EVALUATION OF THE EFFECT OF AIR POLLUTION ON HUMAN HEALTH IN KUWAIT

by

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To Abdullah with love

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ABSTRACT

Even before the 1990 war the populations of some areas of Kuwait was subject to severe atmospheric pollution. However, little was known about the effect of this pollution on health and on the use of health care.

Three areas in Kuwait were chosen for study which were demographically similar and lay at a different distances to the north (i.e. usually downwind) of the industrial area. Plant in this area emits hydrogen sulphide, sulphur dioxide, hydrocarbons, nitrogen oxides, ammonia and carbon monoxide among other pollutants.

A special survey was carried out to gather information on demographic, health and lifestyle factors including age, sex, place of residence, smoking, physical symptoms, psychological effects,life satisfaction, environmental problems, experience of air pollution and use of health care. A random sample of 136 households (1140 persons) was chosen from the three areas and studied over the period from 1st February 1988 to 31st January 1989.

Data on levels of pollution concentrations and meteorological conditions were also collected over the same period for each area studied. Data on use of health care were available from the health centres in the three areas studied and also from the population survey.

The demographic similarity of the three areas studied was generally confirmed by the data from population survey.

The relationships involved were examined for different age groups using cross tabulation, time series analysis and regression analysis. There were clear gradients with increased distance from the industrial area in levels of pollution, levels of self-reported physical and psychological symptoms and in the use of health care.

Of the individual pollutants it appeared that carbon monoxide levels were most closely correlated with levels of symptoms. For those aged less than 18, the link to CO was closest for respiratory symptoms, while for those aged 18 to 64 the link was with headache. The use of primary care is more closely linked to H_2S although this relationship is relatively weak.

Consider the relationship between levels of pollution in the three areas studied and Kuwait City and the levels of pollution in Shuaiba area taking meteorological conditions into account. The purpose of this was to allow for estimates of the effect of pollution reduction in Shuaiba on the health of population elsewhere in the country. However, no way was and of making such estimates with sufficient prison. This analysis confirmed a number of recommendations that have been made by others.

CONTENTS

KUWAIT'S GEOGRAPHY

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

BACKGROUND AND OUTLINE OF THE STUDY

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BACKGROUND AND OUTLINE OF THE STUDY

1.1 Introduction: Pollution, Its Growth and Public Concern

The natural environment is made up of a broad spectrum of media. It consists of the air mantle, rivers, lakes, oceans and land, together with biological life. The natural environment renders many services to man. It is a supplier of agricultural, fishing, mineral and non-mineral resources. It is also an assimilator of wastes from human activities. The environment has a certain capacity for assimilation of waste but exceeding these limits leads to a deterioration in environmental quality (Lundgren, 1981) and its life supporting capacity (Dandake, 1982). At the local levels, severely polluted areas may become uninhabitable. On a global level, damage to the ozone layer or increasing carbon dioxide concentrations in the atmosphere may lead to a general deterioration in living conditions.

Deterioration of environmental quality because of air pollution is not a new phenomenon and neither is public concern about it. Complaints were first recorded hundreds of years ago when coal was first used in London. For over 100 years, from the middle of the 19th century, the atmospheres of major British cities were regularly polluted in winter, giving rise to fog. However, it was not until December 1952, when an estimated 4000 people died prematurely in the two week period following a pollution episode in London (Department of the Environment, 1993) where a high pressure system remained static over Britain, at that time water droplets combined with SO_2 to form acid drops and the PH of the fog was as low as 1.6 resulting in some 4000 deaths, mostly from bronchial complaints (Brimblecombe, 1987).

Other lethal air pollution episodes include those in Belgium where 63 died in 1930, in Donora, Pennsylvania where 20 were killed in 1948 and in New York City in which 200 people were killed in 1953, in the Manse Valley, (Regenstein, 1982).

Methyl isocyanate swept through the Indian city of Bhopal on December 3, 1984, resulting in 2000 estimated deaths (Weiss, 1986). In Czechoslovakia, the burning of sulphurous brown coal has resulted in parts of Bohemia experiencing severe health management problems. The WHO's minimum annual limit for SO_2 deposition is 50 ugm but in northern Bohemia it is around 100-170 ugm and can be as high as 1000 ugm in places. A third of children in northern Bohemia suffer respiratory problems, with infant mortality rates 30% higher than Western Europe (Traynor, 1991).

In warm temperate and tropical countries, high levels of solar radiation cause photochemical smog. These were first identified in Los Angeles during the 1950s and 1960s where high levels of nitrogen monoxide (NO) and nitrogen dioxide (NO_2) produced by vehicle exhausts were trapped under atmospheric inversions. These form peroxacyl nitrate (PAN) under conditions of high solar radiation and are extremely toxic in concentrations as low as 10 parts per 100 million. 10 ug/m can cause visible damage to crops and even concentrations as low as 1 ugm cause severe eye irritation to humans (Mellanby, 1972).

In Athens, problems caused by acid fog and PAN are now becoming acute. The photochemical cocktail known as nefos or "the cloud" consists of PAN and ground level ozone which can reach levels of nearly 400 mgm of air - well above the 300 mgm danger level (Smith, 1991).

Acid precipitation in the form of rain, snow, hail, dew and frost is occurring over large areas of the United States. During the past 25 years, the acidity of rainfall has increased some 50-fold. As a result some officials and scientists predict that in just 15 years, more than 50,000 lakes in the United States and Canada could become "dead", i.e. devoid of fish and plant life. As fish and amphibians such as frogs and salamanders die off, the birds and mammals that feed on them are deprived of an important food source and they, in turn, disappear (Regenstein, 1982).

Polluting discharges are dispersed though the air in both horizontal and vertical directions, becoming more dilute with distance from the source. Dilution of pollutants is desirable, but many conservationists now argue that if all industrialised countries rely on this effect alone, it will stop being effective and the global level of pollutants may rise to an undesirable level.

The most notable example of this at the current time is carbon dioxide. The ability of CO_2 to allow solar radiation to reach the earth's surface but to prevent the longer wave re-radiated heat from the earth's surface from leaving the lower atmosphere is well known (the greenhouse effect) and its effects are experienced routinely in urban areas. More recently the influence of other greenhouse gases such as chloro-flourocarbons (CFCs), methane, nitrous oxide and trophospheric ozone have also been studied as agents of global warming (Greenpeace, 1988). Although all are mixed by the movement of air in the atmosphere, they have reached levels within the atmosphere generally that give general cause for concern.

The burning of fossil fuels and the decline of the world's forest areas have both contributed to a steady rise in CO_2 concentrations in the last half century. The long-term impact of this is still uncertain. Although organisations like Britain's Meteorological Office and the USA's NASA Goddard Center for Space Research both confirm recent rises in global temperatures, it is unclear whether these are due to levels of greenhouse gases or natural variations in global climate (Schoon, 1990).

The behaviour of smoke in the upper atmosphere is different from that of gases. The weight of particles is such that they will ultimately be precipitated on the earth's surface. The igniting of oil wells during the Gulf War of early 1991 created a pall of smoke over the Gulf area and eastward into Iran. However, participate matter and liquid hydrocarbon droplets reached the upper atmosphere. Two French climbers reported in April 1991 that a layer of oily snow 2cm deep had been found high up in the Himalayas. (Beshara, 1991)

Eventually the dispersing discharges reach people, other life forms and sensitive receptors, natural or man made, that can be adversely affected.

There is no possibility of completely removing all pollutants from the air. Instead, the problem is one of balancing the benefits that polluters obtain from venting residuals against the damage that is incurred on and by society as a result of the increased pollution.

One of the most urgent tasks facing Kuwait, particularly since the war, is the conversion of receipts from the sale of oil into productive physical assets and the achievement of accelerated economic growth. This is linked to a need to diversify the economy by encouraging other economic sectors, such as manufacturing industries, to increase their share in the economy.

One area in which activities have developed as part of the task of diversification is the Shuaiba Industrial Area. This is sited 50 km south of Kuwait City on the coastline of the Arabian Gulf. Major process industries have been developed here to exploit the local natural reserves of crude oil and natural gas. These include refineries and fertiliser plants. Since Kuwait has a very limited natural supply of fresh water (insufficient to support an advanced technological industrial area and a growing population), in addition to generating electricity from natural gas, the power stations at Shuaiba provide vital supplies of fresh water by desalination. The desalination plant and the power station form the nucleus around which the Shuaiba Industrial Area has developed rapidly since the site was allocated for industrial development some thirty years ago.

Since then new industries have been introduced and existing ones expanded to accommodate the increase in domestic - and export - demand for water and energy-related products following an unprecedented rise in national per capita income, a high rate of urbanisation and construction, and a substantial population increase.

In the light of Kuwait's development policy, aimed at diversifying sources of income, expanding the base of the economy and reducing its dependence on oil exports, the industrial sector receives special support and encouragement from the government. The Shuaiba Industrial Area is a governmental authority located 50 km south of Kuwait city between Ahmadi south pier and Mina Abdulla along the costline, with an independent budget and attached to the Minister of Commerce and Industry.

Shuaiba Industrial Area is one the biggest industrial complexes in the whole Gulf. It consists mainly of petrochemical industries (petrochemical plants, refineries, melamine plants, sulphur and coke recovery plants, lube oil plants, power and distillation plants, salt and chlorine plants, industrial refilling gases plant, paper industries, automobile plants, cement plants, seaports (for commercial purposes) oil pier facilities, etc, see Appendix A.

Its contribution to the gross domestic produce (GDP) rose from KD 75 million to KD 219.5 million during the years 1974 - 1983. However, despite the swift growth in this sector, it still plays a modest role in the country's economy, accounting for only 3.6% of Kuwait's Gross National Product in 1983. (Shuaiba Industrial Authority, 1988).

Increased industrial activity has been accompanied by an increase in the discharge of waste into the environment. Industrialisation, with its many economic benefits and its influence on standards of living, has created air pollution. This in turn creates many economic, social and health problems, lowering the efficiency of those affected and endangering their lives.

Emissions from the various industries have increased continuously in Shuaiba over the last three decades. The resulting impact on both the performance of the industries and the environment around Shuaiba is a cause for increasing concern to the State Authorities of Kuwait, the Shuaiba Area Authority and even local industry.

This has led to a recognition of the need for the scientific community to develop a sound approach for assessing the wide range of health and environmental effects that result from exposure to toxic chemicals (Santos, 1987).

In 1975, to assess the impact of fast economic growth on environmental quality, a group of consulting engineers was commissioned by the Kuwait Authority to visit the country and carry out an environmental impact assessment of Shuaiba Industrial Area. Their report (Cremer and Warner,1975) was timely and alarming. Timely, as authorities were debating the need to expand basic services by adding new installations to Shuaiba Industrial Area (SIA) or by expanding the existing capacity of certain industries. And alarming, for it gave an account of the environmental cost of growth.

The main environmental risks associated with industrial expansion in Shuaiba are described below:

1. Kuwait and most states along the western shore of the Gulf are unusual in relying upon the sea as their major source of drinking water. In other parts of the world, extreme pollution of seawater can cause interruptions of electrical supplies, but nowhere else is the dependence on seawater so great. The Gulf is virtually a landlocked lake with little through flow to flush out contaminants. It therefore has a much reduced capacity for self-purification compared with other water bodies in the world.

2. Sea-water pollution results from the flow of sewage and wastes which pours into the Gulf waters from factories. This includes very salty water ejected by the water distillation filtering plants, ammoniac solution which comes from by the chemical fertiliser plants, and also oil which leaks into the sea during the loading of oil tankers and is carried to the shore by wave action.

3. Oil burning emits large amounts of sulphur compounds.

4. Gas burners emit large quantities of carbon monoxide and carbon dioxide (up to 11% in the exhaust gases in some phases of operation). Research shows that the degree of ground concentration of carbon monoxide and carbon dioxide in the air within the area of Kuwait is more than the permitted international level (Yousef, 1989).

5. Petrol and diesel engines produce oxides of nitrogen (predominantly NO) and hydrocarbons.

6. Steam spouts are found in the petroleum refineries where petrol is separated from water and the hydrogen gas is polluted with sulphur, forming hydrogen sulphide.

7. Nitrogen, sulphur dioxide and hydrocarbon are added to in-shore water.

8. There is a risk of gross emission of ammonia from refrigerated liquid storage facilities (Cremer and Warner, 1975).

9. Dispersion of pollutants into the Gulf has led to a reduction in the quantity and variety of marine life forms in the Shuaiba Marine Environment. (Purser, 1988). In mid 1975, for example, pollution of the beaches of Kuwait was so bad that swimming was officially banned for a while. (Black, 1982).

10. Analysis of the factors governing environmental quality to Shuaiba and in Kuwait shows that a disturbance of any part of the system may affect not only the receiver next in line but may also produce significant disturbance throughout the interacting networks.

The burning of 732 out of 1080 Kuwaiti wells in 1990 war (these wells centred in the northern, western and southern areas of the country) have been cleaned up now.

In 1978 the Kuwaiti Government pioneered a set of national ambient air quality standards for each air pollutant. These limits are:

Sulphur dioxide	0.025 ppm
Hydrogen sulphide	0.006 ppm
Carbon monoxide	8.0 ppm
Hydrocarbons	0.24 ppm

Ammonia	0.14 ppm and
Nitrogen dioxide	0.05 ppm

depending on the primary and secondary National Ambient Air Quality Standards (WHO, 1972) see Appendix B.

The study of Cremer and Warner revealed the severity of the pollution problem in the Shuaiba area. Pollution was present at high concentration levels. In the atmosphere, the short-range fall-out of noxious materials (including hydrogen sulphide, mercaptans, ammonia, sulphur oxides, acid aerosols, particulate urea, ammonium sulphate and cement dust) derived from low level emissions and process leaks give rise to ground level concentrations above the national ambient air quality standards.

Under adverse meteorological conditions, the polluting effects of sulphur dioxide and ammonium sulphate smoke may be manifest over a much larger region, including the domestic centres of Ahmadi and Fahaheel and along the coastal strip towards Kuwait City.

Based on the recommendations of Cremer and Warner (1975), the Shuaiba Area Authority (SAA) established an Environmental Protection Centre in 1978 aimed at monitoring the environmental projects in the area and producing reports about the status of local environmental conditions. Reports from the SAA indicate that five large companies in the area are responsible for high levels of pollution emission and discharge into the air and water. These companies are the Kuwait Natural Petroleum Company (KNPC), the Kuwait Oil Company (KOC), the Petrochemical Industries Company (PIC), the Melamine Company and the Kuwait Cement Company (KCC).

1.2 The Hypothesis of the Study

The broad hypothesis underlying this study is that prolonged exposure to polluted air lowers health status and thus increases health care costs and medical expenditure. To explore these hypotheses we must take into account other factors affecting health status.

Some of these are shown in Table 1.1 and may be grouped into (1) demographic characteristics of the population, (2) socioeconomic characteristics, (3) other environmental factors, and (4) behavioural factors. These all will need to be kept under consideration throughout the study.

Table (1.1) Factors Affecting Mortality and Morbidity

Demographic	Socioeconomic	Environmental	Personal
Age	Income	Air pollution level	Smoking
Gender	Education	Radiation level	Exercise
Ethnic	Occupation mix	Climate	Diet
	Housing density of crowding		Use of Medical care

Stewart, 1987.

1.3 Aims and Objectives

1. To measure the level of pollution in a sample of areas in Kuwait so as to provide a basis for estimating the pollution experience of the population.

2. To measure the meteorological conditions in the areas included in the study so as to provide a basis for examining any mediating effects of meteorology on the links between pollution and health.

3. To measure the prevalence of pollution-related symptoms and the use of health care in areas experiencing different levels of pollution.

4. To explore the relationships between levels of specific pollutants and the problems of specific physical and psychological symptoms.

5. To estimate the prevalence of pollution related symptoms for the population of Kuwait.

6. To determine the relationship between pollution levels in Shuaiba and pollution levels elsewhere in Kuwait.

7. To predict the effect of pollution on the use of health care for the population of Kuwait.

8. To make recommendations for future policies related to environmental pollution in order to ensure the reduction of air pollution effects on health.

The thesis will mainly focus on the environmental health effects on the population of Kuwait, as measured by its experience of air pollution related symptoms, and on the potential for reducing damage to health by reducing pollution levels.

1.4 Data sources

1. Review of the literature, published and unpublished materials, reports, books, theses, newspapers and other relevant document.

2. Personal communication and interviews with the people and governmental ministries involved in scientific environmental epidmological, policies and health.

3. Data from governmental agencies, such as the Ministry of Public Health, Shuaiba Industrial Authority (SIA), Environmental Protection Council (EPC), Kuwait University, Petro-chemical Industries Company, Kuwait Oil Company, Shuaiba Industrial Board, Kuwait Foundation for the Advancement of Science (KFAS) and Kuwait Institute for Scientific Research (KISR).

4. Survey data on pollution levels and meteorological conditions. To achieve this goal the concentration of air pollution has been measured in the residential areas over a one year period, from February 1989 to January 1990, together with the meteorological data.

5. Survey data on symptoms and possible confounding features from a self-administered questionnaire in areas around Shuiaba Industrial Area.

1.5 Outline of the thesis

The thesis is set out in ten chapters. Chapter 2 provides a detailed literature review on the effects of pollutants on human health.

Chapter 3 presents a background to Kuwait. It outlines some of the physical aspects of the country, the major meteorological features and the health services available. It also describes the major industries in the Gulf countries.

Chapter 4 describes the methods used during this study to investigate the association between air pollution and health in three areas in Kuwait from February 1st, 1989 to January 31st, 1990.

Chapter 5 compares the results for the measured pollutants, meteorological conditions, use of health care and the population survey for the different areas and different times of year.

Chapters 6 provides more detail on the relationships between air pollution and physical symptoms, by using multiple regression analysis. The prediction of change in symptom levels with change in pollutant levels was estimated.

Chapters 7 provides more detail on the relationships between air pollution and psychological symptoms, by using multiple regression analysis. The prediction of change in symptom levels with change in pollutant levels was estimated.

Chapters 8 provides more detail on the relationships between air pollution and use of health care, by using multiple regression analysis.

Chapter 9 analyses the relationship between the pollution levels in Shuaiba and pollution levels elsewhere in Kuwait.

Finally chapter 10 presents the recommendations and implications for future policies.

CHAPTER TWO

REVIEW OF LITERATURE RELATING

AIR POLLUTION AND HEALTH

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2.1 Definition of Air Pollutants and Polluting Effects

Air pollution is a problem of growing national and international interest. Public awareness and concern continues to rise, and a number of extreme proposals for regulating pollution emissions have been made because many policy makers misunderstand the basic physical and economic aspects of air pollution control. Considerable confusion has been generated by loosely defined and indiscriminately used terminology in this field.

Many pollutants are natural constituents of the air. Plants, animals and natural activity would cause some pollution even without man and his technology. Animals exhale carbon dioxide. Decaying vegetation produces methane and decaying animals produce ammonia. Volcanic activity vents sulphur dioxide, and wind results in suspended particulates.

In one sense, any substance not normally present in the environment, or present in greater than normal concentrations may be considered a pollutant. However, a substance is normally considered to be a pollutant if it adversely alters the environment by changing the growth rate of species, interferes with the food chain, is toxic, or has adverse effects on the health, comfort, amenities, or property value of people. Pollutants are introduced into the environment in significant amounts as industrial waste, accidental discharge, domestic waste and sewage, or as a by-product of manufacturing processes or other human activities.

The term air pollution is limited to the situation in which the outdoor ambient atmosphere contains materials in concentrations which are harmful to man and to the environment. Air pollution is usually a mix of sulphur dioxide, particulates, nitrogen oxides, carbon monoxide, hydrocarbons, ozone and ammonia. Lumping these into the single category "air pollution" ignores their different properties and obscures differences in the degree of damage that each can cause. For example some pollutants cause atmospheric haze and impair visibility, others discolour fabrics, and others again cause illness. Air pollution is used as a summary term for these compounds, but care will be taken throughout this study to examine the particular pernicious effect of each pollutant whenever possible. Our investigation will be limited to the association between air pollution and human health.

2.2 Major Pollutants and Health

Environmental pollution may affect health in any of the following ways (Giroult, 1984):

- intensive exposure to toxic materials or agents causing immediate acute health effects.
- low level exposure to toxic materials or agents which may cause acute or chronic disease long after exposure.

- exposures which may cause genetic changes.
- lower resistance to infection.
- produce sub-clinical irritation, nuisance or discomfort.
- contribute to the aggravation of existing disease.
- create conditions incompatible with or derogatory to, the achievement of physical, mental and social well being.

An international conference held in San Antonio April 1991 on Clean Air Act Amendments designated 189 hazardous air pollutants to be regulated under revisions to the National Emissions Standards for Hazardous Air Pollutants. Both new and existing sources will be required to comply with control technology standards and, in some cases, with further controls to meet health and environmental risk standards aimed at reducing the risk of chronic exposure to these pollutants (Bruse, 1991).

It is difficult to distinguish clearly between the effects of air pollution from different sources and it is important to take account of the effect of mixtures of substances. The effect of such mixtures may be simply additive but it is more common to find that they are synergistic although on occasions they may be antagonistic.

2.3 Toxicity of Pollutants

The review of literature, in this chapter, was discussed in term of the effect of the pollutant on human health followed by laboratory studies and community studies.

2.3.1 Sulphur Dioxide and Other Sulphur Compounds

SO_2 irritates the respiratory tract and increases the incidence of respiratory diseases (Ware, 1981). It can cause oedema of the lungs or glottis and can produce respiratory paralysis. It can cause high urinary acidity and alteration of sense of smell with increased fatigue. Pharyngitis, bronchitis, tonsillitis, colds and sore throats are also associated with SO_2 (Ministry of Public Health, 1987).

SO_2 is less abundant in the atmosphere than hydrogen sulphide (H_2S). H_2S can have an irritant action on the eyes, paralyses the sense of smell and cause instant unconsciousness. It can affect the nervous system causing headache, dizziness, excitement and loss of vision.

Koenig (1982) studied the acute effects of inhaled sulphur dioxide (SO_2) in a group of carefully matched healthy adolescents (3 female and 5 male adolescents aged 12-14). The healthy subjects showed small, statistically significant changes consistent with bronchoconstruction after exposure to sulphur dioxide (SO_2). After exposure at rest to 1.0 ppm SO_2 + 1 mg/m sodium chloride (NaCl) droplet aerosol, the healthy adolescents showed small (3%) but significant reductions in forced expiratory volume in one second ($FEV_{1.0}$). No significant changes were seen following exposure to NaCl or SO_2 alone at rest. Exposure to the SO_2 modes during moderate exercise produced greater changes. Following exposure to either the SO_2 + NaCl mixture or 1.0 ppm SO_2 alone, the reduction in $FEV_{1.0}$ were slightly greater (6%) and prolonged compared with those seen at rest. A small decrease (4%) in $FEV_{1.0}$ was seen following exposure to NaCl alone during exercise, but the change was not statistically significant. The changes seen in the healthy adolescents were slight compared to those seen in the asthmatic adolescents previously exposed (changes of 23-67%). They conclude that asthmatic adolescents are much more sensitive to the effects of inhaled SO_2 than are healthy adolescents.

Linn (1984) studied twenty four asthmatic volunteers exposed to 0, 0.3 and 0.6 ppm sulphur dioxide (SO_2) in purified background air at each of three temperatures: 21°C, 7°C and 6°C, in a controlled-environment chamber. Relative humidity was approximately 80%. Exposures consisted of 5 minute heavy exercise periods plus brief warm-up and cool-down periods. Airway resistance, thoracic gas volume, and symptoms were measured immediately before and after exposure. For the group, increasing SO_2 concentration and decreasing temperature (6°C) were associated with statistically significant unfavourable effects on airway resistance and respiratory symptoms. The SO_2 and temperature effects usually appeared to combine in an additive or less-than-additive fashion; there was little evidence of synergism. Individuals' response patterns were variable: a few suggested synergism, but others suggested a mitigating effect of cold on the bronchoconstructive response to SO_2.

Schachter (1984), studied the acute respiratory effects of exposure to low-level, short-term sulphur dioxide (SO_2) in ten asthmatic and ten healthy subjects. Subjects were exposed in an environmental chamber in a double-blind, random sequence to SO_2, levels of 0.0, 0.25, 0.5 and 1.0 ppm for 40 minutes. During the first 10 minutes subjects exercised on a cycloergometer at a level of 450 kpm/min. On separate days, subjects were exposed to 0 and 1.0 ppm SO_2 in the absence of exercise. No changes were seen in healthy individuals on any day (see also section 2.4.1).

Hewitt (1956) found a significant correlation between an air pollution index (duration of exposure to sulphur dioxide) and lung cancer mortality (r=0.70) across nine public health divisions in London.

Zeidberg (1964) found mortality rates for cardiovascular disease to be associated with air pollution levels in Nashville, Tennessee. In white, middle-class males, fifty-five years and older, a consistent pattern of increasing morbidity with increasing values for soiling (coefficient of haze) and twenty-four-hour sulphur dioxide concentrations was observed. Cardiovascular morbidity in white, middle class females, fifty-five years old and older, showed a direct relationship with soiling and sulphur dioxide as well as with mean annual sulphation (sulphur trioxide) dustfall, and twenty-four-hour suspended particulate levels. Results were less consistent for non-whites.

Wicken and Buck (1964) studied bronchitis mortality in six areas of north-east England. The fact that rates were relatively higher in the two urban districts compared with those of four rural districts could not be fully accounted for by age composition, smoking habits, or social-class distribution (based on occupation) of the respective populations. The urban district with the highest bronchitis death rate also had the highest levels of air pollution. Furthermore, within the district, the locality with the higher measured level of air pollution (smoke and sulphur dioxide) had higher bronchitis mortality among males.

Cassell (1969) collected data on daily illness symptoms among 1747 persons living in New York City over a period of three years using weekly interviews with families. These data were correlated with sulphur dioxide levels (and also carbon monoxide, suspended particulates and hydrocarbons) and seven meteorologic factors (precipitation, solar radiation, temperature, humidity, sky cover, pressure and wind speed). Cough was positively correlated with sulphur dioxide (and also particulates and carbon monoxide). There was some indication that the respiratory symptoms were less strongly related to sulphur dioxide than particulates.

Holland (1969) studied respiratory functions in 2205 families with newborn children living in two suburbs of London. One-third of the families underwent ventilatory function tests. Controlling for smoking habits, domestic overcrowding and social class (based on father's occupation) the prevalence of respiratory symptoms in both mothers and children was higher in the area which had a past history of higher daily measurements of smoke and sulphur dioxide.

Lambert and Reid (1970) obtained information from more than 18000 men and women (a random sample of a "healthy" population aged thirty-five to sixty-nine) by means of postal questionnaires. Smoking was measured. They found that the urban-rural gradient in bronchitis symptoms could not be explained by smoking differences alone, although local pollution seemed to have little effect on non-smokers. Because of the many uncontrolled factors, one cannot have great confidence in the association found between bronchitis symptoms (in smokers) and air pollution, which included smoke and sulphur dioxide.

Heimann (1972) examined the situation in Boston during November 1966. The specific pollutants analyzed were suspended particulates, sulphur dioxide, and a soiling index. He found no significant effects of air pollution on total mortality, on mortality or hospitalization of 9697 elderly nursing-home residents, on the frequency of fetal deaths, or on the number of emergency room visits in one hospital for treatment of heart or respiratory disease. He did find that patients with chronic non-specific respiratory disease made more visits to their chest clinics when exposed to higher levels of air pollution.

Similar studies have taken place in other countries. Petrilli and Kanitz (1976), studying mortality and morbidity data for Genoa, Italy, found that the frequency of bronchitis was highly correlated with pollution levels measured daily at a monitoring site located within 2.5 miles of the residential area (sulphur dioxide). The subjects considered were non-smoking women over sixty-five years of age who had lived for a long period in the same area.

In the USSR, Manzhenko (1976) looked at upper-respiratory tract infections in 3009 children (seven to twelve years old) from two school districts with different pollution levels (dust, sulphur dioxide). Family income and living conditions were similar in the two areas and the more polluted district actually had better sanitary facilities. The prevalence of chronic rhinitis was 4.7 times as great in the polluted district as in the relatively unpolluted district. Frequencies for upper-respiratory-tract conditions and chronic sinusitis were 1.9 and 9.0 times as high, respectively. X-ray findings also indicated that the incidence of pulmonary conditions was higher in the polluted area.

Mazumdar (1983) evaluated adverse health effects resulting from exposure to relatively low levels of regulated air pollutants. The determination of short-term or acute effects is necessary for this evaluation. By using methodology that directly addressed the time series nature of the data, this study investigated acute health effects of daily levels of air pollution in Allegheny County, Pennsylvania, using both mortality and morbidity events as the adverse health response to ambient pollution. Health effects were determined using the air quality data for sulphur dioxide (SO_2) and particulates as measured by a coefficient of haze from three monitoring stations located within the county. The mortality analysis provided a replication of a previous study performed in the New York area. Results indicated a possible association between heart disease mortality/morbidity and same day particulate levels. No association between SO_2 and mortality/morbidity was seen at the present level of SO_2. These findings were in agreement with those obtained in the New York City study and in a re-analysis of London winter data.

Schenker (1983) administered respiratory questionnaires to 5557 adult women in a rural area of Western Pennsylvania to evaluate the health effects of air pollution resulting from coal combustion. Air pollution data were derived from 17 air quality monitoring sites and stratified to define low, medium and high pollution areas. The means of 4 years (1975-1978) annual averages for sulphur dioxide in each strata were 62, 66 and 99 $\mu g/m^3$, respectively. Total suspended particulates were not tested as a risk factor because they reflected air pollution from sources other than coal combustion (e.g., agricultural, road dust). Risks of respiratory symptoms were evaluated in a multiple logistic model that adjusted for several potential confounding factors. The risk of "wheeze most days or nights" in non-smokers residing in the high and medium pollution areas was 1.58 and 1.26, respectively, relative to residents in the low pollution area. In the subset of residents who had lived in the same location for at least 5 years, relative risks increased to 1.95 and 1.40, respectively. An increased risk of grade 3 dyspnea in non-smokers was associated with sulphur dioxide but did not achieve statistical significance, and there was no association of cough or phlegm and air pollution in non-smokers. Cigarette smoking characteristics were the major determinant of respiratory symptoms in smokers, and no independent association of air pollution was found. This study suggests that wheezing may be associated with ambient exposure to sulphur dioxide in non-smokers but no effect of sulphur dioxide on cigarette smokers was observed. Chronic cough and phlegm production were not associated with sulphur dioxide at the concentrations observed in this study.

Imai (1986) surveyed death certificates issued in Yokkaichi, Japan during the 21 years from 1963 until 1983 to determine the relationship between changes in air pollution and mortality due to bronchial asthma and chronic bronchitis. The following results were obtained: (1) In response to worsening air pollution, mortality for bronchial asthma and chronic bronchitis began to increase. (2) Mortality due to bronchial asthma decreased immediately in response to improvement of pollution, and mortality due to chronic bronchitis decreased after the concentration of sulphur dioxide (SO_2) began to satisfy the ambient air quality standard. (3) In the polluted area, mortality due to bronchial asthma in subjects who were 20 years of age or more was higher during the period in which higher concentrations of sulphur oxides were prevalent.

Euler (1988) assessed the risk of chronic obstructive pulmonary disease symptoms due to long-term exposure to ambient levels of total suspended particulates (TSP) and sulphur dioxide (SO_2) using a questionnaire on 7445 Seventh-Day Adventists. They were non-smokers, at least 25 years of age, and had lived for 11 years or more in areas ranging from high to low photochemical air pollution in California. Participant cumulative exposures to each pollutant in excess of four thresholds were estimated using monthly residence zip code histories and interpolated dosages from state air monitoring stations. These pollutant thresholds were entered individually and in combination in multiple logistic regression analyses with eight co-variables including passive smoking. Statistically significant associations with chronic symptoms were seen for SO_2 exposure above 4 pphm (p=.03) relative risk 1.18 for 500 hr/yr of exposure; and for total suspended particulates (TSP) above 200 mcg/m^3, relative risk of 1.22 for 750 hour/year.

Charpin (1988) studied the influence of daily changes in sulphur dioxide (SO_2) levels on the induction of respiratory symptoms during the 1983-1984 winter in 450 children, aged 9 to 11 years, living in the Gardanne coal-basin, France. In this area, SO_2 originates mainly from a coal-fuelled power plant. The mean SO_2 level during the winter was 22 $\mu g/m^3$ in low-polluted areas and 93 $\mu g/m^3$ in high polluted areas, with daily SO_2 levels up to 356 $\mu g/m^3$. Children completed a daily diary about respiratory symptoms. Only polluted communities demonstrated a significant association between daily SO_2 levels (after controlling for temperature) and prevalence of upper and lower respiratory symptoms. However, in each polluted town, and for each respiratory symptom, there was no evidence for either a latency period (2-week period) or a delay in the effects of pollutants. Mean daily temperature was also closely correlated with upper and lower respiratory symptoms in most of the polluted and some low-pollution communities. The author concluded that moderate daily changes in SO_2 levels induce a significant but transient increase in the prevalence of respiratory symptoms in children.

Xiping (1991), conducted a study in three representative areas of Beijing to determine respiratory health effects of indoor and outdoor air pollution. In August 1986, the lung function of 1440 adults who were 40-69 years of age who had never smoked were measured. Forced vital capacity (FVC) and forced expiratory volume in 1 second ($FEV_{1.0}$) were adjusted for height, sex and age. Outdoor ambient air pollution measurements from the World Health Organization Global Air Pollution Monitoring Station were very different in the three study areas; the annual mean concentrations of sulphur dioxide (SO_2) in residential, suburban, and industrial areas were 128, 18 and 57 ug/m, respectively, and annual mean concentrations of total suspended particulate matter (TSPM) were 389, 261 and 449 $\mu g/m^3$, respectively. Coal was most frequently used for domestic heating in the residential (92%) and suburban (96%) areas compared with the industrial area (17%). After adjusting for age height and sex, an inverse linear association was found between outdoor SO_2 (or TSPM) concentration and $FEV_{1.0}$ and FVC in subjects who had and had not used coal stove heating. Regression analysis showed that increase in SO_2 (TSPM) concentration could result in a 35.6 ml reduction in $FEV_{1.0}$ and 142.2 ml reduction in FVC. Not only was coal heating an important risk factor for pulmonary function, but it was a major factor in the analysis of outdoor air pollution effects.

Schwartz (1992) in a diary study of student nurses examined the possibility that air pollution exposure can extend the duration of respiratory symptoms. After individual risk factors and temperature were controlled for sulphur dioxide. The relationships continued for concentrations below the current ambient standard. Chest tightness or discomfort was significantly associated with sulphur dioxide ($p=.016$). This diary study had already shown associations between air pollution and incidence rates of respiratory symptoms.

Abbey (1993) also studied seventh-day adventist non-smokers, who, subsequent to 1966, had resided within 8 km (5 miles) of their 1977 residence (N = 3914). They completed a questionnaire in 1977 and again in 1987. For each participant, cumulative ambient concentrations of total suspended particulates (TSP), ozone and sulphur dioxide (SO_2) in excess of several cut off levels were estimated by month and by interpolating ambient concentrations from state air-monitoring stations to their residential and workplace zip codes for the month. Statistically significant relationships between ambient concentrations of TSP and ozone, but not SO_2, were found with several respiratory disease outcomes. Multivariate analyses adjusted for past and passive smoking and occupational exposures.

2.3.2 Carbon Monoxide

Two kinds of health effects are attributed to CO, short term and long term. Exposure to high concentrations of CO raises the level of carboxyhaemoglobin CoHB in the blood. Haemoglobin has a great affinity for CO, some 240 times greater than that for oxygen and it preferentially absorbs CO even when the concentration of CO is very low. The prime result of CoHB formation is to decrease the capacity of the blood to transport oxygen from the lung to the tissues, and this leads to diminution of attention and accuracy in problem-solving tasks, severe headache, weakness, dizziness, nausea, bronchitic cough with sputum production, vomiting, reduced sensory discrimination, visual acuity, collapse and eventually death.

Long exposure to low concentrations of CO may result in asthma, bronchitis and reduced respiratory function (MPH, 1987).

Jones (1983) in a case-control study of 20 to 39 year old female participants in the Tecumseh Community Health Study compared use of cooking fuels and other factors in women from the highest and lowest quartiles of the lung function distribution. Concentration of carbon monoxide (CO) and also nitrogen oxides (NO, NO_2) were found to be higher in homes using gas than in homes using electricity for cooking. The forced expiratory volume in 1 second ($FEV_{1.0}$) was used as the index of ventilatory lung function. The use of a kitchen exhaust fan was significantly associated with low lung function. A larger proportion of women with low $FEV_{1.0}$ used gas for cooking, but this difference was not statistically significant.

Hinderliter (1989) evaluated the effect of acute elevation of carboxyhemoglobin (COHb). Concentration on resting and exercise-induced ventricular arrhythmias were evaluated in 10 patients who had ischaemic heart disease and in whom no ectopy during baseline monitoring was noted. After an initial training session, patients were exposed to air, 100 ppm carbon monoxide (CO), or 200 ppm CO on successive days in a randomized, double-blind, cross-over design. After exposure to 100 and 200 ppm CO, venous COHb levels averaged 4% and 6% respectively. Symptom-limited supine exercise was performed after exposure. Eight of the 10 patients had evidence of exercise-induced angina, 1.0 mm ST depression, or abnormal ejection fraction response-during 1 or more exposure days. Ambulatory electrocardiograms were obtained on each day and analyzed for arrhythmia frequency and severity. On air and CO exposure days, each patient had only 0-1 ventricular premature beat/hr in the 2 h prior to exposure, during the exposure period, during the subsequent exercise test, and in the 5 h following exercise. It was concluded that low-level CO exposure is not arrhythmogenic in patients with coronary artery disease and no ventricular ectopy at baseline.

Kleinman (1989) observed 24 male subjects with stable angina pectoris. They performed graded exercise tests after being exposed to either carbon monoxide (CO) or clean air in a randomized cross-over double-blind experiment in which each subject acted as his own control. Subjects' blood carboxyhaemoglobin levels were increased from a baseline level of approximately 1.5% to 3% of saturation, post-CO exposure. Cardiographic and respiratory gas exchange data were obtained during the tests in which the subjects exercised to the point of onset of anginal pain. The goal of the study was to determine if low-level CO exposure compromised the ability of these individuals to perform work. The time to onset of angina was reduced 6% (p=.046) after CO exposure relative to clean air. Oxygen uptake at angina was reduced by approximately 3% (p=.04). A subgroup of individuals who exhibited depression in the ST segment of their electrocardiograph tracings showed a 12% reduction in time to onset of angina and a 20% reduction in the time to onset of depression; both of these findings were also statistically significant.

Kjaergaard (1992) measured trigeminal sensitivity of the eyes to irritative exposures and examined the influence of individual characteristics, e.g. gender, age, and smoking on this sensitivity. During an experimental study, 158 randomly selected volunteers were examined for sensory irritation threshold in the eyes to carbon dioxide (CO_2). Eyes were exposed to progressive concentrations of CO_2 (10, 20, 40, 80, and 160 ml/l), until the subject claimed a distinct irritation. Each exposure level lasted 2 minutes. A special exposure mask system was used for eyes-only exposure. No significant dependence of gender or smoking was found, but subjects who were less than 40 years of age were more sensitive than were the elderly subjects. Subjects who reported frequent "sick building syndrome" irritation symptoms had lower thresholds (i.e., higher sensitivity). The CO_2 threshold was related to skin irritation sensitivity, i.e., response to lactic acid smeared on the cheek, and there were indications that occupational stress was associated with low thresholds. Studies of irritation to n-decane indicate that the CO_2 threshold may be an important factor in the prediction of individual sensitivity to irritation from airborne pollutants.

Although studies have been made of the behavioural effects of low levels of carbon monoxide in man, there is little information on the behavioural incapacitation resulting from short exposures to high concentrations likely to be encountered in fires. Purser (1983) found that monkeys, trained to perform behavioral tasks during exposures to 900 ppm carbon monoxide, were seriously affected after 20 to 30 minutes exposure, achieving carboxyhemoglobin levels of 25-30%. The tests were as sensitive as tests in man for detecting psychomotor deficits induced by carbon monoxide, and measurements of carbon dioxide production presented a more sensitive method for detecting early deficits. It is concluded that a man exposed to 1000 ppm carbon monoxide while engaged in light activity (e.g., walking) could be seriously affected within 30 min.

The study by Cassell (1969) described earlier in relation to SO_2 found that cough was positively correlated with carbon monoxide as well as sulphur dioxide. In addition, the level of carbon monoxide was positively correlated with headache, eye symptoms, cold and sore throat.

2.3.3 Hydrocarbons

Hydrocarbons have direct and indirect effects on health. They are highly carcinogenic. Their breakdown produces large amounts of CO. They interfere with red blood cell formation in the bone marrow causing leukaemia. Hydrocarbons causes unconsciousness, anoxia and convulsion; they irritate the eyes & respiratory tract (National Academy of Sciences, 1988).

The study by Stocks and Campbell (1955) utilized environmental histories of persons dying from lung cancer and compared percentage distributions according to smoking habits and residence. They found a ten-fold difference between death rates in rural and in urban areas and suggested a relationship with air pollution by showing that concentrations of smoke, 3:4 benzopyrene, other polycyclic hydrocarbons, and sulphur dioxide increased with urbanisation.

The study by Cassell (1969) described earlier in relation to SO_2 also considered hydrocarbons which appeared to have no effect on the symptom investigated additional to those of particulates, carbon monoxide and sulphur dioxide.

2.3.4 Nitrogen Oxides

Nitrogen oxides directly affect health and are also transformed in combination with other air pollutants into harmful secondary pollutants. Nitric oxide (NO) has effects similar to those of CO, causing oxygen deprivation, because of its superior affinity for haemoglobin. NO_2 is an irritant to respiratory tissues and causes chest pains, pulmonary oedema, and death. It also appears to reduce the body's resistance to infection (National Academy of Sciences, 1982). It can cause acute respiratory illness, and there is evidence that inhalation of ambient level of NO_2 (4 ppm) plays a role in facilitation of blood-borne cancer (Richters, 1983). In addition, different patterns of melanoma cell distribution in the lung of NO_2 exposed animals have been found (Ali, 1988).

Nitrogen oxides contribute to the formation of more dangerous chemicals in the air. NO_2 is converted in the atmosphere into nitric acid that precipitates in acid rain, with adverse effects on plant and animal life. NO_x, in the presence of sunlight and sulphur oxides, is a key contributor to photochemical production of sulphates in the air.

Orehek (1976), found that after a 1 hour NO_2 exposure level of 0.11 ppm, 13 out of 20 slight to mild asthmatics experienced substantially more bronchio-constriction in a carbohol provocation test than without the NO_2. This suggested that asthmatics and similar individuals were at risk from adverse effects on pulmonary performance at NO_2 levels well below those previously found to be innocuous in healthy subjects.

Kerr (1978), found that increased NO_2 concentration led to increased airway resistance and increased sensitivity to bronchio-constrictors in sensitive individuals. Seven in thirteen asthmatics, one in seven bronchitics and one in ten normal subjects reported chest tightness, burning of the eyes, headache or dyspnoea with exercise at 0.05 ppm, although the symptoms were mild and there was no objective evidence of reduced lung function.

Richters (1983) reported that inhalation of low levels of NO_2 can facilitate cancer cell metastasis. The study utilized B16 mouse melanoma metastasis model. The results suggested that inhalation of ambient level NO_2 (0.4 ppm) or polluted urban ambient air play a role in facilitation of blood-borne cancer cell metastasis. In addition, results showed different patterns of melanoma cell distribution in the lungs of NO_2 and ambient air exposed animals. They also indicated that extended periods of clean air between NO_2 exposures may diminish the severity of the insult in the sensitive animals. It was concluded that there was strong support for the need of improved air quality and for reduction of noxious pollutants in urban ambient air.

In the study by Linn (1985), Healthy and asthmatic volunteers subjects (N=25 and N=23 respectively) were exposed twice each to purified air (control) and to 4 ppm nitrogen dioxide in a controlled environment chamber. Exposure lasted 75 minutes and included 15 minutes each of light exercise and heavy exercise. Compared to control, NO_2 exposure produced no statistically significant untoward effects on airway resistance, symptoms, heart rate, skin conductance or self-reported emotional state in normal subjects. Exercise was associated with significantly increased airway resistance, although the increase in normals was small. Systolic blood pressure showed small but significant decreases with NO_2 exposure, compared to control.

In another study by Linn (1985), twenty two volunteers with chronic obstructive pulmonary disease were exposed to nitrogen dioxide at 0.0, 0.5, 1.0 and 2.0 ppm in a controlled environment chamber. Exposures lasted 1 hour and included two 15 minute exercise periods. Pulmonary mechanical function was evaluated pre-exposure, after initial exercise and at the end of exposure. Blood oxygenation was measured by ear oximetry per-exposure and during the second exposure period. Symptoms were recorded during exposures and for 1 week periods afterward. NO statistically significant changes in symptoms reported could be attributed to NO_2 exposure at any concentration, compared to 0.0 ppm control condition. Measures of pulmonary mechanics showed either no significant changes, or small and equivocal changes. Arterial oxygen saturation showed marginal improvement with exercise, regardless of nitrogen dioxide concentration.

Mohsenin (1988), studied NO_2 as a common indoor air pollutant. To characterize the acute respiratory responses to the this gas, 18 non-smoking normal subjects (mean age + standard deviation (SD) = 25 ± 4 years) were exposed to filtered air or 2 ppm NO_2 gas for one hour in an environmental chamber on different days, typically one week apart, in a double-blind randomized design. Lung function tests included forced vital capacity, forced expiratory volume in one second, partial expiratory flow at 40% of vital capacity (V_{p40}), functional residual capacity, and specific airway conductance were measured before and after exposure. Airway reactivity to methacholine inhalation was determined within 45 min of each exposure. The dose of methacholine in mg/ml to cause a 40% decrease in specific airway conductance (PD_{40}) was measured. Airway reactivity to methacholine aerosol increased significantly after NO_2, shown by a decrease in the concentration of methacholine. No significant changes were noted in the lung function tests after NO_2 exposure. These findings indicate that normal non-smokers exposed to 2.0 ppm NO_2 for 1 hour develop an increase in airway reactivity to methacholine aerosol, which is not associated with changes in lung volumes, flow rates, or respiratory symptoms.

The study by Huang, Wang and Hsieh (1991) described in relation to asthma also considered nitrogen oxides. Concentration of NO_x was 450-500 ppb, and was 20-fold higher than that of "ambient" air. Methacholine and mite allergen bronchial challengers were completed after 105 breaths of polluted air were inhaled. No difference in pulmonary function was noted after polluted air and ambient air were inhaled, and the methacholine and allergen sensitivities of airways were not increased after polluted air had been inhaled. The authors concluded that short-term exposures to low concentration NO_x did not affect the lung function and did not increase bronchial sensitivity to methacholine and allergen.

Chapman (1973) investigated the prevalence of chronic respiratory disease among parents of high-school students residing in three exposure areas. The prevalence of chronic bronchitis among those adults was not associated with the nitrogen dioxide pollution gradient (current or past) across the three areas.

Love (1982) studied the incidence of acute respiratory illness in families in Chattanooga, Tennessee in 1972 and 1973 to determine if residents of a formerly nitrogen dioxide 'exposure' community continued to experience a high incidence of illness after ambient air concentrations of the pollutant had been reduced substantially. Illness data were collected by telephone at 2 week intervals and illness rates per 100 person weeks of observation were contrasted with air pollution concentrations measured no more than 3.2 km from the home, based on aerometric, meteorologic and topographic data available. One sample was taken every 24-hour from 1968 through 1973 and one sample per week by the National Air Pollution Control Administration for the same period. Data were contrasted by communities designated as high, intermediate, or low pollution exposure. In 1972, higher rates of respiratory illness continued to occur in the designated high pollution area. These were associated with current higher short-term concentrations of nitrogen dioxide even though the long-term mean concentrations of the pollutant were little higher than those in the low pollution area. It was not possible to attribute the excesses in illness to specific pollutants or to specific exposure periods. However, reduction of the illness rate in 1973 associated with a strike at the primary source industry that curtailed nitrogen dioxide pollution in the high exposure community suggested that the short-term exposure may be more important than long-term exposure.

The Tecumseh case-control study by Jones (1983) described earlier in relation to CO also considered nitrogen oxides. Concentration of nitrogen oxides (NO, NO_2)

as well as carbon monoxide (CO) were found to be higher in homes using gas than in homes using electricity for cooking. The forced expiratory volume in 1 second ($FEV_{1.0}$) was used as the index of ventilatory lung function. A larger proportion of women with low $FEV_{1.0}$ used gas for cooking, but this difference was not statistically significant.

The study by Euler (1988) described earlier in relation to SO_2 also considered nitrogen dioxide. Chronic respiratory disease symptoms were not associated with relatively low NO_2 exposure levels.

Adgate (1992) studied the relationship between average and peak personal exposure to nitrogen dioxide and urinary excretion of hydroxyproline and demosine in a population of pre-school children and their mothers. Weekly average personal nitrogen dioxide exposures for subjects who resided in homes with one or more potential nitrogen dioxide source (e.g., a kerosene space heater, gas stove, or tobacco smoke) ranged between 16.3 and 50.6 ppb for children and between 16.9 and 44.1 ppb for mothers. In these individuals, the hydroxyproline-to-creatinine and desmosine-to-creatinine ratios were unrelated to personal nitrogen dioxide exposure, even though continuous monitoring documented home nitrogen dioxide concentration peaks of 100-475 ppb lasting up to 100 hour in duration. Significantly higher hydroxyproline-to-creatinine and desmosine-to-creatinine ratios were observed in children, compared with mothers.

2.3.5 Ammonia

At low concentrations in air, ammonia (NH_3) vapour irritates the eyes, nose and throat and inflames upper respiratory passages (Ali, 1988). At high concentrations it causes convulsive coughing, severe eye, nose and throat irritation; burning of respiratory tract, and sense of suffocation. At high concentrations it can be fatal within minutes (Health Ministry, 1986).

It is thought that gaseous ammonia in breath neutralizes acidic air pollution and thereby potentially mitigates the pulmonary effects of pollution (Norwood, 1992). The efficacy of breath ammonia depletion methods reported in recent acid aerosol exposure-health response studies was investigated. Fourteen subjects (21 to 45 years of age) performed one or more of the following hygiene manoeuvres: (a) acidic oral rinse ($pH < 2.5$); (b) tooth brushing, followed by acidic oral rinse; (c) tooth brushing, followed by distilled water rinse; and (d) distilled water rinse. Initial ammonia levels ranged from 120 to 1280 ppb (147-1570 $\mu g/m^3$). Acidic rinsing resulted in an immediate 90% reduction in exhaled ammonia in all subjects, and a return to 50% of baseline levels occurred within 1 hour. The result from tooth brushing or distilled water alone was not significant. It was concluded that acidic oral rinsing is an effective method of reducing airway ammonia, but repeated oral rinsing may be required to maintain constant, low-breath-ammonia conditions during acid aerosol exposure studies.

2.4 Dependence of Specific Diseases on Pollution Levels

2.4.1 Asthma

The study by Schachter (1984), described earlier in relation to SO_2, examined the acute respiratory effects of exposure to low-level, short-term sulphur dioxide (SO_2) in ten asthmatic and ten healthy subjects. For asthmatic subjects, the average changes in Raw, $FEV_{1.0}$, MEF40% and $V_{max50\%}$ increased as SO_2 levels increased, suggestive of a dose-response relationship with a consistent effect first seen at 0.75 ppm. In individual exercising asthmatics, responses may occur at levels of SO_2 below 0.75 ppm. These results indicate that asthmatic individuals engaged in moderate activity have transient bronchoconstriction following exercise in the presence of SO_2, with consistent changes first being noted for the group when ambient levels reach 0.75 ppm.

In the study by Linn (1985), described earlier in relation to NO_x, NO_2 exposure produced no statistically significant untoward effects on airway resistance, symptoms, heart rate, skin conductance, or self-reported emotional state in asthmatic subjects. Exercise was associated with significantly increased airway resistance in the asthmatic as well as the normal group, although the increase in normals was small. In both groups, systolic blood pressure showed small but significant decreases with NO_2 exposure, compared to control. This effect, if real, may relate to formation of a vasodilating nitrite or nitrate from inhalated NO_2.

In another study by Linn (1986), twenty one mildly asthmatic volunteers were exposed to 0.3, 1.0 and 3.0 ppm nitrogen dioxide (NO_2) in purified background air in an environmental control chamber. Exposures were separated by 1 week periods and occurred in random order. Each lasted 1 hour and included three 10 min bouts of moderately heavy exercise (mean ventilation rate 41 L/min). Exposure temperature was near 22° C and relative humidity near 50%. Specific airway resistance and maximal forced expiratory performance were measured pre-exposure, after the initial exercise, and near the end of exposure. Bronchial reactivity was assessed immediately following exposure, by normocapnic hyperventilation with sub-freezing air. Symptoms were recorded on questionnaires before, during and for 1 week after each exposure. Exercise induced significant bronchoconstriction regardless of NO_2 level. No statistically significant untoward response to NO_2 was observed at any exposure concentration. This negative finding agrees with previous results, but contrasts with finding elsewhere of respiratory dysfunction after exposure to 0.3 ppm.

Imai (1986) described earlier in relation to SO_2, found that: (1) In response to worsening air pollution, mortality for bronchial asthma and chronic bronchitis began to increase. (2) Mortality due to bronchial asthma decreased immediately in response to improvement of pollution, and mortality due to chronic bronchitis decreased after the concentration of sulphur dioxide (SO_2) began to satisfy the ambient air quality standard. (3) In the polluted area , mortality due to bronchial asthma in subjects who were 20 years of age or more was higher during the period in which higher concentrations of sulphur oxides were prevalent.

Huang, Wang and Hsieh (1991) examined the effect of short-term exposure to low levels of SO_2 and also NO_x on pulmonary function and methacholine and allergen bronchial sensitivity in asthmatic children. Their study was designed to evaluate whether short-term, 5 minute exposures to low levels of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) influence pulmonary function and increase bronchial sensitivity to methacholine and specific allergens. Five male and 1 female mite-sensitive asthmatic children (mean age 12 years) were studied during symptom-free periods. Pulmonary function tests were conducted after breathing 5, 15, 35, 65 and 105 breaths of compressed polluted air, which was collected from the Lin-Sun S. Road-tunnel in Taipei city. Concentrations of SO_2 and NO_x were 70-120 ppb and 450-500 ppb, respectively, and were 6-fold and 20-fold, respectively, higher than those of ambient air. Methacholine and mite allergen bronchial challengers were completed after 105 breaths of polluted air were inhaled. No difference in pulmonary function was noted after polluted air and ambient air were inhaled, and the methacholine and allergen sensitivities of airways were not increased after polluted air inhaled. The authors concluded that short-term exposures to low concentrations of SO_2 and NO_x did not affect the lung function and did not increase bronchial sensitivity of methacholine and allergen.

Winkelstein (1971) collected data from twenty-one areas in and around Buffalo, New York, and compared those areas in terms of the level of air pollution (suspended particulates) and the mortality rate for chronic respiratory diseases (asthma, bronchitis, chronic interstitial pneumonia, bronchiectasis and emphysema). Some socioeconomic factors - number of years of school completed, percentage of labourers in the labour force, and percentage of sound housing - were included in the study. The results indicated a close association between air pollution and chronic respiratory disease mortality. No multivariate statistical analysis was performed.

The study by Ponka (1991) considered the effects of relatively low levels of air pollution and weather conditions in patients who had asthma attacks and were admitted to hospital in Helsinki during a 3 year period. The number of admissions increased during cold weather (n=4209), especially among persons who were of working age, followed by elderly. Even after standardization for temperature, all admissions were significantly correlated with ambient air concentrations of NO_2, NO, SO_2, CO, O_3 and total suspended particulates. Regression analysis revealed that NO and O_3 were most strongly associated with asthma problems. Among children, only O_3 and NO were significantly correlated with admissions. Levels of pollutants were fairly low. These results suggest that concentrations of pollutants lower than those given as guidelines in many countries may increase the incidence of asthma attacks.

2.4.2 Cancer

In the study by Richters (1983) described earlier in relation to NO_x, It was suggested that inhalation of ambient level NO_2 (0.4 ppm) or polluted urban ambient air play a role in facilitation of blood-borne cancer cell metastasis. In addition, results show different patterns of melanoma cell distribution in the lungs of NO_2 and ambient air exposed animals. They also indicate that extended periods of clean air between NO_2 exposures may diminish the severity of the insult in the sensitive animals. It concluded that the results provide strong support for the need of improved air quality and for reduction of noxious pollutants in urban ambient air.

The study by Stocks and Campbell (1955) described earlier in relation to SO_2, utilized environmental histories of persons dying from lung cancer and compared percentage distributions according to smoking habits and residence. They found that a ten-fold difference between death rates of rural and for urban areas and suggested a relationship with air pollution by showing that concentrations of smoke, 3:4 benzopyrene, other polycyclic hydrocarbons, and sulphur dioxide increased with urbanisation.

Dean (1966) found that among male non-smokers in Northern Ireland lung cancer mortality was lower in rural than in urban areas. Gardner, Crawford and Morris (1969) using regression analysis, found that air pollution (measured by domestic coal consumption) was significantly associated with four age-sex rates of lung cancer mortality in seven out of eight data sets.

