Air pollution and health

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Objective. To review the effects of air pollution on health, with special reference to data obtained locally in Hong Kong.
Data sources. *Medline* literature search (1960-1999), websites of the World Health Organization and Environmental Protection Department, Hong Kong, and a report from the Sub-Working Group on the Review of Hong Kong's Air Quality Objectives, 1999.
Study selection. Key words for the literature search were 'air pollution' and 'health'.
Data extraction. The author reviewed relevant information and data.
Data synthesis. In many parts of the world and in Hong Kong, air pollution is associated with increased mortality and morbidity rates, as reflected by increased hospital admissions and doctor visits, not only for respiratory illnesses but also for cardiovascular illnesses. Some studies have found that air pollution is also associated with an increase in respiratory symptoms in lower lung function in children. In Hong Kong, air pollution is mostly because of traffic emissions. During the past decade, the annual mean levels of respirable suspended particulates and oxides of nitrogen and ozone have increased and exceeded the air quality objectives set by the Environmental Protection Department of Hong Kong.
Conclusion. The medical profession should be concerned about the health effects of air pollution and should call for action to reduce the current levels of air pollution to an acceptable level.

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Key words: Air pollution; Environmental exposure; Health status; Lung diseases/epidemiology; Risk factors

Introduction

Air pollution is a major environmental health problem worldwide. The World Health Organization (WHO) considers that air pollution is damaging the resources that are needed for the long-term sustainable development of the planet.[1] The sources of air pollution fall into three broad categories:
(1) Mobile sources, which include combustion-engine vehicles such as gasoline-powered cars, diesel-powered vehicles, motorcycles, and aircraft;
(2) Stationary sources, which include rural sources such as agricultural production, mining, and quarrying; industrial sources such as manufacturing; and community sources such as the heating of homes and buildings, municipal waste, and incinerators; and
(3) Indoor sources, which include combustion, tobacco smoking, and biological sources; and emissions from indoor materials or substances such as volatile organic compounds, asbestos, and radon.

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Specific air pollutants

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

Suspended particulate matter

Suspended particulate matter (PM) consists of finely divided small particulates with diameters of less than 10 µm (PM_{10}). Suspended particulate matter comprises a wide variety of substances, which include inorganic and organic carbon (containing polycyclic aromatic hydrocarbons), acidic or neutral sulphates and nitrates, fine soil dust, residues of lead and other metals, asbestos, and other fibres. Exposure of laboratory animals to fine particles has been shown to lead to inflammation of the airways and lungs.[2] Most of these particulates are smaller than 1 µm and remain suspended for hours or days. Particles that are smaller than 2.5 µm in diameter ($PM_{2.5}$) arise mainly from combustion processes, whereas larger particles are generated by grinding and other mechanical or agricultural processes. Small particles efficiently penetrate indoors, where levels are typically 70% to 80% of outdoor levels in the absence of indoor sources. In locations with indoor sources (eg cooking or tobacco smoke), indoor levels may be much higher than those outdoors.

Acid aerosols are a subset of fine particles. Atmospheric oxidation of sulphur dioxide (SO_2) may produce sulphuric acid and partially neutralised sulphate salts. The formation of acid aerosols is hastened by humidity and photochemical processes. When individuals with asthma are exposed to acid aerosols, bronchoconstriction is more likely to develop.[3-5]

Sulphur dioxide

Sulphur dioxide is released into the atmosphere primarily as a result of the industrial combustion of coal and oil. A small proportion is produced by vehicular sources due to sulphur contained in the fuel. Sulphur dioxide is oxidized to sulphuric acid in a humid environment. Indoor levels are typically lower than outdoor levels, owing to the reactivity of SO_2 with indoor surfaces. It is an irritant gas that elicits bronchoconstriction; individuals with asthma are more sensitive to this effect.[6]

