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Air Pollution: costs and paths to a solution

Understanding the connection between visibility, air pollution, health and associated costs in pursuit of accountability, environmental justice and health protection

June 2006

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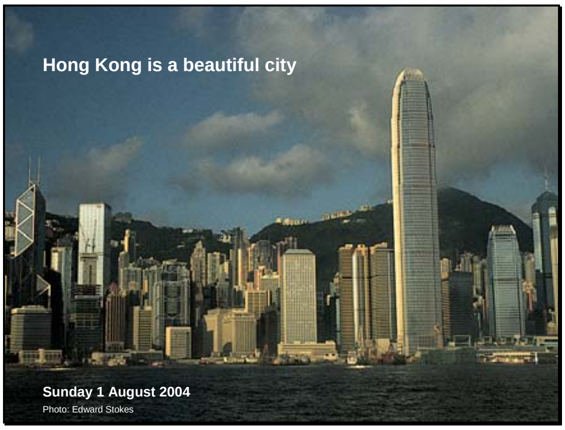

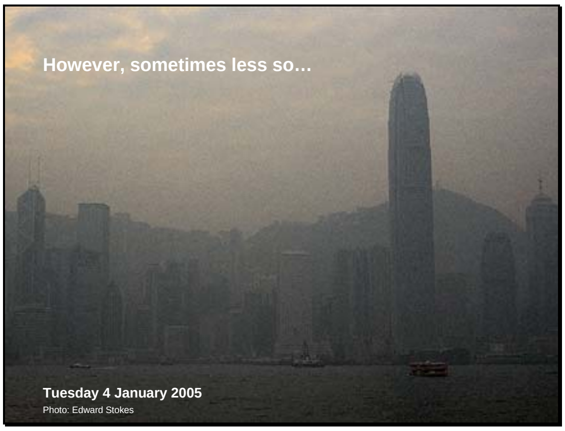

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Air Pollution: Cost and Paths to a Solution

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Air Pollution: Cost and Paths to a Solution

1.0 SUMMARY

Background: Air pollution is now regarded as one of the highest priorities in environmental protection in both developed and developing economies world-wide. The main driver of policy decision-making is the need to reduce the avoidable cardiopulmonary morbidity and mortality from pollutant exposures. However the public health relevance of pollution abatement is not yet given sufficient recognition by the authorities in Hong Kong and the Pearl River Delta. The four criteria air pollutants used to estimate the impact of pollution on population health are respirable suspended particulates (RSP) (measured as PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and the secondary pollutant ozone (O_3) formed from nitrogen oxides and volatile organic compounds under the influence of ultra-violet light.

Visibility is considered a good indicator of air pollution levels. To demonstrate the impact of environmental protection on health and the economy we used photographic evidence to characterize *Poor* and *Better* visibility days. We correlated this measure of local visibility with air pollutants and added two other pollutant levels; *Good* being the minimum concentrations recorded on the better visibility days and *Average* being the Hong Kong annual mean at either general or roadside monitoring stations. We used these four defined levels of pollution to estimate the avoidable health events if air pollution levels were reduced. We used as illustrations the reduction of our actual *Average* levels to those of the *Better* visibility days, or to *Good* days on an annualized basis. We also calculated the health benefits of reducing pollution levels from those of our *Poor* visibility days to the level of *Better* visibility days assuming that these were our annual average levels. We ran separate analyses using the Hong Kong roadside and general monitoring station data.

Findings

Deaths: If we reduced our *Average* levels of air pollution to those of our *Better* visibility days, we would avoid 800 deaths a year and we could avoid 1,600 deaths a year by reducing pollution to the *Good* visibility levels of our lowest pollution days. In previous analyses the *total* attributable deaths from pollution in Hong Kong were estimated at about 2,000, with an upper bound for the confidence interval of 3,500 per annum.

Hospital admissions: In terms of serious illness episodes from cardiopulmonary disease we would avoid 36,000 hospital bed-days by pollutant reductions from *Average* to *Better* days and 64,000 bed-days by improvement from *Average* to *Good* days.

Costs: The annual dollar value of the avoided health care costs resulting from these improvements in air quality would range from $1 billion to $1.5 billion; avoided productivity loss $0.3 to 0.5 billion and avoided intangible costs up to $19 billion including the value of lives lost and willingness to pay to avoid illness.

Conclusions: Air pollution in Hong Kong causes discomfort and illness in children and adults, increased health care utilization at all levels of the health care system, and premature deaths. We estimate from this limited and conservative health impact assessment that the reduction of pollution to the levels in other world cities, such as London, Paris and New York, would avoid over 1,600 deaths and other disbenefits with a value of HK$19 billion annually.

In 1990 by restricting fuel sulphur content to 0.5%, Hong Kong demonstrated to the world that even modest reductions in pollution led to large health gains. Since then our air quality has been progressively degraded. There now needs to be (1) recognition of the real community costs incurred by harm to health and lost productivity caused by air pollution; (2) *comprehensive* approaches to improve urban air quality including cleaner fuels, transportation and infrastructure of urban environments; (3) rapid implementation of laws and regulations which protect the environment and public health.

The Hong Kong SAR can and must take the lead in improving the air quality of the Pearl River Delta by implementing a timely and effective strategy to control the excessive and inefficient combustion of fossil fuels and increase the protection of population health.

2.0 BACKGROUND

Air quality in Hong Kong is poor and compares unfavourably with the current situation in other world cities such as Auckland, Berlin, London, New York, Paris and Vancouver. Particulate levels are about 40% higher than in Los Angeles, the most polluted city in the USA.

Visibility, air pollutants and health

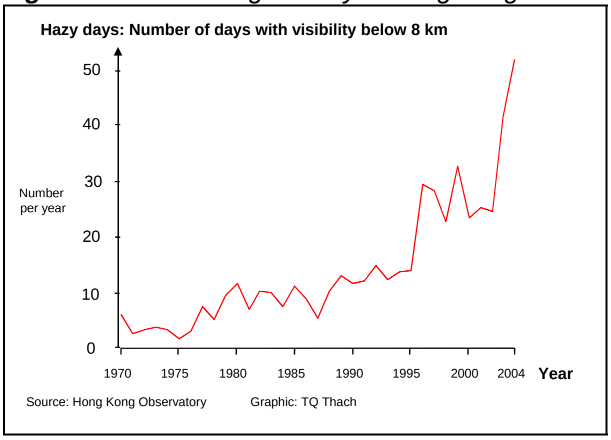
The U.S. Environmental Protection Agency (EPA) identified reduced visibility as the best indicator of all environmental effects of air pollution.[1,2] As well as impairing our quality of life it is clear that daily loss of visibility directly reflects the impact of airborne pollutants on the risks of injury to our cardiovascular and pulmonary systems. The commonest manifestations of these health problems include serious cardiopulmonary events such as increased blood pressure, heart attacks, stroke, and respiratory illnesses including cough, phlegm and wheeze,acute and chronic bronchitis, pneumonia and attacks of asthma.[2]

Effects of air pollution on visibility are apparent to everyone but the health effects may be silent and unobservable until they become very serious and result in symptoms, illness episodes and death. In this analysis we have used the loss of visibility as the basis for demonstrating some of the avoidable health impacts of air pollution and their costs to the community.