Hagstrom, Sprague and Landau (1967) tabulated rates of death from cancer among middle-class residents of Nashville. Using the measures of air pollution, they found the cancer mortality rates to be 25 percent higher in polluted areas than in areas of relatively clean air. They also found significant mortality rate increases associated with individual categories, such as cancer of the stomach, oesophagus and bladder.

Levin (1980) reported the following relationships for all types of cancer: the age adjusted cancer incidence rate was 24% higher for urban males than for rural males in New York State, 36% higher in Connecticut, and 40% higher in Iowa. The incidence rate was 14% higher for urban females than for rural females in New York State, 28% higher in Connecticut, and 34% higher in Iowa. For both males and females the incidence rate for each of sixteen categories of cancer was higher in urban than in rural areas.

Williams and Lloyd (1988) used long-term epidemiological surveillance to test the hypothesis. That air pollution from a steel foundry was causally linked with the epidemic of respiratory cancer in the adjacent residential area of the town of Armadale, Scotland. Mortality data were collected for the period 1956 to 1986, and used to calculate the SMRs for respiratory cancer, non-respiratory cancer, coronary heart disease, bronchitis, emphysema and asthma, cerebrovascular disease, hypertension and total mortality. The SMRs for respiratory cancer were significantly raised between 1968-75, but fell to below the national average in 1976-82 and again in 1983-86. The increase was mainly in the male population aged over 55 years, but under 85 years; the female rate was also raised, although the numbers were much fewer. A statistically significant cluster of deaths was found in a residential area downwind of a steel foundry.

Vena (1983) obtained demographic data on race, sex, age and address at diagnosis on 2201 lung cancer cases from Erie county, reported to the New York State tumour registry during the period 1973 to 1976. Multivariate regression analysis was done to evaluate the association between age-adjusted race- and sex-specific lung cancer incidence rates by census tracts and air pollution as indexed by total suspended particulates, several trace metals and benzo(a)pyrene. Total suspended particulates was the strongest ambient air quality variable found to be associated with lung cancer incidence in white males, all males, the white population, and the total population. Regression analysis did not provide any evidence for an association between ambient air trace metals or ambient benzo(a)pyrene and lung cancer incidence.

The relationship between air pollution and lung cancer was investigated by Shannon (1988) in Hamilton, Ontario. 602 deaths from the disease (1972-1976) were linked with information from a mail questionnaire sent to a sample of residents to elicit age, sex, residential, smoking and occupational histories. Comparable data were obtained for the lung cancer cases from various sources. The city was divided into 4 areas with differing pollution levels. The standardized lung cancer mortality ratios (SMR's) were calculated. The SMR in area 1 (high pollution) was roughly

15% higher than in area 4 (low pollution). It was concluded that there has probably been some effect of air pollution in the city, but when allowance was made for age and smoking it was found to be less than has been previously suggested.

Jacobson (1984) correlated age-adjusted indices of female cancer mortality and total male mortality in 31 California counties with air pollution data which was obtained from a 10 year summary published by California Air Resources Board and with geographic and socio-economic data from the 1970 United States Census and elsewhere. Air quality was the worst in those counties where socioeconomic status was highest. Cancer mortality showed positive correlations with air pollution levels. However, when partial correlation coefficients were calculated, controlling for the confounding variables, both overall male mortality and female cancer mortality showed positive correlations with air pollution indices. Stepwise regression analysis produced similar results.

2.4.3 Bronchitis

Bronchitis mortality rates in England and Wales have been correlated with pollution. Stocks (1959), after eliminating the effects of population density, found significant correlations between bronchitis and smoke. In another study which controlled population density and an index of social class, Stocks (1960) found significant correlations of bronchitis death rates with smoke density.

Douglas and Waller (1966) found a significant relationship between air pollution estimated from domestic coal consumption and lower respiratory tract infections (cough, bronchitis, bronchopneumonia and pneumonia) in 3866 British school children. Boys and girls were similarly affected, and no difference was found between children from middle-class and working-class families.

Winkelstein (1967) collected data from twenty-one areas in and around Buffalo, New York, and compared the areas in terms of the level of air pollution (suspended particulates) and the mortality rate for chronic respiratory diseases (asthma, bronchitis, chronic interstitial pneumonia, bronchiectasis and emphysema). Some socioeconomic factors - number of years of school completed, percentage of labourers in the labour force, and percentage of sound housing - were included in the study. The results indicated a close association between air pollution and chronic respiratory disease mortality. No multivariate statistical analysis was performed. However, the study does provide evidence of relationship between air pollution and chronic respiratory disease mortality, even though it is difficult to estimate its magnitude.

Ishikawa (1969) estimated the incidence of emphysema in Winnipeg, Canada, and Saint Louis. They examined the lungs of 300 victims of accidental death in each city, matching the samples in term of age, sex, race and smoking habits, contrasting residents of the two cities, and controlled for smoking habits. The incidence and severity of emphysema was higher in Saint Louis, the city with the more polluted air for each comparison group (over twenty-five years of age). For example, in the forty-five-year-old age group, 5% of those in Winnipeg and 46% of those in Saint Louis showed evidence of emphysema.

2.5 Atmospheric Transportation and Dilution of Pollutants

2.5.1 The Impact of Meteorology on Air Pollution

Meteorological conditions govern atmospheric transport and dispersion of pollutants, and therefore greatly influence their effects.

The atmosphere provides for the dispersion and dilution of discharged material by turbulent mixing processes which operate between the surface and upper air layers. Under certain conditions, the potential for dispersion is limited and adverse effects may result as pollutants become trapped and accumulate close to the ground.

At present, a generally applicable model is not available. However, as a result of careful and informed empirical studies over the last few decades the basic mechanisms of atmospheric dilution and transport have been described.

2.5.2 Mechanisms of Atmospheric Dilution

It is convenient to distinguish between the dilution of pollutants and their bulk transport from sources of discharge. Such a distinction arises from the nature of turbulent atmospheric motion, which may be viewed as a series of fluctuations superimposed on a mean flow. Dilution of a cloud of pollutants is caused by mixing of the cloud with its local atmospheric environment. The process of mixing or diffusion is primarily due to atmospheric turbulence which may be simply viewed as the random movement of air masses or "eddies". The effect of mixing by molecular diffusion is relatively insignificant. Eddy motions occur over a very wide range of sizes and frequencies, and the extent of dilution of a cloud or plume of pollutant is very much dependent on the scale of the turbulent fluctuations compared with the size of the pollutant cloud (Environment Protection Council, 1990).

There are basically three cases :

1. When the cloud size is greater than the scale of turbulence, eddy dispersion occurs and the cloud is turbulently mixed with the surrounding environment.
2. When the cloud size is smaller than the scale of turbulence, eddy diffusion is limited and the cloud becomes transported through the environment by the advection of the bulk flow with relatively little dilution.
3. When the cloud size and the scale of turbulence are of the same order, eddy motions merely distort the cloud without significant change in dilution.

Atmospheric eddy turbulence covers a wide spectrum of frequency and scale, so that all the dispersion and transport mechanisms above occur simultaneously.
In following a cloud through its development from a small concentrated volume to a large dilute volume, it is common to observe a continuing enhancement of the dilution mechanism as, progressively, each larger and more effective scale of eddy

mixing motion contributes to smaller eddies which are already diluting the expanding pollutant cloud.

In order to explain and anticipate adverse meteorological conditions, it is necessary to consider both vertical mixing, and horizontal diffusion and transport of pollutants.

2.5.3 Vertical Mixing of Pollutants

Mixing and dilution of aerial pollutants in the vertical dimension can take place at very different rates, depending on buoyancy effects, which cause a vertical thermal wind. These rates are intimately related to variations in the vertical temperature, or lapse gradients, which may be classified as stable, neutral, or unstable, in order of increasing potential for diffusion of pollutants.

Atmospheric stability shows a large diurnal variation, a cyclic fluctuation which is governed by solar radiation and differences in heat transfer characteristics according to the terrain. Vertical mixing in the lower boundary layers may also be generated mechanically by the roughness of the underlying surface.

Of most interest is the very stable configuration, the inversion, in which temperature actually increase with height. Inversion layers can be so effective in reducing mixing that, in most cases, vertical diffusion of pollutants by eddy fluctuations is almost completely suppressed.

2.5.4 Horizontal Transportation and Diffusion of Pollutants

Horizontal transport and diffusion of pollutants results from horizontal winds, which are governed by :

1. Global meteorological patterns. These are influenced by the regional climatology which determines the distribution of atmospheric pressure.
2. The coriolis effect owing to the earth's rotation.
3. Surface friction.
4. Mechanically produced horizontal turbulence.
5. Locally generated flows (e.g. daytime sea breeze and night time land breezes). The net effect of these factors is that horizontal winds near the Earths' surface are never steady and display a wide variability in speed and direction.

Pollution travels with this ever-varying wind. The high frequency fluctuations disperse the pollutant and the relatively steady "mean" flow is responsible for bulk transport. A change in mean wind direction transports material toward new receptors and gives respite to previous ones.

For a continuous point source, the ambient concentration of a pollutant is inversely proportional to wind speed. The role of horizontal transport is particularly important during periods of low, strong inversion conditions, when vertical mixing of pollutants is effectively damped out at its level. Pollutants introduced at the ground level become diluted with the sub-inversion air but the absence of mixing motions in the inversion layer itself prevents any vertical dilution. If conditions remained unchanged, pollutant concentrations would continue to increase in this fixed volume. The introduction of a horizontal wind provides a flushing flow of diluting air into the source area across its upwind boundary and at the same time removes an equal volume of polluted air on the downwind side of the area. This net transport of air across the source area puts an end to the unlimited accumulation of a pollutant pall above the area.

2.5.5 Inversion Formation

The effect of dispersion is augmented by the common occurrence of a simultaneous suppression of horizontal mixing. This means that plumes of effluent from stacks or vents will disperse rapidly and, unless discharges possess sufficient thermal "pressure", will not penetrate vertically into the stable strata. There is, therefore, the potential for pollutants to be trapped, and to accumulate close to the ground.

Pollutants tend to occur as part of "cocktails" rather than individually. The UK and American smogs of the 1950s and 1960s were principally due to the direct burning of coal and led to the production of particulate matter and gases such as sulphur dioxide, nitrogen oxides, hydrogen sulphide and carbon monoxide.

Research into the toxic effects of such smogs tended to deal with them as a whole rather than with individual elements of the cocktail. Clean air legislation in both countries banned the burning of poor quality coal and the incidence of many of the pollutants reduced. One of the most significant features of studies on pollution and health appears to be the relative lack of recent work on the toxic effect of individual pollutants. Pollutants directly associated with the burning of coal such as hydrogen sulphide appear never to have been studied, and others such as sulphur dioxide only to a limited extent as their localised incidence reduced with the enforcement of the legislation.

Because of clean air legislation in some countries, significant toxic effects of pollutants tend to be associated with accidental or one-off events. Most studies of the health effects of pollutants tend to be centred around pollutants that regularly occur at industrial plants.

Studies including pollution and health can be classified by method (whether laboratory studies with animals, human, clinical studies, or population studies), by disease (bronchitis, lung cancer, etc.), by type of outcome considered (morbidity, mortality, use of health care or absence from work), by characteristics of the group studied (nationality, age, sex, race, etc.), by pollutant (sulphur dioxide, carbon monoxide, etc.), or duration of effect (day-to-day, acute or chronic).

2.5.6 Temperature

In the study by Linn (1984) described earlier in relation to SO_2, twenty four asthmatic volunteers were exposed to 0, 0.3 and 0.6 ppm sulphur dioxide (SO_2) in purified background air at each of three temperatures : 21°C, 7°C and 6°C, in a controlled-environment chamber. Relative humidity was approximately 80%. Decreasing temperature was associated with statistically significant unfavourable effects on airway resistance and respiratory symptoms, as expected from previous findings. The effects of SO_2 and cold usually appeared to combine in an additive or less-than-additive fashion; there was little evidence of synergism. Individuals' response patterns were variable: a few suggested synergism, but others suggested a mitigating effect of cold on the bronchoconstructive response to SO_2.

In the study by Linn (1986) described earlier in relation to asthma, exposure temperature was near 22°C and relative humidity near 50%. No statistically significant untoward response to NO_2 was observed at any exposure concentration. This negative finding agrees with previous results, but contrasts with finding elsewhere of respiratory dysfunction after exposure to 0.3 ppm.

The study by Ponka (1991), described earlier in relation to asthma, studied the effects of relatively low levels of air pollution and weather conditions on the number of patients who had asthma attacks and were admitted to hospital in Helsinki during a 3 year period. Effect of air pollutants and cold were maximal if they occurred on the same day, except for O_3, which had a more pronounced effect after a 1 day lag. The associations between pollutants, low temperature, and admissions were most significant among adults of working age, followed by the elderly. Among children, only O_3 and NO were significantly correlated with admissions. Levels of pollutants were fairly low, the long-term mean being 19.2

g/m^3 for SO_2, 38.6 g/m^3 for NO_2, 22,0 g/m^3 for O_3, and 1.3 g/m^3 for CO. In contrast, the mean concentration of TSP was 76.3 g/m^3, and the mean temperature was 4.7° C. These results suggest that concentrations of pollutants lower than those given as guidelines in many countries may increase the incidence of asthma attacks.

2.5.7 Humidity

Reinikainen (1992) evaluated the effect of air humidification on a) the dryness of the skin and mucosa, b) allergic and asthmatic reactions, c) the perception of indoor air quality. A total of 290 office workers at the Pasila Office Centre were included in a six-period cross-over trial. One wing of the building was operated with 30-40% humidification, and the other wing operated under conditions of no air humidification (relative humidity from natural conditions was 20-30%). The length of each study period was 1 work week. The workers were instructed to keep a structured daily diary of their symptoms, their perception of the indoor air, and the potential determinants of the symptoms. A total of 211 (72.6%) workers who returned at least two weekly diaries, and who had experienced both humidified and non-humidified conditions, were included in the analysis. The primary outcome dryness symptom score was characterized by dryness, irritation or itching of the skin and eyes, dryness or irritation of the throat, and nasal dryness. Means of the daily symptom scores and perception ratings during the humidified and non-humidified periods were calculated for each participant, and intra-individual differences in the means were used to assess the effect of air humidification. The dryness symptom score was significantly smaller during the humidified phase than during the reference phase ($p<.05$). Allergic symptoms that were considered as a separate outcome, a sensation of dryness, and draught were also significantly less frequent during the humidification phase ($p<.01$). These results suggest that dryness of the skin and mucosa, allergic reactions, and the sensation of dryness can be alleviated by proper air humidification.

2.6 Possible Confounding Features

2.6.1 Urban vs Rural

Wicken (1964) studied bronchitis mortality in six areas of north-east England. The fact that rates were relatively higher in the two urban districts compared with those of four rural districts could not be fully accounted for by age composition, smoking habits, or social-class distribution (based on occupation) of the respective populations. The urban district with the highest bronchitis death rate also had the highest levels of air pollution. Furthermore, within the district, the locality with the highest measured level of air pollution (smoke and sulphur dioxide) had highest bronchitis mortality among males.

Friedman (1967) correlated the rate of mortality from coronary heart disease in white males aged forty-five to sixty-four with the proportion of this group living in urban areas. The sample correlation for thirty-three states was 0.79, and when cigarette consumption was held constant the partial correlation was 0.67. Other studies have merely related the prevalence of cardiovascular diseases to urbanisation.

The study by Lambert and Reid (1970) described earlier in relation to SO_2, found that the urban-rural gradient in bronchitis symptoms could not be explained by smoking differences alone, although local pollution seemed to have little effect on non-smokers. Because of the many uncontrolled factors, one cannot have great confidence in the association found between bronchitis symptoms (in smokers) and air pollution. (The air pollution mentioned included smoke and sulphur dioxide).

Levin (1980) found significant differences between urban and rural age-adjusted mortality and rates in New York State (exclusive of New York City), Connecticut, and Iowa. For males, the death rates were 41 percent higher in urban areas of New York, 57 percent higher in Connecticut, and 184 percent higher in Iowa. For females, the differences were 7 percent, 24 percent, and 47 percent, respectively.

Levin (1980) reported the following relationships for all types of cancer: the age adjusted cancer incidence rate was 24% higher for urban males than for rural males in New York State, 36% higher in Connecticut, and 40% higher in Iowa. The incidence rate was 14% higher for urban females than for rural females in New York State, 28% higher in Connecticut, and 34% higher in Iowa. For both males and females the incidence rate for each of sixteen categories of cancer was higher in urban than in rural areas.

Archer (1990) found an unusual situation in two Utah counties which made it possible to estimate the fraction of respiratory cancer and non-malignant respiratory disease (NMRD) deaths attributable to community air pollution in one county. The two counties were very similar in many ways, including low smoking rates, until a steel mill constructed during World War II caused substantial community air pollution in one of them. Subsequent differences in mortality rates from both respiratory cancer and NMRD are striking. A third county, similar to many counties outside Utah, was included in the analysis for comparison. In one county, 30-40% of the respiratory cancer and NMRD deaths were attributable to community air pollution. In this county, NMRD deaths (but not respiratory cancer deaths) were slightly more frequent than in Salt Lake county where smoking rates were twice as high.

3.6.2 Age/Sex

Douglas and Waller (1966) found a significant relationship between air pollution estimated from domestic coal consumption and lower respiratory tract infections (cough, bronchitis, bronchopneumonia and pneumonia) in 3866 British school children. Boys and girls were similarly affected, and no difference was found between children from middle-class and working-class families.

Gardner, Crawford and Morris (1969) used multivariate regression analysis to estimate the association of total mortality with air pollution (domestic coal consumption) and found that, in those regressions pertaining to males aged forty-five to sixty-four, air pollution was a more important explanatory variable than socio-economic factors. The pollution variable was significant for the death rate for males aged sixty-five to seventy-four. The variable was not statistically significant in explaining the female death rate.

Sultz (1970) analyzed data for children under sixteen years of age in Erie country, New York, who were hospitalised for asthma and eczema. They found a striking association between air pollution (suspended particulates) level and the incidence of asthma and eczema among boys under five years of age.

In the study by Williams and Lloyd (1983) described earlier in relation to cancer, respiratory cancer rates were significantly raised between 1968-75, but fell to below the national average in 1976-82 and again in 1983-86. The increase was mainly in the male population aged over 55 years, but under 85 years; the female rate was also raised, although the numbers were much fewer.

2.6.3 Smoking

Yue Chen (1990) measured the concentrations of serum thiocyanate (SCN) of 80 infants in Chang-Ning District, Shanghia, People's Republic of China. The infants were classified into one of three groups according to the total number of cigarettes family members collectively smoked per day; (1) unexposed, (2) lightly exposed (1-19 cigarettes/d), and (3) heavily exposed (20+ cigarettes/d). The serum SCN levels (X + SD,umol/l) were 27.7 + 10.72 for the unexposed group, 31.9 + 13.5 for the lightly exposed group, and 36.2 + 14.88 for the heavily exposed group. The concentrations in the heavily exposed group were significantly higher than those in the unexposed group ($p < .05$). Environmental exposure to tobacco smoke accounted for 5.3% of total variance of the SCN levels after adjusting the effects of father's education level and type of feeding. It is concluded that passive exposure to cigarette smoke in the household results in higher levels of serum SCN in infants.

Kazuko (1992) investigated the effect of cigarette smoking on the prevalence of summer-type hypersensitivity pneumonitis (SHP) caused by Trichosporon cutaneum. In the adult family members of SHP patients, they found that 27 of 41 (65.9%) non-smokers were SHP patients, compared with 3 of 11 (27.3%) smokers ($p<.05$). Also, the prevalence of anti-T cutaneum antibody was significantly lower in the smokers ($p<.05$). A questionnaire completed by 209 SHP patients revealed that the smoking rates of male and female SHP patients were significantly lower ($p<.01$) than rates in the normal Japanese population. However, no difference was found in serum anti-T cutaneum antibody activities or the bronchoalveolar lavage lymphocyte phenotypes for smoking and non-smoking SHP patients. It was concluded that cigarette smoking had a suppressive effect on the outbreak of SHP, but smoking caused no further suppression after the disease was established.

Shephard (1992) studied respiratory irritation from environmental tobacco smoke. In some environments, the dose of particulate matter and the concentrations of irritant vapours absorbed on the ETS particles reach a level for which a physiological response may be expected, not only in the nose but also the bronchi.

However, direct measurements indicate only small increases of nasal and bronchial resistance if normal subjects are exposed to maximal, likely concentrations of ETS. ETS is readily detected by the non-smoker, but there is no strong evidence that pulmonary reactions have a psycho-genic bases. The condition of approximately 20% of asthmatic patients is exacerbated by ETS exposure.

2.7 Discussion and Conclusion

Most studies of the health effects of pollutants tend to be centred around pollutants that regularly occur at industrial plants.

Sulphur dioxide has been the subject of many analyses of outdoor air pollution effects. It has been found to cause respiratory disease, bronchitis, tonsillitis, colds, sore throat and alteration of sense of smell with increased fatigue. Moderate daily changes in SO_2 levels have been found to induce a significant but transient increase in the prevalence of respiratory symptoms in children. Mortality due to bronchial asthma in subjects who were 20 years of age or more was higher during the period in which higher concentrations of sulphur dioxide were prevalent.

Increasing SO_2 concentration and decreasing temperature have been associated with unfavourable effects on airway resistance and respiratory symptoms.

Hydrogen disulphide is believed to have an irritant effect on the eyes, paralyses the sense of smell and can cause instant unconsciousness. It can also affect the nervous system causing headache, dizziness and loss of vision.

Carbon monoxide has been found to cause severe headache, weakness, depression, nausea, bronchitic cough, loss of visual acuity and respiratory diseases. Concentrations of CO, together with NO_2 and NO, have been found to be higher in homes using gas than homes using electricity for cooking, and the use of kitchen exhaust fans has been associated with low lung function.

It has been concluded that a man exposed to carbon monoxide in short exposures to the kinds of high concentrations likely to be encountered in fires while engaged in light activity could be seriously affected within 30 minutes.

Subjects less than 40 of age who were exposed to different concentrations of CO_2 were more sensitive in the eyes than the elderly subjects, and occupational stress was associated with low thresholds.

Hydrocarbons are believed to be carcinogenic. *Ammonia* causes irritation of eye, nose and throat. *Nitrogen oxides* cause irritation of the respiratory system and chest pain. NO_2 increases sensitivity to bronchio-constrictors in sensitive individuals. Inhalation of ambient level NO_2 or polluted ambient air plays a role in facilitation of blood-borne cancer cell metastasis. Systolic blood pressure shows small but significant decreases with NO_2 exposure compared to control.

After standardisation for temperature, admissions rates were significantly correlated with ambient air concentrations of NO_2, NO, SO_2, CO, O_3 and suspended particulates.

On this basis the following air-borne pollutants will be considered in this study:

Sulphur Dioxide.

Hydrogen Sulphide.

Hydrocarbons.

Carbon Monoxide.

Ammonia.

Nitrogen monoxide

Nitrogen dioxide.

It will be important to consider the effect of mixtures of these substances.

Some of the laboratory studies considered had small number of subjects. The population studies cited suffered from the limitations of descriptive cross-sectional investigations (Ware, 1981). No study no study can hold constant all of the factors hypothesized to affect the incidence of illness, but it is important in such studies to be able to adjust in the analysis for recognised potential sources of confounding.

Decreasing temperature has been associated with unfavorable respiratory symptoms. An increase in the number of hospital admissions has been found in cold weather, especially among persons who were of working age.

Dryness of skin and mucosa and allergic symptoms were significantly smaller during a humidified phase than during the reference phase. Other meteorological factors need to be taken into account when considering the effects of pollution at a specific site on different geographical locations. Mixing and dilution of aerial pollutants in the vertical and horizontal dimensions can take place at very different rates, depending on the vertical and horizontal winds.

Finally age, sex, smoking habits and social circumstances have all be shown to linked with symptoms of a variety of kinds, and will need to be considered.

CHAPTER THREE

KUWAIT'S GEOGRAPHY

INDUSTRY AND HEALTH CARE

CHAPTER THREE

KUWAIT'S GEOGRAPHY, INDUSTRY AND HEALTH CARE

3.1 Introduction

This chapter provides a background to Kuwait. First it describes Kuwait's topography and meteorological conditions. It then describes the main sources of pollution in the Gulf and the major industries in the Gulf countries and in Shuaiba area, and finally Kuwait's population and health services.

3.2 Geographical Location

The State of Kuwait occupies the north-western corner of the Arabian Gulf, which forms its eastern boundary. To the south and west there is a frontier of 250 kilometre with the Kingdom of Saudi Arabia, and to the north and the west a frontier of 240 km with the Republic of Iraq (Fig 3.1).

The distance between the extreme points of state boundaries from south to north is about 200 kilometres (124 miles) and from west to east is about 170 kilometres (105 miles). It is 17,818 square kilometres or approximately 11,000 square miles (Fig 3.2).

3.3 Topography

Most of Kuwait mainland is a flat sandy desert, sloping gently downwards from the extreme west of Shigaya and Salmi (300 metres high) towards sea level in

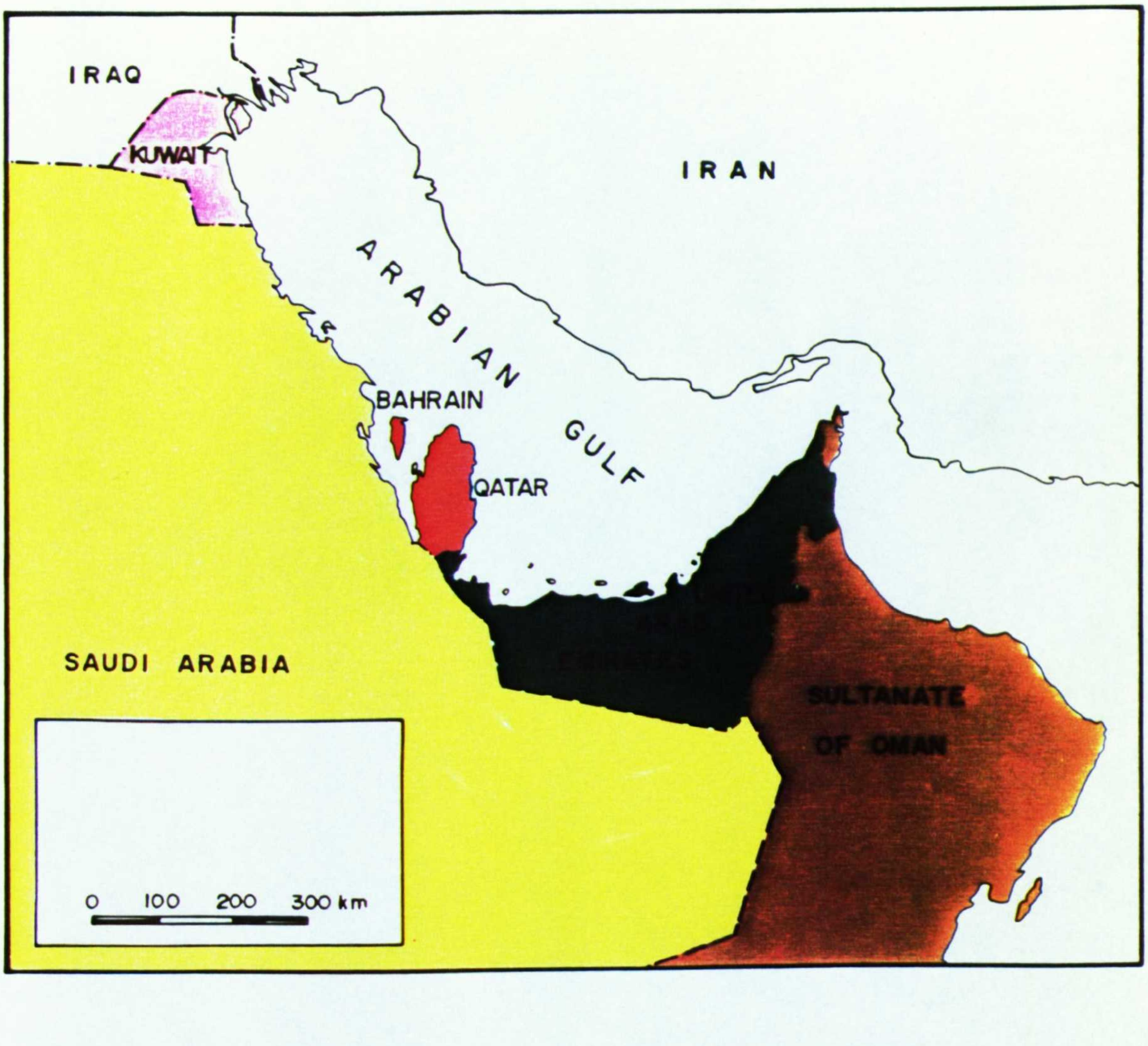


Figure (3.1) The Arabian Gulf

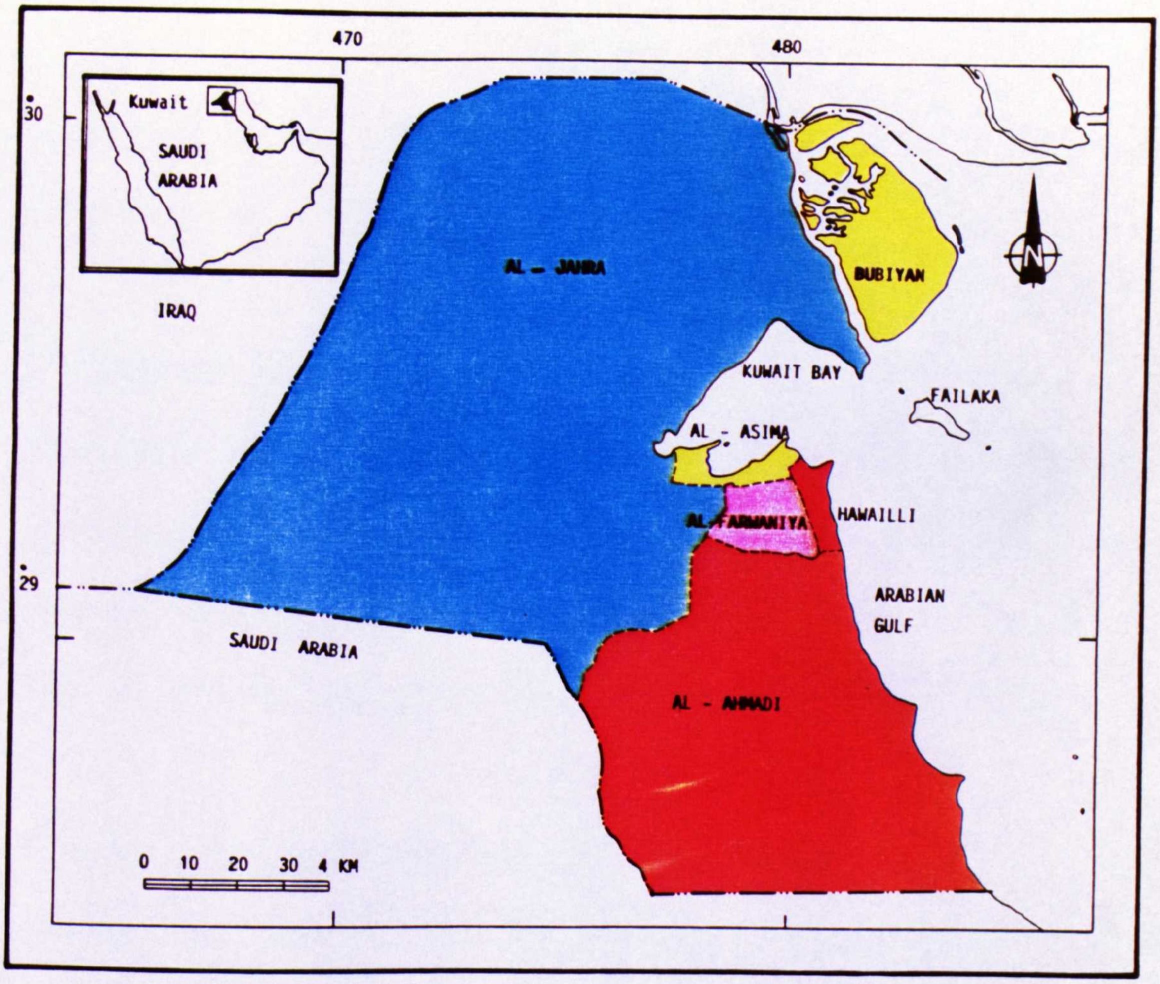


Figure (3.2) The Geographical Location of Kuwait the east except for a few rocky hills. Among those are Al-Zore hill (145 metres high) which extends from the north-east towards the south near Al-Jahra village, and Al-Laiah and Kira Al-Mor hills. Shallows are also found in the desert. Among these are Wadi Al-Bateen which extends from south-west to north-east near the Iraqi boundaries, and Wadi Al-Shagaia which is located in the south-west near the frontier with Saudi Arabia.

The southern part of Kuwait is generally flat with the exception of Ahmadi Hill (137 metres high).

3.4 Meteorological Conditions

The location of Kuwait, between latitudes 28 and 30 North determines the climate of the country, which with long, hot dry summers, and short, warm and sometimes rainy winters is typical of the Sahara geographical region.

Dust storms almost always occur with a rise in humidity during summer.

There is a wide variation of temperature. The average ranges from 45°C in summer to 8°C in winter. Climatic fluctuation is often accompanied by wide variation in the annual rainfall: it may be 22 mm one year and 352 mm the next year. (Ministry of Planning, 1990).

3.4.1 Seasons in Kuwait

- Winter (6th December - 22th February)

The short winter involves a remarkable drop in temperature, which can fall to about 3°C. Strong winds sometimes raise dust storms. During calm nights fog may occur. The lowest temperature ever recorded was -4°C in 1964.

- Spring (23th February - 29th May)

Spring involves mild but variable temperatures with some rain and thunderstorms. Overall temperatures start to rise, and during March hot southerly winds start to blow. The maximum temperature may be as high as 40°C. North-westerly winds are usually colder and lower the temperature considerably.

- Summer (30st May - 4th October)

The long summer months bring considerable increases in temperature and humidity. Severe dust storms occur but the winds are mostly variable. The months of the June and July are dry but hot, with frequent dust storms and temperatures generally above 40°C and sometimes as high as 50°C. From the end of July till early October humid spells are frequent, with maximum temperatures generally in the mid-forties. Starting from September, the temperatures start to decline and the winds become calm.

- Autumn (5th October - 5th December)

The weather becomes mild and clouds and rain make it pleasant. The nights are generally cool.

Temperatures range between 20° C and 30° C.

With the hot climate of the area the Gulf water evaporates. There is very little rainwater except for that entering from the Shatt-Al-Arab river on the northern side, and as a result the percentage of salt in the water is extremely high at around 48 parts per thousand.

3.4.2 Climatic Conditions and Environmental Pollution in Kuwait

In Kuwait, mixing and dilution of pollutants in the atmosphere are limited by the high frequency of inversion. Under these conditions pollutants may be trapped and accumulated close to the ground. The factors which contribute to the creation of an environmental pollution problem are both natural and man made. The natural factors are primaly climatic, some times geographical (since the hinterland at Shuaiba and Kuwait is flat or gently rolling desert and the terrain does little to promote turbulence) and are generally beyond man's sphere of control. Man-made factors, however, involve the discharge of pollutants in quantities sufficient to produce deleterious effects, and are within man's control by industrial, commercial and domestic planning, proper industrial design and proper control of the way in which polluting discharges are released into the environment.

There are two common types of inversion conditions in Kuwait. These are :

1. Inversion with bases at ground level.
2. Elevated inversion, restricting vertical travel of pollutants but allowing mixing below the inversion level.

The first type is associated with natural radiation inversions and the second is associated with short periods of the day when either radiation inversions are being broken by morning isolation, or colder air is subsiding beneath the warmer desert air. This latter type is known as subsidence inversion, and can occur at low levels, below 600 metre, with the sea breeze flowing under the air heated by the desert. (Environment Protection Council, 1990).

Weather conditions at Shuaiba and Kuwait may thus vary from hour to hour, day to day and season to season, and so the susceptibility of the atmosphere to air pollution also varies considerably. Certain times of the day and of the year are more liable to be associated with pollution than others.

In Shuaiba Industrial Area, the pall is not a single point source but is derived from many individual sources within the area. In general, each contributing source is not instantaneous as an explosion, but a continuous, though variable, discharge. When dilution is extremely poor and pollutant concentrations high, it is often observed that the width of a plume or wake increases very little in time, with the result that the mixing motions responsible for dilution do not increase in scale with plume transport.

These variations in atmosphere configuration, together with the characteristics of the sources of discharges, determine the location and times where high concentration of pollutants will occur.

3.5 Population

The first population census in Kuwait was conducted in 1957. Little was known about the population before that date, although some travellers gave unreliable estimates. The Central Statistics Office estimates the population in 1910 to have been 35,000.

From 1910 to about 1935, when prospecting for oil started with promising results, the rate of population growth suddenly accelerated and reached 75,000 prior to the Second World War. In the early 1950's the population was about 100,000. When the first population census was conducted in 1957 the population had increased to 206,000.

Since 1957, a census of the population in Kuwait has been conducted every five years. The results of April 1985 population census indicated that the population was 1,712,133. Estimates from the Central Statistics Office indicate that this had risen by mid-1988 to 1,958,477, to about 2.1 million by 1990, and will grow to 3 million by the year 2000, if the rate of growth remains constant.

Table (3.1) Estimated Mid-Year Population 1980-1990

Year	Kuwaiti	Non-Kuwaiti	Total
1980	569,722	800,035	1,369,757
1981	591,324	840,804	1,432,128
1982	613,744	883,665	1,497,409
1983	637,015	928,723	1.565,738
1984	661,168	976,094	1,637,262
1985	686,237	1,025,896	1,712,133
1986	712,257	1,078,256	1,790,513
1987	739,264	1,133,305	1,872,569
1988	767,295	1,191,182	1,958,477
1989	796,389	1,252,033	2,048,422
1990	826,586	1,316,014	2,142,600

Ministry of Planning 1990.

Growth rates between 1980

1985 Census

Kuwaiti (3.79%), M (3.84%)

F (3.75%)

Non-Kuwaiti (5.10%)

M (4.7%), F (5.62%)

Total Population (4.56%)

M (4.45%), F (4.72%)

3.6 Health Services in Kuwait

Medical care is mostly free of charge. The main provider is the Ministry of Public Health but some Ministries and the major oil companies provide hospitals and medical services for their personnel. The private sector is relatively small and is run under close state supervision. Health services are primarily organized on the basis of population density and distribution (Naim, 1986). The services are provided through a system of three levels of health care, discussed below:

3.6.1 Primary Health Care

Primary health care is provided though 68 health centres. Each health centre provides care for up to forty thousand inhabitants who are registered through the national health registration system. Health centres provide curative, preventive and rehabilitative services. The centres implement regional health plans and programmes as they pertain to preventive health, nutrition, school health, health education, selected training activities and inoculation against specific diseases. The services offered include general practitioner services, maternal and child health services and dental services. Simple laboratory tests and X-rays are carried out at some of the centres. Patients may be referred from health centres to specialized clinics and hospitals. However, the health centres provide services to psychiatric patients in their homes, and social and rehabilitative care for the needy individuals and families.

3.6.2 Secondary Health Care

Secondary health care is provided through six general hospitals, each of which attempts to meet the overall health needs of about 300,000 inhabitants, through an out-patient, a casualty department, and specific inpatient departments. Each of the six hospitals provides inpatient care services in the fields of internal medicine, general surgery, gynaecology and obstetrics, paediatric, thaumatology and orthopaedic, ENT, ophthalmology, psychiatry, dermatology, physical medicine and dental services.

The services provided through the six general hospitals are supplemented by specialist clinics. The rationale of the establishment of these clinics is to reduce the load on the hospitals' out-patient departments. The speciality clinics serve the purpose of making specialist services more readily available and providing an important link between the primary and the secondary health care. Besides, they ensure technical cooperation between these two levels.

The speciality clinics are outside the hospital premises but they are managed by the relevant hospital departments. They provide services in the fields of internal medicine, general surgery, gynaecology and dermatology. The clinics have paramedical services at their disposal and the necessary radiology and laboratory services. The facilities of each of the six hospitals are described in Appendix C.

3.6.3 Tertiary Care

Tertiary care, or the third level, is provided through a number of speciality hospitals and clinics. The facilities of each hospital and clinic are described in

3.6.4 Emergency Medical Services

Emergency medical services are provided through the appropriate facilities in relation to the primary, secondary, or tertiary care. Any emergency patient in need of specialized care is given a prompt referral to the tertiary care facilities. The ambulance network, which effectively covers all the tertiary care of Kuwait, facilitates timely referral, transportation and provision of emergency medical services.

3.7 Industries in Kuwait and the Gulf Countries

Industrialisation in the Gulf Cooperation Council (GCC) countries is generally based on establishing industries that make extensive use of the available capital and energy sources (crude oil and natural gas). Of these the refining industries come first. GCC member states also cater for industries which depend on natural gas as a source of energy or feed. Some of these are mainly for export such as cement, petrochemicals and aluminium smelting and some are for the local market such as cement, iron, steel and other building materials.

3.7.1 Oil Refining

Oil Refining in the GCC member states dates back to 1936 when the Sitra Refinery was established in Bahrain. Later in the 1940's two very large refineries were established in Saudi Arabia and Kuwait, Ras Tanura in 1945 and Al-Ahmadi in

1949 respectively. These are considered to be the oldest and largest of all refineries in the region. Mina Saud Refinery in Saudi Arabia and the Mina Abdulla Refinery in Kuwait were opened in 1958. In the 1960s two more refineries were established in Saudi Arabia, Al-Khafji in the east and Jeddah in the south in 1966 and 1968 and one in Kuwait, Al-Shuaiba in 1968.

The total refinery capacity in GCC member states is about 2.4 billion barrels a day. Of this Saudi Arabia has 53% followed by Kuwait with 26.5%, Bahrain 10.5%, UAD 7.6%, Oman 2.1% and Qatar 0.6% (Gulf Industrial Consultant Organization, 1992).

At present some GCC countries (particularly Saudi Arabia, Kuwait and UAE) are building new refineries as well as enlarging the established ones for the purpose of increasing their exports from refined products. GCC member states give considerable attention to improving the quality of their refining capacities to meet the demands of the export market. With the declining international demand for fuel oil which in turn brought its prices down, most GCC member states are now constructing new units aimed at transforming a significant part of fuel oil produced in their refineries into light distillates. Some countries (Kuwait and Saudi Arabia) have already developed a number of their refineries in this line of production (Al-Majed, 1992).

In all chemical works producing more than one commodity there is danger of the gaseous effluent from the various processes interacting in free air through carrying liquid or solid particulate matter from the processed material. It is, therefore, a primary consideration in siting an oil refinery (emitting acid gases) that it should be kept away from works producing ammonia or products containing ammonia, e.g. fertilizers, and both plants need to be sited in such a way that the prevailing wind will not - so far as can be foreseen or calculated - mix their gaseous emissions. If they should get mixed, a white stable cloud will result from chemical interaction, and may drift for miles. (Parnarouskis, 1980)

Osmogenic emissions from oil refinery stacks will cause several types of smell: oily odours, acrid odours from flue gases, and sulphurous or sour odours from sulphydryls and hydrogen sulphide. Acrid fumes are released at chimney mouth level and the winds carry them rapidly away, spreading and diluting the offensive waste down. Oily and sulphur smells are released near the ground. They are at ambient temperature, hug the ground profile, and may roll along over miles of countryside because they are mostly heavier than air. They are also the more noticeable because they stay on the ground where there may be little air movement. Conditions which prevent air movement or turbulence near the ground will also prevent the dispersal of the cold (oily and sour) emission in contrast to the hot (acid) emission from the chimney tops. Stable warm days and temperature inversions will keep the cold cloud stationary for the duration of the meteorological condition (UNEP, 1980).

3.7.2 Natural Gas

The territories of the GCC member countries contain considerable quantities of proven natural gas reserves estimated at about 264 trillion cubic feet at the beginning of 1984. Saudi Arabia has the largest natural gas reserves in the GCC member countries. Qatar comes second (23.5%) Followed by Kuwait (13.3%) and UAE (11.8%). Kuwait comes first amongst the states in the region using 90% of the total natural gas produced.

Comprehensive measures have been adopted in recent years to increase the utilization of natural gas. The first stage includes programmes to construct two main centres for natural gas gathering, treatment and liquefaction in Al-Juaima and Yanbu. The total capacity is about 1,700,000 barrels a day of ethane, propane, butane and natural gasoline liquids.

Natural gas produced in Kuwait is being extensively used to feed public utilities, (especially power stations and water desalination plants), to feed oil producing companies utilities and the liquefaction plant, to maintain reservoirs' pressure by gas injection operations, and as feedstock in some industries, of which the cement and chemical industries come first. In 1979 the liquefaction plant in Ahmadi came on stream with a processing capacity of 1725 million cubic feet of associated gases to produce liquified propane, butane and natural gasoline. The liquified plant produced 14.3 million barrels of liquid petroleum gas (LPG) in 1982 and in 1988 the processing capacity was 168.6 billion cubic feet.

3.7.3 Fertilizers and Petrochemicals

Fertilizers are produced - for export - in Kuwait, Qatar and Saudi Arabia. In Kuwait, the "Petrochemical Industries Co." (PIC) produces liquid ammonia, urea, ammonium sulphate and sulphuric acid. Daily output of ammonia and urea units reached 2350 million tons and 1950 million tons respectively, (the company is considered to be the largest producer of ammonia and urea in the Middle East). Other units under construction at Shuaiba are due to be commissioned shortly. (Kuwait Chamber of Commerce & Industry, 1990)

3.7.4 Cement

The cement industry in GCC member states was marked by expansion to meet the growing needs of construction and building projects. Most of GCC countries produce substantial quantities of cement. In 1972 "Kuwait Cement Company" started producing Portland Cement and Sulphates Resistant Cement.

3.7.5 Lime

This industry is widely spread over most of the GCC countries especially in Kuwait, Saudi Arabia and Oman. The National Industries Co. in Kuwait currently owns and operates several sand and lime brick factories. It produces lime and lime powder at Mina Abdulla, and there are ready-mix concrete units and other factories for cement production at Shuwaikh and Sulaibiya.

3.7.6 Other Industries

GCC member states are also developing other industries such as foodstuffs, pipes, shipbuilding and repair industries and others.

Kuwait Metal Pipe Industries Co. with 240,000 tons/year capacity, produces metal pipes for local and neighbouring markets.

The Kuwait Melamine Industries Co. uses the urea produced by Kuwait Petrochemical Industries Co. The company's factory in Shuaiba is considered one of the most modern factories of melamine in the Middle East producing 25,000 tons/year capacity of raw melamine powder.

The Arab Shipbuilding and Repair Yard Co. (ASRY) is sponsored by the Organisation of the Arab Petroleum Exporting Countries (OAPEC) whose members are UAE, Bahrain, Saudi Arabia, Iraq, Qatar, Kuwait and Libya. The project is equipped with a dry dock, a number of berthing facilities, heavy workshops and cranes. (Arab Council Comity, 1984)

3.8 Anti-Pollution Measures

Evaporation from storage tanks into the air may be considerable during hot weather. Evaporation has been partly reduced using infra-red reflecting (aluminium) paint on the outer walls and the tops of tanks. A much better solution is the floating roof tank where the roof is directly supported by the surface of the contents. This prevents evaporation to a very considerable extent and the only molecules which gather sufficient thermal energy to move away from their neighbours are those forming a thin film on the inner wall of the cylindrical tank after oil has been drawn off and the roof has moved downwards. The floating roof tank also has the great advantage that since there is never an empty space between oil level and roof no oil fumes are ejected during filling. If fixed roof tanks are used, gaseous effluent and polluted air should be collected from all tanks and conducted to an air deodorization plant. The sulphuric or sour products are refined by washing and neutralising with caustic soda solution (sodium hydroxide, NaOH containing 60-75% of sodium oxide Na_2O) (KNPC, 1992).

If water (direct from the washing process, and without having been neutralised by the alkali or spent caustic soda solution) is discharged into sewers without having been treated to required standards first most of the disagreeable smells will be spread throughout the sewerage system. It is usual to reduce these effluent by steam stripping and burning of the gaseous fraction in furnaces, before discharging liquid into the sewers (Ministry of Public Work, 1987).

Emissions of combustible gases are circulated into the flare system, and burnt. This oxidizes sulphide, hydrogen sulphide and sulphydryls (mercaptans). If the temperature of the flare is high enough, for instance by adding high grade fuel to the stream, it will undergo deodorisation by thermal oxidation (combustion).

Crude oil with high sulphur content and natural gas are sources of sulphur which on recovery from the raw materials commands a high price. The process is based on the burning of one third of the hydrogen sulphide to sulphur dioxide. This is then reacted with the remainder of hydrogen sulphide to yield demential sulphur and water, basically the well known GLAUS process of partial oxidation. The sulphur is extracted in the form of H_2S by absorbing it in an aqueous solution in ethanolamine. Condensers remove the sulphur and after passing through a coalesces, the droplets of sulphur conglomerate. The process reduces hydrogen sulphide to well below 10 ppm and releases the waste gases from a high stack for quick dilution so that no odours pollute the air. Sulphur recovery is better than 95%. All water is available in the form of stream needed in the treatment plant.

The sulphur-containing gases are collected from the entire plant (hydrogenation, hydrofiner, catalytic cracking) and are washed and heated. The sulphur contained in crude oil is eliminated by passing the oil through hydrotreaters where hydrogen sulphide is formed. The H_2S is separated and burnt with insufficient oxygen producing a variety of sulphides. A catalyst transforms the gases into liquid sulphur which is kept heated in storage tanks. Waste gases from this process have no smell and are released to atmosphere. The refinery produces annually some 10,000 tons of pure sulphur (KNPC, 1989).

Amongst the many that have been tried more or less successfully, recent suggestion involves reducing hydrocarbon and carbon monoxide content by adding fresh air at the exhaust valve. Unfortunately this also increases odour intensity quite considerably.

3.9 Pollution Control Strategies In USA, UK and Kuwait

3.9.1 In USA

Air pollution control policy is based on achieving ambient air quality standards through strict adherence to technology standards (technology-forcing) by the private discharger/emitter. Under the Clean Air Act (1969) the National Ambient Air Quality Standards (NAAQSs) were implemented. Plans were developed for 247 air quality control areas, which determined emission levels for existing pollution sources. More stringent limits were set for new and modified sources on an industry-by-industry basis.

In 1977 the Clean Air Act was amended to allow extension of deadlines for achieving NAAQSs and the formation of new technology standards. In non-attainment areas, existing sources were allowed to apply Reasonably Available Control Technology, taking into account technological and economic feasibility. By 1981 the Clean Air Act regulations had achieved a 58% reduction in total annual particulate emissions and 25% reduction in sulphur oxides emissions. These large reductions were achieved despite a growth in coal-fired electricity generation and in general industrial activity.

The Environmental Protection Agency (EPA) commissioned researchers to investigate a county-level model to estimate the health benefits of a variety of national control policies (Pearce, 1990).

3.9.2 In UK

Pollution control policy has been implemented to a large degree on the basis of, and through the process of, negotiations and bargaining with individual polluters. Proponents of this Best Practicable Means (BPM) approach assert that its advantages lie in its flexibility, its adaptability to particular circumstances and its gradualness. Critics have argued that BPM is too flexible, that there are insufficient guidelines to help regulatory officials to judge the merits of a particular case and that all the discussions are too confidential.

Significant on-going changes to the UK's system of pollution control began to be introduced in 1987. A shift in the basic philosophy of control is under way because of pressure for change mandated by policy strategies and directives (carrying the force of law) favoured at the EC level (Pearce, 1990).

3.9.3 In Kuwait

Before 1984 available technology was only able to control particulate emissions, since that new treatment units were introduced until 1990. The most important unit in Shuaiba Industrial Area was the purification of oil from H_2S, which is converted into hot liquid of sulphur, this is then cooled in special treatment unit to solid sulphur for export. The other pollutants are burned in special treatment units.

These units are: Hydrosulphur treatment unit and Tail gas treatment unit (personal communication, 1993).

3.10 Discussion and Conclusion

The location of State of Kuwait between latitude 28 and 30 north implies typical climatic conditions of the Sahara geographical region.

At Shuaiba, the rate of introduction of waste materials and produce into the environment by the various emissions of the industries has increased continuously over the last three decades, and there is now strong evidence to suggest that the atmosphere of Kuwait is overloaded with contaminating substances discharged from industries in this area.

All the pollutants emerging from the literature review as potentially damaging to health can be expected at elevated levels near Shuiba. Individual substances within these sub-groups may be present in the atmosphere as gases, particulates or aerosols.

CHAPTER FOUR

METHODS

CHAPTER FOUR

METHODS

4.1 Introduction

The purpose of this chapter is to describe the data collected, the methods of collection, and the approach to data analysis.

Estimation of the relationship between health and environmental pollutants is composed of two primary activities: (1) assessment of levels of exposure, and (2) assessment of effects on health.

Three types of source of information were used:

1. Measurements of the pollutant concentration levels in three residential areas chosen for the study during the period of February 1st, 1989 to January 31st, 1990 and in the Shuaiba Industrial Area, described in section 4.2.

2. Measurement of meteorological conditions from Kuwait International Airport for the same period, described in section 4.3.

3. A community survey based on a self-administered questionnaire distributed to sample households in the three residential areas selected for the study during the same period, described in section 4.4.

4. Measurements of mortality and health services activity derived from routine sources, described in section 4.5.

4.2 Ambient Air Quality

4.2.1 Selection of Sites

Measurements were taken both within the Shuaiba Industrial Area as the main air pollution source in Kuwait and in centres of residential population at Fahaheel, Reqa and Mushrif. Measurement sites were selected on the basis of the dispersion characteristics of the pollutants in the atmosphere, and to ensure a variety of distances from the Shuaiba Industrial Area and thus a variety of levels of exposure. The distance between SIA and the centre of Fahaheel is 3 km, to the centre of Reqa is 10 km and to centre of Mishrif is 24 km. These areas are located in a line to the north of SIA (Figure 4.1). Also they were known to be broadly similar in terms of social and economic factors.

The sites of the monitoring stations within each area are shown in (Figures 4.2, 4.3 and 4.4). The site in the Fahaheel residential area was in the open car park of the local urban centre, behind the police station. The Reqa site was in the car park of the Adan Hospital. The Mishrif site was in the open car park near the health centre. There were no high rise buildings within 500 metres of the monitoring points in any direction.

4.2.2 Measurement

Monitoring Emissions at Source

Data was obtained for the Shuaiba Industrial Area from the Environmental Protection Centre (Air Monitoring Section). The EPC performs various tasks in monitoring the problems caused by hazardous pollutants involving sampling stations at various locations surrounding the Shuaiba Industrial Area.

There are eight multi-purpose modern and fully computerized Automatic Air Quality Monitoring Stations at sites indicated in the enclosed map. The parameters monitored were total sulphur (TS, SO_2, H_2S), total hydrocarbon (THC, CH_4, Non CH_4), total nitrogen oxides (NO_x, NO, NO_2), ammonia, carbon monoxide, ozone and particulates. In addition to these there are two meteorological stations. One is close to the sea and the other is around seven kilometres from the EPC (Figure 4.5). The data gathered at the monitoring stations is fed to computers situated in the Environmental Protection Centre.

In Fahaheel, Rega and Mishrif mobile laboratories were used for measurement of ambient air quality. These have the advantage that monitoring over a wide area, including Fahaheel, Reqa and Mishrif areas could be carried out over the whole year at relatively low capital cost. Mobile laboratories provided by the Environmental Protection Council consisted of small vans equipped for continuous multi-parameter monitoring, recording, data reduction, data logging and data transmission by telemetry. The equipment in each van included sampling systems, monitors, sensors, data processors and an internal power supply.

