

A Research Project Report

A Study of Health Impact and Risk Assessment of Urban Air Pollution in the Klang Valley, Malaysia

Submitted to

**Western Pacific Regional Office
The World Health Organization
Manila, The Philippines**

Submitted by

**UKM Pakarunding Sdn. Bhd.
Universiti Kebangsaan Malaysia**

In Collaboration with

**Engineering Services Division
Ministry of Health Malaysia**

13 September, 2004

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The authors are solely responsible for the contents of this research report, which was funded by the World Health Organization with support from the Ministry of Health Malaysia, and managed by UKM Pakarunding Sdn Bhd of Universiti Kebangsaan Malaysia. This report does not necessarily reflect the views of the World Health Organization, Ministry of Health Malaysia, Universiti Kebangsaan Malaysia, nor the Government of Malaysia

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Jamal H.H., Pillay M.S., Zailina H., Shamsul B.S., Sinha K., Zaman Huri Z., Khew S.L., Mazrura S., Ambu S., Rahimah A. and Ruzita M.S. 2004. *A Study of Health Impact & Risk Assessment of Urban Air Pollution in Klang Valley, Malaysia*. Kuala Lumpur : UKM Pakarunding Sdn Bhd

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TABLE OF CONTENTS

	Page
Abstract	x
Chapter 1: Introduction	
1.1 The Earth's Atmosphere	1
1.2 Air pollution	1
1.3 Sources of Air Pollution in Malaysia	2
1.4 Malaysian Ambient Air Quality Guidelines	3
1.5 Study Justification	5
1.6 Study Objectives	5
Chapter 2: Literature Review	
2.1 Characteristics of Air Pollution	7
2.2 Air Quality in the Klang Valley	8
2.3 Health Effects of Air Pollutants	9
2.3.1 Respirable Particulate Matter (PM10)	9
2.3.2 Sulfur Dioxide	11
2.3.3 Nitrogen Oxide	12
2.3.4 Ozone	13
Chapter 3 : Study Methodology	
3.1 Study Area	15
3.2 Study Hospitals	15
3.3 Study Periods	16
3.4 Study Population	16
3.5 Study Sample	17
3.5.1 Hospital Morbidity Data	17
3.5.2 Hospital Mortality Data	18
3.5.3 Hospital Outpatient Data	18
3.6 Air Quality	19
3.7 Meteorological Data	20
3.8 Statistical Analyses	22
Chapter 4 : Results	
4.1 Meteorological Data	23
4.2 Air Quality Data	24
4.3 Hospital Morbidity Data	25
4.4 Hospital Mortality Data	28
Chapter 5 : Discussion	
5.1 Hospital Morbidity Data	90
5.1.1 Comparison between Air Pollutants	90
5.1.2 Comparison between Hospitals	92
5.2 Hospital Mortality Data	93
5.3 Conclusion	94
References	96

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Abstract

Aim : The main study objective was to determine the associations between mean daily concentrations of criteria air pollutants and the risks of respiratory and cardiovascular morbidity and mortality at hospitals in the Klang Valley.

Methodology : The study period was from 1 January 2000 to 31 December 2003. Four hospitals were selected. Hospital Kuala Lumpur and Hospital Selayang are public hospitals while Hospital Universiti Kebangsaan Malaysia and University Malaya Medical Centre are university hospitals. The study sample was all respiratory (J00-J99) and cardiovascular (I10-I99) disease cases based on the International Classification of Disease, Tenth Revision, who were admitted to (for morbidity data), or discharged as deceased from (for mortality data), the study hospitals during the study period. Air quality data on respirable particulate (PM₁₀), nitrogen dioxide (NO₂), sulphur dioxide (SO₂), carbon monoxide (CO) and ozone (O₃) were obtained from continuous air quality monitoring (CAQM) stations located nearest to the hospitals. Data on maximum temperature and rainfall were obtained from 4 closest meteorological stations. Poisson regression model was then used to model the daily counts of admissions and mortality for respiratory and cardiovascular disease cases as the dependent variables, while time, maximum temperature, rainfall and air pollutant concentrations act as the independent variables. This was done by age group (adults and children) and hospital. Relative risks (RR) for respiratory and cardiovascular morbidity and mortality were then estimated.

Results and Discussion : Of the 5 criteria air pollutants, PM₁₀ was the pollutant which exceeded its 24-hour Malaysian ambient air quality guideline (MAAQG) of 150 µg/m³ at all 3 CAQM stations. The RR outcomes associated with PM₁₀ increments seemed to be equally significant for both adults and children, as well as for respiratory and cardiovascular morbidity. The other pollutant which exceeded its 24-hour MAAQG of 0.06 ppm at 2 of the CAQM stations was NO₂. NO₂ clearly indicates the greatest impacts on respiratory and cardiovascular morbidity in this study. The RR outcomes associated with its increments seemed to be equally significant for both adults and children, as well as for respiratory and cardiovascular morbidity. Even though the maximum concentration recorded for SO₂ at 0.024 ppm was way below its 24-hour MAAQG of 0.04 ppm, significant RR outcomes associated with its increments were seen at 2 hospitals. Of the 5 air pollutants, only O₃ increments were associated with significant RR outcomes for respiratory and cardiovascular mortality.

Conclusion : The significant RR outcomes associated with PM₁₀ and CO increments were expected as these were consistent with previous studies. However, the dominantly significant RR outcomes associated with NO₂ increments call for further investigation, and the significant RR outcomes associated with very low SO concentrations is a concern. This study clearly demonstrates the effects of low level air pollution below the national guideline on respiratory and cardiovascular health.

Key words : Air pollutants, respiratory diseases, cardiovascular diseases, Malaysia.

CHAPTER I

INTRODUCTION

1.1 The Earth's Atmosphere

The earth's atmosphere is a mixture of gases which vary from trace levels to nitrogen, which comprises approximately 78 % of its mass and volume. This gaseous mixture may be characterized by those substances whose concentrations remain stable or constant over many millennia (Table 1.1) and those that vary daily, seasonally, or over the time course of human experience (Table 1.2) (Godish, 1997). Some of the gases listed in Table 1.2 like carbon monoxide, ozone, nitrogen dioxide and sulfur dioxide are regarded as air pollutants when present in excess amounts in the atmosphere.

1.2 Air Pollution

Air pollution is the presence of undesirable material in air, in quantities large enough to produce harmful effects. The undesirable materials may damage human health, vegetation, human property, or the global environment, as well as create aesthetic insults in the form of brown or hazy air or unpleasant smells (Nevers, 1995).

Air pollution occurs as a consequence of natural processes as well as human activity (anthropogenic). Examples of natural causes of air pollution include volcanic eruptions, forest fires and windblown dust. Anthropogenic air pollution from sources like motor vehicles and industries continues to be a serious problem. Its seriousness is due to the fact that elevated air pollutant levels from these anthropogenic sources tend to occur in environments where serious harm to human health and welfare is more likely, namely the more densely populated urban areas. The Klang Valley of Malaysia, which includes the largest city of Kuala Lumpur and the new capital city of Putrajaya, is one such area.

Table 1.1 : Atmospheric gases – constant concentrations.

Gas	Concentration (ppmv)
Nitrogen	780,840.00
Oxygen	209,460.00
Argon	9,340.00
Neon	18.18
Helium	5.24
Krypton	1.14
Hydrogen	0.50
Xenon	0.09

Source : Godish, 1997

Table 1.2 : Atmospheric gases – variable concentrations.

Gas	Concentration (ppmv)
Water vapor	0.1-30,000.00
Carbon dioxide	360.00
Methane	1.72
Nitrous oxide	0.33
Carbon monoxide	0.11
Ozone	0.02
Ammonia	0.004
Nitrogen dioxide	0.001
Sulfur dioxide	0.001
Nitric oxide	0.0005
Hydrogen sulfide	0.00005

Source : Godish, 1997

1.3 Sources of Air Pollution in Malaysia

In Malaysia, air pollution has been recognized as one of the major concerns that have high potential for deleterious effects on health (Jamal *et al.*, 1998; Jamal *et al.*, 1994; Juliana, 1998; Zailina, 1996; Zailina *et al.*, 1997). Increased urbanization, human activities and changing urban setting in the country as a result of development have resulted in elevated air pollution and the occurrence of urban heat islands.

The sources of air pollutants are both localized and transboundary. Localized sources are both mobile and stationary. Mobile sources are from private and public motor vehicles. These sources are especially significant in the Klang Valley. Stationary sources include power plants, industrial waste incinerators, cement plants, iron & steel mills from the industrial and suburban areas, the clearing and burning of old oil palm trees in plantations, emissions of dusts from urban constructions and quarries, and open burning at some solid waste dumpsites.

The four main local sources of air pollution in Malaysia in 2001 were vehicular emissions (89%) in the downtown areas with very high traffic volumes; power plants (9.2%) which are commonly located in the suburban areas; industrial processes (1.5%) such as cement plants, iron & steel mills from industrial zones; and open burning at solid waste dumpsites (0.3%). The large increase in the number of motor vehicles in Peninsular Malaysia from 7 million in 1994 to 11.3 million in 2001 is the main contributor of high particulate matter in congested industrial and urban areas (DOE, 2002).

Transboundary pollutants from neighboring countries such as Indonesia are fine particulate matter from forest fires during the dry seasons, especially between the months of August and November each year. This transported air pollution from forest fires has resulted in what is now commonly referred to as haze, not only in Malaysia but also in other countries in the region, including Singapore, Brunei Darussalam and Thailand. The worst of these recurring haze episodes was the one that prevailed over much of Southeast Asia in 1997. Widespread forest fires in Kalimantan and Sumatra were triggered by extremely dry weather brought about by the El Nino phenomenon. The Klang Valley and Kuching in Sarawak were among the worst hit areas in Malaysia. (Brauer and Jamal, 1998).

1.4 Malaysian Ambient Air Quality Guidelines

The Malaysian Ambient Air Quality Guidelines (MAAQG) prescribes ambient guidelines for 7 criteria air pollutants as shown by Table 1.3. In this study, 5 criteria pollutants were selected for assessment of their associations with patient morbidity and mortality, namely ozone, carbon monoxide, nitrogen dioxide, sulphur dioxide and

particulate matter (PM10). These 5 pollutants were selected because they tend to have the greatest impacts on human health, especially on respiratory and cardiovascular morbidity and mortality. These 5 pollutants are also used in the computation of the Air Pollutant Index (API).

Table 1.3 : Malaysian ambient air quality guidelines.

Pollutant	Averaging time	Malaysian guideline	
		ppm	ug/m ³
Total suspended particulate (TSP)	24 hour		260
	1 year		90
Particulate matter (PM10)	24 hour		150 [@]
	1 year		50
Nitrogen dioxide	1 hour	0.17	320
	24 hour	0.06	113 [@]
Sulphur dioxide	10 minutes	0.19	500
	1 hour	0.13	350
	24 hour	0.04	105 [@]
Carbon monoxide	1 hour	30	35 *
	8 hour	9	10 * [@]
Ozone	1 hour	0.10	200
	8 hour	0.06	120 [@]
Lead	3 months		1.5

* mg/m³, [@] API = 100

API : 0 - 50 (Good)
 51 - 100 (Moderate)
 101 - 200 (Unhealthy)
 201 - 300 (Very unhealthy)
 301 - 500 (Hazardous)

1.5 Study Justifications

Many studies internationally have shown good relationships between air pollution and morbidity (Linaker *et al.*, 2000; Lee *et al.*, 2002; Heinrich *et al.*, 2003) as well as mortality (Hong *et al.*, 2002; Katsouyanni *et al.*, 1997; Krzyzanowski *et al.*, 2002; Ware, 2000; Pope *et al.*, 2002). Morbidity is usually related to asthma (Lee *et al.*, 2002; Linaker *et al.*, 2000) and respiratory symptoms (Heinrich *et al.*, 2003). Mortality related to air pollution is usually observed among those suffering from respiratory and cardiovascular diseases.

As a country like Malaysia becomes more developed, the cost of medical care especially inpatient hospital care, escalates tremendously. This imposes a significant burden on the country's economy. Even though deteriorating air quality may not have a direct causal relationship with respiratory and cardiovascular diseases, it may exacerbate these diseases which lead to hospital admissions. Deteriorating air quality may also cause premature mortality.

1.6 Study Objectives

The main study objective was to determine the relationships between mean daily concentrations of criteria air pollutants and their associations with the risks of respiratory and cardiovascular morbidity and mortality at hospitals in the Klang Valley.

The specific study objectives are :

- 1.6.1 To review local and foreign literatures on the epidemiology of the 5 criteria air pollutants (PM₁₀, CO, SO₂, NO_x and O₃), and their dose-response relationships on human health effects.
- 1.6.2 To retrieve and collate the daily ambient concentrations of the 5 air pollutants in Kuala Lumpur, from the Department of Environment and Alam Sekitar Malaysia Sdn. Bhd.

1.6.3 To retrieve and collate statistics on inpatient morbidity and mortality on respiratory (J00-J46) and cardiovascular (I10-I99) diseases from selected hospitals in the Klang Valley. The selected diseases are:

- i) Acute upper respiratory tract infection (J00-J06)
- ii) Influenza (J10-J11)
- iii) Pneumonia (J12-J18)
- iv) Rhinitis (J30-J31)
- v) Chronic and unspecified bronchitis (J40-J42)
- vi) Emphysema (J43)
- vii) Other chronic obstructive pulmonary disease (J44)
- viii) Asthma (J45-J46)
- ix) Hypertensive disease (I10-I15)
- x) Ischaemic heart disease (I20-I25)
- xi) Cerebrovascular disease (I60-I69)
- xii) Disease of arteries, vein and lymphatic vessels (I70-I99)

1.6.4 To determine the relationships between daily variations in the 5 air pollutants with variations in inpatient morbidity and mortality statistics.

1.6.5 To compare the health impacts of the 5 air pollutants in the Klang Valley with those of other cities in the world.

1.6.6 To review the results for future planning of air pollution management in the Klang Valley.

CHAPTER II

LITERATURE REVIEW

The Klang Valley is the largest and the most densely populated metropolitan area in Malaysia. It is the home to Malaysia's largest city, Kuala Lumpur; its new capital, Putrajaya; a cybercity, Cyberjaya; a satellite town, Petaling Jaya; and the busiest port, Port Kelang. It has a population of about 3 millions and located in the valleys of the Gombak and Klang rivers. Historically, it contained the world's largest alluvial tin deposits. The Klang Valley is bordered by the Straits of Malacca to the west and hills to the north and east.

2.1 Characteristics of Air Pollution

The main sources of air pollutants are from the combustion of fuels in the form of gasoline, fuel oil, natural gas and coal for the generation of energy. Examples are the combustion of gasoline in an internal combustion engine of a motor vehicle and the combustion of natural gas and coal in a thermal power plant. The combustion of these fuels produces a range of gaseous and particulate emissions which can be typically grouped as :

- i) Greenhouse gases : carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O).
- ii) The common (sometimes called 'criteria') ambient air pollutants : carbon monoxide (CO), nitrogen oxides (NO and NO₂ expressed as NO_x), ozone (O₃), sulfur oxides (SO₂ and other oxidized forms of sulfur expressed as SO_x), particulate matter (TSP, PM₁₀ and PM_{2.5}), and lead (Pb).
- iii) Toxic (or hazardous) air contaminants (also known as air toxics) : aldehydes, polycyclic aromatic hydrocarbons (PAHs), benzene and 1,3 butadiene.

Air pollution in the Klang Valley is mainly due to PM₁₀, SO₂, NO₂ and O₃. These pollutants are trapped due to the valley topography and inadequate flushings along the valley which runs from the hilly terrains to the north and east, to the Straits

of Malacca to the west. The worst areas are normally the City of Kuala Lumpur, Shah Alam and Klang. In the year 2002, Shah Alam, Klang and Kuala Lumpur had 67, 50 and 30 days of unhealthy air pollution levels with API of greater than 100 or with one or more of the criteria air pollutants exceeding their MAAQG levels (DOE, 2003).

2.2 Air Quality in the Klang Valley

The Department of Environment monitors the status of air quality throughout the country to detect any significant change which may cause harm to human health and the environment. This involves the continuous or real-time measurement of pollutants in the ambient air at 50 National Air Quality Monitoring Stations throughout the country. These stations are located strategically to meet the specific objectives. Most of them are located in residential areas to monitor population exposure to environmental pollution hazards, while others are located within industrial or commercial areas to monitor pollution trend in those localities (DOE, 2002; DOE, 2003).

The overall air quality for Malaysia throughout 2001 was good to moderate for most of the year, with the exception of few unhealthy days (when the level of one or more of the 5 criteria air pollutants were above their MAAQG) experienced during the dry season particularly in the month of July 2001. Particulate matters (PM 10) and ozone were the prevalent pollutants throughout the country in 2001 (DOE, 2002). The overall air quality for Malaysia in 2002 dropped slightly compared to 2001. Generally, the air quality was between good to moderate for most of the year, except for a number of unhealthy days at various locations in the States of Selangor, Negeri Sembilan and Sarawak. The overall air quality was affected by peat swamp burning and forest fires during the dry periods between February and March and from mid-July to September 2002 (DOE, 2003).

According to the DOE (2003), the Klang Valley is the most prone region to serious air pollution compared to other parts of the country. With mountains in the east and the Straits of Malacca to the west, and being highly developed and densely populated, the Klang Valley provides a conducive environment for pollutants to accumulate particularly when atmospheric conditions are stable. The unhealthy air

quality in the Klang Valley from February to March 2002 was due to peat swamp and forest fires in several areas of Selangor and Kuala Lumpur due to hot and dry weather with reduced rainfall. The number of days with unhealthy air quality ranged from 17 for Kajang to 67 days for Shah Alam. This represents an increase from 2001 with the number of days with unhealthy air quality ranging from 4 to 37 days. The cleanest among 7 different locations in the Klang Valley was Petaling Jaya with no day with unhealthy air quality (DOE, 2003).

About 70% of the days with unhealthy air quality in the Klang Valley in 2002 were due to high levels of respirable particulate matter (PM10) while the remaining 30 % were due to high ozone levels.

2.3 Health Effects of Air Pollutants

Air pollution affects the respiratory, circulatory and olfactory systems. The respiratory system is the principal route of entry for air pollutants, some of which may alter the function of the lungs. The health effects attributed to air pollution range from mild eye irritation to mortality. In most cases, air pollutants aggravate pre-existing diseases or degrade a person's health status, making the person more susceptible to respiratory infections or chronic diseases. Some of the effects associated with specific pollutants are shown in Table 2.1.

2.3.1 Respirable Particulate Matter (PM10).

Suspended particles vary in size, composition and origins. It is important to classify the aerodynamic properties of the particles because these properties govern the transport and removal of the particles from the air; particle deposition in the respiratory system is dependent upon them; and they are associated with the chemical composition and sources of particles. Respirable particulate matter (PM10) which is made up of particles with an aerodynamic diameter of less than 10 μm , represents a complex mixture of organic and inorganic substances. PM10 in mass and composition is divided into 2 groups, namely coarse and fine particles. Fine particles (PM2.5) are particles with an aerodynamic diameter of less than 2.5 μm . PM10 are particles of

health significance because they can travel pass the nasopharyngeal region of the upper human respiratory tract, to reach the lower respiratory tract, namely the tracheobronchial region and the lung.

Table 2.1 : Specific air pollutants and associated health effects.

Pollutants	Health
CO	Reduction in the ability of the circulatory system to transport O ₂ Impairment of performance on tasks requiring vigilance Aggravation of cardiovascular disease
NO ₂	Increased susceptibility to respiratory pathogens
O ₃	Decrement in pulmonary function Coughing; chest discomfort Increased asthma attacks
Peroxyacetyl nitrate, aldehydes	Eye irritation
SO ₂ /particulates	Increased prevalence of chronic respiratory diseases Increased risk of acute respiratory diseases

Source : Stern, 1984

PM10 is associated with increased cardio–pulmonary mortality. (WHO, 2003). Lung function growth in children is reduced in areas with high PM10 (Ganderman *et al.*, 2000; Ganderman *et al.* 2002). Mortality and morbidity time series studies have shown that the cardiovascular death and morbidity indicators are related to ambient particulate matter concentrations. Long-term exposure to particulate matter concentration may lead to marked reduction in life expectancy due to increased cardio-pulmonary and lung cancer mortality. No association was found with chest pain, but a 10µg/m³ increase in PM 2.5 was positively associated with incidence of shortness of breath and other cardio respiratory symptoms (de Hartog, 2003).

PM10 is also a useful indicator of several sources of outdoor air pollution, such as fossil-fuel combustion (Kunzli *et al.*, 2000). Increase in ambient PM10 concentration can lead to significant impacts on the respiratory health of children, the

elderly, and susceptible individuals, which are normally associated with reduced lung function, asthma, pneumonia, bronchitis and emphysema (Juliana, 1998, Zailina, *et al.*, 1997, Zailina, *et al.*, 1996, Shamsul, 2002). At extremely high levels and long-term exposure, it may even cause death.

In the United States (US), significant correlations were observed between increases in respiratory cases and school absenteeism with increases in PM10 concentrations (Pope, 1991). The team of Dockery *et al.*, (1994) who conducted the 6 cities study in the US, predicted that an increase of $10 \mu\text{g}/\text{m}^3$ of PM10 could lead to increases in outpatients attendance (0.8%), emergency cases (1%), general cause of deaths (1%), respiratory deaths (3.4%) and cardiovascular deaths (1.4%). This study also showed that 15 to 17% of the population exposed to urban air polluted with PM10 die earlier than those who live in less polluted air. Chronic PM10 exposure in an adult can cause significant morbidity and mortality. Every $10 \mu\text{g}/\text{m}^3$ increase of PM10 increased the average mortality rate by 9% for long-term exposure duration (Dockery *et al.*, 1993; Pope *et al.*, 1992). A study in Taiwan also showed that an increase in infant mortality is related to air pollution (Knobel *et al.*, 1995).

2.3.2 Sulfur Dioxide

Much of the available information on the acute and chronic effects of sulfur dioxide (SO_2) is based on animal studies. Laboratory animal exposures at high concentrations indicate that SO_2 exposure can cause chronic bronchitis. SO_2 is highly water soluble and therefore, it is almost entirely removed in the nasal passages, throat and mouth. Only 1% reaches the alveoli and exposure increases during exercise. The physiological effects are changes in the mechanical function of the upper airways which are seen as an increase in nasal flow resistance and a decrease in nasal mucus flow rate (Frank *et al.* 1965, Ferin *et al.* 1973)

Bronchoconstriction was evidence by increased airway resistance, decreased forced expiratory volume (FEV), and symptoms such as chest tightness, shortness of breath and wheezing. In some severe occasion, bronchoconstriction required removal of exposure, medical intervention, or both. Mild to moderate asthmatic children and

adults are at greatest risk for short-term SO₂-induced respiratory effects. Severe asthmatic patients are at lower risk because of their low exercise tolerance which would deter them from engaging in activities that make them vulnerable to attacks (Cohen et al. 1972).

Epidemiological data do not show any evidence of excess asthma mortality associated with SO₂ exposure in urban areas. Exposure data indicate that peak SO₂ concentrations greater than 1.34 µg/m³ may cause mild to moderate asthmatic individuals residing in the vicinity of certain sources to be at increased risk (WHO, 1979).

2.3.3 Nitrogen Oxides

Nitrogen oxides or NO_x are the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO₂) along with particles in the air can often be seen as a reddish-brown layer over many urban areas (Kinney and Ozkaynak, 1991). This is because NO₂ absorbs the blue light and transmits red light of the visible light spectrum.

Nitrogen oxides form when fuel is burned at high temperatures, as in the combustion process of the internal combustion engine. In the United States, the primary sources of NO_x are motor vehicles (49%), electric utilities (27%), and other industrial, commercial, and residential sources that burn fuels (19%), and all other sources (5%) (USEPA, 2003). Since 1970, the USEPA has tracked emissions of the six principal air pollutants, namely carbon monoxide, lead, nitrogen oxides, particulate matter, sulfur dioxide, and volatile organic compounds. Emissions of all of these pollutants have decreased significantly except for NO_x which have increased approximately 10 percent over this period.

NO_x cause a wide variety of health and environmental impacts because of the various compounds and derivatives in the family of nitrogen oxides, including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide (USEPA, 2003).

NO_x and pollutants formed from NO_x can be transported over a long distance by the prevailing winds. This means that problems associated with NO_x are not confined to areas where NO_x are emitted. Therefore, controlling NO_x is often most effective if done from a regional perspective, rather than focusing on sources in a localized area.

NO_x as well as sulfur dioxide (SO₂) will react with water vapors in the atmosphere to form acid precipitations which fall to earth as rain, fog, snow or dry particles. Some may be carried by wind for hundreds of miles. Acid rain damages and causes deterioration of cars, buildings and historical monuments; and acidifies lakes and streams and renders them unsuitable for marine life. The nitric acid and related particles formed when NO_x reacts with ammonia, moisture, and other compounds, have human health implications which include effects on the respiratory system, damage to lung tissue, and premature death. Fine particles penetrate deeply into the deeper reaches of the lungs. These can cause or worsen respiratory diseases like chronic obstructive pulmonary diseases (COPD) which include emphysema and chronic bronchitis, as well as aggravate existing heart disease.

One member of the NO_x group, nitrous oxide, is a greenhouse gas. It accumulates in the atmosphere with other greenhouse gasses causing a gradual rise in the earth's temperature, a phenomenon known as global warming. In the air, NO_x reacts readily with common organic chemicals and even ozone, to form a wide variety of toxic products, some of which may cause biological mutations. Examples of these chemicals include the nitrate radical, nitroarenes, and nitrosamines.

2.3.4 Ozone

Ozone (O₃) is a gas composed of three oxygen atoms. It occurs naturally in the stratosphere at 10 to 30 miles above the earth surface, where it forms a layer that protects life on earth from the sun's harmful rays. At ground level or in the stratosphere, it is created by a chemical reaction between oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) in the presence of heat and sunlight (Sillman, 1999). Motor vehicle exhaust, industrial emissions, gasoline vapors and chemical solvents are some of the major sources of NO_x and VOCs that help to form ozone (Stieb *et al.* 2002). Sunlight and hot weather cause ground-level ozone to form in

harmful concentrations in the air. As a result, it is known as a summertime air pollutant in temperate countries. Many urban areas tend to have high levels of ozone, but even rural areas are also subjected to increased ozone levels because wind carries ozone and pollutants that form hundreds of miles away from their original sources.

Even at very low levels, ground-level ozone triggers a variety of health problems including aggravated asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses like pneumonia and bronchitis. Repeated exposure to ozone for several months may cause permanent lung damage (Stieb *et al.*, 2002). Ozone can irritate lung airways and cause inflammation much like a sunburn (Burnett *et al.*, 1998; Dockery *et al.*, 1993). Other symptoms include wheezing, coughing, pain when taking a deep breath, and breathing difficulties during exercise or outdoor activities (Dockery *et al.*, 1993). Children, people with respiratory diseases like asthma, and people who work or exercise outdoor, are susceptible to adverse health effects such as damage to lung tissue and reduction in lung function.

Other impacts of ozone include damage to vegetations and reduced crop yields. It interferes with the ability of plants to produce and store food, which makes them more susceptible to diseases, insects, other pollutants, and harsh weather. Ozone damages the leaves of trees and other plants, ruining the appearance of cities, national parks, and recreational areas (Sillman, 1999).

CHAPTER III

STUDY METHODOLOGY

3.1 Study Area

The study area selected is the Klang Valley. It is situated within the drainage basins of the Klang and Gombak Rivers, which run from the Main Range in the east and northeast to the Straits of Malacca to the west. It has an area of 2,832 km² and encompasses the city of Kuala Lumpur in the centre; the towns of Petaling Jaya, Shah Alam and Kelang to the west; the town of Kuala Selangor to the northwest; the township of Gombak to the north; and the District of Hulu Langat including the town of Kajang to the south. The population in this area was more than 3.8 millions in 2000, with 1.3 million concentrated in Kuala Lumpur, followed by Petaling Jaya (916,436), Hulu Langat (633,163), Gombak (511,357) and Klang (480,147) (BKWPLK, 1998).

3.2 Study Hospitals

Four major hospitals in the Klang Valley were purposely selected for this study. Two of these are public hospitals, namely Hospital Kuala Lumpur (HKL) and Hospital Selayang (HS). The other two are university hospitals, namely Hospital Universiti Kebangsaan Malaysia (HUKM) and University Malaya Medical Centre (UMMC). HKL which is located in the centre of Kuala Lumpur is currently the largest hospital under the Ministry of Health, and is also considered to be one of the biggest in Asia. It is a government, tertiary referral hospital situated on 150 acres of prime land with 86 wards and 2502 beds. The number of total admissions in 1999 was 135,642 with an average number of daily admissions of 372 cases. Its occupancy rate in 1999 was 67.19% (HKL, 1999).