Visibility, health care and costs

Visibility has been deteriorating in Hong Kong for several years (Figure 1). Loss of visibility is a reliable indicator of pollutant levels and in Hong Kong we have previously analyzed loss of visibility on a daily basis using records from the airport and Observatory, together with air pollutant levels and daily deaths. This analysis demonstrated that after adjustment for humidity and other factors, each one kilometre loss in visibility below 20 kilometres is associated with an increase in mortality risks of between 0.36% to 0.55%. On this basis between 1068 and 1650 deaths a year can be predicted by the loss of our horizon.

***Figure 1:** Deteriorating visibility in Hong Kong*



3.0 APPROACH

Between January 2004 and July 2005, we took landscape photographs (by Edward Stokes) on days with good and poor visibility (Figures 2 to 4). 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.

For the dates on which the photographs were taken, we obtained the hourly concentrations of the four criteria pollutants (RSP (PM_{10}), NO_2, SO_2 and O_3) from the Hong Kong Environmental Protection Department.[3] The hourly values were plotted (Figures 2 to 4) and the daily average concentration of each pollutant was calculated. Four different levels of pollution were defined as shown in Table 1.

Table 1: Four levels of air pollution

Level	Definition*
1 *Good*	The mean of the minimum concentrations on *better* visibility days
2 *Better*	The mean of the concentrations on *better* visibility days
3 *Poor*	The mean of the concentrations on *poor* visibility days
4 *Average*	The annual *average* of all actual daily concentrations in 2004

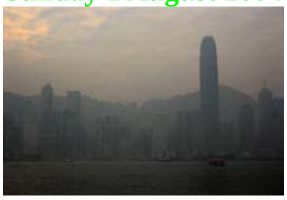
* Based on general monitoring stations except the background monitoring station at Tap Mun Chau

To indicate the possible health and monetary benefits from abatement of air pollution we used the differences between our defined levels to estimate the impact of reductions in air pollution.

Figures 2 – 4: Photographs from poor and better visibility days and hourly pollutant levels

Figure 2: Tsim Sha Tsui to Victoria Harbour

Sunday 1 August 2004



Tuesday 4 Jan 2005

Average pollutant levels across Hong Kong

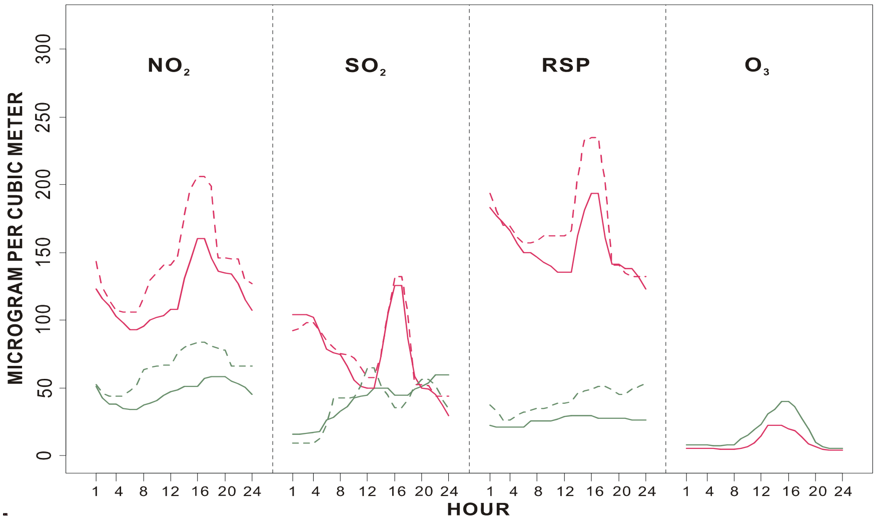


Figure 3: Peak to Victoria Harbour

Sunday 18 July 2004

Wednesday 20 April 2005

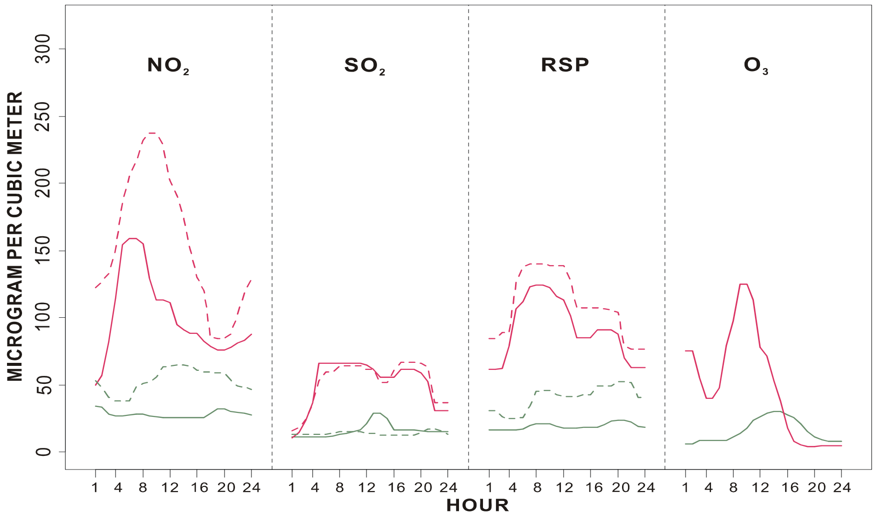
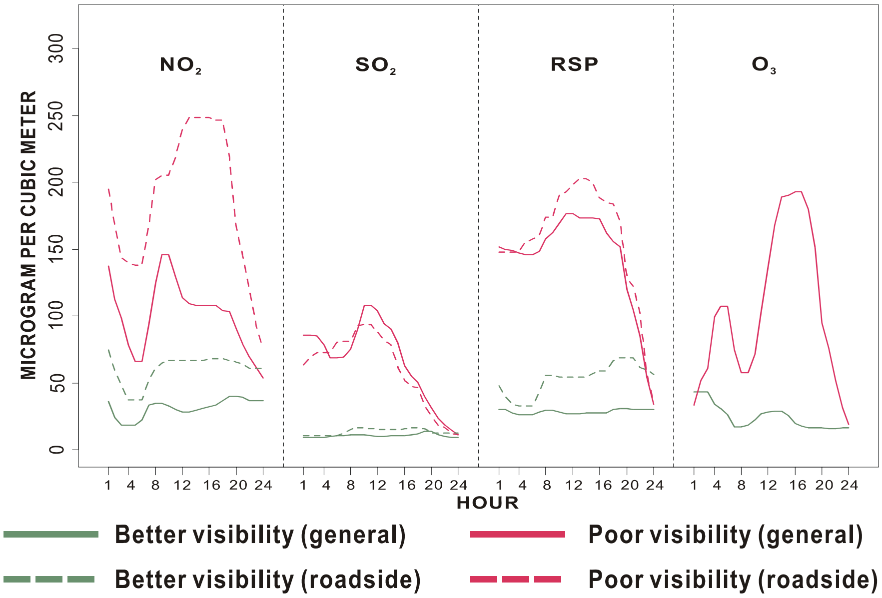