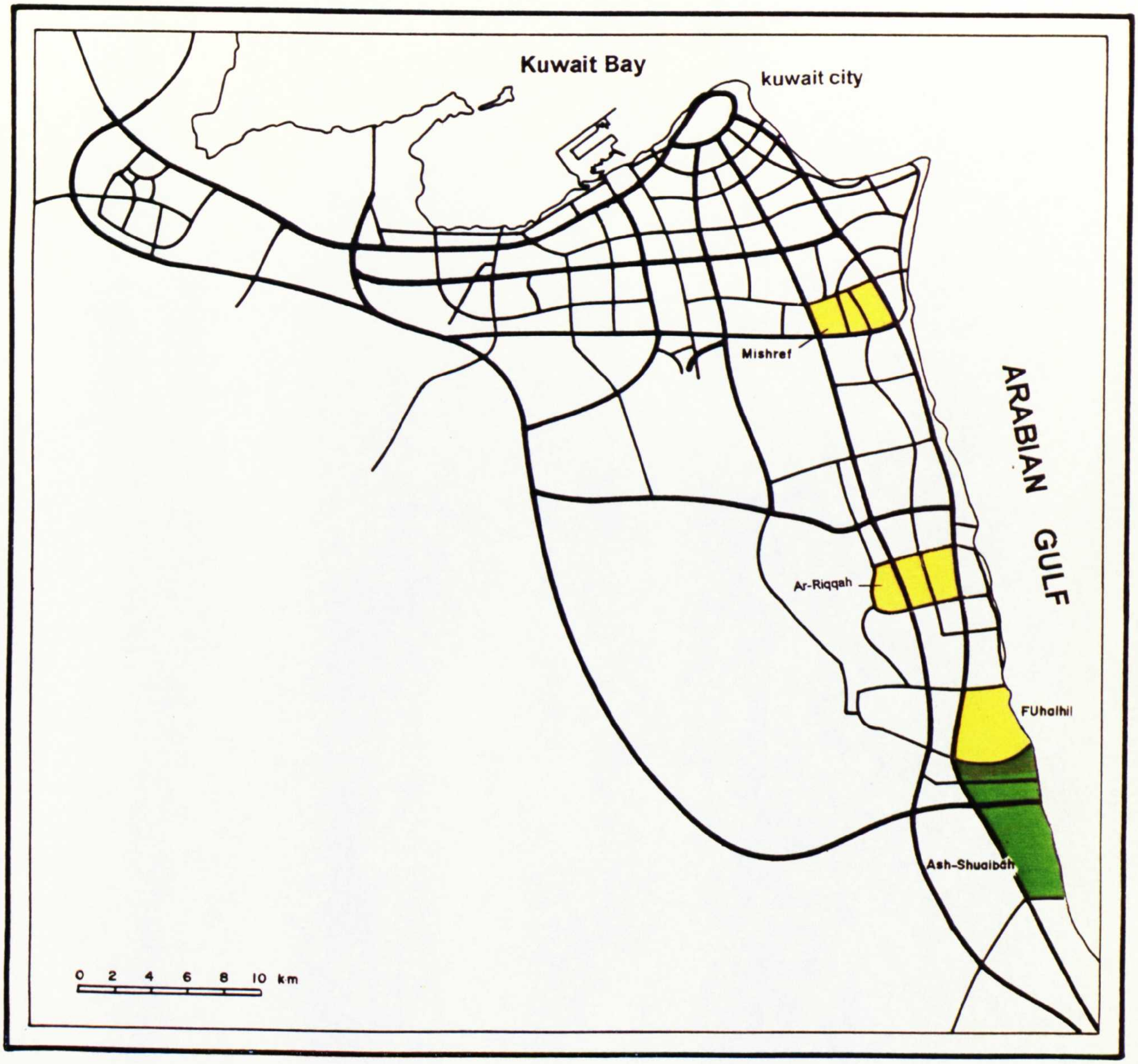
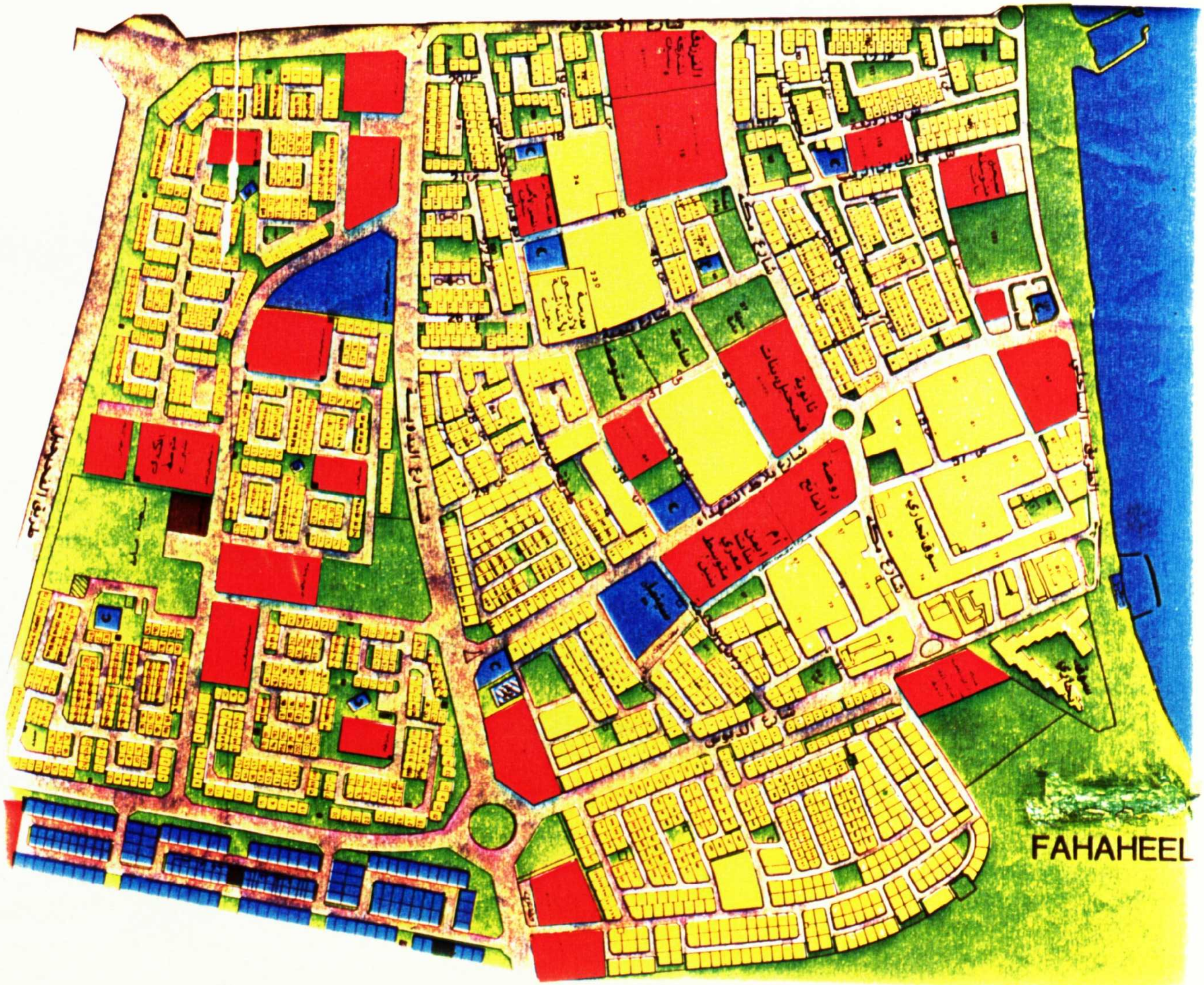
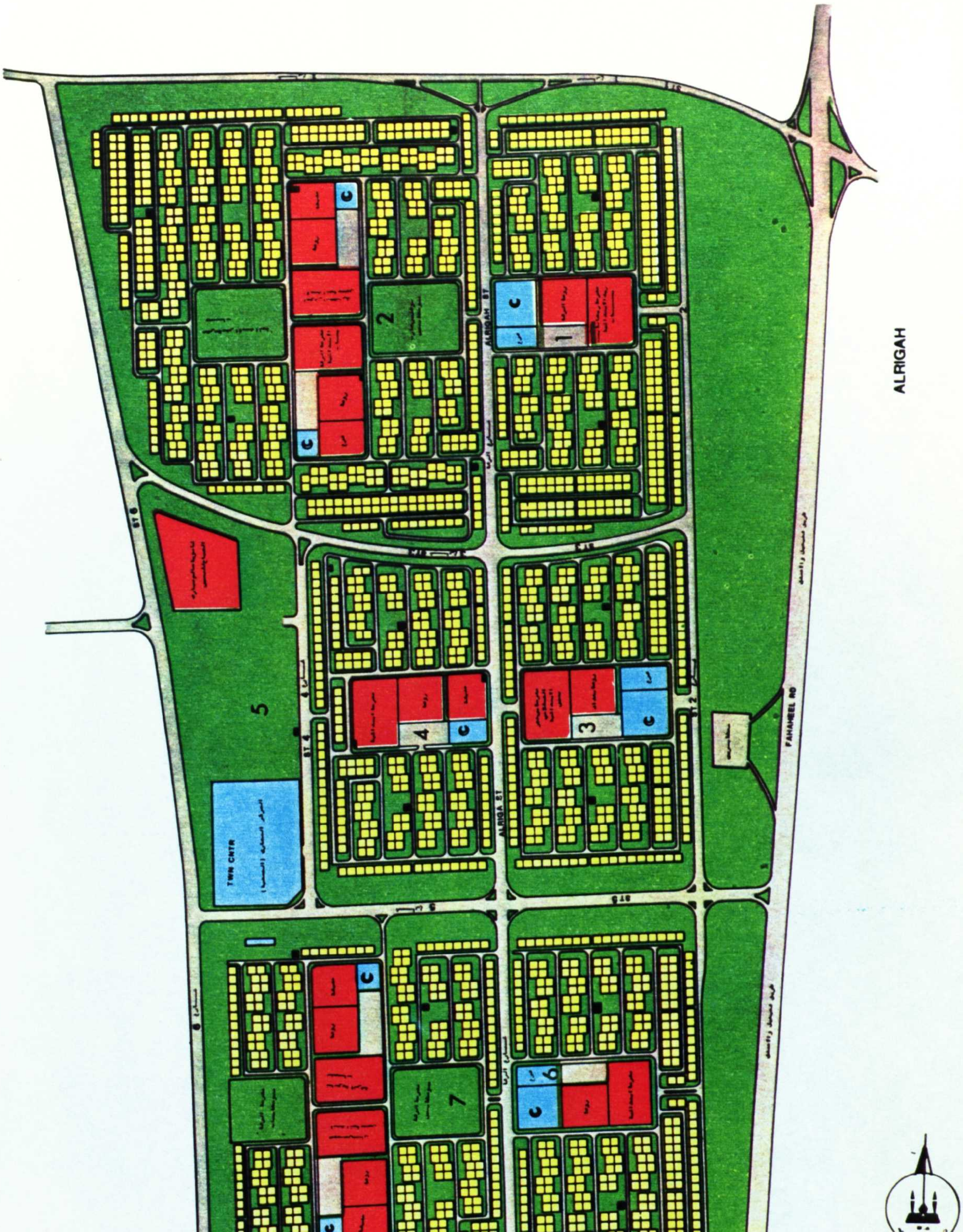


Figure (4.1) Location of the Study Areas

Figure (4.2)
Fahaheel





RIGA

Figure (4.3) Riga

Figure (4.4) Mishrif

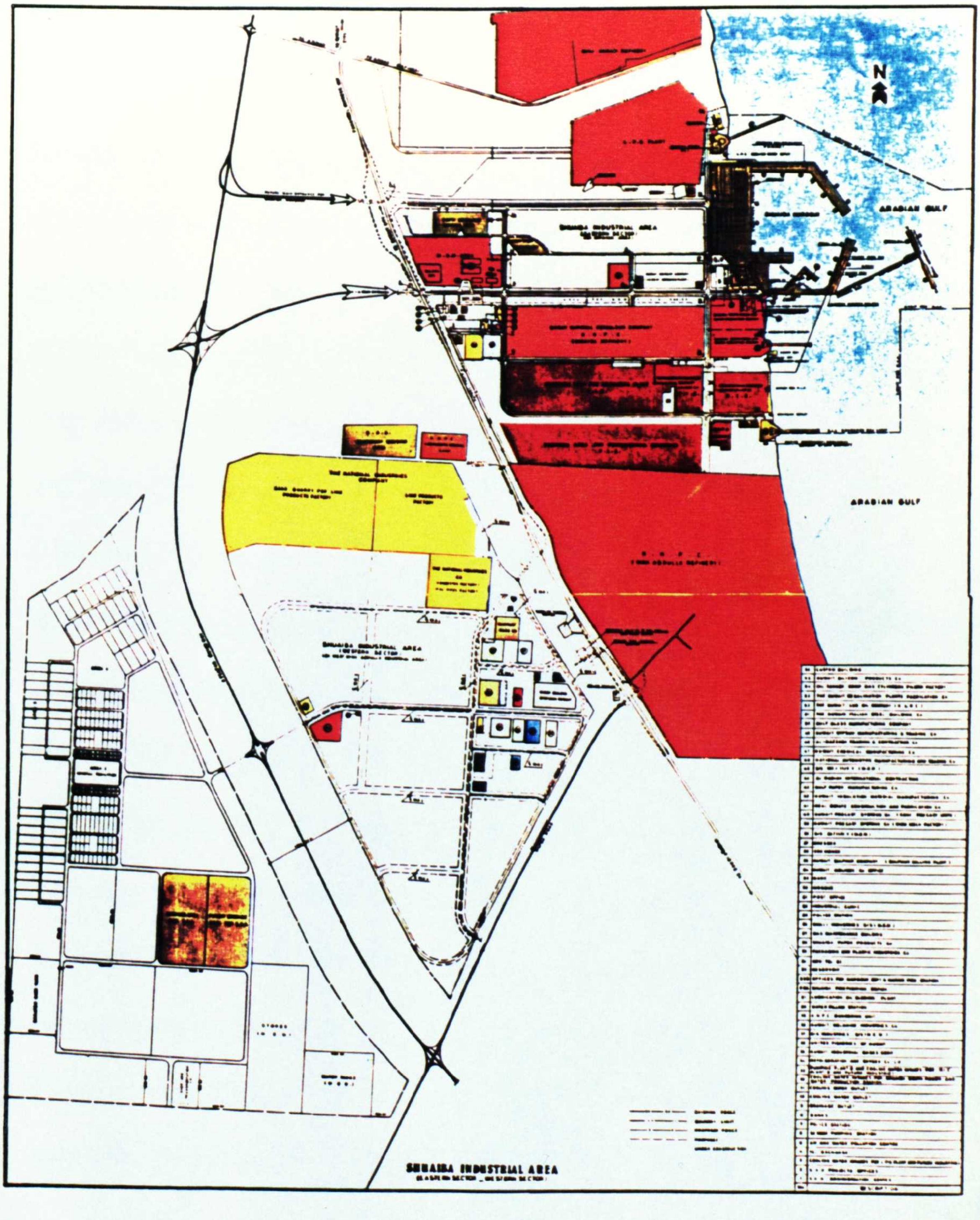


Figure (4.5) Shuaiba Industrial Area

The stations were provided with continuous gas monitors. The monitors were operated automatically with a measurement taken every 5 minutes. All the monitors were provided by HORIBA, Japan.

There is the potential for interference between measurements of different pollutants, e.g., compounds of nitrogen oxides, ammonia, sulphur compounds and other compounds (hydrocarbons and carbon oxides). The non-dispersive infrared (NDIR) method used enabled the measurement of real time values with high selectivity. Repeatability was within 2% of full scale, response time 108 sec, and noise zero and span drift were within 2% of full scale per day. The HORIBA monitors were controlled by a system controller model SYC-820, but output signals and operational function were checked manually. Automatic zero correction was provided. Automatic calibration was also possible at arbitrary times by an external signal. The monitoring of the three stations' operation was carried out through daily visits (a) to ensure the smooth and efficient running of all equipment and apparatus, such as the meters of principal air pollutants as well as the computer, (b) to rectify any error or breakdown of the equipment, (c) to perform any manual gauging of the relevant equipment, (d) to replace air filters fitted to purify the air passed to measurement meters, and (e) to replace the tapes on which results are recorded. Appendix D gives more detail about the equipment.

The mobile laboratories at the three sites could monitor the following :

H_2S, SO_2, hydrocarbons, CO, NH_3, NO, NO_2.

To ensure reliable operation of van and equipment under harsh meteorological conditions of extremely high wet and dry bulb temperatures and dust storms, they were designed with adequate air conditioning and dust proofing.

4.2.3 Data Processing and Calculation

In the Shuaiba Industrial Area one reading (value) was obtained every 15 minutes giving 96 readings per day (24 hrs) and 2880 readings per month. The system incorporated the necessary software to control scan rate, and to compute and store average values, etc. The systems allowed programme access from the console, for possible software changes. On this bases the maximum, minimum and average statistics were calculated for each month.

Signals were tagged to identify e.g. date, time, location, parameter, calibration and zero data, scale factors, etc.

For the three mobile laboratories in Fahaheel, Rega and Mishrif one reading (value) was obtained every 5 minutes giving 288 readings per day (24 hrs). On this basis the maximum, minimum and average statistics were calculated for each day.

4.3 Monitoring Meteorological Conditions

4.3.1 Selection of sites

Data were obtained for temperature, wind speed, wind direction, humidity and precipitation from Kuwait International Airport for the period of the study from February 1st, 1989 to January 31st 1990.

4.3.2 Data Processing and Calculation

One reading was obtained every 5 minutes giving 288 readings per day (24 hrs). On this basis the maximum, minimum and average statistics were calculated for temperature, relative humidity and wind speed. Data were also collected on wind direction and total daily rainfall.

4.4 Subjective Health Experience

4.4.1 Design of Questionnaires

The survey used two questionnaires. One covered characteristics of the dwelling and the demography of the household members, answered by the head of household. A second questionnaire was completed by each member of the household or in the case of children, the sick and the old (or servants unable to read Arabic) by a responsible person.

The second questionnaire covered psychological and physiological symptoms, use of health care, smoking, life satisfaction, environment problems and experience of pollution. It was piloted on 32 persons and minor changes were made as a result. The covering letter for the questionnaire did not identify air pollution as the focus of the study. (See Appendix E.)

The medical aspects of the design of the questionnaires was constructed (Samet, 1973) and discussed with physicians in Kuwait and with Prof. R. Anderson and colleges in St. George's Hospital, UK.

4.4.2 Sampling Frame and Sample Selection

Cluster sampling was used in this study, because a population register was not available. The layout of streets and houses in the study areas is based on a rectangular grid of blocks. Large-scale maps were obtained from Kuwait Municipality for each area, showing residential dwellings or villas.

The sampling procedure was as follows:

1. Divide each area into rectangular sub-areas.

2. Identify a central point in each sub-area.

3. Using a large-scale map which shows individual houses or 'villas', mark a series of lines through the central point. Two are parallel to the directions of the roads, and another two at 45 degrees to them.

4. Choose a random number. Take the first radiating line and identify the sampled house by counting houses lying on the line until the chosen number is reached. Take the second radiating line and repeat, etc.

5. Having decided which houses are to be studied, use a second series of random numbers to determine the season in which they will be sampled.

6. When the questionnaires were delivered, if it was discovered that a house contained more than one household, all the households involved were included in the study.

<u>Fahaheel:</u>

The population of the area was 50.081 in 1989. The area was divided into five sub-areas. Sixteen households were selected in each sub-area by the method described. Apartment buildings in each sub-area were excluded. The 80 households cluster were further randomised into 20 households for each season. (See Appendix F.)

<u>Reqa:</u>

The population of this area was 36.383 in 1989. There were no apartment buildings. The area was divided into six sub-areas. 16 households were chosen in each sub-areas, giving a total of 96. These were sampled to provide 24 household for each season. (See Appendix F.)

<u>Mishrif:</u>

The population of the area was 13.382 in 1989. There were no apartment buildings. The area was divided into six sub-areas. 16 households were chosen in each sub-areas, giving a total of 96. These were sampled to provide 24 households for each season. (See Appendix F.)

4.4.3 Data Processing and Calculation

The techniques used in this study were mainly detailed statistical tabulation and regression analysis to estimate the effect on health outcomes and the use of health care of changes in pollution levels.

The strategy was as following:

1. Describe variation in independent variables:
   - pollutant levels by area and by season.
   - meteorologic conditions by area and by season.
   - demographic/socio-economic factors by area and by season.
   - smoking by area and by season.

2. Describe variation in dependent variables:
   - self-reported symptoms by area and by season.
   - use of health care by area and by season.

3. Describe correlation amongst independent variables.

4. Select independent variables for modelling.

5. Select dependent variables for modelling.

6. Build regression model of selected dependent variables on selected independent variables.

7. Estimate the effects of changing pollution levels on health and use of health care for different areas in Kuwait.

4.5 Routine Indicators of Health Status and Health Services Activity

4.5.1 Mortality

Death rates are available from annual publications (Vital & Health Statistics Abstract, 1989 and Health Statistics, 1986) from the Ministry of Public Health, the *Annual Statistical Abstract* published in 1989 and the Population Census published 1985 by Ministry of Planning. However these measurements tuned out to be of no value for this study because they only show death rates for the whole Kuwait population and for the different governorates, and not specifically for the three areas chosen.

4.5.2 Service Activity

Statistics are available on the daily number of patients (new and follow up) that visited health centres in the three residential areas. These were collected from the relevant health centres - Fahaheel, Reqa and Mishrif - for the period from February 1st, 1989 to January 31st, 1990. The health centres also provided data on the daily number referred to the different hospitals for outpatients or admission by department: Internal Medicine, Surgery, E.N.T., Paediatrics, Dermatology or Ophthalmology.

4.6 Discussion

Since it was not clear in advance which measures of air pollution or which socio-economic variables would be important, many have been studied. Air pollution was represented by the measured levels of the pollutants (hydrogen sulphide, sulphur dioxide, hydrocarbons, carbon monoxide, ammonia, nitrogen dioxide and nitrogen monoxide) for the period of February the 1st, 1989 to January 31st, 1990. The measurement method for the level of pollution was of a high quality. These measurements were taken many times during the day just to ensure reliability.

The meteorological conditions are represented by measuring temperature, humidity, wind speed, wind direction and precipitation for the same period. But since these measurements were taken from Kuwait International Airport, it would be much better to put meteorological monitors in each mobile laboratory so as to measure it, together with the pollution measurement, in each area.

There were considerable difficulties in finding relevant routine statistics on health status and health services activity levels as a result of a lack of cooperation by the government bodies concerned, in particular, and the absence of past studies in

Kuwait in general. Although data existed in large quantities, these data were not organised. There was considerable duplication, ambiguity and invalidity.

A questionnaire was used covering the same period in order to determine the effect of industrial pollution on the local inhabitants.

The questionnaire provided certain data, which were not otherwise available. This information was used to draw a clear picture of the health conditions and use of health care for a selected segment of the population and to determine the changes that had been witnessed in their overall health condition, and finally, to find some connection between these data and the level of the accompanying pollution and the effect of meteorological data.

The sampling method used for choosing households will tend to over-select households situated near the middle of each sub-area. In some cases, particularly in Rega, this bias will be relatively small because in each sub-area the housing was arranged around the perimeter of a large central open square. In the other areas there is nothing to suggest that households nearer the centre were different from those around the outside, each sub-area was developed as a simple unit, so that, for example, no systematic differences would be expected between inner and outer households and how long people had lived where they did.

Since a cluster sampling approach was used standard errors will have to be calculated using a method that takes this into account.

CHAPTER FIVE

AIR POLLUTION, HEALTH AND QUALITY OF LIFE

BY AREA AND SEASON

CHAPTER FIVE

AIR POLLUTION, HEALTH AND QUALITY OF LIFE BY AREA AND SEASON

5.1 The Underlying model

There are many factors affecting self-reported health and use of health care. These include age, life-style and other environmental factors. In a descriptive study of the effect of air pollution, these other factors must be taken into account. The initial model of the links involved underlying this study is shown in Figure 5.1.

According to this model, subjective levels of physical and psychological symptoms are affected by air pollution, life-style, other and social/environmental factors and health expectations. Use of health care is affected by levels of symptoms, health expectations and accessibility of health care. Life satisfaction is affected by levels of symptoms, health expectations, pollution levels and other social/environmental factors. (Thus one complication in the model is that life satisfaction indicators are affected by air pollution, life-style and other social and environmental factors through two pathways: directly and indirectly through health effects.)

In the first part of this chapter data are presented which show variations in the independent variables of primary interest: levels of pollution. In the second part, data are presented on a number of possible confounding factors including demographic socio-economic, smoking and meteorological factors, and their

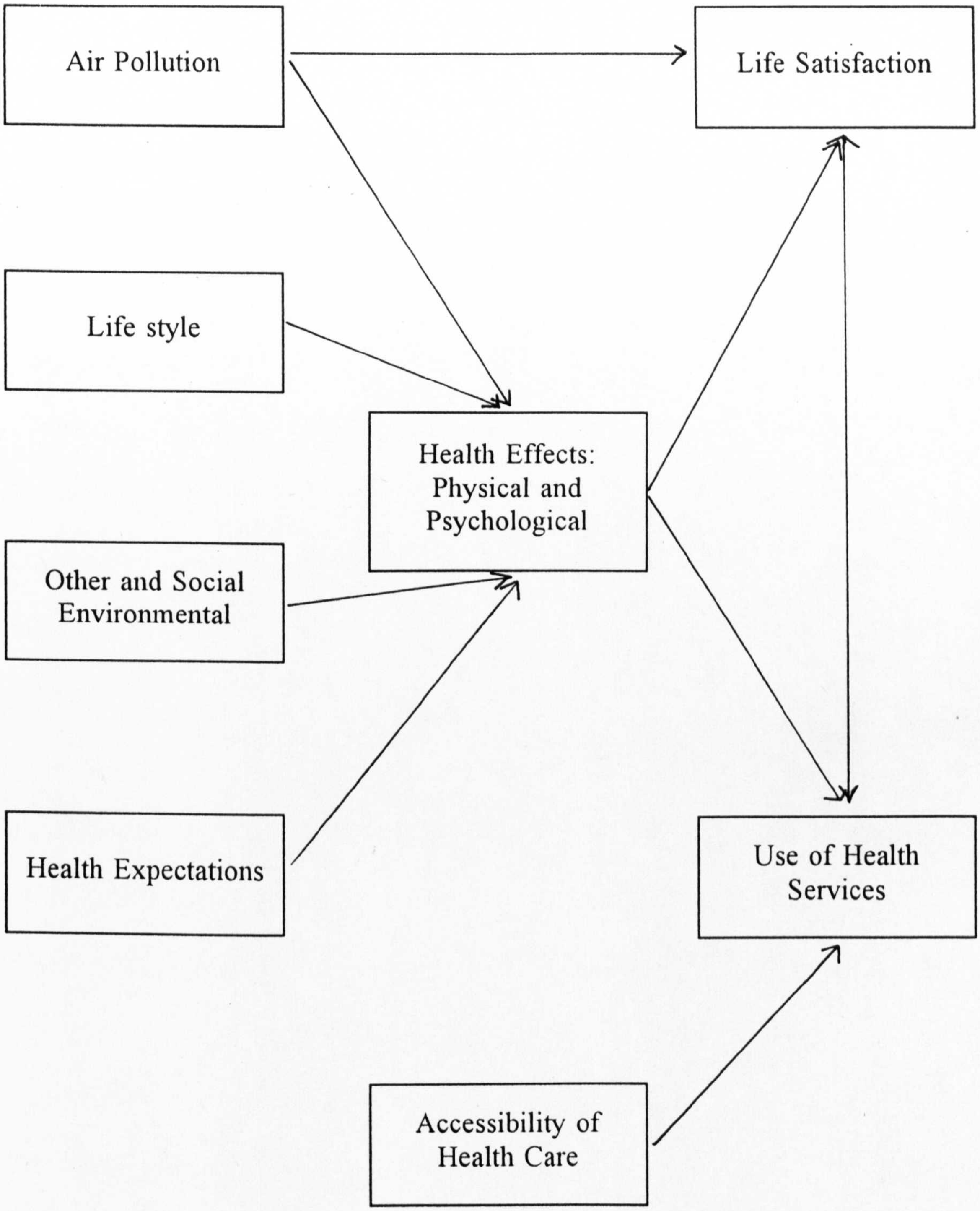


Figure (5.1) A Conceptual Framework Showing Factors

Linking Health and Use of Health Care to Pollution variation between the study areas. In the third part, data are presented on outcome variables: physical symptoms, psychological effects, satisfaction with quality of life, perceived environmental problems, experience of air pollution and use of health care.

In the results presented in this chapter the local area is the main unit of analysis, and the mean values or percentages are given for each area studied. (Regression analyses in which the individuals survey respondent is the unit of analysis are presented in chapter 6.) Another unit of analysis that will be considered in this chapter is the season. If pollution levels vary from one season to another, this presents an opportunity for adding a second dimension to the 'natural experiment'.

5.2 Pollution Levels in The Study Areas

5.2.1 Completeness of the data

In Rega there were machine failures on 14th April and 12th September, 1989.

5.2.2 Pollution Levels by Area

The variation between areas in air pollution is summarized in Table 5.1. For each pollutant there is a gradient in the mean concentrations from Fahaheel to Mishrif, with a clear decrease in the concentrations with increasing distance from the Shuaiba Industrial Area. The average concentration of NCH_4 in Fahaheel (0.33 ppm) was higher than the National Ambient Quality Standard (.24 ppm), and the average concentration of CO in all three areas was higher than the National Ambient Quality Standard (.08 ppm).

5.2.3 Pollution Levels by Season

There is a substantial variation in mean daily reading of pollution levels from one season to another (Table 5.2). The gradients across the study areas were present in every season, but there was some seasonal variation in the relative values (Table 5.3). Figures 5.2 to 5.8 presents the same data as a time series, smoothed by taking 7-day moving averages and transformed to a logarithmic scale.

The pattern of seasonal variation was quite different for the different pollutants:

- H_2S concentration are quite high at the beginning of the year. For example the mean reading for H_2S emission in winter was 1.949, but less than half of this (0.795) in spring, 0.918 in summer and 0.412 in autumn (Table 5.2). There are a sharp drops in July for Rega and Mishrif (Figure 5.2).

- SO_2 levels are relatively constant over the year, with lower levels in Mishrif from September on. In Rega there is a small decrease in SO_2 levels in February, rises again in the beginning of March and increases in summer months (Figure 5.3).

- Hydrocarbon levels fluctuate relatively strongly. The general picture over the study period is one of steady decline, with signs of an increase in

January. Levels in March were well below the trend line, suggesting a marked decrease in industrial activity (Figure 5.4).

- CO levels fluctuate with no particular pattern in the first part of the year. From June on, the trend is then upward, reaching a peak around September (with mean levels 50% higher in autumn than in winter and spring) before declining again from October through to January. There were, however, marked drops in May and in the middle of September (Figure 5.5).

- By contrast with SO_2, ammonia (NH_3) levels more than doubled in spring compared to winter. Thereafter they decline, but there was a sharp local peak at the end of November and a broader one in September (Figure 5.6).

- Nitrogen monoxide (NO) levels dropped in February and again, sharply, in April suggesting another decrease in industrial activity. There was a more gradual decline in Mishrif over the remainder of the year (Figure 5.7).

- Nitrogen dioxide (NO_2) also declined sharply in February, particularly in Fahaheel, and more gradually in Mishrif from June to December. Again, levels in April were well below the trend line and there was a sharp drop in the beginning of January (Figure 5.8).

Table (5.1) Main Daily Reading of Pollution Level

by Area Over The Study Year

	Fahaheel	Rega	Mishrif
H2S:			
mean.	2.276	0.651	0.132
st. dev.	5.336	3.228	0.300
st. er.(mean).	0.0954	0.0917	0.0069
SO2:			
mean.	6.584	1.401	0.462
st. dev.	11.965	2.137	0.582
st. er.(mean).	0.0691	0.0245	0.0088
NCH4:			
mean.	332.332	191.746	67.929
st. dev.	392.459	223.341	77.200
st. er.(mean).	7.3724	1.5713	0.6701
CO:			
mean.	1308.423	941.676	343.146
st. dev.	877.933	724.132	334.201
st. er.(mean).	2.5351	3.4027	2.6296
NH3:			
mean.	191.184	138.028	48.505
st. dev.	212.412	170.186	75.441
st. er.(mean).	2.3918	1.0459	0.3094
NO2:			
mean.	22.019	14.584	4.342
st. dev.	20.245	17.978	5.364
st. er.(mean)	0.1909	0.0566	0.0521
NO:			
mean.	24.041	14.447	6.180
st. dev.	30.565	17.476	5.143
st. er.(mean).	0.2419	0.1799	0.0469
Number:	365	363	365

Measuring units ppt.
Data from the mobile monitoring stations.

Table (5.2) Mean Daily Reading of Pollution Level by Season Over The Study Year

	Winter	Spring	Summer	Autumn
H_2S:				
mean.	1.949	0.795	0.918	0.412
st. dev.	0.738	0.818	0.729	0.383
SO_2:				
mean.	2.727	2.747	4.241	1.588
st. dev.	2.236	2.688	4.273	1.519
NCH_4:				
mean.	212.612	236.087	236.615	103.284
st. dev.	159.114	106.851	133.642	39.554
CO:				
mean.	771.271	710.104	807.317	1170.887
st. dev.	363.837	242.743	408.881	573.020
NH_3:				
mean.	71.864	180.772	112.350	137.904
st. dev.	42.173	74.129	51.079	69.084
NO_2:				
mean.	13.909	21.047	19.030	10.595
st. dev.	11.058	4.718	8.078	5.463
NO:				
mean.	16.612	15.203	14.436	10.482
st. dev.	12.445	6.849	6.888	5.741
Number:	864	837	858	861

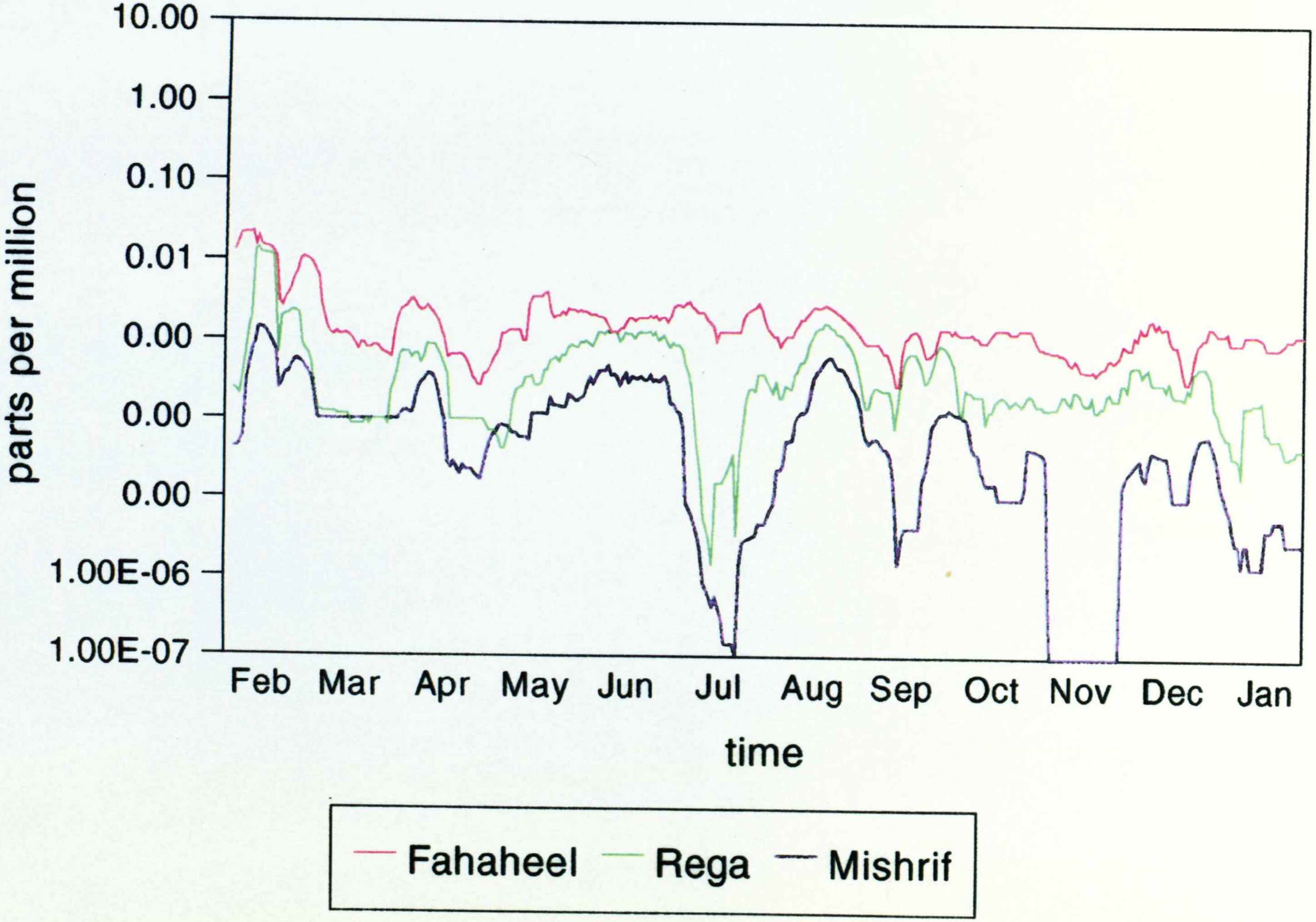
Measuring units ppt.
Data from the mobile monitoring stations.

Table (5.3) Mean Daily Reading of Pollution Levels by Area and Season Over the Study Year

	Winter	Spring	Summer	Autumn
H_2S:				
Fahaheel	4.337	1.946	1.918	0.936
Rega	1.323	0.323	0.640	0.268
Mishrif	0.187	0.116	0.197	0.031
SO_2:				
Fahaheel	5.823	6.539	10.250	3.676
Rega	1.739	1.082	1.800	0.981
Mishrif	0.445	0.619	0.674	0.107
NCH_4:				
Fahaheel	430.231	354.800	396.897	147.520
Rega	153.379	257.703	243.209	110.820
Mishrif	54.227	95.760	69.741	51.514
CO:				
Fahaheel	1194.320	981.617	1258.314	1802.233
Rega	813.397	756.274	895.232	1304.896
Mishrif	306.096	392.422	268.407	405.533
NH_3:				
Fahaheel	124.966	258.875	170.047	209.613
Rega	68.830	202.282	121.144	159.517
Mishrif	21.796	81.159	45.859	44.583
NO_2:				
Fahaheel	29.433	17.439	24.751	16.555
Rega	7.787	12.756	24.734	11.873
Mishrif	4.508	5.947	7.606	3.357
NO:				
Fahaheel	34.021	22.715	22.460	17.116
Rega	10.155	16.745	15.210	11.219
Mishrif	5.662	6.150	5.640	3.111
Number:				
Fahaheel.	90	92	92	91
Rega.	90	91	92	90
Mishrif.	90	92	92	91

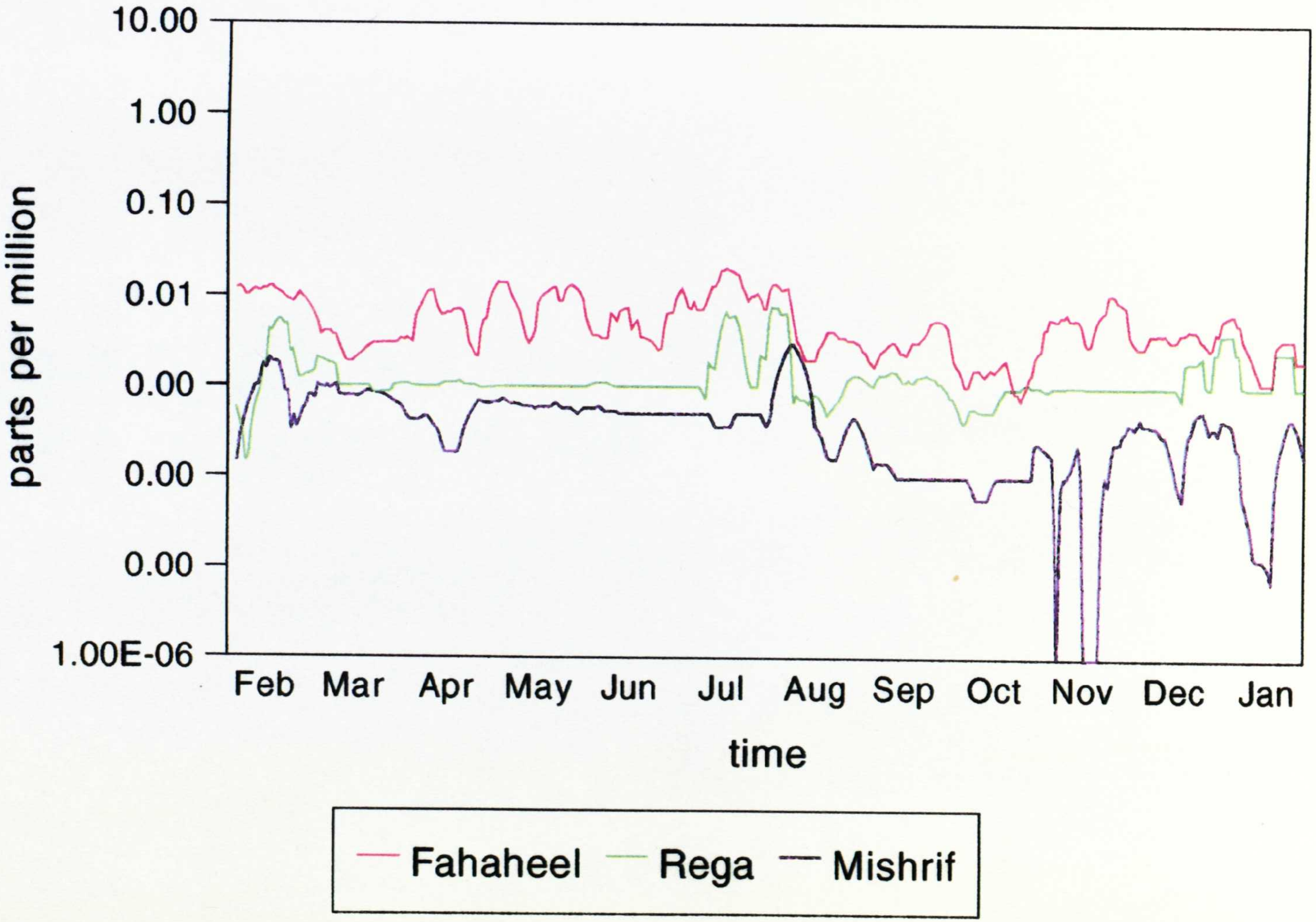
Measuring units ppt.
Data from mobile monitoring stations.

Hydrogen sulphide
1 Feb 89 - 31 Jan 90

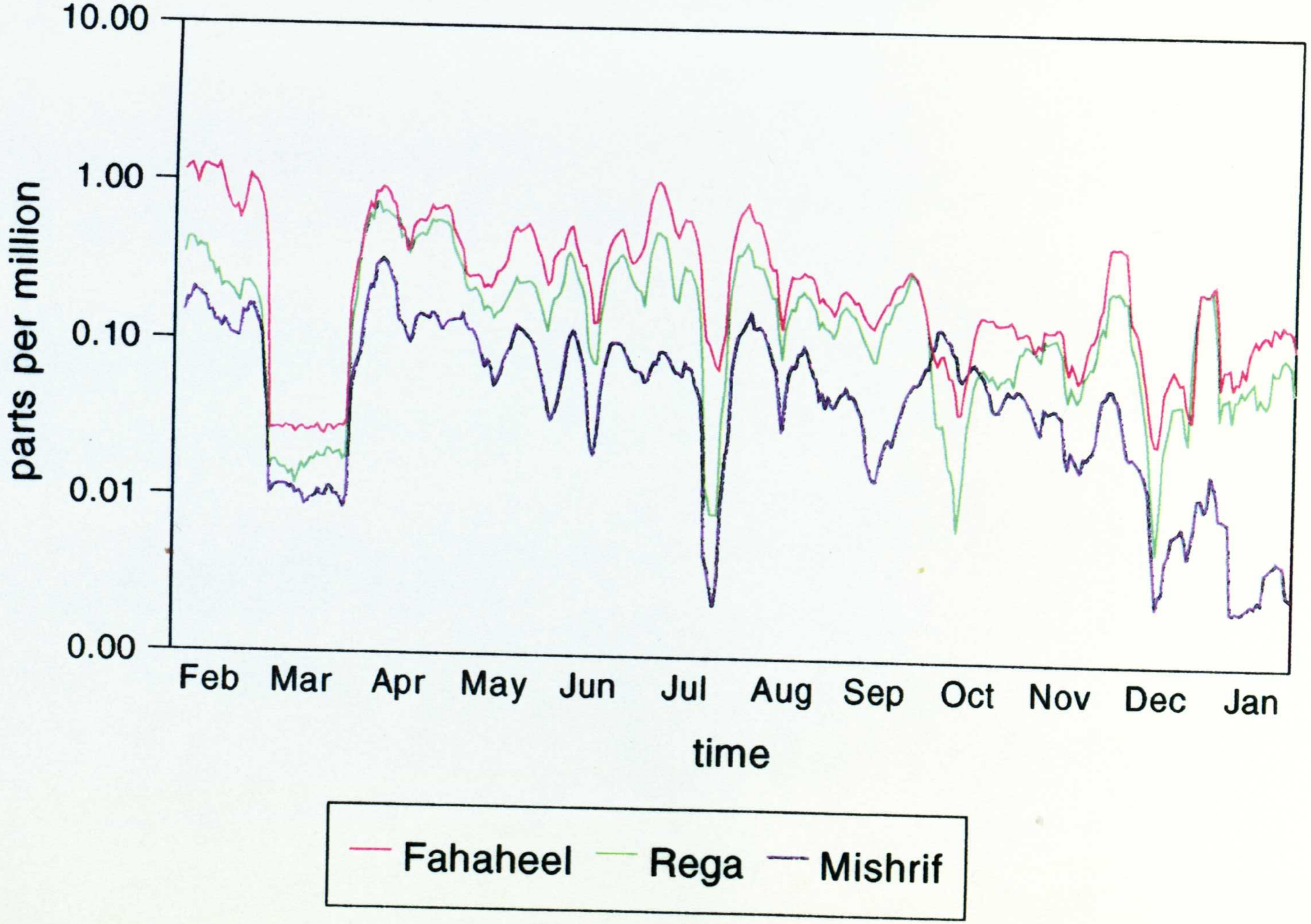


Sulphur Dioxide

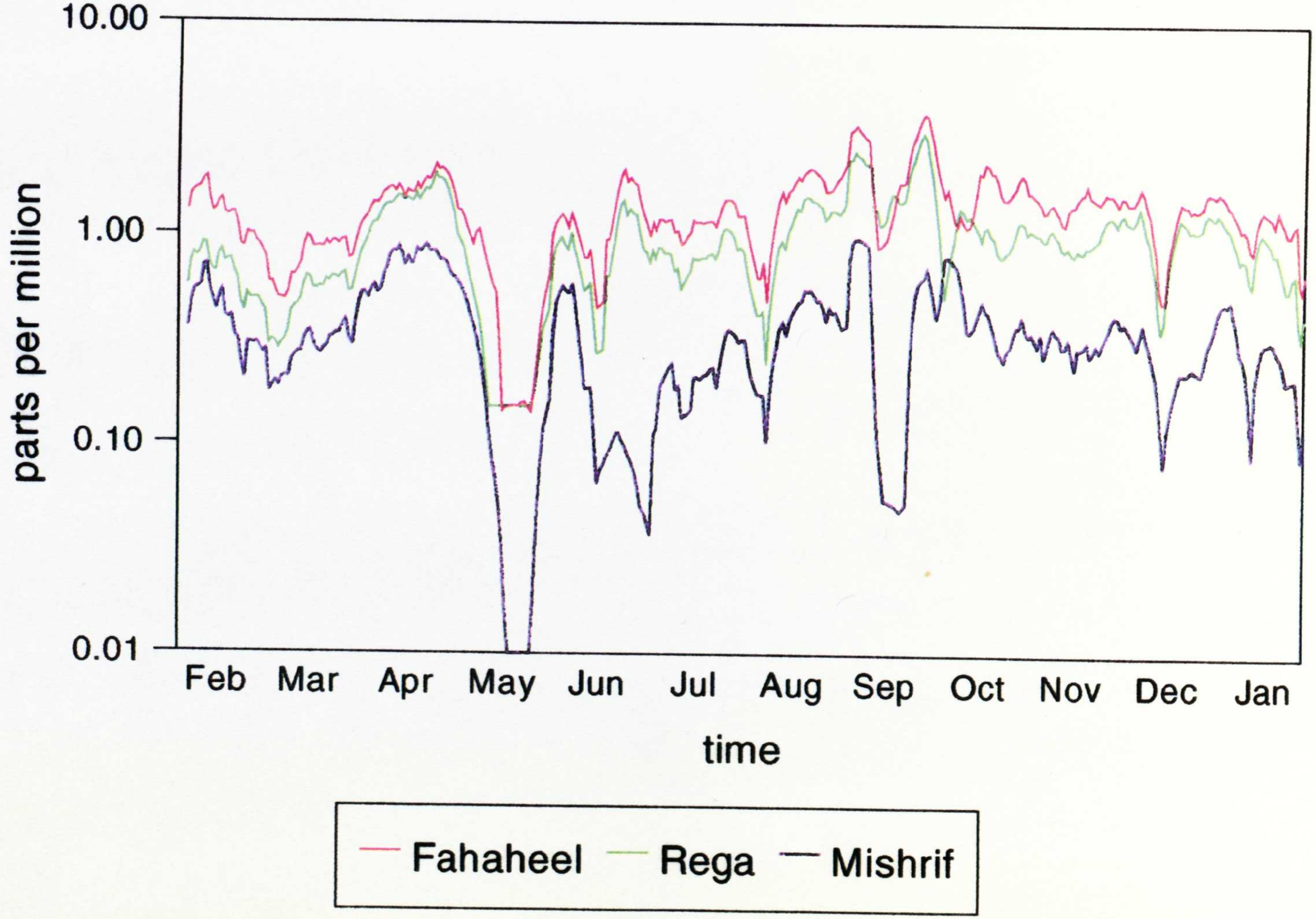
1 Feb 89 - 31 Jan 90



Hydrocarbons
1 Feb 89 - 31 Jan 90

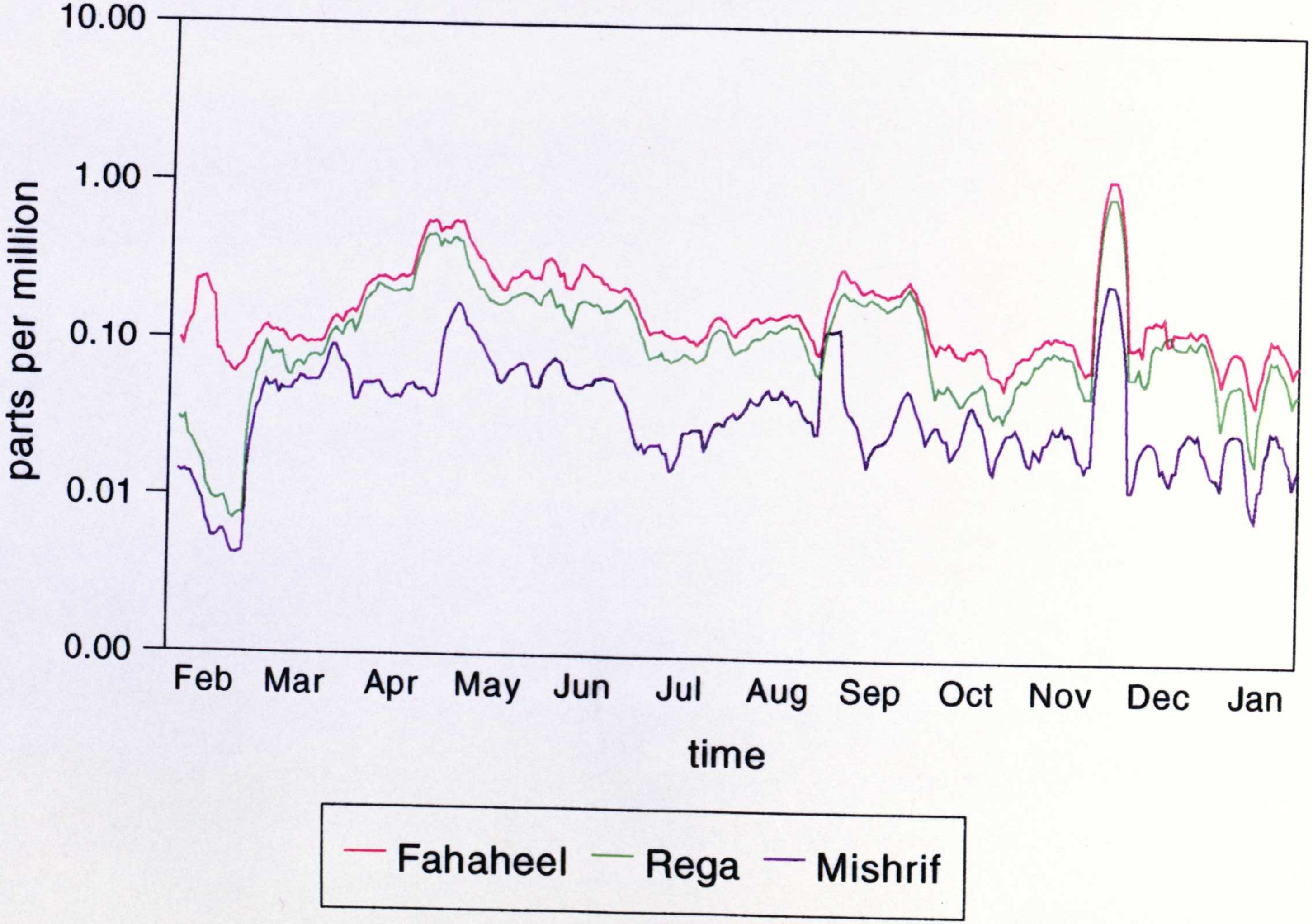


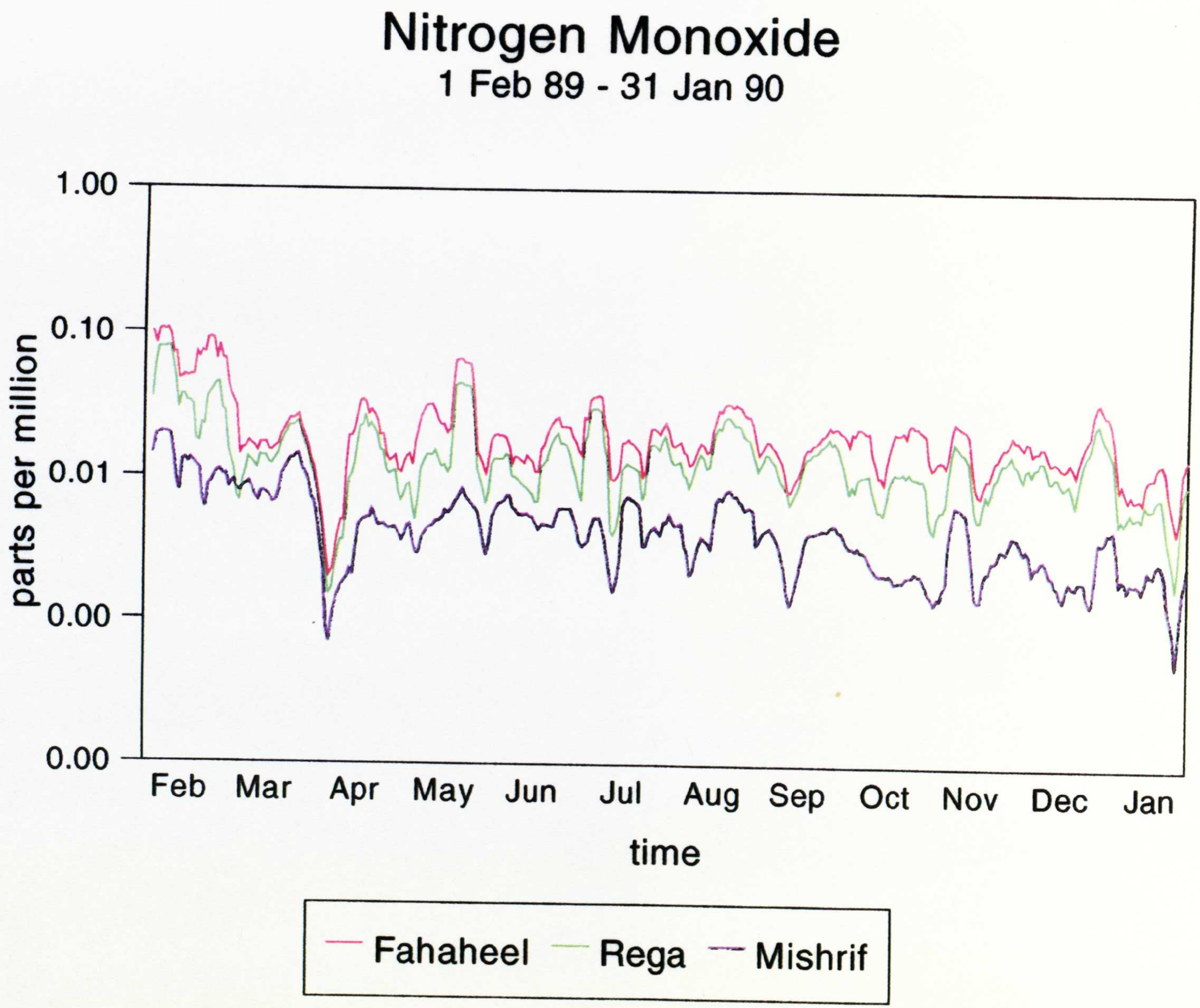
Carbon Monoxide
1 Feb 89 - 31 Jan 90



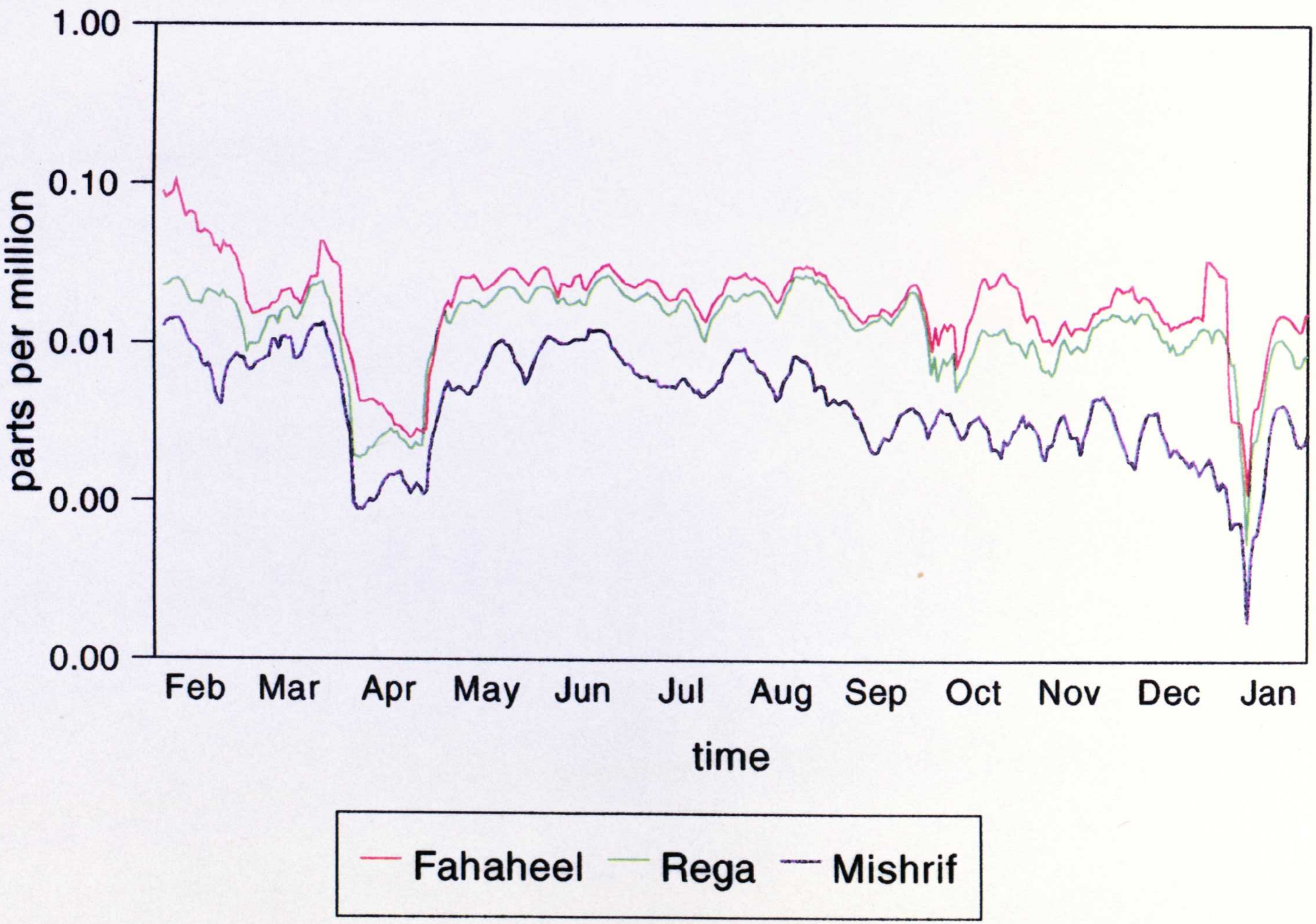
Ammonia

1 Feb 89 - 31 Jan 90




Nitrogen Monoxide
1 Feb 89 - 31 Jan 90
1.00
0.10
0.01
0.00
0.00
parts per million
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
time
Fahaheel
Rega
Mishrif

Nitrogen Dioxide
1 Feb 89 - 31 Jan 90



5.3 Meteorological Data

5.3.1 Completeness of the Data

The meteorological data for this study, from the Kuwait International Airport, were complete.

