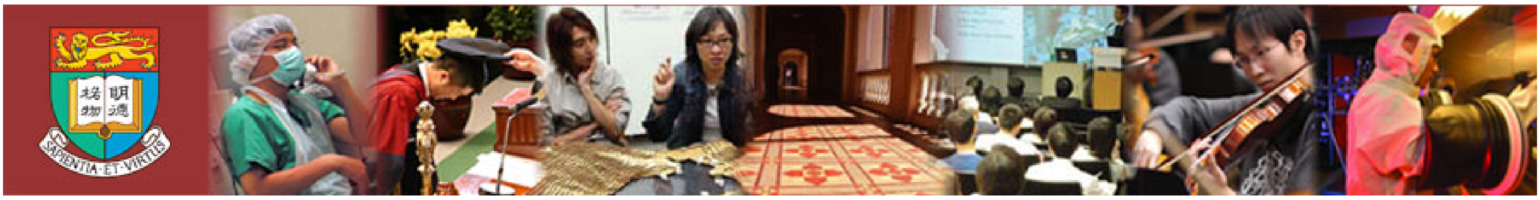

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Air quality as a public health problem in Hong Kong: measuring the risks

J. Peters and A. J. Hedley

Abstract

Hong Kong has an air quality problem with excess levels of such air pollutants as sulphur dioxide, nitrogen oxides, particulates and ozone, occurring from time to time throughout the year. This paper outlines the sources of the major pollutants in Hong Kong, both natural and man-made, and examines the health risks to the Hong Kong population from exposure to such pollutants. The principle man-made sources of these pollutants are mainly diesel vehicle emissions, and high sulphur content fuels burnt in industrial furnaces and power plants. There is concern over levels of these pollutants in ambient air because of their relationship with respiratory health problems, which range from local irritation of the respiratory tract to carcinogenesis. Studies in Hong Kong also demonstrate the importance of environmental tobacco smoke in the home as a cause of children's respiratory health problems, in addition to poor air quality. Epidemiological studies are useful tools for identifying risks and for evaluating the effectiveness of preventive measures, including legislation. In particular we need to identify health risks to young children and the preventable fraction likely to be achieved from different interventions. For optimum effectiveness, a multisectoral approach, developed between regulatory agencies, pubic health authorities and research groups, is needed to contribute to the overall respiratory health of the community.

Keywords: Air pollution; Health risk

Introduction

People need a continuing supply of food, air and water in order to exist, but they need uncontaminated food, pollutant-free air and clean water if they are to remain alive and healthy. Assorted chemicals are emitted into the air from both natural and man-made sources and many of these are potentially detrimental to health. The impact of air pollution is broad, ranging from the direct clinical manifestations resulting from the inhalation of chemicals by an individual to contamination of the biosphere which affects the health of whole populations.

Air quality in Hong Kong

Hong Kong, like a number of other cities in South-east Asia, such as Bangkok, Manila and Tokyo, and cities in China and eastern Europe, has an air quality problem. Recognition of the problem resulted in the declaration of the first two air pollution control zones in 1986, followed by the Statement of Air Quality Objectives (AQO) for these two zones, which came into effect in 1987. At the end of 1992, Hong Kong had thirteen air quality monitoring stations, with one more in the process of being set up[1] (Fig 1).

To safeguard the health and well-being of the population AQOs have been established for seven urban air pollutants: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), total suspended particulates (TSP), respirable suspended particulates (RSP) and lead.[1] Acceptable permissible levels of these air pollutants both in the short term (i.e. within one hour), and in the long term (a period of one year) have been specified (Table 1). These levels are for individual pollutants considered in isolation, but some combinations of these chemicals in ambient air can have additive, synergistic or antagonistic effects on health. Exceedences of these AQOs are, unfortunately, not uncommon although there has been some considerable improvement in