Figure 4: Ap Lei Chau to Aberdeen Harbour

Friday 23 July 2004

Thursday 16 September 2004

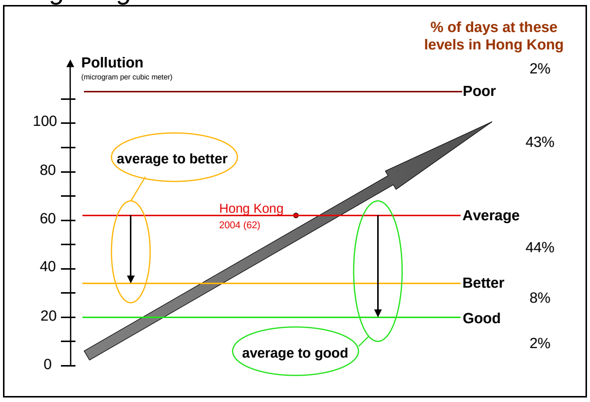


Source of data: Environmental Protection Department

As illustrations (Figure 5) we use improvements in air quality on an annualized basis from:

- *Average* to *Better* (Level 4 to Level 2),
- *Average* to *Good* (Level 4 to Level 1)
- *Poor* to *Better* (Level 3 to Level 2)
- *Better* to *Good* (Level 2 to Level 1).

Figure 5: *Potential improvements in air quality in Hong Kong*



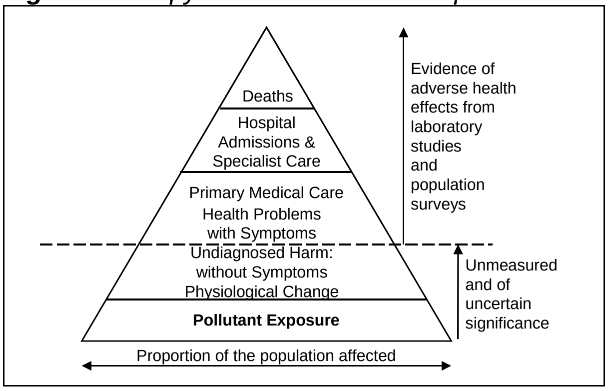
We estimated the annual health effects and value of the costs which would be avoided if, instead of the higher air pollution levels, we had the lower level for a year.

Health outcomes and their risks

The distribution of harm from air pollution to the health of the population can be represented in the form of a pyramid (Figure 6). At the base of the pyramid is the proportion of the population exposed, virtually 100%. Among these, large numbers will have sub-clinical (unobserved) inflammatory changes in body tissues, such as the lungs and arteries, due to the injury caused by pollutants. In some individuals, symptoms will develop leading to self-medication or perhaps increased consultations with traditional or Western medical practitioners at the primary care level. Progression to serious chronic disease will be reflected in admissions to hospital. The proportions of these health care needs or outcomes attributable to pollution provide us with measures of the impact of air pollution on vital organs and health related quality of life.

At the present time the inventory of pollution associated health problems is inevitably incomplete. Gaps in our knowledge include self-medication or use of traditional medicine for symptoms caused by pollution, and a range of maternal and child health problems including retardation of foetal growth during pregnancy and health problems in infants. 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 USA.

Figure 6: *The pyramid of harm from air pollution*



On the other hand we do have substantive local Hong Kong studies on health risks in school-children, on primary and secondary care at all ages, and premature deaths. From these, we obtained the risks, for increased health care utilization and mortality for each $10\mu g/m^3$ increase in air pollutants. In all studies we applied a standard internationally recognized method to obtain the risks. Based on the daily general practitioner consultations in year 2000 and the daily number of hospital admissions/deaths in years 1995 to 2000, Poisson regression was used to estimate the change in risks due to the daily variation of a single pollutant with the adjustment of seasons, temperature, humidity, holidays and influenza periods. The necessary statistical precautions to adjust for auto-correlation and over-dispersion were also taken into account. The risks of adverse health events include general practitioner consultations[4,5,6] and hospital admissions[7] in the Hospital Authority due to cardiac and respiratory disease. In addition mortality risks were estimated from analyses of deaths recorded by the Census and Statistics Department,[8] most of which are also due to diseases of lungs, heart and blood vessels. We used the linear exposure-response relationship between air pollution and health outcomes, to estimate the overall reduction in risks which would be associated with improvements in air quality and from this the total number of avoidable health events.

Avoidable health events and costs

Deaths: We multiplied the total number of deaths in the year 2000[6] by the change in risks of mortality for the different changes in levels of air pollution for *each* pollutant (Figure 5).

Hospital days: We used the number of days spent in public and private hospitals in the year 2000,[6] with private hospital bed days estimated as 6.4% of total hospital bed days.[7] As with the calculation of avoidable deaths, we multiplied these bed-days with the corresponding changes in risks to obtain the proportion of avoidable hospital bed-days.

Direct costs of illness: We estimated these costs in four separate categories:

- public and private hospital admissions;
- public out-patient consultations (general, specialist, accident and emergency)
- family doctor visits.

Utilisation and unit costs (average costs of a bed day and a consultation) were obtained from the Hospital Authority,[9] the Health, Welfare and Food Bureau,[10] the Census and Statistics Department[8] and a local household survey.[11] Patient travel costs were included for hospital admissions (a taxi to the nearest hospital) and doctor visits (21 minutes at average bus fare pervisit), but not for accident and emergency attendances. All unit costs are shown in Table 2.

The avoidable costs were calculated as the product of utilisation, unit costs and the corresponding changes in risks.