5.3.2 Meteorological Data in the Study Areas

The assumption in this study is that weather in each of the study areas will have been the same as at the airport. However, since the survey was carried out on different days in different areas, the possibility that the subjects in different areas might have experienced different weather conditions at the time that they were surveyed needs to be checked.

The variation in average temperature levels for the days on which subjects responded is small across the three areas (Table 5.4). The variation in humidity and precipitation levels is also small in absolute terms. Wind direction code shows that the wind is mostly from the north or north west. The implication is any problem with confounding in between area comparisons of the results of health survey arising out of between-area differences in meteorological factors will have been small.

5.3.3 Meteorological Data by Season

The meteorological data are given by season in Table 5.5. In Figures 5.9 to 5.12, time series for the whole study period, smoothed by taking 7-day averages, are presented for:

1. Average temperature.
2. Mean wind speed.
3. Maximum and minimum humidity.
4. Mean precipitation.

- Temperature shows the expected yearly cycle. Rising in the first half of the year, reaching a peak in mid year and declining in the second half (Figure 5.9).

- Windspeed shows a limited amount of seasonal variation, rising in the first half of the year and declining in the second (Figure 5.10). The day to day variability of the windspeed is greater than it was for temperature.

- For maximum humidity and minimum humidity the seasonal variation is very marked, declining in the middle of the year and increasing sharply in October (Figure 5.11).

- There was some rainfall in the first part of the year and some at the end of the year and some at the end of the year, but a negligible amount during the summer months (Figure 5.12).

Table (5.4) Meteorological Data for the 3 Study Areas on the Days in Which Subjects in the Household Survey Reported

	Fahaheel	Rega	Mishrif
Max. temperature:			
mean.	31.42	32.70	32.20
std. dev.	14.80	13.85	13.33
Min. temperature:			
mean.	19.06	20.44	18.05
std. dev.	10.77	9.57	10.12
Ave. temperature:			
mean.	25.17	26.55	25.43
std. dev.	12.94	11.78	11.77
Max. relative humidity:			
mean.	56.85	62.34	53.73
std. dev.	29.15	31.25	28.69
Min. relative humidity:			
mean.	13.22	19.33	18.09
std. dev.	11.03	23.15	19.90
Precipitation:			
mean.	0.40	0.80	0.48
std. dev.	0.80	1.27	1.32
Ave. wind speed:			
mean.	5.21	5.20	4.87
std. dev.	2.16	2.49	2.23
Wind direction code:			
mean.	6.46	5.58	7.05
std.dev.	2.22	2.40	1.90
Max. wind speed:			
mean.	8.52	8.56	7.93
std. dev.	2.39	2.53	2.44
number:	355	401	384

Data from the airport monitoring unit linked to data from the household survey.

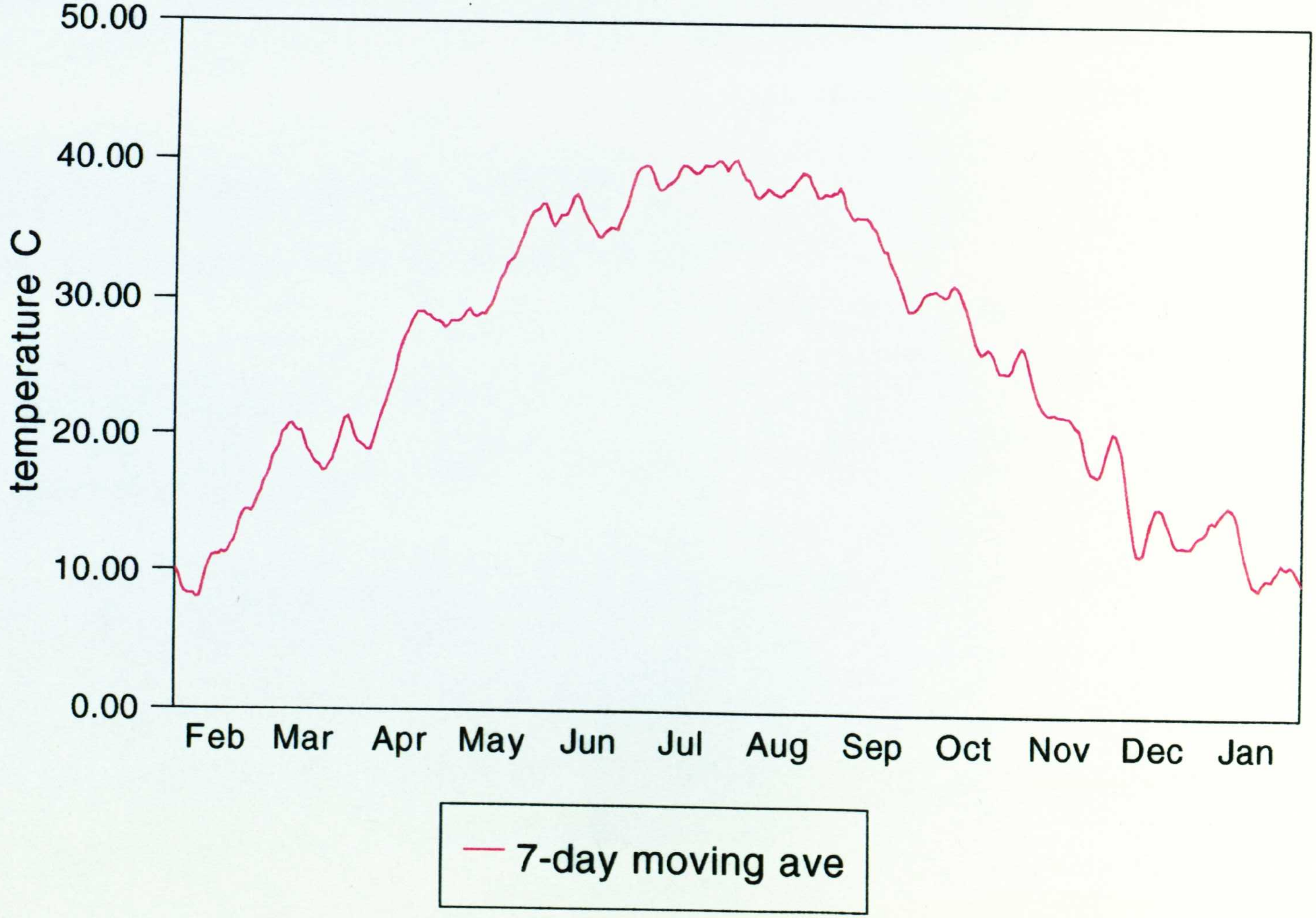
Table (5.5) Mean Daily Reading of Meteorological Data by time of Year

	Winter	Spring	Summer	Autumn
Max. temperature:				
mean.	18.47	45.88	46.30	18.36
st. dev.	1.21	2.25	1.50	2.54
Min. temperature:				
mean.	10.77	29.66	28.03	8.72
st. dev.	3.53	3.65	2.50	3.81
Ave. temperature:				
mean.	14.32	38.38	37.21	13.48
st. dev.	1.48	2.53	1.69	2.73
Max. relative humidity:				
mean.	80.34	18.13	47.88	87.06
st. dev.	10.20	4.96	20.72	8.49
Min. relative humidity:				
mean.	13.67	4.17	6.88	42.94
st. dev.	8.86	1.74	3.74	20.30
Precipitation:				
mean.	1.07	0.00	0.00	1.18
st. dev.	0.88	0.00	0.00	1.86
Ave. wind speed:				
mean.	4.21	7.36	4.64	4.22
st. dev.	0.83	1.86	2.16	2.39
Wind direction code:				
mean.	4.63	7.72	7.13	5.96
st. dev.	2.34	1.25	1.64	2.24
Max. wind speed:				
mean.	8.10	10.08	7.81	7.40
st. dev.	1.55	1.71	2.82	2.69
Number:	288	279	286	287

Data from the airport monitoring unit.

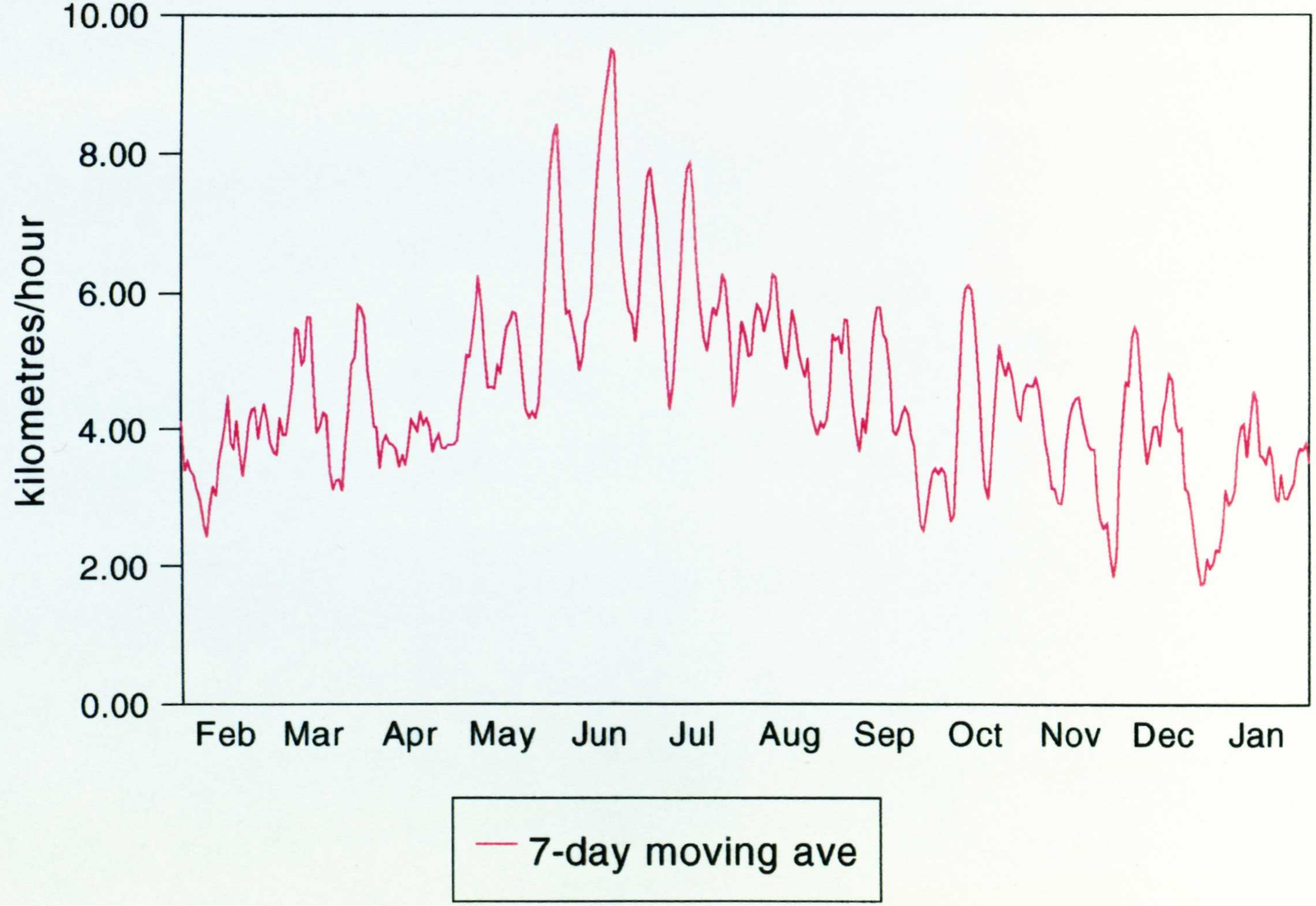
Mean temperature for previous 7 days

1 Feb 89 - 31 Jan 90



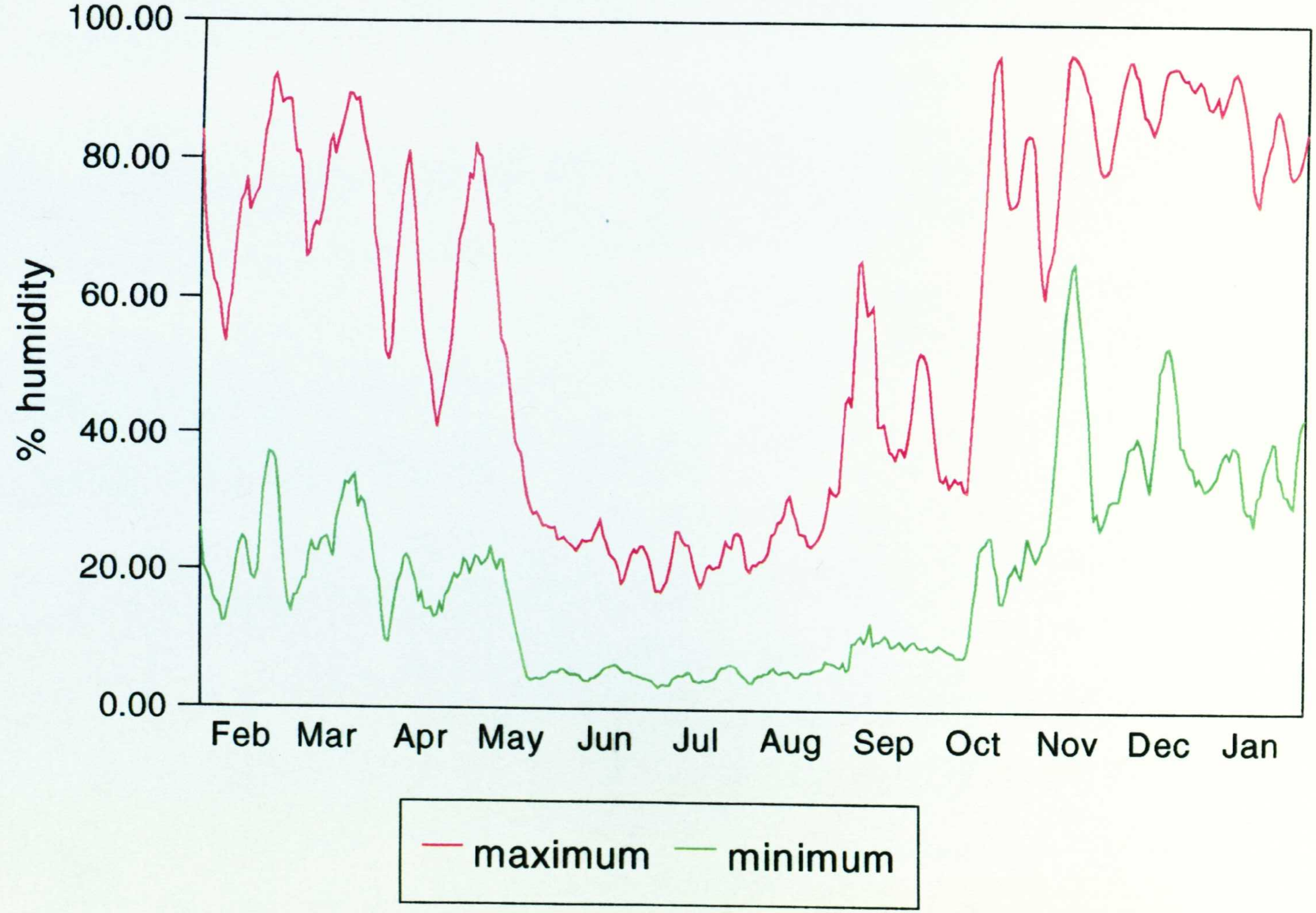
Mean windspeed for previous 7 days

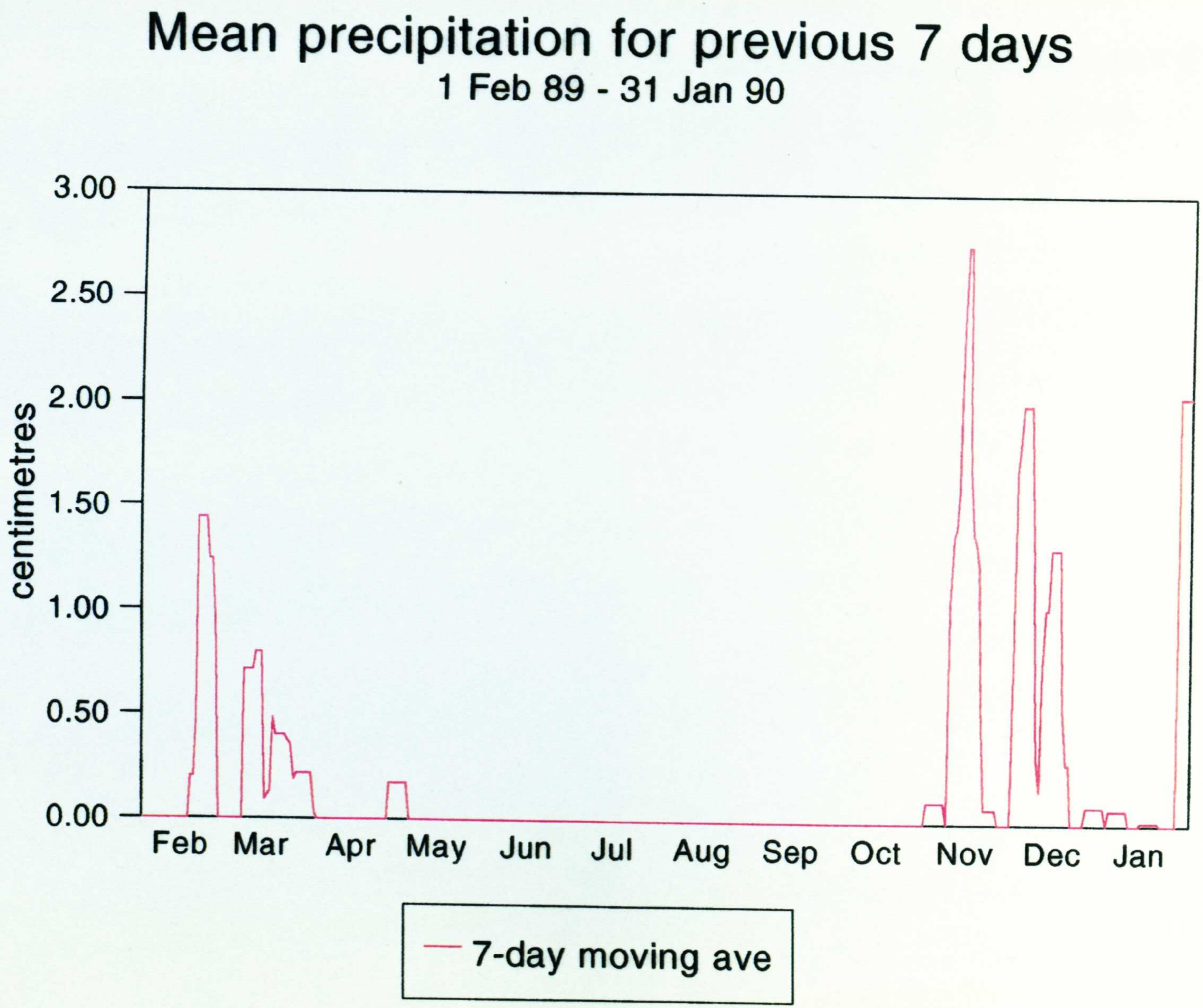
1 Feb 89 - 31 Jan 90



Max & min humidity for previous 7 days

1 Feb 89 - 31 Jan 90





Mean precipitation for previous 7 days
1 Feb 89 - 31 Jan 90
centimetres
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
7-day moving ave

5.4 Survey Data

5.4.1 Response

During the 12 months from February 1st, 1989 to January 31st, 1990. 1400 questionnaires were distributed and 1284 collected (91.7%). 114 of the questionnaires collected were not completed, giving 1140 suitable replies, an overall response rate of 81.4%. 11.4% of the enrollees did not complete the full questionnaire, and refusal to participate at all accounted for only a small part of the non-response.

The response rates for individual areas were 77.2%, 84.1% and 82.9% for Fahaheel, Rega and Mishrif respectively (Table 5.6). The response rates for the different seasons ranged from 82.8%, 77.7%, 83.3% and 82.2% for spring, summer and autumn 1989, and winter 1989/1990.

Table (5.6) Questionnaire Response in the 3 Areas and Season

	Spring	Summer	Autumn	Winter	Total	Responded	%
Fahaheel	108	120	112	120	460	355	77.2
Rega	116	124	115	122	477	401	84.1
Mishrif	125	117	115	106	463	384	82.9
Total	349	361	342	348	1400		
Responded	289	280	285	286		1140	
%	82.8	77.7	83.3	82.2			81.4

Data from household survey.

5.4.2 Demographic features

Table 5.7 shows the population structure and certain socio-economic characteristics by area. The male/female balance and the age structure vary very little. Slightly more in Mishrif had a university education and there was a small difference in the employment rates in the three areas.

Rega has the highest percentage of those living in villas, the lowest percentage of people spending 6 weeks or more away from their home, and the most people having lived in the area for more than 10 years.

There was, however, no consistent gradient with distance from the industrial area for either of these factors. The implication of this is that any problem with confounding between area comparisons of the differences in demographic or social factors will have been small.

When looking at demography with regard to season, it is apparent that there was a much higher absence from home in Kuwait during the summer (Table 5.8). The proportion in villa-dwellers accommodation were down in the summer, as were the proportion who spent at least 6 weeks away during the year.

Table (5.7) Demographic Features for the Three Study Areas

	Fahaheel	Rega	Mishrif
Gender:			
% male.	42.3	44.4	41.9
Age:			
% 0-4.	5.6	5.7	7.8
% 5-14.	23.7	24.9	22.7
% 15-24.	21.7	24.2	20.1
% 25-44.	33.8	29.7	35.2
% 45-64.	7.9	11.5	10.7
% 65+.	7.4	3.9	3.7
Nationality:			
% non-kuwaiti.	18.0	14.5	20.1
Housing:			
% rented.	12.4	0.0	10.2
% villa.	75.8	95.0	88.3
Years living in the area:			
< 5.	22.8	17.2	24.7
> = 5 and < 10.	31.9	24.4	29.4
> = 10 and < 15.	17.8	18.3	22.4
> = 15 and <25.	17.1	37.5	23.2
> 25.	10.4	2.6	0.3
Socioeconomic:			
% employed.	38.6	32.9	41.1
Education:			
% elementary or non.	32.7	33.7	30.2
% university.	16.9	15.2	21.9
Residence:			
% no weeks away.	18.0	24.9	13.5
% 6 + weeks away.	14.1	7.4	11.1
Number:	355	401	384

Data from household survey.

Table (5.8) Demographic Features by Season Over the Study Year

	Winter	Spring	Summer	Autumn
Gender:				
% male.	43.4%	41.0%	44.3%	42.8%
Age:				
% 0-4.	5.9%	6.6%	6.4%	6.7%
% 5-14.	22.7%	25.3%	21.8%	25.4%
% 15-24.	23.4%	21.9%	20.4%	21.9%
% 25-44.	33.9%	32.3%	36.4%	29.0%
% 45-64.	9.1%	9.7%	9.6%	12.0%
% 65+.	4.8%	4.1%	5.3%	4.9%
Nationality:				
% non-kuwaiti.	18.2%	18.1%	18.2%	15.5%
Housing:				
% rented.	5.9%	4.9%	11.4%	7.8%
% villa.	92.0%	88.9%	72.9%	92.9%
Socio-economic:				
% emoloyed.	38.1%	37.8%	39.3%	34.6%
Education:				
% elementary or non.	31.1%	37.2%	28.6%	31.8%
% university.	18.9%	14.2%	20.7%	18.0%
Residence:				
% no weeks away.	12.9%	25.3%	14.3%	23.0%
% 6+ weeks away.	33.1%	23.0%	19.6%	23.3%
Number:	286	288	280	283

Data from household survey.

5.4.3 Smoking

The only life-style factor considered was smoking habits. There is no evidence for between-area or seasonal differences in this respect (Table 5.9 and 5.10).

Older people are more likely to be smokers (Table 5.11 and 5.12) shows smoking by sex. In fact the number of women reported as being smokers was very low indeed (4.2% as against 26.4% for males).

Table (5.9) Smoking for the Three Study Areas

	Fahaheel	Rega	Mishrif
Smoking:			
never.	83.9%	85.8%	88.5%
ex-smoker.	2.3%	1.2%	1.0%
smoker.	12.4%	12.7%	10.4%
no response.	1.4%	0.2%	0.0%
Number:	355	401	384

Data from household survey.

Table (5.10) Smoking by Season Over the Study Year

	Winter	Spring	Summer	Autumn
Smoking:				
never.	85.7%	87.8%	84.2%	87.3%
ex-smoker.	2.4%	1.4%	1.1%	1.1%
smoker.	11.9%	10.4%	12.9%	11.6%
no response.	0.0%	0.3%	1.8%	0.0%
Number:	286	288	279	283

Data from household survey.

Table (5.11) Smoking for Different Age Groups Over the Study Year

	0-4	5-14	15-18	19-24	25-44	45-64	65+
Smoking:							
never.	100.0%	99.6%	96.2%	81.5%	81.3%	73.0%	58.2%
ex-smoker.	0.0%	0.0%	0.0%	0.0%	1.3%	4.3%	17.9%
Smoker.	0.0%	0.4%	3.8%	18.5%	17.3%	22.6%	23.2%
Number:	73	271	105	146	374	115	56

Data from household survey.

Table (5.12) Smoking by Sex Over the Study Year

	Male	Female
Smoking:		
never.	73.6%	95.7%
ex-smoker.	2.7%	1.1%
smoker.	23.8%	3.1%
Number:	489	651

Data from household survey.

5.4.4 Physical Symptoms

Percentage of survey respondents reporting physical symptoms in the three areas were calculated (Table 5.13). The Table also gives standard errors for those reporting symptoms on one day or more in the previous week. The decrease in symptom rates with distance of the area from the Shuaiba is very striking.

The most common symptom was headache. The gradient from Fahaheel to Mishrif was steep, but the rate in Mishrif was still a high rate. Coughing and irritation of nose and throat showed similar gradients as headache, but the general levels were lower.

It appears that eye irritation and tears in the eyes have very similar patterns, with Fahaheel again having the highest rate. Nausea, bronchitis, loss of vision, shortness of breath, wheezing and severe chest discomfort were less common, but the gradient from Fahaheel to Mishrif was seen nonetheless.

The prevalence of faintness was much higher in Fahaheel and Rega than in Mishrif.

One problem with interpretation of these data is that they are based on a cluster sample. Table 5.14 shows standard errors calculated using a method that takes account of the clustering. These standard errors are relatively small in most cases (between 1% and 3%), which indicates that the true values were close enough to the sample values for the differences between areas to be statistically significant.

To examine the effect of clustering for this study, these standard errors are compared with the corresponding standard errors calculated assuming random sampling. The differences between the standard errors based on cluster sampling and those assuming random sampling are small; for loss of vision for example, they were identical. The ratio of the two SEs ranged from 0.65 (irritation of skin in Fahaheel) to 1.41 (irritation of nose and throat in Rega).

The calculation of the standard errors that take account of clustering is a cumbersome procedure, with no well-documented equivalents for estimating the precision of regression coefficients. Since clustering seems to have had little effect on standard errors for physical symptoms in this study, statistical procedures that assume random sampling will be used in the remainder of the analysis.

Table 5.15 shows how physical symptoms vary with the time of the year. For some there were peaks in the winter and autumn, (cough, irritation of the nose and throat, shortness of breath, sore throat, dry throat, mucus of the nose, headache, bronchitis, chest discomfort and episodes of loss of vision). Nausea and tears in the eyes were less common in the spring. The prevalence of faintness and irritation in the eyes appear to be unrelated to time of year. Table 5.16 shows how physical symptoms are related to age. The oldest are most affected by respiratory symptoms, headache and eye problems. In case of nose and throat, the age group most affected was the under 14 years old group. All age groups were similarly subjected to skin infection.

Table (5.13) Physical Symptoms for the Three Study Areas

	Fahaheel %	Fahaheel st.er	Rega %	Rega st.er	Mishrif %	Mishrif st.er	P Value
Headache:							
one day or more.	56.3	2.20	40.6	2.32	22.7	2.25	.0000
two days or more.	25.6		21.4		9.4		
Irritant nose & throat:							
one day or more.	36.9	1.93	22.7	2.94	5.2	0.99	.0000
two days or more.	27.6		14.9		2.8		
Cough:							
one day or more.	33.8	2.62	21.4	1.87	6.2	1.12	.0000
two days or more.	24.5		16.7		4.7		
Sore throat:							
one day or more.	27.3	2.76	13.7	2.64	6.5	1.21	.0000
two days or more.	19.4		6.7		3.9		
Mucus:							
one day or more.	22.3	2.28	18.7	1.85	11.5	1.99	.0039
two days or more.	15.5		13.4		6.5		
Irritation of eyes:							
one day or more.	20.3	2.20	16.5	2.00	4.4	1.09	.0000
two days or more.	10.4		11.2		1.8		
Tears in eyes:							
one day or more.	20.3	2.01	14.0	2.00	3.9	1.01	.0000
two days or more.	9.6		8.7		1.8		
Irritation of skin:							
one day or more.	18.9	1.37	20.2	1.83	10.9	1.38	.0010
two days or more.	16.9		16.5		8.6		
Dryness of throat:							
one day or more.	18.2	1.65	11.2	1.60	5.7	1.16	.0000
two days or more.	20.5		5.7		3.2		
Faint or dizzy:							
one day or more.	13.0	1.72	10.7	1.10	3.6	1.12	.0006
two days or more.	4.8		2.2		1.3		
Chest discomfort:							
one day or more.	11.8	1.65	5.5	0.96	2.6	0.92	.0000
two days or more.	9.1		2.9		0.6		
Nausea:							
one day or more.	9.9	1.80	6.7	1.31	1.6	0.54	.0002
two days or more.	2.5		1.0		0.3		
Wheezing:							
one day or more.	9.6	1.62	5.2	0.88	2.1	0.70	.0022
two days or more.	3.3		1.5		0.3		
Bronchitis:							
one day or more.	9.3	1.61	5.0	0.91	2.9	0.94	.0000
two days or more.	8.2		2.2		0.8		
Shortness of breath:							
one day or more.	8.2	1.44	7.5	1.40	2.3	0.67	.0047
two days or more.	2.8		1.2		1.5		
Loss of vision:							
one day or more.	7.9	1.43	4.5	0.94	2.3	0.74	.0665
two days or more.	3.1		1.5		0.3		
Number:	355		401		384		

Data from household survey.

Table (5.14) Effect of Cluster on the Physical Symptoms

for the Three Study Area

	Fahaheel st.er.	Fahaheel ratio	Rega st.er.	Rega ratio	Mishrif st.er.	Mishrif ratio
Headache:						
cluster.	2.20	0.83	2.32	0.94	2.25	1.05
without cluster.	2.63		2.45		2.13	
Irritation of nose & throat:						
cluster.	1.93	0.99	2.94	1.41	0.99	0.89
without cluster.	1.93		2.07		1.10	
Cough:						
cluster.	2.62	1.04	1.87	0.91	1.12	0.90
without cluster.	2.51		2.03		1.23	
Sore throat:						
cluster.	2.76	1.16	2.64	0.99	1.21	0.96
without cluster.	2.36		2.63		1.26	
Mucous of the nose:						
cluster.	2.28	1.03	1.85	0.96	1.99	1.23
without cluster.	2.21		1.92		1.61	
Irritation of eyes:						
cluster.	2.20	1.03	2.00	1.09	1.09	1.06
without cluster.	2.13		1.83		1.02	
Tears in eyes:						
cluster.	2.01	0.94	2.00	1.17	1.01	1.05
without cluster.	2.13		1.70		0.95	
Irritation of skin:						
cluster.	1.37	0.65	1.83	0.92	1.38	0.87
without cluster.	2.07		1.98		1.57	
Dryness of throat:						
cluster.	1.65	0.99	1.60	1.04	1.16	0.99
without cluster.	1.65		1.54		1.16	
Faint or dizzy:						
cluster.	1.72	0.96	1.10	0.72	1.12	1.21
without cluster.	1.78		1.51		0.92	
Severe chest infection:						
cluster.	1.65	0.96	0.96	0.88	0.92	1.20
without cluster.	1.71		1.08		0.77	
Nausea:						
cluster.	1.80	1.14	1.31	1.08	0.54	0.93
without cluster.	1.58		1.20		0.57	
Wheezing or whistling:						
cluster.	1.62	1.04	0.88	0.83	0.70	1.02
without cluster.	1.56		1.06		0.68	
Bronchitis:						
cluster.	1.61	1.04	0.91	0.90	0.94	1.15
without cluster.	1.54		1.00		0.81	
Shortness of breath:						
cluster.	1.44	0.99	1.40	1.10	0.67	0.87
without cluster.	1.45		1.27		0.77	
Episodes of loss vision:						
cluster.	1.43	1.00	0.94	0.96	0.74	1.01
without cluster.	1.43		0.97		0.72	

Data from household survey.

Table (5.15) Physical Symptoms by Time of the Year

	Winter	Spring	Summer	Autumn	P Value
Headache:					
one day or more.	41.3%	35.8%	35.8%	45.2%	.1660
two days or more.	19.2%	18.1%	14.3%	23.0%	
Irritation of nose & throat:					
one day or more.	30.1%	9.7%	18.6%	26.5%	.0000
two days or more.	23.8%	5.2%	9.7%	20.5%	
Coughing:					
one day or more.	22.7%	14.2%	18.6%	25.1%	.0000
two days or more.	19.9%	10.4%	9.3%	20.5%	
Sore throat:					
one day or more.	22.0%	10.4%	11.1%	18.4%	.0001
two days or more.	15.7%	5.2%	5.0%	12.8%	
Mucus of the nose:					
one day or more.	19.9%	13.5%	15.4%	20.8%	.0141
two days or more.	12.6%	9.0%	8.4%	17.3%	
Irritation in eyes:					
one day or more.	16.4%	9.4%	14.3%	14.5%	.2934
two days or more.	9.4%	4.9%	8.3%	8.9%	
Tear in eyes:					
one day or more.	15.7%	8.3%	14.3%	12.0%	.1327
two days or more.	8.0%	4.1%	7.6%	7.1%	
Irritation in skin:					
one day or more.	17.8%	15.6%	13.3%	19.8%	.0014
two days or more.	15.7%	12.5%	10.4%	17.0%	
Dryness of throat:					
one day or more.	21.3%	10.1%	10.8%	16.3%	.0008
two days or more.	15.7%	5.2%	5.0%	11.7%	
Faint or dizzy:					
one day or more.	9.1%	7.6%	9.7%	9.9%	.8361
two days or more.	3.4%	1.7%	2.9%	2.9%	
Chest infection:					
one day or more.	8.4%	4.9%	4.7%	8.1%	.0882
two days or more.	5.9%	1.7%	3.3%	6.7%	
Nausea:					
one day or more.	7.3%	2.1%	6.5%	8.1%	.0299
two days or more.	2.4%	0.35	0.7%	1.5%	
Wheezing or whistling:					
one day or more.	5.6%	3.8%	5.7%	7.1%	.5984
two days or more.	1.0%	1.4%	1.8%	2.5%	
Bronchitis:					
one day or more.	7.0%	4.2%	3.9%	7.2%	.0850
two days or more.	4.1%	1.7%	2.1%	6.4%	
Shortness of breath:					
one day or more.	7.7%	3.8%	3.9%	8.5%	.0496
two days or more.	3.1%	1.0%	1.1%	2.2%	
Episodes of loss vision:					
one day or more.	5.9%	2.8%	4.7%	6.0%	.0473
two days or more.	1.4%	0.0%	2.5%	2.5%	
Number:	286	288	279	283	

Data from household survey.

Table (5.16) Physical Symptoms for Different Age Groups

	1-4	5-14	15-18	19-24	25-44	45-64	65+
Headache:							
one day or more.	4.1%	24.4%	33.3%	35.0%	51.6%	59.1%	55.4%
two days or more.	0.0%	7.4%	11.4%	13.1%	27.3%	33.0%	39.3%
Irritation of nose:							
one day or more.	22.0%	17.3%	21.9%	24.0%	23.0%	17.3%	21.4%
two days or more.	20.6%	14.7%	12.3%	14.4%	14.3%	13.1%	19.6%
Cough:							
one day or more.	13.7%	21.0%	16.4%	16.4%	18.7%	27.0%	35.7%
two days or more.	13.7%	12.5%	11.4%	12.0%	13.6%	23.5%	33.9%
Sore throat:							
one day or more.	6.8%	14.7%	17.1%	15.8%	17.4%	13.9%	14.3%
two days or more.	4.1%	11.4%	9.5%	9.6%	8.0%	9.6%	12.5%
Mucus:							
one day or more.	42.4%	16.6%	13.4%	11.6%	18.5%	12.2%	9.0%
two days or more.	39.7%	9.6%	6.7%	8.9%	12.6%	6.1%	9.0%
Irritation of eye:							
one day or more.	5.5%	7.8%	16.3%	15.8%	16.7%	12.1%	19.7%
two days or more.	0.0%	4.8%	9.6%	10.3%	8.9%	7.8%	16.1%
Tear:							
one day or more.	4.1%	6.6%	16.3%	13.1%	15.5%	12.1%	19.6%
two days or more.	0.0%	3.3%	11.4%	6.9%	7.2%	6.9%	17.8%
Skin:							
one day or more.	15.0%	13.2%	18.1%	17.8%	17.4%	19.1%	12.6%
two days or more.	12.3%	11.4%	16.2%	15.4%	14.7%	14.8%	10.8%
Dry throat:							
one day or more.	6.8%	13.3%	18.2%	15.1%	15.0%	13.9%	17.9%
two days or more.	4.1%	10.7%	11.5%	8.9%	8.3%	9.6%	16.1%
Faintness:							
one day or more.	6.9%	7.7%	7.7%	7.6%	7.5%	12.1%	23.3%
two days or more.	1.4%	1.1%	2.9%	2.1%	2.2%	6.0%	10.8%
Chest:							
one day or more.	6.8%	7.3%	3.9%	4.8%	3.7%	5.3%	26.8%
two days or more.	4.1%	6.2%	1.0%	4.1%	1.6%	4.4%	21.4%
Nausea:							
one day or more.	5.5%	5.5%	5.7%	2.8%	5.4%	5.2%	17.9%
two days or more.	0.0%	1.1%	0.0%	0.7%	1.1%	1.7%	7.2%
Wheezing:							
one day or more.	4.1%	5.6%	4.9%	2.8%	3.5%	7.0%	21.4%
two days or more.	0.0%	1.5%	2.0%	1.4%	0.3%	3.5%	10.7%
Bronchitis:							
one day or more.	5.5%	6.3%	3.8%	4.2%	2.4%	6.0%	12.4%
two days or more.	2.8%	4.8%	1.9%	3.5%	0.8%	4.3%	19.6%
Breath:							
one day or more.	5.5%	5.5%	2.9%	4.1%	3.2%	10.4%	25.0%
two days or more.	1.4%	1.1%	1.0%	1.4%	1.3%	2.6%	10.7%
Vision:							
one day or more.	4.1%	1.8%	5.8%	1.4%	4.5%	4.3%	23.2%
two days or more.	1.4%	0.0%	1.0%	0.7%	1.6%	3.4%	8.8%
Number:	73	271	105	146	374	115	56

Data from household survey.

5.4.5 Psychological symptoms

The breakdown for a range of variables relating to the respondent's psychological health again shows a higher percentage reporting problems in Fahaheel than in Rega and a much lower percentage than Mishrif (Table 5.17).

The most commonly reported problems were finding it annoying to go outside, and loss of appetite. There were very striking gradients from Fahaheel to Mishrif for both of these.

Feeling tired was also common, but the gradient from Fahaheel to Mishrif was much less steep, with over 50% reporting this problem in Mishrif.

For taking a long time to sleep, laying awake most nights and loss of temper, the differences between the areas were relatively small, although gradients were still seen. Itching skin and under weight are 2.5 times as common in Fahaheel as in Mishrif.

Running out of energy, sleeping badly at night and waking up feeling depressed followed a similar pattern although depression was less common than the other two symptoms in Mishrif. Five times as many subjects took tablets to get to sleep in Fahaheel as in Mishrif. Lose of appetite was 8 times as common, anxiety and waking up feeling depressed were 10 times as common and feeling distress was 15 times as common in Fahaheel as in Mishrif.

Table 5.18 shows psychological symptoms by season. Finding it annoying to go outside, sleeping badly at night, waking up feeling depressed, loss of appetite and tearfulness were most common in winter and autumn. Loss of sense of smell and under weight were also more prevalent in winter.

Taking a long time to go to sleep, taking tablets to go to sleep and loss of temper appears to have been unrelated to time of year. While feeling tired and anxious was slightly higher in summer, running out of energy was lower.

Table 5.19 shows the prevalence of psychological symptoms in different age groups. The oldest are most affected by tiredness, finding it annoying to go outside, loss of energy, loss of appetite and waking up early in the morning. All age groups are similarly subjected to skin itching.

Table (5.17) Psychological Symptoms in the Three Study Area

	Fahaheel	Rega	Mishrif	P Value
Annoying to go outside:				
some of the time.	81.4%	48.6%	1.8%	.0000
most of the time.	20.0%	4.2%	0.5%	
Feeling tired:				
some of the time.	74.6%	63.3%	54.2%	.0000
most of the time.	16.1%	11.5%	1.6%	
Loss of appetite:				
some of the time.	67.0%	36.4%	9.4%	.0000
most of the time.	8.5%	3.7%	0.5%	
Lost of sense of smell:				
some of the time.	54.4%	10.5%	0.8%	.0000
most of the time.	8.5%	2.0%	0.3%	
Feeling depressed:				
some of the time.	48.7%	26.2%	4.7%	.0000
most of the time.	6.2%	1.2%	0.3%	
Poor Sleeping:				
some of the time.	40.0%	26.4%	10.7%	.0000
most of the time.	1.4%	1.0%	0.5%	
Running out of energy:				
some of the time.	39.9%	17.0%	10.4%	.0000
most of the time.	6.5%	3.2%	1.0%	
Loss of weight:				
some of the time.	28.2%	28.4%	8.8%	.0000
most of the time.	26.2%	25.2%	5.7%	
Loss of temper:				
some of the time.	26.8%	23.7%	14.1%	.0004
most of the time.	2.0%	3.0%	0.5%	
Itching skin:				
some of the time.	23.4%	20.4%	9.6%	.0000
most of the time.	12.4%	8.7%	2.9%	
Waking up in early morning:				
some of the time.	22.0%	9.5%	4.4%	.0000
most of the time.	4.8%	1.0%	0.3%	
Problems with sleeping:				
some of the time.	18.6%	24.9%	13.5%	.0011
most of the time.	1.4%	1.2%	0.0%	
Distress & on edge of tears:				
some of the time.	15.8%	15.7%	1.0%	.0000
most of the time.	1.4%	1.7%	0.5%	
Taking sleeping tablets:				
some of the time.	14.9%	9.7%	2.9%	.0000
most of the time.	3.7%	1.2%	0.8%	
Anxiety:				
some of the time.	9.9%	1.7%	1.0%	.0000
most of the time.	4.2%	0.2%	0.3%	
Lying awake most nights:				
some of the time.	7.7%	5.7%	6.0%	.4113
most of the time.	0.6%	0.5%	0.0%	
Number:	355	401	384	

Data from household survey.

Table (5.18) Psychological Symptoms by Time of Year

	Winter	Spring	Summer	Autumn	P Value
Annoying to go outside:					
some of the time.	57.0%	22.2%	42.1%	50.9%	.0000
most of the time.	12.2%	1.7%	4.6%	12.7%	
Tiredness:					
some of the time.	62.9%	60.4%	70.4%	61.5%	.0173
most of the time.	11.9%	8.0%	7.1%	11.3%	
Loss of appetite:					
some of the time.	43.4%	27.8%	32.9%	43.1%	.0001
most of the time.	6.6%	0.7%	3.6%	5.7%	
Lost of sense of smell:					
some of the time.	30.1%	6.9%	23.9%	22.6%	.0000
most of the time.	4.5%	2.1%	3.9%	3.2%	
Feeling depressed:					
some of the time.	35.0%	17.4%	20.4%	31.1%	.0000
most of the time.	3.8%	0.7%	0.7%	4.6%	
Poor Sleeping:					
some of the time.	26.6%	19.4%	22.9%	32.5%	.0062
most of the time.	1.0%	0.0%	0.7%	2.1%	
Running out of energy:					
some of the time.	27.6%	20.5%	14.6%	26.9%	.0032
most of the time.	3.5%	4.2%	2.1%	3.9%	
Loss of weight:					
some of the time.	34.6%	14.9%	17.1%	20.1%	.0000
most of the time.	32.2%	11.8%	13.9%	17.1%	
Loss of temper:					
some of the time.	19.9%	25.0%	20.0%	20.8%	.1223
most of the time.	1.7%	2.1%	0.4%	3.2%	
Itching skin:					
some of the time.	18.5%	13.9%	17.9%	20.1%	.0025
most of the time.	11.9%	3.1%	6.1%	10.2%	
Waking up in early morning:					
some of the time.	15.4%	7.6%	12.1%	11.0%	.0002
most of the time.	5.2%	0.3%	0.4%	1.4%	
Problems with getting to sleep:					
some of the time.	17.8%	19.8%	20.0%	18.7%	.3118
most of the time.	1.7%	0.3%	0.7%	0.7%	
Feeling distress:					
some of the time.	11.9%	8.2%	8.6%	14.5%	.0010
most of the time.	2.1%	0.3%	0.0%	2.5%	
Taking sleeping tablets:					
some of the time.	9.4%	7.6%	8.6%	10.6%	.1924
most of the time.	2.8%	0.0%	1.9%	2.8%	
Anxiety:					
some of the time.	2.8%	3.5%	6.8%	3.2%	.0656
most of the time.	1.4%	1.4%	1.4%	1.8%	
Lying awake most nights:					
some of the time.	3.1%	4.5%	8.9%	9.5%	.0177
most of the time.	0.3%	0.0%	0.4%	0.7%	
Number:	286	288	280	283	

Data from household survey.

Table (5.19) Psychological Symptoms for Different Age Groups

	1-4	5-14	15-18	19-24	25-44	45-64	65+
Annoying:							
some of the time.	16.5%	32.5%	39.1%	45.8%	49.5%	51.3%	66.1%
most of the time.	5.5%	5.9%	6.7%	6.8%	7.5%	9.6%	25.0%
Tiredness:							
some of the time.	16.5%	42.4%	52.4%	61.6%	84.0%	74.7%	92.8%
most of the time.	5.5%	5.9%	4.8%	8.2%	8.3%	13.0%	46.4%
Lost of appetite:							
some of the time.	21.9%	29.9%	28.6%	37.6%	42.8%	36.5%	58.9%
most of the time.	4.1%	7.4%	2.9%	3.4%	2.7%	1.7%	7.1%
Lost of smell:							
some of the time.	2.8%	15.1%	19.1%	26.0%	21.4%	23.4%	48.3%
most of the time.	1.4%	3.7%	4.8%	3.4%	1.6%	1.7%	17.9%
Feeling depress:							
some of the time.	6.9%	19.2%	17.2%	28.1%	31.0%	30.5%	44.6%
most of the time.	1.4%	3.3%	2.9%	0.7%	1.6%	0.9%	12.5%
Poor sleep:							
some of the time.	24.6%	12.5%	18.1%	28.8%	31.6%	27.8%	41.1%
most of the time.	6.8%	0.7%	1.0%	0.0%	0.3%	0.0%	3.6%
Energy:							
some of the time.	5.5%	15.5%	11.4%	19.1%	24.0%	23.0%	69.7%
most of the time.	1.4%	3.0%	1.9%	2.7%	0.5%	4.3%	30.4%
Loss of weight:							
some of the time.	26.1%	29.9%	25.8%	24.0%	17.1%	7.0%	19.7%
most of the time.	24.7%	25.1%	22.9%	22.6%	15.2%	6.1%	16.1%
Loss of temper:							
some of the time.	5.5%	13.2%	15.3%	26.1%	25.9%	35.1%	17.8%
most of the time.	0.0%	0.7%	2.9%	2.1%	1.3%	3.5%	7.1%
Itching skin:							
some of the time.	15.1%	15.5%	19.0%	17.1%	18.5%	19.1%	17.8%
most of the time.	9.6%	7.0%	5.7%	9.6%	8.3%	7.8%	7.1%
Wake up early:							
some of the time.	6.9%	5.2%	2.9%	4.8%	12.3%	20.0%	55.4%
most of the time.	1.4%	0.0%	0.0%	2.1%	2.1%	0.9%	16.1%
Getting to sleep:							
some of the time.	6.8%	7.4%	17.2%	26.0%	27.0%	23.5%	12.5%
most of the time.	2.7%	0.4%	1.0%	0.7%	0.8%	0.9%	1.8%
Distress:							
some of the time.	15.0%	9.6%	4.8%	9.0%	8.4%	11.4%	23.7%
most of the time.	8.2%	1.1%	1.0%	0.0%	0.0%	0.0%	7.3%
Taking tablets:							
some of the time.	1.4%	4.1%	7.6%	9.6%	8.3%	16.5%	28.6%
most of the time.	0.0%	1.1%	1.9%	2.1%	0.8%	1.7%	14.3%
Anxiety:							
some of the time.	1.4%	3.6%	1.9%	2.8%	2.7%	6.2%	23.2%
most of the time.	1.4%	1.8%	0.0%	0.7%	0.8%	0.0%	12.5%
Lying awake:							
some of the time.	1.4%	2.5%	4.8%	8.2%	7.5%	9.6%	12.5%
most of the time.	0.0%	0.7%	0.0%	0.0%	0.3%	0.0%	1.8%
Number:	73	271	105	146	374	115	56

Data from househld survey.

5.4.6 Use of Health Care

There was a striking gradient in prevalence of self-reported ill health from Fahaheel to Mishrif, and corresponding gradients in the use of medical services (Table 5.20). The gradient was particularly strong for hospital admissions.

There was relatively little seasonal variation in self-reported ill health; slightly fewer people reported ill health during the spring. Visiting rates for hospital out-patients were high during winter and autumn and the highest rates of hospital admission were in the autumn (Table 5.21).

The age group reporting the worst levels of overall health and the most use of hospital care was, not surprisingly, the elderly. Children under 5 were most likely to have visited a GP in the previous week (Table 5.22).

Corroborating data on health centre attendance and referral to out-patients were available from the local clinics, and these are presented as time series in Figures 5.13 and 5.14. The daily rates have been smoothed using a 7 day moving average.

In terms of health centre attendance Fahaheel and Rega vary in parallel in terms of health centre attendance, with Fahaheel lower than that in Rega. In Fahaheel and Mishrif there are decreases in February and another decrease in May, and a sustained decrease during the summer months of July, August and September. In Rega, by contrast, there is a small increase in February, followed by a decrease in

May and June. It increases again in July and August, decreases in September and increases in October with the return from vacation (Figure 5.13).

In respect of referral to hospital out-patient, Fahaheel had higher rates than Rega or Mishrif. In Fahaheel and Mishrif there was an increase in the spring, a decrease in the summer months and an increase again in the winter (Figure 5.14).

Table (5.20) Reported Ill Health and Use of Health Care for the Three Study Areas

	Fahaheel	Rega	Mishrif	P Value
In the last 12 months: % health only fairly good or worse.	18.1%	6.7%	2.4%	.0000
Visited GP at least once in previous week:	47.9%	37.6%	31.3%	.0001
Visited hospital outpatient at least once in last 3 months:	26.2%	22.1%	6.8%	.0000
Admitted into hospital at least once in last 12 months:	22.6%	15.7%	5.4%	.0000
Number:	355	401	384	

Data from household survey.

Table (5.21) Reported Ill Health and Use of Health Care by Time of Year for the Three Study Areas

	Winter	Spring	Summer	Autumn	P Value
In the last 12 months: % health only fairly good or worse.	10.8%	5.9%	8.3%	9.9%	.3077
Visited GP at least once in previous week:	40.2%	37.1%	30.5%	46.6%	.0042
Visited hospital outpatient at least once in last 3 months:	22.3%	11.1%	17.2%	22.6%	.0042
Admitted into hospital at least once in last 12 months:	18.2%	9.0%	10.1%	20.2%	.0011
Number:	286	288	278	283	

Data form household survey.