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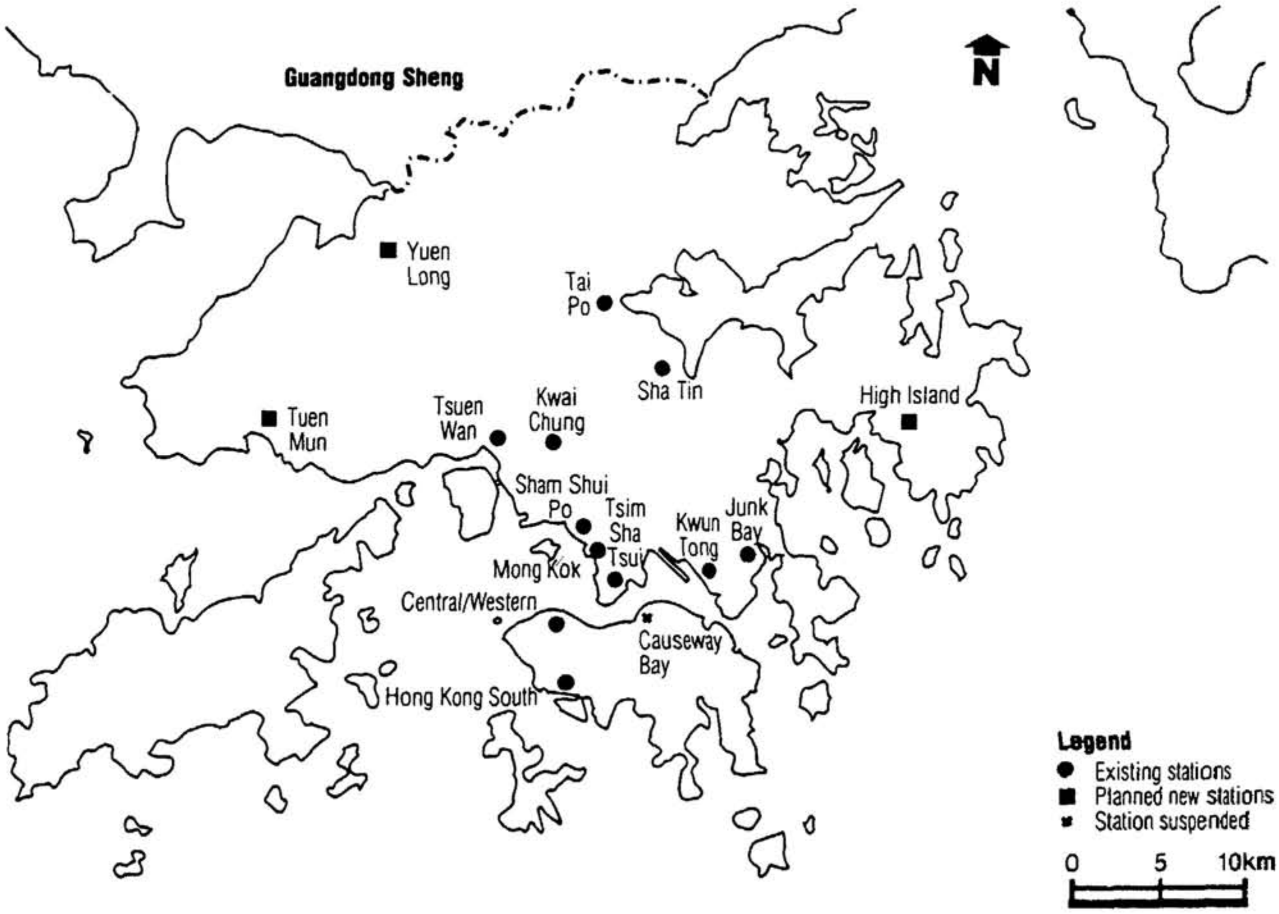

Fig.1. Air quality monitoring stations in Hong Kong, 1991 (Source: EPD, 1992)