Hospital Selayang (HS) which is also under the Ministry of Health, is located in the Gombak District. It has 960 inpatient beds and 20 clinical disciplines. It was established in 1999 but was officially opened in September 2001. Hospital Selayang has been designed, constructed and equipped for a Total Hospital Information System

(T.H.I.S) environment, with the ultimate aim of paperless and filmless hospital operation. It is the first hospital in Malaysia and the world to operate with T.H.I.S., covering all aspects of its operation (Hospital Selayang, 2004).

Hospital Universiti Kebangsaan Malaysia (HUKM) which was officially opened in July 1998, is located in Bandar Tun Razak, Cheras, Kuala Lumpur. It is one of the two university hospitals operating within the Klang Valley and is situated on 56 acres of land. HUKM is a teaching hospital under the Universiti Kebangsaan Malaysia and the Ministry of Education. It has 1054 inpatient beds and provides quality primary, secondary and tertiary care (HUKM, 2004).

The University Malaya Medical Centre (UMMC), previously known as the University Hospital Kuala Lumpur, is the other university hospital within the Klang Valley. It is sited on a low hill overlooking the University of Malaya campus and the bustling satellite town of Petaling Jaya. It functions as the teaching hospital for Malaysia's oldest university, University Malaya. Like HUKM, it is also under the Ministry of Education. Established in 1968, it is also one of the oldest hospitals in the country. The UMMC provides services to over 850 inpatients and a maximum of 1500 outpatients daily. It is equipped with sophisticated diagnostic equipment and facilities for advanced treatment modalities and patient services that are expected of a state-of-the-art hospital (UMMC, 2004).

3.3 Study Period

The study period was for 4 years from 1 January 2000 to 31 December 2003. This study period was chosen as during earlier years, morbidity and mortality data at some of the study hospitals have not been recorded electronically.

3.4 Study Population

The study population was all respiratory and cardiovascular disease patients admitted to hospitals located within the Klang Valley area, as defined in Section 3.1 above. The 4 study hospitals selected are either fully-government hospitals (HKL and HS) or semi-government hospitals (HUKM and UMMC). Therefore, we may further

define the study population as patients that come from the lower to middle socioeconomic classes as the study hospital charge lower medical rates. Thus, patients from the upper economic class who normally patronize private hospitals will tend to be excluded from this study. Nevertheless, it is unlikely that this selection bias will affect the results of this study as the authors have not come across any literature that suggests that respiratory and cardiovascular patients from different socioeconomic status react differently to the threat of air pollution.

3.5 Study Sample

The study sample is all respiratory and cardiovascular disease cases who were admitted to (for morbidity data), or discharged as deceased from (for mortality data), the 4 study hospitals between 1 January 2000 to 31 December 2004. The information was extracted from the electronic records of the hospitals.

3.5.1 Hospital Morbidity Data

Daily morbidity data from the 4 hospitals during the study period were based on daily patient admissions to the hospitals. The date of patient admission was taken as the date of morbidity. The disease diagnosis was based on the patient's discharge diagnosis which was classified according to the International Classification of Disease, Tenth Revision (ICD 10). The diseases selected for this study and their ICD 10 codes are as follows.

For respiratory diseases :

- i. Acute upper respiratory tract infections (J00-J06)
- ii. Influenza (J10-J11)
- iii. Pneumonia (J12-J18)
- iv. Rhinitis and Sinusitis (J30-J32)
- v. Bronchitis (J40-J42)
- vi. Emphysema (J43)
- vii. Other chronic obstructive pulmonary disease(J44)
- viii. Asthma (J45-J46)
- ix. Other diseases of the respiratory system (J20-J22, J33-J39, J47-J99)

For cardiovascular diseases :

- i. Hypertensive diseases (I10-I15)
- ii. Ischaemic heart diseases (I20-I25)
- iii. Cerebrovascular diseases (I60-I69)
- iv. Diseases of arteries, veins and lymphatic vessels (I70-I99)
- v. Diseases of pulmonary circulation and other forms of heart diseases (I00-I09, I26-I52)

The data compiled for each case of hospital admission is as follows.

- i. Patient Registration Number
- ii. Date of admission
- iii. Date of hospital discharge
- iv. Discharge diagnosis with ICD 10 code
- v. Condition at discharge (alive or deceased)
- vi. Residential address or postal codes
- vii. Age
- viii. Sex
- ix. Ethnicity

3.5.2 Hospital Mortality Data

The daily mortality data from the 4 hospitals during the study period were based on patients' discharge data of those who were discharged as deceased. The date of patient discharge was taken as the date of mortality. The cause of mortality was based on the patient's discharge diagnosis which was classified according to the ICD 10. The causes of mortality selected for this study and their ICD 10 codes are similar to ones selected for the morbidity data.

3.5.3 Hospital Outpatient Data

The compilation of outpatient data from the study hospitals was one of the objectives in the study proposal. However, it was found later that outpatient data in all hospitals are not recorded electronically and centralized. The data had to be recorded

manually from various outpatient clinics throughout each hospital. This would require more manpower and financial resources that were initially planned for this study. Therefore, due to financial and time constraint, this study objective had to be dropped. However, the authors are of the opinion that outpatient data may even be a more sensitive indicator for the acute health effects of air pollutants than inpatient data. Therefore, the authors will look for an opportunity to pursue such a study in the future, which may then be compared with the results of this study.

3.6 Air Quality

Data on air quality in the Klang Valley area were obtained from the Alam Sekitar Malaysia Sdn. Bhd.'s (ASMA) continuous air quality monitoring (CAQM) stations located closest to the study hospitals, through the assistance from the Department of Environment. We obtained mean daily ambient concentrations of particulate matter less than 10 microns (PM10) in $\mu\text{g}/\text{m}^3$, sulphur dioxide (SO₂) in ppm, nitrogen dioxide (NO₂) in ppm, ozone (O₃) in ppm and carbon monoxide (CO) in ppm.

Each CAQM station is an integrated ambient air quality monitoring system designed to monitor ambient air for specific pollutants. This is accomplished through the continuous operation of a number of ambient air analyzers and sensors. The data from these analyzers and sensors are recorded on a microcomputer-based data acquisition system (DAS) which also provides output control to the various analyzers and sensors. The data are then transferred to a central computer every hour for evaluation and reporting.

The monitoring instruments and operation protocols of the CAQM stations were those approved by the United States Environmental Protection Agency (USEPA) as shown in Table 3.1 (Tong SL, 1999). These instruments are reliable and durable for long term continuous field applications. Table 3.2 gives all the 6 CAQM stations located within the Klang Valley; their categories, namely residential, traffic, industrial and background stations; the air quality parameters monitored at each station; as well as the CAQM station selected for each study hospital. The CAQM station chosen is located within a 15 kilometer radius of each hospital. Areas which are of the traffic

category such as the Petaling Jaya station, have no monitoring for ozone and carbon monoxide. Therefore, data for these air pollutants were taken from the next nearest station, namely Shah Alam.

3.7 Meteorological Data

The Malaysian Meteorological Services provided data on daily maximum and minimum temperature, relative humidity and rainfall. The data were obtained from 4 meteorological stations located nearest to the study hospitals. These were the Parliament station for Hospital Kuala Lumpur (HKL), the University Malaya station (UM) for University Malaya Medical Center (UMMC), the Malaysian Royal Air Force station (TUDM) for Hospital Universiti Kebangsaan Malaysia (HUKM), and the Forest Research Institute of Malaysia station (FRIM) for Hospital Selayang (HS).

Table 3.1 : Air quality monitoring equipment used in ASMA’s CAQM stations.

Equipment	Parameter measured	Detection Principle
API 100A	Sulphur dioxide	UV Fluorescence
API 200A	Nitrogen Oxides	Chemiluminescence
API 300	Carbon monoxide	Gas filter correlation
API 400	Ozone	UV absorption
BAM 1020	Particulate matter less than 10 microns (PM10)	Beta attenuation

Table 3.2 : ASMA’s continuous air quality monitoring stations (CAQM) stations located in the Klang Valley.

Location ID	Station location	Category	Parameter	Longitude	Lat	Nearest hospital in this study
CA0005	Jabatan Bekalan Air Daerah Gombak	Residential	CO, O ₃ , SO ₂ , NO ₂ , PM ₁₀ , THC, UV	N 03 06.612	E 101 39.103	Hospital Selayang (HS)
CA0011	Sek. Men. Perempuan Raja Zarina, Klang	Residential	CO, O ₃ , SO ₂ , NO ₂ , PM ₁₀ , THC, UV	N 03 00.620	E 101 24.484	
CA0012	Sek. Men. Victoria, Kuala Lumpur	Traffic	CO, O ₃ , SO ₂ , NO ₂ , PM ₁₀ , THC	N 03 08.286	E 101 42.274	Hospital Kuala Lumpur (HKL) and Hospital Universiti Kebangsaan Malaysia (HUKM)
CA0016	Sek. Keb. Seri Petaling, Petaling Jaya	Industrial	SO ₂ , NO ₂ , PM ₁₀	N 30 06.612	E 101 42.274	University Malaya Medical Centre (UMMC)
CA0023	Country Height, Kajang	Residential	CO, O ₃ , SO ₂ , NO ₂ , PM ₁₀ , THC, UV	N 02 59.645	E 101 44.417	
CA0025	Sek. Keb. Raja Muda, Shah Alam	Residential	CO, O ₃ , SO ₂ , NO ₂ , PM ₁₀ , THC, UV	N 03 04.636	E 101 30.673	University Malaya Medical Centre (UMMC)

3.8 Statistical Analyses

The hospital patient data were first stratified into adults and children for separate analyses. Each stratum was further stratified according to morbidity (patient admissions) and mortality (patients discharged as deceased) outcomes. Poisson regression model was then applied to model the daily count data for each outcome as the dependent variable; and day, maximum temperature, rainfall and the 5 air pollutants as the dependent variables. This was done separately for each hospital.

The generalized additive Poisson regression model for the dependent variable Y (morbidity or mortality daily counts) is as follows:

$$\log[E(Y)] = \sum_i S_i(X_i)$$

where the X_i are the independent variables and the S_i are the smooth functions.

For this study, each basic model was built using Loess smoothing function for day, maximum temperature, and rainfall. This basic model was developed first to adjust for variations in morbidity and mortality counts not attributable to pollution. Dummy variables for day of the week and month were also added to investigate seasonal differences. In addition, lag effects of temperature and rainfall up the previous three days were also considered for the basic model. The smoothing parameter for each covariate is determined based on the Akaike's Information Criterion (AIC).

Based on the best model for each category, the effects of the 5 air pollutants were then examined. All models were estimated using the generalized additive model procedure in SAS. Based on the estimated coefficients obtained, relative risks of cardiovascular and respiratory morbidity and mortality for each air pollutant were estimated for 0 up to 3 lag day and for 3 and 5 day moving averages. This was done because air pollutants may not have an acute and immediate effect on respiratory and cardiovascular morbidity and mortality, but more of a sub-chronic effect over 3 to 5 days.

CHAPTER IV

RESULTS

Three sets of data were collected and compiled for this study. The first set is the meteorological data. Meteorological variables, especially extreme values, are known to influence disease morbidity and mortality related to air quality. The second set comprises the air quality data on the 5 criteria air pollutants. The third set represents the dependent variables of cardiovascular and respiratory morbidity and mortality cases. The 3 sets of data were collected and compiled from 4 meteorological stations, 3 air quality monitoring stations and 4 hospitals.

4.1 Meteorological Data

The meteorological data compiled include maximum temperature, relative humidity and rainfall. Complete data for all the 3 variables were only available for the UM station. Meteorology variables may act as co-variables together with the air pollutants under investigation in this study. As such, maximum temperature ($^{\circ}\text{C}$) and rainfall (mm) were included as the smooth functions in the Loess smoothing method for the Poisson regression model generated. Relative humidity was not used as a smooth function as it was not available for all meteorological stations used in this study.

Four meteorological stations were selected for this study. Each was selected based on their closest proximity to the hospital under study. The meteorological stations selected based on the hospitals were the Parliament station for Hospital Kuala Lumpur (HKL), the University Malaya station (UM) for University Malaya Medical Center (UMMC), the Malaysian Royal Air Force station (TUDM) for Hospital Universiti Kebangsaan Malaysia (HUKM), and the Forest Research Institute of Malaysia station (FRIM) for Hospital Selayang (HS).

Table 4.1 gives a summary of the meteorological data for the 4 stations. The sample size for each station (N) is based on the number of days for which morbidity and mortality data were available. The overall study period was from 1 January 2000

to 31 December 2003. For the Parliament station and HKL, the sample size of 1277 days was from 1 January 2000 to 30 June 2003. The UM station and UMMC had the most complete data from 1 January 2000 to 31 December 2003, giving a sample size of 1461 days. The sample size of 730 days for the TUDM station and HUKM refers to data from 1 January 2002 to 31 December 2003. The FRIM station and HS had the smallest sample size of 702 days which covers the period from 1 March 2001 to 31 January 2003.

The daily temperature ranged from 26.2 °C recorded at the UM station to 37.7 °C recorded at the Parliament station. The mean temperature varied from 32.6 °C at the UM and FRIM stations to 33.9 °C at the Parliament station. The highest standard deviation at 1.8 °C was seen for the Parliament station. Therefore, as expected for a tropical country like Malaysia, the variation in temperature over the study period was very small. Relative humidity data was only available for the UM station with a mean of 80 %. The highest rainfall of 148.7 mm was recorded at the UM station. Mean rainfall vary from 6.7 mm at the Parliament station to 8.4 mm at the TUDM station. There seems to be little variation in rainfall between the 4 stations. Tables 4.2 through 4.5 give the percentile distributions of the meteorological variables at the Parliament, UM, TUDM and FRIM stations, respectively.

Overall, variability in meteorological variables, temporarily within the observation period and spatially between the meteorological stations, seems to be very minimal. Therefore, this variability is not expected to influence morbidity and mortality to a great extent.

4.2 Air Quality Data

The air quality data were obtained from 4 continuous air quality monitoring (CAQM) stations operated by ASMA, through assistance from the Department of Environment. These are the Kuala Lumpur (KL), Petaling Jaya (PJ), Shah Alam (SA) and Gombak stations. Table 4.6 shows the descriptive statistics on the 5 criteria air pollutants under study, namely PM₁₀, nitrogen dioxide (NO₂), sulfur dioxide (SO₂), carbon monoxide (CO) and ozone (O₃). For each air pollutant, only 3 CAQM stations were used. The KL station was used for HKL and HUKM, while the Gombak station

was used for HS. Two CAQM stations were used to provide air quality data for the UMMC. The PJ station provided its PM₁₀, NO₂ and SO₂ data, while the SA station provided its CO and O₃ data. This is because the CO and O₃ data were not available from the PJ station. The study period and sample size (N) associated with each hospital and its corresponding air quality station are similar to that described earlier under Section 3.1 for meteorological data.

The 24-hour MAAQG for PM₁₀ of 150 µg/m³ was exceeded at all the 3 air quality monitoring stations on some sampling days (Figures 4.1, 4.6, 4.11 and 4.16). However, the percentage of days with such a high level of PM₁₀ concentration were less than 5 % for all the stations (Tables 4.7 to 4.10). The highest PM₁₀ concentration of 184.6 µg/m³ was observed at the Gombak station (Figure 4.16). The 24-hour MAAQG for NO₂ of 0.06 ppm was also exceeded at all the stations except at the Gombak station (Figures 4.2, 4.7, 4.12 and 4.17). Similarly, the percentage of days with such a high level of NO₂ concentration were less than 5 % for all the stations (Tables 4.7 to 4.10). The highest NO₂ concentration of 0.095 ppm was recorded at the KL station (Figure 4.12). The MAAQG for 24-hour SO₂, (Figures 4.3, 4.8, 4.13 and 4.18); 8-hour CO (Figures 4.4, 4.9, 4.14 and 4.19) and 8-hour O₃ (Figures 4.5, 4.10, 4.15 and 4.20) of 0.04 ppm, 9 ppm and 0.06 ppm, respectively, were never exceeded at any of the 3 stations. Therefore, with respect to the MAAQG, the problematic air pollutants in the Klang Valley area over the study period from 1 January 2000 to 31 December 2003 seem to be PM₁₀ and NO₂, while the ambient levels for SO₂, CO and O₃ are never above their guideline levels.

4.3 Hospital Morbidity Data

The statistical analyses of the hospital morbidity data on admissions for respiratory and cardiovascular diseases were done by hospital, air pollutant and age group (adults and children). Children represent patients who were 0 to 12 years old while adults were those 13 years old and above. The two age groups were analyzed differently because it is believed that their susceptibilities to respiratory and cardiovascular diseases can be very different. Similarly, although they may be related, respiratory and cardiovascular diseases have different sensitivities to different air pollutants. Data for each hospital were also analyzed separately as the meteorological

and air quality data for each hospital are specific, and each hospital may be different with respect to patient admission characteristics and hospital facilities.

Tables 4.11 through 4.15 give the relative risks (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur (HKL) by quartile increments of each of the 5 air pollutant ambient concentrations. A RR is considered significant when its confidence interval (CI) has a range of 1 or greater. While increments in nitrogen dioxide (NO₂) concentrations were associated with significant RR of admissions for respiratory diseases, increments in respirable particulate (PM₁₀) and sulphur dioxide (SO₂) concentrations tend to be associated with significant RR of admissions for cardiovascular diseases. As for increments in carbon monoxide (CO) and ozone (O₃) concentrations, they did not seem to be associated with any significant RR, except when respiratory and cardiovascular diseases were lumped together. The significant RR were more evident for SO₂.

Tables 4.16 through 4.20 give the relative risks (RR) of children admissions for respiratory and cardiovascular cases at HKL by quartile increments of each of the 5 air pollutant ambient concentrations. Unlike for adults, the RR were found to be insignificant for most air pollutants except for O₃, especially when the respiratory and cardiovascular diseases were combined. This was also seen among the adult patients.

Tables 4.21 through 4.25 give the relative risks (RR) of adult admissions for respiratory and cardiovascular cases at the University Malaya Medical Centre (UMMC) by quartile increments of each of the 5 air pollutant ambient concentrations. Unlike what were seen for HKL where diseases and pollutants were specific, increments in NO₂, SO₂ and CO concentrations seemed to be associated with significant RR for both respiratory and cardiovascular diseases. As with HKL, the significant RR were most evident with SO₂.

Tables 4.26 through 4.30 give the relative risks (RR) of children admissions for respiratory and cardiovascular cases at UMMC by quartile increments of each of the 5 air pollutant ambient concentrations. Unlike for HKL, significant RR of admissions for respiratory diseases were observed for increments in NO₂ and SO₂ concentrations.

Tables 4.31 through 4.35 give the relative risks (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia (HUKM) by quartile increments of each of the 5 air pollutant ambient concentrations. The results for HUKM seemed to be more similar to what were seen for UMMC than for HKL. The disease and pollutant specific relationship seen for HKL is not really discernable here. Like for UMMC, increments in NO₂ and CO concentrations seemed to be associated with significant RR for both respiratory and cardiovascular diseases.

Tables 4.36 through 4.40 give the relative risks (RR) of children admissions for respiratory and cardiovascular cases at HUKM by quartile increments of each of the 5 air pollutant ambient concentrations. Again, the results for HUKM seemed to be more similar to that seen for UMMC than for HKL. Unlike HKL which showed insignificant RR for most pollutants, significant RR of admissions for both respiratory and cardiovascular diseases were seen for increment of NO₂ concentration, and for respiratory diseases only for increments in PM₁₀ and CO concentrations.

Tables 4.41 through 4.45 give the relative risks (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Selayang (HS) by quartile increments of each of the 5 air pollutant ambient concentrations. The RR outcomes seen at HS is somewhat in between what were seen at HKL and what were seen at UMMC and HUKM. Like at HKL, the association between air pollutants and diseases tend to be specific, in that significant RR of admissions for respiratory disease cases are associated with increments in PM₁₀ and CO concentrations. However, this differs from the RR outcomes at HKL where increment in NO₂ concentrations had the influence on respiratory diseases. On the other hand, like UMMC and HUKM, increments in NO₂ concentrations seemed to be associated with significant RR for both respiratory and cardiovascular diseases.

Tables 4.46 through 4.50 give the relative risks (RR) of children admissions for respiratory and cardiovascular cases at HS by quartile increments of each of the 5 air pollutant ambient concentrations. The RR outcomes for this hospital seemed to most similar to that of HUKM, where increments in NO₂ concentration were associated with significant RR of admissions for both respiratory and cardiovascular

diseases, while increments in CO concentrations are associated with significant RR for respiratory diseases only.

4.4 **Hospital Mortality Data**

The statistical analyses of the hospital mortality data on combined deaths for respiratory and cardiovascular diseases were done for all hospitals and for both age groups (adults and children) by air pollutants. The reason for combining respiratory and cardiovascular mortality, the hospitals, and age groups was because the mortality counts were too few in numbers. The air pollutant data from the 3 CAQM stations, and the meteorological data from the 4 meteorological stations, were also combined and the daily average was taken.

Tables 4.51a and 4.51b give the relative risks (RR) of adult and children mortality for respiratory and cardiovascular cases at all hospitals by quartile increments of each of the 5 air pollutant ambient concentrations. A RR is considered significant when its confidence interval (CI) has a range of 1 or greater. Of the 5 air pollutants, ozone was found to be associated with significant RR for respiratory and cardiovascular mortality.

Table 4.1 : Descriptive statistics on meteorological parameters by meteorological station and hospital.

Meteorological parameter	Meteorological station			
	Parliament (for HKL) (N=1277)	UM (for UMMC) (N=1461)	TUDM (for HUKM) (N=730)	FRIM (for HS) (N=702)
24-hour max. temperature (°C)				
- Range	26.3 – 37.7	26.2 – 36.1	26.9 – 36.4	26.4 – 36.6
- Median	34.10	32.70	32.90	32.70
- Mean	33.93	32.55	32.84	32.55
- Std. dev.	1.78	1.51	1.40	1.61
24-hour relative humidity (%)				
- Range		28.1 – 96.6		
- Median	- nil -	80.50	- nil -	- nil -
- Mean		80.00		
- Std. dev.		6.97		
Rainfall (mm)				
- Range	0.0 – 112.4	0.0 – 148.7	0.0 – 132.0	0.0 – 140.7
- Median	0.40	0.50	0.80	0.20
- Mean	6.66	7.83	8.40	6.86
- Std. dev.	14.17	16.18	16.19	14.57

Table 4.2 : Percentile distributions of meteorological parameters at the Parliament station for Hospital Kuala Lumpur (HKL).

Meteorological parameter	Year	Percentile						
		5	10	25	50	75	90	95
Minimum Temperature (°C)	2000	31.5600	32.2000	33.8000	35.0000	35.9000	36.4000	36.8000
	2001	29.5200	30.6000	31.9000	33.1000	34.0000	34.6000	35.0000
	2002	31.3700	32.4000	33.3500	34.6000	35.3000	36.0000	36.4300
	2003	30.3000	31.4200	33.3000	34.3000	35.1500	35.8000	36.2900
Maximum temperature (°C)	2000	23.3000	23.8000	24.5000	25.1000	25.6000	26.4000	26.7000
	2001	21.9000	22.1000	23.0000	23.7000	24.3000	24.7000	24.9000
	2002	23.0000	23.4000	23.8000	24.2000	24.7500	25.2600	25.5000
	2003	23.4100	23.7000	24.1000	24.6000	25.0000	25.3000	25.5000
Rainfall (mm)	2000	0.0000	0.0000	0.0000	0.0000	6.6000	21.0400	36.9200
	2001	0.0000	0.0000	0.0000	0.8000	6.8000	20.9600	35.4400
	2002	0.0000	0.0000	0.0000	0.4000	6.7000	24.9200	38.0600
	2003	0.0000	0.0000	0.0000	0.4000	6.5000	18.0800	39.9400

Table 4.3 : Percentile distributions of meteorological parameters at the University Malaya (UM) station for University Malaya Medical Centre (UMMC).

Meteorological parameter	Year	Percentile						
		5	10	25	50	75	90	95
Minimum temperature (°C)	2000	22.1000	22.3000	23.0000	23.5000	24.1000	24.7000	24.9000
	2001	22.2000	22.6000	23.1000	23.7000	24.3000	24.9000	25.2000
	2002	22.6000	22.9000	23.4000	24.0000	24.4250	24.9100	25.3000
	2003	22.3000	22.7000	23.2000	23.8000	24.4000	24.9000	25.1750
Maximum temperature (°C)	2000	30.0000	30.5000	31.5000	32.5000	33.5000	34.0000	34.5000
	2001	29.4750	30.4000	31.5000	32.6000	33.5000	34.1000	34.6250
	2002	30.4000	31.0900	32.1000	33.0000	33.8000	34.6100	35.2000
	2003	29.9250	30.5000	31.7000	32.6000	33.5000	34.3000	35.0000
Rainfall (mm)	2000	0.0000	0.0000	0.0000	0.1000	10.7500	28.2500	47.1000
	2001	0.0000	0.0000	0.0000	0.5000	6.9250	26.5500	39.3250
	2002	0.0000	0.0000	0.0000	0.0000	7.0000	26.4100	37.3600
	2003	0.0000	0.0000	0.0000	1.0500	7.8750	23.1500	34.2500
Relative Humidity (%)	2000	75.3750	78.6000	81.6500	85.9000	89.3000	91.6000	92.6250
	2001	71.1750	73.1500	76.9750	81.1000	84.9000	87.8000	89.5250
	2002	66.2950	68.4900	73.9750	79.2500	83.7250	86.5100	87.3050
	2003	65.0750	67.8500	72.2250	76.7000	80.3000	82.6500	83.9500

Table 4.4 : Percentile distributions of meteorological parameters at the Royal Malaysian Air Force (TUDM) station for Hospital Universiti Kebangsaan Malaysia (HUKM).

Meteorological parameter	Year	Percentile						
		5	10	25	50	75	90	95
Minimum temperature (°C)	2002	22.7000	23.2000	23.6000	24.0000	24.5000	25.0000	25.4000
	2003	23.0000	23.2000	23.7000	24.3000	24.8000	25.2800	25.5400
Maximum temperature (°C)	2002	30.9000	31.4000	32.3000	33.1000	34.0000	34.8000	35.2000
	2003	30.1000	30.8000	31.6000	32.8000	33.6000	34.3000	34.5000
Rainfall (mm)	2002	0.0000	0.0000	0.0000	0.4000	9.4000	27.6400	40.4800
	2003	0.0000	0.0000	0.0000	1.0000	10.0000	24.3600	36.8000

Table 4.5 : Percentile distributions of meteorological parameters at the Forest Research Institute of Malaysia (FRIM) station for Hospital Selayang (HS).

Meteorological parameter	Year	Percentile						
		5	10	25	50	75	90	95
Minimum temperature (°C)	2001	29.2600	30.2000	31.5000	32.6000	33.6000	34.4000	34.9400
	2002	30.2000	30.9000	31.8000	32.8000	33.8000	34.5000	34.9900
	2003	27.5200	28.9600	30.3000	31.9000	33.2000	34.0400	34.4000
Maximum temperature (°C)	2001	21.6300	21.8000	22.3500	23.0000	23.4000	24.0000	24.2000
	2002	21.2000	21.6000	22.2000	23.0000	23.5000	24.0000	24.5000
	2003	21.5200	21.8000	22.0000	22.6000	23.0000	23.3600	23.8200
Rainfall (mm)	2001	0.0000	0.0000	0.0000	0.6000	6.7500	26.4000	42.5900
	2002	0.0000	0.0000	0.0000	0.0000	6.2500	21.5800	31.7900
	2003	0.0000	0.0000	0.0000	1.0000	7.1000	14.0000	29.5600

Table 4.6 : Descriptive statistics on air pollutants by air quality station and hospital.

Air pollutant	Air quality station			
	KL station (for HKL) (N=1277)	PJ & SA stations (for UMMC) (N=1461)	KL station (for HUKM) (N=730)	Gombak station (for HS) (N=702)
PM10 (ppm)				
- Range	31.0 – 168.5	7.0 – 153.2	35.1 – 168.5	19.4 – 184.6
- Median	67.46	48.13	74.54	53.17
- Mean	69.26	51.38	76.68	55.81
- Std. dev.	17.50	18.55	17.94	18.72
NO ₂ (ppm)				
- Range	0.0 – 0.095	0.0 – 0.069	0.009 – 0.095	0.0 – 0.032
- Median	0.026	0.032	0.036	0.016
- Mean	0.026	0.032	0.036	0.016
- Std. dev.	0.013	0.011	0.010	0.006
SO ₂ (ppm)				
- Range	0.0 – 0.015	0.0 – 0.024	0.001 - 0.013	0.0 – 0.008
- Median	0.006	0.007	0.006	0.002
- Mean	0.006	0.007	0.006	0.002
- Std. dev.	0.002	0.004	0.002	0.001
CO (ppm)				
- Range	0.47 – 7.40	0.47 – 7.40	0.9 – 7.4	0.0 – 2.97
- Median	3.03	3.01	3.10	1.08
- Mean	3.05	3.03	3.16	1.14
- Std. dev.	0.862	0.873	0.843	0.387
O ₃ (ppm)				
- Range	0.0 – 0.041	0.0 – 0.041	0.001 – 0.041	0.0 – 0.038
- Median	0.011	0.011	0.012	0.013
- Mean	0.012	0.012	0.013	0.014
- Std. dev.	0.006	0.006	0.006	0.007

Table 4.7 : Percentile distributions of air pollutants at the Kuala Lumpur (KL) station for Hospital Kuala Lumpur (HKL).