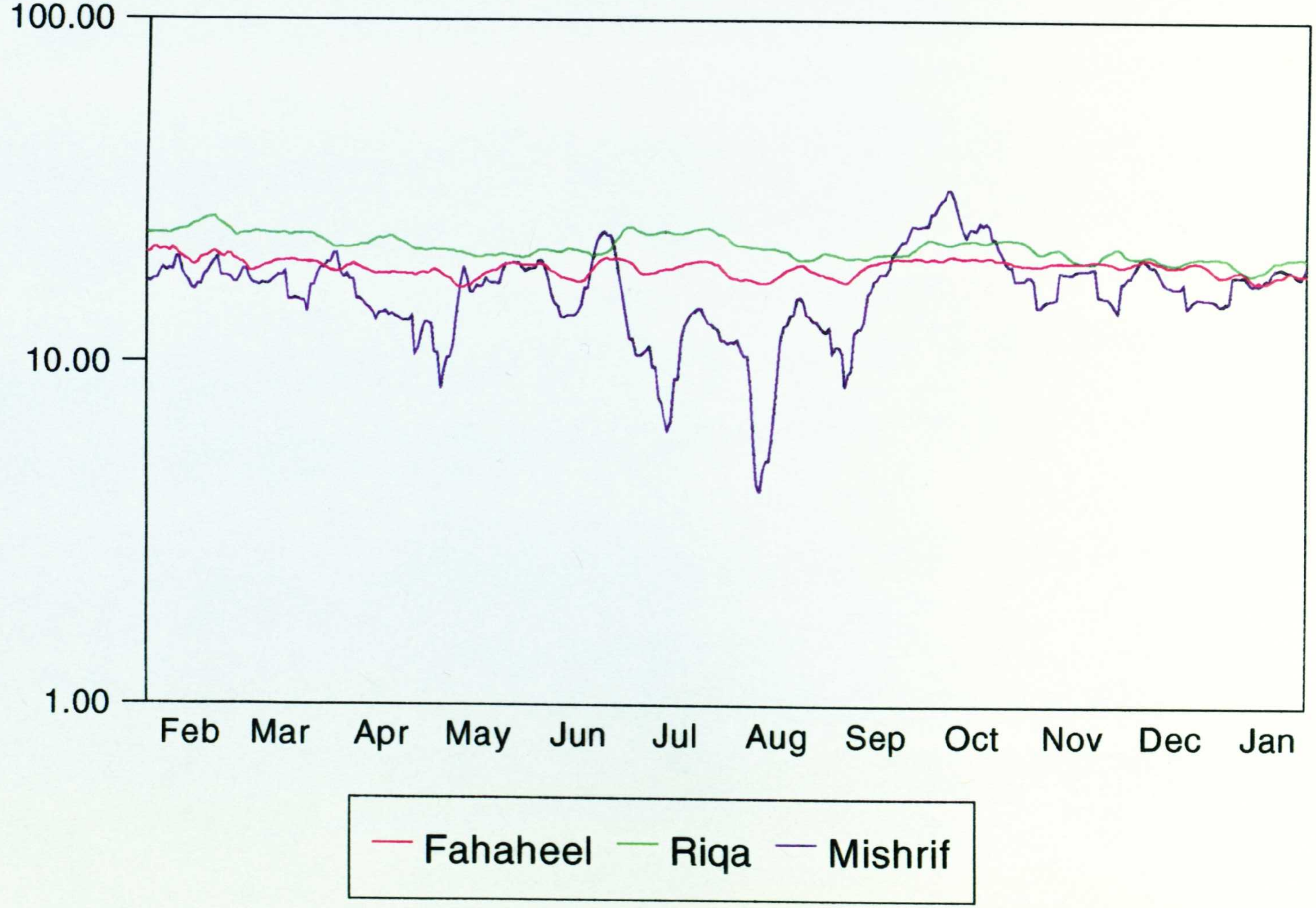
Table (5.22) Reported Ill Health and Use of Health Care for the Different Age Groups

	0-4	5-14	15-18	19-24	25-44	45-64	65+
In the last 12 months: % health only fairly good or worse.	5.5%	6.7%	5.7%	6.2%	3.5%	17.4%	53.6%
Visited GP at least once in previous week:	50.7%	37.6%	36.2%	36.6%	39.8%	36.5%	35.7%
Visited hospital outpatient at least once in last 3 months:	20.5%	19.9%	19.1%	11.7%	11.2%	26.9%	48.2%
Admitted into hospital at least once in last 12 months:	4.1%	12.5%	10.5%	10.2%	10.2%	27.0%	58.9%
Number:	73	271	105	146	374	115	56

Data form household survey.

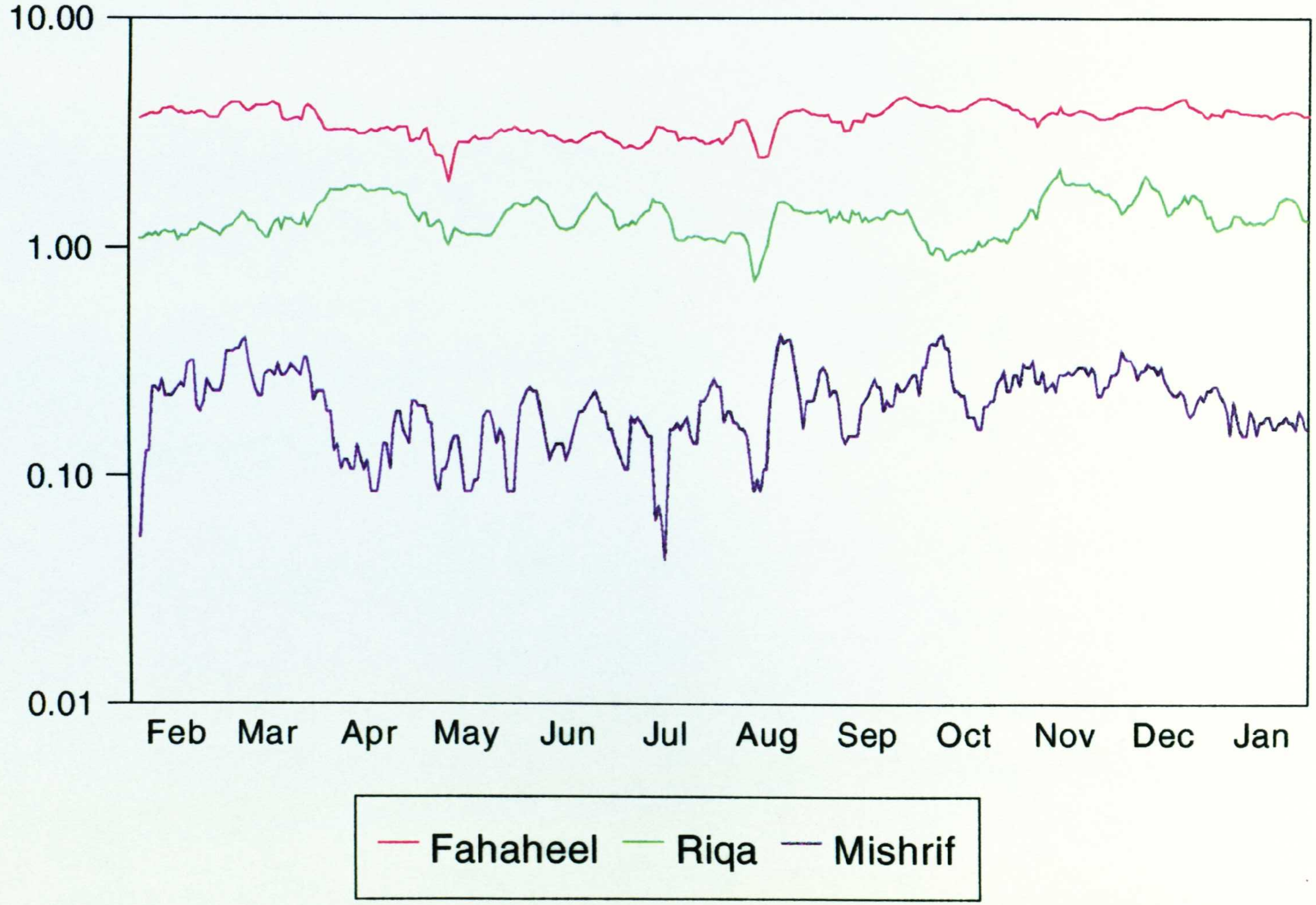
Attendance at health centres per 1000 population

7-day moving average



Outpatient visits per 1000 population

7-day moving average



5.4.6 Satisfaction With Quality of Life

The greatest dissatisfaction with social life was evident in Fahaheel, although contentment with family social life was highest in this area. For interests and hobbies dis-satisfaction was highest in Fahaheel and lowest in Mishrif. Attitudes to employment do not vary in the three areas (Table 5.23).

The proportion who were less than satisfied with their social life drops during the summer months (Table 5.24).

Table (5.23) Quality of Life for the Three Study Areas

	Fahaheel	Rega	Mishrif	P Value
Job: indifferent to very dissatisfied.	5.2%	5.0%	3.4%	.2296
School: indifferent to very dissatisfied.	10.6%	10.7%	5.7%	.0001
Social life: indifferent to very dissatisfied.	39.7%	21.4%	9.4%	.0000
Family social life: indifferent to very dissatisfied.	19.8%	28.9%	33.6%	.0000
Interests & hobbies: indifferent to very dissatisfied.	61.1%	41.6%	35.1%	.0000
Number:	355	401	384	

Data from household survey.

Table (5.24) Quality of Life for the Three Study Areas by Time of the Year

	Winter	Spring	Summer	Autumn	P Value
Job: indifferent to very dissatisfied.	4.1%	3.1%	4.1%	6.7%	.1423
School: indifferent to very dissatisfied.	9.7%	7.0%	9.9%	9.6%	.7047
Social life: indifferent to very dissatisfied.	22.7%	28.4%	18.7%	22.6%	.0000
Family social life: indifferent to very dissatisfied.	15.9%	37.1%	25.1%	32.5%	.0000
Interests & hobbies: indifferent to very dissatisfied.	47.9%	42.0%	36.9%	54.7%	.0000
Number:	286	288	279	283	

Data from household survey.

5.4.7 Environmental Problems

The greatest concern with environmental problems was in Fahaheel, although quite high figures were also seen in Rega (Table 5.25). The most commonly reported problems were with dust, dampness, insects and smell, with strong gradients between the areas studied for smell. However, there were also gradients in factors unrelated to air pollution level, such as dampness, insects, over-crowding, noise, need of repairs and education, and in the number who said they had problems with health care.

Health care problems, litter and dirt pre-occupy people all the year round (Table 5.26). In general, though, concern with environmental problems decreases during spring and summer. For example, dampness as a worrying issue concerns 70.9% of the sample population in winter and 64.6% in autumn, but only 33.3% in spring and 39.4% in summer.

Table (5.25) Environmental Problems for the Three Study Areas

	Fahaheel	Rega	Mishrif	P Value
Overcrowding: rather or very worrying.	27.6%	17.4%	4.1%	.0000
Dampness: rather or very worrying.	85.0%	63.6%	9.7%	.0000
Smells: rather or very worrying.	81.6%	67.3%	1.6%	.0000
Noise: rather or very worrying.	39.1%	21.7%	2.4%	.0000
Needing major repairs: rather or very worrying.	47.0%	37.4%	9.9%	.0000
Litter and dirt: rather or very worrying.	13.1%	12.4%	1.3%	.0000
Lack of liesure facilities: rather or very worrying.	52.7%	53.6%	24.5%	.0000
Transportation: rather or very worrying.	43.9%	48.8%	4.7%	.0000
Lack of children play areas: rather or very worrying.	25.1%	24.2%	10.1%	.0000
Health care: rather or very worrying.	8.2%	10.0%	1.1%	.0000
Education: rather or very worrying.	16.3%	5.7%	0.5%	.0000
Dust: rather or very worrying.	98.9%	97.8%	58.3%	.0000
Insects & mice: rather or very worrying.	87.9%	89.8%	42.4%	.0000
Number:	355	401	384	

Data from household survey.

Table (5.26) Environmental Problems by Time of Year

	Winter	Spring	Summer	Autumn	P Value
Overcrowding: rather or very worrying.	16.0%	12.8%	20.1%	15.9%	.0000
Dampness: rather or very worrying.	70.9%	33.3%	39.4%	64.6%	.0000
Smells: rather or very worrying.	65.7%	35.4%	47.3%	62.5%	.0000
Noise: rather or very worrying.	18.2%	6.6%	25.4%	32.9%	.0000
Needing major repairs: rather or very worrying.	45.6%	16.6%	20.5%	42.4%	.0000
Litter & dirt: rather or very worrying.	9.4%	4.5%	12.6%	12.0%	.1024
Lack of leisure facilities: rather or very worrying.	55.6%	37.1%	36.9%	44.5%	.0000
Transportation: rather or very worrying.	45.4%	15.3%	29.1%	40.3%	.0000
Lack of children's play areas: rather or very worrying.	25.5%	16.0%	15.8%	21.9%	.0003
Health care: rather or very worrying.	9.0%	5.5%	4.7%	6.4%	.3266
Education: rather or very worrying.	6.6%	1.4%	8.9%	12.3%	.0005
Dust: rather or very worrying.	97.9%	79.5%	69.2%	92.6%	.0000
Insects and mice: rather or very worrying.	91.6%	61.8%	60.9%	79.2%	.0000
Number:	286	288	279	283	

Data from household survey.

5.4.8 Sources of Environmental Problems

The most striking result was that smells and fumes from industrial plant represent a cause for concern for 88.5% of people in Fahaheel, but only 48.4% in Rega, while in Mishrif nobody considers this to be a problem (Table 5.27). Metal corrosion was more of an issue in Fahaheel and Rega than Mishrif. Industrial plants were not seen as a major source of noise or of dust pollution. Complaints about smells and fumes from industrial plants were most common during the winter months (Table 5.28).

Table (5.27) Sources of Environmental Problems for the Three Study Areas

	Fahaheel	Rega	Mishrif	P Value
Noise:				
traffic.	55.5%	48.1%	36.6%	.0000
air conditioning.	39.4%	45.6%	15.4%	
industrial factories.	0.6%	0.7%	0.3%	
others.	2.5%	1.0%	0.3%	
no problem.	2.0%	4.5%	47.7%	
Smells & fumes:				
garbage.	1.7%	5.5%	20.6%	.0000
sewage.	6.8%	40.4%	25.5%	
traffic.	0.8%	1.2%	3.9%	
industrial plants.	88.5%	48.4%	0.0%	
no problem.	2.3%	4.5%	50.0%	
Damage to property:				
plumbing.	19.2%	19.2%	12.8%	.0000
corrosion of metal.	55.8%	60.3%	24.0%	
paint removal.	18.9%	16.0%	15.9%	
no problem.	3.1%	3.7%	47.4%	
Infections:				
mice.	19.4%	21.2%	13.0%	.0000
cockroach.	76.3%	75.3%	60.9%	
others.	2.0%	0.7%	3.1%	
no problem.	2.3%	2.7%	22.9%	
Dust:				
sandstorms.	96.6%	95.0%	90.6%	.0000
industrial source.	1.1%	1.2%	1.0%	
others.	1.2%	1.7%	0.3%	
no problem.	1.4%	2.0%	8.1%	
Number:	355	401	384	

Data from household survey.

Table (5.28) Sources of Environmental Problems by Time of the Year

	Winter	Spring	Summer	Autumn	P Value
Noise:					
traffic.	58.0%	45.8%	36.9%	45.6%	.0000
air conditioning.	39.9%	31.6%	30.5%	31.8%	
industrial factories.	0.0%	1.4%	0.7%	0.0%	
others.	0.0%	0.7%	2.9%	1.1%	
no problem.	1.7%	20.5%	29.0%	21.6%	
Smells & fumes:					
garbage.	6.3%	14.6%	6.1%	10.6%	.0000
sewage.	33.6%	35.1%	19.0%	11.7%	
traffic.	0.7%	4.2%	1.8%	1.4%	
industrial plants.	57.3%	24.0%	43.4%	54.1%	
no problem.	2.1%	22.2%	29.7%	22.3%	
Damage to property:					
plumbing.	26.2%	9.4%	7.5%	24.7%	.0000
corrosion of metals.	43.0%	41.7%	44.4%	58.0%	
paint removal.	28.0%	22.2%	12.2%	4.6%	
no problem.	2.8%	26.7%	30.8%	12.7%	
Infections:					
mice.	18.2%	22.6%	19.0%	11.7%	.0000
cockroach.	78.3%	60.8%	64.2%	80.2%	
others.	1.4%	2.1%	1.8%	2.5%	
no problem.	2.4%	14.6%	15.1%	5.7%	
Dust:					
sandstorms.	96.2%	90.6%	91.8%	97.5%	.0001
industrial source.	1.0%	0.7%	2.5%	0.4%	
others.	1.4%	0.3%	1.4%	0.7%	
no problem.	1.4%	8.3%	4.3%	1.4%	
Number:	286	288	279	283	

Data from household survey.

5.4.9 Views about Air Pollution

Awareness of air pollution was highest in Fahaheel, and industrial pollution was held very largely responsible (Table 5.29). In Mishrif by contrast, the percentage reporting air pollution as a problem was very small. The largest percentage of people who were leaving home because of pollution and the least likely to spend time in open air were from Fahaheel, and people from Fahaheel and Rega were most likely to make complaints or suggestions to the authorities about air pollution.

In Fahaheel and Rega respondents considered that pollution levels were lower in the mornings, whereas for Mishrif the levels were lower at nights. Most of the people questioned in Fahaheel believed that pollution was relatively high in spring and summer, less in autumn and lowest in winter. Most believed that humidity was an influential factor in air pollution levels (Table 5.30). The overwhelming perception was that pollution levels were increasing.

Table (5.29) View about Air Pollution for the Three Study Areas

	Fahaheel	Rega	Mishrif	P Value
Presence of air pollution:				
% yes.	40.0%	7.2%	3.9%	.0000
Identify the source:				
one source.	35.8%	18.2%	3.4%	.0000
more than one source.	4.9%	6.7%	0.5%	
Industrial pollution as main source:	96.1%	87.4%	25.0%	.0000
Direction of air pollution:				
capital city.	8.8%	11.6%	0.0%	.0000
industrial area.	90.4%	91.3%	6.0%	.0000
sea.	7.5%	18.8%	42.9%	.0000
desert.	10.1%	9.9%	0.0%	.0000
Variation of pollution level during day:				
% yes.	46.4%	24.7%	2.3%	.0000
From those answering yes to above:				
% high in morning.	27.6%	49.5%	77.8%	.0000
% high in afternoon.	87.6%	63.4%	66.7%	.0000
% high in night.	81.1%	79.4%	14.3%	.0000
Variation of air pollution seasonally:				
% yes.	86.3%	82.1%	64.3%	.0000
From those ansewring yes to above:				
% high in winter.	45.1%	32.7%	18.2%	.0000
% high in spring.	79.2%	94.2%	27.3%	.0000
% high in summer.	82.6%	95.2%	63.6%	.0000
% high in autumn.	62.0%	62.0%	72.75	.0000
Are pollution increasing with:				
higher temperature.	65.1%	93.1%	71.4%	.0000
higher humidity.	79.4%	68.4%	84.6%	.0000
calm days.	81.7%	16.2%	7.7%	.0000
Pollution level are:				
increasing.	80.0%	95.9%	93.7%	.0000
decreasing.	20.0%	4.1%	6.3%	
Time spent in open air:	7.0%	18.7%	16.1%	.0000
Leaving home because of pollution:				
% yes.	26.8%	10.5%	0.3%	.0000
Complaints to authorities at least once:	3.4%	3.7%	0.8%	.0478
Complaints from neighdours:				
% yes.	20.3%	11.7%	0.8%	.0000
% public suggestions:	7.0%	6.5%	2.1%	.0649
Number:	355	401	384	

Data from household survey.

Table (5.30) Views about Air Pollution by Time of the Year

	Winter	Spring	Summer	Autumn	P Value
Presence of air pollution:					
% yes.	12.2%	15.3%	18.3%	19.8%	.0000
Identify the source of pollution:					
one source.	12.9%	20.1%	32.5%	9.2%	.0000
more than one source.	1.4%	3.8%	5.2%	5.7%	
Industrial pollution as main source:	93.2%	80.6%	88.2%	92.9%	.0000
Direction of air pollution:					
capital city.	4.0%	8.2%	13.6%	8.7%	.0014
industrial area.	96.0%	83.7%	85.2%	95.6%	.0000
sea.	4.0%	14.3%	14.6%	13.3%	.0001
desert.	2.0%	6.1%	15.7%	11.1%	.0000
Variation of pollution level during day:					
% yes.	93.8%	75.0%	88.8%	82.1%	.0000
From those ansewring yes to above:					
% high in morning.	32.3%	65.1%	37.9%	22.7%	.0000
% high in afternoon.	60.4%	90.5%	96.8%	72.7%	.0000
% high in night.	87.5%	35.7%	89.5%	77.3%	.0000
Variation of pollution level seasonally:					
% yes.	87.5%	81.6%	88.5%	73.1%	.0000
From those ansewring yes to above:					
% higher in winter.	35.1%	11.1%	72.6%	16.4%	.0000
% higher in spring.	86.6%	53.3%	94.7%	78.7%	.0000
% higher in summer.	87.6%	88.9%	91.6%	73.8%	.0000
% higher in autumn.	57.7%	62.2%	76.6%	42.6%	.0000
Are pollution increasing with:					
higher temperature.	82.3%	91.8%	69.1%	64.5%	.0000
higher humidity.	81.2%	91.7%	86.6%	36.5%	.0000
calm days.	45.8%	53.1%	80.2%	23.8%	.0000
Pollution level are:					
increasing.	82.3%	98.1%	91.1%	79.1%	.0000
decreasing.	17.7%	1.9%	8.9%	20.9%	.0000
Time spent in open air:	11.9%	16.0%	14.3%	14.1%	.1181
Leaving home because of pollution:					
% yes.	9.8%	4.9%	18.3%	15.9%	.0000
Complaints to authorities at least once:	2.4%	3.0%	1.8%	3.2%	.6066
Complaints from neighbours:					
% yes.	11.2%	2.8%	17.9%	11.3%	.0000
% public suggestions:	3.1%	6.9%	4.9%	5.3%	.6483
Number:	286	288	279	283	

Data from household survey.

5.5 Discussion and Conclusion

5.5.1 Response

One possible explanation for the slightly lower response rate in Fahaheel was that it has a higher proportion of older people who are non-readers.

One explanation for the lower response rate in summer was that more people were out of the country during this period, particularly in Rega, with its higher proportion of villa owners. Overall, there was a good response rate; response bias was not a major problem in the study.

5.5.2 Potential Confounders

There were no gross differences between the three areas in terms of the confounders studied: indicators of demographic and socio-economic structure, weather conditions and smoking. The apparent implication was that it was reasonable to link any gradient seen in symptoms and use of health care to any gradient found in levels of pollution. However the gradients from Fahaleel to Mishrif in factors not directly related to air pollution such as dampness, insects, over-crowding, noise, need for repairs and education do give grounds for concern. It seems that the perception of quality of life over a broad range of aspects improve with distance from the Shuaiba industrial area. Either the effect of pollution on perceived quality of life was very far-reaching, or there are other differences between the three areas that the survey data have not picked up. Mishrif was the most recently built of the areas, but Rega, not Fahaheel was the oldest.

Similarly there was a gradient from Fahaheel to Mishrif in the number who said they had problems with health care. Studies outside Kuwait have shown that the accessibility and perceived quality of health care affects utilisation levels, and the differences in reported use described here may have been reduced by differences in supply.

5.5.3 Pollution level and symptoms

There were striking gradients in the levels of pollution between the three study areas, and corresponding gradients in the prevalence of physical and psychological symptoms. These were corroborated by the gradient in self-reported health status. However, since levels of all pollutants declined with distance from Shuaiba, little can be said on the basis of inter-area comparisons alone about links between particular pollutants and particular symptoms.

What do the different patterns of seasonal variation for different pollutants suggest about this? Seasonal variations in the prevalence of headache broadly corresponded to seasonal variation in CO levels. Seasonal variation in irritation of the nose and throat, irritation of the eyes, tears, loss of sense of smell, finding it annoying to go outside, loss of weight and distress broadly corresponded to variation in levels of NO. However, there are clearly limits to what can be inferred from these findings, which need to be reconsidered in the light of the results of the regression analyses described in Chapter 6.

5.5.4 Pollution level and Use of Health Care

There were gradients in the use of health care that broadly corresponded to gradients in levels of pollution.

1. Health centre attendance in Fahaheel was low. This may be due to the presence of private GP in this area but not in the other areas.
2. The low attendance to health centre in Fahaheel during summer was due to going out of the country at that time.

5.5.5 Pollution level and Quality of Life

The population in Fahaheel were clearly aware of industrial pollution as a major source of loss of quality of life, and they made complaints about it. The main problem was seen as being the emission of fumes; industry was not held responsible for noise or dust. In Mishrif however, industrial pollution was hardly an issue at all.

There are two possible explanations for the fact that most of the people questioned in Fahaheel believed that pollution was relatively high in spring and summer. One is that the pollutants like SO_2, NCH_4, NH_3 and NO_2 that are high in summer are more damaging to the quality of life than those like H_2S that is high in winter. The other is that people are out and about more in the summer and exposure is greater. This second explanation almost certainly has a part to play; the importance of the first explanation is more doubtful.

One curious finding was that the dissatisfaction with social life in Fahaheel was accompanied by satisfaction with family life. There may be an element of compensation by turning inward here.

5.5.6 Conclusion

The results presented in this chapter provide strong suggestive evidence for links between pollution levels and a variety of physical and psychological symptoms, based on a 'natural experiment'. They also suggest levels of pollution which are to lead to low prevalence of symptoms and numbers of complaints in the Kuwaiti population (ie the Mishrif levels). However, these analyses do not lend themselves readily to estimating the effects of changing levels of pollution on the prevalence of particular symptoms. This issue will be addressed in chapter 6 by developing a series of regression models.

CHAPTER SIX

RESULTS: REGRESSION ANALYSIS RELATING AIR POLLUTION TO PHYSICAL SYMPTOMS

CHAPTER SIX

RESULTS: REGRESSION ANALYSIS RELATING AIR POLLUTION TO PHYSICAL SYMPTOMS

6.1 Introduction

This chapter is concerned with quantifying the links between air pollution and physical symptoms in Kuwait. Chapter 7 and 8 deal with psychological symptoms and use of health care respectively.

One problem with the analysis of the data is that there are many dependent variables. This results a large numbers of regression equations and the likelihood of chance findings being statistically significant unless relatively demanding significance levels are required. In general only results with a P value of less than 0.01 will be commented upon the text.

A second problem relates to the large number of possible independent variables. This can result in confounding and in inappropriate attribution of effect. The potential for this can be suggested by an examination of the correlation matrix and factor analysis.

6.2 Correlation and Factor Analysis

The correlation matrix for the pollutants is given in Table 6.1. Levels of correlation were generally high, reflecting the existence of the area gradients.

Examination of the correlation matrix suggested relatively strong correlations between the sulphates (H_2S and SO_2), between CO and NH_3 and between the nitrates (NO_2 and NO). This was confirmed by a principal components analysis.

The correlation matrix for physical symptoms is shown in Table 6.2. Examination of this matrix, combined with principal components analysis suggested a number of sets of symptoms that tend to be associated. The first group included cough, wheezing, bronchitis, shortness of breath and chest discomfort ('respiratory symptoms'). The second group included sore throat, dry throat and irritation of nose and throat ('nose and throat symptoms'). The third group included irritation of the eyes and tears ('eye symptoms'). The fourth group included headache, faintness and nausea ('neuro symptoms'). The symptoms that fell into no particular grouping were mucus problems, skin problems, and loss of vision.

Table (6.1) Correlation Matrix for the Different Pollutants

	H_2S	SO_2	CO	NH_3	NCH_4	NO_2	NO
H_2S	.	.887	.537	.467	.507	.578	.730
SO_2	.887	.	.452	.376	.447	.478	.622
CO	.537	.452	.	.809	.793	.581	.731
NH_3	.467	.376	.809	.	.622	.617	.695
NCH_4	.507	.447	.793	.622	.	.659	.686
NO_2	.578	.478	.581	.617	.659	.	.870
NO	.730	.622	.731	.695	.686	.870	.

- .001

Data from mobile monitoring Stations.

Table (6.2) Correlation Matrix for Physical Effects

	Br	Ch	Wh	Br	Co	Fa	Na	He	Ey	Te	Dr	So	Ir	Mu	Sk	Vi
Bronchitis	.	.752	.645	.453	.335	.465	.500	.232	.158	.155	.199	.170	.165	.044	.129	.408
Chest	.752	.	.622	.516	.358	.517	.466	.240	.141	.140	.167	.131	.123	.005	.072	.349
Wheezing	.645	.622	.	.463	.289	.518	.460	.210	.216	.215	.172	.127	.158	.072	.070	.377
Breath	.453	.516	.463	.	.370	.539	.390	.223	.043	.011	.109	.158	.090	.043	.030	.199
Cough	.335	.378	.289	.370	.	.234	.226	.234	.050	.040	.321	.328	.289	.022	.000	.089
Faint	.465	.517	.518	.539	.234	.	.584	.329	.094	.140	.152	.122	.120	.075	.078	.273
Nausea	.500	.466	.460	.390	.226	.584	.	.277	.150	.154	.133	.116	.139	.078	.118	.113
Headache	.232	.240	.210	.223	.234	.329	.277	.	.183	.181	.201	.177	.191	.177	.088	.163
Eyes	.158	.141	.216	.043	.050	.094	.150	.183	.	.843	.039	.004	.106	.029	.085	.295
Tear	.155	.140	.215	.011	.040	.140	.154	.181	.843	.	.074	.029	.124	.041	.096	.316
Dry throat	.199	.165	.172	.109	.321	.152	.133	.201	.039	.074	.	.877	.589	.009	.073	.112
Sore throat	.170	.131	.127	.158	.328	.122	.116	.177	.004	.029	.877	.	.587	.045	.052	.104
Ittitantion	.165	.123	.158	.090	.289	.120	.139	.191	.106	.124	.589	.587	.	.301	.035	.120
Mucus	.044	.005	.072	.043	.022	.075	.078	.177	.029	.041	.009	.045	.301	.	.051	.113
Skin	.129	.072	.070	.030	.000	.078	.051	.088	.085	.096	.073	.052	.035	.051	.	.115
Vision	.408	.349	.377	.199	.089	.273	.113	.163	.295	.316	.112	.104	.120	.113	.115	.

Data from household survey.

6.3 Strategy for Developing the Regression Analysis

The following strategy was used for the development of a model to describe the links between symptoms and pollution levels. The first strategy was to see whether levels of education was an important independent variable. This variable had been included in the survey as a likely indicator of social class, but because very few Kuwaitis aged over 45 considered further education as an option, and because for people under the age under 25 the end point of their educational attainments is still unclear, it was really only a useful indicator for a subset of subjects aged between 25 and 45. Thus a series of analyses were done for the population in this age range, to see whether educational level appeared to have an effect.

The distributions of symptom scores were heavily skewed, and it was not obvious that any relationship between pollution levels and symptoms would be a linear one. As well as untransformed data, log and square transformations for the dependent variable; and logistic regressions were tested. There was little or no advantage to be had from using transformed data in terms of goodness of fit. The untransformed data were used on the grounds of simplicity of interpretation. The indicators of pollution levels used were average levels over the seven days prior to subjects' completion of the survey questionnaire, because they were asked about symptoms over this seven-day period.

The first set of models (the full 7-day models) included all the pollution variables. Then a second set of analyses were carried out using only the one or the two most important pollutants. This was done to provide simpler prediction equations and to check for the possibility of collinearity, as revealed by marked change in regression coefficients when different sets of variables are used.

Symptoms were linked to the result of increased pollution levels over a more extended period, a set of models were developed using mean pollution levels over the thirty days prior to the completion of the questionnaire (the full 30-day models).

The results suggested that it might be worth investigating a third set of models involving the average levels of SO_2 over the previous 30 days and average levels of CO over the previous 7 days (the combined models). Finally, summary analyses were carried out using the sum of all the physical symptom scores as the dependent variable.

6.4 Results of Regression Analysis for Physical Symptoms

6.4.1 Preliminary Results

There was no effect of education on reported physical symptoms in age group 25 to 45, except for nausea where education was statistically significant (Table 6.3). Humidity was not significantly relation with any physical symptoms investigated. As a result, education and humidity were omitted from the subsequent analysis, and untransformed data were used on the grounds of simplicity of interpretation (Table 6.4 and 6.5).

Table (6.3) The Relationship Between Physical Symptoms and Different Pollutants and Demographic Features
Regression coefficient and Statistical Significance for People Aged Between 25 to 45

	Sex		Education		Housing		Smoking		H_2S		SO_2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Cough	-.169	.159	-.044	.437	-.194	.445	.317	.012	-358.4	.025	102.3	.004	-1.018	.146	.384	.006	- 4.84	.011	49.10	.015	12.20	.361	0.163
Breath	.074	.069	.010	.580	-.161	.064	.076	.079	- 71.2	.193	17.0	.168	- .000	.971	.032	.494	- 0.05	.927	3.38	.624	- 5.86	.199	0.040
Sore throat	-.205	.033	-.069	.131	-.015	.938	.068	.497	- 98.7	.439	34.3	.235	- .183	.742	.187	.093	- 2.80	.067	32.71	.043	-10.65	.318	0.096
Dry throat	-.219	.017	-.019	.652	.171	.378	.028	.773	-165.7	.176	62.5	.024	- .237	.657	.151	.158	- 2.29	.118	26.08	.093	- 5.70	.577	0.114
Mucus	.231	.042	-.021	.687	.278	.247	.151	.207	20.2	.893	- 8.3	.807	.934	.158	-.073	.580	0.72	.690	27.74	.147	-23.79	.059	0.043
Headache	.352	.008	.044	.483	.379	.177	.231	.099	79.4	.652	16.3	.683	- .974	.207	.138	.371	- 1.41	.505	19.92	.372	4.57	.756	0.083
Nausea	.111	.018	.061	*.006*	.104	.294	-.017	.731	-111.5	.074	49.0	.000	- .401	.142	.055	.309	- .73	.331	- 5.64	.475	5.78	.267	0.073
Faintness	.142	.014	.030	.272	-.071	.559	.096	.116	-150.5	.052	33.5	.056	- .343	.310	-.051	.450	0.91	.328	17.78	.070	- 7.46	.249	0.054
Irritation	-.047	.677	.024	.649	-.096	.685	.110	.354	-293.5	.050	55.3	.103	.370	.573	.267	.042	- 3.25	.070	53.07	.005	-18.90	.132	0.143
Wheezing	.032	.302	.010	.486	.039	.550	.040	.225	-100.3	.017	23.8	.012	- .213	.247	-.013	.723	0.49	.324	4.55	.392	- 1.33	.704	0.039
Eye	-.268	.006	-.060	.197	-.389	.060	-.166	.107	- 33.0	.799	13.7	.641	.082	.884	.022	.843	- 0.51	.740	39.34	.017	-22.31	.040	0.078
Tear	-.182	.044	.000	.831	-.297	.120	-.165	.085	- 21.1	.860	19.6	.469	- .075	.886	.017	.866	- 0.85	.555	41.26	.007	-20.93	.038	0.085
Skin	.096	.485	.000	.936	.278	.340	-.187	.199	10.7	.953	28.2	.496	- .135	.866	.309	.054	- 3.69	.093	30.73	.187	-22.36	.145	0.060
Bronchitis	.042	.321	.000	.947	-.000	.980	.000	.938	- 94.5	.095	17.3	.174	- .063	.797	.038	.434	- 0.24	.716	4.96	.488	- 3.79	.422	0.020
Chest	-.031	.548	.010	.666	.010	.920	-.043	.421	-114.3	.096	24.8	.111	- .355	.237	.123	.040	- 1.14	.164	- 2.71	.755	5.84	.309	0.026
Vission	.191	.001	.041	.137	-.139	.260	.250	.000	- 25.4	.743	45.7	.009	.103	.759	-.036	.586	0.53	.564	- 7.68	.433	4.08	.528	0.133

Data from household survey and mobile monitoring stations.

Table (6.4) The Relationship Between Cough and Different Demographic Features and Different Pollutants in Three Different Models

	Sex		Age<5		Age 65+		Housing		Smoking		Avetemp		H_2S		SO_2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Linear regression	-.000	.905	-.000	.956	.407	.000	-.159	.381	.330	.000	-.000	.002	-165.19	.067	54.00	.000	.245	.560	.144	.002	-.53	.672	24.05	.068	-10.51	.234	.120
Logestic regression	-.012	.891	-.089	.629	.404	.014	-.016	.961	.474	.000	-.045	.000	-293.54	.322	131.55	.039	1.434	.420	.242	.364	2.59	.516	53.89	.214	-22.62	.436	
Log cough	-.000	.966	-.000	.944	.090	.000	-.030	.363	.060	.000	-.000	.003	- 43.44	.053	15.18	.000	.044	.563	.031	.044	-.17	.448	3.91	.103	- 1.39	.386	.116

Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (6.5) The Relationship Between Sore Throat and Different Demographic Features and Different Pollutants in Three Different Models

	Sex		Age<5		Age 65+		Housing		Smoking		Avetemp		H_2S		SO_2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Linear regression	.020	.599	-.138	.069	-.000	.993	-.176	.190	.056	.257	-.000	.000	- 71.11	.288	42.36	.005	.706	.025	.089	.002	-1.47	.114	24.09	.014	-13.18	.045	.091
Logestic regression	.107	.253	-.464	.056	-.251	.251	-.335	.188	.180	.160	-.048	.000	-159.82	.573	191.42	.002	1.579	.243	.130	.616	1.68	.673	52.24	.219	-36.55	.194	
Log sore Throat	.000	.748	-.021	.081	.010	.440	-.024	.246	.000	.304	-.000	.000	- 11.70	.272	6.48	.006	.124	.013	.031	.168	-.26	.080	13.96	.011	-2.07	.047	.092

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.2 Cough

Using the full 7-day model, the variables most closely associated with coughing were age 65+ (p=.000), smoking (p=.000), SO_2 levels (p=.000) and CO levels (p=.002). There was also an inverse relationship with average temperature (Table 6.6).

When the regression analysis was repeated leaving out all the pollutants except SO_2 and CO, R^2 was reduced only slightly from 0.120 to 0.115, and the coefficients changed very little (Table 6.7). With SO_2 as the only pollutant in the equation, R^2 was dropped to 0.091 and the coefficient increased (Table 6.8). The regression coefficients for age 65+, smoking and average temperature changed very little for these different 7-day models (Table 6.4.2).

Using the full 30-day model, the same set of variables were significant except for average temperature. R^2 increased to 0.128 compared with 0.120 for the full 7 days analysis (Table 6.9). With SO_2 as the only pollutant, however, R^2 decreased markedly to 0.063 (Table 6.10). The combined 30-day and 7-day model did not fit as well as the 7-day SO_2/CO model (Table 6.11).

It would appear that the 7-day, 2 pollutant model provides the best fit of those tested. However, there will be some difficulty in disentangling the effect of SO_2 on cough from the effect of CO.

Table 6.4.2: Summary of regression analyses for cough

	Age 65+	Smoking	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	.407*	.330*	-.862*	54.00*	.144*	0.120	6.5
7 days SO_2 & CO.	.403*	.324*	-.835*	51.85*	.195*	0.115	6.6
7 days SO_2.	.405*	.301*	-.568	76.54*		0.091	6.7
30 days all variables.	.419*	.313*	-.528	119.21*	.363	0.128	6.8
30 days SO_2.	.421	.307*	-.449	49.95*		0.063	6.9
30 day SO_2 & 7 day CO.	.409*	.331*	-.800*	34.46*	.200*	0.106	6.10

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.3 Shortness of Breath

Shortness of breath was the next symptom to be considered. For the full 7-day model the only significant relationship was with age 65+ (p=.000, R^2 = 0.064; Table 6.6). When all the pollutants were dropped except SO_2 and CO, CO also become statistically significant (p=.009, R^2 = 0.061; Table 6.7). When they were all dropped except SO_2, R^2 went down to 0.054 (Table 6.8).

For the full 30-day model, again only age 65+ was statistically significant (p=.000). R^2 and the coefficients were very similar to those in the 7-day model (Tables 6.9 and 6.10). Using the mixed 30-day and 7-day model, age 65+ and CO as statistically significant (p=.000; Table 6.11).

Overall the values of R^2 (0.060) and the coefficients for CO changed very little from one model to the next.

6.4.4 Sore Throat

The third physical symptom to be considered was sore throat. On the basis of the full 7 days, SO_2 (p=.005) and CO (p=.002) were statistically significant and R^2 was 0.091. There was an inverse relationship with average temperature (Table 6.6). The model using SO_2 and CO as the only pollutants gave similar results (Table 6.7). With the removal of CO, the coefficient for SO_2 become more significant (p=.000) but hardly changed. The R^2 decreased again (Table 6.8).

Using the full 30-day model, SO_2 was still statistically significant (p=.000) and R^2 increased to 0.101. There was an inverse relationship with NCH_4 (p=.000; Table 6.9). When only SO_2 over 30 days was used, R^2 dropped sharply to 0.030 (Table 6.10). Using the mixed 30-day SO_2 and 7-day CO model gave a poorer fit (Table 6.11).

It would seem that both SO_2 and CO are linked to sore throat. The results suggest that longer-term exposures may be important.

Table 6.4.4: Summary of regression analyses for sore throat

	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	-.877*	42.63*	0.089*	0.091	6.5
7 days SO_2 & CO.	-.856*	43.47*	0.083*	0.079	6.6
7 days SO_2.	-.701*	46.45*		0.067	6.7
30 days all variables.	-.109	94.93*	0.272	0.101	6.8
30 days SO_2.	-.584*	31.12*		0.030	6.9
30 day SO_2 & 7 day CO.	-.800*	21.59*	0.123*	0.061	6.10

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.5 Dry Throat

Using the full 7-day model for dry throat, both SO_2 and CO emerged as significant (p=.000 and p=.005 respectively). Again average temperature was inversely related (Table 6.6). With the removal of pollutants other than SO_2 and CO from the equation, SO_2 (p=.000) and CO (p=.001) became increasingly significant, but the coefficient for CO decreased from .110 to .068 and R^2 fell from 0.105 to 0.095 (Table 6.7). With SO_2 as the only pollutant in the model, its coefficient was slightly increased and R^2 slightly down (Table 6.8).

With the full 30-day model, both SO_2 and NCH_4 were statistically significant (p=.000), but the relationship with NCH_4 was an inverse one. R^2 was slightly increased to 0.116 (Table 6.9). With SO_2 as the only pollutant considered, its coefficient decreased and R^2 dropped sharply to 0.046 (Table 6.10).

With the mixed model, average temperature, 30-day SO_2 and 7-day CO were statistically significant (p=.000). The regression coefficients changed very little for average temperature and CO but decreased for SO_2, and R^2 decreased to 0.072 (Table 6.11).

Table 6.4.5: Summary of Regression Analyses for Dry Throat

	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	-.802*	59.03*	0.110*	0.105	6.5
7 days SO_2 & CO.	-.794*	53.39*	0.068*	0.095	6.6
7 days SO_2.	-.737*	64.01*		0.087	6.7
30 days all variables.	-.238	100.02*	0.460	0.116	6.8
30 days SO_2.	-.623*	39.90*		0.046	6.9
30 day SO_2 & 7 day CO.	-.824*	30.04*	0.114*	0.072	6.10

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.6 Mucus

Using the full 7-day model, the relationship between mucus and pollution can be seen from (Table 6.6). The strongest relationship was with age <5 (p=.000; R^2 = 0.068). Dropping all the pollutants except SO_2 and CO strengthened the p-value for CO to .007 however, and dropping all but SO_2 strengthened its p-value to .003 (Tables 6.7 and 6.8).

The full 30-day model gave similar results to the full 7-day model (Table 6.9 and 6.10).

The mixed 30-day SO_2 and 7-day CO model suggested a significant effect for CO (p=.000) with an R^2 value of 0.065 similar to that for the 7-day SO_2/CO equation (Table 6.11).

It would appear that of the pollutants considered here, CO is the most likely candidate to be a factor in mucus formation.

6.4.7 Headache

Headache was the next symptom to be considered. With the full 7-day model, sex, age <5, age 65+ and smoking were strongly significant (p=.000), while SO_2 (p=.009) and CO (p=.001) were only slightly less so (R^2= 0.121; Table 6.6). The relationship with age <5 was an inverse one.

Dropping all the pollution variables except SO_2 and CO gave similar coefficients but reduced R^2 (Table 6.7). With SO_2 as the only pollutant, age <5 became less important. The coefficient for SO_2 hardly changed from the previous model but R^2 again decreased (Table 6.8).

In the full 30-day model, the same set of variables as in the 7-day model were significant, but NCH_4 (p=.003) and NO (p=.006) were added to the list and R^2 increased to 0.131. The relationships with NCH_4 and age <5 were inverse. There was a marked increase over the 7-day model in the coefficient for SO_2 and a decrease in the coefficient for CO (Table 6.9). The results using only 30-day SO_2 were similar to those for the 7-day models except that R^2 decreased (Table 6.10).

With the mixed model, sex, age <5, age 65+, smoking, average temperature, 30-day SO_2 and 7-day CO were found to be statistically significant (p=.000). The relationships with age <5 (p=.000) and average temperature (p=.010) were inverse ones (Table 6.11).

It would appear that both SO2 and CO levels are important factors in the prevalence of headaches. The set of coefficients in the full 30-day model are out of line with the others.

Table 6.4.7: Summary of Regression Analyses for Headache

	Sex	Age<5	Age65+	Smoking	SO_2	CO	R^2	Table
7 days all variables.	.272*	-.525*	.387*	.253*	50.40*	.126*	0.121	6.5
7 days SO_2 & CO.	.273*	-.534*	.399*	.259*	57.17*	.117*	0.115	6.6
7 days SO_2.	.274*	-.548*	.401*	.242*	55.28*		0.102	6.7
30 days all variables.	.278*	-.537*	.393*	.245*	106.75*	.061	0.131	6.8
30 days SO_2.	.276*	-.542*	.405*	.240*	45.99*		0.095	6.9
30 day SO_2 & 7 day CO.	.273*	-.527*	.396*	.256*	35.25*	.139*	0.118	6.10

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.8 Nausea

Using the full 7-day model to explain nausea gave age 65+, SO_2 and CO as statistically significant factors (p=.000, .003 and .010 respectively, R^2 = 0.059; Table 6.6). Removing all pollutants except SO_2 and CO from the equation gave the same set of factors, slightly reduced coefficients, slightly reduced p values and very little change in R^2 (Table 6.7). When only SO_2 was used, its coefficient increased but R^2 decreased (Table 6.8).

Using the full 30-day model, age 65+ and SO_2 were significant variables (p=.000 and .009 respectively), with little change in the coefficient for SO_2 or R^2 (Table 6.9). Dropping all the pollutants except SO_2 resulted in a marked decrease in R^2 to 0.033 (Table 6.10). With the mixed model, CO took the place of SO_2 as statistically significant (p=.000), with a slight decrease in R^2 (Table 6.11).

Both SO_2 and CO emerge as factors in nausea, but there does appear to be an element of collinearity: some of the apparent effect of CO may be actually attributable to SO_2 or vice versa.

6.4.9 Faintness

The only significant predictor of faintness using 7-day pollution levels was age 65+ (p=.000, R^2 = 0.048; Table 6.6). With SO_2 and CO as the only pollutants in the regression equation, CO became statistically significant (p=.010) and R^2 dropped only slightly (Table 6.7). When SO_2 was the only pollutant, it came out as statistically significant (p=.000) but R^2 decreased further (Table 6.8).

Using the full 30-day model, again none of the pollutants emerged as significant, and R^2 was slightly less than for the 7-day model (Table 6.9). Dropping all the pollutants except SO_2 made very little difference to the result other than a further decrease in R^2 (Table 6.10). Using the mixed model, CO emerged as statistically significant but its coefficient hardly changed. This equation was a better fit than 7 day SO_2/CO equation (Table 6.11).

CO comes out as a possible factor, although it may be `picking up' smaller effects of one or more other pollutants.

6.4.10 Irritation of the nose and throat

With the full 7-day model for irritation of nose and throat, SO_2, CO and NO (all p=.000), NCH_4 (p=.005) and NO_2 (p=.007) were statistically significant. There were inverse relationships with average temperature and H_2S (both p=.000). R^2 was 0.155 (Table 6.6).

With SO_2 and CO as the only pollutants in the equation their coefficients decreased, as did R^2 (0.117; Table 6.7). When only SO_2 was used, its coefficient increased slightly but R^2 dropped to 0.077 (Table 6.8).

Using the full 30-day model, SO_2 and NCH_4 were statistically significant (p=.008 and .000 respectively). The coefficient for SO_2 decreased but for NCH_4 it increased. R^2 = 0.149 which is slightly smaller than the R^2 for the 7-day model (Table 6.9). When only SO_2 was included, its coefficient decreased and R^2 dropped sharply to 0.024 (Table 6.10).

The mixed model involving average values of SO_2 over 30 days and CO over 7 days gave a poorer fit than 7 day averages for both pollutants (Table 6.11).

There may be relatively complex interactions between the different pollutants at work here. An effect for SO_2 is a relatively consistent result, but other pollutants, most probably NCH_4, may also have parts to play.

Table 6.4.10: Summary of regression analyses for irritation of nose and throat

	Avetemp	SO_2	NCH_4	CO	R^2	Table
7 days all variables.	-.827*	66.34*	.013*	.227*	0.155	6.5
7 days SO_2 & CO.	-.798*	48.70*		.181*	0.117	6.6
7 days SO_2.	-.570*	76.75*			0.077	6.7
30 days all variables.	.278	70.02*	.183*	.884	0.149	6.8
30 days SO_2.	-.382	36.69*			0.024	6.9
30 day SO_2 & 7 day CO.	-.784*	18.99*		.229*	0.093	6.10

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.11 Wheeze

The next symptom to be considered was wheeze. Using the full 7-day model, age 65+ was the only significant predictor (p=.000, R^2 = 0.060; Table 6.6).
With SO_2 and CO as the only pollutants in the equation, SO_2 became significant (p=.008) and R^2 decreased slightly (Table 6.7). With only SO_2, an inverse relationship with average temperature emerged (p=.000); the coefficient for SO_2 increased, but R^2 decreased (Table 6.8).

Using the full 30-day model, again none of the pollution variables emerged as significant. R^2 was 0.056, slightly lower than the value for the full 7-day model (Table 6.9). With SO_2 as the only pollutant it again became significant but again R^2 decreased to 0.046 (Table 6.10). In the mixed model, CO (p=.001) became significant as well as SO_2 (p=.005). R^2 hardly changed (Table 6.11).

It appears that pollution does have an effect on wheeze. It seems likely that SO_2 has an effect, but the contribution of each pollutant to the overall effect is hard to assess from these data.

6.4.12 Irritation of the eyes

With the full 7-day model, irritation of the eyes was linked to type of housing (p=.003), NO_2 (p=.003) and NO (p=.000). R^2 was 0.058 (Table 6.6).
With all but the usual two key pollutants dropped, SO_2 (p=.001) and CO (p=.004) both became statistically significant but R^2 decreased to 0.047 (Table 6.7). When only SO_2 was used, the SO_2 coefficient increased but R^2 went down to 0.039 (Table 6.8).

With the full 30-day model, the R^2 of 0.061 was very similar to the value for the full 7-day model (Table 6.9), but the effects of NO and NO_2 disappeared. With only SO_2, its coefficient dropped but became significant (Table 6.10). The R^2 for the mixed model was the same as that for the 7-day SO_2 and CO model (Table 6.11).

Table 6.4.12: Summary of regression analyses for irritation of the eyes

	Housing	SO_2	CO	R^2	Table
7 days all variables.	- .380*	23.91	.051	0.058	6.5
7 days SO_2 & CO.	- .337*	23.06*	.059*	0.047	6.6
7 days SO_2.	- .288*	32.27*		0.039	6.7
30 days all variables.	- .300*	35.18	.228	0.061	6.8
30 days SO_2.	- .280*	25.86*		0.034	6.9
30 day SO_2 & 7 day CO.	- .327*	20.11*	.074*	0.047	6.10

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.13 Tears

NO again emerged as a significant factor (p=.003) from the full 7-day model for tears in the eyes. Age 65+ (p=.006) and housing (p=.004) were the others, with an R^2 of 0.066 (Table 6.6). However if SO_2 and CO, or SO_2 alone, were forced in as the only pollution variables, SO_2 became statistically significant (p=.000). R^2 slightly decreased (Table 6.7 and Table 6.8).

In the full 30-day model SO_2 (p=.010) was statistically significant. R^2 increased to 0.070 (Table 6.9). In the mixed 30-day and 7-day model, both SO_2 (p=.000) and CO (p=.002) were statistically significant but R^2 was down to 0.056 (Table 6.11).

Table 6.4.13: Summary of regression analyses for tears

	Age65+	Housing	SO_2	R^2	Table
7 days all variables.	.218*	- .351*	23.03	0.066	6.5
7 days SO_2 & CO.	.215*	- .316*	31.78*	0.059	6.6
7 days SO_2.	.216*	- .289	36.96*	0.057	6.7
30 days all variables.	.227*	- .283*	52.67*	0.070	6.8
30 days SO_2.	.219*	- .280	29.43*	0.048	6.9
30 day SO_2 & 7 day CO.	.216*	- .316*	25.12*	0.056	6.10

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.14 Irritation of the skin

For irritation of the skin, the full 7-day model showed an inverse relationship with average temperature (p=.001). R^2 was low at 0.030 (Table 6.6). With SO_2 and CO as the only pollutants in the equation, CO (p=.006) became significant, but R^2 was 0.024 (Table 6.7). With only SO_2, although it became significant, R^2 was down to 0.017 (Table 6.8).

Neither the full nor the reduced 30-day models yielded any statistically significant factors (Table 6.9 and Table 6.10). In the mixed model, only CO and average temperature were significant (p=.001 and .008; Table 6.11).

It appears that the most consistent factor in irritation of the skin was recent temperature. CO may have an independent effect.

6.4.15 Bronchitis

For bronchitis, the factors emerging from the full 7-day model were age 65+ (p=.000), SO_2 (p=.006) and CO (p=.008). R^2 was 0.072 (Table 6.6). With all the pollutants except SO_2 and CO dropped from the equation the coefficient for SO_2 halved but R^2 only decreased slightly (Table 6.7). With only SO_2, its coefficient increased again, and R^2 fell further (Table 6.8).

With the full 30-day model, SO_2 was still significant (p=.002) and R^2 was little different from the full 7-day model value (Table 6.9). However, dropping all other pollution variables reduced the R^2 to .040 (Table 6.10). In the mixed 30- and 7-day model CO was the only significant pollutant (p=.000; Table 6.11).

It seems that there may be interactions between the various pollutants here that make the coefficient for SO_2 unreliable.

6.4.16 Chest discomfort

With the full 7-day model, age 65+, SO_2 (p=.000) and CO (p=.007) were statistically significant (R^2 = 0.100; Table 6.6). With the first reduced form of the equation, the coefficients for both pollutants decreased, and R^2 fell slightly to 0.094 (Table 6.7). Dropping CO from the equation had little further effect on the coefficient of SO_2 but R^2 fell further to 0.079 (Table 6.8).

With the full 30-day model, none of the pollution variables emerged as significant at the level chosen for reporting here. R^2 was unchanged (Table 6.9). With SO_2 as the only pollutant, its effect became statistically significant (p=.000) but R^2 decreased sharply to 0.060 (Table 6.10). In the mixed model, the effect of 7-day CO became significant (p=.000, R^2= 0.087; Table 6.11).

SO_2 seems to be the most important pollutant here, but others probably make a contribution.

Table 6.4.16: Summary of regression analyses for chest discomfort

	Age 65+	SO_2	CO	R^2	Table
7 days all variables.	.564*	45.96*	.088*	0.100	6.5
7 days SO_2 & CO.	.564*	32.20*	.079*	0.094	6.6
7 days SO_2.	.565*	35.48*		0.079	6.7
30 days all variables.	.567*	39.19	.020	0.100	6.8
30 days SO_2.	.575*	19.83*		0.060	6.9
30 day SO_2 & 7 day CO.	.569*	11.64	.100*	0.087	6.10

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.17 Loss of vision

In the case of loss of vision, the factors that emerged from the full 7-day model were age 65+, smoking (p=.000) and CO (p=.009) (R^2 = 0.063; Table 6.6). The results for the first reduced model were similar, although the coefficient for CO was slightly decreased (Table 6.7). With only SO_2, average temperature and SO_2

became significant (p=.000), the coefficients decreasing for average temperature and increasing for SO_2 (Table 6.8).

With the 30-day model, none of the pollutants had a significant effect, even though R^2 was almost the same as for the 7-day model (Table 6.9).
Eliminating all the pollutants except SO_2 more than doubled its coefficient, but it was still not significant at the 1% level (Table 6.10). The mixed model produced a result rather similar to that for the 2-pollutant 7-day model except that both the SO_2 coefficient and the R^2 were reduced (Table 6.11).

Loss of vision was a relatively uncommon symptom, although a serious one. Atmospheric CO levels appear to have an effect here, particularly when combined with smoking.

6.4.18 Total physical symptom score

A final set of models was developed in which the dependent variable was the sum of each individual's scores on all 16 of the physical symptom questions. With the full 7-day model, sex (p=.007), age 65+ (p=.000), average temperature (p=.000), SO_2 (p=.000), CO (p=.003) and NO (p=.000) were all significant (R^2= 0.235; Table 6.6). The relationship with average temperature was an inverse one.

With SO_2 and CO as the only pollutants, the coefficient for SO_2 and R^2 were slightly reduced (R^2= 0.220; Table 6.7). When only SO_2 was used, its coefficient went up markedly but R^2 decreased to 0.172 (Table 6.8).

In the full 30-day model, SO_2 (p=.000) was the only pollutant to have a significant positive effect but there was an inverse relationship with NCH_4 (p=.000). R^2 was about the same as for the full 7-day model at 0.242 (Table 6.9). With all the pollutants except SO_2 dropped out, an inverse relationship with average temperature emerged (p=.004) but R^2 was down to 0.108 (Table 6.10). The implications of the mixed model were broadly similar to this, but with 7-day back CO in the model, R^2 was up to 0.200 (Table 6.11).

The apparently protective effect of NCH_4 on total symptom score in the full 30-day model is again curious but could again be explained partly at least by its correlation with 7-day mean temperature.

