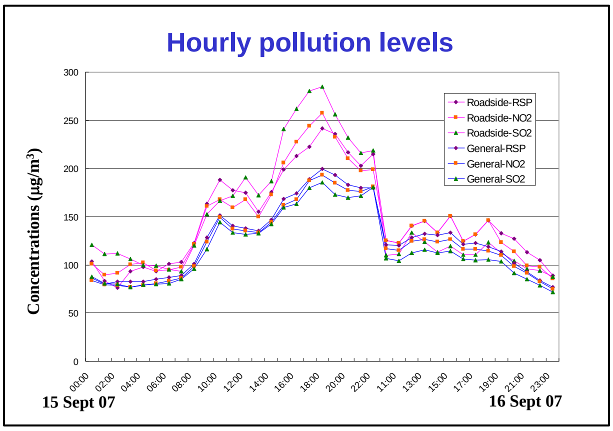


Figure 6: Typical patterns of pollutions at both general roadside monitoring stations often show sharp divergence from apparently stable levels occurring within an hour or two. Note that in this example both general and roadside monitoring station levels are high at 100µg/m^3, rising to over 250µg/m^3.

The background conditions and factors which lead to pollution alerts in other countries, especially for single pollutants such as an ozone alert in Phoenix, Arizona, are quite different from those which generate intense plumes of mixed pollutants in Hong Kong.

While there is no doubt that several criteria and general decision rules are available to facilitate the forecast of pollution levels it is extremely doubtful that any system can be calibrated so that it reliably and efficiently switches alerts on and off without incurring false positive and false negative actions.

What criteria should be used to trigger HAP alerts?

As things stand at present the HAP alert days would be signalled on the basis of an Air Pollution Index (API) calculated using the Hong Kong Air Quality Objective (HKAQO).

The API is determined not by the absolute risk associated with different concentrations and combinations of pollutants but by the HKAQO. The HKAQO is a single arbitrary cut-off value for pollutant concentrations which is now twenty years out of date as a scientific basis for health protection. It is scaled far too high with the effect that an API calculated on this basis will only trigger an alert when pollutants are well past harmful levels which cause both short and long term injury to heart and lungs. This problem does not just apply to particular very high pollution days; it applies to most days of the year in Hong Kong.

How can we estimate possible benefits of HAP alerts?

To illustrate the possible costs and benefits of HAP alerts in a valid and reliable way we will focus on the absolute concentrations of pollutants and consider what health related criteria we could use to trigger an alert. We have reasonably precise health risk estimates for doctor consultations, hospital admissions and deaths associated with each 10μg/m^3 increase in particulates, nitrogen dioxide, sulphur dioxide and ozone. We can illustrate the possible costs and benefits of a HAP alert using selected cut-off points for pollutants as measured at both general and roadside monitoring stations. For example, the assumption might be that we could try to protect health by reducing population exposures to the upper 1%, or 10% of a pollutant such as respirable suspended particulates (RSP or PM_{10}). Alternatively we could use the WHO guidelines for 24 hour levels and estimate the total health benefits which might be gained if we reduced exposure to all pollutants by a certain proportion on alert days (Figure 7). We described a method for combining pollutant-health effects in our 2006 report.[4] Note that if we used the Hong Kong 24 hour HKAQO we would never have had an alert triggered by average general station levels in 2006 because the AQO is set so high.

We can map these chosen criteria for HAP alerts onto the daily levels of pollutants measured across the year. A graphic representation of this gives a rough visual guide to the number of HAP alerts which would be called using different criteria.

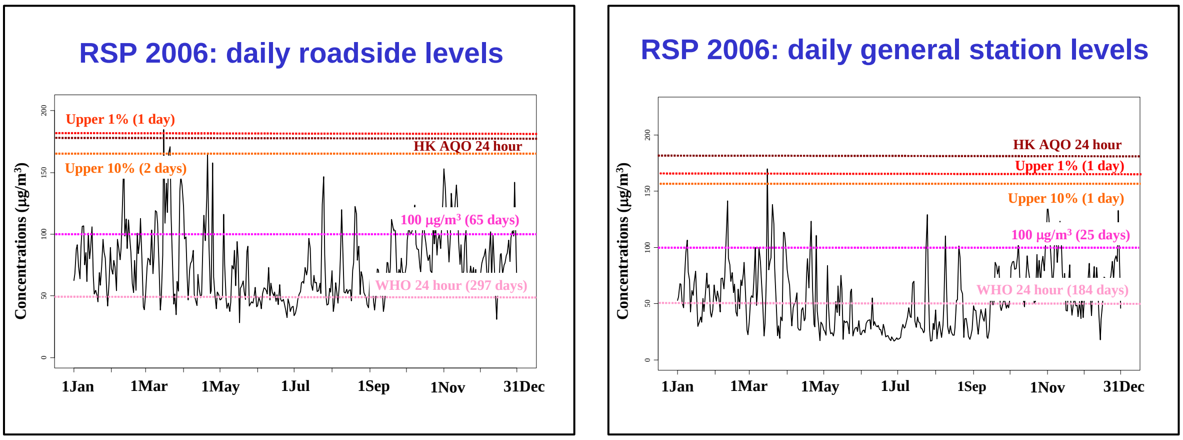


Figure 7: Respirable suspended particulates in 2006 measured at general and roadside monitoring stations, together with possible criteria for declaring a HAP alert and the number of days on which a HAP alert would be called using these criteria.

The number of HAP alerts called using the criteria we chose would range from 1 day up to 359 days. Clearly the low number would confer virtually no population health benefit on an annual basis, whereas the high number would be unacceptable on grounds of costs, social disruption and reputational damage to the image of Hong Kong.

The Council's proposal for HAP alerts include a "passive" approach, in which decisions are left to individuals and an "active" approach in which we assume that government may issue strong advisories or prescribe mandatory measures, presumably backed by legislation. Assume for the time being that HAP alerts could in some way lead to worthwhile gains in health protection by changing the public's usual behaviour and activities of daily living in a way which actually reduced exposures significantly. We then need to assess the values of cost of alerts and the benefits achieved.

What would a HAP alert cost?

The costs associated with mandatory measures during a HAP alert might be analogous to those incurred by a tropical storm ("typhoon") Number 8 signal. During such a period people are required or allowed to leave their workplace and go home, educational institutions and many businesses close. The Labour Department has issued a detailed advisory directed to both employers and employees.[6] Employers are urged to *"make realistic and critical assessment of the essential staff requirements so that only the absolutely essential staff are required to report for duty under adverse weather conditions"* and *"when a typhoon signal No. 8 or above is issued employers should not require their employees to report for work for the sake of safety unless prior agreement to the contrary has been made"*.

In the past the issue of a Typhoon No. 8 has caused concern about its effect on the economy, especially because predicting the impact of an approaching storm is an uncertain business. Legislator, The Hon. James Tien in 2001[7] estimated that the value of a GDP working day, about $1 Billion, was at risk because of the impact on businesses which lost productivity and revenue but still had to pay salaries and costs. Another legislator The Hon. Fred Li estimated that 300,000 SMEs lost between $50,000 to $100,000 because of a Typhoon No. 8 signal.[7] Is it likely that many sectors of the community will be prepared to accept another general warning system, which will be difficult to apply, disrupt essential services and harm businesses and the wider image of Hong Kong as a tourism destination, finance centre and business hub?

SARS created another kind of alert which reduced mobility, emptied restaurants, other leisure venues, airports, transportation systems. We note that SARS changed the forecast for GDP growth from about +2% to -2% because of government and WHO advisories over a period of about 3 months.[8,9,10,11]

We believe that even if HAP alerts were cost-effective in health terms, the business sector, the government and the wider public would see them as a source of reputational damage to the HKSAR in the Asia Pacific region.

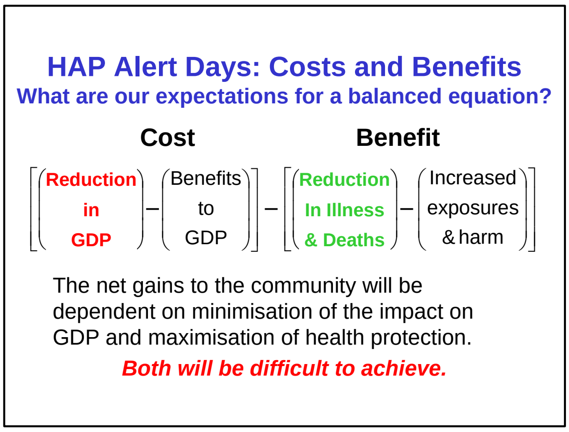


Figure 8: A basic assessment of net costs (cost minus benefits) from HAP alert days.