Air pollutant	Year	Percentile						
		5	10	25	50	75	90	95
PM10 ($\mu\text{g}/\text{m}^3$)	2000	44.0000	48.0000	54.0000	62.0000	72.0000	83.0000	89.6500
	2001	41.9823	45.8750	52.5940	61.8540	69.6978	80.1250	85.0623
	2002	51.7393	55.8330	65.6877	75.7500	85.9065	103.0415	113.7188
	2003	53.1000	59.4168	67.5420	74.7080	86.8750	99.4080	110.7081
Nitrogen dioxide (ppm)	2000	0.0080	0.0110	0.0170	0.0230	0.0290	0.0350	0.0370
	2001	0.0040	0.0065	0.0130	0.0190	0.0240	0.0280	0.0308
	2002	0.0130	0.0205	0.0310	0.0370	0.0420	0.0460	0.0508
	2003	0.0217	0.0240	0.0310	0.0350	0.0410	0.0460	0.0506
Sulfur dioxide (ppm)	2000	0.0030	0.0040	0.0050	0.0060	0.0070	0.0090	0.0090
	2001	0.0030	0.0030	0.0050	0.0060	0.0070	0.0080	0.0090
	2002	0.0030	0.0040	0.0050	0.0060	0.0070	0.0080	0.0090
	2003	0.0030	0.0040	0.0045	0.0060	0.0070	0.0080	0.0090
Carbon monoxide (ppm)	2000	1.5110	1.7870	2.2300	2.8100	3.2225	3.6300	3.8530
	2001	1.4025	1.8000	2.3900	3.0300	3.6775	4.3150	4.9375
	2002	2.0625	2.2600	2.7425	3.1950	3.7475	4.3200	4.5650
	2003	2.0240	2.1600	2.7700	3.1400	3.6400	4.2760	4.6580
Ozone (ppm)	2000	0.0040	0.0050	0.0080	0.0110	0.0140	0.0180	0.0217
	2001	0.0040	0.0060	0.0080	0.0110	0.0160	0.0190	0.0220
	2002	0.0050	0.0060	0.0080	0.0120	0.0170	0.0230	0.0260
	2003	0.0040	0.0054	0.0080	0.0130	0.0175	0.0220	0.0240

Table 4.8 : Percentile distributions of air pollutants at the Petaling Jaya (PJ) and Shah Alam (SA) stations for University Malaya Medical Centre (UMMC).

Air pollutant	Year	Percentiles						
		5	10	25	50	75	90	95
PM10 ($\mu\text{g}/\text{m}^3$)	2000	33.0000	36.30000	41.0000	47.0000	55.0000	63.0000	69.3500
	2001	22.2380	25.4724	29.7080	35.7500	42.0000	49.9502	57.2084
	2002	31.0109	35.1503	43.3648	56.0835	69.2568	83.1928	93.9625
	2003	36.7728	41.1502	49.7500	61.5420	73.3330	83.5498	98.1182
Nitrogen dioxide (ppm)	2000	0.0187	0.0210	0.0240	0.0280	0.0320	0.0370	0.0400
	2001	0.0000	0.0208	0.0250	0.0310	0.0370	0.0420	0.0456
	2002	0.0120	0.0230	0.0293	0.0350	0.0410	0.0470	0.0490
	2003	0.0026	0.0194	0.0270	0.0350	0.0410	0.0466	0.0520
Sulfur dioxide (ppm)	2000	0.0030	0.0040	0.0050	0.0080	0.0100	0.0120	0.0140
	2001	0.0000	0.0040	0.0060	0.0080	0.0100	0.0130	0.0150
	2002	0.0010	0.0030	0.0050	0.0070	0.0090	0.0120	0.0140
	2003	0.0002	0.0020	0.0040	0.0060	0.0090	0.0110	0.0130

Table 4.9 : Percentile distributions of air pollutants at the Kuala Lumpur (KL) station for Hospital Universiti Kebangsaan Malaysia (HUKM).

Air pollutant	Year	Percentile						
		5	10	25	50	75	90	95
PM10 ($\mu\text{g}/\text{m}^3$)	2002	51.8330	55.5624	65.5420	75.5625	85.8855	101.1749	113.1875
	2003	51.2458	54.8750	63.2290	73.6670	86.3750	98.9666	108.3997
Nitrogen dioxide (ppm)	2002	0.0130	0.0203	0.0310	0.0370	0.0420	0.0467	0.0510
	2003	0.0190	0.0220	0.2950	0.0350	0.0420	0.0470	0.0521
Sulfur dioxide (ppm)	2002	0.0030	0.0040	0.0050	0.0060	0.0070	0.0080	0.0090
	2003	0.0030	0.0040	0.0050	0.0060	0.0070	0.0080	0.0090
Carbon monoxide (ppm)	2002	2.0700	2.3060	2.7475	3.1900	3.7425	4.3110	4.5670
	2003	1.6480	2.0080	2.5550	3.0500	3.5300	4.2460	4.6410
Ozone (ppm)	2002	0.0050	0.0060	0.0080	0.0120	0.0170	0.0230	0.0260
	2003	0.0040	0.0060	0.0080	0.0120	0.0160	0.0210	0.0230

Table 4.10 : Percentile distributions of air pollutants at the Gombak station for Hospital Selayang (HS).

Air pollutant	Year	Percentiles						
		5	10	25	50	75	90	95
PM10 ($\mu\text{g}/\text{m}^3$)	2001	31.5083	34.8045	40.8955	47.6995	59.5623	72.5795	88.7671
	2002	34.5420	39.2500	49.6250	58.9170	71.2500	83.6670	92.1670
	2003	29.8180	34.1556	39.4580	47.2310	55.4500	64.3676	72.1168
Nitrogen dioxide (ppm)	2001	0.0000	0.0080	0.0118	0.0150	0.0180	0.0210	0.0220
	2002	0.0000	0.0100	0.0140	0.0170	0.0210	0.0240	0.0260
	2003	0.0000	0.0078	0.0130	0.0160	0.0170	0.0228	0.0260
Sulfur dioxide (ppm)	2001	0.0000	0.0010	0.0010	0.0020	0.0030	0.0030	0.0035
	2002	0.0000	0.0010	0.0020	0.0020	0.0030	0.0040	0.0050
	2003	0.0000	0.0010	0.0020	0.0030	0.0030	0.0040	0.0044
Carbon monoxide (ppm)	2001	0.6010	0.6900	0.8475	1.0500	1.3300	1.7360	1.9445
	2002	0.5700	0.6700	0.8900	1.0700	1.4000	1.6100	1.7900
	2003	0.7580	0.7940	0.8800	1.1500	1.3700	1.5920	1.7400
Ozone (ppm)	2001	0.0000	0.0060	0.0090	0.0130	0.0180	0.0220	0.0255
	2002	0.0000	0.0070	0.0100	0.0150	0.0200	0.0250	0.0280
	2003	0.0000	0.0036	0.0080	0.0100	0.0140	0.0178	0.0194

Table 4.11 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient PM10 concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average	PM10 concentration increment						
		56.94 µg/m ³ (First quartile)		67.90 µg/m ³ (Median)		79.00 µg/m ³ (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.11 [#]	1.02 – 1.21	1.13 [#]	1.02 – 1.25	1.15 [#]	1.02 – 1.30	0.018*
	1	1.03	0.94 – 1.12	1.03	0.93 – 1.15	1.04	0.92 – 1.17	0.535
	2	1.06	0.98 – 1.16	1.08	0.97 – 1.19	1.09	0.97 – 1.23	0.147
	3	1.01	0.93 – 1.10	1.01	0.92 – 1.12	1.02	0.90 – 1.14	0.783
	MA3	1.09	0.99 – 1.21	1.11	0.99 – 1.25	1.12	0.98 – 1.30	0.091
	MA5	1.06	0.96 – 1.17	1.07	0.95 – 1.20	1.08	0.95 – 1.24	0.253
Cardiovascular	0	1.06 [#]	1.00 – 1.12	1.07 [#]	1.00 – 1.15	1.08 [#]	1.00 – 1.17	0.054
	1	1.04	0.98 – 1.10	1.05	0.98 – 1.12	1.06	0.98 – 1.14	0.196
	2	1.07 [#]	1.01 – 1.13	1.08 [#]	1.01 – 1.16	1.10 [#]	1.02 – 1.19	0.015*
	3	1.08 [#]	1.01 – 1.14	1.09 [#]	1.01 – 1.17	1.11 [#]	1.02 – 1.20	0.015*
	MA3	1.08 [#]	1.01 – 1.14	1.09 [#]	1.01 – 1.17	1.11 [#]	1.02 – 1.20	0.015*
	MA5	1.11 [#]	1.04 – 1.20	1.14 [#]	1.05 – 1.24	1.16 [#]	1.06 – 1.29	0.003**
Both	0	1.14 [#]	1.06 – 1.23	1.17 [#]	1.08 – 1.28	1.20 [#]	1.09 – 1.33	<0.001***
	1	1.10 [#]	1.03 – 1.19	1.12 [#]	1.03 – 1.23	1.14 [#]	1.04 – 1.27	0.006**
	2	1.11 [#]	1.03 – 1.19	1.13 [#]	1.04 – 1.23	1.15 [#]	1.05 – 1.27	0.004**
	3	1.11 [#]	1.04 – 1.19	1.14 [#]	1.05 – 1.23	1.16 [#]	1.06 – 1.28	0.003**
	MA3	1.17 [#]	1.07 – 1.26	1.20 [#]	1.08 – 1.32	1.23 [#]	1.10 – 1.38	<0.001***
	MA5	1.20 [#]	1.10 – 1.31	1.24 [#]	1.11 – 1.38	1.28 [#]	1.13 – 1.45	<0.001***

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.12 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient nitrogen dioxide concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average	Nitrogen dioxide concentration increment						
		0.017 ppm (First quartile)		0.026 ppm (Median)		0.036 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.06 [#]	1.02 – 1.09	1.09 [#]	1.04 – 1.14	1.12 [#]	1.05 – 1.20	0.001***
	1	1.04 [#]	1.01 – 1.08	1.07 [#]	1.02 – 1.12	1.09 [#]	1.02 – 1.17	0.010*
	2	1.06 [#]	1.02 – 1.09	1.09 [#]	1.03 – 1.14	1.12 [#]	1.05 – 1.20	0.001***
	3	1.05 [#]	1.02 – 1.09	1.08 [#]	1.03 – 1.13	1.11 [#]	1.04 – 1.19	0.002**
	MA3	1.07 [#]	1.03 – 1.11	1.11 [#]	1.05 – 1.17	1.15 [#]	1.07 – 1.25	<0.001***
	MA5	1.08 [#]	1.04 – 1.13	1.13 [#]	1.06 – 1.20	1.18 [#]	1.09 – 1.28	<0.001***
Cardiovascular	0	1.01	0.99 – 1.03	1.01	0.98 – 1.05	1.02	0.97 – 1.07	0.478
	1	0.99 [#]	1.03 – 1.01	0.99 [#]	1.05 – 1.02	0.98 [#]	1.07 – 1.03	0.422
	2	0.99	0.97 – 1.02	0.99	0.96 – 1.03	0.99	0.94 – 1.04	0.611
	3	0.99	0.97 – 1.01	0.98	0.95 – 1.02	0.98	0.93 – 1.03	0.382
	MA3	1.00	0.97 – 1.02	1.00	0.96 – 1.04	0.99	0.94 – 1.05	0.819
	MA5	0.99	0.97 – 1.02	0.99	0.95 – 1.03	0.99	0.93 – 1.05	0.650
Both	0	1.09 [#]	1.07 – 1.12	1.15 [#]	1.10 – 1.19	1.21 [#]	1.15 – 1.28	<0.001***
	1	0.99	0.99 – 1.03	0.99 [#]	1.05 – 1.02	0.98 [#]	1.07 – 1.03	0.422
	2	1.08 [#]	1.08 – 1.11	1.12 [#]	1.08 – 1.17	1.17 [#]	1.11 – 1.24	<0.001***
	3	1.08 [#]	1.05 – 1.10	1.12 [#]	1.08 – 1.16	1.17 [#]	1.11 – 1.23	<0.001***
	MA3	1.12 [#]	1.09 – 1.15	1.19 [#]	1.14 – 1.24	1.27 [#]	1.19 – 1.35	<0.001***
	MA5	1.13 [#]	1.10 – 1.17	1.21 [#]	1.15 – 1.27	1.30 [#]	1.22 – 1.39	<0.001***

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.13 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient sulfur dioxide concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average ³	Sulphur dioxide concentration increment						
		0.005 ppm (First quartile)		0.006 ppm (Median)		0.007 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.04	0.98 – 1.10	1.05	0.98 – 1.13	1.06	0.98 – 1.15	0.172
	1	1.03	0.97 – 1.10	1.04	0.97 – 1.12	1.05	0.96 – 1.14	0.289
	2	1.06 [#]	1.00 – 1.13	1.08 [#]	1.00 – 1.16	1.09 [#]	1.00 – 1.18	0.048*
	3	1.02	0.96 – 1.09	1.03	0.96 – 1.10	1.03	0.95 – 1.12	0.444
	MA3	1.09 [#]	1.00 – 1.18	1.11 [#]	1.00 – 1.22	1.12 [#]	1.00 – 1.26	0.045*
	MA5	1.11 [#]	1.00 – 1.22	1.13 [#]	1.00 – 1.27	1.15 [#]	1.01 – 1.32	0.042*
Cardiovascular	0	1.08 [#]	1.04 – 1.13	1.10 [#]	1.05 – 1.15	1.12 [#]	1.06 – 1.18	<0.001***
	1	1.05 [#]	1.01 – 1.09	1.06 [#]	1.01 – 1.11	1.07 [#]	1.01 – 1.13	0.022*
	2	1.04 [#]	1.00 – 1.08	1.05 [#]	1.00 – 1.10	1.06 [#]	1.00 – 1.12	0.056
	3	1.04 [#]	1.00 – 1.08	1.04 [#]	1.01 – 1.09	1.05 [#]	1.01 – 1.11	0.085
	MA3	1.11 [#]	1.05 – 1.17	1.13 [#]	1.06 – 1.21	1.16 [#]	1.07 – 1.25	<0.001***
	MA5	1.17 [#]	1.10 – 1.25	1.21 [#]	1.12 – 1.31	1.25 [#]	1.14 – 1.37	<0.001***
Both	0	1.07 [#]	1.02 – 1.12	1.08 [#]	1.02 – 1.14	1.09 [#]	1.02 – 1.17	0.009**
	1	1.06 [#]	1.01 – 1.11	1.07 [#]	1.01 – 1.13	1.08 [#]	1.01 – 1.16	0.025*
	2	1.03	0.98 – 1.08	1.04	0.98 – 1.10	1.04	0.97 – 1.11	0.226
	3	1.04	0.99 – 1.09	1.05	0.99 – 1.11	1.06	0.99 – 1.13	0.107
	MA3	1.10 [#]	1.03 – 1.18	1.12 [#]	1.04 – 1.22	1.15 [#]	1.05 – 1.26	0.004**
	MA5	1.16 [#]	1.07 – 1.25	1.19 [#]	1.09 – 1.31	1.23 [#]	1.10 – 1.37	<0.001***

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.14 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient carbon monoxide concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average	Carbon monoxide concentration increment						
		2.54 ppm (First quartile)		3.04 ppm (Median)		3.55 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.05	0.97 – 1.13	1.06	0.97 – 1.15	1.07	0.96 – 1.18	0.206
	1	1.01	0.94 – 1.09	1.01	0.93 – 1.10	1.01	0.91 – 1.12	0.811
	2	1.05	0.98 – 1.13	1.06	0.97 – 1.16	1.07	0.97 – 1.18	0.193
	3	1.01	0.94 – 1.08	1.01	0.92 – 1.10	1.01	0.91 – 1.12	0.858
	MA3	1.06	0.97 – 1.17	1.07	0.96 – 1.20	1.09	0.95 – 1.24	0.215
	MA5	1.07	0.96 – 1.19	1.09	0.96 – 1.23	1.10	0.95 – 1.27	0.198
Cardiovascular	0	1.05 [#]	1.00 – 1.10	1.05	0.99 – 1.12	1.06	0.99 – 1.14	0.076
	1	1.01	0.96 – 1.06	1.01	0.95 – 1.07	1.01	0.94 – 1.08	0.778
	2	1.04	0.99 – 1.10	1.05	0.99 – 1.12	1.06	0.99 – 1.14	0.085
	3	1.05 [#]	1.00 – 1.10	1.05 [#]	1.00 – 1.12	1.06	0.99 – 1.14	0.073
	MA3	1.06	0.97 – 1.17	1.07	0.96 – 1.20	1.09	0.95 – 1.24	0.215
	MA5	1.07	0.96 – 1.19	1.09	0.96 – 1.23	1.10	0.95 – 1.27	0.198
Both	0	1.12 [#]	1.05 – 1.18	1.14 [#]	1.06 – 1.22	1.17 [#]	1.07 – 1.27	<0.001***
	1	1.09 [#]	1.02 – 1.15	1.10 [#]	1.03 – 1.19	1.12 [#]	1.03 – 1.22	0.007**
	2	1.10 [#]	1.04 – 1.18	1.13 [#]	1.05 – 1.21	1.15 [#]	1.06 – 1.25	0.001***
	3	1.11 [#]	1.04 – 1.28	1.13 [#]	1.05 – 1.21	1.15 [#]	1.06 – 1.25	0.001***
	MA3	1.18 [#]	1.09 – 1.28	1.22 [#]	1.11 – 1.34	1.26 [#]	1.13 – 1.41	<0.001***
	MA5	1.26 [#]	1.15 – 1.38	1.32 [#]	1.18 – 1.47	1.38 [#]	1.21 – 1.56	<0.001***

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.15 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient ozone concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average	Ozone concentration increment						
		0.008 ppm (First quartile)		0.011 ppm (Median)		0.016 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.01	0.98 – 1.04	1.02	0.98 – 1.06	1.03	0.97 – 1.09	0.369
	1	1.02	0.99 – 1.05	1.02	0.98 – 1.06	1.03	0.97 – 1.10	0.321
	2	1.02	0.99 – 1.05	1.02	0.98 – 1.07	1.03	0.97 – 1.10	0.268
	3	1.02	0.99 – 1.05	1.03	0.99 – 1.07	1.05	0.99 – 1.11	0.138
	MA3	1.03	0.99 – 1.07	1.04	0.98 – 1.10	1.06	0.97 – 1.15	0.191
	MA5	1.00 [#]	1.00 – 1.00	1.00 [#]	1.00 – 1.00	1.00 [#]	1.00 – 1.00	0.159
Cardiovascular	0	1.02	0.99 – 1.04	1.02	0.99 – 1.05	1.03	0.99 – 1.07	0.142
	1	1.01	0.99 – 1.03	1.01	0.98 – 1.04	1.02	0.98 – 1.06	0.410
	2	1.01	0.99 – 1.03	1.01	0.98 – 1.04	1.01	0.97 – 1.06	0.499
	3	1.00	0.98 – 1.02	1.00	0.97 – 1.02	0.99	0.95 – 1.03	0.759
	MA3	1.03	0.99 – 1.07	1.04	0.98 – 1.10	1.06	0.97 – 1.15	0.178
	MA5	1.00 [#]	1.00 – 1.00	1.00 [#]	1.00 – 1.00	1.00 [#]	1.00 – 1.00	0.159
Both	0	1.05 [#]	1.03 – 1.08	1.07 [#]	1.04 – 1.11	1.10 [#]	1.05 – 1.16	<0.001***
	1	1.05 [#]	1.05 – 1.07	1.06 [#]	1.03 – 1.10	1.09 [#]	1.04 – 1.15	<0.001***
	2	1.03 [#]	1.01 – 1.06	1.05 [#]	1.01 – 1.08	1.07 [#]	1.02 – 1.12	0.007**
	3	1.03 [#]	1.01 – 1.06	1.04 [#]	1.01 – 1.08	1.06 [#]	1.01 – 1.12	0.013*
	MA3	1.09 [#]	1.05 – 1.13	1.13 [#]	1.07 – 1.18	1.19 [#]	1.11 – 1.27	<0.001***
	MA5	1.00 [#]	1.00 – 1.00	1.00 [#]	1.00 – 1.00	1.00 [#]	1.00 – 1.00	<0.001***

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.16 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient PM10 concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average	PM10 concentration increment						p value
		56.94 µg/m ³ (First quartile)		67.90 µg/m ³ (Median)		79.00 µg/m ³ (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.64	0.51 – 0.81	0.59	0.45 – 0.78	0.55	0.40 – 0.75	<0.001***
	1	0.71	0.57 – 0.89	0.67	0.51 – 0.87	0.63	0.46 – 0.86	0.003**
	2	0.75	0.60 – 0.94	0.71	0.54 – 0.93	0.68	0.50 – 0.92	0.014*
	3	0.81	0.64 – 1.01	0.78	0.59 – 1.01	0.75	0.55 – 1.02	0.065
	MA3	0.62	0.47 – 0.81	0.56	0.41 – 0.77	0.51	0.36 – 0.74	<0.001***
	MA5	0.62	0.47 – 0.83	0.57	0.40 – 0.80	0.52	0.35 – 0.77	0.001***
Cardiovascular	0	1.15	0.10 – 13.53	1.18	0.06 – 21.82	1.21	0.04 – 35.44	0.913
	1	1.38	0.11 – 17.89	1.47	0.07 – 30.37	1.56	0.05 – 51.95	0.804
	2	1.85	0.15 – 0.15	2.07	0.10 – 0.10	2.32	0.07 – 0.07	0.633
	3	0.60	0.03 – 10.47	0.54	0.02 – 16.11	0.50	0.01 – 24.94	0.725
	MA3	1.36	0.07 – 24.90	1.44	0.05 – 44.91	1.52	0.03 – 81.71	0.835
	MA5	0.48	0.01 – 15.96	0.42	0.01 – 26.54	0.37	0.00 – 44.44	0.681
Both	0	0.12	0.02 – 0.72	0.08	0.01 – 0.68	0.05	0.00 – 0.64	0.021*
	1	1.13	0.25 – 5.02	1.15	0.20 – 6.75	1.18	0.15 – 9.11	0.873
	2	0.39	0.07 – 2.07	0.33	0.05 – 2.37	0.28	0.03 – 2.72	0.272
	3	0.08	0.01 – 0.56	0.05	0.00 – 0.50	0.03	0.00 – 0.45	0.011*
	MA3	0.57	0.09 – 3.54	0.52	0.06 – 4.47	0.47	0.04 – 5.66	0.548
	MA5	0.11	0.01 – 0.82	0.07	0.01 – 0.80	0.05	0.00 – 0.77	0.032*

Note : MA3 = 3-day moving average * Significant at p<0.05
 MA5 = 5-day moving average ** Significant at p<0.01
 # CI ≥ 1 *** Significant at p<0.001

Table 4.17 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient nitrogen dioxide concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average	Nitrogen dioxide concentration increment						
		0.017 ppm (First quartile)		0.026 ppm (Median)		0.036 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.88	0.81 – 0.96	0.82	0.72 – 0.93	0.76	0.64 – 0.91	0.003**
	1	0.89	0.89 – 2.53	0.84	0.84 – 4.13	0.78	0.78 – 7.13	0.827
	2	0.92	0.84 – 0.84	0.88	0.77 – 0.77	0.84	0.70 – 0.70	0.046*
	3	0.91	0.84 – 0.99	0.87	0.76 – 0.99	0.82	0.69 – 0.98	0.029*
	MA3	0.87	0.79 – 0.96	0.81	0.70 – 0.94	0.75	0.61 – 0.92	0.006**
	MA5	0.86	0.77 – 0.95	0.79	0.67 – 0.93	0.72	0.58 – 0.90	0.004**
Cardiovascular	0	0.83	0.34 – 2.03	0.75	0.19 – 2.95	0.67	0.10 – 4.48	0.683
	1	0.89	0.31 – 2.53	0.84	0.17 – 4.13	0.78	0.09 – 7.13	0.827
	2	1.57	0.51 – 4.84	1.99	0.35 – 11.17	2.52	0.25 – 25.74	0.436
	3	0.78	0.31 – 1.96	0.68	0.17 – 2.79	0.59	0.08 – 4.14	0.597
	MA3	0.97	0.30 – 3.08	0.95	0.16 – 5.59	0.93	0.09 – 10.15	0.956
	MA5	0.69	0.21 – 2.30	0.57	0.09 – 3.58	0.47	0.05 – 5.57	0.549
Both	0	0.43	0.23 – 0.78	0.27	0.11 – 0.68	0.17	0.05 – 0.60	0.006**
	1	0.38	0.20 – 0.70	0.22	0.09 – 0.58	0.13	0.04 – 0.48	0.002**
	2	0.40	0.21 – 0.74	0.25	0.09 – 0.63	0.15	0.04 – 0.54	0.004**
	3	0.31	0.16 – 0.61	0.17	0.06 – 0.46	0.09	0.02 – 0.36	0.001***
	MA3	0.26	0.12 – 0.57	0.13	0.04 – 0.43	0.06	0.01 – 0.32	0.001***
	MA5	0.15	0.06 – 0.40	0.06	0.01 – 0.24	0.02	0.00 – 0.15	<0.001***

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.18 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient sulphur dioxide concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average	Sulphur dioxide concentration increment						p value
		0.005 ppm (First quartile)		0.006 ppm (Median)		0.007 ppm (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.76	0.76 – 1.04	0.87	0.72 – 1.04	0.85	0.68 – 1.05	0.132
	1	0.81	0.81 – 1.11	0.94	0.78 – 1.13	0.93	0.75 – 1.16	0.518
	2	0.80	0.80 – 1.09	0.92	0.76 – 1.11	0.91	0.73 – 1.13	0.402
	3	0.80	0.80 – 1.09	0.93	0.77 – 1.11	0.91	0.74 – 1.13	0.414
	MA3	0.70	0.70 – 1.07	0.84	0.65 – 1.08	0.81	0.60 – 1.10	0.180
	MA5	0.63	0.63 – 1.06	0.79	0.58 – 1.07	0.76	0.53 – 1.09	0.130
Cardiovascular	0	2.88	0.53 – 15.70	3.56	0.47 – 27.22	4.41	0.41 – 47.22	0.221
	1	1.67	0.30 – 9.40	1.85	0.23 – 14.71	2.05	0.18 – 23.02	0.561
	2	4.30	0.59 – 31.13	5.75	0.53 – 61.92	7.70	0.48 – 123.16	0.149
	3	13.79 [#]	1.36 – 139.74	23.30 [#]	1.45 – 375.30	39.38 [#]	1.54 – 1007.95	0.024*
	MA3	5.52	0.50 – 60.68	7.78	0.44 – 137.93	10.95	0.38 – 313.52	0.162
	MA5	74.68 [#]	2.74 – 2035.88	176.94 [#]	3.35 – 9343.37	419.25 [#]	4.10 – 42879.92	0.011*
Both	0	0.52	0.18 – 1.55	0.46	0.12 – 1.69	0.40	0.68 – 1.05	0.240
	1	0.39	0.12 – 1.23	0.32	0.08 – 1.28	0.27	0.75 – 1.16	0.058
	2	0.34	0.11 – 1.04	0.27	0.07 – 1.05	0.22	0.73 – 1.13	0.109
	3	0.44	0.14 – 1.33	0.37	0.10 – 1.41	0.31	0.74 – 1.13	0.145
	MA3	0.34	0.07 – 1.60	0.27	0.04 – 1.75	0.22	0.60 – 1.10	0.171
	MA5	0.15	0.02 – 1.05	0.10	0.01 – 1.06	0.07	0.53 – 1.09	0.056

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.19 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient carbon monoxide concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average	Carbon monoxide concentration increment						
		2.54 ppm (First quartile)		3.04 ppm (Median)		3.55 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.93	0.77 – 1.13	0.92	0.73 – 1.15	0.90	0.69 – 1.18	0.460
	1	1.00	0.82 – 1.21	1.00	0.79 – 1.26	1.00	0.76 – 1.31	0.973
	2	0.99	0.81 – 1.20	0.99	0.78 – 1.25	0.98	0.75 – 1.29	0.912
	3	0.96	0.79 – 1.16	0.95	0.76 – 1.20	0.94	0.72 – 1.24	0.673
	MA3	0.95	0.74 – 1.22	0.94	0.69 – 1.27	0.93	0.65 – 1.33	0.689
	MA5	0.96	0.71 – 1.28	0.95	0.67 – 1.34	0.94	0.63 – 1.41	0.755
Cardiovascular	0	2.94	0.33 – 25.98	3.68	0.26 – 51.03	4.60	0.21 – 100.20	0.332
	1	1.25	0.12 - 13.56	1.31	0.07 – 23.27	1.38	0.05 – 39.93	0.853
	2	14.65 [#]	1.28 - 167.40	25.56 [#]	1.35 – 483.57	44.57 [#]	1.42 – 1396.88	0.031*
	3	3.67	0.47 – 28.35	4.80	0.41 – 56.68	6.28	0.35 – 113.34	0.213
	MA3	0.74	0.10 - 5.75	0.70	0.06 – 8.31	0.66	0.04 – 11.86	0.777
	MA5	0.13	0.01 – 1.35	0.08	0.00 – 1.44	0.06	0.00 – 1.53	0.088
Both	0	2.31	0.59 – 9.08	2.72	0.73 – 1.15	3.21	0.47 – 21.84	0.232
	1	0.87	0.18 – 4.10	0.85	0.79 – 1.26	0.82	0.09 – 7.19	0.861
	2	0.28	0.06 – 1.30	0.22	0.78 – 1.25	1.17	0.02 – 1.45	0.105
	3	0.14	0.03 – 0.77	0.10	0.76 – 1.20	0.07	0.01 – 0.69	0.023*
	MA3	0.74	0.09 – 5.87	0.70	0.69 – 1.27	0.66	0.04 – 11.86	0.777
	MA5	0.13	0.01 – 1.36	0.08	0.67 – 1.34	0.06	0.00 – 1.53	0.088

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.20 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Kuala Lumpur by quartile increments of ambient ozone concentration, 2000 – 2003 (N = 1277).