***Table 1.* Air quality objectives for air pollutants in Hong Kong (Source: EPD 1992)**

Pollutant	Concentration in micrograms per cubic metre (i) averaging time				
	1 hr (ii)	8 hrs (iii)	24 hrs (iii)	3 months (iv)	1 year (iv)
Sulphur dioxide	800		350		80
Total suspended particulates (v)			260		80
Respirable suspended particulates (v)			180		55
Nitrogen dioxide	300	150	80		
Carbon monoxide	30000	10000			
Photochemical oxidants (as ozone) (vi)	240				
Lead				1.5	

(i) Measured at 298°K (25°C) and 101.325 kPa (one atmosphere).
(ii) Not to be exceeded more than three times per year.
(iii) Not to be exceeded more than once per year.
(iv) Arithmetic means.
(v) Respirable suspended particulates means suspended particles in air with a nominal aerodynamic diameter of 10 micrometres and smaller.
(vi) Photochemical oxidants are determined by measurement of ozone only.

the last two years. Between 1988 and 1991 at the monitoring stations functioning during this period, maximum daily pollution concentrations exceeded AQO concentrations on 38 occasions in 1988, 36 in 1989, 12 in 1990 but only 4 in 1991.[1-4] SO_2 levels fell dramatically (by 84%) after the enactment of the Air Pollution Control (Fuel Restriction) Regulations in July 1990. TSP and RSP levels also fell by 19% and 23% respectively.[1] This exceedence of AQOs is not just a problem for Hong Kong; between 1981 and 1985, Beijing's mean concentrations of both TSP and SO_2 also exceeded WHO recommended limits.[5] Finally, although objectives have been set, there is still a problem of determining concentrations of these pollutants below which no significant health effect occurs.

Many people are concerned about the effects of the environment upon their health. In 1991, the EPD received 6,480 complaints about pollution of the environment, 2,578 of these (40% of all complaints received that year) were related to air pollution. A similar number, 2,634, were received in 1990 although this was only 30% of the total. In addition, the number of complaints relating to vehicular emissions increased from 767 in 1990 to 1,161 in 1991.[1,4] However, in a study on health perceptions of members of the general population, carried out by telephone questionnaire in 1990, only 4% stated that a change in the 'environment' would allow them to enjoy better health.[6]

The pollutants

Particulates

Airborne particulates are a complex mixture of organic and inorganic substances and are defined according to their size and composition. Large particles, those above 100 μm in diameter, tend to settle out and produce dust but particles smaller than 100 μm remain suspended in air, giving rise to the fraction TSP. Particulates smaller than 10 μm in diameter are known as RSP and these are further subdivided into: coarse particulates, 2.5 to 10 μm in diameter, such as those producing black diesel smoke and dust; fine particulates, less than 2.5 μm in diameter, which contain secondarily formed aerosols, combustion particles, recondensed organic and metallic vapours. Particulates of 0.1 to 1 μm in diameter are responsible for visibility-reducing hazes.

In general, the main sources of particulates are natural and include volcanic activity, salt aerosol from the sea, soil blow off, pollen grains, fungal spores, and other organic matter. With no area of Hong Kong being more than 2 km from the sea, salt spray is a major source of particulates in Hong Kong. However, human activities in construction, mining, earth moving and use of carbon-based fuels, especially from motor vehicles, contribute considerably to airborne particulate levels. In Hong Kong, in 1991, motor vehicles contributed 51% of the overall emissions of TSP, with diesel vehicles emitting 98% of these.[1] In addition, in places where leaded fuel is still used, and Hong Kong is one of these, lead particulates produced by the combustion of alkyl lead, an additive in petrol, contribute 89 to 90% of all lead emissions in the atmosphere. Other major products of vehicle combustion include hydrocarbons.

Sulphur dioxide (SO_2)

The major source of SO_2 in air is man-made: from the burning of high sulphur content fuels (coal, oil) in industrial furnaces and power plants (for energy generation) and in motor vehicle combustion (primarily diesel powered). SO_2 in the presence of certain metal catalysts and cold moist air forms sulphuric acid and under certain weather conditions, particulates and SO_2 give risk to industrial or winter-type smogs.

