Air Pollution and Health
A Briefing Paper

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Introduction

Air pollution is a major environmental health problem globally. The World Health Organization (WHO) considers that air pollution is damaging the resources needed for the long-term sustainable development of the planet (1). Air pollution degrades the environment, reduces visibility, producing serious health effects. This article reviews the health effects of air pollution with special reference to Hong Kong and meteorological/geographical and regional influences that affect air pollution locally.

I: Sources of air pollution

Air pollution comes from 3 major sources:

1) Any form of combustion-engine vehicles such as gasoline powered cars, diesel-powered vehicles, motorcycles and aircrafts;
2) Industrial (manufacturing) and community (air condition or heating of homes and buildings, municipal waste and incinerators) sources; and
3) Indoor sources such as tobacco smoke and emission from indoor materials.

II: Sources of Air pollution in Hong Kong

Diesel vehicles are the primary cause of street level pollution and acute pollution in urban areas of Hong Kong. The city has over 500,000 vehicles with about 150,000 powered by diesel. Diesel emissions account for nearly 98% of RSP and 80% of nitrogen dioxide emitted by all vehicles. There are many other sources of ambient air pollution in Hong Kong: power stations, marine vessels, fuel combustion and aircraft. They account for about 53% of the total RSP and 68% of total nitrogen dioxide emission. The smog that reduces visibility is a combination of ground level ozone and fine particles in the air.

Serious air pollution episodes in the urban environment do not generally result from sudden increases in the emission of pollutants but from the reduced ability of the atmosphere to disperse pollutants due to meteorological conditions (2). Regional air pollution contributes to levels of ambient air pollution in Hong Kong. Pollution from Hong Kong sources can also affect mainland China depending on wind direction. Studies have shown that total suspended particulate (TSP) levels are highest in winter months when the prevailing winds come from the North and West, blowing emissions from mainland China towards Hong Kong (3). Pollutants such as nitrogen oxides, ozone and sulphur dioxide can remain in the atmosphere for several days, allowing time for the prevailing winds to blow them over the border. Indeed, new scientific research is beginning to show that airborne pollutants can travel a very way away from their original sources, which makes air quality management a complex science that have regional implications.

Within the urban areas in Hong Kong, there are areas prone to have high pollution levels, such as Causeway Bay and Mongkok, where there are roadside monitoring stations. These two areas have very high traffic density. In both areas but especially Causeway Bay, the density of high-rise buildings prevents the dispersion of emissions generated by vehicles resulting in the so-called “street canyon effect”.

III: Specific air pollutants

Air pollutants are usually classified into suspended particulate matter (dusts, fumes, mists, smokes), gaseous pollutants (gases and vapours) and odours.
Suspended particulate matter

Suspended particulate matter consists of finely divided small particulates with diameters less than 10 µm (PM$_{10}$), most are smaller than 1 µm, which remain suspended for hours or days. They consist of a wide variety of substances and include inorganic and organic carbon (containing polycyclic aromatic hydrocarbons, PAH), acidic or neutral sulphates and nitrates, fine soil dust, residues of lead and other metals, asbestos and other fibres.

Particles are classified by their size. PM$_{10}$ refers to particles smaller than 10 µm, while PM$_{2.5}$ to particles smaller than 2.5 µm in diameter. Ultrafine particles contribute very little to the overall mass but are very high in number. Because of their size, ultrafine particles are efficiently deposited in the airways, escape the surveillance of the alveolar macrophages (cells that mop up undesirable materials) and gain access to the lungs, causing inflammation in the airways and the lungs as shown in laboratory animals. Particles smaller than 2.5 µm arise mainly from combustion processes, while grinding and other mechanical processes generate larger particles and generally consist of earth crustal materials and are thought to be less toxic.

Acid aerosols are a subset of fine particles. Atmospheric oxidation of sulphur dioxide (SO$_2$) may produce sulphuric acid, and partially neutralized sulphate salts. Formation of acid aerosols is hastened by humidity and by photochemical processes. Asthmatics may develop chest tightness and difficulty in breathing when exposed to acid aerosols (4).