Admission cases	Lag day/ moving average	Ozone concentration increment						
		0.008 ppm (First quartile)		0.011 ppm (Median)		0.016 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.02	0.95 – 1.11	1.03	0.93 – 1.15	1.05	0.90 – 1.23	0.541
	1	1.07	0.99 – 1.15	1.09	0.98 – 1.22	1.14	0.97 – 1.33	0.112
	2	1.05	0.97 – 1.13	1.06	0.95 – 1.18	1.09	0.93 – 1.28	0.268
	3	1.09 [#]	1.01 – 1.18	1.13 [#]	1.01 – 1.25	1.19 [#]	1.02 – 1.39	0.027*
	MA3	1.09	0.98 – 1.21	1.13	0.97 – 1.31	1.19	0.96 – 1.48	0.119
	MA5	1.18 [#]	1.03 – 1.34	1.25 [#]	1.05 – 1.49	1.38 [#]	1.07 – 1.78	0.013*
Cardiovascular	0	0.90	0.38 – 2.14	0.86	0.26 – 2.84	0.08	0.14 – 4.57	0.809
	1	2.89 [#]	1.11 – 7.56	4.31 [#]	1.15 – 16.15	8.38 [#]	1.23 – 57.19	0.030*
	2	1.39	0.59 – 3.27	1.57	0.48 – 5.09	1.92	0.35 – 10.67	0.454
	3	1.51	0.68 – 3.34	1.76	0.59 – 5.24	2.28	0.47 – 11.13	0.309
	MA3	0.69	0.33 – 1.46	0.60	0.21 – 1.69	0.48	0.11 – 2.14	0.334
	MA5	2.60 [#]	1.04 – 6.48	3.71 [#]	1.05 – 13.06	6.74 [#]	1.08 – 42.00	0.041*
Both	0	0.47	0.26 – 0.85	0.35	0.15 – 0.80	0.22	0.07 – 0.72	0.013*
	1	1.52	0.84 – 2.75	1.78	0.79 – 4.03	2.32	0.71 – 7.59	0.166
	2	2.74 [#]	1.55 – 4.83	3.99 [#]	1.82 – 8.73	7.49 [#]	2.40 – 23.37	0.001***
	3	1.72	0.97 – 3.05	2.10	0.95 – 4.64	2.95	0.93 – 9.33	0.065
	MA3	2.45 [#]	1.11 – 5.42	3.43 [#]	1.15 – 10.22	6.01 [#]	1.23 – 29.41	0.027*
	MA5	2.60 [#]	1.04 – 6.48	3.71 [#]	1.05 – 13.06	6.74 [#]	1.08 – 42.00	0.041*

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.21 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of ambient PM10 concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag day/ moving average	PM10 concentration increment						p value
		38.54 µg/m ³ (First quartile)		49.00 µg/m ³ (Median)		62.00 µg/m ³ (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.72	0.65 - 0.79	0.66	0.58 - 0.75	0.59	0.51 - 0.69	<0.001***
	1	0.72	0.65 - 0.78	0.65	0.58 - 0.73	0.58	0.50 - 0.68	<0.001***
	2	0.70	0.64 - 0.78	0.64	0.57 - 0.72	0.57	0.49 - 0.66	<0.001***
	3	0.72	0.65 - 0.79	0.66	0.58 - 0.74	0.59	0.51 - 0.68	<0.001***
	MA3	0.67	0.60 - 0.74	0.60	0.52 - 0.68	0.52	0.44 - 0.62	<0.001***
	MA5	0.64	0.57 - 0.71	0.56	0.49 - 0.65	0.48	0.41 - 0.58	<0.001***
Cardiovascular	0	NA	NA	NA	NA	NA	NA	NA
	1	0.71	0.64 - 0.78	0.64	0.57 - 0.73	0.57	0.49 - 0.67	<0.001***
	2	0.70	0.63 - 0.77	0.63	0.56 - 0.71	0.56	0.48 - 0.65	<0.001***
	3	0.71	0.64 - 0.78	0.65	0.57 - 0.73	0.58	0.49 - 0.67	<0.001***
	MA3	0.66	0.60 - 0.73	0.59	0.52 - 0.68	0.52	0.44 - 0.61	<0.001***
	MA5	0.63	0.57 - 0.70	0.56	0.48 - 0.64	0.48	0.40 - 0.57	<0.001***
Both	0	0.73	0.65 - 0.81	0.67	0.58 - 0.76	0.60	0.50 - 0.71	<0.001***
	1	0.73	0.65 - 0.81	0.67	0.58 - 0.77	0.60	0.51 - 0.72	<0.001***
	2	0.72	0.65 - 0.81	0.66	0.58 - 0.76	0.59	0.50 - 0.71	<0.001***
	3	0.74	0.67 - 0.83	0.69	0.60 - 0.79	0.62	0.52 - 0.74	0.100
	MA3	0.68	0.61 - 0.77	0.62	0.53 - 0.72	0.54	0.45 - 0.66	0.100
	MA5	1.00	0.88 - 1.12	1.00	0.85 - 1.16	0.99	0.81 - 1.20	0.926

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
CI ≥ 1 *** Significant at p<0.001

Table 4.22 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of ambient nitrogen dioxide concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag day/ moving average	Nitrogen dioxide concentration increment						
		0.026 ppm (First quartile)		0.032 ppm (Median)		0.038 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	2.16 [#]	1.88 – 2.48	2.58 [#]	2.17 – 3.06	3.08 [#]	2.51 – 3.78	<0.001***
	1	1.24 [#]	1.11 – 1.40	1.31 [#]	1.14 – 1.51	1.38 [#]	1.16 – 1.63	<0.001***
	2	1.07	0.96 – 1.19	1.09	0.95 – 1.24	1.10	0.94 – 1.29	0.230
	3	1.08	0.97 – 1.20	1.10	0.96 – 1.26	1.12	0.96 – 1.31	0.154
	MA3	1.53 [#]	1.32 – 1.77	1.69 [#]	1.41 – 2.03	1.87 [#]	1.51 – 2.31	<0.001***
	MA5	1.47 [#]	1.25 – 1.73	1.61 [#]	1.32 – 1.97	1.76 [#]	1.39 – 2.24	<0.001***
Cardiovascular	0	2.15 [#]	1.87 – 2.46	2.56 [#]	2.16 – 3.03	3.05 [#]	2.49 – 3.74	<0.001***
	1	1.25 [#]	1.11 – 1.40	1.31 [#]	1.14 – 1.51	1.38 [#]	1.17 – 1.63	<0.001***
	2	1.08	0.97 – 1.20	1.10	0.96 – 1.25	1.12	0.95 – 1.31	<0.001***
	3	1.06	0.96 – 1.19	1.08	0.95 – 1.23	1.10	0.94 – 1.28	0.174
	MA3	1.56 [#]	1.34 – 1.80	1.72 [#]	1.44 – 2.06	1.91 [#]	1.54 – 2.36	0.254
	MA5	1.46 [#]	1.24 – 1.72	1.60 [#]	1.31 – 1.95	1.74 [#]	1.38 – 2.21	<0.001***
Both	0	2.00 [#]	1.72 – 2.33	2.35 [#]	1.95 – 2.83	2.76 [#]	2.21 – 3.45	<0.001***
	1	1.24 [#]	1.09 – 1.42	1.31 [#]	1.11 – 1.54	1.38 [#]	1.14 – 1.67	0.001***
	2	1.05	0.92 – 1.18	1.06	0.91 – 1.23	1.07	0.89 – 1.28	0.472
	3	1.11	0.99 – 1.25	1.14	0.98 – 1.32	1.17	0.98 – 1.39	0.081
	MA3	1.48 [#]	1.25 – 1.74	1.61 [#]	1.32 – 1.98	1.77 [#]	1.39 – 2.25	<0.001***
	MA5	1.48 [#]	1.23 – 1.78	1.62 [#]	1.29 – 2.03	1.77 [#]	1.35 – 2.32	<0.001***

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.23 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of ambient sulphur dioxide concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag day/ moving average	Sulphur dioxide concentration increment						p value
		0.005 ppm (First quartile)		0.007 ppm (Median)		0.009 ppm (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.36 [#]	1.26 – 1.46	1.54 [#]	1.39 - 1.71	1.74 [#]	1.52 – 1.99	<0.001***
	1	1.17 [#]	1.09 – 1.25	1.24 [#]	1.13 – 1.36	1.32 [#]	1.17 – 1.49	<0.001***
	2	1.06 [#]	1.00 – 1.13	1.09 [#]	1.00 – 1.19	1.12	0.99 – 1.26	0.061
	3	1.08 [#]	1.02 – 1.15	1.12 [#]	1.02 – 1.22	1.16 [#]	1.03 – 1.30	0.014*
	MA3	1.30 [#]	1.20 – 1.42	1.45 [#]	1.29 – 1.63	1.61 [#]	1.38 – 1.87	<0.001***
	MA5	1.16 [#]	1.06 – 1.28	1.23 [#]	1.08 – 1.41	1.31 [#]	1.11 – 1.55	0.002**
Cardiovascular	0	1.35 [#]	1.26 – 1.46	1.53 [#]	1.38 - 1.69	1.72 [#]	1.51 – 1.97	<0.001***
	1	1.16 [#]	1.09 – 1.24	1.24 [#]	1.12 – 1.36	1.31 [#]	1.16 – 1.48	<0.001***
	2	1.06 [#]	1.00 – 1.14	1.09 [#]	1.00 – 1.20	1.12 [#]	1.00 – 1.26	0.060
	3	1.09 [#]	1.02 – 1.16	1.12 [#]	1.03 – 1.23	1.16 [#]	1.03 – 1.30	0.011*
	MA3	1.30 [#]	1.19 – 1.41	1.44 [#]	1.28 – 1.62	1.60 [#]	1.37 – 1.86	<0.001***
	MA5	1.17 [#]	1.07 – 1.29	1.25 [#]	1.10 – 1.42	1.33 [#]	1.12 – 1.57	<0.001***
Both	0	1.35 [#]	1.24 - 1.46	1.51 [#]	1.35 – 1.70	1.71 [#]	1.48 – 1.97	<0.001***
	1	1.17 [#]	1.08 – 1.26	1.24 [#]	1.12 – 1.38	1.32 [#]	1.15 – 1.51	<0.001***
	2	1.05	0.98 – 1.13	1.08	0.97 – 1.19	1.10	0.97 – 1.25	0.154
	3	1.07 [#]	1.00 – 1.15	1.10	0.99 – 1.21	1.13	0.99 – 1.28	0.066
	MA3	1.29 [#]	1.18 – 1.42	1.43 [#]	1.26 – 1.63	1.59 [#]	1.34 – 1.88	<0.001***
	MA5	1.12 [#]	1.01 – 1.25	1.18 [#]	1.02 – 1.37	1.23 [#]	1.02 – 1.49	0.031*

Note : MA3 = 3-day moving average * Significant at p<0.05
 MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.24 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of ambient carbon monoxide concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag day/ moving average	Carbon monoxide concentration increment						
		2.44 ppm (First quartile)		3.00 ppm (Median)		3.51 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.17 [#]	1.03 - 1.33	1.21 [#]	1.03 - 1.43	1.25 [#]	1.04 - 1.1	0.018*
	1	1.12	0.99 - 1.28	1.15	0.98 - 1.35	1.18	0.98 - 1.42	0.082
	2	1.09	0.96 - 1.24	1.11	0.95 - 1.30	1.13	0.94 - 1.36	0.195
	3	1.06	0.93 - 1.20	1.07	0.92 - 1.25	1.09	0.91 - 1.30	0.374
	MA3	1.23 [#]	1.03 - 1.45	1.28 [#]	1.04 - 1.58	1.34 [#]	1.05 - 1.71	0.019*
	MA5	1.23 [#]	1.01 - 1.48	1.28 [#]	1.02 - 1.62	1.34 [#]	1.02 - 1.76	0.037*
Cardiovascular	0	1.17 [#]	1.02 - 1.33	1.21 [#]	1.03 - 1.42	1.25 [#]	1.03 - 1.51	0.021*
	1	1.13	0.99 - 1.29	1.16	0.99 - 1.36	1.19	0.99 - 1.44	0.069
	2	1.10	0.97 - 1.25	1.13	0.96 - 1.32	1.1	0.96 - 1.38	0.139
	3	1.05	0.93 - 1.20	1.07	0.91 - 1.25	1.08	0.90 - 1.30	0.414
	MA3	1.24 [#]	1.05 - 1.48	1.31 [#]	1.06 - 1.61	1.37 [#]	1.07 - 1.75	0.013*
	MA5	1.45 [#]	1.19 - 1.77	1.59 [#]	1.24 - 2.02	1.71 [#]	1.29 - 2.28	<0.001***
Both	0	1.16 [#]	1.01 - 1.34	1.20 [#]	1.01 - 1.43	1.24 [#]	1.01 - 1.52	0.042*
	1	1.08	0.94 - 1.24	1.10	0.93 - 1.31	1.12	0.91 - 1.37	0.274
	2	1.05	0.91 - 1.21	1.07	0.89 - 1.27	1.08	0.88 - 1.32	0.474
	3	1.07	0.93 - 1.23	1.08	0.91 - 1.29	1.10	0.90 - 1.35	0.358
	MA3	1.16	0.97 - 1.40	1.20	0.96 - 1.51	1.24	0.95 - 1.62	0.110
	MA5	1.45 [#]	1.17 - 1.81	1.58 [#]	1.21 - 2.07	1.71 [#]	1.25 - 2.35	<0.001***

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.25 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of ambient ozone concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag day/ moving average	Ozone concentration increment						p value
		0.008 ppm (First quartile)		0.011 ppm (Median)		0.015 ppm (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.14 [#]	1.06 – 1.22	1.19 [#]	1.08 – 1.31	1.27 [#]	1.12 - 1.45	<0.001***
	1	1.00 [#]	1.06 – 1.06	1.00 [#]	1.08 – 1.08	1.00 [#]	1.12 – 1.11	0.956
	2	0.96	0.91 – 1.02	0.95	0.88 – 1.03	0.93	0.84 – 1.04	0.207
	3	0.97	0.92 – 1.03	0.96	0.89 – 1.04	0.94	0.85 – 1.05	0.290
	MA3	1.04	0.95 – 1.13	1.05	0.93 – 1.19	1.07	0.91 – 1.26	0.402
	MA5	0.98	0.88 – 1.08	0.97	0.84 – 1.11	0.96	0.79 – 1.16	0.647
Cardiovascular	0	1.14 [#]	1.07 – 1.22	1.20 [#]	1.09 – 1.32	1.28 [#]	1.13 - 1.46	<0.001***
	1	1.00	0.94 – 1.06	1.00	0.92 – 1.08	0.99	0.89 - 1.11	0.911
	2	0.97	0.92 – 1.03	0.96	0.89 – 1.04	0.94	0.85 - 1.05	0.291
	3	0.97	0.92 – 1.03	0.96	0.89 – 1.04	0.95	0.86 - 1.06	0.358
	MA3	1.05	0.96 – 1.14	1.06	0.94 – 1.20	1.09	0.92 - 1.28	0.320
	MA5	1.03	0.93 – 1.14	1.04	0.90 – 1.20	1.06	0.87 - 1.29	0.565
Both	0	1.12 [#]	1.04 - 1.21	1.17 [#]	1.05 - 1.30	1.24 [#]	1.07 - 1.43	0.004**
	1	1.01	0.95 - 1.08	1.01	0.93 - 1.11	1.02	0.90 - 1.15	0.746
	2	0.95	0.89 - 1.01	0.93	0.85 - 1.01	0.91	0.80 - 1.02	0.100
	3	0.95	0.89 - 1.01	0.93	0.86 - 1.02	0.91	0.81 - 1.03	0.127
	MA3	1.06	0.96 - 1.18	1.09	0.95 - 1.25	1.12	0.93 - 1.35	0.236
	MA5	1.02	0.90 - 1.14	1.02	0.87 - 1.20	1.03	0.83 - 1.29	0.779

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.26 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of PM10 concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag day/ moving average	PM10 concentration increment						p value
		38.54 µg/m ³ (First quartile)		49.00 µg/m ³ (Median)		62.00 µg/m ³ (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.81	0.70 – 0.93	0.76	0.64 – 0.91	0.71	0.57 – 0.88	0.002**
	1	0.77	0.67 – 0.88	0.71	0.60 – 0.85	0.65	0.52 – 0.81	<0.001***
	2	0.75	0.65 – 0.86	0.69	0.58 – 0.82	0.62	0.50 – 0.78	<0.001***
	3	0.79	0.69 – 0.90	0.74	0.62 – 0.88	0.69	0.55 – 0.85	0.001***
	MA3	0.74	0.63 – 0.86	0.68	0.56 – 0.83	0.62	0.48 – 0.79	<0.001***
	MA5	0.71	0.61 – 0.83	0.65	0.53 – 0.79	0.58	0.45 – 0.75	<0.001***
Cardiovascular	0	0.00	0.00 – 0.00	0.00	0.00 – 0.00	0.00	0.00 – 0.00	<0.001***
	1	0.66	0.40 – 1.08	0.59	0.31 – 1.10	0.51	0.23 – 1.13	0.096
	2	0.57	0.35 – 0.94	0.49	0.26 – 0.92	0.41	0.19 – 0.90	0.026*
	3	0.58	0.35 – 0.97	0.50	0.26 – 0.96	0.41	0.18 – 0.95	0.037*
	MA3	0.64	0.38 – 1.08	0.57	0.29 – 1.10	0.49	0.21 – 1.13	0.094
	MA5	0.59	0.33 – 1.04	0.51	0.25 – 1.05	0.43	0.17 – 1.06	0.068
Both	0	0.80	0.70 – 0.93	0.76	0.63 – 0.91	0.70	0.56 – 0.88	0.002**
	1	0.77	0.67 – 0.89	0.72	0.60 – 0.86	0.66	0.52 – 0.83	<0.001***
	2	0.75	0.66 – 0.87	0.70	0.59 – 0.84	0.64	0.51 – 0.80	<0.001***
	3	0.80	0.70 – 1.09	0.75	0.63 – 1.11	0.70	0.56 – 1.15	0.002**
	MA3	0.74	0.64 – 0.87	0.69	0.56 – 0.83	0.62	0.48 – 0.80	<0.001***
	MA5	1.16 [#]	1.00 – 1.35	1.21 [#]	1.00 – 1.47	1.27	0.99 – 1.62	0.057

Note : MA3 = 3-day moving average * Significant at p<0.05
 MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.27 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of nitrogen dioxide concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag Day	Nitrogen dioxide concentration increment						p value
		0.026 ppm (First quartile)		0.032 ppm (Median)		0.038 ppm (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	2.22 [#]	1.83 - 2.68	2.66 [#]	2.11 - 3.36	3.20 [#]	2.43 - 4.21	<0.001***
	1	1.41	0.81 - 2.44	1.52	0.77 - 3.00	1.64	0.74 - 3.68	0.226
	2	1.26 [#]	1.08 - 1.47	1.33 [#]	1.10 - 1.60	1.40 [#]	1.11 - 1.75	0.004**
	3	1.26 [#]	1.08 - 1.47	1.33 [#]	1.10 - 1.61	1.40 [#]	1.12 - 1.76	0.003**
	MA3	1.97 [#]	1.60 - 2.42	2.30 [#]	1.79 - 2.97	2.69 [#]	1.99 - 3.64	<0.001***
	MA5	1.94 [#]	1.55 - 2.43	2.26 [#]	1.71 - 2.98	2.63 [#]	1.89 - 3.65	<0.001***
Cardiovascular	0	1.69	0.94 - 3.02	1.91	0.93 - 3.90	2.15	0.92 - 5.04	0.078
	1	1.41	0.81 - 2.44	1.52	0.77 - 3.00	1.64	0.74 - 3.68	0.226
	2	0.82	0.48 - 1.43	0.79	0.40 - 1.55	0.75	0.34 - 1.68	0.488
	3	1.11	0.63 - 1.96	1.13	0.56 - 2.29	1.16	0.50 - 2.68	0.724
	MA3	1.59	0.79 - 3.21	1.77	0.75 - 4.20	1.97	0.71 - 5.50	0.194
	MA5	1.89	0.83 - 0.83	2.18	0.80 - 0.80	2.53	0.76 - 0.76	0.130
Both	0	2.24 [#]	1.85 - 2.71	2.69 [#]	2.13 - 3.41	3.24 [#]	2.45 - 4.29	<0.001***
	1	1.42 [#]	1.21 - 1.67	1.54 [#]	1.26 - 1.89	1.67 [#]	1.32 - 2.12	<0.001***
	2	1.28 [#]	1.10 - 1.50	1.36 [#]	1.12 - 1.65	1.44 [#]	1.15 - 1.81	0.001***
	3	1.27 [#]	1.09 - 1.49	1.35 [#]	1.11 - 1.63	1.42 [#]	1.14 - 1.78	0.002**
	MA3	1.98 [#]	1.61 - 2.44	2.32 [#]	1.79 - 2.99	2.71 [#]	2.00 - 3.68	<0.001***
	MA5	1.93 [#]	1.54 - 2.42	2.25 [#]	1.70 - 2.97	2.62 [#]	1.88 - 3.65	<0.001***

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.28 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of sulphur dioxide concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag day/ moving average	Sulphur dioxide concentration increment						
		0.005 ppm (First quartile)		0.007 ppm (Median)		0.009 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.38 [#]	1.25 – 1.52	1.57 [#]	1.37 – 1.80	1.79 [#]	1.49 – 2.14	<0.001***
	1	1.19 [#]	1.08 – 1.31	1.28 [#]	1.12 – 1.46	1.37 [#]	1.16 – 1.62	<0.001***
	2	1.13 [#]	1.03 – 1.24	1.18 [#]	1.04 – 1.34	1.24 [#]	1.05 – 1.46	0.011*
	3	1.12 [#]	1.02 – 1.23	1.17 [#]	1.03 – 1.33	1.23 [#]	1.04 – 1.45	0.014*
	MA3	1.38 [#]	1.23 – 1.55	1.58 [#]	1.34 – 1.85	1.80 [#]	1.46 – 2.21	<0.001***
	MA5	1.19 [#]	1.04 – 1.36	1.28 [#]	1.06 – 1.53	1.37 [#]	1.08 – 1.73	0.010**
Cardiovascular	0	1.43 [#]	1.02 – 2.00	1.65 [#]	1.03 – 2.64	1.90 [#]	1.03 – 3.49	0.039*
	1	1.47 [#]	1.05 – 2.05	1.71 [#]	1.07 – 2.74	1.99 [#]	1.09 – 3.65	0.026*
	2	0.94	0.67 – 1.32	0.92	0.57 – 1.48	0.90	0.49 – 1.66	0.740
	3	1.01	0.72 – 1.42	1.01	0.63 – 1.63	1.02	0.55 – 1.87	0.959
	MA3	1.51 [#]	1.00 – 2.27	1.78 [#]	1.00 – 3.15	2.09 [#]	1.00 – 4.37	0.049*
	MA5	1.16	0.73 – 1.85	1.23	0.64 – 2.36	1.30	0.56 – 3.02	0.540
Both	0	1.38 [#]	1.25 – 1.52	1.57 [#]	1.36 – 1.80	1.78 [#]	1.49 – 2.13	<0.001***
	1	1.18 [#]	1.07 – 1.29	1.26 [#]	1.10 – 1.43	1.34 [#]	1.13 – 1.59	0.001***
	2	1.14 [#]	1.03 – 1.25	1.19 [#]	1.05 – 1.36	1.26 [#]	1.06 – 1.49	0.008**
	3	1.13 [#]	1.03 – 1.24	1.18 [#]	1.04 – 1.35	1.24 [#]	1.05 – 1.47	0.011*
	MA3	1.38 [#]	1.23 – 1.55	1.57 [#]	1.33 – 1.84	1.78 [#]	1.44 – 2.20	<0.001***
	MA5	1.19 [#]	1.04 – 1.36	1.28 [#]	1.06 – 1.54	1.37 [#]	1.08 – 1.74	0.010**

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.29 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of carbon monoxide concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag Day	Carbon monoxide concentration increment						
		2.44 ppm (First Quartile)		3.00 ppm (Median)		3.51 ppm (Third Quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.08	0.90 - 1.29	1.10	0.88 - 1.37	1.12	0.86 - 1.45	0.409
	1	1.28 [#]	1.07 - 1.54	1.36 [#]	1.09 - 1.70	1.43 [#]	1.10 - 1.86	0.007**
	2	1.14	0.95 - 1.36	1.17	0.94 - 1.46	1.20	0.93 - 1.55	0.162
	3	1.16	0.97 - 1.38	1.20	0.96 - 1.49	1.23	0.96 - 1.59	0.107
	MA3	1.29 [#]	1.02 - 1.63	1.36 [#]	1.02 - 1.82	1.44 [#]	1.03 - 2.02	0.035*
	MA5	1.37 [#]	1.06 - 1.79	1.48 [#]	1.07 - 2.04	1.58 [#]	1.08 - 2.31	0.018*
Cardiovascular	0	0.83	0.42 - 1.64	0.79	0.34 - 1.84	0.76	0.29 - 2.03	0.588
	1	0.76	0.39 - 1.46	0.71	0.32 - 1.59	0.67	0.26 - 1.72	0.404
	2	0.97	0.50 - 1.90	0.96	0.42 - 2.20	0.96	0.36 - 2.51	0.929
	3	1.05	0.10 - 2.17	1.07	0.44 - 2.59	1.08	0.38 - 3.05	0.886
	MA3	0.73	0.30 - 1.75	0.68	0.23 - 1.99	0.63	0.18 - 2.24	0.479
	MA5	1.37	0.49 - 3.81	1.47	0.42 - 5.19	1.57	0.36 - 6.86	0.549
Both	0	1.09	0.91 - 1.31	1.11	0.89 - 1.40	1.14	0.87 - 1.48	0.346
	1	1.31 [#]	1.09 - 1.57	1.39 [#]	1.11 - 1.74	1.47 [#]	1.13 - 1.91	0.004**
	2	1.14	0.95 - 1.37	1.18	0.94 - 1.47	1.21	0.93 - 1.57	0.151
	3	1.16	0.97 - 1.38	1.20	0.96 - 1.49	1.23	0.96 - 1.59	0.106
	MA3	1.31 [#]	1.04 - 1.66	1.40 [#]	1.05 - 1.87	1.48 [#]	1.05 - 2.08	0.024*
	MA5	1.83 [#]	1.39 - 2.41	2.10 [#]	1.50 - 2.95	2.38 [#]	1.60 - 3.54	<0.001***

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.30 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at University Malaya Medical Centre by quartile increments of ozone concentration, 2000 – 2003 (N = 1461).