Nitrogen dioxide (NO_2)

The major sources of nitrogen oxides are natural and include bacterial and volcanic action and lightning. Man-made emissions are from the combustion of fossil fuels in power plants, gas-fuelled appliances (e.g. domestic cookers and heaters, oil stoves) and motor vehicles, primarily diesel powered ones. Last year, vehicles in Hong Kong were responsible for 75% of NO_2 levels, with diesel vehicles producing 82% of this.[1]

Carbon monoxide (CO)

This is produced from the incomplete combustion of carbon containing materials and in some industrial and biological processes. Total emissions of CO to the atmosphere equal or exceed those of all other pollutants combined.[7] Petrol-fuelled vehicles are a major source of CO. Indoor CO sources include unvented combustion appliances, such as water heaters.

Ozone (O_3)

Ozone is produced, at ground level, from the atmospheric reaction of hydrocarbons and nitrogen oxides (mainly from vehicle exhaust emissions) stimulated by the action of sunlight. It is one of the more biologically active pollutants in photochemical smogs. These smogs are common in summer in places which have sunny climates and high levels of dense traffic, e.g. Los Angeles, Athens, and Sydney, although both industrial and photochemical smogs can co-exist in a given area at the same time. Ozone exposures in summer-type episodes usually follow a typical diurnal pattern with peak concentration in the afternoon and low levels during the night and early morning. Ozone also plays an important role in accelerating the photochemical conversion of SO_2 into sulphuric acid in sunny conditions in the presence of nitrogen oxides and hydrocarbons.

Factors affecting pollutant levels

Ambient pollutant levels are affected by rainfall, wind speeds and currents, atmospheric inversion, and human activities. Low wind velocities hinder horizontal dispersion and high pressure and temperature inversions limit vertical dispersion. Local geographical features are also a contributor. Hong Kong's weather patterns result in elevated levels of pollutants in the winter months because of reduced rain and wind and increased build up of inversion layers in the atmosphere.

Health risks

Air pollutant effects

Concern over levels of pollutants arises because of the adverse health effects demonstrated both directly on the airways and indirectly, by their presence in ambient air. Most individuals will react with significant symptoms to the challenge of large amounts of dust, high levels of water-soluble gases, e.g. SO_2, or extreme temperature changes. The symptoms produced include nasal irritation, sneezing, moderate discharge and some mucosal congestion.[8]

All of these air pollutants not only constitute independent risks, they also act synergistically with other factors. For example, gaseous acid pollutants can be adsorbed onto the surface of particulates and carried into the lungs. It is difficult to distinguish the effects of individual pollutants upon health, but collectively an increased risk of respiratory symptoms has been demonstrated among young children living in a city with high levels of air pollutants,[9] and a correlation exists between increased hospital admissions for asthma and exposure to any of the several major air pollutants.[10] As further confirmatory evidence of the ill effects of air pollutants upon health, lung function has been shown to improve following a sustained reduction in air pollution levels.[11]

Particulates

Particulates are inhaled into the respiratory system and depending upon size, penetrate to a greater or lesser extent as far as the lower respiratory tract (TSP) and into the alveoli (RSP). In normal breathing, particulates larger than 10 μm are deposited in the proximity of the glottis, 2 to 10 μm in the bronchioles, and smaller than 2 μm in the alveoli, although mouth breathing, as in exercise or when speaking, produces greater deposition of larger particles in the bronchioles. Materials that dissolve the mucus of the airways or the surfactant layer in the alveolar region diffuse into the underlying epithelia and blood stream, thereby gaining access to other body tissues where they may cause chronic damage, e.g. in the liver, spleen, kidneys. In addition, any particulates carried by ciliary action up out of the upper respiratory tract may be swallowed and pass into the body via the gastrointestinal tract.