Oxides of nitrogen

Oxides of nitrogen are most frequently produced by the combustion of fossil fuels. Nitric oxide (NO) may be oxidised to nitrogen dioxide (NO_2), the precursor of ozone in photochemical smog. In addition to NO_2 itself, potentially harmful NO oxidation products include nitric and nitrous acid. In indoor environments without combustion sources, indoor levels of NO_2 are lower than levels outdoors. Homes with unvented gas combustion devices, such as gas stoves, generally have higher NO_2 levels than outdoors during cooking. In experimental exposure studies, no consistent effects on lung function have been documented for NO_2. However, exposure of asthmatic individuals to high levels of NO_2 (0.2-0.5 ppm) has been shown to increase non-specific airway hyperresponsiveness[7] and an enhanced specific airway response to inhaled allergens such as house dust mite allergens.[8-9]

Photo-oxidants

Photo-oxidants are produced by photochemical reactions in air containing oxides of nitrogen and reactive hydrocarbons. Ozone (O_3) is the most important photo-oxidant. Photochemical pollution causes eye irritation and small temporary changes in lung function, particularly among children or people exercising vigorously. Because O_3 is highly reactive, indoor concentrations are significantly lower than outdoor levels. In both healthy subjects and asthmatic individuals, exposure to O_3 causes a reproducible decrease in lung function and an increase in non-specific airway hyperresponsiveness.[3] The dose-response curve may be non-linear and there is no threshold effect. Exposure of people with asthma to ozone has been shown to increase the specific response to inhaled allergens.[10,11] Ozone exposure causes inflammation of the nasal mucosa and bronchoalveolar lining, thereby resulting in a reduction in lung function, which is worse in those with asthma.[12]

Volatile organic compounds

Examples of volatile organic compounds (VOCs) are alkanes, alkenes, alkynes, aromatics, aldehydes, ketones, alcohols, esters, benzene, and some chlorinated hydrocarbons. The major sources of VOCs come from the burning of fossil fuels and industrial processes involving solvents. Benzene is emitted from motor vehicle exhausts and/or from evaporated petrol.[13] Indoor levels of VOC are usually much higher than outdoor levels, because VOCs are present in many building materials, such as paints, adhesives, and sealants. Volatile organic compounds are also released from laser printers and photocopiers. In the indoor environment, exposure to low levels of VOC may result in headache and irritation of the eyes and nose. Some VOCs have been shown to be carcinogenic.[6]

Carbon monoxide

Carbon monoxide (CO) is produced by the incomplete combustion of fossil fuels. Concentrations in urban areas depend on traffic density, topography, and weather conditions. In the absence of indoor combustion devices, indoor levels may be close to outdoor levels. Unvented combustion devices may produce additional CO indoors. 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 levels reduces the time to angina and leads to electrocardiographic changes in exercising men with coronary artery disease.[14]

Health effects of air pollution on humans

In a recent American Thoracic Society statement on the adverse health effects of air pollution,[15] the following were considered adverse health effects:

(1) Any detectable effects on clinical outcomes such as visits to the emergency department, hospital admissions, and mortality;
(2) Symptoms related to air pollution associated with diminished quality of life or with a change in clinical status;
(3) Any permanent loss of lung function;
(4) All reversible loss of lung function in combination with the presence of respiratory symptoms; and
(5) Decreased health-related quality of life.

Changes in levels of biomarkers and a transient, small loss of lung function that is by itself related to air pollution were not considered to be adverse health effects.[15] The evidence for some of the adverse health effects of air pollution is briefly discussed below.

Mortality

Sudden large increases in mortality due to episodes of extreme air pollution have been described in the Meuse Valley in Belgium,[16] Pennsylvania, United States (US),[17] and in London, England.[18] Recent studies have shown that mortality is associated with much lower levels of air pollution.[19-21] In a six-city study in the US, a significantly increased mortality rate ratio of 1.26 was found in the most polluted city, as compared with the least polluted city.[19] The relationship was stronger for fine particles than for other air pollutants. A study that examined mortality in London during the winters of 1958 to 1972, identified a significant relationship between mortality and levels of particulate matter, SO_2, and black smoke.[20] A multicentre epidemiological study in Europe[21] was performed to evaluate short-term effects of air pollution on health using time-series analysis. Similar to US studies, an association was found between mortality and daily concentrations of particles, SO_2, and NO_2, with a time lag of 0 to 5 days.