**Asthma – what is it?**

Asthma is a disease characterized by episodic cough, wheeze and shortness of breath, variable narrowing of the airways and presence of nonspecific airway hyperirritability. The last two features can be demonstrated by objective testing. Asthmatics are people with the disease.

**Sulphur dioxide (SO$_2$)**

Sulphur dioxide is released into the atmosphere primarily as a result of industrial combustion of coal and oil. A small proportion is produced by vehicular sources (diesel cars, buses, and trucks) due to sulphur contained in the fuel. It is oxidized to sulphuric acid in a humid environment. It is an irritant gas and induces narrowing of the airways; individuals with asthma are more sensitive to these effects (5).

**Oxides of nitrogen (NOx)**

Oxides of nitrogen are most frequently produced by combustion of fossil fuels for transport, heating and power generation. Nitric oxide (NO) generated by these activities may be oxidized to nitrogen dioxide (NO$_2$), the precursor of ozone in photochemical smog. In addition to NO$_2$, NO oxidation products, nitric and nitrous acid are also potentially harmful. Healthy individuals are not affected by exposure to NO$_2$ in experimental exposure studies. However, asthmatics exposed to levels of NO$_2$ (0.2 to 0.5 ppm) often develop heightened nonspecific airway hyperirritability (manifested as cough, chest tightness and difficulties in breathing when exposed to very low levels of irritants such as passive smoke, fumes and also to cold air) and enhance airway response to specific inhaled allergen, such as house dust mite or pollen (induce an asthmatic attack when exposed to a low level of allergen that normally will not generate a response) (6-8).
Photo-oxidants (e.g. ozone, $O_3$)

Ground level ozone is produced by complex chemical reactions in air masses containing oxides of nitrogen and reactive hydrocarbons such as volatile organic compounds (VOC) in the presence of sunlight. Volatile organic compounds are a variety of compounds including alkanes, alkenes, alkynes, aromatics, aldehydes, ketones, alcohols, esters, benzene, and some chlorinated hydrocarbons. The major sources are fossil fuels and industrial processes involving solvents. Trees and other vegetation also produce VOC. Thus measures to reduce NOx do not necessarily reduce VOC. Ozone can be reduced by 3 strategies: lowering VOC emissions, lowering NOx emissions or lowering both. It is important to study the local situation to find out which is the most effective method of controlling ozone level.

Photochemical pollution causes eye irritation and small temporary changes in lung function, particularly among children or people exercising vigorously. In both healthy people and asthmatics, exposure to $O_3$ causes a reproducible decrease in lung function and increase in nonspecific airway hyperirritability (9). In asthmatics, exposure to ozone also increases the airway response to specific inhaled allergens (10,11). These changes are due to inflammation of the lining of the nose and airways from ozone exposure.

Carbon monoxide (CO)

Carbon monoxide is produced by the incomplete combustion of fossil fuels. Concentrations in urban areas depend upon traffic density, topography and weather conditions. The health hazards of CO exposure are related to the binding of this gas to haemoglobin. An increase in carboxyhaemoglobin of 3.6% over baseline reduces the time to angina and ECG changes in exercising men with coronary heart disease (12).

IV: Adverse health effects of air pollution on human

Mortality

There is no doubt that mortality increases with increase in air pollution. Sudden increases in mortality have been described in episodes of extreme air pollution in the Meuse Valley in Belgium (13), Donora in Pennsylvania (14) and London in England (15). However much lower levels of air pollution are also associated with increase in mortality. In the six-city study in the United States, a significantly increased mortality was found in the most polluted as compared with the least polluted city (16). In Europe, a multicentre study using time-series analysis, demonstrated associations of daily concentrations of particles, $SO_2$, and $NO_2$ with mortality with lag periods varying from 0 to 5 days similar to the six-city study in the US (17).