The effects of particulates on respiratory health are both short and long term. In children, they cause local irritation, with cough, bronchitis and chest illness[12,13] and higher admissions to hospital for bronchitis and asthma in pre-school children.[14] High levels of TSPs are associated with increased mortality.[15] Pulmonary changes include reduced lung function in both children and adults.[16,17]

Some particulates have specific effects on the body, e.g. lead. Thirty to 50% of inhaled lead particulates are ultimately absorbed by the body and pass into the blood stream. High levels of lead in blood can result in reduced haem synthesis in adults and children[7] and have been shown to reduce children's IQ by 4.4 points.[18]

In addition, some other specific particulates are probably or possibly carcinogenic; the sources include diesel and petroleum exhausts (lung,[19,20] bladder[20]), chromium dust (lung), and asbestos (lung cancer, mesothelioma).

Sulphur dioxide

SO_2 is a respiratory irritant. An increased prevalence of pneumonia, asthma and respiratory infections in the first two years of life has been found in children living in areas with higher levels of SO_2.[21] In addition, increased levels of SO_2 are associated with increased mortality,[21] specifically respiratory deaths[22] and a reduction in SO_2 and an improvement in ambient air quality has been followed by a subsequent decline in mortality figures.[23]

Observed effects of winter-type smog (primarily SO_2 and particulates) include transient changes in pulmonary function, increased morbidity among chronic bronchitics, increased hospital admissions due to respiratory and cardiovascular conditions and depending upon the severity and nature of the exposure, an increase in mortality,[24] as demonstrated in the London smog of 1952.[25]

Nitrogen dioxide

Exposure to NO_2 is associated with reduced pulmonary function[26, 27] but it has proved difficult to determine respiratory effects from the low levels of NO_2 which exist in ambient air. Therefore a number of studies have considered the respiratory health effects from exposure to higher levels of NO_2 which exist inside buildings, where combustion of fossil fuels occurs, e.g. use of gas appliances. The effects on respiratory health of indoor levels of NO_2 have produced conflicting results ranging from no health effects[28, 29] to increased prevalence of respiratory symptoms and respiratory illness in children.[30]

Carbon monoxide

Health effects associated with CO include decreased physical performance, increased angina attacks in angina sufferers, diminution of visual perception, manual dexterity, ability to learn and perform sensorimotor tasks.[31]

Ozone

This is the main source of the health effects of summer type smogs which cause irritation of the eyes and chest discomfort,[32] increased bronchial reactivity[33] and impaired lung function.[34]

Indoor air pollutants

The air pollutants already discussed can be found both outside and within a building. There are a number of additional gaseous irritants which are predominantly present indoors. These include volatile organic compounds such as epoxy-resins, formaldehydes, benzene, solvents, radon, and tobacco smoke. Symptoms associated with these pollutants include headaches, drowsiness, nausea, eye and upper respiratory tract irritation, dizziness, skin itching and eruption, difficulty with breathing, and sinus congestion.[35] Also present in indoor air are biological agents including viruses, bacteria, fungal spores, animal dander, and arthropod droppings, all of which may act as allergens and promote a respiratory response. A study of the air quality in street level shops and offices in Hong Kong found levels of CO, RSP, and CO_2 which exceeded the AQOs and may be a hazard to health.[36]

However, in many domestic and commercial premises the most important source of indoor air pollution is environmental tobacco smoke (ETS). Sidestream smoke produces one hundred times as many toxic compounds as main stream smoke. These include CO, acrolein, ammonia, nitroamines, naphthylamine, cadmium, nickel, and polonium. The detrimental health effects of ETS, which have been comprehensively reviewed recently,[37] include: cancer of the lung in adults; and in children, increased risk of lower respiratory tract infections, such as bronchitis and pneumonia, increased prevalence of fluid in the middle ear, respiratory tract irritation, a reduction of lung function, and increased severity of symptoms in asthmatics besides being a risk factor for asthma.