A basic cost-benefit equation, to indicate the net value of a HAP alert day, would include the cost incurred by reduced human activity; less any possible economic benefits of a HAP day arising from business (eg patronage of cinemas and restaurants) which would not otherwise have occurred. The benefits include all the potential reductions in direct health costs and lost productivity, which in turn may be reduced if increased harm results from actions taken during a HAP alert (Figure 8).

So what are our expectations for a balanced cost-benefit equation from a HAP alert?

What would the cost be in terms of the value of a GDP day?

- We have conservatively estimated the potential annual impact on GDP from repeated HAP alerts at only 0.5%, one quarter of the change in GDP forecast associated with the SARS impact.

- We optimistically rate the benefits of a HAP alert at about 25% reduction of the harm associated with the identified upper fraction of the daily pollution level which triggers the alert.
- At this stage, for simplicity, we have omitted any estimates of the relatively smaller values associated with economic benefits of a HAP alert or the additional harm to health which might result. They are unlikely to change the overall cost-benefit equation.

Table 1 shows that, in 2006, if we choose the upper 1%, or 10% of the annual pollutant range or, alternatively, cut-off values for RSP or NO_2 of 100µg/m^3, 75µg/m^3, or 50µg/m^3 (ie 100% above, 50% above, or the actual 2006 WHO 24 hour air quality guideline), then we would call HAP alerts on between 1 day and 226 days a year.

The most parsimonious option, using only the upper 1% of the annual pollutant distribution at general monitoring stations (Table 1; Scenario 1), leads to only 1 HAP alert day, costing $5 million but yielding only $30,000 in benefits, a cost benefit ratio of 167:1. If we select an alert cut-off of 100µg/m^3 benefits rise to $8 million but at a cost of $125 million and cost-benefit ratio of 16:1. Adopting the WHO 24 hour guideline would push benefits to about $100 million and the cost benefit ratio improves to almost 10:1, but the total cost is $1.1 billion.

Scenario 1:
RSP general level + NO_2 general level as the basis for an alert

(Million HK$)	HAP Criteria (Number of HAP alert days)				
	1% (1 days)	10% (2 days)	100 µg/m^3 (25 days)	75 µg/m^3 (81 days)	50 µg/m^3 (226 days)
Costs (0.5% GDP ~)	5	10	125	405	1,130
Benefits (25% exposure redn.)	0.03	0.36	8	30	99
Total = Costs – Benefits (Costs : Benefits)	**4.97 (167:1)**	**9.64 (28:1)**	**117 (16:1)**	**375 (14:1)**	**1,031 (11:1)**

Note:
Benefit = RSP + 0.41*NO2
Days = maximum number of exceedance days for RSP and NO_2

Scenario 2:
RSP roadside level + NO_2 roadside level as the basis for an alert

(Million HK$)	HAP Criteria (Number of HAP alert days)				
	1% (1 days)	10% (2 days)	100 µg/m^3 (163 days)	75 µg/m^3 (265 days)	50 µg/m^3 (359 days)
Costs (0.5% GDP ~)	5	10	815	1,325	1,795
Benefits (25% exposure redn.)	0.03	0.42	44	120	252
Total = Costs – Benefits (Costs : Benefits)	**4.97 (167:1)**	**9.58 (24:1)**	**771 (19:1)**	**1,205 (11:1)**	**1,543 (7:1)**

Table 1: Possible scenarios for estimating the costs and benefits of HAP alert days. Increasing the number of HAP alerts might possibly increase benefit, but at costs which will be very much higher than the value of these benefits.

If we rate costs and benefits by the much higher roadside levels it would be possible (under the doubtful assumption that significant benefits could be achieved) to improve the cost benefit ratio. But the costs would be prohibitive and the HKSAR would be paralyzed by pollution alerts (Table 1; Scenario 2).

What will be the economic impact and cost of a HAP alert?

It will depend on:
- perceived seriousness of the hazard
- frequency of alerts
- increased harm
- health benefits
- the sectors of the economy affected
- The cumulative effect on Hong Kong's image as a centre for business, finance, and tourism destination

Table 2: The economic impact of HAP alerts will depend on several factors in many different sectors.

It is worth noting again that the new WHO 24 hour guideline should not be exceeded on more than 3 days in a year. However applying this criterion in Hong Kong would result in alerts being called on 226 up to 359 days a year.

These data may be manipulated under a range of different assumptions, but because of Hong Kong's high pollution levels it is again highly unlikely that the public, legislators or government will find that the intervention of a HAP alert day is value for money. Further detailed consideration should be given to the complex issues associated with evaluation of HAP alerts (Table 2).

Will an alert do more harm than good?

We have no empirical evidence applicable to Hong Kong that it is possible to reduce exposure (as measured by the "intake fraction" of pollutants) by issuing a general alert to the population. On the other hand exposures to ambient pollution are likely to be higher in those who take public transport as opposed to riding in the sealed environment of a private car. The vast majority take public transport but if an alert moved further significant numbers of people from private vehicles while air pollutants remain high then harm is likely to increase overall rather than decrease.

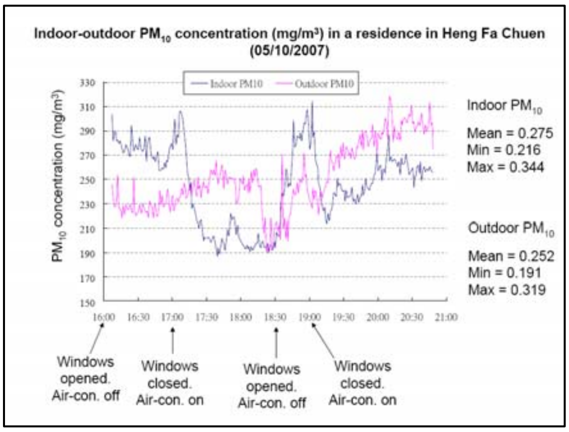
Reduction in the vehicle kilometers contributed by private cars may not make much difference to roadside pollutants. Beijing has discovered that arbitrary restrictions on cars do not lead to significant reductions in regional pollutants. Although we might expect some mitigation of roadside pollution, the same is likely to be true in the HKSAR where major emission sources are marine, commercial vehicles (especially those using mainland diesel) and power generation. HAP alerts are not designed to reduce these sources. In fact if HAP alerts tend to keep more people indoors power consumption may increase. Modern private cars contribute less pollution than outdated (pre-Euro, Euro I) commercial vehicles but have increased by 23% since 1995, while taxi numbers remain static. On the other hand heavy and medium goods vehicles have increased by 80% and 13% respectively, but the cleaner transportation provided by cargo trains has declined by 15%.

One suggestion is that exposures would be reduced by staying at home, including "working from home". Those who stay more at home might include infants and the elderly but their exposures are unlikely to be significantly reduced in a way which would protect their health.

A systematic study of the relationship between indoor and outdoor air pollutant concentrations will provide more information but, in general, indoor levels are determined by the outdoor environment. This is clearly shown by the example of measurements made at a Heng Fa Chuen 13th floor apartment on Friday 5th October (Figure 9). Closing windows and using extractors and air conditioners may reduce pollutants but the levels remain extremely high and a clear hazard to health. Particulates were measured with a portable meter, the *Sidepak* (TSI Inc.).

Changes in indoor respirable suspended particulates (PM_{10}) in the apartment during a 5 hour period with windows open and closed were compared with outdoor levels. Note that the scale in Figure 9(a) is in milligrams/cubic metre. The lowest pollutant level recorded with the windows closed is about 190μg/m^3 which is 10μg/m^3 above the 24 hour HKAQO and 140μg/m^3 above the WHO 24 hour guideline of 50μg/m^3.