The association between air pollution levels and daily mortality counts has been interpreted by some as the effects of air pollution on some frail individuals with severe underlying heart or lung disease or the “harvesting effect” of air pollution, i.e. death in these frail individuals is hastened by the presence of air pollution. However, such a notion is not valid since increase in mortality associated with air pollution was found among all ages, not just the very young and the very old (18).

Life expectancy has been shown to be 2 to 3 years shorter in communities with high particulate matter pollution than in communities with low particulate matter pollution in two studies in the United States by following individuals over a period of time (18).
Health care utilization

PM$_{10}$, ozone, sulphate particles, are each associated with hospital admissions for asthma and other respiratory diseases independently (19,20), the higher the levels of these pollutants, the higher the number of hospital admissions. The relationship between PM$_{10}$ and hospital admissions for all respiratory diagnoses or asthma is a linear one (Table 1) (21). Studies of emergency room visits for respiratory diseases in the United States (22,23) and Spain (24,25) have also demonstrated similar findings. The effects of air pollution on health care utilization may be delayed from 1 to 5 days.

Improvement in air pollution in the Utah Valley, United States, with a marked reduction in PM$_{10}$ concentration, was associated with a 50% drop in hospital admissions for respiratory disease in children (26,27). The estimated decrease in respiratory admission was 7.1% with each 10µg/m$^3$ decrease in PM$_{10}$. This observation gives an indication of the public health and economic benefits of reducing particulate air pollution.

Impairment of lung function

Long term exposure to O$_3$ has been found to be associated with a lower level of lung function and a faster rate of decline in lung function, and that the combination of O$_3$ and acid sulphate may be more important than the effects of ozone alone (28). In Germany, children aged 9-11 living in areas with the greatest amount of urban traffic had significantly lower lung function than those living in areas with lesser traffic (29).

Asthma and allergies

It is well known that outdoor air pollutants exacerbate asthma (22-24,28,29). The relationship is strongest with particles and ozone; the higher the pollution, the higher the number of asthma patients with acute exacerbation.

There has been a general increase throughout the industrialized world in the occurrence of asthma and allergies in children (30). In Hong Kong, the occurrence of asthma in young adults increased from 4.8% in 1989 to 7.2% in 1994 (31,32). Despite striking relationships between exposure to air pollution and asthma aggravation, air pollution has not been regarded as a cause of the disease. Increasingly, however, studies have been suggesting that air pollution may, indeed, be a cause of asthma. In France, Israel and Taiwan, studies have shown an increase in the frequency of asthma or asthma-like symptoms among children living in communities with high pollution than those living in less polluted areas (33-35).

Cancer

Known or suspected carcinogens are detectable in vehicle emissions, eg benzene and other polycyclic aromatic hydrocarbons. Attempts have been made to quantify the cancer risk from vehicle emissions. A level of diesel particles of 5-23 ug/m$^3$ in the atmosphere has been estimated to yield 1 to 2.6 additional lung cancer per 100,000 persons per year in Austria (36). Another study showed an increase of 20 µg/m$^3$ sulphate particles increased the risk of mortality from lung cancer by 1.36 (95% CI of 1.11-1.66) (37). It should be pointed out that quantifying risks from epidemiologic data alone is difficult because it is based on assumptions and multiple confounding factors such as individual susceptibility to exposure, exposure to cigarette smoke and other dietary differences have to be accounted for. Nevertheless, the results of these studies provide grounds for concern.
**Respiratory symptoms**

Greater frequencies of upper and lower respiratory tract symptoms have been observed in children living in areas with the highest flow of urban traffic in several countries such as Germany (26,38), United States (39,40), the Netherlands, (41,42) and in Switzerland (43). Table 1 shows the estimated increase in respiratory symptoms with each increase in 10ug/m³ of PM$_{10}$.