Associations between air pollution levels and daily mortality counts have been interpreted by some researchers as being due to the effects of air pollution on frail individuals with severe underlying heart or lung disease—the so-called 'harvesting effect'.[22] Some mortality time-series studies, however, have found effects across all ages, and not just among the very young and the very old.[15,22] Two cohort studies from the US have suggested that life expectancy may be 2 to 3 years shorter in communities with high levels of particulate matter than in communities with low levels.[15] The time-series studies also seem to indicate that combustion-related fine particles present a greater risk than naturally occurring particles such as dust storms, volcanic emissions, and road dust.[1]

It has been shown that the level of PM_{10}, O_3, and sulphate particles are independently associated with hospital admissions for asthma.[23,24] The relationship between the PM_{10} level and hospital admissions for all respiratory diagnoses or asthma is a linear one (Table 1).[24-32] Studies of visits to emergency departments for respiratory diseases in the US[33,34] and Spain[35,36] have also demonstrated similar findings. The effects of air pollution on health care utilisation may not occur on the same day and can be delayed up to 5 days. A marked reduction in PM_{10} concentration in regions in the US has been associated with a 50% drop in hospital admissions of children for respiratory disease.[37,38] The estimated decrease was 7.1% in all respiratory admissions, with a 10 $\mu g/m^3$ decrease in PM_{10} levels. 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.[26] Furthermore, the combination of O_3 and acid sulphate may be more important than the effects of O_3 alone. In Germany, children aged 9 to 11 years living in areas with the greatest amount of urban traffic had significantly poorer lung function than those living in areas with less traffic.[27]

Asthma and allergies

Air pollution is known to be associated with acute asthma exacerbation.[26,27,33-35] The relationship is strongest with particles and O_3; the higher the pollution, the higher the number of asthma patients with acute

Table 1. Percentage increase in adverse health effect with each 10 $\mu g/m^3$ increase in PM_{10}

Health effect	References	Increase (%)	Hong Kong data[25] (% increase)
Respiratory symptoms			
cough	24	1.2	-
lower respiratory tract symptoms	24	3.0	-
upper respiratory tract symptoms	24	0.7	-
Asthma attack	24	3.0	-
Bronchodilator use	24	2.9	-
Health care utilisation			
all respiratory disease admissions	24	0.8	1.6
admissions for asthma	24	1.9	1.5
emergency department visits for asthma	26-29	1.0	-
admissions for cardiovascular disease	30	-	0.6
Mortality			
total mortality	31	1.0	-
respiratory mortality	31	3.4	-
cardiovascular mortality	31	1.4	-

exacerbation. There has been a general increase throughout the industrialised world in the prevalence of asthma and allergies in children.[28] The reason for this increase is not known and there is no clear evidence that air pollution is causally related. However, there are now several experimental studies showing that diesel particles, SO_2, and O_3 can act as an adjuvants, which enhance the production of immunoglobulin E antibodies and possibly increase the prevalence of atopic sensitisation and asthma.[29,39,40]

Cancer

Known or suspected carcinogens, such as benzene and other polycyclic aromatic hydrocarbons, are detectable in vehicle emissions. Attempts have been made to quantify the cancer risk from vehicle emissions. In Austria, a level of diesel particles of 5 to 23 $\mu g/m^3$ in the atmosphere has been estimated to yield 1 to 2.6 additional cases of lung cancer per 100 000 persons per year.[41] Other studies have shown a significantly increased mortality risk ratio for lung cancer of 1.36 (95% confidence interval, 1.11-1.66) for an increase of approximately 20 $\mu g/m^3$ sulphate particles.[37,38,42] It should be pointed out that quantitative assessment of risks from epidemiological data alone is difficult. Even well-performed quantitative risk assessment is based on assumptions. Furthermore, there are multiple confounding factors, such as individual susceptibility to exposure and exposure to cigarette smoke. Nevertheless, the fact that these studies have demonstrated a relationship between air pollution levels and cancer mortality provides grounds for concern that air pollution may increase the risks of lung cancer.