We acknowledge the issues about comparability between hand-held types of particulate meter, such as the *Sidepak* (TSI Inc.), and the TEOM (Tapered Element Oscillating Microbalance) system used in the EPD fixed monitoring stations in Hong Kong. These issues are highly technical and apply to the performance of both portable equipment and TEOM.* [12,13]



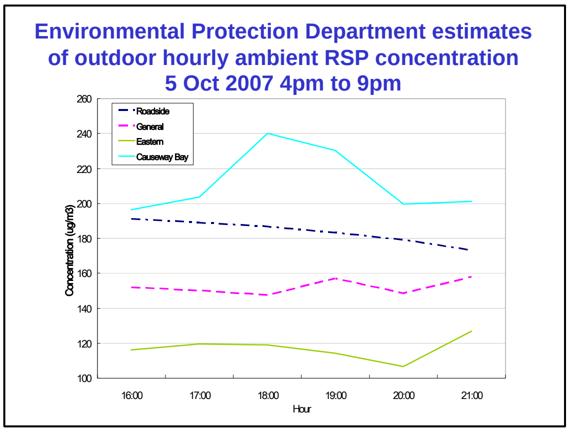


Figure 9: Outdoor and indoor RSP (PM10) levels tracked closely together in a Heng Fa Chuen apartment, when windows were open. Closing windows did not reduce RSP to safer levels. RSP levels reported by the Environmental Protection Department at Causeway Bay, show very high levels of particulates across the monitoring period 4pm to 9pm. Mean roadside levels (Causeway Bay, Central, Mongkok) were more or less stable, with a slight downward trend, between 190-180µg/m^3 across the period. Mean levels at general stations varied between 150-160µg/m^3 with a slight upward trend. Causeway Bay, the station with possibly the most relevance to the Heng Fa Chuen area, showed RSP ranging from 200µg up to 240µg/m^3. The Sidepak monitor estimate of outdoor RSP at 6pm was 250µg/m^3 compared with the EPD Causeway Bay level of 240µg/m^3.

In our single illustration of indoor levels we simply demonstrate that the portable meter recorded outdoor particulate levels of very similar magnitude to those recorded by the Environmental Protection Department during the same time period. The indoor levels tracked the outdoor levels very closely.

In these findings reflect the general relationship between indoor and outdoor pollutant levels, the conclusion must be that staying at home is unlikely to confer any worthwhile health benefit for the majority during a very high pollution episode. For the fortunate minority of workers who enjoy the advantages of a sophisticated air filtration system in their workplace, a day at home would probably be an extra hazard.

Who could *try* to benefit?

By "working at home", walking to work, taking public transport…………..

Potential target groups	Possible consequences
Civil servants:	Close public offices
Children/teachers:	Close schools
Health care staff:	Close clinics
Retail trade:	Close shops
Port activities:	Close terminals
Taxi drivers Bus drivers Train drivers	Shutdown public transport
Delivery services Van drivers Porters	Close wholesale industry

Table 3: Those who might benefit most by "working at home" are those least able to leave their worksites

The idea of "working from home" is an unrealistic proposition for the majority of workers. A list of common occupations clearly indicates that those at greatest risk of pollution related health effects, because of their disadvantaged socio-economic status would be least able to protect themselves even if staying off work did confer any benefit (Table 3). If any benefit did result from staying at home then those most likely to gain would probably be excluded from work this opportunity. Furthermore they may be penalised unless they were compensated for staying away from work and some of the

* There are reasons why portable meters may either under or overestimate inhalable particulate levels. The *Sidepak* is one of the instruments which may overestimate. However all portable monitors usually show good linearity, when measuring particles in the respirable range, compared with standard reference samplers. TEOM systems may underestimate levels of particles which are of relevance to health risk exposures because of loss of volatile and other fractions in the mix of particulates.

priority business activities of the HKSAR were disrupted as a result. There are important interactions between outdoor pollution exposures and life-style factors such as smoking,[14] exposures during exercise[15] and probably the nutritional value of diets. Investment in *effective* lifestyle modification programmes may be one beneficial approach to partial protection against pollution effects. However the issue of exercise is particularly difficult to address. In the 1998 Hong Kong lifestyle and mortality study those who took no exercise had the highest mortality risks[16] and when we examined the pollution effects those with the lowest and highest exercise levels had the highest pollution related mortality risks after adjustment for other health risks. Those who, by chance, calibrated their exercise to intermediate levels had lower risks of an exercise-pollution mortality interaction.[15] These findings relate to the lifestyles of adults 10 years before they died.

Can we reliably identify those at high risk?

The question as to whether employers should be required to allow employees with respiratory or heart disease to work from home raises many additional problems. The question is naïve in terms of the issues we have raised about levels of indoor air pollutants in domestic settings and the lack of opportunity for many workers to take their service jobs to their homes.

A major issue would be the identification of high risk groups in a way which is medically sound, ethical and protects privacy. People who are susceptible to pollution do not wear this label on their chest. For some the status of their cardiovascular risk factors is known, for others it is not. Some have established diagnoses and treatment, others do not. We know that pollution causes illness and premature death but those events occur in groups which are heterogeneous in terms of their past medical history. For everyone concerned this information is usually sensitive and often confidential. It is simply not feasible that a sophisticated, valid, privacy protected system could be implemented which classifies the entire working population in terms of its daily susceptibility to pollution.

Although those with severe chronic established medical problems would be eligible it is likely that any high risk labelling scheme would incur many false negatives and therefore be inefficient and inequitable.

Labelling individuals as being at high risk is likely to be stigmatizing, may lead to prejudice and put the jobs of some at risk. Even if such a scheme was remotely feasible and people were willing to join it, it is not clear where the resources would come from to fund the certification process which presumably would be required.

Can we protect child health with HAP alerts?

The community is now increasingly aware and concerned about the threat to both short and long term health of children. The incontrovertible evidence from Hong Kong surveys and longer term follow-up in other countries shows that growing up in pollution, even at levels well below those experienced in Hong Kong, will cause permanent impairment of lung growth and development in children and adolescents.

There is a demand for guidance on many issues, including how to manage school sports events.[17] We believe this is a difficult and perhaps impossible dilemma to resolve through simple advisories. The evidence from cohort studies in the United States points to impairment of lung development in some adolescents incurred by living in pollution levels which are associated with proximity to busy roadways.[1]

The principal cause of damage to children is caused by average daily high levels not simply the less common very high pollution days. There is no question that we should try to avoid exposing children and adolescents to extremely high pollutant levels, especially during sporting events, but parents should not be misled into thinking that a HAP alert, or moving events indoors, at any level of pollution, will influence long term respiratory and other health problems which may result from usual daily exposures in Hong Kong. The biggest health impact of pollutants will occur over the larger number of near average pollution days. This includes those when endurance training takes place, at lower pollutant levels than those which might lead to cancellation of sports events.

When is it safe to exercise?

The lack of practical usefulness of the HKAPI and likely failure of an alert in relation to sports events is demonstrated by the pattern of pollutants on the day of the Hong Kong (Standard Chartered) Marathon on 4 Marathon on 4 March 2007 (Figure 10). If we based the alert on the WHO 24 hour guideline then we would just accept the early morning levels as permissible and no alert would be issued. However during the period of the running events general and roadside particulates rose to 60% above this level.

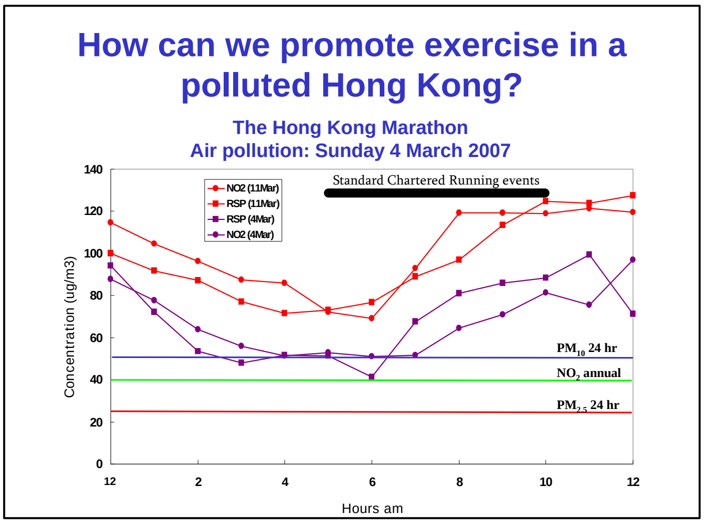


Figure 10: The rapidly changing nature of hourly pollutant levels emphasises the difficulty of "predicting" HAP which would trigger an alert. On 4 March the early morning levels would justify an alert; at the start of the running events particulate levels just approximated to the upper bound of the WHO 24 hour guide, but within an hour were rising sharply and reached very high levels before completion of the events.

If the races had been run the following weekend the runners would have faced RSP levels which reached 140% (120µg/m^3) above the WHO 24 hour guideline. The Environmental Protection Department has advised that an API of 200 is an appropriate level for schools to abandon sports events we believe that this is advisory is unsafe. However the HKAQO 24 hour level for particulates is 180µg/m^3 so on neither of these days would an API based on the HKAQO have triggered an alert. However the levels recorded during the marathon would predictably have adverse effects on the normal physiological functioning of even young fit healthy individuals.

What are current trends in Hong Kong's pollutants?