**V: Health effects of air pollution in Hong Kong**

Interest in air pollution and health in Hong Kong started in the late 1980s. A number of studies have been carried out by different research groups and summarized below:

**Frequency of chest symptoms and airway hyperirritability**

- In 1989, a study was done to compare respiratory morbidity among school children living in a heavily polluted district (Kwai Tsing) with those living in a less polluted one (Southern) in Hong Kong (44). The children were similar in age, gender, socioeconomic background, allergic status and parental smoking. The frequencies of sore throat, cough and wheeze were significantly higher among children living in the more polluted district than the less polluted one.

- When legislation was implemented to reduce fuel sulphur levels in 1990, there was a significant reduction in sulphur dioxide levels and sulphate concentration in respirable particles. The reduction in air pollution was associated with a significant reduction of respiratory symptoms, more so in children living in the more polluted district (45).

- In the same study, measurement of non-specific airway hyperirritability (a feature of asthma) was carried out. Children living in the more polluted district had a significantly higher frequency of nonspecific airway hyperirritability compared with those living in the less polluted district (46).

- The degree of non-specific airway hyperirritability decreased in children living in polluted areas after the introduction of the vehicular fuel control legislation in 1990, lowering air pollution levels (47).

**Hospital admissions for cardiovascular, respiratory diseases and asthma**

- Significant associations were found between hospital admissions for all respiratory diseases, all cardiovascular diseases, and chronic obstructive pulmonary diseases and heart failure in 1994-5 and concentrations of all four pollutants lag for varying periods of 0 to 5 days (48).

- A time-series study of childhood admissions for asthma and air pollution carried out for the period 1993-1994 in a large teaching hospital showed a significant increase in daily asthma admission with increasing ambient levels of nitrogen dioxide, sulphur dioxide and PM$_{10}$ (49). Ozone level was not investigated.

**Mortality from all causes, cardiovascular and respiratory diseases**

- A study was carried out to assess the effects of four air pollutants on daily death counts between 1995-1997 for all non-accidental causes, cardiovascular and respiratory diseases (50). During the cool season, all oxidant pollutants (NO$_2$, SO$_2$ and ozone) were associated with all daily mortality outcomes in a dose-dependent manner, with the exception of SO$_2$ on respiratory mortality. PM$_{10}$
was marginally related to respiratory mortality but not for other outcomes.

*Emergency room visits for asthma*

- Daily air pollution and meteorologic data were collected for Hong Kong for one year beginning December 1998 (51). Daily visits for asthma to the Accidents and Emergency departments of two central hospitals were tabulated for the same period. Associations were observed at some day lags for all the air pollutants evaluated except carbon monoxide. The adverse effects of ozone were found to be more consistent than the effects of particles.

Thus the results of local studies of health effects from air pollution are similar to those in other parts of the world.

**VI: Magnitude of adverse health effects in Hong Kong**

Table 1 shows the percentage increase in adverse health effects with each 10 µg/m³ increase in PM₁₀ level. The magnitude of increase in health care utilization in Hong Kong for each 10 µg/m³ increase in PM₁₀ is similar to those reported in other countries. One can appreciate the size of the problem since the increase in PM₁₀, for example, can be 100 µg/m³ above the usual level during a bad episode of air pollution. The increase in hospital admissions for 100 µg/m³ in PM₁₀ for all respiratory illnesses would be 16%, and for asthma 15% based on local data. Since respiratory and cardiovascular admissions account for the majority of hospital admissions, the increase would be considerable. As there is usually a lag period of 1 to 3 days, the increase in health care utilization may not be evident the same day.

It should be noted that deaths and hospital admissions are only the “tip of the iceberg” for adverse health effects. Below the tip are visits to emergency room for treatment for respiratory and cardiovascular diseases, unscheduled doctor visits, increase in usage of medications for acute exacerbations of asthma or chronic obstructive lung disease, loss of productivity due to absence from work and impaired quality of life. All these parameters should be taken into consideration if the direct and indirect cost of air pollution to health were to be calculated.