Respiratory symptoms

A greater frequency of wheezing has been observed among children aged 9 to 11 years living in areas with the highest flow of urban traffic in Munich, Germany.[27] Another study in Germany has found a significantly higher prevalence of asthma-like symptoms and allergic rhinitis in children aged 12 to 15 years living near busy roads, especially roads with a high density of trucks.[43] Studies from the US,[31,44] Netherlands,[45,46] and Switzerland[47] have demonstrated an increase in upper (runny nose, sore throat, head cold, and sinusitis) and lower (wheezing, dry cough, phlegm, and shortness of breath) respiratory tract symptoms with increased air pollution.

Health studies in Hong Kong

There have been several health studies on air pollution and health performed in Hong Kong since 1989. As these studies have been reviewed thoroughly by the Sub-Working Group on the Review of Hong Kong's Air Quality Objectives,[48] the results will be described only in brief below.

A 1989 study[49] compared respiratory morbidity among school children living in a heavily polluted district with those living in a less polluted area. These children were similar in terms of age, gender, socioeconomic status, atopic status, and parental smoking. The prevalence of sore throat, cough, and wheeze was found to be significantly higher among children living in the more polluted district. When legislation was implemented to reduce fuel sulphur levels in 1990, there was a significant reduction in SO_2 and sulphate concentrations in respirable particles. This reduction in pollution was associated with a significant reduction of respiratory symptoms, especially among those living in the more polluted district.[50] Moreover, children living in the more polluted district had a significantly higher prevalence of non-specific airway hyperresponsiveness compared with those living in the less polluted district.[51] The degree of airway hyperresponsiveness decreased in children living in the polluted areas after the introduction of the fuel legislation in 1990.[52] A study of hospital admissions for all respiratory diseases, all cardiovascular diseases, chronic obstructive pulmonary disease, and heart failure in 1994 to 1995 in Hong Kong showed a significant association with concentrations of all four pollutants, with a time lag of 0 to 5 days.[25] Thus, the findings of local studies of the health effects from air pollution agree with those in other parts of the world.

Magnitude of adverse health effects

Table 1 shows the percentage increase in adverse health effects with each 10 $\mu g/m^3$ increase in the PM_{10} level. The magnitude of the increase in health care utilisation in Hong Kong for each increment in the PM_{10} level is similar to those reported in other countries. The increase in the PM_{10} level can be 100 $\mu g/m^3$ above the usual level during a bad episode of air pollution. The percentage increase in hospital admissions in Hong Kong in such a situation would be 16% for all respiratory illnesses and 15% for asthma, based on local data. Because respiratory and cardiovascular diseases account for the majority of hospital admissions, this increase would be considerable. As there is usually a time lag of up to 5 days, the increase in health care utilisation might not be immediately evident.

The Sub-Working Group on the Review of Hong Kong's Air Quality Objectives has estimated the number of avoidable hospital admissions and deaths on removal of 30% of the highest levels of pollutants, assuming that the maximum of the separate effects of each pollutant apply.[48] Using data from The University of Hong Kong for 1996, 1596 to 2218 hospital admissions and 217 to 239 deaths from respiratory and cardiovascular diseases would be avoided each year. Using data from The Chinese University of Hong Kong for 1994 to 1995, there would be 1349 to 2072 avoidable hospital admissions each year. It should be noted that deaths and hospital admissions are only the 'tip of the iceberg' of adverse health effects. Below the 'tip of the iceberg' are visits to emergency departments for treatment of respiratory and cardiovascular diseases, unscheduled doctor visits, increases in drug treatment for the acute exacerbation of asthma or chronic obstructive lung disease, loss of productivity due to absence from work, and impaired quality of life. All these factors should be taken into consideration when calculating the direct and indirect cost of air pollution to health.