The levels of pollution in Hong Kong, based on general and roadside levels of particulates and nitrogen dioxide, are very high and more or less stable on an annual basis. We have repeatedly pointed out that, because of yearly random fluctuations in pollutants, government claims (based on selecting two data points) that there have been significant reductions, are invalid. There is no reliable current evidence that pollution trends are improving.

Statistically fitted curves to particulate data during the past nine years show no significant trend. The curves are essentially flat (Figure 11). Even if the government claims were true and small reductions have been achieved, albeit difficult to measure, the health protection offered by these small changes would be negligible compared with the burden of disease created by average levels.

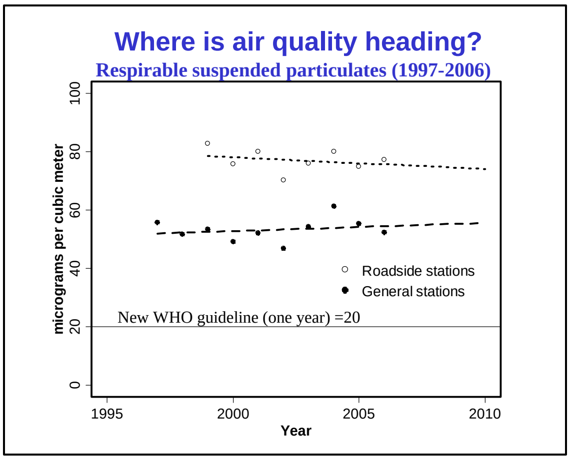


Figure 11: Changes in average ambient annual levels of pollutants such as particulates cannot be reliably assessed by selecting two points on the timescale. Appropriate numerical methods should be used to take account of uncertainty associated with the underlying trends. The curves in this figure are derived from a log linear regression model. They show that there is no significant downturn in particulate pollution and no trend which would reach WHO guidelines within the foreseeable future.

For sulphur dioxide (SO_2) levels, the gains in abatement made in the early 1990s are now being lost. Recent hourly levels of SO_2 in many sites in Hong Kong have been well over 100µg/m^3 compared with the WHO 24 hour guideline of 20µg/m^3.

Until and unless we can demonstrate a marked statistically significant downturn in the trends of all pollutants, which has a clear relationship to health protection, there should be a moratorium on statements which mislead the public. HAP alerts will not make any material difference to the trends illustrated here.

Conclusions

For discussion and debate, we suggest that:

- HAP alert days in Hong Kong would be a highly inefficient use of scarce resources.
- The estimated costs of any HAP alert system and the low level of benefits clearly indicate that these resources should be re-allocated to *efficient* pollution abatement strategies. They should particularly be allocated to *mandatory actions* on clean transportation and fuels and other interventions which need to be part of a comprehensive air quality strategy.
- HAP alert days will not work and will be rejected by an informed public, legislature and government when they understand the implications of the cost-benefit equation.

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Attachment 4

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Air Pollution: Costs and Paths to a Solution in Hong Kong—Understanding the Connections Among Visibility, Air Pollution, and Health Costs in Pursuit of Accountability, Environmental Justice, and Health Protection

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Air Pollution: Costs and Paths to a Solution in Hong Kong—Understanding the Connections Among Visibility, Air Pollution, and Health Costs in Pursuit of Accountability, Environmental Justice, and Health Protection

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Air quality has deteriorated in Hong Kong over more than 15 yr. As part of a program of public accountability, photographs on Poor and Better visibility days were used as representations of the relationships among visibility, air pollution, adverse health effects, and community costs for health care and lost productivity. Coefficients from time-series models and gazetted costs were used to estimate the health and economic impacts of different levels of pollution. In this population of 6.9 million, air quality improvement from the annual average to the lowest pollutant levels of Better visibility days, comparable to the World Health Organization air quality guidelines, would avoid 1335 deaths, 60,587 hospital bed days, and 6.7 million doctor visits for respiratory complaints each year. Direct costs and productivity losses avoided would be over US$240 million a year. The dissemination of these findings led to increased demands for pollution controls from the public and legislators, but denials of the need for urgent action arose from the government. The outcome demonstrates the need for more effective translation of the scientific evidence base into risk communication and public policy.

The Hong Kong Special Administrative Region (SAR) is a territory of 1100 km^2 comprising an archipelago of 2 major islands and many smaller outer islands, a peninsula, and land adjacent to the mainland of the People's Republic of China. Annual deaths total about 30,000 and age-standardized total mortality (0.4%) is about 18% lower than in the West, with cardiovascular disease 47% lower and respiratory disease 40% higher. The annual gross domestic product (GDP) per capita is US$25,000 in a mostly service-based economy. In recent years the manufacturing sector moved north of the boundary into the mainland, and over 70,000 factories operate around the Pearl River Delta.

In 1990, by restricting fuel sulfur content to 0.5% by weight, the Hong Kong SAR demonstrated that even modest reductions in pollution led to significant health gains (Peters et al., 1996; Wong et al., 1998; 1999; Hedley et al., 2002). Since then air quality has been continuously degraded. Despite the progressive establishment of a large evidence base on air pollution health effects, there has been (1) a lack of recognition of the real community costs incurred by harm to health and lost productivity produced by air pollution; (2) a lack of comprehensive approaches to improve urban air quality, including cleaner fuels, transportation, and infrastructure of urban environments; and (3) a failure to implement new laws and regulations on emissions and air quality standards. As a result, air quality in Hong Kong now compares unfavorably with the current situation in other cities such as Auckland, Berlin, London, New York, Paris, and Vancouver. Particulate matter (PM) levels are about 40% higher than in Los Angeles, the most polluted city in the United States (U.S. EPA, 2003).

VISIBILITY, AIR POLLUTANTS, AND HEALTH

Watson (2002) cited the U.S. Environmental Protection Agency (EPA) as identifying impaired visibility as the "best understood of all environmental effects of air pollution." In addition to impairing quality of life, daily loss of visibility directly reflects the risk of injury by airborne pollutants to cardiovascular and pulmonary systems. The commonest manifestations of these health problems include serious cardiopulmonary

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events such as heart attacks, stroke, and respiratory illnesses, including bronchitic symptoms of cough, phlegm and wheeze, acute and chronic bronchitis, pneumonia, and attacks of asthma (Samet et al., 2006; Saldiva et al., 2006; Forastiere et al., 2006).

Effects of air pollution on visibility are apparent to everyone but the adverse health effects may be silent and unobservable until they result in symptoms, illness episodes, and death. Even then, direct attribution of illnesses in an individual exposed daily to air pollution is not possible in the same way as noted with infectious diseases. This uncertainty and lack of direct evidence is associated with lower perceptions of risk by some sections of the public, who are potentially important drivers of policy, and with lack of political will by decision makers, and it provides scope for arguments against interventions and air quality controls by vested interests.

Visibility has been deteriorating in Hong Kong for several years (Figure 1). This trend is now raising concern in the tourism and hospitality industry because of its impact on Hong Kong's attractiveness as a destination, and in the finance and foreign business sector because of increasing difficulties in recruiting overseas personnel. However, the threat of pollution to the health of the local community, demonstrated in many recent scientific reports (Peters et al., 1996; Wong et al., 1998, 1999, 2001, 2002a, 2002b, 2002c, 2006; Hedley et al., 2002; McGhee et al., 2005), has not prompted the necessary radical action. In this analysis the loss of visibility was used as an index with face validity as the basis for representing some of the avoidable adverse health impacts of air pollution and their costs to the community.

METHODS

Photographic Records. Daily concentrations of pollutant levels were contributed to by both local and regional sources of emissions. Variations in pollutant levels in Hong Kong are also

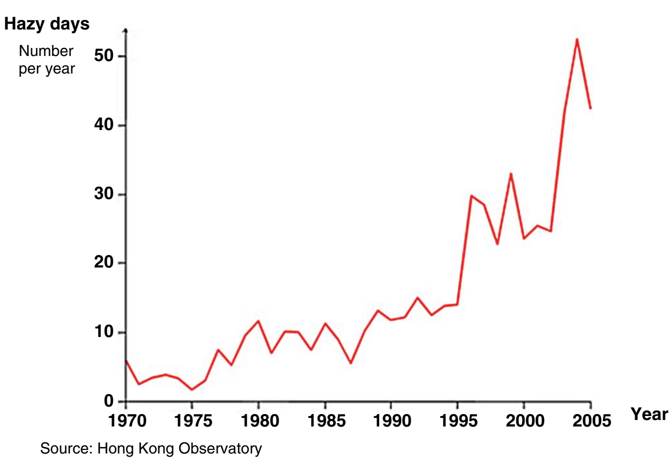

FIG. 1. Deteriorating visibility (<8km) due to haze based on direct observation of landmarks by the Hong Kong Observatory 1970–2005.

strongly influenced by southerly or northerly air mass movements and show a marked seasonal pattern. On six occasions between January 2004 and July 2005, landscape photographs were taken at random by a professional photographer on days that were perceived to have low and higher visibility (Figure 2). The photographs were taken at three different locations: (1) Tsim Sha Tsui across Victoria Harbour to Central; (2) from the Peak across Victoria Harbour to Kowloon; and (3) Ap Lei Chau across Aberdeen Harbour. Pairs of photographs with poor and better visibility were recorded for each location. On the low visibility days, data from the Hong Kong Observatory indicated that visibility averaged 5 km and on higher visibility days between 20 to 30 km (Figure 3).