**VII: Trends in air pollution**

In most of the cities of Western Europe, measures to reduce air pollution levels have resulted in a major reduction in levels of SO₂. In most cities, the annual mean concentrations of SO₂ in residential areas have not exceeded 50 µg/m³ with notable exceptions of several cities in China (1). Such a downward trend is not seen in NO₂ concentration. On the contrary, NO₂ levels have risen since 1960 due mainly to emissions from vehicles in many cities (1). In addition, diesel emission has become a major problem in many parts of the world. Diesel vehicles produce much higher emissions of the ultrafine particles (particles that are smaller than 0.1 µm in diameter) than gasoline fuelled vehicles. Ultrafine particles have been found to produce acute inflammatory responses in animal studies but human epidemiological data is not conclusive regarding the relative toxicity of particles of different sizes. Diesel vehicles produce substantially more of the toxic types of particles. They also have traces of PAH adsorbed on them creating potential problems that are not well studied.

**VIII: Trends of air pollution in Hong Kong**

All air pollutants increased progressively in Hong Kong over the past decade with the exception of SO₂. The reduction in SO₂ levels occurred after the implementation of Hong Kong Government fuel regulations restricting the sulphur content of fuels to 0.5%. SO₂ levels fell in many districts (Figure 1).
Since 1991, the annual mean roadside measurements of RSP and NO₂ have consistently exceeded (Figure 1) the one-year Air Quality Objectives (AQO) set by the Environment Protection Department (52). The 24-hour or 1-hour measurements have exceeded the AQOs many times each year. Ozone levels and visibility have deteriorated significantly in the last few years. In 1999, only 14% of the monitoring stations complied with the short-term AQO of ozone and 50% complied with the long term AQO.

In 1998, among 36 major cities in the world, Hong Kong ranked as 9\textsuperscript{th} and 15\textsuperscript{th} respectively for worst levels of RSP and NO₂ pollution while Singapore ranked 21\textsuperscript{st} and 30\textsuperscript{th} for the respective pollutants. Of special concern in Hong Kong is the emission of fine particles from diesel vehicles that are responsible for 79% of the total distance traveled on the roads.

**IX: Air quality guidelines**

Traditionally, guidelines for air quality have been developed to protect human health with the understanding that there is a threshold concentration below which no health hazards occur. However, results of recent studies showed that such threshold values may not exist. The 1999 WHO guidelines were based on sophisticated statistical analyses using a database containing many time-series studies relating daily occurrence of events such as deaths and hospital admissions to daily average concentrations of pollutants while taking into account confounding factors such as season, temperature and day of the week (1). The results of these studies have been remarkably consistent, demonstrating associations between daily average concentrations of particles, O₃, SO₂, and NO₂ and health outcomes. No threshold effect for particles or O₃ was found as very low concentrations of these pollutants are also associated with health outcomes. Thus the ‘guideline’ is a relationship relating events to airborne concentrations. This is a significant departure from the concept of a guideline value as a level of exposure at which the great majority of people, even in sensitive groups, would be unlikely to experience any adverse effects.

Figure 1 shows the summary estimate of the relative increase in daily mortality as a function of PM concentration as an example. Estimates for morbidity are also available. These figures allow the estimation, with caution, of how many subjects would be affected over a short period of time with increased PM levels, for a population of a given size, having known mortality and morbidity characteristics. When deriving an air quality standard for PM\textsubscript{10} or PM\textsubscript{2.5}, which curve should be used has to be decided and what level of risk is considered acceptable.

Table 2 shows the ambient air quality standards/guidelines for key air pollutants in Hong Kong, the United States and the WHO. It should be noted that the determination of AQO is mainly based on the health effects of acute exposure. There are no data on the health consequences of long-term low-level exposure, short-term peaks and possible synergism among pollutants. There are also no data on the possible risk of lower level pollutants inducing genetic mutations, birth defects and cancer.