Admission cases	Lag day/ moving average	Ozone concentration increment						p value
		0.008 ppm (First quartile)		0.011 ppm (Median)		0.015 ppm (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.16 [#]	1.05 – 1.27	1.23 [#]	1.08 – 1.40	1.32 [#]	1.11 – 1.58	0.002**
	1	1.01	0.93 – 1.10	1.02	0.91 – 1.14	1.03	0.88 – 1.20	0.747
	2	0.95	0.88 – 1.03	0.93	0.83 – 1.04	0.91	0.78 – 1.06	0.214
	3	1.01	0.94 – 1.09	1.02	0.91 – 1.13	1.02	0.88 – 1.18	0.779
	MA3	1.06	0.93 – 1.19	1.08	0.91 – 1.27	1.11	0.88 – 1.39	0.388
	MA5	1.03	0.89 – 1.18	1.04	0.85 – 1.26	1.05	0.80 – 1.37	0.724
Cardiovascular	0	0.93	0.67 – 1.28	0.90	0.58 – 1.41	0.87	0.47 – 1.60	0.656
	1	0.90	0.67 – 1.21	0.86	0.57 – 1.30	0.82	0.47 – 1.43	0.474
	2	0.67	0.50 – 0.90	0.58	0.39 – 0.87	0.47	0.27 – 0.83	0.008**
	3	1.00	0.76 – 1.33	1.01	0.68 – 1.48	1.01	0.59 – 1.71	0.975
	MA3	0.66	0.43 – 1.02	0.56	0.31 – 1.03	0.46	0.20 – 1.04	0.062
	MA5	0.83	0.51 – 1.36	0.78	0.40 – 1.53	0.71	0.28 – 1.78	0.469
Both	0	1.17 [#]	1.07 – 1.29	1.25 [#]	1.09 – 1.42	1.35 [#]	1.13 – 1.61	0.001***
	1	1.02	0.94 – 1.10	1.02	0.91 – 1.15	1.03	0.88 – 1.20	0.685
	2	0.97	0.89 – 1.05	0.96	0.85 – 1.07	0.94	0.81 – 1.09	0.421
	3	1.02	0.94 – 1.10	1.02	0.92 – 1.14	1.03	0.89 – 1.19	0.698
	MA3	1.14 [#]	1.00 – 1.29	1.19 [#]	1.00 – 1.42	1.27 [#]	1.00 – 1.62	0.051
	MA5	1.12	0.96 – 1.30	1.16	0.95 – 1.43	1.23	0.93 – 1.63	0.152

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.31 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient PM10 concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	PM10 concentration increment						p value
		64.08 µg/m ³ (First quartile)		74.54 µg/m ³ (Median)		86.04 µg/m ³ (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.51 [#]	1.09 – 2.10	1.61 [#]	1.10 – 2.37	1.73 [#]	1.12 – 2.71	0.015*
	1	1.45 [#]	1.04 – 2.02	1.54 [#]	1.05 – 2.27	1.65 [#]	1.05 – 2.58	0.028*
	2	1.35	0.97 – 1.87	1.42	0.97 – 2.08	1.50	0.97 – 2.32	0.073
	3	1.49 [#]	1.07 – 2.08	1.59 [#]	1.08 – 2.34	1.70 [#]	1.09 – 2.67	0.020*
	MA3	1.70 [#]	1.14 – 2.53	1.86 [#]	1.17 – 2.95	2.04 [#]	1.20 – 3.48	0.009**
	MA5	1.93 [#]	1.24 – 3.03	2.15 [#]	1.28 – 3.63	2.43 [#]	1.33 – 4.43	0.004**
Cardiovascular	0	1.56 [#]	1.21 – 2.01	1.67 [#]	1.25 – 2.25	1.81 [#]	1.29 – 2.55	0.001***
	1	1.47	1.14 – 1.90	1.56 [#]	1.16 – 2.11	1.68 [#]	1.19 – 2.36	0.003**
	2	1.28	0.99 – 1.65	1.34	0.99 – 1.79	1.40	0.99 – 1.96	0.055
	3	1.28	0.99 – 1.66	1.34	0.99 – 1.80	1.40	0.99 – 1.97	0.055
	MA3	1.28	0.99 – 1.66	1.34	0.99 – 1.80	1.40	0.99 – 1.97	0.055
	MA5	1.67 [#]	1.24 – 2.26	1.82 [#]	1.28 – 2.58	1.99 [#]	1.33 – 2.98	0.001***
Both	0	1.32	0.94 – 1.84	1.38	0.93 – 2.03	1.45	0.92 – 2.26	0.109
	1	1.12	0.79 – 1.57	1.14	0.76 – 1.69	1.16	0.73 – 1.83	0.524
	2	1.10	0.79 – 1.55	1.12	0.76 – 1.66	1.14	0.73 – 1.80	0.566
	3	1.13	0.81 – 1.59	1.15	0.78 – 1.71	1.18	0.75 – 1.86	0.476
	MA3	1.26	0.84 – 1.89	1.31	0.82 – 2.09	1.36	0.79 – 2.34	0.259
	MA5	1.19	0.76 – 1.85	1.22	0.73 – 2.05	1.26	0.70 – 2.28	0.442

Note : MA3 = 3-day moving average * Significant at p<0.05
 MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.32 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient nitrogen dioxide concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	Nitrogen dioxide concentration increment						p value
		0.031 ppm (First quartile)		0.036 ppm (Median)		0.042 ppm (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.83 [#]	1.31 – 2.57	2.02 [#]	1.37 – 2.99	2.27 [#]	1.44 – 3.59	<0.001***
	1	1.76 [#]	1.40 – 2.22	1.93 [#]	1.47 – 2.53	2.15 [#]	1.57 – 2.95	<0.001***
	2	1.61 [#]	1.15 – 2.24	1.74 [#]	1.18 – 2.55	1.90 [#]	1.21 – 2.99	0.005**
	3	1.69 [#]	1.21 – 2.37	1.84 [#]	1.25 – 2.72	2.04 [#]	1.29 – 3.22	0.002**
	MA3	2.23 [#]	1.48 – 3.34	2.53 [#]	1.58 – 4.06	2.96 [#]	1.70 – 5.13	<0.001***
	MA5	2.76 [#]	1.75 – 4.36	3.26 [#]	1.92 – 5.53	3.97 [#]	2.14 – 7.35	<0.001***
Cardiovascular	0	1.93 [#]	1.54 – 2.42	2.15 [#]	1.65 – 2.80	2.44 [#]	1.80 – 3.32	<0.001***
	1	1.76 [#]	1.40 – 2.22	1.93 [#]	1.47 – 2.53	2.15 [#]	1.57 – 2.95	<0.001***
	2	1.63 [#]	1.29 – 2.06	1.77 [#]	1.35 – 2.31	1.94 [#]	1.42 – 2.66	<0.001***
	3	1.53 [#]	1.23 – 1.92	1.64 [#]	1.27 – 2.13	1.78 [#]	1.32 – 2.41	<0.001***
	MA3	2.29 [#]	1.75 – 3.00	2.62 [#]	1.91 – 3.59	3.07 [#]	2.13 – 4.44	<0.001***
	MA5	2.50 [#]	1.86 – 3.37	2.90 [#]	2.06 – 4.10	3.47 [#]	2.32 – 5.18	<0.001***
Both	0	1.69 [#]	1.26 – 2.27	1.84 [#]	1.31 – 2.59	2.04 [#]	1.37 – 3.03	0.001***
	1	1.47 [#]	1.11 – 1.95	1.57 [#]	1.13 – 2.17	1.69 [#]	1.15 – 2.47	0.007**
	2	1.40 [#]	1.05 – 1.86	1.48 [#]	1.06 – 2.06	1.58 [#]	1.07 – 2.32	0.022*
	3	1.56 [#]	1.17 – 2.09	1.68 [#]	1.20 – 2.36	1.83 [#]	1.23 – 2.72	0.003**
	MA3	1.82 [#]	1.29 – 2.57	2.00 [#]	1.34 – 2.99	2.25 [#]	1.41 – 3.59	0.001***
	MA5	2.00 [#]	1.37 – 2.92	2.24 [#]	1.44 – 3.48	2.56 [#]	1.53 – 4.28	<0.001***

Note : MA3 = 3-day moving average * Significant at p<0.05
 MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.33 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient sulphur dioxide concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	Sulphur dioxide concentration increment						p value
		0.005 ppm (First quartile)		0.006 ppm (Median)		0.007 ppm (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.86	0.67 – 1.12	0.84	0.62 – 1.14	0.84	0.62 – 1.14	0.263
	1	0.86	0.66 – 1.11	0.83	0.61 – 1.13	0.83	0.61 – 1.13	0.234
	2	0.79	0.61 – 1.03	0.76	0.56 – 1.03	0.76	0.56 – 1.03	0.078
	3	0.82 [#]	1.58 – 1.06	0.79 [#]	1.74 – 1.08	0.79	1.74 – 1.08	0.133
	MA3	0.73 [#]	1.95 – 1.05	0.69 [#]	2.23 – 1.06	0.69	2.23 – 1.06	0.088
	MA5	0.60	0.36 – 0.98	0.54	0.30 – 0.98	0.54	0.30 – 0.98	0.042*
Cardiovascular	0	0.95	0.77 – 1.17	0.94	0.73 – 1.21	0.94	0.73 – 1.21	0.640
	1	0.92	0.74 – 1.13	0.90	0.70 – 1.16	0.90	0.70 – 1.16	0.419
	2	0.91	0.74 – 1.13	0.90	0.70 – 1.16	0.90	0.70 – 1.16	0.404
	3	0.86	0.70 – 1.07	0.84	0.65 – 1.08	0.84	0.65 – 1.08	0.176
	MA3	0.89	0.66 – 1.20	0.87	0.61 – 1.24	0.87	0.61 – 1.24	0.439
	MA5	0.76	0.54 – 1.08	0.72	0.47 – 1.10	0.72	0.47 – 1.10	0.125
Both	0	0.97	0.74 – 1.27	0.96	0.70 – 1.33	0.96	0.70 – 1.33	0.826
	1	0.88	0.66 – 1.16	0.85	0.61 – 1.19	0.85	0.61 – 1.19	0.349
	2	0.84	0.64 – 1.10	0.81	0.58 – 1.13	0.81	0.58 – 1.13	0.208
	3	0.90	0.69 – 1.19	0.89	0.64 – 1.23	0.89	0.64 – 1.23	0.472
	MA3	0.81	0.55 – 1.18	0.77	0.49 – 1.23	0.77	0.49 – 1.23	0.271
	MA5	0.66	0.42 – 1.05	0.61	0.36 – 1.05	0.61	0.36 – 1.05	0.077

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.34 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient carbon monoxide concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	Carbon monoxide concentration increment						
		2.68 ppm (First quartile)		3.11 ppm (Median)		3.64 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.55 [#]	1.17 – 2.04	1.66 [#]	1.20 – 2.29	1.81 [#]	1.24 – 2.64	0.002**
	1	1.42 [#]	1.08 – 1.86	1.50 [#]	1.09 – 2.06	1.60 [#]	1.10 – 2.33	0.013*
	2	1.45	1.10 – 1.90	1.54 [#]	1.12 – 2.10	1.65 [#]	1.14 – 2.39	0.008**
	3	1.46 [#]	1.11 – 1.92	1.55 [#]	1.13 – 2.13	1.67 [#]	1.15 – 2.43	0.007**
	MA3	2.02 [#]	1.38 – 2.95	2.26 [#]	1.45 – 3.51	2.59 [#]	1.54 – 4.35	<0.001***
	MA5	2.66 [#]	1.70 – 4.17	3.12 [#]	1.85 – 5.25	3.79 [#]	2.06 – 6.96	<0.001***
Cardiovascular	0	1.41 [#]	1.13 – 1.75	1.49 [#]	1.15 – 1.92	1.59 [#]	1.18 – 2.15	0.003**
	1	1.28 [#]	1.03 – 1.59	1.33 [#]	1.03 – 1.72	1.40 [#]	1.04 – 1.88	0.028*
	2	1.33 [#]	1.07 – 1.66	1.39 [#]	1.08 – 1.80	1.47 [#]	1.09 – 1.99	0.012*
	3	1.46 [#]	1.18 – 1.82	1.56 [#]	1.21 – 2.00	1.68 [#]	1.25 – 2.26	0.001***
	MA3	1.79 [#]	1.20 – 2.66	1.96 [#]	1.24 – 3.11	2.20 [#]	1.28 – 3.78	0.004**
	MA5	1.78 [#]	1.15 – 2.77	1.95 [#]	1.17 – 3.26	2.19 [#]	1.20 – 3.99	0.010**
Both	0	1.50 [#]	1.14 – 1.97	1.60 [#]	1.16 – 2.20	1.73 [#]	1.19 – 2.51	0.004**
	1	1.30	0.98 – 1.73	1.36	0.98 – 1.89	1.43	0.97 – 2.10	0.068
	2	1.30	0.98 – 1.73	1.36	0.98 – 1.89	1.43	0.97 – 2.10	0.070
	3	1.45 [#]	1.10 – 1.91	1.54 [#]	1.12 – 2.12	1.66 [#]	1.14 – 2.41	0.008**
	MA3	1.79 [#]	1.20 – 2.66	1.96 [#]	1.24 – 3.11	2.20 [#]	1.28 – 3.78	0.004**
	MA5	1.78 [#]	1.15 – 2.77	1.95 [#]	1.17 – 3.26	2.19 [#]	1.20 – 3.99	0.010**

Note : MA3 = 3-day moving average * Significant at p<0.05
 MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.35 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient ozone concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	Ozone concentration increment						p value
		0.008 ppm (First quartile)		0.012 ppm (Median)		0.017 ppm (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.94	0.83 – 1.07	0.92	0.76 – 1.10	0.89	0.68 – 1.15	0.365
	1	0.95	0.85 – 1.07	0.93	0.78 – 1.10	0.90	0.71 – 1.15	0.400
	2	0.89	0.80 – 1.00	0.85	0.72 – 1.00	0.79	0.62 – 1.00	0.048*
	3	0.90	0.81 – 1.01	0.86	0.73 – 1.01	0.80	0.64 – 1.02	0.067
	MA3	0.86	0.72 – 1.01	0.79	0.62 – 1.02	0.72	0.50 – 1.03	0.071
	MA5	0.76	1.61 – 0.93	0.66	2.04 – 0.90	0.56	2.75 – 0.86	0.008**
Cardiovascular	0	1.04	0.94 – 1.15	1.06	0.91 – 1.23	1.08	0.87 – 1.34	0.477
	1	1.05	0.95 – 1.15	1.07	0.93 – 1.23	1.10	0.90 – 1.34	0.340
	2	0.94	0.86 – 1.03	0.92	0.80 – 1.05	0.88	0.73 – 1.07	0.213
	3	0.92	0.84 – 1.01	0.89	0.77 – 1.02	0.84	0.69 – 1.02	0.082
	MA3	0.94	0.78 – 1.13	0.91	0.68 – 1.21	0.87	0.58 – 1.30	0.503
	MA5	0.86	0.69 – 1.07	0.79	0.57 – 1.11	0.72	0.45 – 1.16	0.176
Both	0	0.97	0.85 – 1.12	0.96	0.78 – 1.18	0.95	0.70 – 1.27	0.709
	1	0.99	0.87 – 1.12	0.98	0.81 – 1.19	0.98	0.75 – 1.28	0.861
	2	0.94	0.83 – 1.07	0.91	0.75 – 1.10	0.88	0.67 – 1.15	0.346
	3	0.94	0.83 – 1.06	0.91	0.75 – 1.10	0.87	0.67 – 1.14	0.313
	MA3	0.92	0.76 – 1.11	0.88	0.67 – 1.17	0.84	0.56 – 1.24	0.376
	MA5	0.86	0.69 – 1.07	0.79	0.57 – 1.11	0.72	0.45 – 1.16	0.176

Note : MA3 = 3-day moving average
 MA5 = 5-day moving average
 # CI ≥ 1

* Significant at p<0.05
 ** Significant at p<0.01
 *** Significant at p<0.001

Table 4.36 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient PM10 concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	PM10 concentration increment						
		64.08 µg/m ³ (First quartile)		74.54 µg/m ³ (Median)		86.04 µg/m ³ (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.36 [#]	1.06 – 1.75	1.43 [#]	1.07 – 1.91	1.52 [#]	1.09 – 2.14	0.015*
	1	1.30 [#]	1.01 – 1.66	1.35 [#]	1.01 – 1.80	1.42 [#]	1.01 – 1.99	0.042*
	2	1.37 [#]	1.06 – 1.76	1.44 [#]	1.07 – 1.93	1.53 [#]	1.09 – 2.15	0.015*
	3	1.38 [#]	1.07 – 1.77	1.45 [#]	1.08 – 1.94	1.54 [#]	1.09 – 2.18	0.013*
	MA3	1.71 [#]	1.21 – 2.43	1.87 [#]	1.24 – 2.81	2.08 [#]	1.29 – 3.35	0.003**
	MA5	2.27 [#]	1.50 – 3.45	2.59 [#]	1.60 – 4.20	3.05 [#]	1.73 – 5.37	<0.001***
Cardiovascular	0	1.73	0.82 – 3.66	1.89	0.79 – 4.51	2.10	0.76 – 5.83	0.153
	1	1.77	0.85 – 3.71	1.94	0.82 – 4.58	2.17	0.80 – 5.93	0.129
	2	1.42	0.69 – 2.95	1.51	0.65 – 3.51	1.62	0.60 – 4.35	0.341
	3	3.23 [#]	1.69 – 6.16	3.89 [#]	1.84 – 8.24	4.91 [#]	2.04 – 11.80	<0.001***
	MA3	1.13	0.43 – 2.97	1.15	0.37 – 3.54	1.18	0.32 – 4.40	0.805
	MA5	1.00	0.33 – 3.02	1.00	0.28 – 3.61	1.00	0.22 – 4.49	0.996
Both	0	1.57	0.80 – 3.06	1.69	0.78 – 3.67	1.81	0.74 – 4.58	0.187
	1	0.89	0.44 – 1.80	0.87	0.39 – 1.97	0.85	0.33 – 2.22	0.742
	2	0.98	0.49 – 1.96	0.98	0.44 – 2.18	0.98	0.38 – 2.49	0.961
	3	1.81	0.96 – 3.42	1.99	0.95 – 4.16	2.23	0.94 – 5.31	0.069
	MA3	1.13	0.43 – 2.97	1.15	0.37 – 3.54	1.18	0.32 – 4.40	0.805
	MA5	1.00	0.33 – 3.02	1.00	0.28 – 3.61	1.00	0.22 – 4.49	0.996

Note : MA3 = 3-day moving average * Significant at p<0.05
 MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.37 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient nitrogen dioxide concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	Nitrogen dioxide concentration increment						
		0.031 ppm (First quartile)		0.036 ppm (Median)		0.042 ppm (Third Quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.69 [#]	1.29 – 2.20	1.83 [#]	1.35 – 2.50	2.03 [#]	1.41 – 2.91	<0.001***
	1	2.17 [#]	1.02 – 4.63	2.46 [#]	1.02 – 5.93	2.86 [#]	1.03 – 7.97	0.044*
	2	1.72 [#]	1.32 – 2.24	1.88 [#]	1.38 – 2.55	2.09 [#]	1.46 – 2.99	<0.001***
	3	1.88 [#]	1.44 – 2.46	2.08 [#]	1.53 – 2.84	2.35 [#]	1.64 – 3.38	<0.001***
	MA3	2.19 [#]	1.59 – 3.00	2.48 [#]	1.72 – 3.58	2.89 [#]	1.88 – 4.43	<0.001***
	MA5	2.99 [#]	2.11 – 4.24	3.57 [#]	2.38 – 5.35	4.41 [#]	2.74 – 7.08	<0.001***
Cardiovascular	0	2.25 [#]	1.07 – 4.74	2.57 [#]	1.08 – 6.09	3.01 [#]	1.10 – 8.23	0.032*
	1	2.17 [#]	1.02 – 4.63	2.46 [#]	1.02 – 5.93	2.86 [#]	1.03 – 7.97	0.044*
	2	1.90	0.90 – 3.99	2.11	0.89 – 4.99	2.38	0.87 – 6.52	0.090
	3	2.21 [#]	1.14 – 4.30	2.51 [#]	1.16 – 5.44	2.93 [#]	1.19 – 7.21	0.019*
	MA3	3.00 [#]	1.19 – 7.54	3.58 [#]	1.23 – 10.44	4.43 [#]	1.27 – 15.43	0.020*
	MA5	3.79 [#]	1.39 – 10.32	4.70 [#]	1.47 – 15.04	6.09 [#]	1.57 – 23.62	0.009**
Both	0	0.66	0.31 – 1.38	0.61	0.26 – 1.45	0.57	0.21 – 1.54	0.265
	1	1.12	0.54 – 2.28	1.13	0.49 – 2.61	1.16	0.44 – 3.06	0.766
	2	0.97 [#]	2.00 – 2.13	0.96 [#]	2.23 – 2.41	0.96 [#]	2.55 – 2.79	0.928
	3	2.21 [#]	1.14 – 4.30	2.51 [#]	1.16 – 5.44	2.93 [#]	1.19 – 7.21	0.190
	MA3	0.86	0.37 – 2.03	0.84	0.31 – 2.27	0.82	0.26 – 2.60	0.734
	MA5	3.79 [#]	1.39 – 10.32	4.70 [#]	1.47 – 15.04	6.09 [#]	1.57 – 23.62	0.009**

Note : MA3 = 3-day moving average * Significant at p<0.05
 MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.38 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient sulphur dioxide concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	Sulphur dioxide concentration increment						p value
		0.005 ppm (First quartile)		0.006 ppm (Median)		0.007 ppm (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.79	0.63 – 0.99	0.75	0.57 – 0.99	0.72	0.52 – 0.99	0.042*
	1	0.78	0.62 – 0.98	0.74	0.56 – 0.97	0.70	0.51 – 0.97	0.032*
	2	0.79	0.63 – 1.01	0.76	0.57 – 1.01	0.73	0.52 – 1.01	0.056
	3	0.86	0.68 – 1.09	0.83	0.63 – 1.11	0.81	0.58 – 1.13	0.210
	MA3	0.65	0.47 – 0.90	0.60	0.41 – 0.88	0.55	0.35 – 0.86	0.009**
	MA5	0.66	0.45 – 0.97	0.61	0.38 – 0.97	0.56	0.32 – 0.96	0.036*
Cardiovascular	0	1.03	0.52 – 2.03	1.03	0.46 – 2.34	1.04	0.40 – 2.69	0.937
	1	1.16	0.57 – 0.57	1.19	0.51 – 0.51	1.23	0.45 – 0.45	0.687
	2	1.31	0.65 – 2.62	1.38	0.60 – 3.18	1.45	0.55 – 3.85	0.451
	3	2.39 [#]	1.18 – 4.84	2.84 [#]	1.22 – 6.64	3.39 [#]	1.26 – 9.10	0.016*
	MA3	1.31	0.48 – 3.55	1.38	0.42 – 4.58	1.46	0.36 – 5.90	0.594
	MA5	1.57	0.47 – 5.25	1.72	0.41 – 7.32	1.89	0.35 – 10.20	0.462
Both	0	0.69	0.35 – 1.37	0.64	0.28 – 1.46	0.59	0.23 – 1.55	0.289
	1	1.00	0.50 – 1.98	0.99	0.44 – 2.27	0.99	0.38 – 2.60	<0.001***
	2	0.62	0.31 – 1.23	0.56	0.24 – 1.28	0.51	0.19 – 1.33	0.168
	3	0.89	0.45 – 1.74	0.86	0.38 – 1.95	0.84	0.33 – 2.18	0.725
	MA3	0.61	0.24 – 1.56	0.56	0.18 – 1.71	0.50	0.14 – 1.86	0.305
	MA5	0.52	0.18 – 1.49	0.46	0.13 – 1.62	0.40	0.09 – 1.75	0.226

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.39 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient carbon monoxide concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	Carbon monoxide concentration increment						
		2.68 ppm (First quartile)		3.11 ppm (Median)		3.64 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.36 [#]	1.06 – 1.75	1.43 [#]	1.07 – 1.91	1.52 [#]	1.09 – 2.14	0.015*
	1	1.30 [#]	1.01 – 1.66	1.35 [#]	1.01 – 1.80	1.42 [#]	1.01 – 1.99	0.042*
	2	1.37 [#]	1.06 – 1.76	1.44 [#]	1.07 – 1.93	1.53 [#]	1.09 – 2.15	0.015*
	3	1.38 [#]	1.07 – 1.77	1.45 [#]	1.08 – 1.94	1.54 [#]	1.09 – 2.18	0.013*
	MA3	1.71 [#]	1.21 – 2.43	1.87 [#]	1.24 – 2.81	2.08 [#]	1.29 – 3.35	0.003**
	MA5	2.27 [#]	1.50 – 3.45	2.59 [#]	1.60 – 4.20	3.05 [#]	1.73 – 5.37	<0.001***
Cardiovascular	0	1.73	0.82 – 3.66	1.89	0.79 – 4.51	2.10	0.76 – 5.83	0.153
	1	1.77	0.85 – 3.71	1.94	0.82 – 4.58	2.17	0.80 – 5.93	0.129
	2	1.42	0.69 – 2.95	1.51	0.65 – 3.51	1.62	0.60 – 4.35	0.341
	3	3.23 [#]	1.69 – 6.16	3.89 [#]	1.84 – 8.24	4.91 [#]	2.04 – 11.80	<0.001***
	MA3	1.13	0.43 – 2.97	1.15	0.37 – 3.54	1.18	0.32 – 4.40	0.805
	MA5	1.00	0.33 – 3.02	1.00	0.28 – 3.61	1.00	0.22 – 4.49	0.996
Both	0	1.57	0.80 – 3.06	1.69	0.78 – 3.67	1.84	0.74 – 4.58	0.187
	1	0.89	0.44 – 1.80	0.87	0.39 – 1.97	0.85	0.33 – 2.22	0.742
	2	0.98	0.49 – 1.96	0.98	0.44 – 2.18	0.98	0.38 – 2.49	0.961
	3	1.81	0.96 – 3.42	1.99	0.95 – 4.16	2.23	0.94 – 5.31	0.069
	MA3	1.13	0.43 – 2.97	1.15	0.37 – 3.54	1.18	0.32 – 4.40	0.805
	MA5	1.00	0.33 – 3.02	1.00	0.28 – 3.61	1.00	0.22 – 4.49	0.996

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.40 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Universiti Kebangsaan Malaysia by quartile increments of ambient ozone concentration, 2000 – 2003 (N = 730).