Pollutant Levels. For the dates on which the photographs were taken, the hourly concentrations were obtained of four criteria pollutants (NO_2, SO_2, PM_{10}, and O_3) from the Hong Kong Environmental Protection Department (Hong Kong Environmental Protection Department, 2005). The hourly values were plotted for *Poor* and *Better* visibility days (Figure 2), and the daily average concentration of each pollutant was calculated based on hourly values from 10 general monitoring stations on those 3 dates. Four different levels of pollution were defined: three of them using the pollutant levels associated with the visibility recorded in the photographs and the fourth with additional data from routine annual air pollutant monitoring (Table 1). The four levels of air quality were defined in terms of pollutant concentrations for NO_2, SO_2, PM_{10}, and O_3, at both general and roadside monitoring stations (Table 1), and were used to estimate economic gains from air quality improvements under the assumption that these levels represented the annual mean concentrations of pollutants in Hong Kong:

Poor: mean of concentrations observed on *Poor* visibility days.
Better: mean of concentrations on *Better* visibility days.
Good: mean of the minimum concentrations recorded on *Better* visibility days.
Average: Hong Kong annual mean pollutant concentrations for 2004.

The *Good* levels were close to or better than those proposed in the new WHO 2006 Air Quality Guidelines (WHO, 2006) (Table 1) but in terms of PM_{10} they currently comprise only 2% of all days in a year. The mean PM_{10} level of *Better* days accounts for 8%, with 43% of days between *Better* and the current *Average*, and 45% of days having concentrations higher than *Average* (Figure 4).

On *Poor* visibility days, data showed that all pollutant levels were high at all general and roadside stations, with marked diurnal variation (Figure 2). On *Better* visibility days the pollutant levels were uniformly lower with an absence of peaks.

To illustrate the possible adverse health and monetary benefits from abatement of air pollution, the differences between the air quality levels defined were used (Table 2) to

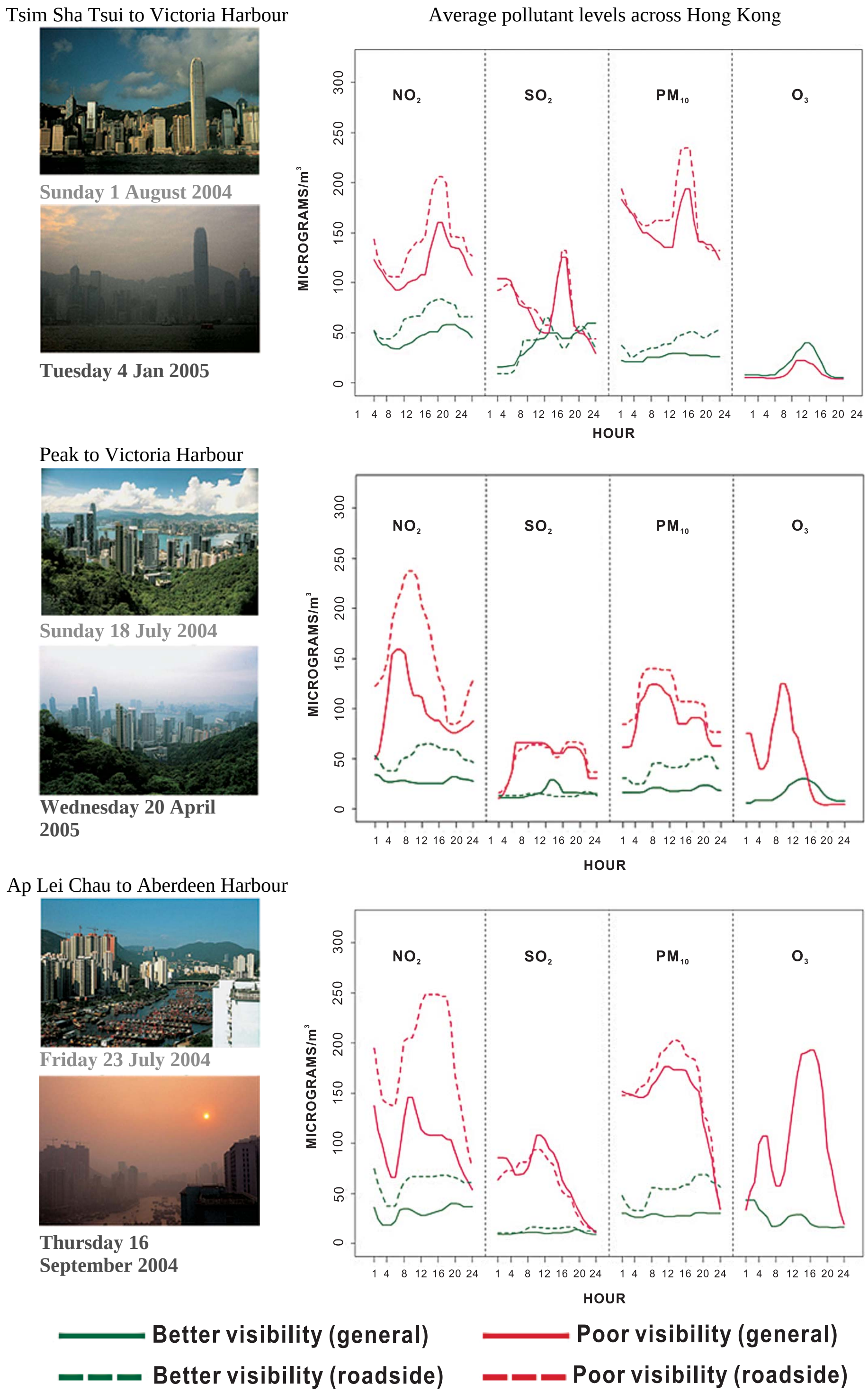

FIG. 2. Landscape photographs on higher *(Better)* and lower *(Poor)* visibility days with associated air pollutant levels at general and roadside monitoring stations on those days. Source: Environmental Protection Department 2004–2005. http://epic.epd.gov.hk/ca/uid/airdata/p/1.

calculate the value of reductions in air pollution on an annualized basis. As illustrated in (Figure 4), improvements in air quality from *Average* to *Better* and *Average* to *Good* were used.

Avoidable Health Events

From previously published local studies on air pollution and associated increased daily utilization of primary and

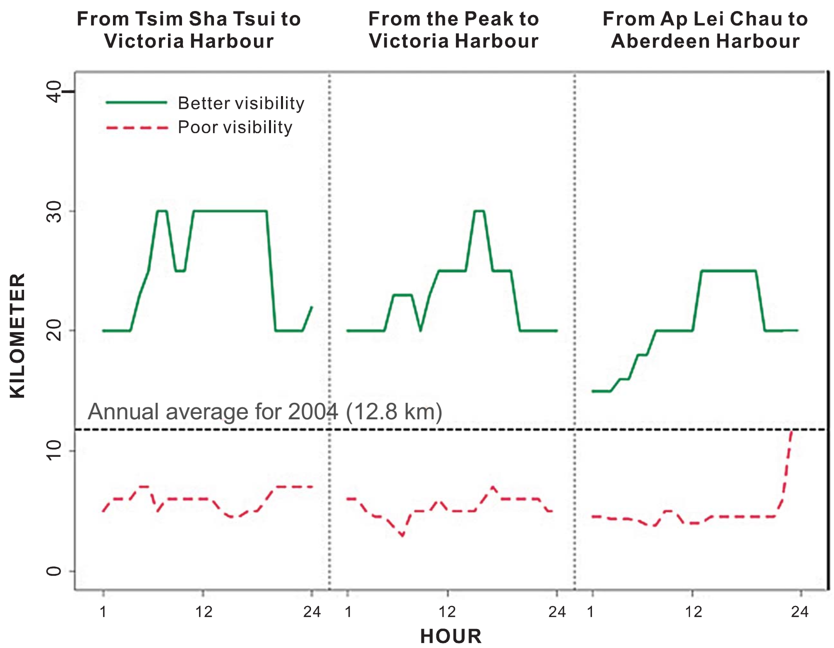

FIG. 3. Hourly visibility on the days photographs were taken for *Poor* and *Better* visibility days and the annual average visibility for 2004. Source: Hong Kong Observatory 2004–2005.