Deficiencies in knowledge

There remain some gaps in our knowledge on air pollution and health. Firstly, although acute and chronic effects of air pollutants have been studied, it is not known which specific air pollutant is responsible for adverse health effects, or how the pollutants interact with each other and with other factors such as allergens, diet, and housing. Secondly, there have not been adequate studies making use of personal monitoring to quantify the total dose received by individuals in their daily lives. Thirdly, 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. Fourthly, the effects of long-term exposure on the development of asthma, allergies, and lung cancer are unknown. Finally, a better understanding is needed of the biological mechanism(s) through which air pollutants may lead to mortality.

Air quality guidelines

Guidelines of the World Health Organization

The 1987 WHO air quality guidelines for Europe were based on evidence from epidemiological and toxicological literature published in Europe and North America.[30] In view of the different conditions in developing countries, the WHO revised these guidelines in 1999.[1] The objective of the 1999 guidelines was to help countries derive their own national air quality standards and help protect human health from air pollution. The WHO 1999 guidelines are technologically feasible and have considered socio-economic and cultural constraints.

Since 1987, a new database of time-series studies has become available. These studies relate the daily occurrence of events such as deaths and hospital admissions to daily average concentrations of pollutants,

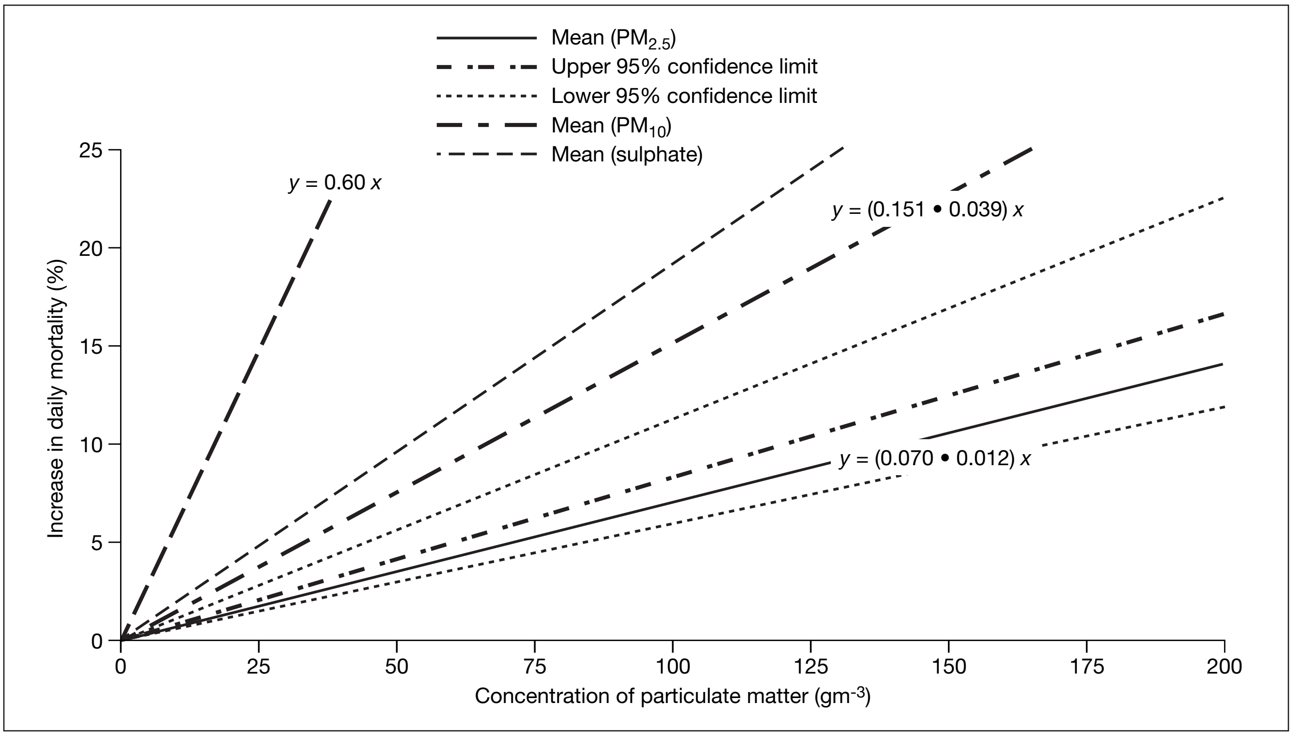

Fig 1. Percentage increase in daily mortality as a function of particle concentration[1]