Long-term effects

If respiratory health is compromised in childhood, the effects have been shown to continue into adulthood.[38, 39]

Acid rain

The above are the direct effects on health, mainly respiratory health, of these air pollutants but that is not the whole story. Sulphur dioxide, nitrogen oxides and other substances react with water and sunlight to form acid rain which causes extensive damage to foliage, including that of crops, and acidification of freshwater lakes, resulting in the death of fauna present. The outcome of acid rain therefore may be famine and malnutrition. In addition the destruction of the habitat of many animal species may result in breaks in the food chain and possible loss of a number of species for ever.

Global warming

Increased levels of so-called greenhouse gases, carbon dioxide, methane, nitrous oxide, chlorofluorocarbons lead to global warming. Results of this are predicted to produce polar ice melting and expansion of sea waters resulting in a rise in sea level and flooding of low-lying land, much of which is used for crop growing. In addition, current local patterns of disease may be changed with increased environmental temperatures resulting in tropical diseases becoming more widespread, even in current temperate zones of the world.[40]

Air pollution and health in Hong Kong

A study of government outpatient department clinics in 1991 found that the most common cause of visits to the clinics (66%) was for respiratory complaints.[41] A study of respiratory health and air pollution was carried out by the Departments of Community Medicine and Paediatrics, The University of Hong Kong between 1989 and 1992.[42, 43] Respiratory health of primary school children and their parents, living in two districts of Hong Kong with differing air quality, Kwai Tsing and Southern, was examined by self-completed questionnaires based on validated international instruments. In addition, information was collected on the general health of the parents, smoking practices

Table 2. Adjusted odds ratios (95% CI) for respiratory symptoms in 1989 in children associated with (a) living in Kwai Tsing, and (b) living in a smoking family

Symptoms	Living in Kwai Tsing	Living in a smoking family: With 1 smoker	Living in a smoking family: With 2 or more
Morning cough	1.18 (0.87, 1.61)	0.99 (0.75, 1.31)	1.66 (1.21, 2.28)
Evening cough	1.26 (0.96, 1.65)	1.11 (0.84, 1.45)	1.78 (1.23, 2.56)
Cough for 3 months	1.78 (1.21, 2.63)	1.49 (1.02, 2.16)	1.74 (0.96, 3.15)
Morning phlegm	1.25 (0.96, 1.63)	1.12 (0.90, 1.38)	1.52 (1.14, 2.03)
Phlegm day or night	0.94 (0.71, 1.25)	1.29 (1.02, 1.64)	1.81 (1.24, 2.64)
Phelgm for 3 months	1.43 (0.94, 2.20)	1.57 (1.09, 2.26)	1.66 (0.95, 2.88)
Sore throat	1.53 (1.11, 2.11)	1.20 (0.89, 1.62)	1.68 (1.10, 2.57)
Blocked nose	1.20 (1.00, 1.43)	1.03 (0.86, 1.23)	1.41 (1.09, 1.82)
Wheezing	1.51 (1.17, 1.94)	1.20 (0.93, 1.54)	1.17 (0.80, 1.72)

of family members and children, sociodemographic data and opinion of the air quality in the home and school attended. Twenty seven schools took part in the study and 12,500 children in total, from primary three to six grades, have participated over the four years. More than two thousand of these children have been measured every year for the four years of the study. In addition, with the exception of the first year of the study, a histamine challenge test has been administered to a subgroup of children from eight schools (four in each district) and one class in each of primary four, five and six.

The results of the first year of the study in 1989, showed that after adjustment for differences in sociodemographic factors between the two districts, including type and size of housing, size of family, parental education level attained, parental occupational status, type of fuel used for cooking and heating, the burning of incense and mosquito coils in the home, and family smoking habits, there was an excess risk to respiratory health for children living in Kwai Tsing indicated by the adjusted odds ratios (OR) for children's respiratory symptoms (Table 2). The excess risk ({OR − 1} x 100%) to children, associated with living in Kwai Tsing, ranged from 20% for blocked nose up to 78% for cough for three months. Overall, assuming that 100% of children in Kwai Tsing are exposed to the air pollutants, we have estimated that the population attributable risk (or preventable fraction) in 1989 was at least 35%.