**X: AQOs in Hong Kong**

A working group on Air Pollution and Health was established to review the appropriateness of the current AQOs established in Hong Kong based on evidence derived from local health studies (53). The following were the conclusions:

- Excess health risks were noted even on days when the levels of SO₂, RSP, NO₂, and O₃, were below the current set of AQOs. Therefore the current set of AQOs for these four pollutants are insufficient for protecting the health of the public.
• Based on the 1996 data, the working group reviewed Hong Kong’s AQO and estimated the health impact on removal of 30% upper levels of pollutant concentration. They found that 217 to 239 deaths and 1,596 to 2,218 hospital admissions per year from respiratory and cardiovascular diseases would be avoided assuming that only the maximum of the separate effects of each pollutant applied.

• In order to achieve worthwhile health benefits, ambient levels of the four pollutants would have to be maintained at or below levels corresponding to only 50% or even 25% of the current AQOs established in Hong Kong.

• Hong Kong’s studies also showed that there is no safe level of human exposure to SO₂, RSP, NO₂, and O₃ at least at the levels commonly experienced in urban environment.

XI: Future Research

There are still many gaps in our knowledge. Firstly, we need to understand the science relating to air quality better. Secondly, we need to understand the effect of air pollution and health.

(a) Science of air quality management

Air quality management is a growing area of research and study worldwide. Research done in other parts of the world may be instructive for Hong Kong and the Pearl River Delta region but since each region has its own geographical, topological, meteorological as well as its own unique mix of polluting sources, there is no substitute for doing one’s own data collection and analysis to understand the nature of one’s own regional air quality characteristics. With a stronger understanding in air quality of a specific locale, more effective control methods can be devised.

The Hong Kong Environmental Protection Department (HKEPD) has a strong background in collecting pollution samples and analysing them. It is currently working with international researchers to analyse various types of samples, using the latest methods, in order to understand the nature of air pollution in the region better. Furthermore, Hong Kong and Guangdong Province have collaborated on joint air monitoring over the last two years, the results of which is expected in April 2002. These efforts provide a good base for further cross-border collaborative research in the future. Indeed, the trend in other parts of the world is for regions to work together to improve air quality management since pollution control in one’s own city is unlikely to be effective when pollution can be blown in from elsewhere.

To be able to be at the forefront of air quality studies, Hong Kong will need to be willing to fund research as well as to create opportunities to collaborate with international researchers as well as scientists in mainland China to maximize learning. It will also require collaboration between the public and private sector as well as the academic sector.

(b) Science of air pollution and health

As the science of air quality management is a new area of research, the connection between air pollution and human health is also gaining in importance. Hong Kong has yet to establish another set of AQOs. How low should they be and how air pollutants can be effectively lowered to be cost effective to protect human health have yet to be determined. In addition, there are many areas of more basic research that still needs to be carried out, including the following:
Although acute and chronic effects of air pollutants have been studied, it is not known which specific air pollutant is responsible for the health effects, how the pollutants interact with each other and with other factors such as allergens, diet and housing.

There have not been adequate studies making use of personal monitoring to quantify the total dose received by individuals in their daily lives.

Some pollutants that pose a particular risk to health, such as dioxins, polycyclic aromatic hydrocarbons, acid aerosols, and toxic metals, have not been sufficiently monitored and studied.

Effects of long-term exposure on the development of asthma, allergies and lung cancer.

Understanding of the biological mechanism through which air pollutants may lead to mortality.

Likewise with air quality studies, Hong Kong must be willing to invest in the research for air pollution and health. It provides many opportunities for the accumulation of knowledge and collaboration between the public and private sectors, including among members of the medical and public health stakeholders.

XII: Research and Public Policy

The science of air quality management as well as air pollution and health are complex. Hong Kong does not have a tradition in funding these kinds of research. Firstly, a key public policy decision is for the authorities to recognize the importance of these areas and be willing to commit long-term funding for them. A good way to proceed is to ensure that Hong Kong and mainland Chinese researchers and scientists can work with international experts so that Hong Kong and China can build up its own research capabilities for the longer-term. Hong Kong and South China has a direct interest in building up their own capacities to carry out long-term air monitoring research as well as public health studies to ensure the best air quality and health management for the Pearl River Delta region.