TABLE 1
Four Levels of Air Quality with Corresponding Concentrations of Four Criteria Pollutants, Defined by Either Visibility or Routine Air Quality Monitoring, at General and Roadside Stations

			Concentrations ($\mu g/m^3$)			
Level	Definition		NO_2	SO_2	PM_{10}	O_3
Poor	The mean of the concentrations on *Poor* visibility days	G	107	64	129	53
		R	163	66	145	–
Better	The mean of the concentrations on *Better* visibility days	G	35	22	25	19
		R	60	23	45	–
Good	The mean of the minimum concentrations on *Better* visibility days	G	20	8	16	6
		R	36	9	23	–
Average	The annual *Average* of all daily concentrations in 2004	G	62	25	61	39
		R	101	23	80	–

G: 10 General monitoring stations except the background monitoring station at Tap Mun Chau.

R: 3 Roadside monitoring stations.

secondary health care and mortality (Wong et al., 2001, 2002a, 2002b, 2006), the excess risks for each 10-$\mu g/m^3$ increase in air pollutants were obtained (Table 3). In all of these studies Poisson regression adjusted for autocorrelation and overdispersion was employed to estimate the change in risks due to the daily variation of a single pollutant, taking into account season, temperature, humidity, holidays, and influenza periods (Wong et al., 2001, 2002a, 2002c). The total number of primary care events was based on a survey of daily family doctor visits for respiratory complaints in year 2000 (Wong et al., 2002c, 2006), and the daily numbers of hospital admissions and deaths in the years 1995 to 2000 were obtained from the Hong Kong Hospital Authority and the Census and Statistics Department death registration (Hong Kong Hospital Authority, 2002; Hong Kong Census and Statistics Department, 2001). In the present study, data from an updated report were used (Wong et al., 2002b). All analyses were based on daily pollutant levels obtained from the Hong Kong Environmental Protection Department (2005).The linear exposure-response relationship was employed between air pollution and adverse health outcomes to estimate the overall reduction in risks that would be associated with the defined improvements in air quality. This risk reduction was applied to population mortality and health care utilization data to obtain the annual number of avoidable deaths and health care events. For primary care these estimates were restricted to respiratory complaints; for hospital admissions, for cardiovascular and respiratory diseases; and for deaths, from all nonaccidental causes of death.

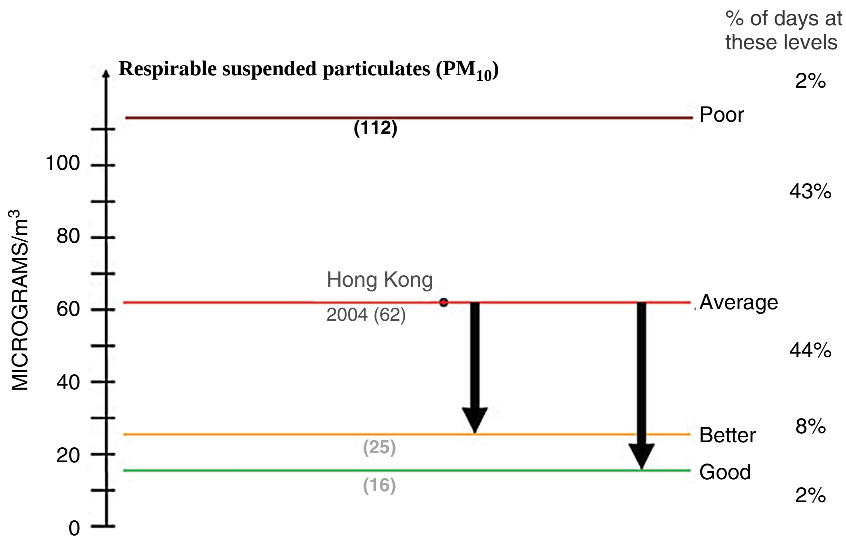

FIG. 4. Measures of potential improvements in air quality in Hong Kong, illustrated for respirable suspended particulates (PM_{10}), used to estimate avoidable adverse health effects and community costs.

TABLE 2
Mean Reduction ($\mu g/m^3$) in Air Pollutants with Improvement in Levels of Air Quality

Differences between air quality levels	NO_2	SO_2	PM_{10}	O_3
Average – Better	27	3	37	20
Average – Good	42	17	46	33
Poor – Better	72	41	104	34
Better – Good	15	14	9	13

For each pollutant (P) the impact (I_P) in avoidable health events (avoidable mortality and avoidable health care utilization) for each type of health outcome resulting from air quality improvements was estimated as

$$I_P = N_I * ER_P \times L_P$$

where N_I is the annual number of the event I in the population; ER_P the excess risk for 10 $\mu g/m^3$ of pollutant P (assumed equivalent to the reduction in risk with a fall of 10 $\mu g/m^3$ of pollutant); L_P the change in the level of pollutant P for the reduction from one defined level to the other; and P, each of the criteria pollutants.

An illustration of estimated changes in risk and health events with improved air quality is the calculation of the number of deaths avoided from reduction of a single pollutant. The excess risk of mortality associated with a 10-$\mu g/m^3$ increase in NO_2 was 0.64%. With reduction in the pollution level for NO_2 of 27 $\mu g/m^3$ (Table 2) associated with air quality improvement from *Average* to *Better* and the assumption of a linear exposure-response relationship, the resulting decrease in mortality risk would be 1.7%. The number of avoided deaths attributable to this change in NO_2 is 545, i.e., 1.7% of the total nonaccidental deaths in Hong Kong in the year 2000. Similar calculations were performed for the other pollutants. The numbers of avoidable deaths after adjusting for the correlation between pollutants were subsequently summed up.

Combining the effects of pollutants. Hourly concentrations for NO_2, SO_2, PM_{10}, and O_3 in 2004 were aggregated as daily means from general and roadside stations. Using 1 to represent the 100% contribution of PM_{10}, first the correlation was obtained between PM_{10} and NO_2 (r), then the proportional variation of NO_2 explained by PM_{10} (r^2) was calculated and subtracted from 1. This obtained value was then reduced by the correlation between NO_2 and SO_2 adjusted by PM_{10} and between PM_{10} and NO_2 adjusted by SO_2 (Figure 5). For our main estimate it was assumed that only the contributions of PM_{10} and O_3 were 100%, so the total number of avoidable health events associated with pollution was estimated on the basis of:

$$T = PM_{10} + 0.41\, NO_2 + 0.84\, SO_2 + O_3$$

To determine the sensitivity of our results to the assumptions made in the analysis, four additional analyses for each health outcome were performed: (1) SO_2 as the dominant pollutant in place of PM_{10} (T = SO_2+0.88 PM_{10}+0.31 NO_3+O_3); (2) NO_2 as the dominant pollutant (T = NO_2+0.75 SO_2+0.46 PM_{10}+O_3); (3) a single pollutant with the greatest

TABLE 3
Excess Risks and 95% Confidence Intervals (CI) for Mortality, Hospital Admissions and Family Doctor Visits per 10 μg/m^3 Change in Pollutant

	Excess risk (%) (95% CI per 10 μg/m^3)			
	NO_2	SO_2	PM_{10}	O_3
Mortality				
All causes	0.64 (0.36, 0.91)	1.36 (0.93,1.78)	0.24 (0.01, 0.46)	–0.11 (–0.37, 0.16)
Hospital admissions				
Respiratory	0.54 (0.27, 0.80)	0.76 (0.34, 1.18)	0.50 (0.28, 0.71)	0.55 (0.31, 0.79)
Cardiovascular	0.73 (0.48, 0.98)	1.08 (0.72, 1.44)	0.37 (0.18, 0.57)	0.24 (0.01, 0.47)
Family doctor visits				
Respiratory	3.42 (–0.62, 7.63)	0.68 (–3.03, 4.54)	3.28 (2.54, 4.05)	1.5 (–1.18, 4.26)
URTI[a]	1.25 (–0.94, 3.79)	–0.77 (–5.13, 3.78)	3.01 (1.54, 4.50)	1.74 (–0.67, 4.20)

Remarks: [a]Upper Respiratory Tract Infection. We assumed excess risks as 0 for negative excess risks.
Taken from Wong et al., 2001; 2002a; 2002b; 2002c; 2006.