Admission cases	Lag day/ moving average	Ozone concentration increment						
		0.008 ppm (First quartile)		0.012 ppm (Median)		0.017 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.92	0.83 – 1.03	0.89	0.75 – 1.05	0.85	0.67 – 1.08	0.172
	1	0.94	0.84 – 1.04	0.91	0.78 – 1.06	0.87	0.70 – 1.09	0.223
	2	0.95	0.86 – 1.05	0.93	0.80 – 1.08	0.90	0.72 – 1.12	0.341
	3	0.93	0.84 – 1.03	0.90	0.77 – 1.04	0.86	0.69 – 1.06	0.159
	MA3	0.88	0.75 – 1.02	0.82	0.65 – 1.03	0.76	0.55 – 1.05	0.094
	MA5	0.80	0.67 – 0.97	0.72	0.55 – 0.95	0.63	0.43 – 0.93	0.021*
Cardiovascular	0	1.00	0.70 – 1.43	1.00	0.59 – 1.70	1.00	0.47 – 2.12	0.998
	1	1.15	0.84 – 1.58	1.23	0.77 – 1.99	1.35	0.69 – 2.65	0.388
	2	0.89	0.64 – 1.24	0.84	0.51 – 1.38	0.78	0.39 – 1.58	0.487
	3	0.99	0.72 – 1.37	0.99	0.61 – 1.60	0.98	0.50 – 1.95	0.964
	MA3	1.33	0.87 – 2.03	1.53	0.81 – 2.89	1.82	0.74 – 4.49	0.191
	MA5	0.98	0.60 – 1.58	0.96	0.47 – 1.99	0.95	0.34 – 2.65	0.922
Both	0	1.04	0.76 – 1.42	1.06	0.66 – 1.70	1.08	0.55 – 2.12	0.821
	1	1.12	0.84 – 1.50	1.19	0.76 – 1.84	1.27	0.68 – 2.37	0.447
	2	1.29	0.98 – 1.71	1.47	0.97 – 2.24	1.72	0.95 – 3.13	0.073
	3	1.06	0.80 – 1.42	1.10	0.71 – 1.70	1.14	0.61 – 2.11	0.678
	MA3	1.11	0.74 – 1.66	1.17	0.64 – 2.14	1.25	0.53 – 2.95	0.614
	MA5	0.98	0.60 – 1.58	0.96	0.47 – 1.99	0.95	0.34 – 2.65	0.922

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.41 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient PM10 concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	PM10 concentration increment						p value
		43.81 µg/m ³ (First quartile)		54.04 µg/m ³ (Median)		66.60 µg/m ³ (Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.24 [#]	1.13 – 1.38	1.31 [#]	1.16 – 1.48	1.40 [#]	1.21 – 1.63	<0.001***
	1	1.19 [#]	1.07 – 1.31	1.23 [#]	1.09 – 1.39	1.30 [#]	1.11 – 1.50	0.001***
	2	1.17 [#]	1.06 – 1.28	1.21 [#]	1.08 – 1.36	1.27 [#]	1.10 – 1.46	0.001***
	3	1.19 [#]	1.08 – 1.31	1.23 [#]	1.10 – 1.39	1.30 [#]	1.13 – 1.50	<0.001***
	MA3	NA	NA	NA	NA	NA	NA	NA
	MA5	NA	NA	NA	NA	NA	NA	NA
Cardiovascular	0	1.19 [#]	1.06 – 1.33	1.23 [#]	1.08 – 1.42	1.30 [#]	1.10 – 1.54	0.003**
	1	1.16 [#]	1.03 – 1.29	1.20 [#]	1.04 – 1.38	1.25 [#]	1.05 – 1.48	0.012*
	2	1.11	0.99 – 1.24	1.13	0.98 – 1.30	1.17	0.98 – 1.39	0.088
	3	1.06	0.94 – 1.19	1.07	0.93 – 1.23	1.09	0.91 – 1.30	0.354
	MA3	NA	NA	NA	NA	NA	NA	NA
	MA5	NA	NA	NA	NA	NA	NA	NA
Both	0	1.06	0.88 – 1.28	1.08	0.86 – 1.35	1.10	0.83 – 1.45	0.519
	1	1.00	0.83 – 1.21	1.00	0.79 – 1.26	1.00	0.75 – 1.33	0.999
	2	1.20 [#]	1.00 – 1.44	1.25 [#]	1.00 – 1.57	1.32 [#]	1.00 – 1.74	0.052
	3	1.12	0.92 – 1.35	1.14	0.91 – 1.44	1.18	0.89 – 1.57	0.250
	MA3	NA	NA	NA	NA	NA	NA	NA
	MA5	NA	NA	NA	NA	NA	NA	NA

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.42 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient nitrogen dioxide concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	Nitrogen dioxide concentration increment						
		0.013 ppm (First quartile)		0.016 ppm (Median)		0.020 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.25 [#]	1.13 - 1.37	1.31 [#]	1.17 - 1.48	1.41 [#]	1.21 - 1.63	<0.001***
	1	1.17 [#]	1.05 - 1.29	1.21 [#]	1.07 - 1.37	1.27 [#]	1.08 - 1.48	0.003**
	2	1.23 [#]	1.11 - 1.35	1.28 [#]	1.14 - 1.44	1.37 [#]	1.18 - 1.58	<0.001***
	3	1.24 [#]	1.12 - 1.36	1.30 [#]	1.15 - 1.46	1.38 [#]	1.20 - 1.60	<0.001***
	MA3	1.46 [#]	1.29 - 1.66	1.60 [#]	1.37 - 1.86	1.79 [#]	1.48 - 2.18	<0.001***
	MA5	1.67 [#]	1.44 - 1.94	1.88 [#]	1.57 - 2.26	2.20 [#]	1.76 - 2.77	<0.001***
Cardiovascular	0	1.16 [#]	1.05 - 1.28	1.20 [#]	1.07 - 1.36	1.26 [#]	1.08 - 1.47	0.003**
	1	1.17 [#]	1.05 - 1.29	1.21 [#]	1.07 - 1.37	1.27 [#]	1.08 - 1.48	0.003**
	2	1.12 [#]	1.01 - 1.23	1.15 [#]	1.01 - 1.29	1.19 [#]	1.02 - 1.38	0.029*
	3	1.15 [#]	1.04 - 1.27	1.18 [#]	1.05 - 1.34	1.24 [#]	1.06 - 1.44	0.007**
	MA3	1.26 [#]	1.11 - 1.43	1.33 [#]	1.13 - 1.55	1.42 [#]	1.17 - 1.73	<0.001***
	MA5	1.36 [#]	1.18 - 1.57	1.46 [#]	1.22 - 1.75	1.61 [#]	1.29 - 2.01	<0.001***
Both	0	1.36 [#]	1.16 - 1.60	1.46 [#]	1.20 - 1.79	1.61 [#]	1.25 - 2.07	<0.001***
	1	1.29 [#]	1.09 - 1.51	1.36 [#]	1.11 - 1.67	1.47 [#]	1.15 - 1.89	0.003**
	2	1.21 [#]	1.03 - 1.41	1.26 [#]	1.04 - 1.53	1.33 [#]	1.05 - 1.70	0.020*
	3	1.20 [#]	1.02 - 1.41	1.25 [#]	1.03 - 1.52	1.32 [#]	1.04 - 1.69	0.025*
	MA3	1.50 [#]	1.22 - 1.84	1.65 [#]	1.28 - 2.12	1.87 [#]	1.36 - 2.55	<0.001***
	MA5	1.67 [#]	1.32 - 2.10	1.88 [#]	1.41 - 2.49	2.20 [#]	1.54 - 3.13	<0.001***

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.43 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient sulphur dioxide concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	Sulphur dioxide concentration increment						
		0.002 ppm (First quartile)		0.002 ppm (Median)		0.003 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.02	0.95 - 1.09	1.02	0.95 - 1.09	1.03	0.93 - 1.13	0.630
	1	1.00	0.94 - 1.07	1.00	0.94 - 1.07	1.00	0.91 - 1.11	0.939
	2	0.99	0.93 - 1.06	0.99	0.93 - 1.06	0.99	0.89 - 1.09	0.795
	3	1.01	0.95 - 1.08	1.01	0.95 - 1.08	1.02	0.92 - 1.12	0.712
	MA3	1.01	0.92 - 1.11	1.01	0.92 - 1.11	1.02	0.89 - 1.17	0.814
	MA5	1.39 [#]	1.24 - 1.57	1.39 [#]	1.24 - 1.57	1.65 [#]	1.38 - 1.97	<0.001***
Cardiovascular	0	1.01	0.94 - 1.09	1.01	0.94 - 1.09	1.01	0.91 - 1.14	0.812
	1	1.00	0.93 - 1.08	1.00	0.93 - 1.08	1.00	0.89 - 1.12	1.000
	2	1.00	0.93 - 1.08	1.00	0.93 - 1.08	1.00	0.89 - 1.12	0.964
	3	0.99	0.92 - 1.07	0.99	0.92 - 1.07	0.98	0.88 - 1.10	0.758
	MA3	1.00	0.91 - 1.11	1.00	0.91 - 1.11	1.01	0.86 - 1.17	0.933
	MA5	1.15 [#]	1.03 - 1.30	1.15 [#]	1.03 - 1.30	1.24 [#]	1.04 - 1.48	0.016*
Both	0	1.09	0.96 - 1.23	1.09	0.96 - 1.23	1.14	0.95 - 1.36	0.169
	1	1.02	0.90 - 1.15	1.02	0.90 - 1.15	1.03	0.86 - 1.23	0.787
	2	0.96	0.85 - 1.09	0.96	0.85 - 1.09	0.95	0.79 - 1.13	0.538
	3	0.97	0.86 - 1.09	0.97	0.86 - 1.09	0.95	0.79 - 1.14	0.586
	MA3	1.04	0.89 - 1.23	1.04	0.89 - 1.23	1.06	0.84 - 1.36	0.613
	MA5	1.20 [#]	1.00 - 1.44	1.20 [#]	1.00 - 1.44	1.31 [#]	1.00 - 1.73	0.051

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.44 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient carbon monoxide concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	Carbon monoxide concentration increment						
		0.86 ppm (First quartile)		1.07 ppm (Median)		1.36 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.10 [#]	1.00 – 1.21	1.13 [#]	1.00 – 1.26	1.16 [#]	1.00 – 1.34	0.043
	1	1.09 [#]	1.00 – 1.20	1.12 [#]	1.00 – 1.25	1.15 [#]	1.00 – 1.33	0.050*
	2	1.12 [#]	1.02 – 1.22	1.15 [#]	1.03 – 1.28	1.19 [#]	1.04 – 1.37	0.014*
	3	1.12 [#]	1.03 – 1.22	1.15 [#]	1.03 – 1.29	1.20 [#]	1.04 – 1.38	0.011*
	MA3	NA	NA	NA	NA	NA	NA	NA
	MA5	NA	NA	NA	NA	NA	NA	NA
Cardiovascular	0	1.05	0.95 – 1.17	1.06	0.93 – 1.21	1.08	0.92 – 1.28	0.353
	1	1.01	0.91 – 1.12	1.01	0.89 – 1.15	1.01	0.86 – 1.19	0.865
	2	1.07	0.96 – 1.18	1.08	0.95 – 1.23	1.11	0.94 – 1.30	0.213
	3	1.09	0.99 – 1.21	1.11	0.98 – 1.27	1.15	0.98 – 1.35	0.092
	MA3	NA	NA	NA	NA	NA	NA	NA
	MA5	NA	NA	NA	NA	NA	NA	NA
Both	0	0.98	0.83 – 1.16	0.97	0.79 – 1.20	0.97	0.74 – 1.26	0.811
	1	0.99	0.83 – 1.16	0.98	0.80 – 1.21	0.98	0.75 – 1.27	0.862
	2	1.10	0.93 – 1.29	1.12	0.92 – 1.37	1.16	0.89 – 1.49	0.269
	3	1.03	0.88 – 1.22	1.04	0.85 – 1.28	1.05	0.81 – 1.37	0.685
	MA3	NA	NA	NA	NA	NA	NA	NA
	MA5	NA	NA	NA	NA	NA	NA	NA

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.45 : Relative risk (RR) of adult admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient ozone concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	Ozone concentration increment						
		0.010 ppm (First quartile)		0.014 ppm (Median)		0.019 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.02	0.96 - 1.08	1.03	0.95 - 1.12	1.04	0.93 - 1.16	0.510
	1	1.03	0.97 - 1.09	1.04	0.96 - 1.13	1.06	0.95 - 1.19	0.323
	2	1.00	0.94 - 1.06	1.00	0.92 - 1.08	1.00	0.89 - 1.12	0.979
	3	1.02	0.96 - 1.08	1.03	0.95 - 1.12	1.04	0.93 - 1.16	0.496
	MA3	NA	NA	NA	NA	NA	NA	NA
	MA5	NA	NA	NA	NA	NA	NA	NA
Cardiovascular	0	0.99	0.93 – 1.06	0.99	0.90 – 1.08	0.98	0.87 – 1.11	0.782
	1	1.02	0.96 – 1.09	1.03	0.94 – 1.13	1.05	0.92 – 1.19	0.480
	2	0.95	0.89 – 1.02	0.94	0.85 – 1.03	0.91	0.81 – 1.04	0.162
	3	0.98	0.92 – 1.05	0.98	0.89 – 1.07	0.97	0.86 – 1.10	0.624
	MA3	NA	NA	NA	NA	NA	NA	NA
	MA5	NA	NA	NA	NA	NA	NA	NA
Both	0	1.08	0.97 – 1.20	1.11	0.96 – 1.29	1.16	0.95 – 1.42	0.152
	1	1.04	0.94 – 1.16	1.06	0.91 – 1.23	1.08	0.88 – 1.32	0.452
	2	0.98	0.88 – 1.09	0.97	0.84 – 1.13	0.96	0.79 – 1.17	0.709
	3	1.03	0.92 – 1.14	1.04	0.90 – 1.20	1.05	0.86 – 1.28	0.622
	MA3	NA	NA	NA	NA	NA	NA	NA
	MA5	NA	NA	NA	NA	NA	NA	NA

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
CI ≥ 1 *** Significant at p<0.001

Table 4.46 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient PM10 concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	PM10 concentration increment						
		43.81 µg/m ³ (First quartile)		54.04 µg/m ³ (Median)		66.60 µg/m ³ (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.12 [#]	1.03 – 1.22	1.15 [#]	1.04 – 1.28	1.19 [#]	1.05 – 1.35	0.007**
	1	1.04	0.97 – 1.14	1.06	0.96 – 1.17	1.07	0.95 – 1.21	0.275
	2	1.06	0.97 – 1.15	1.07	0.97 – 1.19	1.09	0.96 – 1.24	0.171
	3	1.10 [#]	1.01 – 1.19	1.12 [#]	1.01 – 1.23	1.15 [#]	1.01 – 1.30	0.030*
	MA3	1.11 [#]	1.00 – 1.22	1.13 [#]	1.01 – 1.28	1.17 [#]	1.01 – 1.35	0.043*
	MA5	1.15 [#]	1.03 – 1.28	1.19 [#]	1.04 – 1.36	1.24 [#]	1.05 – 1.46	0.012*
Cardiovascular	0	1.52 [#]	1.00 – 2.30	1.67 [#]	1.00 – 2.79	1.88 [#]	1.00 – 3.54	0.049*
	1	1.50 [#]	1.00 – 2.27	1.65	0.99 – 2.75	1.86	0.99 – 3.47	0.053
	2	1.72 [#]	1.14 – 2.61	1.95 [#]	1.18 – 3.27	2.28 [#]	1.22 – 4.30	0.010**
	3	1.50 [#]	1.00 – 2.26	1.65	0.99 – 2.73	1.86	0.99 – 3.45	0.052
	MA3	1.88 [#]	1.17 – 3.04	2.18 [#]	1.21 – 3.95	2.61 [#]	1.26 – 5.43	0.010**
	MA5	2.01 [#]	1.17 – 3.47	2.36 [#]	1.21 – 4.64	2.88 [#]	1.26 – 6.63	0.012*
Both	0	1.19	0.96 – 1.48	1.24	0.95 – 1.62	1.31	0.94 – 1.81	0.114
	1	1.06	0.85 – 1.32	1.07	0.81 – 1.41	1.09	0.78 – 1.53	0.615
	2	1.01	0.81 – 1.27	1.02	0.77 – 1.35	1.02	0.73 – 1.44	0.894
	3	0.96	0.77 – 1.21	0.95	0.72 – 1.26	0.94	0.67 – 1.33	0.744
	MA3	1.13	0.87 – 1.46	1.16	0.84 – 1.59	1.20	0.81 – 1.77	0.371
	MA5	1.15	0.88 – 1.50	1.18	0.85 – 1.64	1.23	0.82 – 1.85	0.308

Note : MA3 = 3-day moving average * Significant at p<0.05
MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.47 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient nitrogen dioxide concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	Nitrogen dioxide concentration increment						
		0.013 ppm (First quartile)		0.016 ppm (Median)		0.020 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.25 [#]	1.15 – 1.36	1.32 [#]	1.19 – 1.46	1.41 [#]	1.24 – 1.60	<0.001***
	1	1.58 [#]	1.07 – 2.35	1.76 [#]	1.08 – 2.68	2.03 [#]	1.10 – 3.73	0.023*
	2	1.19 [#]	1.10 – 1.29	1.24 [#]	1.12 – 1.37	1.31 [#]	1.15 – 1.48	<0.001***
	3	1.18 [#]	1.09 – 1.28	1.23 [#]	1.12 – 1.36	1.30 [#]	1.15 – 1.47	<0.001***
	MA3	1.39 [#]	1.25 – 1.54	1.50 [#]	1.32 – 1.71	1.66 [#]	1.41 – 1.95	<0.001***
	MA5	1.51 [#]	1.34 – 1.71	1.66 [#]	1.43 – 1.93	1.89 [#]	1.57 – 2.28	<0.001***
Cardiovascular	0	1.29	0.88 – 1.90	1.37	0.85 – 2.21	1.48	0.82 – 2.69	0.196
	1	1.58 [#]	1.07 – 2.35	1.76 [#]	1.08 – 2.86	2.03 [#]	1.10 – 3.73	0.023*
	2	1.67 [#]	1.12 – 2.49	1.88 [#]	1.15 – 3.07	2.20 [#]	1.19 – 4.07	0.012*
	3	1.52 [#]	1.03 – 2.22	1.67 [#]	1.04 – 2.67	1.90 [#]	1.05 – 3.41	0.033*
	MA3	1.94 [#]	1.18 – 3.17	2.25 [#]	1.23 – 4.13	2.76 [#]	1.29 – 5.90	0.009**
	MA5	2.26 [#]	1.30 – 3.90	2.72 [#]	1.39 – 5.34	3.49 [#]	1.50 – 8.12	0.004**
Both	0	1.02	0.84 – 1.23	1.02	0.81 – 1.29	1.03	0.77 – 1.38	0.838
	1	1.09	0.90 – 1.32	1.12	0.88 – 1.41	1.15	0.85 – 1.54	0.361
	2	1.07	0.89 – 1.30	1.09	0.86 – 1.38	1.11	0.83 – 1.49	0.477
	3	0.92	0.76 – 1.10	0.90	0.72 – 1.12	0.88	0.66 – 1.16	0.349
	MA3	1.11	0.87 – 1.41	1.13	0.84 – 1.52	1.17	0.80 – 1.69	0.418
	MA5	1.00	0.76 – 1.32	1.00	0.71 – 1.40	1.00	0.66 – 1.53	1.000

Note : MA3 = 3-day moving average * Significant at p<0.05
 MA5 = 5-day moving average ** Significant at p<0.01
[#] CI ≥ 1 *** Significant at p<0.001

Table 4.48 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient sulphur dioxide concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	Sulphur dioxide concentration increment						
		0.002 ppm (First quartile)		0.002 ppm (Median)		0.003 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.02	0.97 – 1.08	1.02	0.97 – 1.08	1.04	0.95 – 1.12	0.401
	1	1.02	0.97 – 1.08	1.02	0.97 – 1.08	1.03	0.95 – 1.12	0.451
	2	1.00	0.95 – 1.06	1.00	0.95 – 1.06	1.01	0.93 – 1.09	0.870
	3	0.98	0.93 – 1.04	0.98	0.93 – 1.04	0.97	0.90 – 1.06	0.529
	MA3	1.03	0.96 – 1.11	1.03	0.96 – 1.11	1.05	0.94 – 1.17	0.363
	MA5	1.35 [#]	1.22 – 1.48	1.35 [#]	1.22 – 1.48	1.56 [#]	1.35 – 1.80	<0.001***
Cardiovascular	0	0.94	0.71 – 1.26	0.94	0.71 – 1.26	0.92	0.60 – 1.41	0.696
	1	1.03	0.78 – 1.37	1.03	0.78 – 1.37	1.05	0.69 – 1.60	0.832
	2	1.41 [#]	1.07 – 1.86	1.41 [#]	1.07 – 1.86	1.68 [#]	1.11 – 2.54	0.014*
	3	1.14	0.86 – 1.50	1.14	0.86 – 1.50	1.21	0.80 – 1.84	0.361
	MA3	1.22	0.83 – 1.79	1.22	0.83 – 1.79	1.35	0.76 – 2.39	0.305
	MA5	1.52 [#]	1.00 – 2.33	1.52 [#]	1.00 – 2.33	1.88 [#]	1.00 – 3.55	0.052
Both	0	0.99	0.85 – 1.15	0.99	0.85 – 1.15	0.98	0.79 – 1.23	0.866
	1	0.98	0.85 – 1.14	0.98	0.85 – 1.14	0.97	0.78 – 1.21	0.812
	2	0.90	0.78 – 1.05	0.90	0.78 – 1.05	0.86	0.69 – 1.07	0.183
	3	0.81	0.70 – 0.94	0.81	0.70 – 0.94	0.73	0.59 – 0.92	0.007**
	MA3	0.92	0.76 – 1.13	0.92	0.76 – 1.13	0.89	0.66 – 1.20	0.442
	MA5	0.83	0.66 – 1.04	0.83	0.66 – 1.04	0.75	0.54 – 1.06	0.102

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.49 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient carbon monoxide concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	Carbon monoxide concentration increment						
		0.86 ppm (First quartile)		1.07 ppm (Median)		1.36 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	1.02	0.94 – 1.10	1.02	0.93 – 1.12	1.03	0.91 – 1.16	0.636
	1	1.03	0.95 – 1.11	1.03	0.94 – 1.13	1.04	0.93 – 1.17	0.495
	2	1.09 [#]	1.01 – 1.17	1.11 [#]	1.01 – 1.22	1.14 [#]	1.02 – 1.29	0.023*
	3	1.11 [#]	1.03 – 1.19	1.14 [#]	1.04 – 1.25	1.18 [#]	1.05 – 1.32	0.006**
	MA3	1.08	0.98 – 1.19	1.10	0.97 – 1.24	1.13	0.97 – 1.31	0.123
	MA5	1.17 [#]	1.05 – 1.30	1.22 [#]	1.06 – 1.39	1.28 [#]	1.08 – 1.52	0.005**
Cardiovascular	0	0.84	0.56 – 1.25	0.80	0.45 – 1.31	0.76	0.40 – 1.41	0.381
	1	1.44	0.99 – 2.09	1.57	0.99 – 2.50	1.78	0.99 – 3.20	0.055
	2	1.26	0.87 – 1.81	1.33	0.84 – 2.10	1.44	0.81 – 2.56	0.219
	3	1.27	0.88 – 1.83	1.34	0.85 – 2.12	1.45	0.82 – 2.60	0.205
	MA3	1.06	0.82 – 1.37	1.08	0.78 – 1.48	1.10	0.73 – 1.64	0.652
	MA5	1.14	0.85 – 1.52	1.17	0.82 – 1.68	1.23	0.78 – 1.94	0.383
Both	0	1.00	0.82 – 1.22	1.00	0.78 – 1.28	1.00	0.73 – 1.37	0.984
	1	1.07	0.88 – 1.30	1.08	0.85 – 1.38	1.11	0.81 – 1.51	0.520
	2	1.06	0.87 – 1.30	1.08	0.85 – 1.38	1.10	0.81 – 1.51	0.534
	3	1.02	0.84 – 1.25	1.03	0.81 – 1.32	1.04	0.76 – 1.42	0.808
	MA3	1.06	0.82 – 1.37	1.08	0.78 – 1.48	1.10	0.73 – 1.64	0.652
	MA5	1.14	0.85 – 1.52	1.17	0.82 – 1.68	1.23	0.78 – 1.94	0.383

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.50 : Relative risk (RR) of children admissions for respiratory and cardiovascular cases at Hospital Selayang by quartile increments of ambient ozone concentration, 2000 – 2003 (N = 702).

Admission cases	Lag day/ moving average	Ozone concentration increment						
		0.010 ppm (First quartile)		0.014 ppm (Median)		0.019 ppm (Third quartile)		p value
		RR	95% CI	RR	95% CI	RR	95% CI	
Respiratory	0	0.99	0.94 – 1.04	0.98	0.92 – 1.05	0.98	0.89 – 1.07	0.603
	1	0.99	0.95 – 1.04	0.99	0.93 – 1.06	0.99	0.90 – 1.08	0.828
	2	0.98	0.94 – 1.03	0.97	0.91 – 1.04	0.97	0.88 – 1.06	0.446
	3	0.99	0.94 – 1.03	0.98	0.92 – 1.05	0.97	0.89 – 1.06	0.541
	MA3	0.98	0.91 – 1.04	0.97	0.88 – 1.06	0.95	0.84 – 1.09	0.480
	MA5	0.96	0.88 – 1.04	0.94	0.84 – 1.05	0.92	0.79 – 1.07	0.270
Cardiovascular	0	1.09	0.85 – 1.40	1.13	0.80 – 1.61	1.18	0.74 – 1.90	0.486
	1	0.96	0.74 – 1.24	0.95	0.66 – 1.36	0.93	0.57 – 1.51	0.768
	2	1.14	0.89 – 1.46	1.20	0.84 – 1.70	1.28	0.80 – 2.06	0.310
	3	1.47 [#]	1.15 – 1.88	1.72 [#]	1.22 – 2.42	2.09 [#]	1.31 – 3.32	0.002**
	MA3	1.02	0.85 – 1.22	1.03	0.80 – 1.33	1.04	0.73 – 1.47	0.835
	MA5	0.99	0.80 – 1.22	0.98	0.74 – 1.31	0.98	0.66 – 1.45	0.909
Both	0	0.99	0.87 – 1.13	0.99	0.83 – 1.18	0.98	0.77 – 1.25	0.887
	1	1.00	0.88 – 1.14	1.00	0.84 – 1.20	1.00	0.79 – 1.28	0.986
	2	1.03	0.91 – 1.17	1.05	0.88 – 1.25	1.07	0.84 – 1.36	0.602
	3	0.98	0.86 – 1.11	0.97	0.81 – 1.16	0.96	0.76 – 1.22	0.742
	MA3	1.02	0.86 – 1.22	1.03	0.80 – 1.32	1.04	0.74 – 1.45	0.826
	MA5	0.99	0.80 – 1.22	0.98	0.74 – 1.31	0.98	0.66 – 1.45	0.909

Note : MA3 = 3-day moving average
MA5 = 5-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.51a : Relative risk (RR) of adult and children mortality for respiratory and cardiovascular cases at all hospitals by quartile increments of ambient air pollutants concentrations, 2000 – 2003.

Pollutant	Lag day/ moving average	Air pollutant concentration increment						p value
		(First quartile)		(Median)		(Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
PM10	0	1.01	0.86 – 1.17	1.01	0.84 – 1.20	1.01	0.82 – 1.24	0.939
	1	1.04	0.89 – 1.20	1.05	0.88 – 1.24	1.05	0.86 – 1.29	0.620
	2	1.00	0.86 – 1.16	1.00	0.84 – 1.19	1.00	0.82 – 1.22	1.000
	3	0.92	0.79 – 1.06	0.91	0.76 – 1.08	0.89	0.73 – 1.09	0.266
	MA3	1.02	0.85 – 1.22	1.03	0.83 – 1.27	1.03	0.81 – 1.32	0.823
			First quartile = 56.23 ppm		Median = 65.83 ppm		Third quartile = 76.14 ppm	
Nitrogen dioxide	0	1.14 [#]	1.00 – 1.30	1.17 [#]	1.00 – 1.37	1.20 [#]	1.00 – 1.44	0.056
	1	1.10	0.96 – 1.26	1.12	0.95 – 1.31	1.14	0.94 – 1.37	0.181
	2	1.04	0.91 – 1.20	1.05	0.90 – 1.24	1.06	0.88 – 1.28	0.532
	3	0.98	0.86 – 1.13	0.98	0.84 – 1.15	0.98	0.81 – 1.18	0.827
	MA3	NA	NA	NA	NA	NA	NA	NA
			First quartile = 0.026 ppm		Median = 0.003 ppm		Third quartile = 0.036 ppm	
Sulfur dioxide	0	1.08	0.99 – 1.19	1.10	0.98 – 1.24	1.13	0.98 – 1.29	0.089
	1	1.13 [#]	1.03 – 1.24	1.17 [#]	1.04 – 1.31	1.20 [#]	1.05 – 1.38	0.008**
	2	0.96	0.87 – 1.05	0.95	0.84 – 1.07	0.94	0.81 – 1.08	0.390
	3	0.94	0.85 – 1.03	0.92	0.82 – 1.04	0.91	0.78 – 1.05	0.177
	MA3	1.11	0.98 – 1.26	1.14	0.97 – 1.33	1.17	0.97 – 1.41	0.104
			First quartile = 0.004 ppm		Median = 0.005 ppm		Third quartile = 0.006 ppm	

Note : MA3 = 3-day moving average
[#] CI ≥ 1

* Significant at p<0.05
** Significant at p<0.01
*** Significant at p<0.001

Table 4.51b : Relative risk (RR) of adult and children mortality for respiratory and cardiovascular cases at all hospitals by quartile increments of ambient air pollutants concentrations, 2000 – 2003.

Pollutant	Lag day/ moving average	Air pollutant concentration increment						p value
		(First quartile)		(Median)		(Third quartile)		
		RR	95% CI	RR	95% CI	RR	95% CI	
Carbon monoxide	0	1.09	0.94 – 1.26	1.11	0.94 – 1.30	1.12	0.93 – 1.36	0.234
	1	1.05	0.90 – 1.21	1.05	0.89 – 1.25	1.06	0.87 – 1.29	0.542
	2	0.96	0.83 – 1.11	0.95	0.80 – 1.13	0.94	0.77 – 1.15	0.559
	3	0.90	0.78 – 1.04	0.89	0.75 – 1.04	0.87	0.72 – 1.05	0.149
	MA3	1.07	0.86 – 1.33	1.08	0.85 – 1.38	1.10	0.82 – 1.46	0.525
			First quartile = 2.33 ppm		Median = 2.67 ppm		Third quartile = 3.10 ppm	
Ozone	0	1.06 [#]	1.00 – 1.13	1.09 [#]	1.01 – 1.19	1.12 [#]	1.01 – 1.25	0.035*
	1	1.11 [#]	1.05 – 1.17	1.16 [#]	1.07 – 1.26	1.22 [#]	1.09 – 1.36	<0.001***
	2	1.07 [#]	1.01 – 1.14	1.11 [#]	1.02 – 1.20	1.14 [#]	1.02 – 1.27	0.017*
	3	1.07 [#]	1.01 – 1.13	1.10 [#]	1.02 – 1.20	1.14 [#]	1.02 – 1.27	0.018*
	MA3	1.18 [#]	1.08 – 1.28	1.26 [#]	1.12 – 1.42	1.36 [#]	1.16 – 1.59	<0.001***
			First quartile = 0.009 ppm		Median = 0.013 ppm		Third quartile = 0.017 ppm	

Note : MA3 = 3-day moving average * Significant at p<0.05
[#] CI ≥ 1 ** Significant at p<0.01
 *** Significant at p<0.001

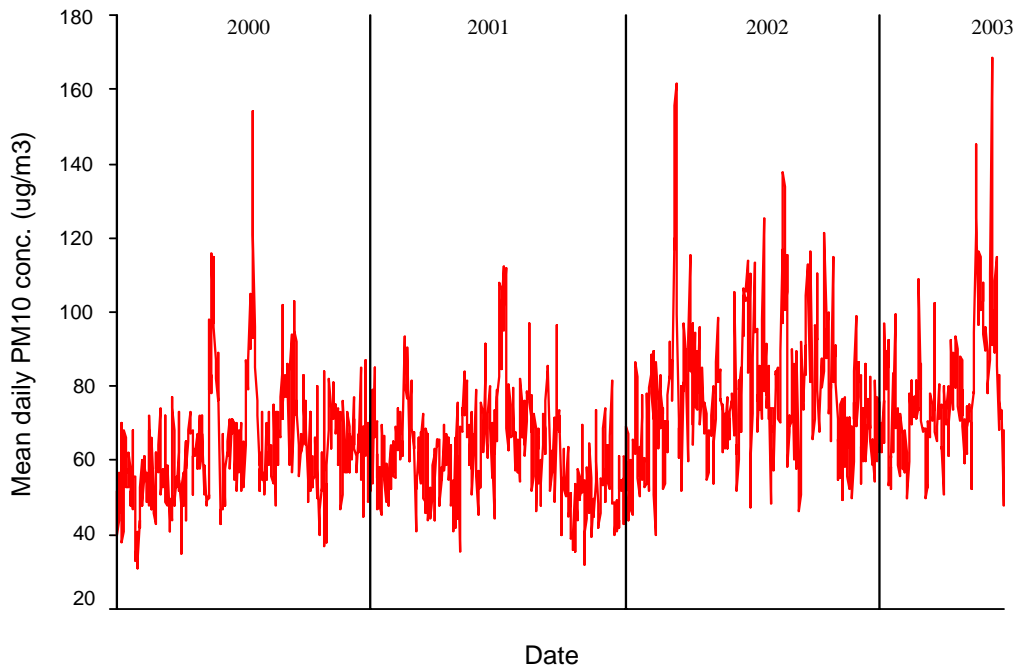


Figure 4.1 : Mean daily PM10 concentrations at the Kuala Lumpur (KL) station for Hospital Kuala Lumpur (HKL).