Secondly, as air quality and public health management involve many stakeholders it is critical that they are included in a process whereby they can collaborate to improve air quality. It is vital that public sector regulators, private sector polluters, and the scientific research community have a chance to deliberate what to monitor and how monitoring should be done. Front-end collaboration should help to minimize disputes later about the results. Subsequent arguments about data collection methodologies used can delay decision-making about control strategies.

Thirdly, political leaders, who have the final decision-making power to change regulatory standards, impose pollution taxes and penalize polluters, are usually generalists. Their decision-making will be smoother if the various stakeholders have a high level of general agreement about how research is conducted. At least if the science is not in dispute, it makes it much easier to then concentrate the political debate on the public policy aspects of what is in the best public interest and the costs involved.

Conclusion

In Hong Kong, particulate, NO$_2$ and ozone levels are high. The annual means of these pollutants measured by the roadside exceeded the AQOs set by the Hong Kong Environmental Protection Department. In terms of health, local data have indicated that even below the AQOs, significant health effects could be detected. Of special concern in Hong Kong is the very fine particle emission by diesel vehicles.
As air pollution is a regional rather than a local problem in Hong Kong, it is important to cooperate with scientists and authorities in mainland China in research and policy making and to develop long-term air quality management program for Hong Kong and for Southern China. Moreover, science can play an important role in informing public policy, which can be particularly effective if multi-stakeholder collaboration can be created for problem solving.

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[a summary version of this paper is available on the Civic Exchange website]
References


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Legend to figures:

Figure 1: Percent increase in daily mortality, as a function of PM$_{10}$ concentration. Derived from reference 1.

Figure 2: Long-term trend of RSP, NO$_2$, SO$_2$ and O$_3$ in Hong Kong 1990-2000. Derived from reference 52.
Table 1: % increase in adverse health effect with each 10 µg/m³ increase in PM₁₀

<table>
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LRT=lower respiratory tract; URT=upper respiratory tract; A and E=Accident and Emergency
### Table 2. Ambient Air Quality Standards/Guidelines for Hong Kong, United States and the WHO.

All concentrations in µg/m³ except CO in mg/m³

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<tr>
<td></td>
<td>1 hr</td>
<td>30</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>8 hr</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>O₃</strong></td>
<td>30 min</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1 hr</td>
<td>240</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>8 hr</td>
<td>-</td>
<td>157</td>
<td>120</td>
</tr>
<tr>
<td><strong>Suspended matter (TSP)</strong></td>
<td>24 hr</td>
<td>260</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>annual</td>
<td>80</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Particulate &lt; 10 µm (PM₁₀)</strong></td>
<td>24 hr annual</td>
<td>180</td>
<td>150</td>
<td>No guideline value (impact relationship)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td><strong>Particulate &lt; 2.5 µm (PM₂.₅)</strong></td>
<td>24 hr annual</td>
<td>-</td>
<td>65</td>
<td>No guideline value (impact relationship)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td><strong>Pb</strong></td>
<td>24 hr</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3 months</td>
<td>1.5</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>annual</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*http://www.epa.gov/airprogm/oar/oaqps/greenbk/criteria.html
**http://www.who.int/peh/air/airguides2.htm

Currently, the US EPA has a standard for PM₁₀ of 50 µg/m³ (annual average) and 150 µg/m³ for a 24-hour average. For PM₂.₅, the annual and 24-hour standards are 15 and 65 µg/m³, respectively.

In its most recent revision of Air Quality Guidelines, the WHO elected not to set a threshold value, but instead has derived a linear relationship between PM₁₀ or PM₂.₅ concentrations and various health impacts (http://www.who.int/peh/air/airguides2.htm). This revision is based upon the absence of scientific evidence to support a no-effects threshold concentration for airborne particulate matter. These relationships allow each country to manage particulate air pollution by assessing the health effects associated with different levels of particulate matter.
Figure 1. Increase in daily mortality as a function of PM concentration.