while taking into account confounding factors such as season, temperature, and day of the week. Using powerful statistical techniques, coefficients have been produced, which relate daily average concentrations of pollutants to effects. The results of these studies have been remarkably consistent, demonstrating associations between daily average concentrations of particulates, O_3, SO_2, and NO_2, and health outcomes. An important finding is that these studies fail to show any threshold effect for particles and O_3, because very low concentrations of these pollutants are already associated with health outcomes. Thus, the 'guideline' is a relationship that relates events to airborne concentrations. This concept represents an important departure from the one of a guideline value where the 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 a summary estimate of the relative increase in daily mortality as a function of the concentration of particulate matter. Estimates for morbidity are also available.[1] These data allow the estimation, with caution, of how many subjects would be affected over a short period of time with increased levels of particulate matter, for a population of a given size and for known mortality and morbidity characteristics. When deriving an air quality standard for PM_{10} or $PM_{2.5}$, it has to be decided which curve should be used and what level of risk is considered to be acceptable. Table 2 shows the ambient air quality standards/guidelines for key air pollutants in Hong Kong, some member regions of the Association of South-East Asian Nations, the US, and the WHO.[53,54] It can be seen that most places have yet to change guidelines regarding respirable suspended particulates, as suggested by the WHO. It should be pointed out that the determination of air quality objectives of various pollutants is based mainly on the health effects of acute exposure. There are no data on the health consequences of long-term low-level exposure, exposure to short-term peaks, and possible synergism among pollutants. There are also no data on the possibility of lower level pollutants inducing genetic mutations, birth defects, and cancer.

Air quality objectives in Hong Kong

One of the aims of the Sub-Working Group on the Review of Hong Kong's Air Quality Objectives was to

Table 2. Ambient air quality standards/guidelines for Hong Kong, the United States, the World Health Organization, and some member regions of the Association of South-East Asian Nations[53]

Pollutant	Averaging time	Hong Kong	Thailand	Indonesia*	Philippines	Singapore	United States[54]	WHO†
SO_2 (μg/m³)	10 min	-	-	-	-	-	-	500
	1 h	800	-	900	850	-	-	-
	24 h	350	300	300	370	365	365	125
	annual	80	100	60	-	80	80	50
NO_2 (μg/m³)	30 min	-	-	-	300	-	-	-
	1 h	300	320	-	-	-	-	200
	annual	90	-	100	-	100	100	40
CO (mg/m³)	15 min	-	-	-	-	-	-	100
	30 min	-	-	-	-	-	-	60
	1 h	30	50	30	35	40	40	30
	8 h	10	20	10	10	10	10	10
O_3 (μg/m³)	30 min	-	-	-	200	-	-	-
	1 h	240	200	160	-	235	-	-
	8 h	-	-	-	-	-	157	120
Suspended matter (μg/m³)	24 h	260	330	230	180	260	-	-
	annual	80	100	90	-	75	-	-
Particulates <10 μm (PM_{10})† [μg/m³]	24 h	180	-	-	-	-	150	No guideline value (impact relationship)
	annual	55	-	-	-	-	50	
Particulates <2.5 μm ($PM_{2.5}$)† [μg/m³]	24 h	-	-	-	-	-	65	No guideline value (impact relationship)
	annual	-	-	-	-	-	15	
Lead	24 h	-	10	2	-	-	-	-
	3 months	1.5	-	-	20	1.5	1.5	-
	annual	-	-	-	-	-	-	0.5

* Draft standards

† Currently, the US Environmental Protection Agency has a standard for PM_{10} of 50 μg/m³ (annual average) and 150 μg/m³ for a 24-hour average; for $PM_{2.5}$, the annual and 24-hour standards are 15 and 65 μg/m³, respectively. In its most recent revision of the air quality guidelines, the WHO elected not to set a threshold value, but instead derived a linear relationship between PM_{10} or $PM_{2.5}$ concentrations and various health impacts.[1] 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/region to manage particulate air pollution by assessing the health effects associated with different levels of particulate matter

review the evidence available from Hong Kong studies on pollution and health, with a view to assessing the appropriateness of the current air quality objectives.[48] In the report published in July 1999, the members of the working group concluded the following:

(1) In line with other overseas findings, studies from Hong Kong also show that there appears to be no safe level of human exposure to SO_2, respirable suspended particulates, NO_2, and O_3—at least at the levels commonly experienced in most urban environments;
(2) Excess health risks were noted even on days when the levels of SO_2, respirable suspended particulates, NO_2, and O_3, were below the current set of air quality objectives. Hence, the current set of air quality objectives for these four pollutants are insufficient for the protection of public heath; and
(3) Achieving compliance with lower objective limits of air quality for the four pollutants would provide further protection to public health. This benefit is illustrated by estimating gains in the health of young children and in avoidable hospital admissions and hospital deaths due to respiratory and circulatory diseases.

Trends in air pollution exposure

In most of the cities of western Europe, measures to reduce air pollution levels, such as the regulation of fuel for domestic heating (low sulphur content in oil and coal, and the introduction of natural gas), the building of high chimney stacks for industrial emissions, the introduction of filtering techniques, and the reduction of lead content in petrol, have resulted in a major reduction in levels of SO_2 and lead. In most cites, the annual mean concentrations of SO_2 in residential areas have not exceeded 50 $\mu g/m^3$. Notable exceptions are several cities in China: SO_2 concentrations in 1994 were 330 $\mu g/m^3$ in Chongqing and 100 $\mu g/m^3$ in Beijing.[1] Mexico City has experienced the most dramatic reduction of air pollution, from SO_2 levels between 100 and 140 mg/m^3 in 1990/1991 to levels between 32 and 37 $\mu g/m^3$ in 1995/1996.[1] However, there have been no comparable downward trends in NO_2 concentrations. In fact, in many cities, NO_2 levels have increased since 1960, mainly because of emissions from vehicles.[1] In Europe, road transport contributes up to half of NO_2 emissions.

Diesel vehicles produce much higher emissions of the smallest particles (ultrafine particles that are smaller than 0.1 μm in diameter) than do gasoline-fuelled vehicles. Ultrafine particles have been shown to produce acute inflammatory responses in animal studies,[55] but the human epidemiological data are not conclusive regarding the relative toxicity of ultrafine particles versus particles of other sizes. Diesel vehicles not only produce more particle mass, but they also may produce substantially more of the toxic types of particles. They also have traces of adsorbed polycyclic aromatic hydrocarbon, which create potential problems that have not been well studied.[56]

Trends in air pollution in Hong Kong

The trends in air pollution in Hong Kong are similar to those in other countries. The most important achievement has been the reduction in SO_2 levels after the implementation of government fuel regulations that restrict the sulphur content of fuels to 0.5%. Sulphur dioxide levels have fallen in many districts, and the levels of respirable suspended particulates have also been reduced slightly in some areas (Fig 2).[57]

Since 1991, the annual mean roadside measurements of respirable suspended particulates and NO_2 have progressively increased (Fig 2) and exceeded the 1-year air quality objectives that have been recently set by the Environment Protection Department.[57] The 24-hour or 1-hour measurements have exceeded the air quality objectives many times each year. Thus, the findings in Hong Kong are similar to many of the major cities around the world. Among 36 major cities in the world in 1998, Hong Kong ranked 9th and 15th for the worst levels of respirable suspended particulates and NO_2 pollution, respectively; Singapore ranked 21st and 30th. Of special concern in Hong Kong is the emission of fine particles from diesel vehicles, which are responsible for 79% of the total mileage travelled on the roads.[48]

Conclusion

In Hong Kong, levels of particulates, NO_2, and O_3 are high. The annual means of these pollutants measured by the roadside have exceeded the air quality objectives set by the Environmental Protection Department. In terms of health, local data have indicated that even below the air quality objectives, significant health effects can be detected. It is important that there should be a concerted effort by the medical profession to express concern about the health effects of air pollution and to call for action to reduce the current concentrations of air pollution to an acceptable level.