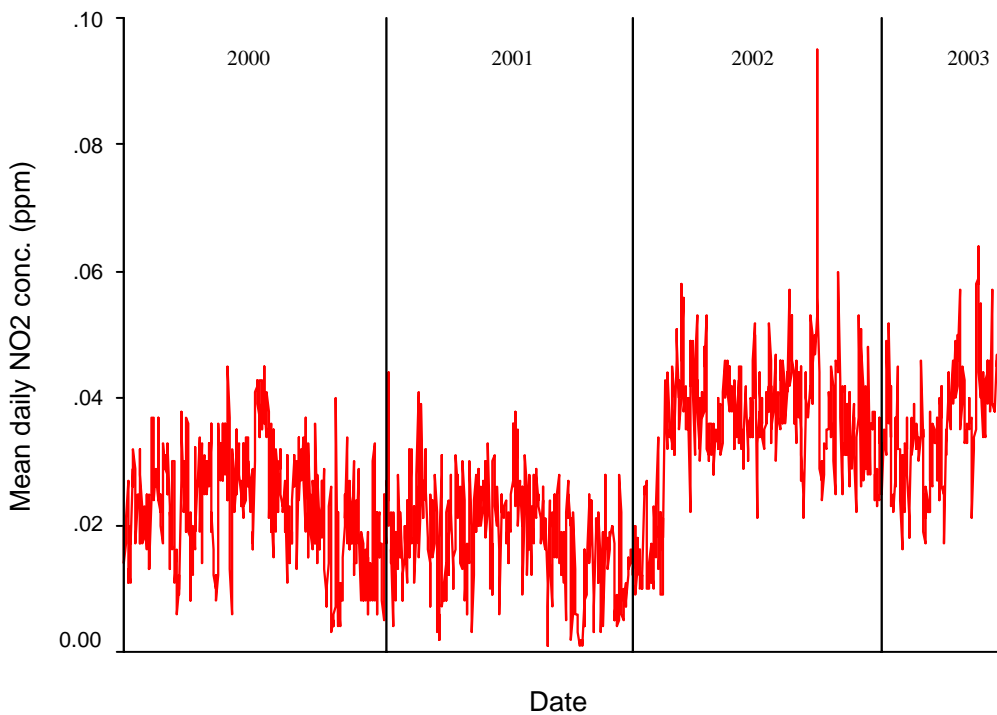


Figure 4.2 : Mean daily NO₂ concentrations at the Kuala Lumpur (KL) station for Hospital Kuala Lumpur (HKL).

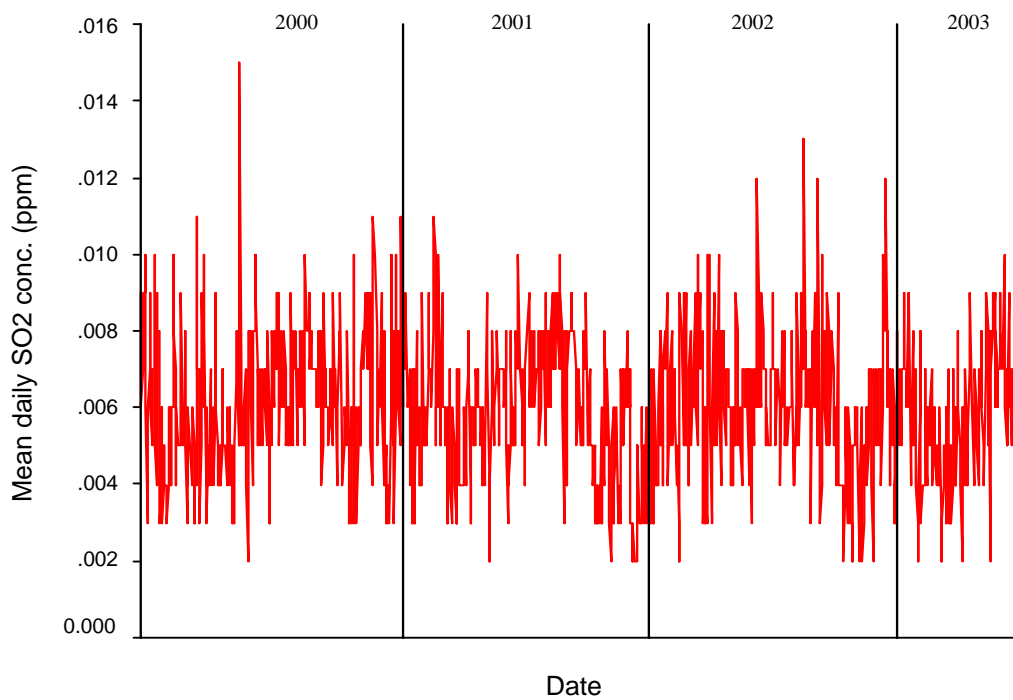


Figure 4.3 : Mean daily SO₂ concentrations at the Kuala Lumpur (KL) station for Hospital Kuala Lumpur (HKL).

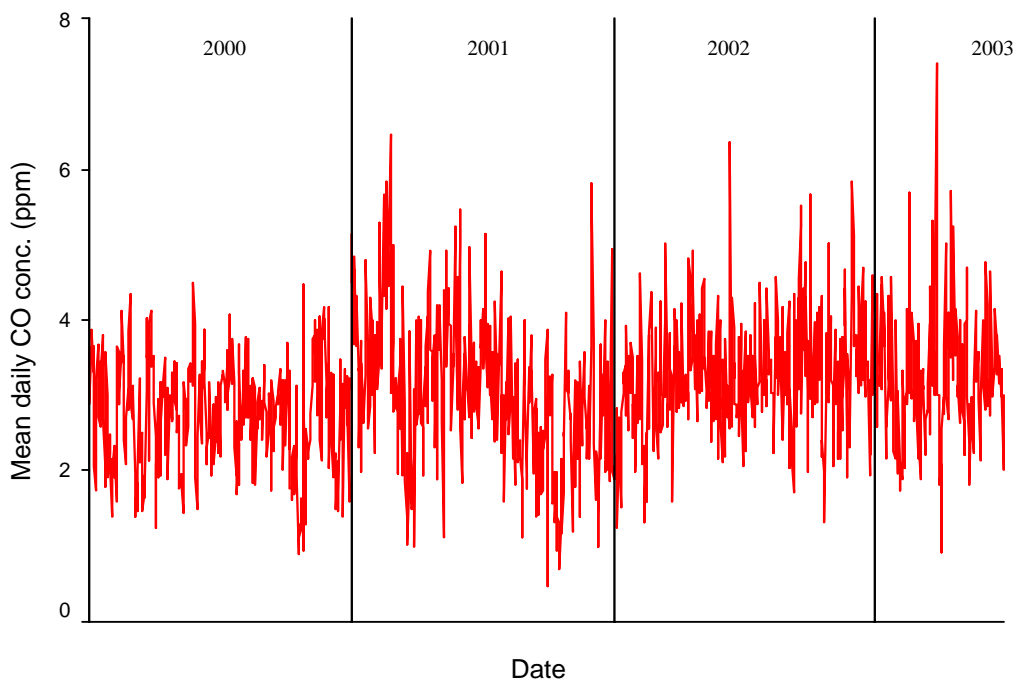


Figure 4.4 : Mean daily CO concentrations at the Kuala Lumpur (KL) station for Hospital Kuala Lumpur (HKL).

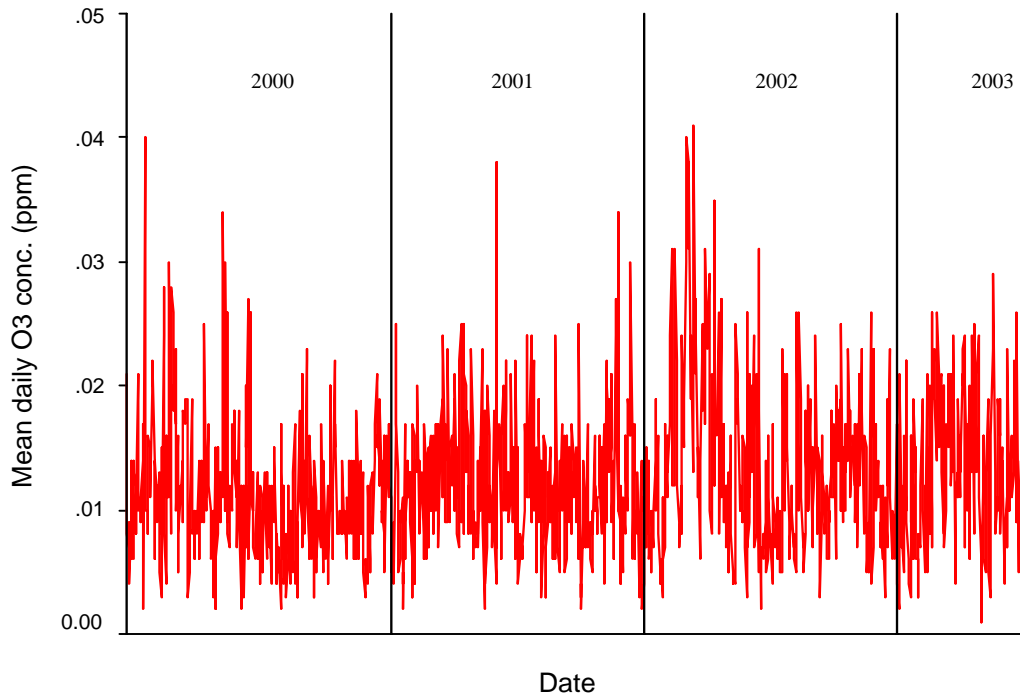


Figure 4.5 : Mean daily O₃ concentrations at the Kuala Lumpur (KL) station for Hospital Kuala Lumpur (HKL).

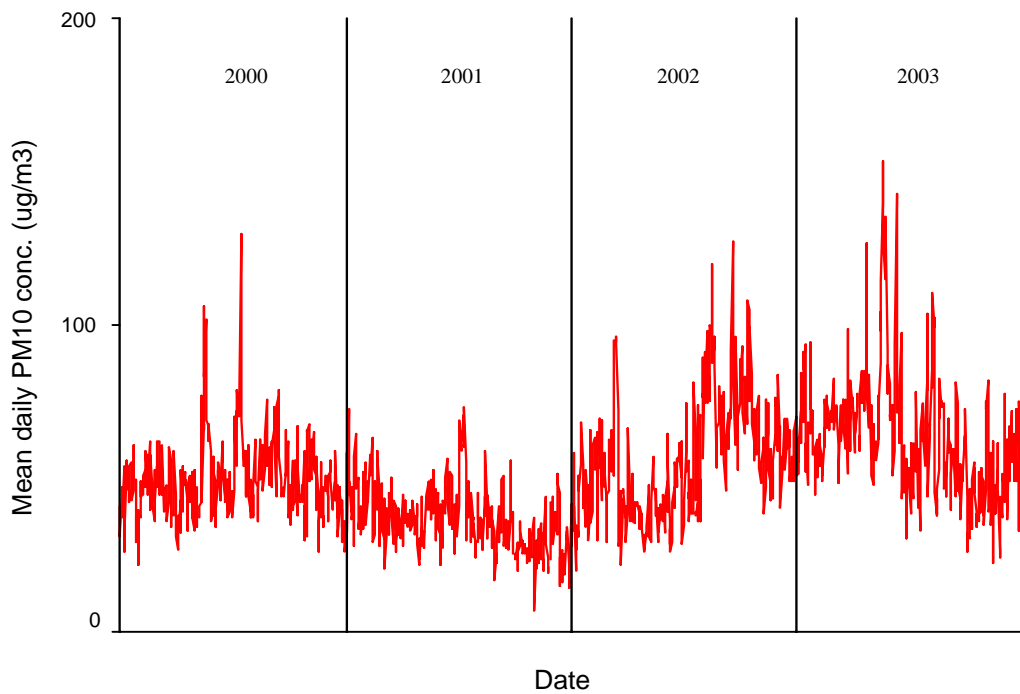


Figure 4.6 : Mean daily PM₁₀ concentrations at the Petaling Jaya (PJ) station for University Malaya Medical Centre (UMMC).

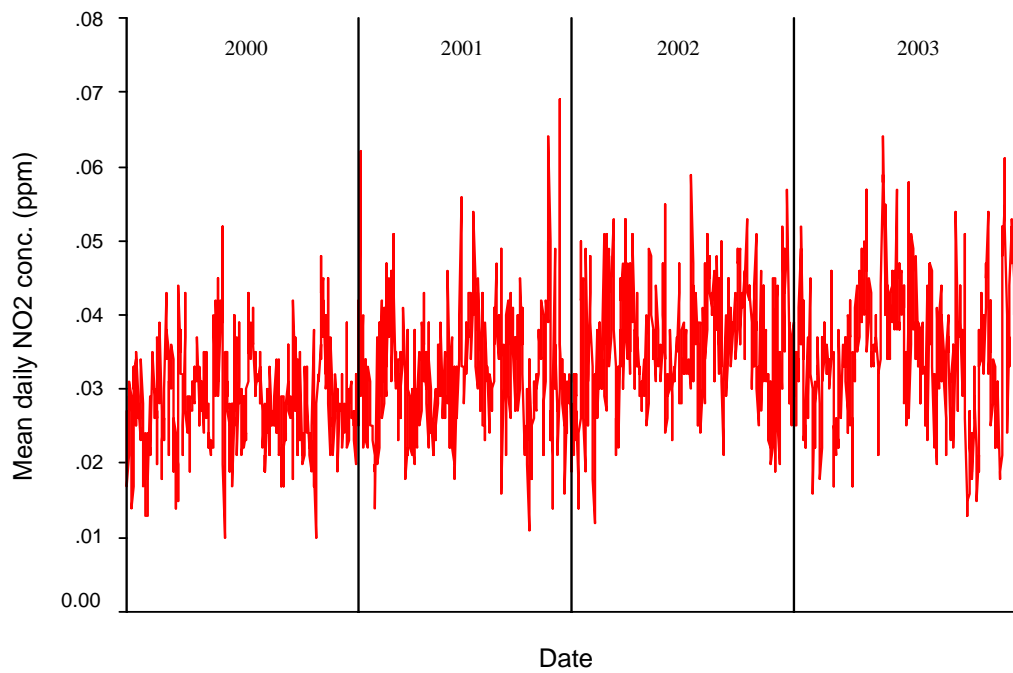


Figure 4.7 :Mean daily NO₂ concentrations at the Petaling Jaya (PJ) station for University Malaya Medical Centre (UMMC).

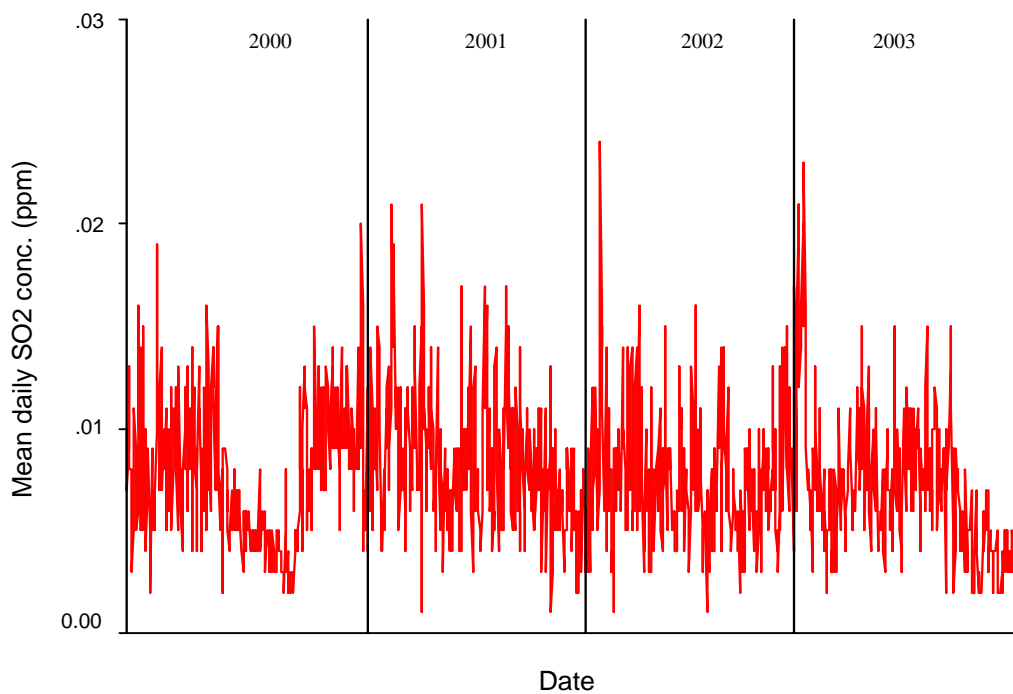


Figure 4.8 : Mean daily SO₂ concentrations at the Petaling Jaya (PJ) station for University Malaya Medical Centre (UMMC).

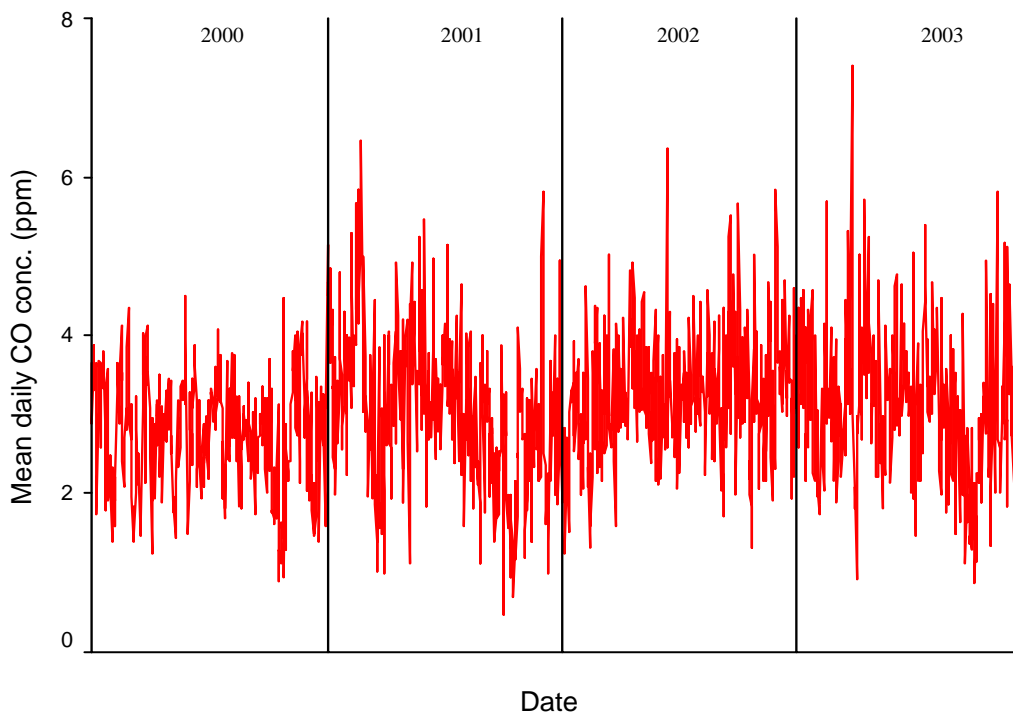


Figure 4.9 : Mean daily CO concentrations at the Shah Alam (SA) station for University Malaya Medical Centre (UMMC).

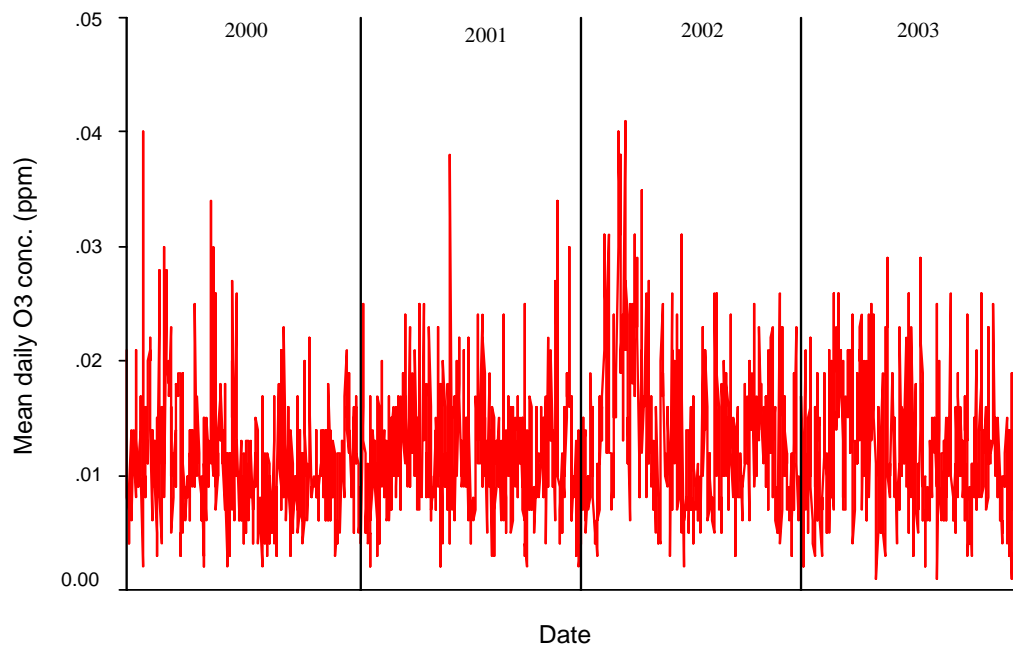


Figure 4.10 : Mean daily O₃ concentrations at the Shah Alam (SA) station for University Malaya Medical Centre (UMMC).

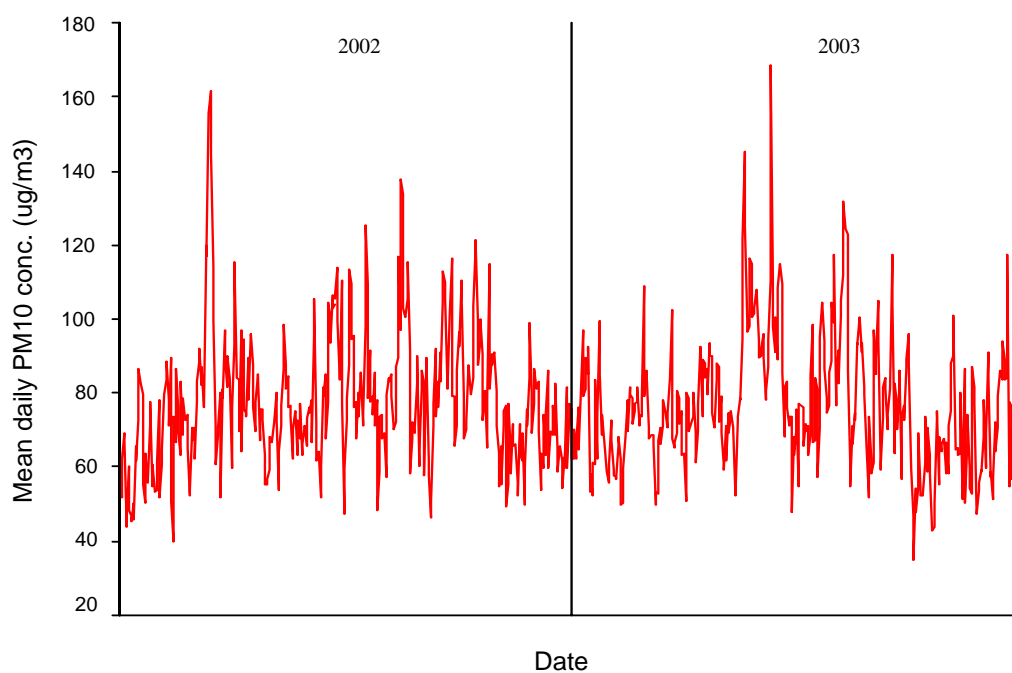


Figure 4.11 : Mean daily PM10 concentrations at the Kuala Lumpur (KL) station for Hospital Universiti Kebangsaan Malaysia (HUKM).

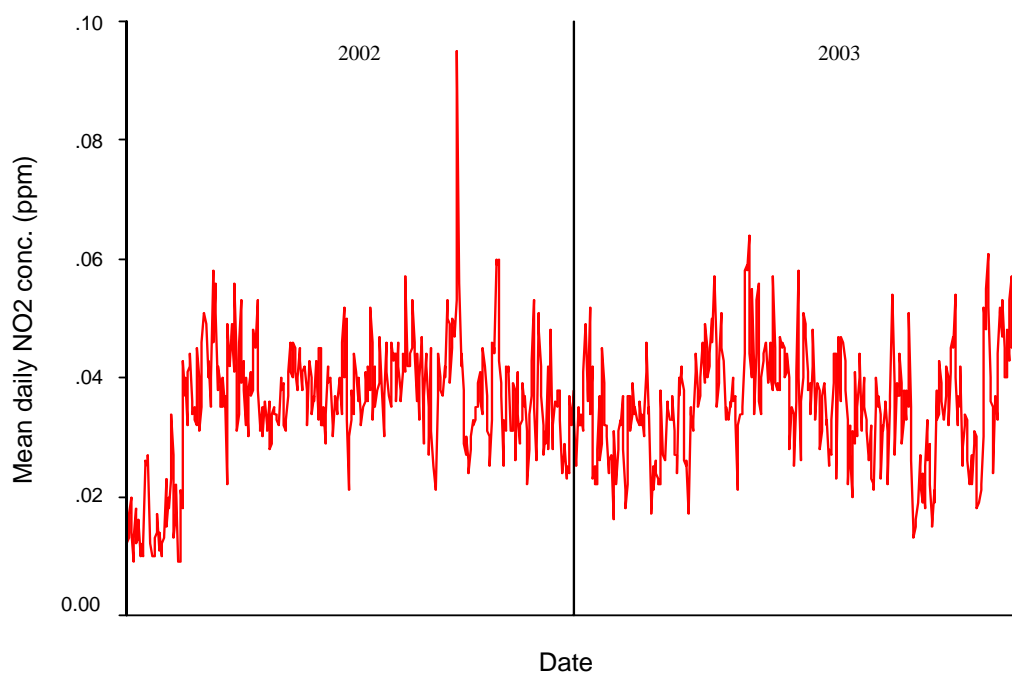


Figure 4.12 : Mean daily NO₂ concentrations at the Kuala Lumpur (KL) station for Hospital Universiti Kebangsaan Malaysia (HUKM).