Table 6.4.18: Summary of regression analyses for total physical symptom score

	Sex	Age 65+	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	.724*	3.559*	-.067*	466.66*	1.196*	0.235	6.5
7 days SO_2 & CO.	.681*	3.512*	-.060*	400.38*	1.174*	0.220	6.6
7 days SO_2.	.692*	3.518*	-.044*	582.88*		0.172	6.7
30 days all variables.	.701*	3.612*	.019	825.86*	1.785	0.242	6.8
30 days SO_2.	.725*	3.644*	-.035*	375.05*		0.108	6.9
30 day SO_2 & 7 day CO.	.694*	3.558*	-.061*	258.92*	1.496*	0.200	6.10

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (6.6) The Relationship Between Physical Symptoms and Different Pollutants and Demographic Features
Regression Coefficient and Statistical Significance for Seven Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		H_2S		SO2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Cough	-.000	.905	-.000	.956	.407	*.000*	-.159	.381	.330	*.000*	-.862	*.002*	-165.19	.067	54.00	*.000*	.245	.560	.144	*.002*	-0.53	.672	24.05	.068	-10.51	.234	0.120
Breath	.024	.289	.012	.777	.361	*.000*	-.131	.097	.040	.239	-.177	.158	35.11	.371	0.85	.923	.137	.454	.043	.240	-0.02	.964	- 5.09	.375	- .22	.953	0.064
Sore throat	.020	.599	-.138	.069	-.000	.993	-.176	.190	.066	.257	-.877	*.000*	- 71.11	.288	42.36	*.005*	.706	.025	.089	*.002*	-1.47	.114	24.09	.014	-13.18	.045	0.091
Dry throat	.023	.547	-.118	.121	.161	.069	-.141	.295	.087	.136	-.802	*.000*	-105.70	.116	59.03	*.000*	.474	.133	.110	*.005*	-1.90	.043	22.07	.025	- 8.90	.177	0.105
Mucus	.105	.015	.616	*.000*	-.100	.302	.087	.556	.010	.872	-.296	.208	- 62.19	.399	14.07	.396	.191	.579	.056	.416	- .57	.577	14.55	.177	- 5.31	.462	0.068
Headache	.272	*.000*	-.525	*.000*	.387	*.000*	.050	.773	.253	*.000*	-.480	.082	- 97.31	.261	50.40	*.009*	-.650	.108	.126	*.001*	0.08	.946	3.91	.757	7.46	.379	0.121
Nausea	.031	.114	-.000	.821	.211	*.000*	.095	.157	-.028	.336	-.438	.683	- 31.40	.350	16.06	*.003*	.000	.991	.069	*.009*	-0.61	.193	3.26	.507	- 1.29	.694	0.059
Faintness	.047	.073	-.011	.822	.275	*.000*	-.148	.104	.031	.422	-.405	.779	- 65.11	.151	18.81	.065	-.322	.129	.064	.134	-0.22	.720	8.35	.209	- 2.85	.520	0.048
Irritation	.088	.053	.104	.236	.083	.412	-.187	.227	.068	.311	-.827	*.000*	-276.80	*.000*	66.34	*.000*	.013	*.005*	.227	*.002*	3.51	*.001*	52.69	*.000*	20.26	*.007*	0.155
Wheezing	-.000	.980	-.000	.883	.254	*.000*	-.048	.506	.050	.104	-.361	.975	- 33.68	.349	20.10	.013	-.302	.073	.047	.165	0.22	.661	- 0.66	.900	- 0.73	.835	0.060
Eye	-.055	.141	-.159	.029	.157	.063	-.380	*.003*	.018	.734	-.486	.018	- 14.62	.819	3.91	.786	.270	.368	.051	.854	0.07	.929	31.98	*.000*	18.48	*.003*	0.058
Tear	-.023	.510	-.140	.041	.218	*.006*	-.351	*.004*	.030	.556	-.266	.167	- 20.87	.729	23.03	.090	-.037	.894	.030	.600	-0.55	.508	26.00	*.003*	13.33	.024	0.066
Skin	.137	.015	-.010	.919	-.095	.449	.016	.932	-.052	.524	-.982	*.001*	22.35	.814	-2.25	.916	.105	.813	.000	.980	0.87	.510	32.63	.019	-24.14	.019	0.030
Bronchitis	.012	.690	.013	.828	.421	*.000*	-.140	.187	-.048	.287	-.269	.111	- 83.42	.115	28.49	*.006*	.019	.937	.091	*.008*	-0.19	.793	7.17	.355	- 6.03	.245	0.072
Chest	-.000	.779	.043	.511	.564	*.000*	-.000	.932	.018	.705	-.311	.090	-138.85	.016	45.96	*.000*	.033	.902	.088	*.007*	-0.11	.888	8.71	.302	- 4.87	.388	0.100
Vision	.049	.028	.036	.409	.253	*.000*	-.075	.329	.131	*.000*	.226	.854	- 10.08	.794	10.33	.234	.123	.496	.021	*.009*	0.14	.791	0.93	.868	- 1.65	.661	0.063
Total score	.724	*.007*	-.295	.547	3.559	*.000*	-.693	.051	.950	.011	-.067	*.000*	-169.49	.013	466.66	*.000*	2.074	.305	1.196	*.003*	-8.28	.169	252.42	*.000*	123.80	*.003*	0.235

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (6.7) The Relationship Between Physical Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Seven Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO2		CO		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Cough	-.010	.836	-.010	.921	.403	*.000*	-.095	.590	.324	*.000*	-.835	*.001*	51.85	*.000*	.195	*.000*	0.115
Breath	.024	.284	.015	.728	.358	*.000*	-.134	.086	.039	.250	-.169	.075	2.64	.413	.036	*.004*	0.061
Sore throat	.015	.687	-.135	.076	-.012	.889	-.096	.469	.055	.344	-.856	*.000*	43.47	*.000*	.083	*.000*	0.079
Dry throat	.091	.618	-.118	.124	.154	.081	-.065	.624	.077	.186	-.794	*.000*	53.39	*.000*	.068	*.001*	0.095
Mucus	.103	.017	.615	*.000*	-.103	.287	.124	.397	.000	.916	-.273	.187	11.88	.155	.063	*.007*	0.065
Headache	.273	*.000*	-.534	*.000*	.399	*.000*	.036	.833	.259	*.000*	-.523	.018	57.17	*.000*	.117	*.000*	0.115
Nausea	.030	.121	-.000	.821	.211	*.000*	.109	.100	-.030	.297	-.510	.308	11.63	*.002*	.036	*.000*	0.056
Faintness	.047	.077	-.014	.773	.279	*.000*	-.142	.115	.031	.425	-.523	.629	9.58	.062	.037	*.010*	0.043
Irritation	.078	.091	.102	.255	.069	.503	.019	.902	.048	.479	-.798	*.000*	48.70	*.000*	.181	*.000*	0.117
Wheezing	-.000	.985	-.000	.846	.258	*.000*	-.058	.412	.051	.096	-.290	.799	10.77	*.008*	.026	.023	0.055
Eye	-.059	.116	-.158	.031	.148	.080	-.337	*.008*	.023	.670	-.318	.181	23.06	*.001*	.059	*.004*	0.047
Tear	-.026	.462	-.140	.041	.215	*.006*	-.316	*.008*	.026	.612	-.211	.341	31.78	*.000*	.033	.087	0.059
Skin	.132	.018	-.000	.934	-.104	.405	.045	.810	-.056	.492	-.732	*.010*	14.06	.194	.085	*.006*	0.024
Bronchitis	.010	.741	.011	.844	.419	*.000*	-.118	.262	-.052	.255	-.324	.061	14.11	*.008*	.072	*.000*	0.068
Chest	-.012	.719	.039	.550	.564	*.000*	.020	.858	-.021	.661	-.207	.044	32.20	*.000*	.079	*.000*	0.094
Vision	.049	.030	.036	.405	.251	*.000*	-.069	.365	.130	*.000*	.199	.955	8.70	.047	.034	*.005*	0.062
Total score	.681	*.008*	-.310	.529	3.512	*.000*	-.113	.198	.887	.019	-.060	*.000*	400.38	*.000*	1.174	*.000*	0.220

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (6.8) The Relationship Between Physical Symptoms and Different Pollutants and Demographic Features
Regression Coefficient and Statistical Significance for Seven Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Cough	-.000	.861	-.029	.776	.405	*.000*	-.034	.849	.301	*.000*	-.568	.018	76.54	*.000*	0.091
Breath	.025	.279	.011	.804	.359	*.000*	-.104	.179	.033	.321	-.136	.190	9.27	.021	0.054
Sore throat	.016	.674	-.145	.058	-.011	.897	-.028	.833	.042	.463	-.701	*.000*	46.45	*.000*	0.067
Dry throat	.020	.607	-.126	.101	.155	.081	-.000	.942	.067	.251	-.737	*.000*	64.01	*.000*	0.087
Mucus	.103	.017	.607	*.000*	.102	.291	.176	.225	-.000	.966	-.171	.379	21.78	*.003*	0.059
Headache	.274	*.000*	-.548	*.000*	.401	*.000*	.132	.442	.242	*.001*	-.385	.093	55.28	*.000*	0.102
Nausea	.031	.118	-.013	.733	.212	*.000*	.139	.035	-.035	.221	-.040	.646	17.27	*.000*	0.047
Faintness	.047	.076	-.019	.707	.279	*.000*	-.111	.213	.025	.510	-.606	.957	15.38	*.000*	0.038
Irritation	.080	.091	.080	.382	.071	.502	.129	.415	.021	.753	-.570	*.007*	76.75	*.000*	0.077
Wheezing	-.000	.995	-.011	.786	.258	*.000*	-.037	.601	.048	.124	.012	*.000*	14.85	*.000*	0.051
Eye	-.059	.121	-.165	.024	.148	.079	-.288	.023	.032	.561	-.147	.386	32.27	*.000*	0.039
Tear	-.025	.468	-.144	.035	.216	*.006*	-.289	.015	.021	.679	-.107	.501	36.96	*.000*	0.057
Skin	.133	.018	-.019	.859	-.103	.410	.115	.541	-.069	.403	-.534	.034	27.21	*.005*	0.017
Bronchitis	.011	.726	.000	.960	.420	*.000*	-.058	.575	-.062	.174	-.164	.242	25.31	*.000*	0.053
Chest	-.011	.738	.029	.654	.565	*.000*	.085	.455	.033	.505	-.199	.192	35.48	*.000*	0.079
Vision	.049	.029	.032	.462	.251	*.000*	-.040	.591	.125	*.000*	.054	*.000*	14.10	*.000*	0.056
Total score	.692	*.008*	-.453	.372	3.518	*.000*	-.145	.868	.722	.063	-.044	*.000*	582.88	*.000*	0.172

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (6.9) The Relationship Between Physical Symptoms and Different Pollutants and Demographic Features
Regression Coefficient and Statistical Significance for Thirty Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		H_2S		SO2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Cough	-.000	.868	-.029	.772	.419	.000	-.113	.531	.313	.000	-.528	.407	- 58.30	.597	119.21	.000	-.248	.000	.363	.432	0.12	.980	23.73	.354	- 6.53	.803	0.128
Breath	.025	.275	.016	.716	.360	.000	-.137	.082	.040	.235	-.097	.728	9.99	.836	0.29	.982	.128	.734	.275	.173	-2.01	.341	0.26	.981	- 5.06	.658	0.064
Sore throat	.015	.691	-.160	.035	-.000	.978	-.139	.299	.049	.392	-.109	.817	109.08	.183	94.93	.000	-.718	.000	-.272	.426	5.28	.141	- 7.58	.690	14.16	.466	0.101
Dry throat	.018	.632	-.142	.061	.161	.067	-.109	.418	.071	.219	-.238	.616	167.32	.042	100.22	.000	-.649	.000	-.460	.181	6.95	.054	-16.63	.384	22.64	.247	0.116
Mucus	.106	.014	.614	.000	-.102	.288	.092	.532	.000	.953	.782	.134	-134.01	.138	50.05	.045	-.367	.053	.173	.647	0.53	.893	44.81	.033	-38.35	.074	0.074
Headache	.278	.000	-.537	.000	.393	.000	.030	.862	.245	.001	-.970	.113	-199.02	.060	106.75	.000	-.427	.003	.061	.890	4.37	.345	67.69	.006	-55.35	.027	0.131
Nausea	.030	.119	-.012	.740	.218	.000	.103	.126	-.030	.295	-.004	.998	17.04	.679	15.37	.009	-.404	.211	.170	.325	-1.07	.553	- 5.61	.558	7.54	.442	0.060
Faintness	.047	.074	-.014	.775	.283	.000	-.140	.126	.030	.445	.017	.957	- 14.06	.801	8.18	.602	-.133	.761	.187	.423	-1.47	.546	- 1.07	.934	6.49	.625	0.043
Irritation	.080	.080	.084	.341	.102	.315	-.108	.487	.050	.456	.278	.613	79.90	.403	70.02	.008	.183	.000	.884	.027	6.00	.150	15.71	.478	46.92	.038	0.149
Wheezing	.232	.980	-.000	.826	.258	.000	-.057	.427	.049	.112	.029	.360	- 33.56	.450	23.76	.053	-.365	.294	.033	.856	0.56	.769	11.89	.249	-13.37	.204	0.056
Eye	-.058	.120	-.159	.029	.159	.058	-.300	.010	.030	.586	-.371	.415	-151.34	.055	35.18	.107	.044	.942	.228	.488	-1.43	.678	5.75	.753	6.36	.733	0.061
Tear	-.025	.470	-.145	.034	.227	.004	-.283	.010	.020	.699	-.181	.673	-115.88	.119	52.67	.010	-.459	.430	.115	.710	-0.45	.889	3.99	.817	6.67	.705	0.070
Skin	.136	.015	-.014	.894	-.106	.395	.074	.699	-.069	.401	-.031	.962	-290.25	.013	67.89	.017	-.775	.397	-.151	.756	4.67	.361	58.86	.030	-59.16	.033	0.036
Bronchitis	.011	.716	.000	.899	.420	.000	-.148	.165	-.051	.263	.187	.619	51.69	.428	23.13	.002	-.792	.121	.174	.522	0.07	.980	4.49	.766	- 9.90	.522	0.070
Chest	-.011	.735	.029	.652	.567	.000	-.010	.925	.023	.638	.089	.827	72.54	.307	39.19	.046	-.506	.928	.020	.944	2.12	.494	- 2.61	.874	4.05	.928	0.100
Vision	.048	.031	.033	.446	.254	.000	-.068	.380	.130	.000	-.145	.595	47.03	.322	3.95	.763	.075	.997	.085	.666	-0.33	.872	-12.88	.243	10.01	.374	0.065
Total score	.701	.005	-.434	.374	3.612	.000	-.314	.129	.818	.028	.019	.516	-426.51	.420	825.86	.000	-.828	.000	1.785	.419	9.47	.620	160.91	.190	-69.54	.579	0.242

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (6.10) The Relationship Between Physical Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Thirty Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Cough	-.000	.924	-.021	.836	-.421	.066	-.000	.996	.307	*.000*	-.449	.066	49.95	*.000*	0.063
Breath	.025	.268	.011	.789	.361	*.000*	-.112	.151	.035	.304	-.117	.258	5.19	.172	0.051
Sore throat	.020	.612	-.140	.073	.000	.959	-.081	.554	.051	.329	-.584	*.001*	31.12	*.000*	0.030
Dry throat	.024	.549	-.120	.127	.170	.061	-.052	.703	.074	.216	-.623	*.000*	38.90	*.000*	0.046
Mucus	.105	.016	.609	*.000*	.097	.314	.166	.260	-.000	.989	-.136	.482	14.13	.048	0.056
Headache	.276	*.000*	-.542	*.000*	.405	*.000*	.154	.376	.240	*.001*	-.350	.129	45.99	*.000*	0.095
Nausea	.032	.107	-.011	.768	.217	*.000*	.122	.069	-.033	.260	-.004	.960	9.39	*.004*	0.033
Faintness	.048	.072	-.017	.730	.282	*.000*	-.115	.205	.026	.499	.013	.909	10.79	.014	0.033
Irritation	.086	.078	.087	.355	.097	.370	.030	.855	.036	.611	-.382	.079	36.69	*.000*	0.024
Wheezing	-.000	.981	-.000	.816	.260	*.000*	-.036	.614	.048	.124	.027	.776	11.28	*.001*	0.046
Eye	-.057	.129	-.161	.028	.151	.075	-.280	.030	.032	.557	-.121	.476	25.86	*.000*	0.034
Tear	-.024	.495	-.140	.042	.219	*.006*	-.280	.020	.021	.686	-.077	.630	29.43	*.000*	0.048
Skin	.134	.017	-.016	.880	-.102	.417	.127	.503	-.070	.396	-.518	.040	22.96	.013	0.016
Bronchitis	.012	.683	.000	.930	.426	*.000*	-.086	.417	-.058	.208	-.107	.448	13.08	*.010*	0.040
Chest	-.000	.794	.032	.622	.575	*.000*	.051	.661	.028	.578	-.125	.417	19.83	*.000*	0.060
Vision	.050	.027	.033	.445	.255	*.000*	-.052	.500	.127	*.000*	.080	.429	8.21	.029	0.049
Total score	.725	*.008*	-.397	.452	3.644	*.000*	-.436	.637	.765	.058	-.035	*.004*	375.05	*.000*	0.108

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (6.11) The Relationship Between Physical Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance

	Sex B	Sex P	Age < 5 B	Age < 5 P	Age 65+ B	Age 65+ P	Housing B	Housing P	Smoking B	Smoking P	Avetemp B	Avetemp P	SO2 30 days B	SO2 30 days P	CO 7 days B	CO 7 days P	R^2
Cough	-.000	.859	-.000	.997	.409	*.000*	-.128	.479	.331	*.000*	-.800	*.001*	34.46	*.000*	.200	*.000*	0.106
Breath	.024	.281	.016	.716	.359	*.000*	-.137	.079	.039	.242	-.186	.077	2.15	.580	.039	*.000*	0.060
Sore throat	.017	.653	-.127	.100	-.000	.975	-.159	.240	.065	.264	-.800	*.000*	21.59	*.001*	.123	*.000*	0.061
Dry throat	.022	.585	-.107	.165	.163	.068	-.125	.359	.087	.138	-.824	*.000*	30.04	*.000*	.114	*.000*	0.072
Mucus	.103	.017	.617	*.000*	-.102	.291	.119	.416	.000	.902	-.264	.181	8.50	.245	.072	*.000*	0.065
Headache	.273	*.000*	-.527	*.000*	.396	*.000*	.066	.703	.256	*.000*	-.593	*.012*	35.25	*.000*	.139	*.000*	0.118
Nausea	.031	.115	-.000	.868	.214	*.000*	.092	.168	-.027	.345	-.086	.337	5.76	.084	.047	*.000*	0.051
Faintness	.047	.076	-.013	.799	.279	*.000*	-.143	.115	.031	.417	-.064	.599	7.36	.102	.044	*.001*	0.042
Irritation	.081	.083	.111	.217	.083	.423	.115	.468	.063	.356	-.784	*.000*	18.99	*.006*	.229	*.000*	0.093
Wheezing	-.000	.992	-.000	.885	.258	*.000*	-.057	.422	.052	.094	-.032	.739	8.67	*.005*	.033	*.001*	0.054
Eye	-.059	.117	-.153	.035	.147	.082	-.327	*.010*	.024	.666	-.251	.145	20.11	*.001*	.074	*.000*	0.047
Tear	-.025	.472	-.134	.050	.216	*.006*	-.316	*.009*	.027	.595	-.174	.283	25.12	*.000*	.055	*.002*	0.056
Skin	.132	.018	-.000	.952	-.107	.391	.069	.715	-.059	.472	-.678	*.008*	15.89	.093	.091	*.001*	0.025
Bronchitis	.011	.724	.014	.809	.423	*.000*	-.141	.183	-.048	.292	-.257	.071	6.48	.217	.085	*.000*	0.065
Chest	-.011	.744	.043	.507	.569	*.000*	.012	.914	.016	.744	-.301	.052	11.64	.043	.100	*.000*	0.087
Vision	.049	.029	.038	.384	.252	*.000*	-.079	.306	.131	*.000*	.006	.947	4.93	.199	.042	*.000*	0.060
Total score	.694	*.007*	-.235	.637	3.558	*.000*	-.392	.114	.939	.014	-.061	*.000*	258.92	*.000*	1.496	*.000*	0.200

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

6.5 Estimation of Effects of Changing Pollution Levels

6.5.1 Methods

In this section, an attempt is made to estimate the likely effects of changes of pollution levels on physical symptoms. In the light of the large numbers of physical symptoms for which data were available and the inter-correlation between them described in section 6.2, summary scores were calculated for each of the symptom `clusters' identified (respiratory, nose & throat, eyes and `neuro') by summing each respondent's scores for the constituent symptoms in each cluster. Stepwise regression was then used as a basis for identifying the demographic, meterological and pollution factors most closely linked to each symptom cluster score.

In each case, two pollutants were found to be important. In general the levels of two pollutants were correlated, which leads to problems over attribution of effect. To address this, two coefficients were derived for each pollutant. The first coefficient (`full loading') was that obtained by making the pollutant in question the only one in the regression equation. This coefficient was thus based on a model which attributes as much effect to the pollutant in question as possible. The second coefficient (`shared loading') was that obtained by putting both pollutants into the regression equation simultaneously, without any others. This is based on a model in which any effect on symptoms which could, in the event of collinearity of the two pollutants, be attributable to either of them, is split between the two.

The final step was to use the regression equations derived from the stepwise analyses to predict *current* mean symptom scores in each of the three study areas, and also mean symptom scores under different assumptions about reductions in levels of the two key pollutants. A `lower' estimate for each area and pollutant was based on the first of the two regression coefficients described in the previous paragraph (full loading), ie the one that was a maximum estimate of the true effect of reductions in pollution levels. An `upper' estimate was based on the second of the two coefficients (partial loading), which was probably more realistic.

6.5.2 Respiratory Symptoms

It was found from the stepwise analysis that both SO_2 and CO were related to respiratory symptoms (cough, shortness of breath, wheezing, bronchitis and chest discomfort). The model actually used, which included age 65+ and smoking (Table 6.12), gave quite accurate predictions of the actual mean symptom scores for the Fahaheel, Rega and Mishrif (Table 6.13).

The full-loading model predicts that a 50% decrease in SO_2 levels would reduce the mean respiratory symptom score in Fahaheel from 1.48 to 0.95, and a 100% reduction would take it down to 0.41. (The 0.41 value in this case is the predicted residual symptom level resulting from factors other than SO_2.) According to the partial-loading model it would only be reduced to 1.12 and 0.77 respectively.

In Rega, and particularly in Mishrif, the initial symptom levels are lower, and the effect of reducing SO_2 is much less, because a relatively small proportion of the respiratory symptoms are attributable to SO_2.

For CO, the full-loading model predicts that a 50% decrease in atmospheric concentration would reduce the mean respiratory symptom score in Fahaheel from 1.48 to 1.16, and a 100% decrease would reduce it to 0.83. Thus the models suggest that for Fahaheel, reductions in CO levels would be less effective in reducing respiratory symptoms than reductions in SO_2. In Rega, by contrast, reducing CO would be more helpful than reducing SO_2, because the initial levels of CO were relatively high.

6.5.3 Nose & throat symptoms

The stepwise regression analyses identified SO_2 and NCH_4 as related to nose & throat symptoms (sore throat, dry throat and irritation of nose and throat) (Table 6.12). The predicted values for the mean symptom scores in the three study areas were not as close to the actual ones as they were for respiratory symptoms (Table 6.13).

For full loading of effect on SO_2, the predicted result of reducing concentrations in Fahaheel by 50% was to reduce the mean symptom score from 1.62 to 0.96 (Table 6.13). Eliminating SO_2 altogether would take the mean score down to 0.31. However a more likely result is given by the partial loading model, for which the corresponding reductions are to 1.14 and 0.67. These are of the same order of magnitude as those for respiratory symptoms.

For both full and partial loading of effect on NCH_4, changes in NCH_4 appear to be more effective than changes in SO_2 in reducing nose and throat symptoms. In fact under full loading of effects, complete elimination of NCH_4 reduced the predicted score in Fahaheel from 1.62 to an impossible -0.01. The implication is that the model is inappropriately specified. The most likely explanations are either that relationship between NCH_4 and nose and throat symptoms is a non-linear one or that the assumption of full loading is wrong.

6.5.4 Eye Symptoms

The stepwise analysis suggested that SO_2 and NO were related to eye symptoms (irritation of the eyes and tears) (Table 6.12). However this model was less good than those for the other symptom clusters, with an R^2 of 0.055, and poor predictions of actual mean area levels (Table 6.13).

In Rega and Mishrif, the predicted effects on eye symptoms of reductions in SO_2 levels were quite small, even assuming full loading of effect (Table 6.13). In Fahaheel the effect was more substantial because of the relatively very high initial SO_2 levels.

The predicted effect of reductions of NO were more substantial, roughly halving symptom levels in all three areas even with partial loading.

6.5.5 `Neuro' symptoms

As for respiratory symptoms, SO_2 and CO were the two pollutants linked to `neuro' symptoms (headache, nausea and faintness) (Table 6.12). The predictions of the actual mean symptom scores in Rega and Mishrif were only fair (Table 6.13). The effects of reductions in SO_2 levels were proportionately less strong for neuro symptoms than they were for respiratory symptoms. In Fahaheel the effects of 50% and 100% reduction were to reduce predicted symptom scores from 1.14 t 0.87 and 0.59 respectively (Table 6.13). However the difference between full-loading and partial loading models was not so great in this case, with corresponding figures from the partial-loading model of 0.96 an 0.78. The predicted effect of complete elimination of SO_2 was to leave all three study areas with broadly similar prevalence of these kinds of symptom.

In terms of the effects of reducing CO levels, the full-loading model again suggested relatively modest gains in Rega and Mishrif compared to the effects on respiratory symptoms. Even in Fahaheel elimination of CO only reduced the predicted `neuro' score from 1.14 to 0.81. In Rega it was reduced from 0.77 to 0.53 and in Mishrif from 0.52 to 0.43. In fact the models suggest that the contribution of environmental pollution to `neuro' symptoms was relatively small.

Table (6.12) Models Used for Predicting the Effect on Symptom Levels of Reductions in Pollution Levels

	Constant	Sex	Age<5	Age 65+	Housing	Smoking	Avetemp	SO_2	CO	NCH_4	NO	R^2
Respiratory	0.454			2.00		0.331	-0.017	107.9	0.359			0.126
	0.630			2.01		0.280	-0.014	162.1				0.104
	0.488			2.06		0.386	-0.015		0.495			0.109
Nose & throat	0.961						-0.029	143.32		3.198		0.123
	1.003						-0.024	198.3				0.096
	1.078						-0.026			4.893		0.088
Eyes	0.696		-0.300	0.365	-0.588			40.50			16.42	0.055
	0.808		-0.293	0.391	-0.729						26.39	0.049
	0.773		-0.310	0.361	-0.524			66.83				0.049
Neuro	0.227	0.353	-0.561	0.892		0.259		54.95	0.178			0.113
	0.359	0.354	-0.578	0.895		0.234		82.90				0.098
	0.272	0.360	-0.554	0.923		0.291			0.250			0.101

Data from household survey, mobile monitoring stations and airport monitoring unit.

Table 6.13: The effects on symptom scores of % reductions in pollution levels

Respiratory symptoms	*Effect of reduction in SO2*						*Effect of reduction in CO*					
	Fahaheel		*Rega*		*Mishrif*		*Fahaheel*		*Rega*		*Mishrif*	
	lower	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*
Actual symptom score	1.50		0.75		0.25		1.50		0.75		0.25	
Predicted score	1.48		0.76		0.25		1.48		0.76		0.25	
25% reduction	1.21	1.30	0.70	0.72	0.24	0.24	1.32	1.36	0.64	0.67	0.21	0.22
50%	0.95	1.12	0.64	0.68	0.22	0.23	1.16	1.25	0.52	0.59	0.17	0.19
75%	0.68	0.95	0.59	0.64	0.20	0.22	0.99	1.13	0.41	0.50	0.13	0.16
100%	0.41	0.77	0.53	0.60	0.18	0.20	0.83	1.01	0.29	0.42	0.08	0.13

Throat symptoms	*Effect of reduction in SO2*						*Effect of reduction in NCH4*					
	Fahaheel		*Rega*		*Mishrif*		*Fahaheel*		*Rega*		*Mishrif*	
	lower	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*
Actual symptom score	1.71		0.75		0.28		1.71		0.75		0.28	
Predicted score	1.62		0.79		0.33		1.62		0.79		0.33	
25% reduction	1.29	1.38	0.72	0.74	0.30	0.31	1.21	1.35	0.56	0.64	0.24	0.27
50%	0.96	1.14	0.65	0.69	0.28	0.29	0.80	1.08	0.32	0.48	0.16	0.22
75%	0.64	0.91	0.58	0.64	0.26	0.28	0.40	0.82	0.09	0.33	0.08	0.16
100%	0.31	0.67	0.51	0.59	0.23	0.26	-0.01	0.55	-0.15	0.18	-0.01	0.11

Table 6.13 (cont): The effects on symptom scores of % reductions in pollution levels

Eye symptoms	*Effect of reduction in SO2*						*Effect of reduction in NO*					
	Fahaheel		*Rega*		*Mishrif*		*Fahaheel*		*Rega*		*Mishrif*	
	lower	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*
Actual symptom score	0.64		0.53		0.12		0.64		0.53		0.12	
Predicted score	0.70		0.39		0.20		0.70		0.39		0.20	
25% reduction	0.58	0.63	0.37	0.38	0.19	0.20	0.54	0.60	0.30	0.33	0.16	0.18
50%	0.47	0.56	0.35	0.36	0.19	0.19	0.38	0.50	0.20	0.27	0.12	0.15
75%	0.36	0.50	0.32	0.35	0.18	0.19	0.22	0.40	0.11	0.22	0.08	0.13
100%	0.25	0.43	0.30	0.34	0.17	0.18	0.06	0.30	0.01	0.16	0.04	0.10

Neuro symptoms	*Effect of reduction in SO2*						*Effect of reduction in CO*					
	Fahaheel		*Rega*		*Mishrif*		*Fahaheel*		*Rega*		*Mishrif*	
	lower	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*
Actual symptom score	1.18		0.85		0.40		1.18		0.85		0.40	
Predicted score	1.14		0.77		0.52		1.14		0.77		0.52	
25% reduction	1.00	1.05	0.74	0.75	0.51	0.51	1.06	1.08	0.71	0.73	0.50	0.50
50%	0.87	0.96	0.71	0.73	0.50	0.51	0.98	1.02	0.65	0.69	0.48	0.49
75%	0.73	0.87	0.68	0.71	0.49	0.50	0.89	0.97	0.59	0.64	0.46	0.47
100%	0.59	0.78	0.65	0.69	0.48	0.49	0.81	0.91	0.53	0.60	0.43	0.46

6.6 Discussion

These results confirm and add to the findings of the more aggregated types of analyses presented in the previous chapter. SO_2 and CO are the pollutants most closely linked with physical symptoms, but the degree of correlation between their levels in different areas means that for most symptoms it is impossible to be precise about how much of the prevalence can be attributed to SO_2 and how much to CO. Other pollutants also seem to have parts to play; in particular, NO was linked to eye-related problems and NCH_4 was linked to symptoms of the nose and throat.

The main demographic factor was age, which was expected. The only available indicator of income or social class was education. There are no Kuwaiti studies validating education as such an indicator, and even this was only really interpretable within a limited age band. Thus the fact that educational level was not linked to physical symptoms could have been because of its failings as an indicator.

Housing was a factor in eye-related symptoms. Most of the housing in the three study areas consists of modern villas, but there were a few buildings constructed in the traditional arab style, and these appeared to be the source of the problem. It may be that they are more dusty, but this is speculative.

Smoking was a factor in cough, headache and vision loss. The first two of these links are unsurprising (eg, Lambert and Reid, 1970) and in a sense validate the other results. Vision loss is a relatively rare but plainly severe symptom which merits more detailed study.

Average temperature was linked to sore throat, dry throat, irritation of the throat and irritation of the skin. The most ready explanation is that these are seasonal effects. However it was average temperature over the past 7 days that emerged as significant, rather than average temperature over the past 30 days. This suggests that short-term changes in temperature are at least as important as seasonal changes.

The distributions of symptom scores and pollution levels in these models were quite skewed, and so some of the assumptions underlying the regression analyses were violated. The decision to use untransformed data was based on the observation that the log, logistic and square transformations did not materially improve the fit, so that the assumption of linearity was a good as any, and the coefficients would be easier to interpret.

The problems caused by skewness lie not so much in the estimates of the coefficients but in estimates of standard errors of coefficients, in the p-values derived, and in any attempt to construct confidence or prediction intervals. There are already question-marks over the validity of standard errors because of the use of cluster sampling rather than random sampling. In the event, most of the p-values were so extreme (< .01) that the results should be reasonably robust to erroneous standard error estimates. The issue of confidence or prediction intervals was more problematic however, and so although evidently desirable, no attempt was made to calculate them.

To what extent are these findings consistent with the results of earlier epidemiological studies? Cassell (1969) for example also found that cough was correlated with SO_2 and CO. However he found that headache and sore throat were positively correlated with carbon monoxide, whereas in this study SO_2 was implicated in these two symptoms as well. He also found that NCH_4 appeared to have a protective effect on sore throat, but did not address the possibility that this might be due to inadequate accounting for meteorological effects.

Lambert and Reid (1970) found a proportionate rise in prevalence of cough with increased air pollution in a large sample of people aged 35-39. The range of annual SO_2 concentration over which the effect observed was <100-200ug/m. Schenker (1983) found no significant link between SO_2 and cough in non-smokers. This study has been criticised because only annual average pollution levels were used. The results for cough described above, 30-day SO_2 levels gave slightly better results than 7-day levels, and it may be seasonal factors are important here.

The finding from this study of a relationship between SO_2 levels and bronchitis symptoms may be seen as extending the link established by Winken and Buck (1964) between SO_2 and bronchitis mortality.

The study Schenker (1983) already mentioned also addressed the issue of wheeze. He found a small increased risk in non-smokers with increased SO_2 concentration. In this study, surprisingly perhaps, smoking did not emerge as a factor.

Schwartz (1992) used ordinary regression analysis to examine the possibility that air pollution exposure can extend the duration of respiratory symptoms. Temperature, family income and smoking were all controlled for. Cough, sore throat and chest discomfort were all considered, with average levels for SO_2, CO and NO_2 during the week and the month before the episode began. Only SO_2 was significantly associated with chest discomfort (p=.016).

The laboratory studies tend not to be comparable because they generally involve exposure to higher levels of pollution for fewer subjects and shorter periods of time. Also they tend to use more physiological outcome measures, and may focus on subjects with specific diseases. For example in the study by Kerr (1978) NO_2 was found to increase in airway resistance and sensitivity to bronchio-constriction in sensitive individuals. Known asthmatics and bronchitics exposed to .05 ppm NO_2 reported chest discomfort, burning of the eyes, headache and dyspnoea with exercise. In the study by Linn (1985), healthy and asthmatic volunteers were exposed to NO_2 at 4 ppm for 75 minutes, but this produced no significant effects, which is more in line with the results reported here. Huang, Wang and Hsieh (1991) concluded that short-term exposures to low concentration of SO_2 and NO_2

did not affect the lung function and did not increase bronchial sensitivity, but they only had six subjects (5 male and 1 female), 10 to 14 years of age.

It would appear then that this Kuwaiti study goes considerably further than others reported in the literature in terms of the range of symptoms studied and pollutants considered. This has allowed a more detailed consideration of the effects of correlation, which would otherwise have to be approached by controlled studies in the laboratory, with all their drawbacks in terms of cost, possible bias in the selection of subjects, limited duration of exposure and assessment of implications for the real world.

The relationship between the reduction in pollution levels in the residential areas (Fahaheel, Rega and Mishrif) and the prevalence of symptoms was predicted using a series of models to estimate how far a reduction in the level of SO_2, CO, NO and NCH_4 concentrations to 25%, 50%, 75% and 100% would affect symptom scores. Analyses of this kind, although a natural extension of descriptive studies, appear to be new. However the results must be treated with some caution for a number of reasons. First, correlation between levels of different pollutants limits the precision with which effects can be attributed to one pollutant rather than another, and hence the confidence that can be placed in estimates of the outcome of changes in one pollutant alone. Second, the predictions made using these models will inevitably be subject to error as a result of random or unexplained variation. With cluster sampling and skewed distributions, orthodox calculations of standard errors, and hence confidence intervals, may give misleading results.

In view of these results abatement projects should be implemented in each industrial unit in SIA in order to minimize the release of pollutants into the air and so reduce the harmful effects of these pollutants on human health.

CHAPTER SEVEN

RESULTS: REGRESSION ANALYSIS RELATING AIR POLLUTION TO PSYCHOLOGICAL SYMPTOMS

CHAPTER SEVEN

RESULTS: REGRESSION ANALYSIS RELATING AIR POLLUTION TO PSYCHOLOGICAL SYMPTOMS

7.1 Introduction

This chapter is concerned with quantifying the links between air pollution and psychological symptoms in Kuwait. As with the physical symptoms, there are many dependent and independent variables, and consequently many regression analyses and derived coefficients. As in chapter 7, in general only results with a p-value of less than 0.01 will be commented upon the text. First, consideration will to be given to correlation within the psychological symptoms.

7.2 Correlation and factor analysis.

The correlation matrix for psychological effects is shown in Table 7.1. Examination of this matrix, combined with principal components analysis suggested a number of sets of symptoms that tend to be associated. The first group included tiredness, finding it annoying to go outside, loss of energy, waking up early in the morning, feeling depressed, loss of sense of smell and loss of appetite ('lassitude symptoms'). The second group included going to sleep, taking sleeping tablets and lying awake most nights ('sleep disorders'). The third group included under weight, anxiety and distress ('anxiety symptoms'). The symptoms that fell into no particular grouping were temper and itching skin.

Table (7.1) Correlation Matrix for Psychological Symptoms

	App	Sme	Wal	Dep	Ene	Tir	Poo	Wak	GOs	Tab	Lay	Un W	Dis	Tem	Anx	Skin
Appetite	.	.504	.520	.488	.435	.360	.357	.270	.182	.246	.136	.308	.296	.240	.200	.056
Smell	.504	.	.545	.420	.406	.301	.279	.327	.070	.246	.140	.191	.178	.195	.247	.096
Walk out	.520	.545	.	.510	.429	.419	.325	.276	.189	.305	.099	.241	.281	.195	.187	.154
Depressed	.488	.420	.510	.	.418	.379	.280	.243	.162	.271	.162	.201	.360	.197	.241	.000
Energy	.435	.406	.429	.418	.	.462	.314	.341	.097	.264	.165	.177	.313	.177	.271	.037
Tired	.360	.301	.419	.379	.462	.	.280	.245	.261	.296	.170	.110	.204	.237	.185	.045
Poor sleep	.357	.279	.325	.280	.314	.280	.	.186	.219	.245	.198	.176	.264	.117	.176	.083
Wake up	.270	.327	.276	.243	.341	.245	.186	.	.076	.171	.134	.048	.163	.067	.147	.069
Go sleep	.182	.070	.189	.162	.097	.261	.219	.076	.	.243	.207	.075	.102	.160	.068	.056
Tablets	.246	.246	.305	.271	.264	.296	.245	.171	.243	.	.247	.105	.186	.188	.238	.024
Laying	.136	.140	.099	.162	.165	.170	.198	.134	.207	.247	.	.023	.207	.115	.160	.048
Und weight	.308	.191	.241	.201	.177	.110	.176	.048	.075	.105	.023	.	.256	.010	.085	.046
Distress	.296	.178	.281	.360	.313	.204	.264	.163	.102	.186	.207	.207	.	.068	.198	.033
Temper	.240	.195	.195	.197	.177	.237	.117	.070	.160	.188	.115	.010	.068	.	.012	.043
Anxious	.200	.247	.187	.241	.272	.185	.176	.176	.068	.238	.160	.085	.198	.012	.	.068
Skin	.056	.096	.154	.000	.037	.045	.083	.083	.056	.024	.048	.046	.033	.043	.068	.

Data from household survey.

7.3 Strategy for developing the Regression Analysis

The strategy that was used in the previous chapter to develop models for the links between pollution levels and physical symptoms and was also used for examining the links with psychological symptoms.

7.4 Results of regression analyses for psychological symptoms

7.4.1 Preliminary Results

Regression analyses involving educational level in age group 25 to 44 appeared to have an influence on only three of the psychological symptoms (reported tiredness, p=.009; temper, p=.000; and loss of weight, p=.000; Table 7.2). However, when included in analyses for the whole population it ceased to be significant. Because of doubts over its validity as an indicator for the whole population, it was omitted from the analyses reported here. Humidity was not significantly related to any of the psychological symptoms investigated, it too was omitted from the reported analyses.

7.4.2 Tiredness

Using the full 7-day model for factors affecting tiredness, sex, age<5, age 65+ (p=.000), SO_2 (p=.004) and CO (p=.002) were statistically significant, with R^2 = 0.182 (Table 7.3). The relationship with age <5 was an inverse one. With SO_2 and CO as the only pollutants in the equation, the coefficient for sex increased, SO_2 decreased and CO slightly increased and R^2 slightly reduced to 0.176 (Table 7.4).

For the equation that included only SO_2 the coefficient for SO_2 slightly increased but R^2 fell to 0.171 (Table 7.5).

The full 30-day model gave results very similar to those from the full 7-day model, but there was an inverse relationship NCH_4 ($p=.003$) and the coefficient for SO_2 increased (Table 7.6). With SO_2 as the only pollutant in the model, the coefficient for SO_2 fell back and R^2 dropped to 0.160 (Table 7.7).

Similar results were found in the mixed model and the fit was almost as good as in the 7-day SO_2/CO model (Table 7.8).

Table 7.4.2: Summary of regression analysis for tiredness

	Sex	Age<5	Age65+	SO_2	CO	R^2	Table
7 days all variables.	.239*	- .490*	.639*	38.55*	.046*	0.182	6.12
7 days SO_2 & CO.	.295*	- .494*	.641*	32.38*	.054*	0.176	6.13
7 days SO_2.	.260*	- .501*	.641*	40.73*		0.171	6.14
30 days all variables.	.262*	- .496*	.647*	62.60*	.058*	0.185	6.15
30 days SO_2.	.262*	- .496*	.646*	31.13*		0.160	6.16
30 day SO_2 & 7 day CO.	.260*	- .488*	.641*	25.37*	.077*	0.173	6.17

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.3 Finding it annoying to go outside

Regression analysis for 'finding it annoying to go outside' using the full 7-day model gave sex ($p=.005$), age 65+, average temperature, SO_2, CO, NO and NO_2

(p=.000) as the significant factors. R^2 was surprisingly high at 0.482; Table 7.3). The relationships with age <5 and average temperature were inverse.

With SO_2 and CO as the only pollutants in the model the coefficient for CO increased and R^2 fell a little to 0.459 (Table 7. 4). Entering SO_2 only, its coefficient increased and that for average temperature decreased, with R^2 more markedly reduced to 0.345 (Table 7.5).

Using the full 30-day model, the R^2 was 0.488, a little higher than the full 7-day model, but an inverse relationship with NCH_4 (p=.000) emerged. The coefficients for both SO_2 and CO increased (Table 7.6). With SO_2 as the only pollutant its coefficient, while still significant (p=.000), decreased, while R^2 dropped sharply to 0.207 (Table 7.7).

Using the mixed model gave an R^2 of 0.423, which was not as good as the 7-day SO_2/CO model (Table 7.8).

Table 7.4.3: Summary of regression analysis for finding it annoying to go outside

	Sex	Age<5	Age65+	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	.080*	-.243*	.282*	-.999*	90.23*	.229*	0.482	6.12
7 days SO_2 & CO.	.073*	-.244*	.272*	-.819*	90.50*	.252*	0.459	6.13
7 days SO_2.	.075*	-.275*	.274*	-.669*	129.50*		0.345	6.14
30 days all variables.	.077*	-.255*	.292*	-.439	134.67*	.867*	0.488	6.15
30 days SO_2.	.082*	-.262*	.262*	-.300	90.75*		0.207	6.16
30 day SO_2 & 7 day CO.	.075*	-.227*	.277*	-.859*	66.08*	.319*	0.423	6.17

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.4 Problems with getting to sleep

Using the full 7-day model, the variables most closely associated with problems with getting to sleep were sex and smoking (p=.000) but the R^2 was low at 0.044 (Table 7.3). Repeating the analysis with SO_2 and CO as the only pollutants, the same set of variables were significant and R^2 was only slightly reduced at 0.040 (Table 7.4). Even with SO_2 as the only pollutant in the model, it did not become significant, although the coefficient did increase (R^2 = 0.040; Table 7.5).

With the full 30-day model, there was an inverse relationship with H_2S (p=.009), with R^2 up to 0.054 (Table 7.6). The coefficient for SO_2 again increased substantially. The mixed model gave no better fit than the 7-day SO_2/CO model (R^2 = 0.041; Table 7.8).

7.4.5 Loss of temper

In the full 7-day model, loss of temper was associated with sex (p=.003) and smoking (p=.000). There was an inverse relationship with age <5 (p=.004). None of the pollutants had a significant effect and again the R^2 was low ($R^2 = 0.046$; Table 7.3).

With SO_2 and CO as the only pollutants in the model the coefficients hardly changed, but R^2 fell to 0.036 (Table 7.4). With SO_2 as the only pollutant it became statistically significant (p=.002), although the coefficient hardly changed and R^2 fell slightly further to 0.033 (Table 7.5).

With the full 30-day model, the same set of significant variables were found as in the full 7-day model and R^2 was about the same ($R^2 = 0.047$; Table 7.6). Using only 30-day SO_2, it again became significant (p=.006) but R^2 fell sharply to 0.031 (Table 7.7). The fit for the mixed model was similar to that for the 2-pollutant 7-day model ($R^2 = 0.037$; Table 7.8).

7.4.6 Running out of energy

The factors in running out of energy derived from the full 7-day model were sex, age 65+, average temperature SO_2 (p=.000) and CO (p=.001) ($R^2 = 0.230$; Table 7.3). The relationship with average temperature was inverse.

Removing all the pollutants except SO_2 and CO from the equation, the coefficients for the two pollutants dropped but R^2 remained about the same at 0.226 (Table 7.4). With CO out of the equation the coefficient for SO_2 increased again but R^2 fell to 0.200 (Table 7.5).

With the full 30-day model, SO_2 (p=.002) and NCH_4 (p=.003) came out as significant. R^2 was about the same as the full 7-day model at 0.226 (Table 7.6). There was an inverse relationship with NCH_4. With all the pollutants except SO_2 excluded, an inverse relationship with average temperature emerged (p=.000) but R^2 was down to 0.167 (Table 7.7).

In the mixed model, 30-day SO_2 and 7-day CO were both significant (p=.000). The inverse relationship with average temperature was there (p=.000) but with R^2 at 0.216 this model did not fit quite as well as the 7-day SO_2/CO model (Table 7.8).

Table 7.4.6: Summary of regression analyses for running out of energy

	Sex	Age65+	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	.130*	.734*	-.570*	54.02*	.144*	0.230	6.12
7 days SO_2 & CO.	.131*	.741*	-.596*	31.59*	.096*	0.226	6.13
7 days SO_2.	.132*	.742*	-.562*	46.53*		0.200	6.14
30 days all variables.	.133*	.740*	-.307	49.37*	.023	0.226	6.15
30 days SO_2.	.134*	.752*	-.490*	30.24*		0.167	6.16
30 day SO_2 & 7 day CO.	.132*	.745*	-.702*	20.85*	.121*	0.216	6.17

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.7 Poor sleep

With the full 7-day model, smoking (p=.001) and SO_2 (p=.008) emerged as the significant factors in poor sleep. R^2 was down to .106 (Table 7.3). With pollutants other than SO_2 and CO forced out of the model, CO became significant as well (p=.000), with R^2 and the coefficient for SO_2 hardly changed (Table 7.4). With SO_2 as the only pollutant in the equation, its coefficient increased but R^2 dropped sharply to 0.066 (Table 7.5).

With the full 30-day model, none of the pollutants became significant even though R^2 was slightly higher than the full 7-day model at 0.110 (Table 7.6). With SO_2 only, the coefficient for SO_2 decreased and R^2 fell to 0.047 (Table 7.7). With the mixed model SO_2 (p=.003) and CO (p=.000) were both significant but R^2 at 0.103 was about the same as for the 7-day SO_2/CO model (Table 7.8).

Table 7.4.7: Summary of regression analyses for poor sleep

	Smoking	SO_2	CO	R^2	Table
7 days all variables.	.134*	27.78*	.073	0.106	6.12
7 days SO_2 & CO.	.135*	28.16*	.105*	0.105	6.13
7 days SO_2.	.120*	34.49*		0.066	6.14
30 days all variables.	.129*	34.20*	.014	0.110	6.15
30 days SO_2.	.122*	23.83*		0.047	6.16
30 day SO_2 & 7 day CO.	.136*	24.71*	.118*	0.103	6.17

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

6.4.8 Waking up early in the morning

For waking up early in the morning, the full 7-day model yielded sex (p=.001), age 65+ (p=.000), smoking (p=.003), SO_2 (p=.000) and NH_3 (p=.002) as significant factors (R^2 = 0.198; Table 7.3). The relationship with NH_3 was inverse.

The coefficient for SO_2 was changed very little when SO_2 and CO were the only pollutants in the model; R^2 was down slightly to 0.186 (Table 7.4). With SO_2 only, its coefficient increased slightly and R^2 hardly changed (Table 7.5).

Using the full 30-day model, sex (p=.001), age 65+ (p=.000), smoking (p=.004), H_2S (p=.001), SO_2 (p=.010), NO (p=.005), NO_2 (p=.000) and NCH_4 (p=.000) were all statistically significant. R^2 a little higher than for the full 7-day model at 0.213 (Table 7.6). The relationship with NCH_4 was inverse. With SO_2 as the only pollutant in the model its coefficient decreased and R^2 dropped to 0.148 (Table 7.7).

In the mixed model, SO_2 (p=.000) and CO (p=.000) were statistically significant. The coefficient for SO_2 was low and R^2 fell to 0.162. This model was a poorer fit than the 7 days SO_2/CO model (Table 7.8).

Table 7.4.8: Summary of regression analyses for waking up early in the morning

	Sex	Age65+	Smoking	SO_2	R^2	Table
7 days all variables.	.072*	.567*	.096*	30.33*	0.198	6.12
7 days SO_2 & CO.	.071*	.564*	.090*	31.56*	0.186	6.13
7 days SO_2.	.071*	.564*	.087*	34.81*	0.184	6.14
30 days all variables.	.069*	.579*	.093*	32.85*	0.213	6.15
30 days SO_2.	.073*	.573*	.091*	20.06*	0.148	6.16
30 day SO_2 & 7 day CO.	.072*	.570*	.097*	16.82*	0.162	6.17

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.9 Feeling depressed

Using the full 7-day model for 'feeling depressed' gave sex (p=.000), age <5 (p=.002), age 65+ (p=.000), average temperature (p=.000), SO_2 (p=.000) and CO (p=.003) as significant factors (R^2 = 0.231; Table 7.3). The relationships with age <5 and average temperature were inverse. Removing all pollutants except SO_2 and CO from the model increased their coefficients slightly and had little effect on R^2

(R^2 = 0.221; Table 7.4) but for the SO_2 only model the drop in R^2 was marked (R^2 = 0.154; Table 7.5).

Using the full 30-day model, CO ceased to be significant and the coefficient for SO_2 decreased, but an inverse relationship with NCH_4 appeared (p.000). R^2 was about the same as for the full 7-day model at 0.229 (Table 7.6). With 30-day SO_2 as the only pollutant its coefficient decreased further and R^2 dropped sharply to 0.094 (Table 7.7). The mixed model did not fit as well as 7 days SO_2/CO model (R^2 = 0.206; Table 7.8).

Table 7.4.9: Summary of regression analyses for 'feeling depressed'

	Sex	Age<5	Age65+	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	.151*	-.166*	.250*	-.664*	56.25*	.134*	0.231	6.12
7 days SO_2 & CO.	.148*	-.171*	.248*	-.642*	63.60*	.151*	0.221	6.13
7 days SO_2.	.150*	-.190*	.249*	-.432*	60.07*		0.154	6.14
30 days all variables.	.151*	-.176*	.254*	-.069	44.58*	.346	0.229	6.15
30 days SO_2.	.153*	-.184*	.263*	-.329	37.27*		0.094	6.16
30 day SO_2 & 7 day CO.	.149*	-.164*	.252*	-.646*	23.26*	.181*	0.206	6.17

* significant at .01.

Average temperature =-.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.10 Taking sleeping tablets

Results from the full 7-day model for taking sleeping tablets suggested that sex (p=.002), age 65+ (p=.000), smoking (p=.003), SO_2 (p=.006) and CO (p=.004) were all significant factors. The R^2 was relatively low at 0.081 (Table 7.3). With all pollutants other than SO_2 and CO forced out, the coefficients for SO_2 and CO decreased but R^2 remained the same (Table 6.4). With SO_2 as the only pollutant its coefficient for SO_2 increased but R^2 dropped to 0.072 (Table 7.5).

With the full 30-day model none of the pollution variables were statistically significant but R^2 was similar to that for full 7-day model (Table 7.6). With SO_2 only in the model it became significant (p=.000), but its coefficient decreased and R^2 fell to 0.064 (Table 7.7). There was very little to choose between the mixed model and the 7-day SO_2/CO model in terms of fit (Table 7.8).

Table 7.4.10: Summary of regression analyses for taking sleeping tablets

	Sex	Age65+	Smoking	SO_2	CO	R^2	Table
7 days all variables.	.067*	.276*	.093*	15.70*	.051*	0.081	6.12
7 days SO_2 & CO.	.067*	.277*	.092*	12.24*	.038*	0.081	6.13
7 days SO_2.	.078*	.277*	.087*	18.27*		0.072	6.14
30 days all variables.	.068*	.279*	.092*	17.49	.250	0.081	6.15
30 days SO_2.	.068*	.280*	.087*	13.16*		0.064	6.16
30 day SO_2 & 7 day CO.	.067*	.277*	.093*	9.48*	.047*	0.079	6.17

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.11 Itching skin

Using the full 7-day model, none of the independent variables came out as significant factors in itching skin (Table 7.3), and R^2 was low at 0.043. However, with only SO_2 and CO of the pollutants left in the equation, SO_2 did become significant (p=.000, R^2 = 0.035; Table 7.4). With only SO_2, its coefficient increased but R^2 fell to a very low 0.031 (Table 7.5).

Using the full 30-day model, SO_2 was significant (p=.000) and there was an inverse relationship with H_2S (p=.008). Compared to the full 7-day model both the coefficient for SO_2 and R^2 increased (R^2 = 0.054; Table 7.6). With SO_2 as the only pollutant in the model the fit was much worse (R^2 = 0.027; Table 7.7). Unusually the mixed model, with SO_2 (p=.000) and CO (p=.002) statistically significant, but the fit was still poor (R^2=.037; Table 7.8).

7.4.12 Loss of sense of smell

For loss of sense of smell, the full 7-day model gave sex (p=.009), age <5, age 65+, average temperature, SO_2, NO and NO_2 (p=.000) as statistically significant. In this case R^2 was high at 0.380 (Table 7.3). The relationships with age <5 and average temperature were inverse. With SO_2 and CO as the only pollutants the results were similar and R^2 was still high at 0.365 (Table 7.4). Even with SO_2 as the only pollutant its coefficient increased but R^2 only fell to 0.365 (Table 7.5).

Using the full 30-day model, SO_2 (p=.000), H_2S (p=.006) and NCH_4 (inverse, p=.000) were significant. The coefficient for SO_2 increased but R^2 was about the same as for the 7-day model (Table 7.6). With SO_2 only, the coefficient for SO_2

decreased and R^2 was down to 0.239 (Table 7.7). The mixed model did not fit as well as the 7-day SO_2/CO model (Table 7.8).

Table 7.4.12: Summary of regression analyses for loss of sense of smell

	Age<5	Age65+	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	-.171*	.331*	-.626*	73.66*	.046	0.380	6.12
7 days SO_2 & CO.	-.166*	.320*	-.637*	87.47*	.070*	0.365	6.13
7 days SO_2.	-.175*	.321*	-.338*	98.43*		0.350	6.14
30 days all variables.	-.185*	.328*	-.089	133.46*	.051	0.378	6.15
30 days SO_2.	-.165*	.334*	-.230	72.99*		0.239	6.16
30 day SO_2 & 7 day CO.	-.150*	.326*	-.470*	62.39*	.137*	0.304	6.17

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.13 Loss of appetite

With the full 7-day model, loss of appetite was associated with sex, SO_2 (p=.000), NO, CO and age 65+ (p=.003). There was an inverse relationship with average temperature, and R^2 was a relatively high 0.257 (Table 7.3). Repeating the analysis with SO_2 and CO only, the significant variables were unchanged, with the coefficients for SO_2 and CO slightly increased and R^2 down slightly to 0.249 (Table 7.4). With SO_2 as the only pollutant in the model, its coefficient increased but R^2 dropped sharply to 0.179 (Table 7.5).

Using the full 30-day model, sex (p=.000), age 65+ (p=.003) and SO_2 (p=.000) were statistically significant. R^2 was steady at 0.259 (Table 7.6). With only SO_2, the coefficient for average temperature increased but R^2 dropped very sharply to 0.127 (Table 7.7).