Productivity losses: We estimated productivity losses from premature deaths, public and private hospital admissions, and family doctor visits for people aged 15 to 64 years. Productivity losses due to premature deaths were derived from the *person-years of life lost* for those who died before age 65 in the year 2000, adjusted by labour force and employment rates and multiplied by sex-specific median salaries.[12] Productivity losses due to hospital admissions were estimated in the same way using bed-days for those aged 15 to 64 years and those due to family doctor visits using days of sick leave granted after consultation for a respiratory disease.[4]

Table 2: Unit costs used in the estimation of avoidable costs

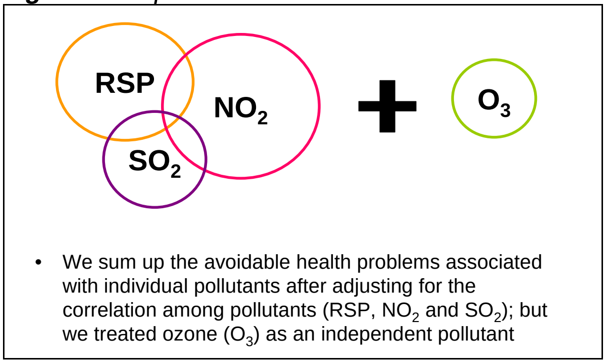
	Unit costs (HK$)
Direct costs of illness:	
Public hospital bed-day:	
Acute general ward	3,132
Chronic Infirmary ward	2,735
Coronary care unit	5,188
Public out-patients visits:	
Department of Health general clinic	219
Hospital Authority general clinic	302
Specialist clinic	660
Accident and emergency department	571
Family doctor visits	163
Travel costs:	
Taxi (roundtrip and less than 5 km per trip)	72
Bus (roundtrip)	8.40
Productivity loss:	
Median monthly income males	12,000
Median monthly income females	8,800
Overall median monthly income	10,000
Intangible costs:	
Willingness-to-pay to avoid a death	10,000,000
Willingness-to-pay to avoid a hospital admission	4,900/4,100*
Willingness-to-pay to avoid a day of coughing	184

We valued private hospital days the same as public hospital days
* respiratory/cardiovascular admission

Intangible costs: These cover other aspects of the value of avoided mortality and morbidity besides the utilisation and productivity losses. To *value a life* saved, we used a middle estimate of the value of a life[13] after validation in a local household telephone survey and applied this to the number of avoidable deaths. Amounts that local respondents said they were *willing to pay* to avoid hospital admissions and respiratory symptoms[14] were used to value the avoidable admissions and respiratory problems.

Combining the effects of pollutants: There is evidence in Hong Kong, as elsewhere, that each air pollutant such as sulphur dioxide (as an indicator of all pollutants associated with sulphur rich fuels) exerts an independent effect on health outcomes.[15-17] However, air pollution is a complex mix of chemical pollutants and there is uncertainty about the net contribution made by all pollutants acting together. We took a conservative approach summing the avoidable costs for each pollutant and then subtracting the possible “overlapping” effects by using the statistical correlation between pollutants as measured at air quality monitoring stations. For example, 25% of the variation of NO_2 can be explained by the variation of SO_2, so we summed up NO_2+ 75%SO_2. However we did not make adjustment of the concentrations of the secondary pollutant O_3. The total number of avoidable health events associated with pollution was estimated on the basis of: NO_2+ 75%SO_2 + 46% RSP+ O_3.

***Figure 7:** Air pollution: Combination of effects*



Roadside monitoring stations

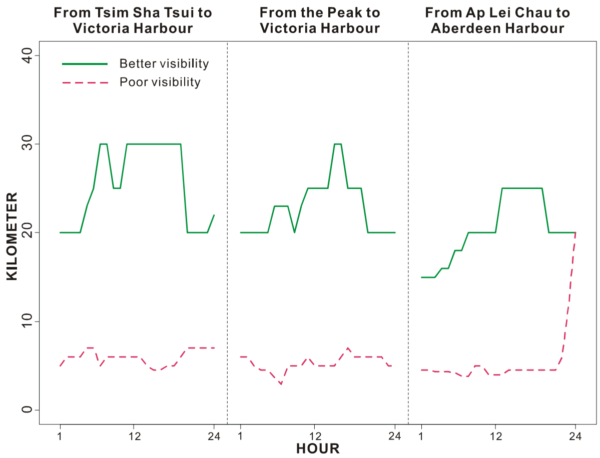
A separate analysis using data from the roadside monitoring stations, situated in Causeway Bay, Central and Mongkok, was made in addition to that based on the general monitoring stations, because many people (at least 50%[14]) live and/or work beside busy roads. The methodology for deriving the changes in risks and avoidable health events and costs was the same as that described for the general monitoring stations.

4.0 FINDINGS

The photographs (Figures 2-4) clearly demonstrate the marked variation in visibility (Figure 8) on the recorded dates. The hourly concentrations of air pollutants on the days with *Poor* visibility were generally much higher than on those with *Better* visibility (Table 3). In particular, RSP and NO_2 showed clearly elevated patterns at all monitoring stations on poor visibility days. On over 75% of days in the year we were exposed to concentrations of RSP and O_3 in excess of those in Level 2.

To illustrate the estimation of changes in risk with improved air quality, we can calculate the number of deaths avoided from reduction of a single pollutant. The risk of mortality associated with NO_2 per 10µg/m^3 increase was 0.64%. When the pollution level changed from *Average* (Level 4) to *Better* (Level 2), with the assumption of a linear exposure-response relationship, the change in risk was 1.7%. The number of deaths avoidable which were attributable to NO_2 was 545, ie 1.7% of total number of deaths in Hong Kong in year 2000. Similar calculations were performed for other pollutants. We then summed up the numbers of deaths avoidable after adjusting for the correlation between pollutants.

***Figure 8**: Hourly visibility on the days the photographs were taken*



Source of data: Hong Kong Observatory

Table 3: Mean levels of air pollutants (µg/m^3) at general monitoring stations by the four defined levels of visibility and the differences between them

Level	NO_2	RSP	SO_2	O_3
1 *Good*	20	16	8	6
2 *Better*	35	25	22	19
3 *Poor*	107	129	64	53
4 *Average*	62	61	25	39
4 – 2	27	37	3	20
4 – 1	42	46	17	33
3 – 2	72	104	41	34
2 – 1	15	9	14	13

Health and economic gains from improvement from overall *Average* levels to *Better* or *Good* pollutant levels

The numbers of deaths avoidable by achieving improvement from *Average* (Level 4) to *Better* (Level 2) levels of air pollution were 769 and 1,583 (approx 1,600) for improvement from *Average* to *Good* (Level 1) (Figure 9). Avoidable bed days for hospital admissions were 36,326 for the difference between *Average* and *Better* and 64,207 (approx 64,000) for improvement from *Average* to *Good* (Figure 10).