One major contaminant of indoor air quality is environmental tobacco smoke (ETS). The 1989 data from the same study found an excess risk, indicated by the adjusted odds ratios, for a range of respiratory symptoms if the children lived in a home where family members smoked; the association was particularly strong when smokers other than parents lodged in the house (Table 2). The excess risk to children's respiratory health associated with living with one smoker ranged from 29% for production of phlegm day or night to 57% for phlegm in the past three months. Living with two or more smokers in the home resulted in excess risks as high as 81% for phlegm day or night (Table 2).

Prevalence ratios for doctor consultations for complaints of cough, phlegm and wheeze by the children, in smoking and non-smoking families show a clear gradient between families with no smoking members and those in which there are two or more smokers. The pattern is especially clear among younger children. The increased risk is reflected in the odds ratios for different levels of smoking in the home, after adjustment for age, gender, parental education, housing type and district of residence (Table 3).[44]

It is expected that data from the last two years of the study, which are now being analysed, will provide some insight into the effects on health following the Territory's 1990 legislation banning the use of

Table 3. Adjusted odds ratios (95% CI) for doctor visits in 1991 and 1992 for respiratory symptoms associated with living in a smoking family

Symptoms	Smokers in home 1991: 1	Smokers in home 1991: 2 or more	Smokers in home 1992: 1	Smokers in home 1992: 2 or more
Cough	0.99 (0.85–1.15)	1.22 (0.97–1.53)	1.17 (1.04–1.33)	1.26 (1.06–1.51)
Phlegm	1.08 (0.86–1.35)	1.67 (1.23–2.26)	1.31 (1.09–1.59)	1.36 (1.04–1.77)

liquid fuels with a sulphur content of more than 0.5% by weight or of solid fuels with a sulphur content of more than 1% by weight.

The role of epidemiology

Epidemiological studies are useful tools for identifying areas of need and for evaluating the effectiveness of preventive measures, such as legislative control of air pollutants, on health. It is not easy to establish cause and effect relationships in the field of environmental pollutant impact upon health. Large scale well-planned epidemiological population studies are one tool which can be used to address this problem. To this end, they can collect evidence on factors/areas which are major causes of ill health thus helping to identify where effective interventions may be possible.

However, there are both practical and analytical problems in carrying out epidemiological studies on a sufficiently large scale to assess risk. First, practical problems include resource issues such as number of subjects required to take account of number of people exposed and variation in exposure levels, and gaining access to suitable subjects. A further problem which arises in the assessment of the detrimental effects of air pollution on health is that these effects may be masked in people who smoke or who are exposed to ETS. Second, analytical issues include the methodology employed to analyse the effects of air pollutants on health in population studies. Epidemiological studies are helping to provide evidence for health effects associated with exposure to air pollution in a population, although currently most of the studies originate in the West and in other areas of the world, where the pollution mix may be different. The consequent effects on health in response to pollutants in South-east Asia remains to be fully documented. All countries need a system of surveillance of both the levels of pollutants and their effects on health. Given this information, the preventable fraction of health problems can be targeted by the health professionals. To collect such information requires collaboration. A multisectoral approach is needed among regulatory agencies, such as the Environmental Protection Department, which collects and monitors air quality in the territory, public health physicians and other scientists from the Department of Health who collect and monitor health status in the community, and academic research units, which can contribute the epidemiological expertise. In every case continual monitoring is needed to obtain good quality intelligence, to identify trends and to evaluate the effectiveness of any controls. Finally the last two steps in the chain of action are education, and legislation where necessary, to establish and enforce the practice of a sound air quality policy.

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