The mixed 30-day SO_2 and 7-day CO over 7 model gave an R^2 of 0.245, generally similar to the value for the 7-day SO_2/CO equation (Table 7.8).

Table 7.4.13: Summary of regression analyses for loss of appetite

	Sex	Age65+	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	.148*	.207*	-.825*	46.51*	.145*	0.257	6.12
7 days SO_2 & CO.	.145*	.206*	-.703*	52.28*	.176*	0.249	6.13
7 days SO_2.	.147*	.208*	-.458*	79.63*		0.179	6.14
30 days all variables.	.149*	.206*	-.094	64.97*	.287	0.259	6.15
30 days SO_2.	.150*	.217*	-.376	60.25*		0.127	6.16
30 day SO_2 & 7 day CO.	.146*	.205*	-.747*	43.91*	.211*	0.245	6.17

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.14 Laying awake most nights

The only variable significantly associated with 'laying awake most nights' using the full 7-day model was average temperature (p=.000), but R^2 was very low indeed at 0.027 (Table 7.3). With SO_2 and CO as the only pollutants in the model, and with SO_2 only, R^2 was further reduced to 0.024 and 0.019 respectively (Table 7.4 and Table 7.5).

Using the 30-day model, R^2 was only very slightly increased (Table 7.6 and Table 7.7). With the mixed model, average temperature (.002) and CO (p=.001) became significant but R^2 was hardly changed at 0.025 (Table 7.8).

7.4.15 Anxiety

The variables most closely associated with anxiety in the full 7-day model were age 65+, SO_2 (p=.001) and NH_3 (p=.008), with an inverse relationship with housing (p=.000). The results were broadly similar with SO_2 and CO as the only pollutants (R^2 down from 0.141 to 0.134; Table 7.4). With SO_2 as the only pollutant, R^2 was unchanged (Table 7.5).

Using the full 30-day model, NH_3 was no longer significant, but R^2 was hardly changed (Table 7.6). With SO_2 only, its coefficient decreased and R^2 went down to 0.129 (Table 7.8). The fit for the mixed model was very similar to that for the 7-day SO_4/CO model (R^2 = 0.132; Table 7.8).

Table 7.4.15: Summary of regression analyses for anxiety

	Age 65+	Housing	SO_2	R^2	Table
7 days all variables.	.311*	- .281*	20.76*	0.141	6.12
7 days SO_2 & CO.	.313*	- .298*	19.04*	0.134	6.13
7 days SO_2.	.313*	- .296*	19.3*	0.134	6.14
30 days all variables.	.308*	- .291*	13.53	0.139	6.15
30 days SO_2.	.313*	- .284*	17.09*	0.129	6.16
30 day SO_2 & 7 day CO.	.312*	- .293*	15.94*	0.132	6.17

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.16 Loss of weight

Using the full 7-day model for loss of weight, both SO_2 (p=.000) and CO (p=.001) were statistically significant. Average temperature and smoking were inversely related (p=.000 and .004 respectively; R^2 = 0.099; Table 7.3). With the removal of all pollutants other than SO_2 and CO, the coefficient for SO_2 decreased and R^2 fell to 0.083 (Table 7.4). With only SO_2, its coefficient increased somewhat but R^2 fell further to 0.076 (Table 7.5).

Using the full 30-day model, SO_2, NO and NO_2 were statistically significant (p=.000) and there were inverse relationships with smoking (p=.001) and H_2S (p=.000). R^2 was 0.140, higher than that for full 7-day model (Table 7.6). With SO_2 as the only pollutant, its coefficient decreased and R^2 fell to a low 0.056 (Table 7.7). The mixed model did not fit as well as the 7-day SO_2/CO form (R^2 = 0.075; Table 7.8).

7.4.17 Distress

The last psychological symptom to be considered was distress. With the full 7-day model, sex (p=.003), age <5, age 65+ (p=.000) and CO (p.=010) were statistically significant, but R^2 was quite low at 0.082 (Table 7.3). Forcing out all the pollutants except SO_2 and CO brought in an inverse relationship with average temperature (p=.005) but R^2 hardly changed (Table 7.4). With SO_2 as the only pollutant, it became a significant factor (p=.000) but R^2 fell to a very low 0.045 (Table 7.5).

With the full 30-day model sex (p=.002), age <5 and age 65+ (p=.000) were significant but none of the pollution factors were. R^2 was slightly more than for the full 7-day model at 0.090 (Table 7.6). With only SO_2, R^2 collapsed to 0.038 (Table 7.7).

The mixed model gave a very similar R^2 to the 7-day SO_2/CO version, but the coefficient for SO_2 was doubled (Table 7.8).

Table 7.4.17: Summary of regression analyses for distress

	Sex	Age<5	Age65+	Avetemp	CO	R^2	Table
7 days all variables.	.063*	.155*	.194*	-.234	.084*	0.082	6.12
7 days SO_2 & CO.	.064*	.155*	.195*	-.268*	.078*	0.081	6.13
7 days SO_2.	.066*	.146*	.196*	-.175		0.045	6.14
30 days all variables.	.066*	.158*	.199*	-.128	.454	0.090	6.15
30 days SO_2.	.066*	.147*	.199*	-.525		0.038	6.16
30 day SO_2 & 7 day CO.	.064*	.156*	.194*	-.274*	.078*	0.081	6.17

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

7.4.18 Total psychological symptom score

As for physical symptoms, a new variable was constructed consisting of the sum of the scores for each psychological symptom. For the full 7-day model, sex, age 65+, SO_2, NO (p=.000), CO and NO_2 (p=.003) were statistically significant. There were also inverse relationships with age <5 and average temperature. R^2 was a high 0.386 (Table 7.3). With all the pollutants except SO_2 and CO forced out, R^2 was reduced to 0.356, with the coefficient for SO_2 decreased and for CO increased (Table 7.4). With SO_2 as the only pollutant, its coefficient SO_2 increased sharply but R^2 fell to 0.314 (Table 7.5).

With the full 30-day model, SO_2 (p=.000) was a significant factor and there was an inverse relationship with NCH_4 (p=.000). R^2 was 0.401, a slightly better fit that the full 7-day model (Table 7.6). In the SO_2 only model R^2 dropped sharply to

0.223 (Table 7.7). The R^2 for the mixed model was the same as that for the 7-day SO_2/CO version (Table 7.8).

Table 7.4.18: Summary of regression analyses for total psychological symptom score

	Sex	Age65+	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	1.461*	3.846*	-.063*	564.18*	1.228*	0.389	6.12
7 days SO_2 & CO.	1.444*	3.841*	-.061*	368.69*	1.597*	0.356	6.13
7 days SO_2.	1.467*	3.853*	-.041*	690.13*		0.314	6.14
30 days all variables.	1.467*	3.906*	-.043	928.02*	3.763	0.401	6.15
30 days SO_2.	1.494*	3.954*	-.033	496.39*		0.223	6.16
30 day SO_2 & 7 day CO.	1.444*	3.841*	-.061*	368.69*	1.597*	0.356	6.17

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (7.2) The Relationship Between Pshchological Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for People Aged Between 25 to 45

	Sex		Education		Housing		Smoking		H_2S		SO_2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Tiredness	.116	.112	.091	*.009*	4.049	.979	-.133	.083	285.6	.003	73.74	.009	-.354	.405	.019	.820	0.27	.814	3.87	.753	8.95	.270	0.095
Outside	.037	.598	.035	.296	-.024	.873	.056	.454	14.8	.875	48.66	.024	-.406	.329	.467	.000	3.64	.001	34.52	.004	-10.43	.189	0.483
Go sleep	.057	.426	.037	.282	-.216	.156	.112	.139	74.4	.437	- 9.55	.659	.556	.185	-.071	.391	2.26	.049	-18.92	.119	11.73	.143	0.046
Temper	.242	.000	.222	*.000*	-.004	.997	.231	.001	267.7	.003	52.74	.010	-.923	.019	.182	.021	-1.49	.180	- 6.70	.557	23.34	.002	0.185
Energy	.147	.019	-.048	.105	-.212	.109	.101	.124	256.9	.002	80.59	.000	-.410	.260	.283	.000	2.69	.007	8.70	.408	- 1.93	.781	0.199
Poor sleep	-.000	.992	-.083	.012	-.108	.452	.089	.218	-200.7	.028	59.64	.003	-.698	.080	.238	.003	-1.71	.117	5.38	.640	6.73	.376	0.159
Wake up	.065	.255	-.035	.207	-.076	.532	-.055	.365	1.5	.983	44.56	.010	.446	.184	.138	.039	2.76	.002	11.71	.228	- 5.99	.350	0.202
Depress	.169	.012	-.024	.451	.127	.373	.066	.350	-125.1	.164	47.13	.020	.341	.386	.187	.017	-1.14	.289	8.21	.470	4.28	.568	0.277
Tablets	.099	.031	.022	.299	.000	.993	.141	.003	- 78.1	.201	18.94	.170	-.251	.348	.012	.818	0.46	.525	- 5.92	.444	8.88	.082	0.054
Itching	.106	.245	.034	.439	-.014	.939	-.019	.838	- 15.5	.898	40.34	.143	-.603	.259	.295	.005	-3.56	.015	15.59	.313	- 9.15	.369	0.074
Smell	.138	.011	.030	.250	-.044	.697	.078	.174	13.2	.855	89.74	.000	.546	.085	.032	.608	-1.13	.192	16.19	.078	11.91	.049	0.435
Appetite	.143	.044	.031	.359	-.134	.375	-.029	.692	-149.8	.115	71.16	.001	-.590	.156	.266	.001	-1.77	.119	28.06	.020	- 5.51	.156	0.324
Laying	-.026	.547	.011	.574	.112	.219	-.012	.781	10.7	.851	.68	.958	-.328	.194	-.031	.534	1.12	.104	1.01	.889	- 1.27	.791	0.026
Anxiety	.023	.475	.000	.982	.357	.000	.000	.800	14.1	.743	13.42	.170	-.314	.097	-.023	.537	0.75	.148	- 0.77	.887	- 1.07	.766	0.151
Loss weight	-.069	.523	-.195	*.000*	-.294	.202	-.148	.198	- 66.9	.645	7.24	.825	.127	.841	.220	.083	-3.14	.070	29.36	.110	-21.92	.071	0.081
Distress	.066	.119	-.047	.018	-.016	.854	.000	.927	- 24.3	.662	3.98	.757	.277	.263	-.015	.751	0.96	.150	0.55	.938	- 3.01	.523	0.092

Data from household survey and mobile monitoring stations.

Table (7.3) The Relationship Between Psychological Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Seven Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		H_2S		SO2		NCH		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Tiredness	.239	*.000*	-.490	*.000*	.639	*.000*	-.010	.932	.077	.140	.006	.973	- 79.67	.195	38.55	*.004*	.144	.611	.046	*.002*	-0.64	.444	4.68	.598	5.63	.343	0.182
Outside	.080	*.005*	-.243	*.000*	.282	*.000*	-.095	.340	.095	.022	-.999	*.000*	-125.80	.011	90.23	*.000*	.367	.113	.229	*.000*	-1.04	.133	47.58	*.000*	25.88	*.000*	0.482
Go sleep	.130	*.000*	-.081	.105	.107	.066	-.167	.061	.177	*.000*	-.135	.339	- 2.43	.956	0.47	.961	.093	.652	.065	.118	1.17	.058	- 2.09	.746	.87	.839	0.044
Temper	.083	*.003*	-.156	*.004*	.052	.414	-.061	.533	.147	*.000*	-.139	.372	-103.05	.034	26.93	.014	-.251	.271	.019	.668	.22	.743	- 2.33	.743	8.72	.068	0.046
Energy	.130	*.000*	-.131	.016	.734	*.000*	-.087	.367	.067	.105	-.570	*.000*	- 96.88	.044	54.02	*.000*	-.336	.136	.144	*.001*	- .14	.824	- 6.63	.346	5.73	.225	0.230
Poor sleep	.069	*.012*	.104	.050	.138	.025	-.162	.085	.134	*.001*	-.266	.076	- 47.78	.309	27.78	*.008*	.047	.828	.073	.101	0.59	.362	- 2.84	.679	2.20	.631	0.106
Wake up	.072	*.001*	-.000	.886	.567	*.000*	.063	.404	.096	*.003*	-.216	.074	- 30.02	.427	30.33	*.000*	.316	.074	.068	.055	-1.58	*.002*	7.62	.169	1.13	.758	0.198
Depressed	.151	*.000*	-.166	*.002*	.250	*.000*	.041	.664	.058	.095	-.664	*.000*	-149.90	*.001*	56.24	*.000*	.230	.299	.134	*.003*	-0.25	.703	12.13	.080	- 3.45	.457	0.231
Tablets	.067	*.002*	-.061	.148	.276	*.000*	-.112	.131	.093	*.003*	-.087	.461	- 21.42	.563	15.70	*.006*	-.011	.948	.051	*.004*	-0.23	.651	0.32	.951	0.76	.833	0.081
Itching	.074	.041	-.000	.985	-.051	.530	-.000	.939	.038	.480	-.509	.563	74.26	.231	8.05	.563	.222	.443	-.011	.840	0.50	.560	20.31	.025	-17.84	.013	0.043
Smell	.065	*.009*	-.171	*.000*	.331	*.000*	-.171	*.045*	.064	.081	-.626	*.000*	9.46	.823	73.66	*.000*	.403	.042	.046	.253	-0.47	.422	27.90	*.000*	19.92	*.000*	0.380
Appetite	.148	*.000*	-.111	.065	.207	*.003*	-.143	.178	.041	.371	-.825	*.000*	- 37.67	.477	46.51	*.000*	-.063	.799	.145	*.003*	-0.12	.869	22.83	*.003*	9.34	.072	0.257
Laying	.000	.743	-.044	.160	.047	.190	-.014	.798	.039	.103	.300	*.000*	- 30.26	.275	2.81	.652	-.075	.560	.060	.021	-0.68	.079	0.73	.856	1.81	.503	0.027
Anxiety	-.013	.406	-.000	.955	.311	*.000*	-.281	*.000*	-.019	.419	-.069	.439	- 1.53	.956	20.76	*.001*	-.088	.503	-.048	.073	1.03	*.008*	- 2.81	.495	1.47	.594	0.141
Loss weight	.096	.043	.095	.300	-.018	.862	-.156	.336	-.198	*.004*	-.012	*.000*	-168.99	.036	80.17	*.000*	-.107	.775	.193	*.001*	-1.30	.248	20.03	.090	-19.10	.015	0.099
Distress	.063	*.003*	.155	*.000*	.194	*.000*	-.050	.495	.041	.195	-.234	.043	- 5.94	.870	5.09	.536	.044	.793	.084	*.010*	-0.03	.938	- 4.64	.386	2.48	.488	0.082
Total score	1.461	*.000*	-.307	*.000*	3.846	*.000*	-.451	.038	.887	*.003*	-.063	*.000*	-829.39	.015	564.18	*.000*	.979	.543	1.228	*.000*	-4.46	.351	157.82	*.001*	72.81	.030	0.389

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (7.4) The Relationship Between Psychological Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Seven Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO_2		CO		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Tiredness	.295	*.000*	-.494	*.000*	.641	*.000*	-.014	.901	.077	.141	-.047	.769	32.38	*.000*	.054	*.006*	0.176
Outside	.073	.013	-.244	*.000*	.272	*.000*	-.000	.988	.087	.046	-.819	*.000*	90.50	*.000*	.252	*.000*	0.459
Go sleep	.130	*.000*	-.083	.096	-.108	.062	-.177	.044	.180	*.000*	-.306	.796	1.08	.829	.000	.621	0.040
Temper	.084	*.003*	-.163	*.003*	-.044	.484	.056	.559	.151	*.000*	-.200	.124	10.21	.066	.031	.048	0.036
Energy	.131	*.000*	-.135	.013	.741	*.000*	-.094	.323	.069	.097	-.596	*.000*	31.59	*.000*	.096	*.000*	0.226
Poor sleep	.069	.012	.101	.056	.138	.024	-.164	.078	.135	*.000*	-.242	.053	28.16	*.000*	.105	*.000*	0.105
Wake up	.071	*.001*	-.000	.921	.564	*.000*	-.022	.762	.090	*.006*	-.301	.013	31.56	*.000*	.021	.087	0.186
Depress	.148	*.000*	-.171	*.001*	.248	*.000*	.085	.367	.065	.113	-.642	*.000*	63.60	*.000*	.151	*.000*	0.221
Tablets	.067	*.002*	-.061	.143	.277	*.000*	-.107	.143	.092	*.003*	-.117	.237	12.24	*.003*	.038	*.001*	0.081
Itching	.071	.049	.000	.960	-.060	.457	.000	.943	.034	.528	-.269	.105	28.63	*.000*	.044	.028	0.035
Smell	.060	.016	-.166	*.000*	.320	*.000*	-.119	.161	.055	.132	-.637	*.000*	87.47	*.000*	.070	*.000*	0.365
Appetite	.145	*.000*	-.113	.059	.206	*.003*	-.116	.270	.039	.392	-.703	*.000*	52.28	*.000*	.176	*.000*	0.249
Laying	.000	.739	-.045	.152	.050	.169	-.000	.910	.038	.112	.220	*.003*	1.75	.577	.021	.017	0.024
Anxiety	-.013	.419	-.000	.897	.313	*.000*	-.298	*.000*	-.016	.510	.001	.985	19.04	*.000*	.000	.815	0.134
Loss weight	.091	.056	.095	.300	-.020	.844	-.100	.535	-.209	*.003*	-.012	*.000*	49.42	*.000*	.178	*.002*	0.083
Distress	.064	*.002*	.155	*.000*	.195	*.000*	-.052	.471	.041	.189	-.268	*.005*	1.86	.654	.078	*.000*	0.081
Total score	1.444	*.000*	-.236	*.001*	3.841	*.000*	-.171	.100	.890	*.003*	-.061	*.000*	368.69	*.000*	1.597	*.000*	0.356

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (7.5) The Relationship Between Psychological Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Seven Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Tiredness	.260	*.000*	-.501	*.000*	.641	*.000*	.059	.622	.069	.187	.027	.865	40.73	*.000*	0.171
Outside	.075	.020	-.275	*.000*	.274	*.000*	.205	.061	.050	.294	-.669	*.001*	129.50	*.000*	0.345
Go sleep	.130	*.000*	-.084	.092	-.108	.062	-.171	.049	.179	*.000*	-.020	.858	9.63	.998	0.040
Temper	.084	*.003*	-.167	*.002*	-.044	.488	.082	.393	.146	*.000*	-.157	.222	15.06	*.002*	0.033
Energy	.132	*.000*	-.147	*.008*	.742	*.000*	-.015	.872	.055	.193	-.562	*.000*	46.53	*.000*	0.200
Poor sleep	.070	.013	.089	.101	.139	.026	-.077	.410	.120	*.003*	-.095	.447	34.49	*.000*	0.066
Wake up	.071	*.001*	-.000	.875	.564	*.000*	-.000	.940	.087	*.008*	-.272	.016	34.81	*.000*	0.184
Depress	.150	*.000*	-.190	*.000*	.249	*.000*	.209	.032	.043	.313	-.432	*.001*	60.07	*.000*	0.154
Tablets	.067	*.002*	-.066	.116	.277	*.000*	-.075	.300	.087	*.007*	-.063	.520	18.27	*.000*	0.072
Itching	.072	.048	-.000	.978	-.060	.461	.044	.714	.027	.609	-.207	.205	35.47	*.000*	0.031
Smell	.061	.016	-.175	*.000*	.321	*.000*	-.061	.473	.045	.224	-.338	*.003*	98.43	*.000*	0.350
Appetite	.147	*.000*	-.135	.032	.208	*.004*	.028	.795	.013	.778	-.458	*.001*	79.63	*.000*	0.179
Laying	.000	.730	-.047	.130	.050	.168	-.011	.835	.035	.145	.250	*.000*	1.55	.581	0.019
Anxiety	-.013	.419	-.000	.891	.313	*.000*	-.296	*.000*	-.016	.501	.439	.953	19.37	*.000*	0.134
Loss weight	.092	.055	.086	.352	-.020	.850	-.035	.824	-.221	*.001*	-.011	*.000*	61.59	*.000*	0.076
Distress	.066	*.002*	.146	*.000*	.196	*.000*	.011	.875	.032	.320	-.157	.107	14.24	*.000*	0.045
Total score	1.467	*.000*	-.475	*.000*	3.853	*.000*	-.072	.920	.692	.029	-.041	*.000*	690.13	*.000*	0.314

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (7.6) The Relationship Between Psychological Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Thirty Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		H_2S		SO2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Tiredness	.262	*.000*	-.496	*.000*	.647	*.000*	.000	.993	.073	.165	.866	.044	- 73.27	.326	62.60	*.002*	-.701	*.003*	.058	*.007*	-1.18	.717	24.60	.155	- 7.71	.663	0.185
Outside	.077	*.007*	-.255	*.000*	*.292*	*.000*	-.021	.824	.077	.070	.439	.209	- 58.01	.338	134.67	*.000*	-.901	*.000*	.867	*.000*	-3.37	.202	16.65	.236	3.64	.799	0.488
Go sleep	.132	*.000*	-.075	.132	-.111	.054	-.167	.059	.178	*.000*	.369	.238	-141.65	*.009*	9.30	.535	.121	.775	.187	.408	-1.45	.539	-31.63	.012	-26.22	.041	0.054
Temper	.086	*.002*	-.164	*.003*	.045	.478	.056	.566	.145	*.000*	.363	.294	-151.69	.011	41.50	.012	-.828	.078	-.139	.582	2.52	.335	35.31	.011	-25.83	.069	0.047
Energy	.133	*.000*	-.140	*.010*	.740	*.000*	-.129	.182	.067	.110	-.307	.914	53.71	.366	49.37	*.002*	-.376	*.003*	.023	.924	2.35	.365	10.80	.434	-14.01	.321	0.226
Poor sleep	.070	*.010*	.097	.067	.137	.025	-.167	.075	.129	*.001*	.044	.894	- 25.09	.663	34.20	.032	-.686	.129	-.014	.950	2.41	.338	10.29	.442	- 9.53	.486	0.110
Wake up	.069	*.001*	-.013	.755	.579	*.000*	.045	.543	.093	*.004*	-.013	.960	147.02	*.001*	32.85	*.010*	-.513	*.000*	.413	.032	-4.16	.039	29.94	*.005*	42.41	*.000*	0.213
Depress	.151	*.000*	-.176	*.001*	.254	*.000*	.036	.700	.063	.124	.069	.836	53.02	.364	44.58	*.005*	-.595	*.000*	.346	.157	-0.57	.820	2.25	.868	7.91	.568	0.229
Tablets	.068	*.001*	-.061	.148	.279	*.000*	-.109	.141	.092	*.004*	.157	.549	- 18.17	.690	17.49	.166	-.261	.466	.250	.190	-1.60	.422	7.45	.482	- 7.58	.484	0.081
Itching	.073	.042	-.000	.976	-.059	.466	.049	.691	.024	.646	.219	.617	-199.97	*.008*	81.82	*.000*	-.754	.204	.035	.912	1.95	.560	39.65	.024	-43.34	.016	0.054
Smell	.059	.017	-.185	*.000*	.328	*.000*	-.113	.182	.048	.189	.089	.767	143.93	*.006*	133.46	*.000*	-.807	*.000*	.051	.815	3.27	.151	16.73	.168	14.82	.232	0.378
Appetite	.149	*.000*	-.112	.061	.206	*.003*	-.124	.241	.031	.493	-.094	.801	- 28.68	.569	64.97	*.000*	-.120	.028	.287	.291	-0.79	.780	15.50	.305	8.68	.573	0.259
Laying	.000	.728	-.050	.111	.049	.172	-.019	.729	.036	.126	.511	*.009*	16.71	.623	11.65	.216	-.688	.011	.066	.639	1.22	.409	4.91	.534	3.99	.621	0.031
Anxiety	-.014	.400	-.000	.896	.308	*.000*	-.291	*.000*	-.017	.475	-.420	.203	63.06	.070	13.53	*.000*	.000	.979	-.234	.107	2.64	.082	11.91	.140	6.84	.407	0.139
Loss weight	.100	.031	.091	.308	.000	.979	-.087	.580	-.219	*.001*	.010	.056	-691.44	*.000*	181.79	*.000*	-.185	*.004*	.864	.033	-3.67	.387	145.74	*.000*	17.77	*.000*	0.140
Distress	.066	*.002*	.158	*.000*	.199	*.000*	-.054	.461	.040	.204	.128	.618	- 78.74	.077	7.23	.558	.066	.848	.454	.015	-3.22	.099	16.92	.101	13.15	.213	0.090
Total score	1.467	*.000*	-.384	*.000*	3.906	*.000*	-.176	.090	.786	*.008*	.043	.068	-928.93	.013	928.02	*.000*	-.893	*.000*	3.763	.031	-4.71	.796	319.92	*.001*	59.39	.017	0.401

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (7.7) The Relationship Between Psychological Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Thirty Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Tiredness	.262	*.000*	-.496	*.000*	.646	*.000*	.063	.605	.069	.188	.066	.681	31.31	*.000*	0.160
Outside	.082	.022	-.262	*.000*	.296	*.000*	.175	.148	.056	.283	-.300	.062	90.75	*.000*	0.207
Go sleep	.130	*.000*	-.084	.093	-.113	.052	-.144	.101	.176	*.000*	-.049	.671	5.65	.186	0.041
Temper	.085	*.003*	-.166	*.002*	-.043	.496	.089	.356	.146	*.000*	-.149	.246	12.84	*.006*	0.031
Energy	.134	*.000*	-.142	.012	.752	*.000*	-.037	.707	.059	.173	-.490	*.000*	30.24	*.000*	0.167
Poor sleep	.071	.011	.092	.091	.145	.022	-.087	.366	.122	*.003*	-.049	.700	23.83	*.000*	0.047
Wake up	.073	*.001*	-.000	.938	.573	*.000*	-.031	.682	.091	*.006*	-.207	.043	20.06	*.000*	0.148
Depress	.153	*.000*	-.184	*.001*	.263	*.000*	.172	.091	.049	.267	-.329	.015	37.27	*.000*	0.094
Tablets	.068	*.001*	-.064	.128	.280	*.000*	-.078	.292	.087	*.006*	-.041	.676	13.16	*.000*	0.064
Itching	.073	.046	.000	.977	-.059	.470	.066	.592	.025	.638	-.192	.240	31.02	*.000*	0.027
Smell	.065	.017	-.165	*.001*	.334	*.000*	-.064	.491	.047	.238	-.230	.061	72.99	*.000*	0.239
Appetite	.150	*.000*	-.126	.051	.217	*.003*	.031	.781	.014	.767	-.376	.012	60.25	*.000*	0.127
Laying	.000	.710	-.047	.131	.052	.149	-.000	.968	.036	.126	.266	*.000*	1.65	.537	0.018
Anxiety	-.012	.439	-.000	.944	.313	*.000*	-.284	*.000*	-.017	.471	.011	.874	17.09	*.000*	0.129
Loss weight	.095	.050	.092	.323	-.010	.924	-.046	.772	-.218	*.002*	-.011	*.000*	43.58	*.000*	0.056
Distress	.066	*.002*	.147	*.000*	.199	*.000*	.000	.944	.032	.310	-.525	.165	9.14	.012	0.038
Total score	1.494	*.000*	-.404	*.001*	3.954	*.000*	-.132	.864	.707	.036	-.033	*.000*	496.39	*.000*	0.223

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (7.8) The Relationship Between Psychological Symptoms and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO_2 30 days		CO 7 days		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Tiredness	.260	*.000*	-.488	*.000*	.641	*.000*	-.014	.906	.079	.134	-.068	.676	25.37	*.000*	.077	*.000*	0.173
Outside	.075	.014	-.227	*.000*	.277	*.000*	-.027	.795	.094	.036	-.859	*.000*	66.08	*.000*	.319	*.000*	0.423
Go sleep	.130	*.000*	-.084	.094	-.113	.052	-.145	.099	.176	*.000*	-.052	.657	5.50	.210	.000	.887	0.041
Temper	.084	*.003*	-.162	*.003*	-.046	.471	.066	.497	.150	*.000*	-.214	.103	9.95	.040	.037	.011	0.037
Energy	.132	*.000*	-.129	.018	.745	*.000*	-.114	.237	.073	.081	-.702	*.000*	20.85	*.000*	.121	*.000*	0.216
Poor sleep	.069	.012	.105	.048	.138	.024	-.162	.084	.136	*.000*	-.255	.042	24.71	*.003*	.118	*.000*	0.103
Wake up	.072	*.001*	.000	.966	.570	*.000*	-.062	.416	.097	*.003*	-.292	.014	16.82	*.000*	.049	*.000*	0.162
Depress	.149	*.000*	-.164	*.002*	.252	*.000*	.057	.548	.070	.089	-.646	*.000*	23.26	*.000*	.181	*.000*	0.206
Tablets	.067	*.001*	-.059	.158	.277	*.000*	.108	.143	.093	*.003*	-.124	.211	9.48	*.010*	.047	*.000*	0.079
Itching	.072	.049	.000	.902	-.062	.440	.027	.826	.032	.543	-.301	.071	26.25	*.000*	.061	*.002*	0.037
Smell	.062	.017	-.150	*.002*	.326	*.000*	-.151	.091	.064	.098	-.470	*.000*	62.39	*.000*	.137	*.000*	0.304
Appetite	.146	*.000*	-.104	.085	.205	*.003*	-.102	.334	.039	.388	-.747	*.000*	43.91	*.000*	.211	*.000*	0.245
Laying	.000	.731	-.045	.149	.051	.158	-.015	.775	.039	.101	.228	*.002*	3.31	.228	.021	*.001*	0.025
Anxiety	-.013	.427	-.000	.984	.312	*.000*	-.293	*.000*	-.015	.516	-.064	.850	15.94	*.000*	.014	.077	0.132
Loss weight	.092	.054	.104	.257	-.017	.872	-.121	.456	-.204	*.004*	-.013	*.000*	34.57	*.000*	.116	*.000*	0.075
Distress	.064	*.002*	.156	*.000*	.194	*.000*	-.045	.533	.041	.196	-.274	*.005*	2.87	.431	.078	*.000*	0.081
Total score	1.444	*.000*	-.236	*.001*	3.841	*.000*	-.171	.100	.890	*.004*	-.061	*.000*	368.69	*.000*	1.597	*.000*	0.356

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

7.5 Estimation of Effects of Changing Pollution levels

7.5.1 Method

In this section, an attempt is made to estimate the likely effects of changes of pollution levels on psychological symptoms. Again, the methods are the same as those used for physical symptoms.

7.5.2 Lassitude

It was found from the stepwise regression analysis that both SO_2 and CO were related to lassitude (feeling tired, finding it annoying to go outside, loss of energy, waking up early in the morning, feeling depressed, loss of sense of smell and loss of appetite). The model actually used included age and smoking (Table 7.9).

When all the effect was attributed to SO_2, 100% elimination of SO_2 reduced the predicted score in Fahaheel from 11.46 to 8.28. In Rega it was reduced from 9.34 to 8.66 and in Mishrif from 8.01 to 7.79 (Table 7.10).

If the effect on symptoms was split between SO_2 and CO as implied by 'partial-loading' regression model, then eliminating SO_2 entirely reduced the predicted symptom score in Fahaheel to 9.07 rather than 8.28. In Rega it was reduced to 8.83 rather than 8.66 and in Mishrif 7.84 rather than 7.79.

When all the effect was attributed to CO, 100% elimination of CO reduced the predicted score in Fahaheel from 11.46 to 9.82. In Rega it was reduced from 9.34

to 8.16 and in Mishrif from 8.01 to 7.58. Thus for Fahaheel, elimination of SO_2 was predicted to be more effective than eliminating CO as a means of reducing psychological symptoms, but for Rega and Mishrif the opposite was the case.

If the effect on symptoms was split between CO and SO_2 as implied by the regression model, the predicted effect of 100% elimination of CO was to reduce the mean symptom score in Fahaheel to 10.41 rather 9.82. In Rega it was reduced to 8.59 rather than 8.16 and in Mishrif, to 7.74 rather 7.58.

7.5.3 Sleep disorders

It was found from the regression analysis that the only factor related to sleep disorder (poor sleep, taking sleeping tablets and laying awake most night) was NH_3. Comparison of the predicted mean scores for this group of symptoms with the actual values in the three study areas suggests that this model is a fairly good predictor.

Elimination of NH_3 entirely only reduced the predicted score in Fahaheel from 3.44 to 3.21. In Rega it was reduced from 3.38 to 3.21 and in Mishrif from 3.28 to 3.22. It would appear that pollution is only a minor factor here.

7.5.4 Anxiety

It was found from the regression analysis that SO_2, CO and NO_2 were related to symptoms of anxiety (reported anxiety, underweight and distress). This model was a good predictor of mean symptom scores in the three study areas (Table 7.10). Although NO_2 was a significant factor, it was the least influential one, and only changes in SO_2 and CO levels are addressed here.

When all the effect was attributed to SO_2, 100% elimination of SO_2 reduced the predicted score in Fahaheel from 3.44 to 2.82. In Rega it was reduced from 3.38 to 3.25 and in Mishrif from 3.28 to 3.24.

If the effects were split between SO_2 and CO as implied by regression model, the effect of eliminating SO_2 entirely was to reduced the symptom score in Fahaheel to 2.98 rather 2.82. In Rega it was reduced to 3.28 rather than 3.25 and in Mishrif 3.25 rather 3.24.

When all the effect was attributed to CO, elimination of CO entirely reduced the predicted score in Fahaheel from 3.44 to 3.13. In Rega it was reduced from 3.38 to 3.15 and in Mishrif from 3.28 to 3.20.

If the effects split between CO and SO_2 as implied by regression model, the effect of eliminating CO entirely was to reduce the symptom score in Fahaheel from 3.44 to 3.24 rather 3.13. In Rega it was reduced from 3.38 to 3.24 rather than 3.15 and in Mishrif, from 3.28 to 3.23 rather 3.20.

Table (7.9) Models Used for Predicting the Effect on Symptom Levels of Reductions in Pollution Levels

	Constant	Sex	Age<5	Age 65+	Housing	Smoking	Avetemp	SO_2	CO	NH_3	NO_2	R^2
Lassitude	8.13	0.891	-1.33	2.99		0.486	-0.038	362.8	0.799			0.458
	8.52	0.897	-1.42	3.01		0.372	-0.030	483.5				0.389
	8.21	0.933	-1.29	3.19		0.694	-0.029		1.257			0.340
Sleep disorder	3.40	0.205	-0.187	0.225	-0.311	0.313				1.203		0.057
Anxiety	4.01	0.142	0.243	0.551	-0.412	-0.186	-0.015	79.48	0.209		-12.73	0.124
	3.92	0.139	0.248	0.506	-0.406	-0.194	-0.015	69.31	0.150			0.118
	3.87	0.142	0.229	0.509	-0.283	-0.212	-0.013	93.64				0.102
	4.22	0.141	0.542	0.542	-0.673	-0.164	-0.014		0.239			0.090

Data from household survey, mobile monitoring stations and airport monitoring unit.

Table 7.10: The effects on psychological symptom scores of % reductions in pollution levels

Lassitude	*Effect of reduction in SO2*						*Effect of reduction in CO*					
	Fahaheel		*Rega*		*Mishrif*		*Fahaheel*		*Rega*		*Mishrif*	
	lower	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*
Actual symptom score	11.60		9.35		7.89		11.60		9.35		7.89	
Predicted score	11.46		9.34		8.01		11.46		9.34		8.01	
25% reduction	10.66	10.86	9.17	9.21	7.95	7.97	11.05	11.20	9.04	9.15	7.90	7.94
50%	9.87	10.27	9.00	9.09	7.90	7.93	10.64	10.94	8.75	8.96	7.79	7.87
75%	9.07	9.67	8.83	8.96	7.84	7.88	10.23	10.68	8.45	8.78	7.69	7.80
100%	8.28	9.07	8.66	8.83	7.79	7.84	9.82	10.41	8.16	8.59	7.58	7.74

Sleep	*Effect of reduction in NH3*		
	Fahaheel	*Rega*	*Mishrif*
Actual symptom score	3.47	3.42	3.23
Predicted score	3.44	3.38	3.28
25% reduction	3.38	3.34	3.27
50%	3.33	3.30	3.25
75%	3.27	3.26	3.24
100%	3.21	3.21	3.22

Table 7.10 (cont): The effects on psychological symptom scores of % reductions in pollution levels

Anxiety	*Effect of reduction in SO2*						*Effect of reduction in CO*					
	Fahaheel		*Rega*		*Mishrif*		*Fahaheel*		*Rega*		*Mishrif*	
	lower	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*	*lower*	*upper*
Actual symptom score	3.83		3.72		3.17		3.83		3.72		3.17	
Predicted score	3.44		3.38		3.28		3.44		3.38		3.28	
25% reduction	3.29	3.33	3.35	3.36	3.27	3.27	3.36	3.39	3.32	3.34	3.26	3.27
50%	3.13	3.21	3.31	3.33	3.26	3.26	3.28	3.34	3.27	3.31	3.24	3.25
75%	2.98	3.10	3.28	3.31	3.25	3.26	3.21	3.29	3.21	3.27	3.22	3.24
100%	2.82	2.98	3.25	3.28	3.24	3.25	3.13	3.24	3.15	3.24	3.20	3.23

7.4 Discussion

High levels of SO_2 were linked to most of the symptoms considered: tiredness, finding it annoying to go outside, running out of energy, feeling depressed, loss of sense of smell, loss of appetite, poor sleep, waking up in the early morning, taking sleeping tablets, anxiety, loss of weight and distress.

High levels of CO were linked to tiredness, finding it annoying to go outside, loss of energy, feeling depressed, taking sleeping tablets, loss of appetite, loss of weight and distress.

High levels of NO were linked to finding it annoying to go outside, loss of sense of smell and loss of appetite.

In general the loss of R^2 incurred by forcing all the pollutants except SO_2 and CO out of the models was low. Where the fit was reasonably good (ie R^2 more than 0.100) the changes in coefficients of SO_2 between the full and the 2-pollutant reduced models were small, suggesting genuine independent effects. (The main exception to this was the model for total psychological symptom score.) The differences in the coefficients of CO between the two models tended to be rather larger, suggesting more of a problem with collinearity; some of the effects attributed to CO in the 2-pollutant models may actually have been due to something else.

In general the differences in R^2 between the full 7-day models and the full 30-day models were small, although on balance to 30-day models were slightly better. One case in which the 30-day model was clearly superior was for loss of weight. It seems that within this range of lengths of exposure, the period over which the average is taken is not too critical. The coefficients in the 30-day models were generally larger, reflecting the narrower range of variation in 30-day means when compared to 7-day means.

Taken overall, the amounts of variance explained by the models of psychological variables described in this chapter were higher than they were for the models of psychological variables described earlier. This may have been partly because prevalence levels for most of the psychological symptoms were higher, and the proportional differences in prevalence between the three study areas were less extreme. It may also have been because the demographic variables were more useful in predicting the psychological variables.

At the same time the predicted impact of pollution abatement in terms of % drop in prevalence is less for psychological than for physical symptoms. It would seem, then, that pollution levels, and in particular SO_2 and CO levels, may be more important than demographic factors in terms of physical symptoms, but less important in terms of psychological ones.

No other studies have been found in the literature that have reported on the links between self-reported psychological symptoms in a general population and short-term or long-term exposure to air pollution. This is a worthy topic for further research.

CHAPTER EIGHT

RESULTS: REGRESSION ANALYSIS RELATING AIR POLLUTION TO USE OF HEALTH CARE

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RESULTS: REGRESSION ANALYSIS RELATING AIR POLLUTION TO USE OF HEALTH CARE

8.1 Introduction

This chapter is concerned with quantifying the links between air pollution and use of health care in Kuwait. As supplementary background to this, data are presented first on self-reported general health.

8.2 Strategy for developing the regression analysis

The strategy used to develop models in this chapter is the same as that used for physical and psychological symptoms.

8.3 Results of the regression analyses

8.3.1 Preliminary Results

For the age group 25 to 44, educational level appeared to have little effect on reported use of health care (Table 8.1). A p-value of .015 was found for admission rates, but this was reduced when data for the whole population were analyzed. Humidity was not significantly related to use of health care, and both these variables were omitted from the analyses described below.

8.3.2 Overall Health

Using the 7-day model, the variables most closely associated with overall health were age 65+, SO_2 (p=.000) and CO (p=.004 Table 8.2). Average temperature and smoking were also significant at lower levels (.028 and .037 respectively). When the regression analysis was repeated forcing out all the pollutants except SO_2 and CO, R^2 was slightly reduced from 0.231 to 0.225 (Table 8.3). Then forcing CO out as well had very little effect on R^2 (Table 8.4).

Using the full 30-day model, SO_2 (p=.010) and NO_2 (p=.008) were the significant pollutants. There was an inverse relationship with average temperature (p=.000) and R^2 slightly was slightly better than for the full 7-day model, at 0.233 (Table 8.5). With SO_2 as the only pollutant, R^2 reduced to 0.203 (Table 8.6).

In the mixed model with 30-day SO_2 and 7-day CO model did not fit as well as the 7-day SO_2/CO model (R^2 = 0.214; Table 8.7).

It would seem likely that SO_2 does have a real independent effect on self-reported health. The evidence here for CO having an independent effect is rather weak. There is little to choose between the 7-day and 30-day models.

Table 8.5.2: Summary of regression analyses for overall health

	Age 65+	SO_2	CO	R^2	Table
7 days all variables.	.591*	29.53*	.021*	0.231	6.19
7 days SO_2 & CO.	.589*	23.17*	.017*	0.225	6.20
7 days SO_2.	.590*	25.88*		0.223	6.21
30 days all variables.	.594*	62.84*	.158	0.233	6.22
30 days SO_2.	.594*	18.53*		0.203	6.23
30 day SO_2 & 7 day CO.	.592*	15.77*	.035*	0.214	6.24

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

8.3.3 GP Visits

The effect of pollution on rates of GP visits was the first aspect of use of health care to be considered. In the survey, respondents were asked whether they had visited their GP in the previous week. With the full 7-day model, the variables most closely associated use of GPs were sex ($p=.001$), age <5 ($p=.004$), NO ($p=.000$) and average temperature (an inverse relationship, $p=.005$). However, R^2 was low at 0.046 (Table 8.2). Dropping all the pollution variables except SO_2 and CO, SO_2 ($p=.001$) became significant with a very large increase in its coefficient, but R^2 was down to 0.032 (Table 8.3). Dropping CO at this point made very little difference (Table 8.4).

Using the full 30-day model, the same set of variables as in the 7-day model were significant, but SO_2 and NCH_4 (inverse, $p=.000$) were added to the list. R^2 at 0.080 was much higher than for the 7-day model, but still not particularly impressive

(Table 8.5). With SO_2 as the only pollutant, its coefficient decreased and R^2 fell sharply to 0.026 (Table 8.6). With the mixed model, none of the pollution variables was significant and with an R^2 of 0.027, this gave an even poorer fit than the 7-day SO_2/CO equation (Table 8.7).

It would seem that SO_2 and CO have a fairly weak link with rates of GP visits. Other pollutants, in particular NO, may also be weakly implicated.

Table 8.5.3: Summary of regression analyses for rates of GP visits

	Sex	Age<5	Avetemp	SO_2	NO	R^2	Table
7 days all variables.	.115*	.195*	-.361*	3.10	29.46*	0.046	6.19
7 days SO_2 & CO.	.112*	.197*	-.363*	23.17*		0.032	6.20
7 days SO_2.	.112*	.198*	-.364*	22.11*		0.032	6.21
30 days all variables.	.113*	.173*	-.839*	134.93*	56.34*	0.080	6.22
30 days SO_2.	.113*	.200*	-.328*	14.10*		0.026	6.23
30 day SO_2 & 7 day CO.	.113*	.202*	-.360*	12.68		0.027	6.24

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

8.3.4 Attendance at outpatients

In the survey, respondents were asked whether they had attended an outpatients department in the previous three months. Using the full 7-day model to explain attendance rates gave age 65+, SO_2 (p=.000), CO, NO and NO_2 (p=.007) as statistically significant factors. R^2 was 0.095 (Table 8.2). Smoking was significant at a lower lever (p=.042). With SO_2 and CO as the only pollution variables, R^2 fell to 0.085 (Table 8.3). With only SO_2, R^2 fell further to 0.075 (Table 8.4).

Using the full 30-day model, SO_2 (p=.000) and NO (p=.002) were statistically significant, and there was also an inverse relationship with H_2S (p=.000). R^2 was 0.114, slightly better than for the full 7-day model (Table 8.5). With 30-day SO_2 as the only pollutant, R^2 fell to 0.058 (Table 8.6) and the mixed model was slightly inferior to the 7-day SO_2/CO model (R^2 = 0.079; Table 8.7).

The changes in coefficient from one 7-day model to another were quite small and R^2 declined at each step, suggesting that SO_2, CO and probably NO all have independent effects. There was no consistent picture as to whether the 7-day models were better than the 30-day models or vice versa.

Table 8.5.4: Summary of regression analysis for outpatient attendance rate

	Age 65+	SO_2	CO	R^2	Table
7 days all variables.	.336*	32.39*	.041*	0.095	6.19
7 days SO_2 & CO.	.332*	32.63*	.047*	0.085	6.20
7 days SO_2.	.332*	31.01*		0.075	6.21
30 days all variables.	.343*	72.77*	.133	0.114	6.22
30 days SO_2.	.337*	22.17*		0.058	6.23
30 day SO_2 & 7 day CO.	.333*	17.12*	.065*	0.079	6.24

* significant at .01.

Data from household survey, mobile monitoring stations and airport monitoring unit.

8.3.5 Hospital admission rates

In the survey, respondents were asked whether they had been admitted to hospital in the previous year. Analysis using the full 7-day model revealed age 65+ (p.000) and CO (p=.001) as statistically significant, and there was an inverse relationship with average temperature (p=.006). R^2 was quite high at 0.245 (Table 8.2). Removing all pollutants except SO_2 and CO from the equation, age 65+, SO_2 and CO (p=.001) were statistically significant and R^2 was essentially unchanged at 0.242 (Table 8.3). With SO_2 as the only pollutant in the equation, R^2 fell a little to 0.225 (Table 8.4).

Using the full 30-day model only age 65+ (p=.000) and temperature (inverse, p=.005) were significant. R^2 was about the same as for the full 7-day model at 0.249 (Table 8.5). With SO_2 as the only pollutant in the equation, it became significant but R^2 fell to 0.209 (Table 8.6).

With the mixed model, CO (p=.000) was the only significant pollutant. R^2 at 0.238 was similar to the value for the 7-day SO_2/CO model (Table 8.7).

The evidence for pollutants other than SO_2 or CO having an effect on hospital admission rates was weak. SO_2 levels did appear to be an effective predictor of hospital admission rates, and there may be a real causal relationship.

Table 8.5.5: Summary of regression analyses for hospital admission

	Age65+	Avetemp	SO_2	CO	R^2	Table
7 days all variables.	.598*	-.238*	20.83	.058*	0.245	6.19
7 days SO_2 & CO.	.595*	-.234*	17.02*	.069*	0.242	6.20
7 days SO_2.	.596*	-.238*	21.72*		0.225	6.21
30 days all variables.	.605*	-.243*	28.89	.452	0.249	6.22
30 days SO_2.	.603*	-.188*	16.60*		0.209	6.23
30 day SO_2 & 7 day CO.	.598*	-.234*	10.16	.083*	0.238	6.24

* significant at .01.

Average temperature = -.001.

Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (8.1) The Relationship Between Use of Health Care and Different Pollutants and Demographic Features
Regression Coefficient and Statistical Significance for Age between 25 to 45

	Sex		Education		Housing		Smoking		H_2S		SO_2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Health	.010	.696	.018	.166	.000	.917	.028	.328	- 70.6	.054	32.87	.000	-.149	.352	-.025	.421	0.39	.367	- 0.57	.900	2.47	.418	0.102
GP visit	.058	.477	-.051	.198	.025	.884	-.046	.592	91.8	.405	-10.91	.661	.167	.729	.130	.175	-3.53	.007	26.91	.054	- 9.17	.320	0.060
Outpatient	-.057	.265	-.012	.608	.066	.545	-.134	.013	- 60.0	.382	18.84	.225	-.066	.825	.019	.741	-0.79	.336	25.08	.004	-11.30	.049	0.071
Admission	.063	.229	.061	.015	-.038	.728	.024	.661	4.5	.947	7.96	.613	.270	.375	-.013	.822	0.17	.832	1.11	.899	- 0.98	.866	0.235

Data from household survey and mobile monitoring stations.

Table (8.2) The Relationship Between Use of Health Care and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Seven Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		H_2S		SO2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Health	.019	.292	.000	.984	.591	*.000*	-.000	.898	.055	.037	-.132	.028	- 53.65	.080	29.53	*.000*	.074	.602	.021	*.004*	0.48	.260	6.79	.130	3.54	.238	0.231
GP visit	.115	*.001*	.195	*.004*	.131	.097	-.040	.734	.000	.961	-.361	*.005*	4.84	.935	3.10	.817	.255	.362	.013	.808	-1.64	.050	29.46	*.000*	11.97	.041	0.046
Outpatient	-.000	.761	.028	.552	.336	*.000*	.069	.416	-.075	.042	-.100	.082	- 83.77	.049	32.39	*.000*	.131	.510	.041	*.007*	0.28	.632	16.84	*.007*	11.13	*.007*	0.095
Admission	.000	.805	-.081	.110	.598	*.000*	.114	.207	.058	.135	-.238	*.006*	- 41.05	.362	20.83	.039	.196	.350	.058	*.001*	-0.16	.789	6.26	.342	3.27	.458	0.245

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (8.3) The Relationship Between Use of Health Care and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Seven Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO_2		CO		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Health	.017	.333	-.000	.959	.589	*.000*	.000	.941	.055	.037	-.135	.099	23.17	*.000*	.017	*.007*	0.225
GP visit	.112	*.001*	.197	*.003*	.125	.113	.016	.892	-.000	.926	-.363	*.004*	22.22	*.001*	-.000	.970	0.032
Outpatient	-.011	.661	.026	.580	.332	*.000*	.101	.230	-.078	.034	-.110	.331	32.63	*.000*	.047	*.000*	0.085
Admission	.000	.850	-.082	.107	.595	*.000*	.136	.128	.055	.151	-.234	*.005*	17.02	*.000*	.069	*.000*	0.242

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (8.4) The Relationship Between Use of Health Care and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Seven Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Health	.017	.329	-.000	.910	.590	*.000*	.018	.756	.052	.047	-.110	.171	25.88	*.000*	0.223
GP visit	.112	*.001*	.198	*.003*	.125	.113	.015	.895	-.000	.928	-.364	*.001*	22.11	*.000*	0.032
Outpatient	-.010	.676	.021	.666	.332	*.000*	.141	.095	-.085	.021	-.044	.693	31.01	*.000*	0.075
Admission	.000	.832	-.090	.078	.596	*.000*	.192	.031	.045	.243	-.238	*.005*	21.72	*.000*	0.225

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (8.5) The Relationship Between Use of Health Care and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Thirty Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		H_2S		SO_2		NCH_4		CO		NH_3		NO		NO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Health	.016	.360	-.000	.800	.594	*.000*	.010	.859	.052	.049	-.346	*.000*	63.01	.094	62.84	*.010*	-.597	.043	-.158	.239	2.08	.205	19.49	.062	23.46	*.008*	0.233
GP visit	.113	*.001*	.173	*.010*	.127	.101	-.000	.938	-.016	.750	-.839	*.000*	-103.63	.153	134.93	*.000*	-.328	*.000*	-.429	.157	6.50	.040	56.34	*.000*	42.54	.013	0.080
Outpatient	-.000	.723	.019	.688	.343	*.000*	.126	.136	-.086	.018	-.395	.187	-227.25	*.000*	72.77	*.000*	-.889	.028	.133	.539	0.38	.865	36.08	*.002*	29.00	.018	0.114
Admission	.000	.829	-.087	.087	.605	*.000*	.126	.163	.054	.159	-.243	*.005*	10.21	.853	28.89	.059	-.951	.028	.452	.050	-3.37	.163	- 0.57	.964	6.43	.623	0.249

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (8.6) The Relationship Between Use of Health Care and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance for Thirty Days

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO_2		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Health	.018	.302	-.000	.972	.594	*.000*	.014	.810	.053	.046	-.078	.335	18.53	*.000*	0.203
GP visit	.113	*.001*	.200	*.003*	.130	.101	.000	.973	-.000	.958	-.328	*.009*	14.10	*.000*	0.026
Outpatient	-.000	.722	.024	.622	.337	*.000*	.136	.114	-.084	.025	-.006	.955	22.17	*.000*	0.058
Admission	.000	.784	-.088	.091	.603	*.000*	.173	.058	.049	.217	-.188	*.004*	16.60	*.000*	0.209

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

Table (8.7) The Relationship Between Use of Health Care and Different Pollutants and Demographic Features Regression Coefficient and Statistical Significance

	Sex		Age < 5		Age 65+		Housing		Smoking		Avetemp		SO_2 30 days		CO 7 days		R^2
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	
Health	.018	.319	.000	.941	.592	*.000*	-.000	.988	.058	.030	-.141	.089	15.77	*.000*	.035	*.000*	0.214
GP visit	.113	*.001*	.202	*.003*	.129	.104	-.000	.949	-.000	.991	-.360	.026	12.68	.034	.018	.308	0.027
Outpatient	-.010	.678	.031	.521	.333	*.000*	.094	.269	-.076	.040	-.120	.293	17.12	*.000*	.065	*.000*	0.079
Admission	.000	.832	-.079	.123	.598	*.000*	.120	.183	.058	.132	-.234	*.003*	10.16	.023	.083	*.000*	0.238

Average temperature = -.001.
Data from household survey, mobile monitoring stations and airport monitoring unit.

8.4 Discussion

It is striking that the same two pollutants, SO_2 and CO, emerged as the best general predictors of self-reported overall health as of the physical and psychological symptoms considered in previous chapters. This suggests that these kinds of symptom are substantial determinants of people's views about their own health, and are important to their quality of life.

Given the relationships found in chapter 6 between pollution and physical symptoms, and the rather weaker relationships found in chapter 7 with psychological symptoms, it may seem curious that the link between pollution and GP visits is relatively weak. There are many reasons for going to GPs however, and the effect of pollution may have become swamped.

Broadly, this study suggests that together with age and average temperature (which may be an indicator of time of year) increasing ambient levels of SO_2, CO and NO increase hospital out-patient visits, and increasing levels of SO_2 (and possibly CO) increase hospital admissions. The strength of these relationships may have been underestimated. First, there is the risk of under or over estimation when asking patients about events in the last 3 months (outpatient attendances) or last 12 months (hospital admission). However, these are the periods commonly used in surveys of this kind. Second, temperature levels over the previous 7 and 30 days might be expected to be poor predictors of events over the past 3 or 12 months. In particular, the inverse relationship between reported hospital admissions in the past year and ambient temperature over the past 7 days does seem surprising, and may reflect an element of recall bias.

The results of earlier epidemiological studies are inconsistent. Heimann (1972) found no significant effects of SO_2 on hospitalization of elderly patients, or on the number of emergency room visits in one hospital for treatment of heart or respiratory diseases.

The results of the Kuwait study are more in line with more recent work by Ponke (1991). He studied the effects of relatively low levels of air pollution on the number of patients who were admitted to hospital in Helsinki as a result of asthma attacks during a 3 year period. The frequency of all admissions for asthma was significantly correlated with daily concentrations of SO_2, NO, NO_2 and CO, and with minimum temperature. The association between pollutants and admissions was most significant among adults of working age, followed by the elderly. Among children, only O_3 and NO were significantly correlated with admissions. After standardization for age, the number of cases seen on the emergency wards was positively correlated with all pollutants except CO, and the number of all cases with all pollutants.

Neither of these studies controlled for sex, housing conditions and smoking, but these factors did not emerge from the present study as strongly predictive.

CHAPTER NINE

THE EFFECT OF POLLUTION FROM THE SHUAIBA INDUSTRIAL AREA ON RESIDENTIAL AREAS IN KUWAIT

CHAPTER NINE

THE EFFECT OF POLLUTION FROM THE SHUAIBA INDUSTRIAL AREA ON RESIDENTIAL AREAS IN KUWAIT

9.1 Introduction

This chapter considers the possibility of estimating the effects of given changes in the levels of different pollutants released from Shuaiba Industrial Area on levels of pollution in Fahaheel, Rega, Mishrif and Kuwait City.

9.2 Methods

Eight stations located in the Shuaiba Industrial Area provide continuous monitoring of local air pollution (Fig 4.5). Apart from observations from particular stations, for the purpose of the analysis two summary variables were constructed: 'meanall' (the mean concentration for all eight stations) and 'mean 4/5' (the mean concentration of the pollutants measured at the two stations located nearest the residential areas).

Data for each pollutant in the Shuaiba Industrial Area were used to predict the level of the same pollutant in four residential areas: Fahaheel, Rega, Mishrif and Kuwait City. The data from the first three areas were taken from mobile stations in the centre of these areas provided for the purpose of this study. Data for Kuwait City was provided by the Environmental Protection Council.

'Pdnwind' is the percentage of observations of wind direction over the relative period for which the wind is northerly, the dominant wind direction in Kuwait. Average temperature is also considered.