***Figure 9**: Deaths avoided with air quality improvement from "Average to Good"*

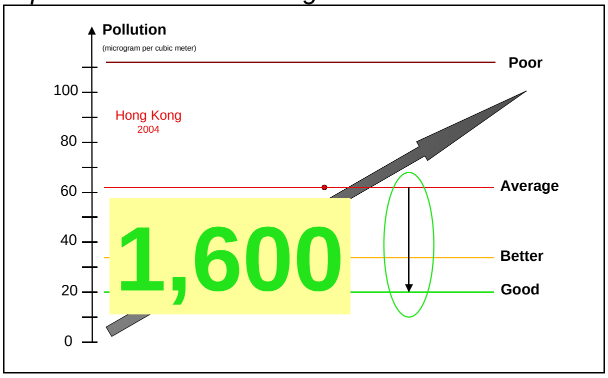
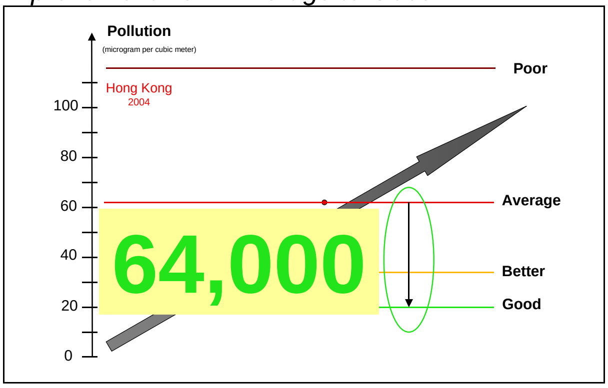


***Figure 10**: Saved hospital-days with air quality improvement from "Average to Good"*



The avoidable dollar values for these gains are shown in Table 4. The avoidable direct costs of illness were almost $1 billion up to $1.5 billion for moving from *Average* to *Better* or *Good* levels of air pollution respectively. About 76% of these costs were due to avoided family doctor visits and 19% due to costs of public health care (public hospital admissions and out-patient visits). Avoidable productivity losses were up to $0.5 billion while avoidable intangible costs were from $10 up to $19 billion. The value of lost lives accounts for most of the intangible costs.

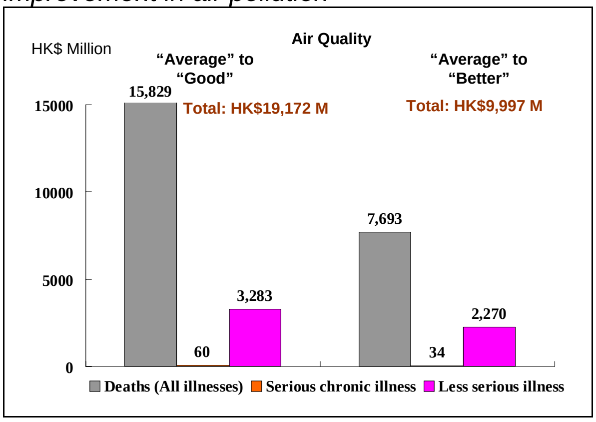
Effect of moving from *Poor* pollution levels to *Better* and from *Better* to *Good* levels

In recent years the number of days with air pollution levels worse than average amounted to 45% of the calendar year. In terms of respirable suspended particulates this includes a range of approximately 60-111 micrograms per cubic metre at general monitoring stations. The pollutant levels on our *Poor* visibility days were over 110 μg/m^3 and the trend has been towards *Poor*. On an annualized basis, the numbers of deaths avoided with air quality improvement from *Poor* (Level 3) to *Better* (Level 2) were 3,172 and an additional 814 for *Better* to *Good*. Avoidable hospital days for these changes were 114,223 and 27,880 respectively, a total of over 142,000. The avoidable intangible costs are shown graphically in Figure 11.

Table 4: Avoidable costs differences between levels of air pollution *Average* to *Better* and to *Good*

Direct cost of illness:	Avoidable Costs (HK$)	
	Average to Better Level 4-2	**Average to Good Level 4-1**
Public hospital admissions	103,314,117	182,595,046
Public out-patient visits	84,315,594	133,527,565
Private hospital admissions	7,281,544	12,870,139
Family doctor visits	734,520,232	1,113,504,483
Travel costs	40,709,783	61,894,109
Total direct cost	**970,141,270**	**1,504,391,343**
Productivity loss:		
Hospital admissions	1,744,263	3,102,961
Family doctor visits	82,223,270	124,647,322
Premature deaths	182,845,220	376,237,624
Total productivity loss	**266,812,753**	**503,987,907**
Intangible costs:		
Deaths	7,692,517,649	15,828,767,946
Serious chronic illness	34,024,336	59,797,014
Less serious illness	2,270,028,285	3,283,378,006
Total intangible costs	**9,996,570,270**	**19,171,942,967**

***Figure 11:** Avoidable intangible costs due to improvement in air pollution*



Effects associated with pollutant levels at roadside monitoring stations

The roadside concentrations for each level of air pollutant, except ozone, are shown in Table 5. Avoidable health events estimated by using roadside levels of pollution were higher than those using general levels, at 964 and 1,988 avoidable deaths, for improvement from *Average* to *Better* levels and *Average* to *Good* levels respectively, with corresponding avoidable bed days of 34,913 and 65,560.

Based on roadside levels, avoidable deaths, on an annualised basis, were 3,821 and 1,024 for air quality improvements from *Poor* to *Better* and for *Better* to *Good* respectively, with corresponding avoidable hospital days of 120,231 and 30,660.

Table 5: Mean levels of air pollutants (μg/m^3) at roadside monitoring stations by the four defined levels and the differences between them

Level	NO_2	RSP	SO_2
1 Good	36	23	9
2 Better	60	45	23
3 Poor	163	145	66
4 Average	101	80	23
4-2	41	35	0
4-1	65	57	14
3-2	103	101	42
2-1	23	22	14

Avoidable costs were also slightly higher at $1.0 and $1.7 billion for direct costs of moving from *Average* to *Better* and *Good* levels respectively, $0.3 and $0.6 billion for productivity losses and $12 and $23 billion for intangible costs. Differences between *Poor* and *Better* and *Better* and *Good* were respectively $2.9 and $0.7 billion for direct costs, $1.2 and $0.3 billion for productivity losses and $43 and $11 billion for intangible costs.

5.0 POLLUTION ABATEMENT: A PUBLIC HEALTH PRIORITY

This analysis has face validity in that it uses conservative, validated and robust methods to estimate the potential health gains and reduction in community costs which could be achieved by consistent steps towards cleaner fuels, cleaner power units and improved efficiency in all forms of power generation. The analytical methods used to estimate health risks have been subjected to independent international scientific peer review and published in high impact science journals. The analysis is conservative in that many health outcomes are not yet included.

Hong Kong has already demonstrated, albeit sixteen years ago, that it is possible to achieve major improvements in air quality and large reductions in adverse health impacts through even very modest interventions in fuel quality.[15] The success of the July 1st 1990 restriction on sulphur in fuel oil in reducing sulphur dioxide (Figure 12) and nickel and vanadium (Figure 13), based on the reduction of fuel sulphur content to 0.5% by weight, was associated with

(a) reductions in bronchitic symptoms in both children and adults;
(b) improved lung function in primary school children (Figure 14); and
(c) a reduction in all cause mortality by 2.1% (equivalent to 600 deaths per annum), because of a 1.8% to 4.8% decline in deaths in different age groups mainly from heart, lung and vascular disease (Figure 15).[15]

Figure 12: *Air pollutants concentrations in Hong Kong 1988-95: half yearly mean levels showing effect of fuel sulphur restriction*