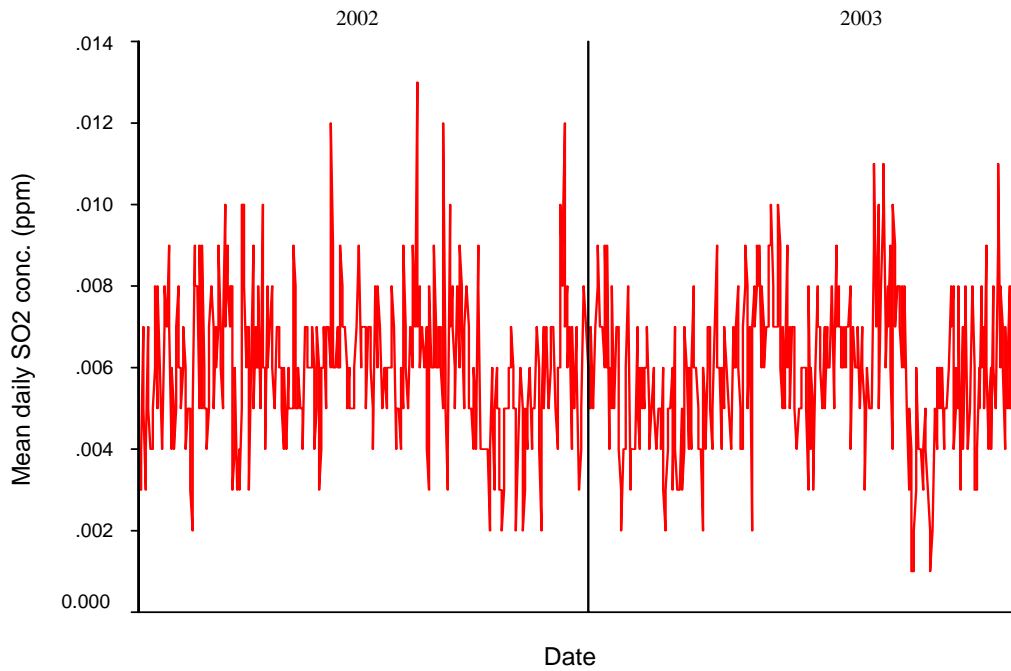


Figure 4.13 : Mean daily SO₂ concentrations at the Kuala Lumpur (KL) station for Hospital Universiti Kebangsaan Malaysia (HUKM).

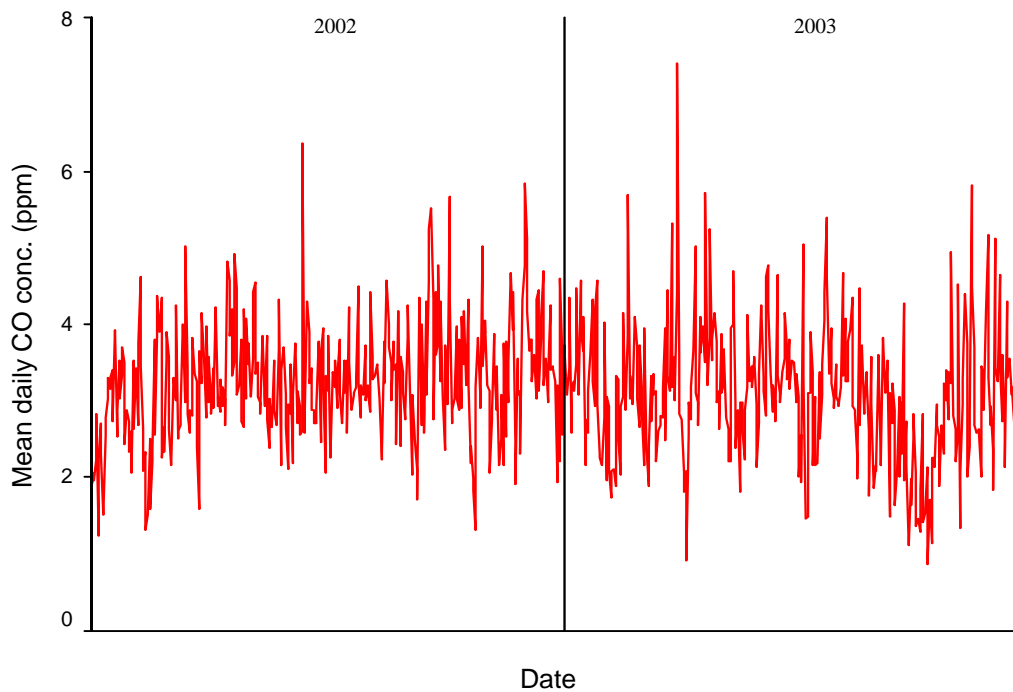


Figure 4.14 : Mean daily CO concentrations at the Kuala Lumpur (KL) station for Hospital Universiti Kebangsaan Malaysia (HUKM).

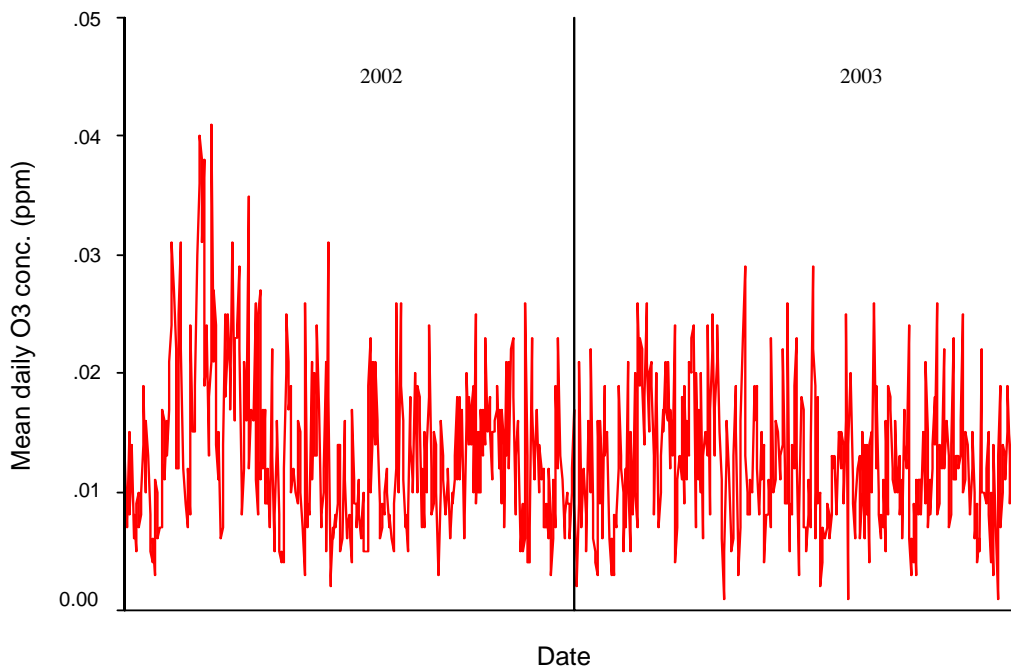


Figure 4.15 : Mean daily O₃ concentrations at the Kuala Lumpur (KL) station for Hospital Universiti Kebangsaan Malaysia (HUKM).

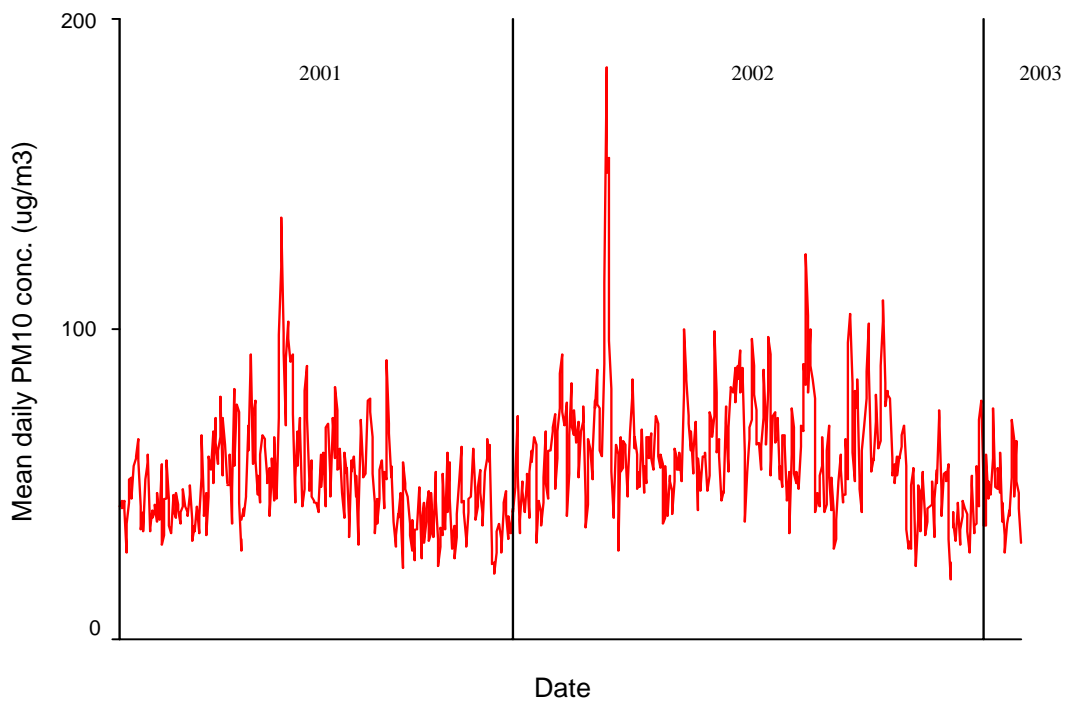


Figure 4.16 : Mean daily PM₁₀ concentrations at the Gombak station for Hospital Selayang (HS).

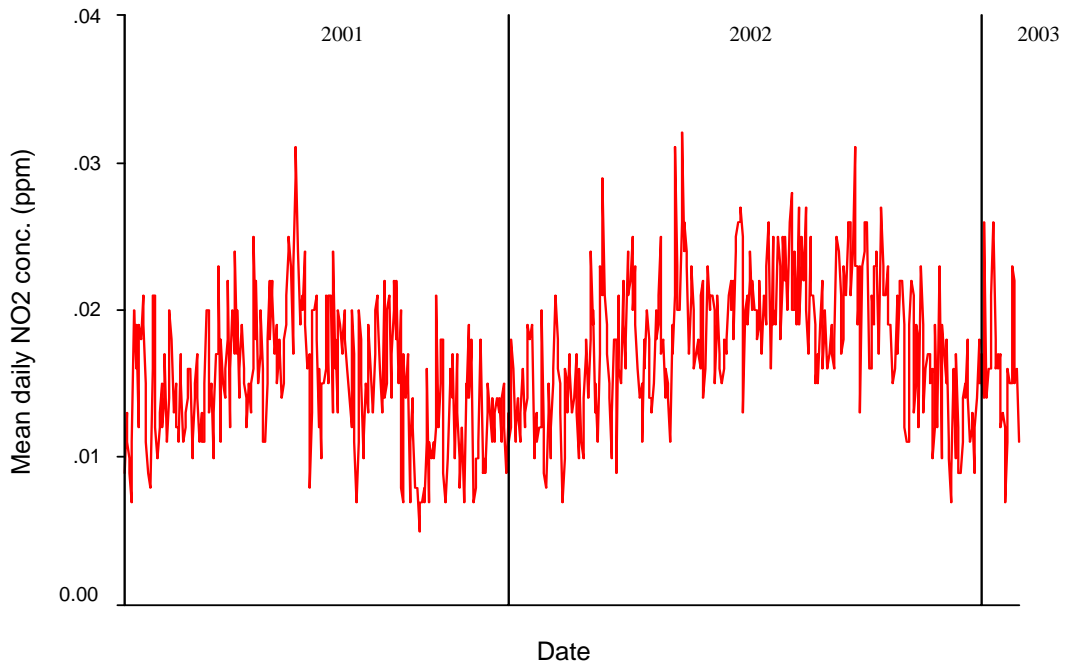


Figure 4.17 : Mean daily NO₂ concentrations at the Gombak station for Hospital Selayang (HS).

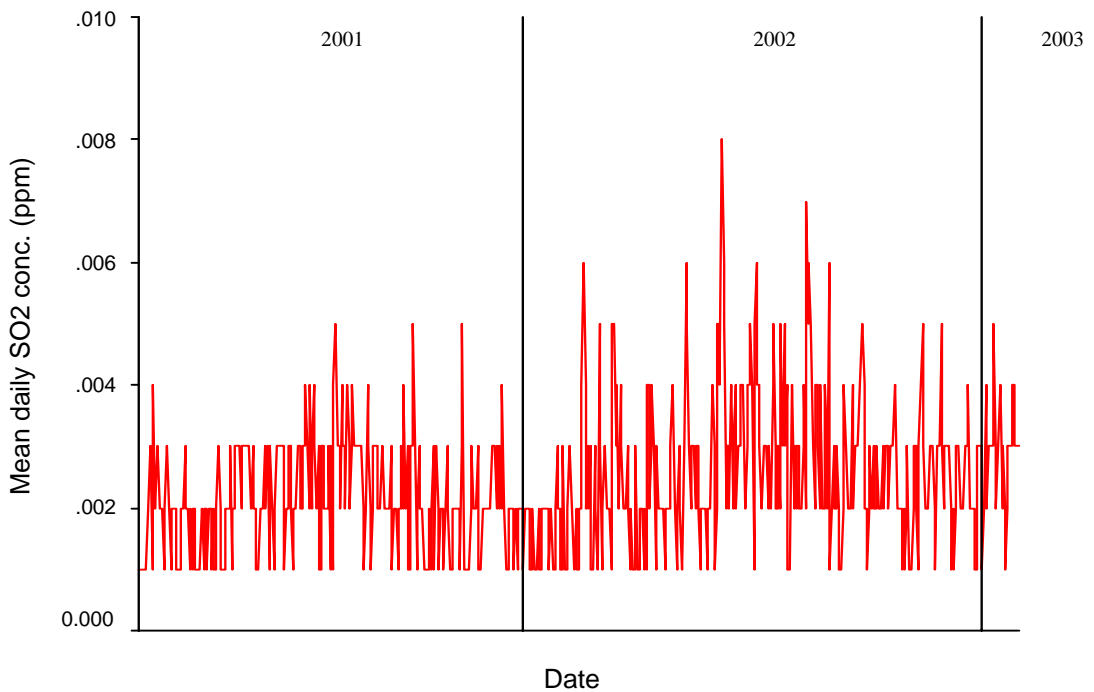


Figure 4.18 : Mean daily SO₂ concentrations at the Gombak station for Hospital Selayang (HS).

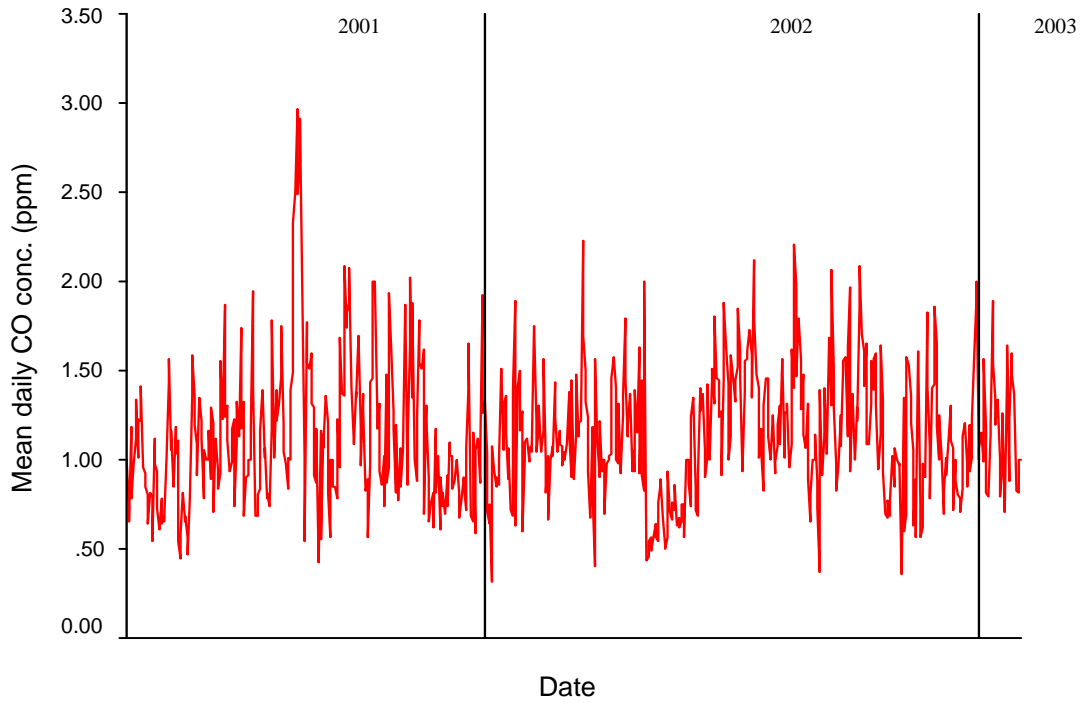


Figure 4.19 : Mean daily CO concentrations at the Gombak station for Hospital Selayang (HS).

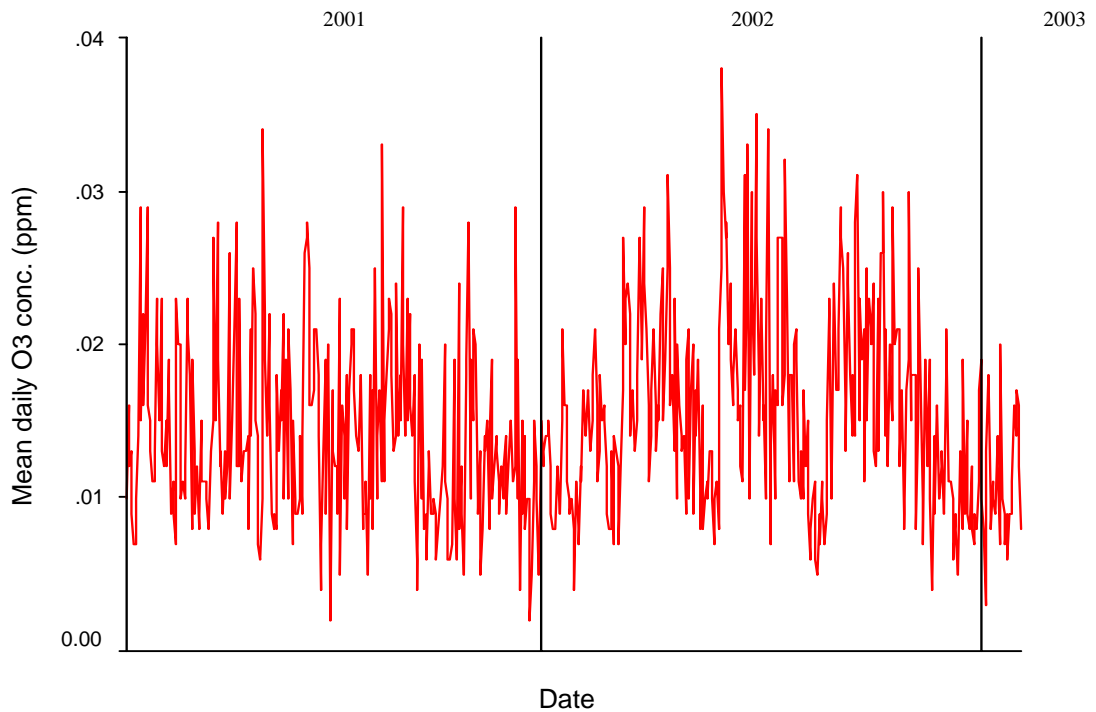


Figure 4.20 : Mean daily O₃ concentrations at the Gombak station for Hospital Selayang (HS).

CHAPTER V

DISCUSSION

5.1 Hospital Morbidity Data

For each air pollutant, 2 sets of relative risks (RR) outcomes for respiratory and cardiovascular case admissions were computed for each hospital, one was for adults and the other for children. Therefore, there were 8 sets of RR outcomes computed for each air pollutant.

5.1.1 Comparison between Air Pollutants

Of the 5 criteria air pollutants, respirable particulate (PM₁₀) was the pollutant which exceeded its 24-hour Malaysian ambient air quality guideline (MAAQG) of 150 µg/m³ at all 3 continuous air quality monitoring (CAQM) stations. Despite exceeding its MAAQG, the RR of case admissions for PM₁₀ increment were significant for only 5 out of the 8 sets of RR outcomes. The RR seemed to be equally significant for both adults and children, as well as for respiratory and cardiovascular diseases.

This seems to concur with the observations made by Dockery and Pope (1994; 1996) which found that increment in PM₁₀ level as low as 10 µg/m³ may show effects in the form of increased hospital admissions for asthma, pneumonia, chronic obstructive pulmonary disease (COPD), coronary artery disease, dysrhythmias and congestive heart failure, as well as respiratory and cardiovascular deaths. In this study, the lowest PM₁₀ increment associated with significant RR was 43.8 µg/m³ for adults as well as children. It does seem that respiratory and cardiovascular cases observed in this study are less sensitive to increment in PM₁₀ than what was suggested by those earlier observations made by Dockery and Pope.

The other air pollutant which had its 24-hour MAAQG of 0.06 ppm exceeded at 2 of the CAQM stations was nitrogen dioxide (NO₂). The RR of case admissions for NO₂ increment were significant for 7 out of the 8 sets of RR outcomes. Similarly,

the RR seemed to be equally significant for both adults and children, as well as for respiratory and cardiovascular morbidity, with may be a small tendency of having a slightly greater impact on respiratory morbidity. In comparison with other air pollutants, NO₂ clearly indicates the greatest impacts on respiratory and cardiovascular morbidity in this study.

Many of the previous studies have shown association between respiratory and cardiovascular morbidity with mainly particulate pollutant and carbon monoxide. One study by Linaker *et al.* (2000) showed that personal exposure to NO₂ increases the risk of airflow obstruction in asthmatic children with upper respiratory tract infections (URTI). Thus, exposure to NO₂ has the potential to exacerbate asthma following URTI and leading to hospital admissions. It seems that due attention had not been given by researchers to the potential impact of NO₂ on respiratory and cardiovascular morbidity, as much emphasis had been given to particulate pollutant.

The RR of case admissions for sulphur dioxide (SO₂) increments were significant for only 3 out of the 8 sets of RR outcomes. The RR seemed to be more significant for adults than for children, but equally significant for respiratory as well as for cardiovascular morbidity. Even though the sets of RR outcomes found to be significant were minimal, this was rather unexpected. This is because the MAAQG for 24-hour SO₂ of 0.04 ppm was never exceeded at any of the 3 CAQM stations during the study period. The highest SO₂ concentration that was reached was only 0.024 ppm at the Petaling Jaya (PJ) CAQM station, which is only half of its MAAQG level.

The associations between SO₂ with respiratory and cardiovascular morbidity and mortality have been well documented ever since the London Fog episode of 1952 (UK Ministry of Health, 1954). However, such associations were mostly seen with much higher levels of SO₂ and usually in co-existence with also elevated levels of particulate pollutant. For example during the London Fog episode, the SO₂ levels were in excess of 0.6 ppm, while the highest seen in this study was only 0.024 ppm.

Similarly, the RR of case admissions for carbon monoxide (CO) increments were significant for only 3 out of the 8 sets of RR outcomes. The RR seemed to be

equally significant for adults as well as children, but slightly more significant for respiratory than for cardiovascular morbidity. The MAAQG for 8-hour CO of 9 ppm was never exceeded at any of the 3 CAQM stations during the study period. The highest CO concentration that was reached was only 7.4 ppm at both the Kuala Lumpur and Shah Alam CAQM stations.

Even though the ambient levels of CO observed in this study were low and below its MAAQG, the findings of this study are consistent with that of other researchers, who also found significant impacts of CO on respiratory and cardiovascular morbidity at levels below prescribed ambient guideline values. Sheppard *et al.* (1999) found a significant RR [1.06 (95% CI = 1.03-1.09)] for asthma hospital admissions among children and adults younger than 65 years old, associated with an interquartile range change of 0.9 ppm at a 3-day lag period. In this study, we found a more significant RR [1.12 (95% CI = 1.03-1.22)] for respiratory disease admissions among adults at Hospital Selayang, associated with an increment in CO concentration of 0.86 ppm also at a 3-day lag period. Among children at the same hospital, we also observed a significant RR [1.11 (95% CI = 1.03-1.19)] for respiratory disease admissions, associated with a CO increment of 0.86 at a 3-day lag period.

Of the 5 air pollutants, ozone (O₃) seemed to be the least associated with respiratory and cardiovascular morbidity, whereby only 1 out of the 8 sets of RR outcomes was significant

5.1.2 Comparison between Hospitals

For both Hospital Kuala Lumpur (HKL) and the University Malaya Medical Centre (UMMC), the increased RR for adult respiratory and cardiovascular admissions seemed to be most significant for increments in SO₂ concentrations. This was however not seen at Hospital Universiti Kebangsaan Malaysia (HUKM) or Hospital Selayang (HS). This association with SO₂ was observed besides the fact that the MAAQG for 24-hour SO₂ was never exceeded at any of the 3 CAQM stations during the study period. Nevertheless, the children did not seem to be sensitive to SO₂ like the adults at any of the hospitals.

As shown in Table 4.6, the mean (0.007 ppm) and maximum (0.024 ppm) concentrations for SO₂ were the highest for UMMC, while the mean (0.006 ppm) and maximum (0.015 ppm) SO₂ concentrations for HKL were the second highest. Even though the difference in the mean SO₂ values between the four hospitals may be small, this difference may contribute to the results seen here. What is of concern here is that we are seeing clearly significant RR for adult respiratory and cardiovascular admissions at such very small increments in SO₂ concentrations of only 0.005 ppm. What is even more alarming is that this small increment is actually happening within a range of SO₂ concentrations that is well below the MAAQG.

The RR outcomes for UMMC and HUKM seemed to be more similar for both adults and children than with the other two hospitals. Even though the associations between air pollutants and diseases vary between the two hospitals, NO₂ stood out prominently at both hospitals for respiratory and cardiovascular diseases among adults and children. Both these hospitals are university teaching hospitals. However, there is no indication that this commonality might somewhat contribute towards the uniformity in the RR outcomes seen for both hospitals.

Table 4.6 indicates that for HUKM, the mean (0.036 ppm) and maximum (0.095 ppm) NO₂ concentrations associated with the hospital are the highest among the four hospitals. Correspondingly for UMMC, the mean (0.032 ppm) and maximum (0.065 ppm) NO₂ concentrations associated with the hospital are the second highest among the four hospitals. As were discussed for SO₂ above, this may be a legitimate explanation for seeing the significant association between NO₂ and respiratory and cardiovascular admissions.

5.2 Hospital Mortality data

The relationship between air pollution and respiratory and cardiovascular mortality especially among the elderly population has been well established since the study on the London Fog episode of 1952 (UK Ministry of Health, 1954). In that episode, it was the probably the lethal combination of particulate pollutant and SO₂ which resulted in most of the deaths. Many more recent studies continued to show the

effects of particulate pollutant, SO₂ and NO₂ on respiratory and cardiovascular mortality (Wong *et al.*, 2001; Zmirou *et al.*, 1998; Schwartz and Dockery, 1992).

Ozone (O₃) however has been less rigorously studied and its association with respiratory and cardiovascular mortality has been less established compared with other air pollutants. In this study, the effect of O₃ on combined respiratory and cardiovascular mortality was more clearly demonstrated than the other air pollutants. However, this result is not entirely inconsistent with that of other researchers, as Zmirou *et al.* (1998) did find a moderate association between O₃ and daily mortality with a RR of 1.02 (95% CI = 1.02-1.10). In this study, the RR for respiratory and cardiovascular mortality associated with an increment in O₃ concentration of 0.009 ppm ranged from a low of 1.06 (95% CI = 1.00-1.13) to a high of 1.18 (95% CI = 1.08-1.28). However, the significant association between O₃ and respiratory and cardiovascular mortality seems to contradict its non-association with respiratory and cardiovascular morbidity as discussed earlier. No explanation is however available for this phenomenon.

5.3 Conclusion

The associations between air pollution and respiratory and cardiovascular morbidity and mortality have been well established by many researchers throughout the world ever since the fateful incident of the London Fog of 1952. Most of the associations have tended to point towards 2 major pollutants of concern, namely particulate pollutant and SO₂, and more recently, CO. Therefore, the significant RR outcomes for respiratory and cardiovascular morbidity associated with PM10 and CO increments, as demonstrated by this study were expected. These results add to the wealth of evidence already published on the incriminating impacts of these air pollutants.

On the other hand, the dominantly significant RR outcomes for respiratory and cardiovascular morbidity associated with NO₂ increments warrant further in-depth scientific assessment. Fewer researchers have demonstrated the morbidity impact of this pollutant. As NO₂ in urban areas like the Klang Valley is unlikely to decrease in

the near future due to our over-dependence on motor vehicles, the potential threat from this pollutant calls for greater attention from researchers and regulators.

The other concern brought to light by this study is the significant RR outcomes associated with very low levels of ambient SO₂. Even though evidence on the health impact of high levels of SO₂ has been extensively published, the effect of low level SO₂ has not been well documented.

This study adds further insights into our understanding of the complex interactions between air pollution and humans, in particular with respect to his respiratory and cardiovascular health. There are many other covariates and confounders which may act in tandem with air pollution to result in the observed outcomes of respiratory and cardiovascular health. Nevertheless, the use of more advanced statistical tools such as the Poisson regression modelling as applied in this study, tends to minimize the influence of meteorological variables and time trend. Therefore, the authors confidently come to the conclusion that the results of this study, though limited in its subject coverage and duration, have clearly demonstrated the potential impact of common air pollutants on human health, even at levels well below the Malaysian ambient air quality guidelines.

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