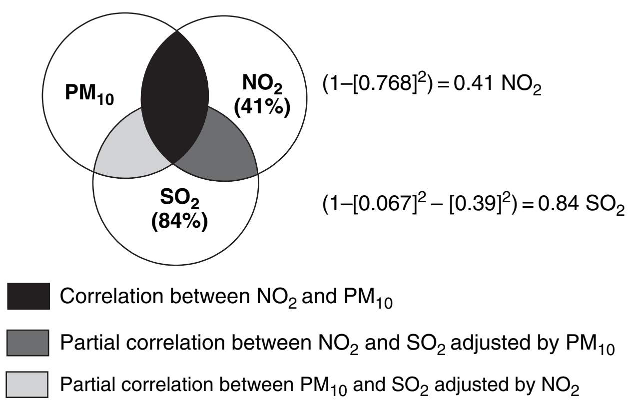

FIG. 5. Method for combining pollutant effects based on correlation between PM_{10}, NO_2 and SO_2 at monitoring stations.

impact (excess risk×pollutant reduction); and (4) PM_{10} plus O_3 only.

In addition, data were used from roadside monitoring stations, situated in the districts of Causeway Bay, Central, and Mongkok, in place of general monitoring station data. At least 50% of the Hong Kong population live or work beside busy roads (McGhee et al., 2005).

Monetary Valuation

Direct Costs of Illness. Costs in four categories were estimated: public and private hospital admissions, public outpatient consultations (general, specialist, accident, and emergency), and family doctor visits (Table 4). Unit costs (average costs of a bed day and a consultation) were obtained from the Hong Kong Hospital Authority (2002), the Health, Welfare and Food Bureau (2000), the Census and Statistics Department (2001), and a Hong Kong household survey (McGhee et al., 1998). All costs were adjusted to year 2000 values. Patient travel costs were included for hospital admissions (a taxi to the nearest hospital) and doctor visits (21 min and

TABLE 4
Unit Costs Used in the Estimation of Avoidable Costs from Different Sources of Care, Travel Costs and Productivity Losses

	Unit costs (US$)
Direct costs of illness:	
Sources of care:	
Public hospital bed-day:*	
Acute general ward	403
Chronic Infirmary ward	352
Coronary care unit	667
Public out-patients visits:	
Department of Health general clinic	28
Hospital Authority general clinic	39
Specialist clinic	85
Accident and emergency department	73
Family doctor visits	21
Travel costs:	
Taxi (roundtrip and less than 5 km per trip)	9
Bus (roundtrip)	1
Productivity loss:	
Median monthly income: males	1,542
Median monthly income: females	1,131
Overall median monthly income	1,285

*Private hospitals are assumed to have the same unit cost.

average bus fare per visit), but not for accident and emergency attendances. The avoidable monetary costs were the product of avoidable health care utilization and unit costs.

Productivity Losses. Avoidable productivity losses from premature deaths and from time lost from work due to public and private hospital admissions and family doctor visits for people aged 15 to 64 yr were estimated.. For premature deaths the *person-years of life lost under age 65* in the year 2000 was multiplied, adjusted by labor force and employment rates (Hong Kong Census and Statistics Department, 2005), by the proportion avoidable due to reductions in air pollution. Then these years were given a value using gender-specific median salaries (Table 4). Productivity losses due to hospital admissions were estimated using avoidable hospital bed days for those aged 15 to 64 yr, adjusted by labor force and employment rates, and gender-specific median daily salaries, and those due to family doctor visits in the same way but using days of sick leave granted after consultation for a respiratory disease (Wong et al., 2002c).

RESULTS

Health Gains From Air Quality Improvement

On an annualized basis deaths avoidable were 611 for improvement from *Average* to *Better* and 1335 from *Average* to *Good* levels of air quality. Avoidable bed days for hospital admissions were 35,244 for *Average* to *Better* and 60,587 for improvement from *Average* to *Good*. Avoidable family doctor visits for respiratory problems alone totalled 6.7 million for improvement from *Average* to *Good* (Table 5).

In recent years the number of days with air pollution levels worse than average amount to about 45% of the calendar year. In terms of PM_{10} this includes a range of approximately 60–111 μg/m^3 at general monitoring stations. The pollutant levels on *Poor* visibility days were over 110 μg/m^3 and the trend has been toward *Poor*. On an annualized basis, the numbers of deaths avoided with air quality improvement from *Poor* to *Better* were 2912 and an additional 724 for improvement from *Better* to *Good.* Avoidable hospital days for these changes were 115,895 and 25,343, respectively. Doctor visits avoided for respiratory disease were 13 and 1.95 million, respectively.

TABLE 5
Avoidable Deaths and Health Care Utilization Events Associated with Air Quality Improvements

	Mortality (all causes)	Hospital bed days#	Family doctor visits§
General			
Average to Better	611	35,244	4,777,924
Average to Good	1,335	60,587	6,732,174
Poor to Better	2,912	115,895	13,010,852
Better to Good	724	25,343	1,954,250
Roadside*			
Average to Better	615	36,193	5,133,977
Average to Good	1,505	69,698	8,437,168
Poor to Better	3,171	123,263	13,808,230
Better to Good	891	33,521	3,303,476

*Roadside concentration of O_3 was assumed to be the same as the general concentration of O_3.
#cardiovascular+respiratory admissions.
§respiratory symptoms.

Sensitivity Analyses

Avoidable deaths and costs associated with alternative assumptions about combinations of pollutants and their effects were estimated, and also the use of roadside levels with changes in pollutant levels from *Average* to *Good* were determined (Table 6). The majority of the population was exposed to roadside levels for varying periods on a daily basis. Estimates of deaths and health care utilization were stable with different combinations of four pollutants. The lowest overall estimate was associated with the assumption of independent

TABLE 6
Results of Sensitivity Analyses for Annual Avoidable Mortality and Costs if Pollution Levels Reduce from *Average* to *Good* levels

	No. of avoidable deaths	Direct cost US$ million	Productivity loss US$ million
Original assumption			
General stations	1,335	190	57
Roadside pollutant levels	1,505	235	66
Alternative assumptions			
General stations			
SO_2 as the dominant pollutant	1,326	170	55
NO_2 as the dominant pollutant	1,583	193	65
Single pollutant with largest effect*	860	103	35
$PM_{10}+O_3$	348	136	23
1990 sulfur restriction	597	–	–
Roadside stations			
Roadside $PM_{10}+O_3$	437	162	28
Roadside single pollutant with largest effect**	1,319	153	54

*Mortality NO_2; Admissions NO_2; doctor visits PM_{10}.
**Mortality NO_2; Admissions NO_2; doctor visits PM_{10}.

effects confined to PM_{10} and O_3. Intermediate values were obtained from the single pollutant with the largest effect (NO_2 for deaths and admissions; PM_{10} for doctor visits) and for the observed effects on mortality for SO_2 reduction following the 1990 fuel sulfur restriction.

Monetary Cost

The avoidable direct costs of illness were US$131 million up to US$190 million for improvements in air quality from *Average* to *Better* or to *Good*, respectively (Table 7). About 77% of these costs were due to avoided family doctor visits and 18% due to costs of public health care from public hospital admissions and outpatient visits. Avoidable productivity losses were valued up to US$57 million (Table 7).

DISCUSSION

According to the U.S. Environmental Protection Agency (2006), governments should "develop, implement and enforce the environmental laws and regulations and policies" in order to achieve environmental justice and to safeguard the poor and socially deprived and the health of the whole community.

At the present time the inventory of pollution associated adverse health problems in Hong Kong is inevitably incomplete. In these analyses the proportion of the population exposed was assumed to be 100%, although detailed quantification of exposure is lacking. Gaps in our evidence base concerning pollution-related adverse health effects and costs include (1) use of self-medication or traditional medicine practitioners for symptoms produced by pollution, (2) a range of maternal and child health problems including retardation of fetal growth during pregnancy and health problems in infants (Glinianaia et al., 2004), and (3) relationship between visibility and sudden infant deaths as reported in Taiwan (Knobel et al., 1995). Similarly there is a lack of long-term follow-up studies, which are needed to examine the risks of stunting of lung growth in children and adolescents, as recently demonstrated in the United States (Gauderman et al., 2004).