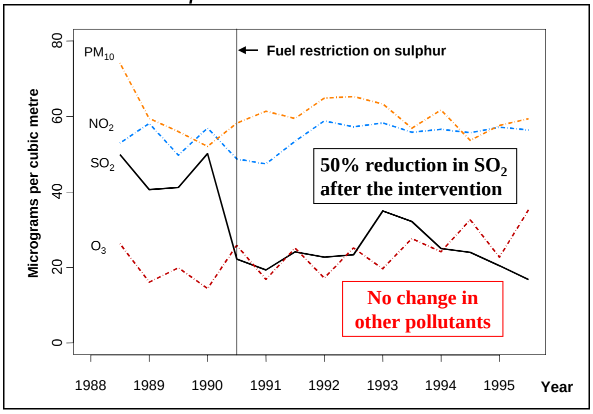


Figure 13: *Effects of conversion to low sulphur fuel (0.5%) on transition metal concentrations in Hong Kong*

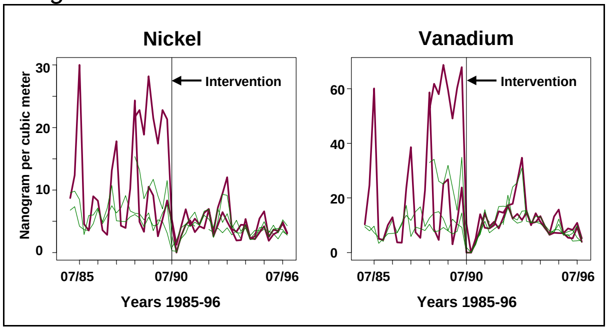
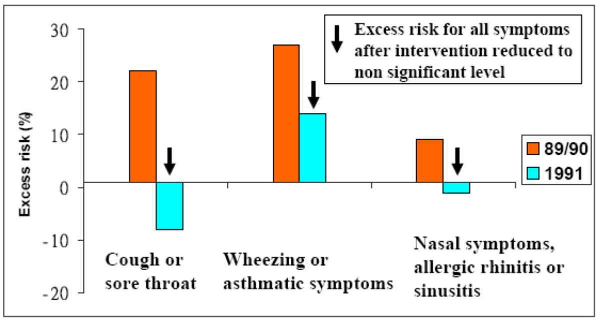
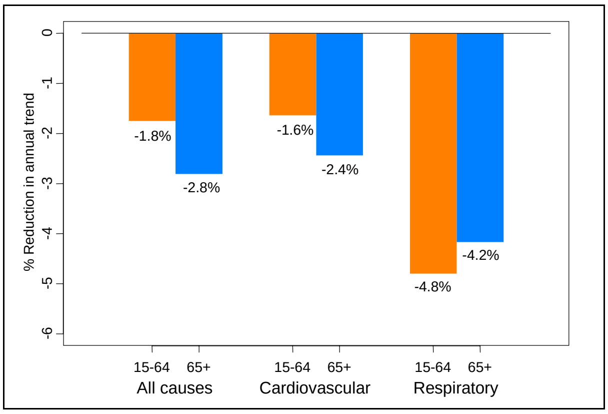


Figure 14: *Benefits of low sulphur fuels: Reduction in excess risk (%) between Southern and Kwai Tsing Districts for childhood respiratory symptoms*



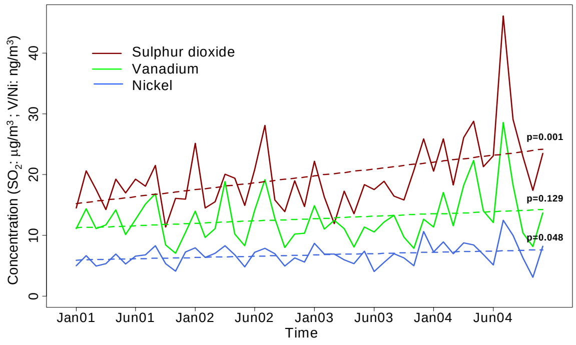
Source: International Journal of Epidemiology 1996; 25:821-828

Figure 15: *Reductions in deaths after sulphur restriction 1990-95*



Relatively small reductions in ambient air concentrations of pollutants lead to important health gains and the results of the Hong Kong intervention is now recognized world-wide as one of the most important pieces of evidence in the causal relationship between air pollutants and the injury to cardiopulmonary systems. However since 1990 air quality in Hong Kong has been progressively degraded. A particular concern is the upward trend in those pollutants which are the signature emissions of sulphur rich fuels (Figure 16).

Figure 16: *Monthly concentration of sulphur dioxide, nickel and vanadium, 2001-2004*



Our results indicate that the costs of health care consultations and the value of lives lost are major components of the avoidable costs due to air pollution. According to the United States Environmental Protection Agency,[18] 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.

6.0 POSSIBLE WAYS FORWARD

In addressing the causes of the problem and opportunities for interventions, there are several important distinctions to be made between:

(1) local and regional sources;
(2) near term technical solutions, mid term planning priorities, and long term structural solutions.

Local priorities

Recognizing tasks and priorities

With respect to the impact of local sources on health, we should be equally, or even more, concerned about emissions from the transport sector in addition to those from the power sector.

While the power sector in Hong Kong emits its pollutants from the top of tall exhaust gas stacks and makes an important contribution to the regional burden of pollution, the transport sector emissions occur within a few metres of pedestrians and within a few tens of metres of office, retail and residential units along major traffic corridors.

In addition, under typical urban conditions common in Hong Kong, the *street canyon effect* works to potentiate pollutant build-up during peak traffic periods. Since health impacts are a function of the concentrations at which pollutants are inhaled as well as the duration of exposures, transport presents the greatest exposure risk for some pollutants even if total emissions are higher from the power sector. Roadside concentrations of pollutants are very high in Hong Kong and exceed even the very permissive Hong Kong air quality objectives. We estimate that approximately 50% of the population live and/or work in roadside environments and are therefore exposed to some of the highest levels of pollution in the HKSAR.

This is not to say that we should ignore the power sector, but rather note the many different tasks among risk reduction priorities.

Near term

With respect to policies for reducing exposure risks from local transport pollution in the short term we should focus on:

(i) rationalizing bus routes and bus service scheduling to facilitate higher occupancy,
(ii) banning the use of *pre-Euro* and *Euro I* powered commercial vehicles on Hong Kong's urban roads during peak periods, and
(iii) providing better ventilation in the construction of under-story bus termini.

Given that the diesel fuel sulphur content north of the boundary is 40 times higher than in Hong Kong (0.2% versus 0.005%) there should be an urgent review of the system of monitoring the tank contents of cross-boundary vehicles. The current regulation permits 75% of a tank to be filled with mainland fuel. This permissive arrangement and violations of the regulations restricting fuelling on the mainland side represent a direct threat to community health.

For the power sector the Hong Kong SAR government must act to expedite the siting of China Light and Power's proposed Liquified Natural Gas facility.

Mid term

In the mid term we should:

(i) impose mandatory requirements for all diesel vehicles to move to *Euro IV* and *Euro V* standards,
(ii) reduce competing bus services where rail lines have excess capacity,
(iii) turn many mini-bus routes into feeder bus services to rail and long haul bus stations.