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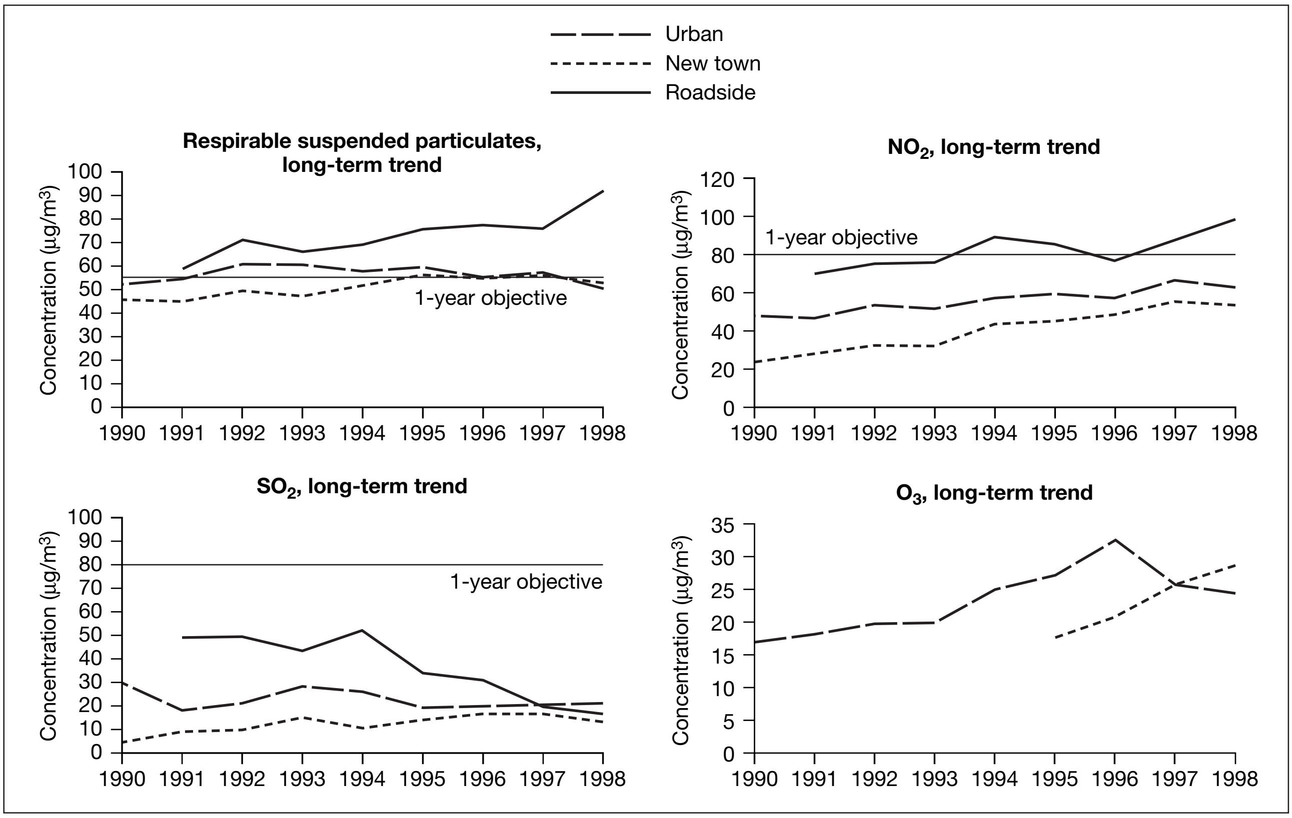

Fig 2. Long-term trends of levels of respirable suspended particulates, NO_2, SO_2, and O_3 in Hong Kong, 1990 to 1998[57]

Table 2 and very useful comments, which have been incorporated into the text, and Mr P Ho of the Environmental Protection Department for providing the air pollution data for Hong Kong.

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