TABLE 7
Annual Avoidable Costs for Reductions in Levels of Air Pollution from *Average* to *Better* and to *Good* Air Quality

	Avoidable Costs (US$)	
Avoidable costs	Average to Better	Average to Good
Direct cost of illness:		
Public hospital admissions	12.9	22.1
Public out-patient visits	11.3	16.8
Private hospital admissions	0.9	1.6
Family doctor visits	100.4	141.4
Travel costs	5.6	7.9
Total direct cost	**131.0**	**189.8**
Productivity loss:		
Hospital admissions	0.2	0.4
Family doctor visits	11.2	15.8
Premature deaths	18.7	40.8
Total productivity loss	**30.1**	**57.0**
Total direct and productivity costs	**161.1**	**246.8**

This analysis has face validity in that it uses simple, conservative, validated, and robust methods to estimate the potential health gains and reductions in community costs that might be achieved by consistent steps toward cleaner fuels, cleaner power units, and improved efficiency in all forms of power generation.

The analysis is conservative in that many health outcomes are not yet included. However, although underestimation of adverse health effects may arise because of incomplete epidemiological information and the use of short-term risk estimates from time-series analyses compared with cohort studies, overestimation may occur through double counting of outcomes by treating each of the criteria pollutants as independent risks. There are no statistical or epidemiological methods to reliably define the effects of individual pollutants, and natural experiments are rare, such as the closure of the Utah steel mill (Pope, 1989), the Dublin ban on coal sales (Clancy et al., 2002), and the Hong Kong fuel sulfur restriction (Hedley et al., 2002).

A range of sensitivity analyses was presented to provide a lower bound for our estimates of morbidity deaths and costs. There was little variation among all estimates based on combinations of pollutants, with different assumptions about the dominant pollutant, with annual deaths ranging from 1335 to 1583. The highest estimates were associated with roadside monitoring data concerning air to which a large proportion of the Hong Kong population is exposed for long periods on a daily basis. The combination of PM_{10} and O_3, suggested by the WHO Working Group (2003), provided the lowest estimate for deaths and overall costs, although direct costs were relatively high because of the marked association between PM_{10} and doctor visits for respiratory problems. However, this estimate was lower than the observed effect on deaths following the Hong Kong 1990 fuel sulfur restriction and reduction of a single pollutant, SO_2. This short-term effect is the most significant evidence for an independent effect of a single pollutant or at least a surrogate for other pollutants, such as metals from sulfur rich fuels. Similarly, from Hong Kong time-series estimates, single pollutants with the largest effect for mortality (NO_2), hospital admissions (NO_2), and doctor visits (PM_{10}) gave intermediate values, with 860 deaths avoided each year.

Our approach to estimation of adverse health effects from a combined analysis of four pollutants is justified if one considers the evidence for possible independent effects of pollutants in Hong Kong. The 1990 sulfur restriction in fuel was associated with a temporary (18 mo) reduction in sulfate in respirable particulates and a sustained long-term reduction in SO_2 and particulate subspecies of nickel and vanadium. There was no decline in trends for particulates overall measured as PM_{10}. All of PM_{10}, NO_2, and O_3 showed stable or upward trends during 5 yr following the intervention, in which the proportional increase in deaths declined (Hedley et al., 2002). Sulfur dioxide was also identified as an independent risk for mortality in the American Cancer Society cohort (Pope et al., 2002). In Hong Kong, PM_{10} was significantly associated with hospital admissions and deaths, but the strongest consistent effects in recent analyses were associated with NO_2 and SO_2, robust in two-pollutant models (Wong et al., 2001, 2002a). In a standardized comparison between Hong Kong and London the largest effects in copollutant models for admissions for respiratory (ICD9 460–519) and cardiac (ICD9 390–429) diseases were for NO_2 and SO_2 in Hong Kong and for PM_{10} and O_3 in London (Wong et al., 2002a). Analyses in other Chinese cities including Shanghai and Wuhan also demonstrated robust dominant effects of NO_2 and SO_2 for mortality. On this basis it is possible to conclude that estimates of health impacts and costs based only on PM_{10} and O_3 are likely to underestimate the community burden.

The Hong Kong SAR and the mainland air quality objectives (AQO) are long outdated and provide no health protection from pollution. The Hong Kong AQO (Hong Kong Environmental Protection Department) date from 1987 and were based on the standards adopted by the U.S. Environmental Protection Agency. None of the subsequent international revisions of air quality standards have been reflected in any changes to the Hong Kong SAR objectives. In addition, they have come to be regarded as legal, safe, and permissive levels in environmental impact assessments. Through that mechanism the AQO has become an instrument by which air pollution in different zones may actually be legally increased under the Environmental Impact Assessment Ordinance.

For some time, the local community in Hong Kong has raised concerns about levels of air pollution, but the use of outdated standards as the basis for a daily air pollution index (Environmental Protection Department, 2006) prevented communication of the true degree of hazard associated with current pollution levels. By using an easily understood and highly apparent indicator such as visibility and associating different levels of visibility with potential changes in costs incurred, our aim was to promote a better understanding of the impacts of air pollution.

In October 2006 WHO promulgated the new Air Quality Guidelines (AQG), which were agreed on by the Working Group in October 2005 (Krzyzanowski, 2005). The lowest pollutant concentrations observed in Hong Kong during the 24 h of *Better* visibility days, which were defined as *Good*, are similar to the levels in the WHO 2006 AQG. However, these only comprise between 2 and 8% of days in the year. The general pattern in the Hong Kong SAR shows that pollutant concentrations far exceeded even the outdated Hong Kong objectives for PM_{10} and NO_2. For SO_2, the pollutant with the lowest average annual levels relative to the new WHO AQG, the AQG are violated for about 35% of the year.

Hong Kong has already demonstrated, although 17 yr ago, that it is possible to achieve major improvements in air quality and large reductions in adverse health impacts through even modest interventions in air quality. The July 1, 1990, restriction on sulfur in fuel oil to 0.5% and in solid fuel to 1% by weight led to an immediate 50% decline in the annual average SO_2 concentration, which was associated with reductions in bronchitic symptoms in both children and adults (Peters et al., 1996), improved lung function in primary school children (Wong et al., 1998) and their mothers (Wong et al., 1999), and a reduction in all-cause mortality by 2.2%, equivalent to 600 deaths per annum, because of a 1.8–4.8% decline in deaths in different age groups mainly from cardiopulmonary diseases (Hedley et al., 2002). Since 1990, air quality in Hong Kong has been progressively degraded. A particular concern is the upward trend in those pollutants, including SO_2, nickel, and vanadium, that are the signature emissions of sulfur-rich fuels. Among these the most important may be the transition metal nickel (Lippmann et al., 2006). Our current hypothesis is that the change in these pollutants is likely to have been causally related to the evidence of reduced injury to cardiovascular and pulmonary systems in both children and adults. These recent increases in pollutant levels from sulfur-rich fuels originate from power company emissions, cross-border traffic using high-sulfur diesel, and the large-scale industrial use of bunker fuel on the mainland side of the boundary by both Hong Kong, Guangdong, and foreign-based business interests.

Our monetary costing of the value of the air pollution impacts on health used the actual costs of providing the health care services and the productivity losses associated with attending them. In this respect it is a minimum value in that it does not include (1) a value of the pain and suffering, (2) loss of life beyond lost production, and (3) value that individuals might place on being able to avoid the occurrence of health problems. In a preliminary analysis these intangible costs were given a value at about US$2.5 billion. In addition to acute and chronic illness outcomes, the silent pathophysiological effects may predictably include stunting of lung growth in generations of young children and adolescents (Gauderman et al., 2004) on both sides of the boundary between Hong Kong and mainland China. At present it was not possible to value this potentially serious and long-term impact. Our estimate of costs represents a real dollar value that may eventually be saved by reduced levels of air pollution comparable to those now promulgated by WHO as targets for governments around the world.

The findings in our analyses of avoidable adverse health effects and health care costs were presented to government, chambers of commerce, and the media. This achieved wide coverage and stimulated debate on strategic approaches to pollution abatement. However, the government response was either muted or a denial that current pollution levels are hazardous to health. Government rejects the need for immediate and urgent action without further evidence of adverse health effects, and an external consultancy is scheduled not to report until January 2009 on the formulation of revised air quality objectives.

Hong Kong must integrate both its local and cross-boundary actions in new strategies to achieve specific air quality targets on clearly defined time scales. The present situation, in which targets and time scales are only considered "on a best endeavour basis" (Hong Kong Advisory Council on the Environment, 2002), is unacceptable from an environmental and public health viewpoint.

CONCLUSION

At both the population and individual level, the clear and urgent indications are that the Hong Kong SAR government needs to act to ensure that radical pollution abatement measures are implemented, enforced, and monitored both locally and in relation to cross-boundary movements. The major continuing challenge to public health and environmental specialists is the translation and promotion of the scientific evidence base into risk communication and public policy.

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