In power plants the long overdue Flue Desulphurisation Gas facility at Castle Peak should be expedited. Given that the demonstration of health risks from sulphur rich fuels was clearly evident from analyses more than 12 years ago and that the use of fuels with high sulphur and transition metal content is illegal in other sectors of Hong Kong, there should be a moratorium on its use in power generation on both sides of the boundary.

Long term

Over the longer term, the government should set out an explicit policy (common virtually everywhere else in the world) of providing a specific fraction (e.g. 50-70%) of the construction cost of new rail lines as a direct grant to the rail company. This will allow additional service in the most congested parts of the territory and extension of the system to more areas of medium density. In other words government must *act* to make rail the backbone of the transport system.

Urban design also needs to be reconsidered. We need to plan new areas and the redevelopment of older areas with an eye to facilitating air circulation to help reduce and protect people from transport pollution. For example some buildings might (like the Hong Kong Bank in Queen's Road Central) be built with an open ground floor. Likewise, buildings could be mandated to be of different height and with required spacing between them.

The development of new roads through densely occupied urban areas, such as Central, must be recognized as the antithesis of pollution abatement policies in our inner cities.

In power generation the Hong Kong SAR government must set a clear long term policy on whether the use of coal will be permitted at all, and if permitted, under what specific conditions in terms of sulphur and ash content and emission controls.

Regional priorities, including Air Pollution 'Imports' from Guangdong

General issues

Hong Kong contributes to the burden of pollutants in the Pearl River Delta (PRD) but, due to the prevailing air mass movement patterns, pollution emitted in Shenzhen, Dongguan and the eastern PRD generally has an important impact on Hong Kong's air quality. Within these cities and area, we need to focus on three sectors: manufacturing establishments, power plants, transport.

Manufacturing

The first target should be the manufacturing sector since so much of it is owned and managed by Hong Kong based firms. The near term focus should be on energy efficiency and (once China rationalizes its fuel pricing policy) on Hong Kong owned and managed firms committing to using cleaner fuels in their factory operations, including auxiliary power generators. The present trend in increasing concentrations of pollutants from sulphur rich fuels can and must be reversed. *The widespread use of bunker fuel and production of residual oil fly ash (ROFA) rich in metals is now one of the biggest threats to community health from air pollution but also the most easily prevented.*

Power sector

For the power sector in Guangdong, we accept that there may be difficulties for Hong Kong in encouraging the on-going expansion of the generation capacity (so as to reduce inefficient industrial self-generation) and the introduction of cleaner fuels and better emission controls. Nonetheless, there may be a role for Hong Kong's power companies to provide expert advice on plant operation and maintenance so as to improve efficiency and reduce emissions.

Transport

Apart from factory-based power generation, transport in the PRD presents the greatest long term threat to air quality in Hong Kong because it is growing so rapidly. Hong Kong must be in a position to collaborate with Guangdong authorities to ensure that only clean diesel and petrol are available in the market, that vehicles have the latest emission control technologies and that in the short term Hong Kong's air quality is protected by tighter cross-boundary fuel controls.

Hong Kong should also encourage Guangdong to implement high fuel and vehicle registration taxes, while supporting development of a good public transport system of buses and rail. Given the increasing popularity of individually owned road vehicles in the mainland and the SAR, it may be useful to distinguish between ownership and use. The disincentives for use of a car on a regular basis during peak periods should be particularly high, including road pricing and higher car parking charges.

7.0 SETTING NEW TARGETS

The new WHO Air Quality Guidelines 2006[19]

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 timescales are only considered *"on a best endeavour basis"* is totally unacceptable from an environmental and public health viewpoint.

The Hong Kong and mainland air quality objectives (AQO) are long outdated and provide no health protection from pollution. What is worse is that they have come to be regarded as safe and permissive levels in environmental impact assessments. Through that mechanism the AQO has become an instrument by which air pollution may be legally increased. This process has in fact been formally approved under the Environmental Impact Assessment Ordinance for several years.

The Hong Kong AQO are based on the 1987 WHO Air Quality Guidelines for Europe. These were revised in 2000 but these amendments were not reflected in any changes to the HKSAR objectives. In September 2006 WHO will promulgate the new Global Air Quality Guidelines (AQG), which were agreed by the Working Group in October 2005.[19]

The new AQG have been agreed, on the basis of consensus, on the best evidence available from both observational and analytic studies of associations between air pollutant concentrations and a wide range of health outcomes. They should not be regarded as either *safe* or *permissive* levels.[20] The evidence underpinning the AQG is derived from animal and human experimental studies, epidemiological analyses and (rarely) interventions. The annual patterns of pollutant concentrations in relation to the existing Hong Kong AQO and proposed WHO AQG are shown in Figures 17-19.

The general pattern shows that pollutant concentrations far exceed even the outdated Hong Kong objectives for PM_{10} and NO_2. Even for SO_2, the pollutant with the lowest levels relative to the new WHO AQG, the AQG were violated for 35% of the year.

Figure 17: *Monthly concentrations of respirable suspended particulates (PM_{10}), 2001-2005 at roadside and general stations, with Hong Kong (1987) and WHO (2006) air quality objectives/ guidelines shown*

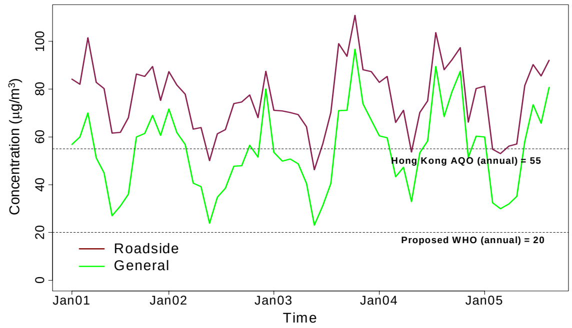


Figure 18: *Monthly concentration of nitrogen dioxide, 2001-2005 with WHO (2006) air quality guideline*

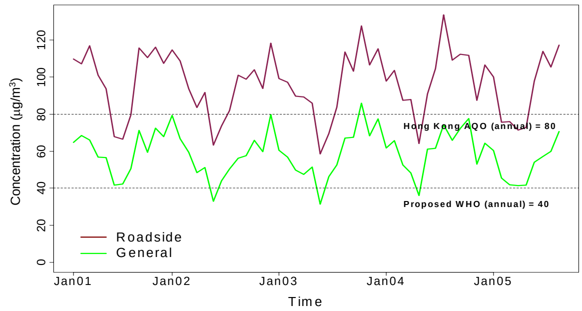
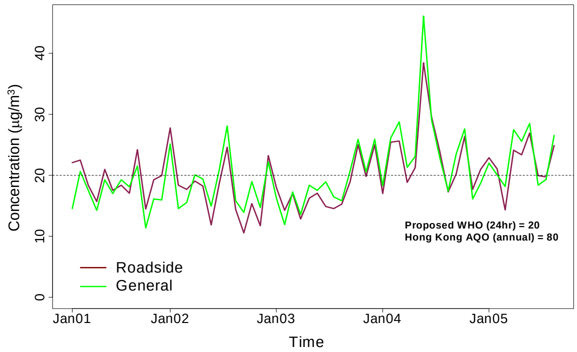


Figure 19: *Monthly concentration of sulphur dioxide, 2001-2005 with WHO (2006) air quality guideline*



This is of enormous public health importance. What is even more significant is the increasing annual trend in pollutants from sulphur rich fuels. Among these the most important may be the transition metals nickel and vanadium. The Hong Kong intervention (sulphur fuel restriction) on July 1st 1990 led to a sharp reduction in these transition metals in addition to sulphur dioxide, and our current hypothesis is that this change is likely to have been causally related to the marked evidence of reduced injury to cardiovascular and pulmonary tissues in both children and adults. These recent increases in pollutants from sulphur rich fuels are likely to originate from the large scale burning of bunker fuel on the mainland side of the boundary by Hong Kong and Guangdong based business interests. In addition to acute and chronic illness outcomes the silent pathophysiological effects will predictably include stunting of lung growth in generations of young children and adolescents on both sides of the boundary.

8.0 CONCLUSION

At both the population and individual level the clear and urgent indications are that the HKSAR government should act to ensure that radical pollution abatement measures are implemented, enforced and monitored both locally and in relation to cross boundary movements.

In addition the HKSAR must take the lead in vigorously addressing all aspects of regional pollution and the prevention of the serious widespread health effects which are now known to be a consequence of this. There is a net loss to our community from air pollution.

As members of Asia's World City, its citizens have reasonable expectations that their health and that of their children is fully protected by all available measures.

9.0 KEY POINTS

- We have lost control of regional quality in Hong Kong and the Pearl River Delta.
- Air pollution has a major impact on health and the economy.
- Comprehensive strategies for pollution abatement must be implemented and enforced without further delay.

REFERENCES

1. Watson JG. Visibility: Science and regulation. *Journal of the Air & Waste Management Association* 2002; 52: 628-713.
2. Knobel HH, Chen CJ, Liang KY. Sudden infant death syndrome in relation to weather and optimetrically measured air pollution in Taiwan. *Pediatrics* 2005;96: 1106-1110.
3. Environmental Protection Department, Hong Kong SAR. Past air monitoring station data. http://www.epd.gov.hk/epd/english/environmentinhk/air/data/air_data.html (accessed 12Dec2005)
4. Wong TW, Wun YT, Yu TS, Tam W, Wong CM, Wong AHS. Air pollution and general practice consultations for respiratory illnesses. Journal of Epidemiology and Community Health 2002; 56: 949-950.
5. Wong TW, Tam W, Yu I TS, Wun YT, Wong A HS, Wong CM. The association between air pollution and general practitioner visits for respiratory diseases in Hong Kong. *Thorax* doi.10.1136/thx.2005.051730
6. Wong CM, McGhee SM, Yeung RYT, Thach TQ, Wong TW, Hedley AJ. Short term health impact and costs due to road traffic-related air pollution. Final Report submitted to Environmental Protection Department. Hong Kong Air Pollution and Health Joint Research Group, 2002. http://www.epd.gov.hk/epd/english/environmentinhk/air/studyrpts/files/ap_health_impact_02.pdf (accessed 20May2006)
7. Hong Kong Hospital Authority. Hospital Authority Annual Report 2000-2001. Hong Kong: Hong Kong Hospital Authority, 2001.http://www.ha.org.hk/hesd/nsapi/?MIval=ha_view_template&group=AHA&Area=ANR&Subj=R01&ustamp=2006%2d05%2d18+15%3a41%3a16%2e893 (accessed 18May2006)
8. Hong Kong Census and Statistics Department. Hong Kong Annual Digest of Statistics. Hong Kong Printer, 2001.
9. Hospital Authority Costing Exercise 2000. Personal communication with Hospital Authority dated 4Feb2002.
10. Health, Welfare and Food Bureau. Lifelong investment in health: Consultation document on health care reform. Hong Kong: Government Printing, 2000.
11. McGhee SM, Bacon-Shone J, Hung J, Ma SK, Brudevold C, Hedley AJ. Household survey report 1998. Report prepared for Harvard University. Department of Community Medicine and Social Sciences Research Centre, The University of Hong Kong, 1998.
12. Hong Kong Census and Statistics Department. Men and women in Hong Kong key statistics (2005 edition). Hong Kong Printer, 2005.
13. Sommer H, Seethaler R, Chanel O, Herry M, Masson S, Vergnaud J Ch. Economic Evaluation: Technical Report on Economy. Health Costs due to Road Traffic-related Air Pollution: An impact assessment project of Austria, France and Switzerland. Bern: Federal Department of Environment, Transport, Energy and Communications Bureau for Transport Studies, June 1999. http://www.euro.who.int/Document/Trt/Health_costs.pdf
14. McGhee SM, Yeung RYT, Wong LC, Chau J, Wong CM, Ho LM, Fielding R. The health benefits of reduced air pollution: value and trade-offs. Health Care and Promotion Fund. Health, Welfare and Food Bureau, Hong Kong SAR Government, April 2005. Final report reference number 213018. http://hwfbgrants.netsoft.net/english/funded_search/funded_search.php
15. Hedley AJ, Wong CM, Thach TQ, Ma SLS, Lam TH, Anderson HR. Cardiorespiratory and all-cause mortality after restrictions on sulphur content of fuel in Hong Kong: an intervention study. *Lancet* 2002; 360: 1646-1652.
16. Wong CM, Atkinson RW, Anderson HR, Hedley AJ, Ma SLS, Chau YK, Lam TH. A tale of two cities: effects of air pollution on hospital admissions in Hong Kong and London compared. *Environmental Health Perspectives* 2002; 110: 67-77.
17. Wong CM, Ma SLS, Hedley AJ, Lam TH. Effect of air pollution on daily mortality in Hong Kong. *Environmental Health Perspectives* 2001; 109: 335-340.
18. US Enviornmental Protection Agency. Environmental Justice. http://www.epa.gov/compliance/environmentaljustice/index.html (accessed 27Jan2006)
19. Krzyzanowski M, Regional Adviser, Air Quality and Health. WHO Regional Office for Europe. European Centre for Environment and Health, Bonn Office. WHO Air Quality Guidelines. Global Update 2005. http://www.euro.who.int/Document/E87950.pdf (access date 18Apr2006) and http://www.healtheffects.org/annual.htm (accessed 18Apr2006)
20. Maynard RL. UK Health Protection Agency. The use of ambient air standards: a global overview. Health Effects Institute Annual Conference, San Francisco, 9 April 2006. http://www.healtheffects.org/annual.htm (accessed 18Apr2006)