Unfortunately it was necessary to use monthly averages in these models since these were the only data available for the Shuaiba industrial Area and Kuwait City.

9.3 Results

The first six rows in each table report six uni-variate regression models, each with a different dependent variable for pollution in Shuaiba. In the first model, the dependent variable is 'meanall'. In the second it is 'mean 4/5'. In the third only data from station 4 in the Shuaiba Industrial Area were used. In the fourth only data from station 5 were used. In the fifth model, the 'percentage northerly wind direction' was used, and in the sixth, 'average temperature'.

The second part of each table shows different models combining pollution levels with 'percentage northerly wind direction'. Temperature was omitted as it appeared to have no independent effect.

9.3.1 H_2S

The results of the analysis of the relationship between the concentration of H_2S in the Shuaiba Industrial Area and its concentration in the residential areas are given in Table 9.1.

In general the models provide a poor fit, with low R^2, and it seems that the relationship between H_2S levels in SIA and pollution in the areas studied is a weak one. The effect on R^2 values of adding wind direction to the different indicators of pollution levels was small.

9.3.2 SO_2

The results of the analysis of the relationship between the concentration of SO_2 in the Shuaiba Industrial Area and its concentration in the three study areas and Kuwait City are shown in Table 9.2.

In some models the R^2 were quite high. For Fahaheel, regression on Shuaiba station 5 gave $R^2 = 0.482$ and the coefficient was statistically significant. Adding wind direction increased R^2 to 0.617.

In Rega, regression on Shuaiba station 4 gave $R^2 = 0.445$, increasing to 0.487 when the effect of wind direction was added.

For Mishrif and Kuwait City the values of R^2 were rather lower (0.224 and 0.118) and none of the coefficients were statistically significant.

It is striking that for SO_2 the best models for Fahaheel and Rega were derived from data from different stations. There was, as might expected, a general decrease in explanatory power with increasing distance from the SIA.

9.3.3 NCH_4

The results of the analysis of the relationship between the concentration of NCH_4 in the Shuaiba Industrial Area and its concentration in the residential areas are given in Table 9.3.

The fits for models of pollution levels for Fahaheel were generally disappointingly poor in the light of the higher values for R^2 for Rega. For Rega, regression on Shuaiba station 4 gave $R^2 = 0.456$ and a statistically significant coefficient. Adding wind direction slightly increased the R^2 0.482.

Again, for Mishrif and Kuwait City, none of the coefficients were statistically significant. The best models were based on data from station 4.

9.3.4 CO

The results of the analysis of the relationship between the concentration of CO in the Shuaiba Industrial Area and its concentration in the residential areas are shown in Table 9.4.

Models for Fahaheel and Rega were all rather poor. For Mishrif and Kuwait City, regression on wind direction gave some of the best models.

9.3.5 NH_3

The results of the analysis of the relationship between the concentration of NH_3 in the Shuaiba Industrial Area and its concentration in the residential areas are shown in Table 9.5. No data were available for NH_3 from Kuwait City.

Some models for Fahaheel and Rega provided a reasonable fit. For Fahaheel, regression on Shuaiba station 4 gave $R^2 = 0.401$ and a significant coefficient. Adding wind direction increased this to 0.513. In Rega, regression on Shuaiba station 4 gave $R^2 = 0.424$, again with a significant coefficient, increasing to 0.523 when the effect of wind direction was added. The models for Mishrif were all very poor however.

8.3.6 NO_2

The results of the analysis of the relationship between the concentration of NO_2 in the Shuaiba Industrial Area and its concentration in the residential areas are given in Table 9.6.

The models for NO_2 provided the highest R^2 found. For Fahaheel, regression on Shuaiba meanall gave $R^2 = 0.562$, and a highly significant coefficient. Adding wind direction increased this to 0.673. Regression on Shuaiba station 4 gave $R^2 = 0.489$, increasing to 0.523 when the effect of wind direction were taken into account.

In Rega, regression on wind direction gave $R^2 = 0.384$. This increased to 0.639 if only the readings from stations 4 and 5 were used. In this case the effect of temperature also appeared to be significant.

For Mishrif, regression on the average of all the Shuaiba readings, and on the reading from station 4 alone, both gave reasonable models with significant coefficients, improved by adding in wind direction.

For Kuwait City the picture was similar. Regression on the Shuaiba average, and on the reading from station 4 alone, both gave reasonable models, improved slightly by adding in wind direction.

9.3.7 NO

The results of the analysis of the relationship between the concentration of NO in the Shuaiba Industrial Area and its concentration in the residential areas are given in Table 9.7.

This was another case in which the models for areas near the Shuaiba Industrial Area were generally poorer than those for Mishrif and Kuwait City. For Fahaheel, regression on Shuaiba meanall gave $R^2 = 0.304$. Adding wind direction increased this slightly to 0.332. For Rega, regression on Shuaiba average 4/5 and wind direction gave $R^2 = 0.247$, with a marked increase to 0.369 when wind direction was used.

For Mishrif, regression on the Shuaiba overall average gave $R^2 = 0.414$. Shuaiba meanall was significant ($p=.023$), and adding wind direction increased R^2 to 0.420.

For Kuwait City, regression on Shuaiba station 4 gave $R^2 = 0.559$, with a significant coefficient ($p=.005$). When wind direction was added, R^2 increased to 0.648. The results for Shuaiba station 5 were broadly similar.

Table (9.1) The Relationship Between H_2S Levels in Fahaheel, Rega, Mishrif and Kuwait City and H_2S Levels in Different Shuaiba Stations by Regression Coefficient and Statistical Significance

Independent	Fahaheel				Rega			Mishrif			Kuwait City		
	R^2	B	SE B	P	R^2	B	P	R^2	B	P	R^2	B	P
H_2S ave all	0.106	-0.031	.028	.300	0.039	-0.006	.533	0.045	-0.001	.504	0.054	-0.000	.464
H_2S ave 4&5	0.023	-0.000	.000	.635	0.047	-0.006	.533	0.034	-0.000	.564	0.030	-0.000	.590
H_2S sh4	0.029	-0.291	.593	.637	0.046	-0.128	.549	0.083	-0.028	.418	0.113	-0.022	.341
H_2S sh5	0.046	-0.443	.666	.522	0.008	-0.067	.784	0.010	-0.012	.767	0.089	0.024	.372
% n. wind	0.010	-0.001	.010	.749	0.000	0.000	.988	0.005	0.000	.812	0.008	0.000	.776
Temperature	0.118	-0.000	.000	.274	0.063	-0.000	.430	0.002	-0.000	.879	0.021	0.000	.646
H_2S ave all +	0.107	-0.032	.033	.347	0.049	0.008	.511	0.079	-0.001	.418	0.098	-0.001	.367
% n. wind		0.000	.004	.347		0.000	.770		0.000	.579		0.000	.524
H_2S ave 4&5 +	0.039	-0.000	.000	.632	0.048	-0.000	.516	0.038	-0.000	.596	0.036	-0.000	.624
% n. wind		-0.001	.004	.729		-0.000	.966		0.000	.855		0.000	.818
H_2S sh4 +	0.030	-0.279	.646	.677	0.060	-0.142	.542	0.123	-0.032	.385	0.181	-0.025	.303
% n. wind		-0.000	.005	.929		0.000	.756		0.000	.547		0.000	.471
H_2S sh5 +	0.059	-0.358	.750	.645	0.009	-0.062	.823	0.024	-0.017	.706	0.089	0.023	.442
% n. wind		-0.001	.005	.755		-0.000	.961		0.000	.741		0.000	.955

Data from mobile monitoring stations in Fahaheel, Rega, Mishrif and Kuwait City, fixed stations in Shuaiba Industrial Area and Airport monitoring unit.

Table (9.2) The Relationship Between SO_2 Levels in Fahaheel, Rega, Mishrif and Kuwait City and SO_2 Levels in Different Shuaiba Stations by Regression Coefficient and Statistical Significance

Independent	Fahaheel				Rega			Mishrif			Kuwait City		
	R^2	B	SE B	P	R^2	B	P	R^2	B	P	R^2	B	P
SO_2 ave all	0.016	-2.554	6.265	.692	0.000	0.003	.965	0.143	-0.055	.224	0.226	0.044	.118
SO_2 ave 4&5	0.002	0.114	0.720	.876	0.001	0.009	.914	0.008	-0.001	.777	0.011	-0.001	.739
SO_2 sh4	0.329	5.071	2.556	.082	0.445	0.074	*.035*	0.004	0.004	.855	0.015	-0.004	.729
SO_2 sh5	0.482	29.172	9.558	*.012*	0.012	0.053	.728	0.019	0.042	.665	0.169	-0.080	.183
% n. wind	0.159	7.583	5.511	.198	0.172	0.097	.179	0.006	0.011	.805	0.005	-0.006	.823
Temperature	0.129	0.151	0.124	.249	0.000	-0.000	.962	0.017	0.000	.683	0.071	0.000	.402
SO_2 ave all + % n. wind	0.175	-2.514 7.571	6.048 5.754	.687 .220	0.173	0.003 0.007	.958 .203	0.149	-0.055 0.010	.249 .806	0.231	0.044 0.006	.138 .816
SO_2 ave 4&5 + % n. wind	0.167	-0.224 8.229	0.738 6.156	.767 .214	0.186	-0.003 1.073	.709 .186	0.022	-0.002 0.017	.709 .727	0.012	-0.000 -0.003	.796 .912
SO_2 sh4 + % n. wind	0.407	4.040 5.693	2.785 5.935	.190 .369	0.487	0.064 0.052	.087 .477	0.021	0.075 0.019	.978 .735	0.017	-0.005 0.003	.738 .923
SO_2 sh5 + % n. wind	0.617	28.456 6.986	8.674 3.925	*.009* .108	0.181	-0.048 0.000	.764 .206	0.024	-0.041 0.010	.689 .829	0.178	-0.081 -0.008	.202 .768

SO_2 =-.001.
Data from mobile monitoring stations in Fahaheel, Rega, Mishrif and Kuwait City, fixed stations in Shuaiba Industrial Area and Airport monitoring unit.

Table (9.3) The Relationship Between NCH_4 Levels in Fahaheel, Rega, Mishrif and Kuwait City and NCH_4 Levels in Different Shuaiba Stations by Regression Coefficient and Statistical Significance

Independent	Fahaheel				Rega			Mishrif			Kuwait City		
	R^2	B	SE B	P	R^2	B	P	R^2	B	P	R^2	B	P
NCH_4 ave all	0.038	-0.362	.656	.538	0.016	-0.116	.692	0.043	-0.072	.516	0.053	-0.068	.476
NCH_4 ave 4&5	0.050	-0.042	.065	.481	0.062	-0.023	.431	0.112	-0.011	.285	0.103	-0.009	.308
NCH_4 sh4	0.081	0.193	.547	.690	0.456	0.472	*.022*	0.253	0.130	.114	0.259	0.111	.109
NCH_4 sh5	0.001	-0.025	.234	.916	0.072	-0.101	.396	0.066	-0.037	.417	0.032	-0.021	.577
% n. wind	0.003	-0.074	.403	.587	0.108	-0.085	.674	0.075	-0.066	.386	0.054	-0.048	.466
Temperature	0.000	-0.000	.009	.954	0.082	0.004	.365	0.024	0.000	.628	0.019	0.000	.662
NCH_4 ave all +	0.039	-0.387	.662	.573	0.024	-0.078	.819	0.085	-0.038	.758	0.075	-0.047	.657
% n. wind		0.040	.464	.932		-0.063	.819		0.055	.533		-0.033	.653
NCH_4 ave 4&5 +	0.050	-0.043	.064	.519	0.067	-0.021	.509	0.147	-0.009	.409	0.124	-0.008	.417
% n. wind		0.010	.436	.981		-0.043	.843		-0.047	.560		-0.031	.650
NCH_4 sh4 +	0.021	0.221	.526	.685	0.482	0.511	*.026*	0.254	0.126	.166	0.259	0.112	.148
% n. wind		0.077	.477	.874		0.108	.542		-0.009	.905		0.007	.966
NCH_4 sh5 +	0.003	-0.003	.298	.991	0.072	-0.103	.486	0.093	-0.022	.686	0.058	-0.009	.844
% n. wind		-0.071	.505	.890		0.006	.977		-0.046	.620		-0.039	.627

Data from mobile monitoring stations in Fahaheel, Rega, Mishrif and Kuwait City, fixed stations in Shuaiba Industrial Area and Airport monitoring unit.

Table (9.4) The Relationship Between CO Levels in Fahaheel, Rega, Mishrif and Kuwait City and CO Levels in Different Shuaiba Stations by Regression Coefficient and Statistical Significance

Independent	Fahaheel				Rega			Mishrif			Kuwait City		
	R^2	B	SE B	P	R^2	B	P	R^2	B	P	R^2	B	P
CO ave all	0.002	-0.063	.402	.877	0.002	-0.055	.882	0.015	0.054	.696	0.059	0.080	.443
CO ave 4&5	0.011	0.038	.116	.738	0.010	0.033	.751	0.000	0.002	.942	0.000	0.000	.978
CO sh4	0.007	0.029	.110	.799	0.008	0.027	.793	0.037	0.022	.567	0.114	0.029	.309
CO sh5	0.005	-0.165	.713	.821	0.019	-0.280	.669	0.025	0.123	.618	0.019	0.081	***.037***
% n. wind	0.030	-0.362	.642	.586	0.039	-0.369	.536	0.422	0.457	***.022***	0.363	0.322	***.038***
Temperature	0.029	0.007	.011	.592	0.044	0.008	.508	0.004	-0.001	.834	0.005	-0.000	.822
CO ave all + % n. wind	0.042	-0.143 -0.433	.435 .709	.749 .556	0.052	-0.163 -0.436	.734 .508	0.427	0.033 0.473	.777 ***.031***	0.367	0.022 0.311	.808 .066
CO ave 4&5 + % n. wind	0.038	0.032 -0.343	.118 .681	.788 .626	0.046	0.026 -0.353	.806 .576	0.424	0.005 0.460	.866 ***.030***	0.365	0.005 0.325	.844 ***.048***
CO sh4 + % n. wind	0.021	0.017 -0.281	.126 .778	.894 .746	0.029	0.013 -0.290	.906 .688	0.409	0.000 0.461	.988 .055	0.365	0.015 0.285	.555 .112
CO sh5 + % n. wind	0.032	-0.111 -0.348	.750 .686	.884 .624	0.051	-0.227 -0.340	.740 .591	0.487	0.198 0.483	.312 ***.019***	0.414	0.134 0.340	.394 ***.035***

Data from mobile monitoring stations in Fahaheel, Rega, Mishrif and Kuwait City, fixed stations in Shuaiba Industrial Area and Airport monitoring unit.

Table (9.5) The Relationship Between NH_3 Levels in Fahaheel, Rega and Mishrif and NH_3 Levels in Different Shuaiba Stations by Regression Coefficient and Statistical Significance

Independent	Fahaheel				Rega			Mishrif		
	R^2	B	SE B	P	R^2	B	P	R^2	B	P
NH_3 ave all	0.236	0.095	.054	.108	0.263	0.093	.087	0.000	0.000	.970
NH_3 ave 4&5	0.061	0.012	.013	.436	0.060	0.011	.441	0.035	0.002	.555
NH_3 sh4	0.401	0.041	.017	***.049***	0.424	0.042	***.041***	0.034	0.003	.609
NH_3 sh5	0.143	-3.614	2.794	.225	0.122	-3.090	.265	0.085	-0.802	.357
% n. wind	0.014	-0.052	.135	.704	0.022	-0.059	.642	0.039	-0.024	.538
Temperature	0.073	0.002	.024	.395	0.110	0.002	.290	0.055	0.000	.459
NH_3 ave all + % n. wind	0.262	0.115 0.081	.251 .096	.116 .587	0.284	0.109 -0.068	.102 .617	0.051	-0.007 -0.032	.742 .504
NH_3 ave 4&5 + % n. wind	0.083	0.013 -0.063	.065 .078	.433 .653	0.091	0.012 -0.069	.430 .595	0.083	0.003 -0.026	.526 .512
NH_3 sh4 + %n. wind	0.513	0.058 0.158	.080 .107	***.031*** .246	0.523	0.058 0.148	***.030*** .266	0.065	0.000 -0.023	.925 .642
NH_3 sh5 + % n. wind	0.199	-4.268 -0.105	.823 .597	.183 .447	0.188	-3.748 -0.106	.208 .414	0.169	-1.033 -0.037	.265 .364

Data from mobile monitoring stations in Fahaheel, Rega and Mishrif fixed stations in Shuaiba Industrial Area and Airport monitoring unit.

Table (9.6) The Relationship Between NO_2 Levels in Fahaheel, Rega, Mishrif and Kuwait City and NO_2 Levels in Different Shuaiba Stations by Regression Coefficient and Statistical Significance

Independent	Fahaheel				Rega			Mishrif			Kuwait City		
	R^2	B	SE B	P	R^2	B	P	R^2	B	P	R^2	B	P
NO_2 ave all	0.562	0.674	.189	***.005***	0.040	0.103	.531	0.400	0.134	***.027***	0.436	0.136	***.019***
NO_2 ave 4&5	0.084	0.003	.003	.356	0.100	0.001	.314	0.102	0.000	.309	0.135	0.000	.238
NO_2 sh4	0.489	2.877	.961	***.015***	0.002	0.107	.892	0.370	0.578	***.046***	0.425	0.593	***.029***
NO_2 sh5	0.018	0.081	.187	.672	0.100	0.013	.315	0.264	0.072	.087	0.170	0.056	.182
% n. wind	0.015	0.007	.019	.694	0.384	0.021	***.031***	0.043	0.002	.516	0.091	-0.004	.338
Temperature	0.023	-0.000	.000	.630	0.591	0.000	***.003***	0.032	0.000	.574	0.015	0.000	.696
NO_2 ave all + % n. wind	0.673	0.756 0.021	.039 .007	***.002*** .112	0.385	0.020 0.021	.885 ***.050***	0.551	0.156 0.005	***.011*** .115	0.453	0.129 -0.001	***.037*** .600
NO_2 ave 4&5 + % n. wind	0.129	0.002 0.013	.001 .010	.305 .511	0.639	0.002 0.026	***.032*** ***.005***	0.197	0.000 0.047	.221 .330	0.180	0.000 -0.003	.349 .503
NO_2 sh4 + % n. wind	0.523	2.819 0.009	.089 .010	***.022*** .535	0.598	0.055 0.026	.918 ***.008***	0.443	0.554 0.003	.058 .335	0.507	0.617 0.003	***.026*** .280
NO_2 sh5 + % n. wind	0.024	0.061 0.005	.122 .027	.781 .821	0.389	0.027 0.020	.787 .068	0.264	0.072 0.000	.134 .999	0.434	0.088 0.007	***.044*** .070

Data from mobile monitoring stations in Fahaheel, Rega, Mishrif and Kuwait City, fixed stations in Shuaiba Industrial Area and Airport monitoring unit.

Table (9.7) The Relationship Between NO Levels in Fahaheel, Rega, Mishrif and Kuwait City and NO Levels in Different Shuaiba Stations by Regression Coefficient and Statistical Significance

Independent	Fahaheel				Rega			Mishrif			Kuwait City		
	R^2	B	SE B	P	R^2	B	P	R^2	B	P	R^2	B	P
NO ave all	0.304	0.123	.058	.062	0.048	0.115	.492	0.414	0.026	*.023*	0.178	0.034	.170
NO ave 4&5	0.071	0.003	.003	.402	0.247	0.013	.099	0.084	0.000	.358	0.044	0.000	.508
NO sh4	0.011	-0.028	.091	.758	0.099	0.192	.343	0.014	-0.006	.720	0.599	0.078	*.005*
NO sh5	0.010	0.041	.125	.747	0.008	0.083	.774	0.104	0.204	.306	0.534	0.106	*.006*
% n. wind	0.005	0.005	.024	.825	0.046	0.047	.499	0.032	0.002	.634	0.544	0.020	*.006*
Temperature	0.065	-0.000	.000	.422	0.316	0.006	.056	0.022	-0.000	.641	0.040	-0.000	.529
NO ave all + % n. wind	0.332	0.134 0.010	.021 .007	.070 .643	0.070	0.083 0.029	.645 .654	0.420	0.028 0.001	*.034* .764	0.574	0.015 0.018	.443 *.017*
NO ave 4&5 + % n. wind	0.071	0.003 0.000	.002 .000	.444 .984	0.369	0.018 0.060	.060 .219	0.091	0.000 0.001	.431 .796	0.545	0.000 0.020	.889 *.011*
NO sh4 + % n. wind	0.019	-0.049 -0.008	.023 .003	.704 .804	0.175	0.059 0.067	.845 .412	0.058	-0.015 -0.003	.526 .561	0.648	0.053 0.010	.074 .181
NO sh5 + % n. wind	0.048	0.112 0.020	.009 .006	.538 .566	0.153	0.402 0.097	.314 .245	0.112	0.030 0.007	.367 .781	0.642	0.062 0.012	.150 .133

Data from mobile monitoring stations in Fahaheel, Rega, Mishrif and Kuwait City, fixed stations in Shuaiba Industrial Area and Airport monitoring unit.

9.5 Conclusion

The aim in this chapter has been to examine the possibility of using simple models to predict the effects in residential areas of Kuwait of changes in levels of different pollutants in the Shuaiba Industrial Area, allowing for the possible effects of wind and temperature.

A number of models have been derived. To summarise the results for specific pollutants:

- for H_2S there was no clear link between levels in the SIA and levels in the residential areas;
- for SO_2 there were links between levels at station 5 in the SIA and levels in Fahaheel, and between levels in SIA station 4 and levels in Rega;
- for NCH_4 there were links between levels at SIA station 4 with levels in Rega but not elsewhere;
- for CO there the best overall predictor levels in the residential areas was wind direction;
- for NH_3 SIA there were links between levels at SIA station 4 and levels in Fahaheel and Rega;
- for NO_2 the best predictors for Fahaheel, Mishrif and Kuwait City were the mean level for all stations in the SIA and the level at station 4;
- for NO the models for Fahaheel and Rega were poor and those for Mishrif and Kuwait City inconsistent.

In many cases the addition of wind direction to levels of pollution in the SIA improved the model, and for some models
the amount a variance explained, as indicated by R^2, seemed quite high.

However the constraint of using monthly means severely limits the number of observations on which the models were based. This has meant that in general the models lack precision, and prediction intervals would be wide. Also since the observations are essentially for five geographical locations over twelve months, they can hardly be regarded as fully independent of each other.

One approach would be to monitor pollution levels at shorter intervals. However, recent studies of the dispersal of pollutants suggest that as a result of instabilities in the atmosphere, more complex meteorological models would be necessary for reliable prediction of shorter-term changes in pollution levels. Studies of time series over many years might be one approach. This would mean keeping local monitoring machinery in place and serviceable, but evaluation of historical trends in environmental pollution and relating these to health is an important component of risk assessment and risk management.

CHAPTER TEN

POLICY FOR FIGHTING POLLUTION

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POLICY FOR FIGHTING POLLUTION

10.1 Introduction

To safeguard health from the effects of air pollution, it is necessary for the government to have a long-term plan for preventive measures. Criteria considered for evaluating the programme for environmental protection include: a) the effect on levels of pollutants in the air, b) the effect on the incidence of disease or complaints related to air pollution, c) the cost effectiveness of the strategies for control and monitoring pollution programmes.

10.2 Strategies for preventing pollution

1. *Determination of allowed limits for the emission of pollutants from industrial sources.* This study has indicated that industrial pollution does affect human health directly. For this reason accurate determinations of the industrial pollutants in the State of Kuwait have become a matter of great importance, in view of the fact that the country is moving toward increased industrialisation. For this reason, standards for allowed limits must be set. These should be equal to or below the allowed limits specified by the World Health Organisation (WHO) in view of the close distances (as indicated by the study) between the industrial and residential areas.

2. *Control projects for new and existing plant.* Despite the threat posed by air pollution in general, and industrial pollution in particular in the State of Kuwait, most of the main industrial units which are the cause of the high levels of pollution do not have control projects. All new industrial units should be subjected to environmental feasibility studies to determine the amount of pollution that may be emitted by them and the extent to which their emissions affect human health. Control projects should also be established for the existing industrial units. The technical efficiency of these projects is high. The levels of concentration of pollutants in some of the units for which control projects have been established dropped sharply after their introduction, in some cases eliminating 95% of the total emissions (of eg SO_2). Priority should be given to those units whose emissions are particularly harmful to human health choosing the most cost effectiveness methods to abate the pollutants.

3. *Coordination of existing data sources.* Although data on pollution levels exist in large quantities, they are not properly organised or analyzed, and are inaccurate at best. There is considerable duplication with regard to their collection and maintenance because of the large number of bodies responsible for following up air pollution matters. There are eight different government bodies in this area (Environmental Protection Council, Shuaiba Area Authority, Ministry of Oil, Ministry of Electricity and Water, Ministry of Planning, Kuwait Municipality, Ministry of Communications and Ministry of Public Work). For this reason, one single public authority (eg, Ministry of Environment), similar

to the Public Authority for the Shuaiba Industrial Area, should be set up and should take responsibility for all matters relating to pollution in general and the provision of information relating to it. The environmental monitoring networks of the Environmental Protection Council should be connected to those of the Shuaiba Authority in order to obtain more accurate information and avoid duplication and provide an effective and efficient administration network.

4. *Improvement in the quality of environmental monitoring.* In order to conduct accurate studies of the effect of the various pollutants on human health, the environmental monitoring programmes should be made more effective by increasing the efficiency of the existing stations (eg, adding meteorological monitors and improving the filtering system). There should also be an increase in the number of stationary and mobile monitoring stations, so as to cover all parts of Kuwait. Establishing these stations sooner rather than later is to be encouraged, as it will enable the effectiveness of current control measures to be determined. Lack of long-term monitoring data has hampered the understanding of air quality. There should therefore be a commitment to maintaining a number of air quality monitoring stations at fixed locations for extended periods, so as to adequately follow trends. The economic evaluation of air pollution should be undertaken to determine the siting and number of such monitoring stations in order to obtain maximum information from the minimum number of stations.

5. *Facilitation of research.* Further research will be required on the effect of multi-agents in multi-media in Kuwait. For example, mathematical models for forecasting the levels of pollutants in the various areas of Kuwait should be developed for assessing the effects of environmental pollutants on human health. People with an interest in research in this field of pollution and its effects on health and the quality of life need to be drawn together and supported. Access should be provided to official sources of data. Funds need to be available for the necessary equipment and for training in the relevant research methods.

6. *A specialised environmental medicine unit.* A specialised unit should be established that includes specialists in ENT, respiratory, chest diseases and allergic diseases, for this study has suggested the existence of a causal relationship between the spread of these diseases and the increased concentrations of certain pollutants in Kuwait.
7. *Increased public awareness.* The population should be informed about the negative and positive impacts of the application of technology, and its impact on health. Public information campaigns are needed to inform them how to get the maximum benefits and avoid the adverse health effects.

10.3 Policies and measures for implementing the proposed strategy

10.3.1 Air Pollution Control

1. The formation of a team consisting of representatives of the various competent bodies, to review pollution levels and determine their future development.

2. Setting emission standards

- Reviewing the literature for emission standards adopted in the developed countries and the Gulf States.
- Further analysis of the data available may help.
- Circularise these standards among the bodies concerned, such as the Kuwait Oil Company, the Kuwait National Petroleum Company and the Shuaiba Area Authority for implementation and observation.
- Preparation of the necessary legislation and follow-up.

3. Revision and updating of air pollution emissions for industrial plants. This would include SO_2, NO_x and CO

- Making an investigation to determine the emission source.
- Production and emission factors and the probability of changing with time.

4. Control of certain pollutants (SO_2, NO_x and CO)

- Determination of sources.
- Reviewing the monitoring findings.
- Setting strategies for control.
- Reviewing of effectiveness and follow up.

5. Linking the Air Quality Monitoring System in Shuaiba Area Authority with the state network

- Discussions with the SAA.
- Upgrading the computer at Environmental Protection Council, and transmission capabilities.
- Selection of mathematical models.
- Selection of control strategy and follow up.

6. Building up an optimization air shed model

- Studying the available packages.
- Selection of appropriate type.
- Calibration of the models.
- Inviting a group of experts to help calibrate the models.

7. Expanding on the air quality monitoring stations and upgrading the mobile stations

- Selection of additional sites.
- Upgrading the capabilities and order of mobile labs.
- Study the inversion layer.

8. Preparation of periodical reports

- Aiming at following up the extent to which the various industrial units observe these standards.

- Enactment of legislations required to ensure proper observation of the set standards.

9. Review of the various available data obtaining from the results of the environmental monitoring activities or the establishment of a system for the transfer of information and data.

10. Preparation of mathematical models

- Dealing with the environmental monitoring data.
- Selection of a specific models that are appropriate to the conditions prevailing in Kuwait.

10.3.2 Control of the impact of technology on public health and safety

1. Study the prevalence of diseases related to air pollution

- Study the pollutants that are causing specific health problems as chronic bronchitis, cancer and allergies.
- Recognise the probable causative pollutants for public health problems.
- Integrate air pollution data with health statistics and seek positive correlations.
- Control the pollutants that affect the health of the population.

2. Study the health impact of industrial development and air pollution and study the appropriate controls

- Involve the health care planning department in studies of the impact on health of the different types of air pollution.
- Study the health impacts of the different types of air pollution and the effect of multiple exposures.
- Set priorities and strategies for air protection based on the health impacts.

10.3.3 Training and Education

1. Train a number of qualified personal at the Diploma or BS level

- Study the training needs of different organizations by distributing a questionnaire.
- Prepare a suitable curriculum.
- Convene a working group from the organizations interested in employing the graduates to discuss the curriculum.
- Study the need for teachers and trainers.
- Review the appropriateness of the curriculum and the principal needs and the development of the programme.

2. Post Graduate training in air pollution aspects

- Discuss with the University of Kuwait the establishment of an MS programme in Environmental Science and contact universities abroad for training Ph.D. candidates.

- Encourage postgraduate candidates to select air pollution topics for their PhD dissertations.
- Ask the Ministry of Education to assign a number of fellowships for candidates studying environmental topics.
- Contact the Civil Service Commission to assign fellowships for postgraduate training of the staff employed by different organizations.

3. Seminars and workshops

- Propose a list of topics and circulate it among different organizations to elicit their response.
- Set priorities according to the number of positive responses, the lack of information and the availability of training opportunities.
- Evaluate the outcome of each seminar.

4. Practical training

- Review the local institutions where there may be opportunities for training.
- Ask the institutions to accept a number of candidates for training in their laboratories.

5. Build up a specialised environmental library.

- Provide key periodicals.
- Subscribe to relevant data bases and computer based information systems.

- Update the information.

10.3.4 Research programme

1. A long-term environmental research programme

- Circulate different programmes among the different organizations to elect their response.
- Establish contact with the Kuwait Foundation of Advancement of Sciences (KFAS) for financial support for relevant topics.
- Discuss with research groups at Kuwait University the assignment of a the role in supporting research.

2. Make better use of the outcome of the research projects

- Improve contacts with and between the different organizations likely to use the results of research.
- Circulate the recommendations among the interested organizations.

10.3.5 Education of the public

1. Better support for the protection programmes

- Provide scientific materials and better methods of health education tailored to the target groups.
- Follow up the effectiveness of the educational programmes to find out how far they change behaviour and attitudes.

2. Environmental education of school children

- Revise the recommendations arrived at by the working group convened to study the requirement for environmental education.
- Select topics and items that are appropriate for the different school levels.
- Follow up the outcome and effectiveness of the programme.

3. Design a field investigation to compare the different methods used for public education targeted at different age groups

- Review the methods presently used.
- Determine their appropriateness and shortcomings.
- Test the effectiveness of selected methods in terms of outcome (information, behaviour and attitude).
- Circulate findings among the interested organizations.
- Follow up, setting priorities.

CONCLUSIONS

CONCLUSIONS

This is the first detailed national study of the effect of air pollution on human health in Kuwait. It has linked the prevalence of physical and psychological symptoms with levels of air pollution for the period from February 1st, 1989 to January 31st, 1990.

The study has developed a method for identifying and quantifying air pollutants in the atmosphere and related this to health problems through a population based survey carried out at the same time.

Measurement sites were selected on the basis of the dispersion characteristics of the pollutants in the atmosphere, and to ensure a variety of distances from the Shuaiba Industrial Area and thus a variety of levels of exposure. The measurement methods used for the level of pollution in this study, were of a high standard: the instruments used to measure pollution and the method of monitoring was of a very high quality which few of the studies discussed in literature review in chapter 2 were able to achieve. The monitoring instruments used were operated automatically with a measurement taken every 5 minutes to ensure reliability. The non-dispersive infrared method was used to enable the measurement of real time values with high selectivity. Output signals and operational function were checked manually. Daily visits were carried out by the researcher to ensure the smooth and efficient running of all the equipment, to rectify any error or breakdown that had occurred, to perform any manual gauging of the relevant equipment, to replace air filters and to replace the tapes on which results were recorded.

The sites of the monitoring stations within each area were placed in the open air, unobstructed by any obstacles: there were no high rise buildings within 500 meters of the monitoring points in any direction.

Many previous studies used less efficient equipment, took only a few readings per day and often the siting of these monitors were not appropriate to the areas studied. In the study by Love (1982), for example, air pollution concentrations were measured in a station sited 3.2 km away from the houses, and only one sample was taken every 24 hours. In the study by Schenker (1983) mean annual averages of air pollution were considered.

A cluster sample was used for choosing individuals for the purpose of the study. Given the lack of a population register this was a practicable method, but it does have potential disadvantages at the analysis stage. Overall, a good response rate was found, response bias was not a major problem, and the clustering of the respondents did not appear to create serious problems from the point of view of interpreting the results.

There were 1140 individuals of different ages between 1 to 99 years in this study. This is a much larger sample than those found in other studies. In Koenig (1982) only 8 individuals ages 12 to 14 years were included in the study; Mohsenin (1988) used 18 people with mean age 25 years; in a laboratory study Linn (1984) used 24 volunteers, in 1985 he used 22 volunteers and in 1986 used 21 volunteers. More individuals were included in other studies but there were often restricted to certain age ranges; for example, in a community study, Xiping (1991) examined 1440 adults aged 40 to 69 years; and in a study by Manzhenko (1976), 3009 individuals aged 7 to 12 years were used.

This Kuwaiti study goes considerably further than others reported in the literature in terms of the range of symptoms studied and pollutants considered. This has allowed a more detailed consideration of the effects of correlation, which would otherwise have to be approached by controlled studies in the laboratory, with all their drawbacks in terms of cost, possible bias in the selection of subjects, limited duration of exposure and assessment of implications for the real world.

In the present work the study design enabled the effect of pollution to be evaluated at graduated distances from a major source of pollution. Few other studies have used a `natural experiment' in this way, or the seasonal variations for different pollutants. There were no gross differences between the three areas in terms of demographic or socio-economic structures. There were steady gradients for physical symptoms, psychological symptoms, self-reported ill health and use of health care from Fahaheel to Mishrif.

The number of observations and the gradients in terms of distance, weather and pollutants allowed us to explore statistical relationships in some depth. This study has used cross tabulation, time series analysis and regression analysis.

The study incorporated two ranges of indicators of air pollution: mean levels over 7 days and mean levels over 30 days. These showed a high degree of correlation between health and levels of some pollutants (in particular SO_2, CO and NO), broadly consistent with earlier studies. Having established these relationships it was possible to use these estimates to model the likely impact on symptom levels of reduction in levels of exposure to SO_2, CO, NO, NH_3 and NCH_4.

The relationships between levels of pollution in SIA and pollution levels in the residential areas taking into account the wind direction and average temperature were also investigated. Some links were found, and for some pollutants there was the expected decrease in explanatory power with increasing the distance from SIA. However, these models had to be based on relatively small numbers of observations, and very little confidence could be placed in any predictions based on them.

Unfortunately, it was not possible to validate the subjective descriptions of illness with clinical examinations nor was it possible to explore the effects of long-term exposure to pollution. These aspects are worthy of further study. The results did, however, provide a sufficient evidence for abatement projects in each industrial unit in order to reduce the harmful effects of air pollution on the human health.

This study thus has important implications for pollution control. The data from it still have much to yield, and should play a fundamental part in environmental policy associated with any industrial development in Kuwait. Finally the results given here provide pointers to a number of topics for further research, so far only hinted at.

APPENDICES

APPENDIX A

SHUAIBA INDUSTRIAL AREA

SHUAIBA INDUSTRIAL AREA

Shuaiba Area Authority is a governmental authority with an independent budget and attached to the Ministry of Commerce and Industry. It was set up on May 14, 1964 under the name of Shuaiba Industrial Development Board and was later named Shuaiba Area Authority in accordance with an Amiri Decree issued on March 16, 1970. 80% of the industry in Kuwait is located in S.I.A.

Location

Shuaiba Industrial Area is located 50 km south of Kuwait City between Al-Ahmadi South Pier and Mina Abdulla along the coastline. The location is marked by the following features :

1. Proximity to the source of energy and raw materials such as oil and natural gas.
2. Proximity to the country's main road Kuwait / Nawaiseeb, Fahaheel and Ahmadi cities and motorway.
3. Availability of virgin plots for future expansion of the Area.
4. On the coastline with water of adequate depth for the construction of the harbour and sea cooling intakes.

The present total area of Shuaiba Industrial Area is estimated at 24 million sq. m.

Distribution of Industrial Plots in the Area

The expanded S.I.A. currently covers 35 factories belonging to 29 companies and establishments. The gross domestic product was 3.7% of the economy of Kuwait, (raised at 1980 to 7.9% from industries only.) There is an imbalanced economy in Kuwait where 85% comes from the oil sector and 15% from other sectors.

Industrial Services and Utilities Available in the Area

A. Services rendered by Shuaiba Area Authority directly

- Distribution of industrial plots for long term and temporary uses.
- Sea Cooling Water: Cooling water is supplied through three pumping stations.
- Shuaiba Ports.
- Roads in its services.
- Environmental Protection Centre. The S.A.A. set up an environmental protection centre in 1968, which contains seven key laboratories, automatic air and water network. These stations measure the pollutants automatically and convey the results to the main computer at the centre. Some of the data for this study were taken from this centre.

The Policy for Fighting Pollution

1. Selection of sites for industrialization is related to prevailing winds.
2. Tree belts of at least 1 km width should be planted around the industrial areas.

3. For heavy industries, restrictions are imposed and special preventive arrangements for fighting pollution such as building high chimneys and the dispersion of poisonous gases and liquids.
4. Observation posts for measuring the rate of pollution and monitoring industries to ensure that they comply with the permitted international levels of pollutants.
5. Oil-burning chimneys should be over 200 metres high or sulphur should be eliminated from oil before burning.
6. Public Relations.
7. Industrial safety and security.

B. Services coordinated by the Shuaiba Area Authority in cooperation with other public bodies

- Electric power - Ministry of Electricity and Water
- Fuel gas - Ministry of Electricity and Water
- Fresh and Distilled Water - Ministry of Electricity and Water
- Postal and Telecommunications Services - Ministry of Communications
- Public Security Services in the area
- Fire Fighting Services
- Health Services
- Customs Services
- Meteorological and Marine Forecast Services

- Other Services such as banking, travel agency, insurance agency

Public and Government Production Units and Industries in Shuaiba Industrial Area

1. Shuaiba North Power and Water Production Station

These plants operated by Ministry of Electricity and Water, were set up in 1965. Thus they are one of the earliest industries in the area. They comprise a number of stream turbo alternators and a number of water distillation plants. Power production has developed during the period 1965 - 1969 from 140 to 400 MW, and for distilled water from one million gallons/day to 14 million gallons/day in 1971.

These plants provide electricity and water for S.I.A. and also for other areas in Kuwait.

2. Shuaiba South Power and Water Production Station

The first 13 k MW unit of 6 power generators was commissioned in 1970 and the total capacity is 80 k MWs and the total production of water is 30 million imperial gallons/day.

3. The Kuwait National Petroleum Company K.S.C.

This was the world's first all hydrogen refinery which came on stream in 1968. The original charge capacity was 95,000 barrels/day. This has been increased to 195,000 barrels/day. It hydrocrackes heavy crude vacuum into lower sulphur reconstituted crude. The products are exported worldwide via Shuaiba Liquid Products Pier and through pipeline to local marketing depot in Sabhan. Turbine fuel to KAFCO, gas oil for MEW power station.

4. Petrochemical Industries Company K.S.C.

It was founded on 18th July 1963. The company is wholly owned by the State of Kuwait and is administrated as a component of the Kuwait Petroleum Corporation.

PIC is a pioneering company in the production of chemical fertilizers. The company was the first in the Middle East to utilise Natural Gas for the manufacture of Ammonia, Urea, Ammonium Sulphate and Sulphuric Acid. Salt, Chlorine and their by-products.

Manpower: In 1983 the total number of employees at PIC reached 1796 most of them engineers, technicians and skilled workers.

Production: The fertilizer division comprises of the following plants:

PLANTS	ANNUAL CAPACITY
3 Ammonia	660,000 MTS
3 Urea	792,000 MTS
3 Urea	792,000 MTS
1 Ammonia Sulphate	165,000 MTS
1 Sulphuric Acid	132,000 MTS

A fourth Ammonia line was operated in 1984 with capacity of 1000 MTS/day. The annual capacity of PIC is about 1,000,000 MTS.

Export: PIC fertilizers are exported to more than 50 countries all over the world.

5. Kuwait Cement Co. K.S.C.

The Kuwait Cement Co. is a share-holding company established in November 1968, with a capacity of K.D. 2500,000/- this capital had been increased in 1983 into K.D. 26,616,250/- which is fully paid up.

The first plant for the production of ordinary Portland Cement and Sulphate resisting cement in 1972 with production capacity of 300,000 tons/annum. In 1978 it was increased to 1,350,000 tons/annum, and in 1983 increased again to 2,070,000 tons/annum. The company has a white cement plant with production capacity 75,000 tons/annum which was introduced in 1979 for local use and export to Saudi Arabia and Jordan.

6. Kuwait Industrial Refinery Maintenance and Engineering Company (KREMENCO)

KREMENCO is a Kuwaiti Joint Stock Co. established in 1969 in cooperation with KREMENCO Foster Wheeler International and the West German company Hans Lifter GMBH. It renders the following services both in Kuwait and other countries.

Manufacture, erection, repair maintenance and testing of steam generating and refinery units.

7. Refrigeration and Oxygen Company Limited

This is a private company specializing in the production and marketing of medical and industrial gases, mainly Oxygen, Nitrogen, Argon, Acetylene, Nitrous Oxide, Carbon Dioxide, Hydrogen Helium Ammonia and Refrigerant Gases.

Most of these gases are consumed locally. Excess production is exported to neighbouring countries in the Gulf and Iran.

8. Dresser (Kuwait)

1.	Barite	: 192 m tons/day
2.	Bentonite	: 120 sacks/day -25 kg
3.	Spersene	: 800 sacks/day -25 kg
4.	XP-20	: 800 sacks/day -25 kg
5.	Pipelax	: 10 drums/day -55 gal
6.	Drilling Detergent	: 10 drums/day -55 ga.

Rock-bite and other drilling products.

9. Packaging and Plastic Industries Co.

They co-produce bags of polyethylene and woven polyethylene. They produce garbage bags, agricultural, construction sheeting and food packaging. Production capacity is 15 millions polyethylene bags - urea size, 50 millions polyethylene bags - different sizes.

10. Kuwait Industrial Gases Corp.

It produces liquid and gaseous Nitrogen, Oxygen and Argon Gas, and an Hydrous Ammonia, also Ammonia solutions.

Production capacity:

Liquid Nitrogen	:	140 cu mtres/hr
Liquid Oxygen	:	140 cu mtres/hr
Argon Gas	:	6 cu mtrs/hr
Freon 12		
Freon 22		

11. Kuwait Sulphur Company (Agricultural, Industrial W.L.L.)

This is a Kuwaiti company incorporated in 1972 with the objective of processing and marketing Sulphur in the course of oil refinery. Its capacity is 40 thousand tons/day. Exports of its products are routed overland or by sea through Shuaiba Commercial Harbour.

12. Kuwait Melamine Industries Co.

It is a public share-holding company established in April 1976, its capital reached 12 million in 1981. 40% is shared by Kuwait Petroleum Corporation and 60% is owned by Kuwaiti private shareholders.

the Far East. 1200 Mt/annum Ammonia as a side product.

In 1982 it started to produce 20,000 MT of Formaldehyde and 10,000 MT of MC/annum.

13. Shuaiba Paper Products Co

It was established in 1978 with initial capitalization at KD 375,000/-, the company is supplying the local market and exporting to Saudi Arabia and Jordan paper bags, lime, animal feeds and various packaging bags.

The present annual production capacity is increased from 30 million to 90 million bags. The company capital increased to KD 825,000/-.

14. The National Industries Co. - Lime Products Factory

Type of company	:	Kuwait Share-holding Co.
Present capital	:	One million bricks/day
Import	:	Inorganic pigments and spare parts.

15. The National Industries Co. - Kuwait Asbestos Industries

Purpose of company	:	Asbestos Cement pressure pipes.
Capacity of production	:	60 thousand tons/year.
Present actual production	:	Asbestos Cement pressure pipe die from 100 mm - 200 mm. Total production is 60,000 tons/year.

16. Kirby Building Systems

It is considered the most modern steel building manufacturing plant in the Middle East, its annual capacity being 60,000 metric tons.

Kirby's range of products include rigid frames, secondary members and repainted cladding. Its products are used in warehouses, factories, office buildings, hangers, workshops, schools, showrooms, filling stations, labour camps, fire stations, car parks, dairy farms, cold stores and residential complexes.

17. Sanitary Ware Co.

This has a production capacity is 250,000 large pieces of sanitary ware or 50,000 completed bathrooms of different colours/year.

18. Real Estate Construction and Fabrication Co., Kuwait

RECAFCO has a modern 10,000 sq. meters factory situated on 80,000 m^2 of land. It produces all types of pre-cast and pre-stressed concrete products. Hollow core floor and roof units, double tees, bridges and other pre-stressed beams, delouse armour units, round piles, fair fated exposed aggregate, bask hammered, etc.

19. Kuwait Precast Systems Co.

The company incorporated in March 1977 with initial capital KD 1,010,000. In 1983 it is increased to 1,500,000 KD and the factory was extended from 29,999 M2 to 54,250 M2.

20. Kuwait Insulating Material Manufacturing Co.

Considered one of the leading companies in manufacturing glass wool insulation in the Middle East. It has a capacity of 8000 tons/year.

KIMMCO covers all the requirements for Kuwait market and exports to other neighbouring countries through a network of sales offices in the Gulf countries.

21. Al Rabiah International Contracting Co. W.L.L.

It produces pre-cast and pre-stressed beams with length range up to 19m, width on 25 tons/piece, and also produces complicated shapes of facades.

22. Gulf Paper Manufacturing Co.

Company objectives	:	To supply the market with different grades of paper.
Output	:	18,000 tons/annum

23. National Automotive Manufacturing and Trading Co.

The objectives	:	To manufacture locally whole or in part the automobiles and their parts.

NAMTCO are considered the agents in Kuwait for BMW cars, Renault and Magirus trucks. Alfa Romeo, Dlawoo D.M.C. Korean car, P.P.M. France, K.H.D. Tractors and Magirus Fire Bridge.

24. Kuwait Chemical Manufacturing Co.

Production : Alkyd resins 5500 tons/year Unsaturated Polyester Resins 6000 tons/year

Polyvinyl Acetate and other Copolymer Emulsions 5000 tons/year.

THE RULE OF ENVIRONMENTAL PROTECTION CENTER IN S.I.A.

The State of Kuwait endeavours to combat pollution and to protect environmental equilibrium through its participation in international and regional agreements and through the legislation and regulation.

As an authority responsible for an industrial area accommodating several industrial establishments that emit a variety of wastes and pollutants, Shuaiba Area Authority set up the Air and Water Pollution Control Centre in 1968 which is now known as the "Environmental Protection Centre".

In cooperation with the governmental ministries and agencies, the industries in the area and other internal consultancy bodies, the authority has drawn up codes of practice and environmental guidelines, and recommended a number of preventive measures to the existing industries.

The authority has also increased the efficiency of the environment protection centre by constructing a new building containing seven key laboratories and four branch laboratories well equipped.

There are automatic air and water pollution monitoring stations are within the Shuaiba Industrial Area and the neighbouring coastal waters. Eight of these stations are for air monitoring, and six are for monitoring water in the industrial outlets, inlets of the cooling water pumping station and inlets of the desalination plants. In addition, hydrographic monitoring towers were constructed for monitoring the marine environment. These stations measure pollutants automatically and transmit the results to the main computer at the centre.

The main tasks of the centre are planning and implementing the necessary procedures and measures to control pollution, suggesting the means to reduce pollution and specifying the suitable methods for analysis. The centre prepares periodical reports and statistics on environmental pollution and is constructing a detailed data bank.

The centre performs environmental impact assessments for new industries and expansions of existing ones in order to forecast the environmental effects of such companies. As a result, guidelines are set and remedial measures are suggested for each industry.

Air Pollution Control Section

This section has continuous measurement of the air pollution by 8 automatic air quality monitoring stations located in the Shuaiba area and Mina Abdulla and Ahmadi areas. Also a meteorological station has been installed to measure wind direction, wind speed, temperature and humidity to determine the distribution of the pollutants. Data will be transferred to the main computer in the centre. Samples from different locations are analyzed in the air lab with the aim of obtaining data about the area.

Follow up and Environmental Research Section

This section performs the following tasks:

1. Follow up of the environmental protection incidents resulting from industries and investigation of the immediate causes, results and control of these episodes.
2. Coordination of environmental issues with the relevant governmental bodies and industries in the Shuaiba Industrial Area.
3. Recommending short and long term measures to combat pollution problems arising from the existing industries.
4. Carrying out the necessary environmental research and projects.
5. Performing environmental impact assessment for proposed industries and recommend the necessary environment guidelines and measures to be implemented.

APPENDIX B

THE NATIONAL AMBIENT AIR QUALITY STANDARDS

THE NATIONAL AMBIENT AIR QUALITY STANDARDS

The Clean Air Amendments of 1970 required that the Environmental Protection Agency established primary and secondary national ambient air quality standard (NAAQS) for each air pollutant for which criteria had been issued under the 1967 Clean Air Act (sulphur dioxide, suspended particulates, carbon monoxide, photochemical oxidants, hydrocarbons and nitrogen dioxide). The proposed rules establishing these standards were published June 30, 1971, and final rules were promulgated on April 30, 1971.

Primary Standard

The primary standard was to be that level of ambient air quality which "requisite to protect the public Health".

The Senate Committee on Public Works (where the concept first arose) described the standards as follows:

In requiring that national ambient air quality standards be established at a level necessary to protect the health of persons, the Committee recognizes that such standards will not necessarily provide for the quality of air required to protect those individuals who are otherwise dependent on a controlled internal environment such as patients in intensive care units or newborn infants in nurseries. However, the Committee emphasizes that included among those persons whose health should be protected by the ambient standard are particularly sensitive citizens such as bronchial asthmatic and emphysematics who in the normal course of daily activity are exposed to the ambient environment. In establishing ambient standard necessary to protect the health of those persons, reference should be made to a representative sample of persons comprising the sensitive group rather than to a single person in such a group. Ambient air quality is sufficient to protect the health of such persons whenever there is an absence of adverse effects on the health of a statistically related sample of persons in sensitive groups from exposure to the ambient air. An ambient at quality standard, therefore, should be the maximum permissible ambient air level of an air pollution agent or class of such agent (related to a period of time) which will protect the health of any group of the population.

Furthermore, in establishing the primary standard, the administrator was to apply an "adequate margin of safety". Thus, if conflicting or ambiguous evidence was presented, he was to resolve the issue on the side of protecting the public health.

Secondary Standard

In establishing the secondary standard ambient air quality standard, the administrator was directed to establish numerical indexes for those parameters of air quality which is necessary to protect "Public Welfare" defined in the act as any effects on soils, waters, crops, vegetation, man-made materials, animal wildlife, weather visibility and climate, damage to or deterioration of property and hazards to transportation, as well as effects on economic values and on personal comfort and well being. Thus its purpose was to establish the level of ambient air quality than in no way would affect man or the environment.

National, Primary and Secondary Ambient Air Quality Standards :

Air Pollutant	Federal Standard	
	Primary	Secondary
Sulfur dioxide	80 ug per cubic meter (0.03) annual arithmetic mean 365 ug per cubic meter (0.14 ppm) maximum in 24 hours.	60 ug per cubic meter (0.02 ppm) annual arithmetic mean 260 ug per cubic meter (0.1ppm) maximum in 24 hours 1,300 ug per cubic meter (0.5 ppm) maximum in 3 hours
Suspended particulates	75 ug per cubic meter annual geometric mean 260 ug per cubic meter maximum in 24 hours	60 ug per cubic meter annual geometric mean 150 ug per cubic meter maximum in 24 hours
Carbon monoxide	10 ug per cubic meter (9 ppm) maximum in eight hours 40 mg per cubic meter (35 ppm) maximum in 1 hour	10 mg per cubic meter (9 ppm) maximum in 8 hours 40 mg per cubic meter (35 ppm) maximum in 1 hour
Photochemical oxidants	160 ug per cubic meter (0.08 ppm) maximum in 1 hour	160 ug per cubic meter (0.08 ppm) maximum in 3 hours, 6 am to 9 am
Hydrocarbons (corrected for non-methane)	160 ug per cubic meter (0.08 ppm) maximum in 3 hours, 6 am to 9 am	160 ug per cubic meter (0.08 ppm) maximum in 3 hours, 6 am to 9 am
Nitrogen dioxide	100 ug per cubic meter (0.05 ppm) annual arithmetic mean	100 ug per cubic meter (0.05 ppm) annual arithmetic mean

Note : Maximum concentrations are not to be exceeded more than once per year.

APPENDIX C

HEALTH SERVICES IN KUWAIT

HEALTH SERVICES IN KUWAIT

Medical care is mostly free of charge. The main provider is the Ministry of Public Health but some Ministries and the major oil companies provide hospitals and medical services for their personnel. The private sector is relatively small and is run under close state supervision. Health services are primarily organized on the basis of population density and distribution (Naim, 1986). The services are provided through a system of three levels of health care, discussed below:

Primary Health Care

Primary health care is provided though 68 health centres. Each health centre provides care for up to forty thousand inhabitants who are registered through the national health registration system. Health centres provide curative, preventive and rehabilitative services. The centres implement regional health plans and programmes as they pertain to preventive health, nutrition, school health, health education, selected training activities and inoculation against specific diseases. The services offered include general practitioner services, maternal and child health services and dental services. Simple laboratory tests and X-rays are carried out at some of the centres. Patients may be referred from health centres to specialized clinics and hospitals. However, the health centres provide services to psychiatric patients in their homes, and social and rehabilitative care for the needy individuals and families.

Secondary Health Care

Secondary health care is provided through six general hospitals, each of which attempts to meet the overall health needs of about 300,000 inhabitants, through an out-patient, a casualty department, and specific inpatient departments. Each of the six hospitals provides inpatient care services in the fields of internal medicine, general surgery, gynaecology and obstetrics, paediatric, thaumatology and orthopaedic, ENT, ophthalmology, psychiatry, dermatology, physical medicine and dental services.

The services provided through the six general hospitals are supplemented by specialist clinics. The rationale of the establishment of these clinics is to reduce the load on the hospitals' out-patient departments. The specialty clinics serve the purpose of making specialist services more readily available and providing an important link between the primary and the secondary health care. Besides, they ensure technical cooperation between these two levels.

The specialty clinics are outside the hospital premises but they are managed by the relevant hospital departments. They provide services in the fields of internal medicine, general surgery, gynaecology and dermatology. The clinics have paramedical services at their disposal and the necessary radiology and laboratory services.

The facilities of each of the six hospitals are now described:

Al Sabah Hospital

The hospital was established in 1962 and has a total bed capacity of 611. With reaginalization in operation, this is the general hospital for the Al Shuwaikh health region. Other hospitals in the area, which provide specialized services, now form part of the Sabah General Centre for Medical Specialities, which is the national tertiary care centre.

Al Amiri Hospital

The Al Amiri hospital, which has 400 beds and 8 intensive care beds, was opened in 1984 and replaced the old Amiri hospital which had been operating since 1949. The hospital provides services through out-patient as well as inpatient departments.

Al Farwaniya Hospital

This hospital started functioning in 1980. It has a capacity of 538 beds, which are allocated among general medicine, surgery, ENT, ophthalmology, paediatrics, neo-natal care, obstetrics and gynaecology, orthopaedics and an intensive care unit.

Al Jahra Hospital

Al Jahra is a twin of Al Farwaniya hospital. Although it started receiving patients in 1980, the hospital was not completed and did not reach full capacity until 1982. It provides the same services as are provided by Al Farwaniya hospital.

Mubarak Al Kabir Hospital

The first patients were received in February 1981. The hospital has a capacity of 550 beds, and is unique in being the teaching hospital. Its services also include a kidney transplant unit, a coronary care unit, and a rheumatology unit.

Al Adan Hospital

The hospital was opened in May 1980, and has a capacity of 550 beds. It is a twin of Mubarak Al kabir hospital in that it offers the same services. However, it is a non-teaching general hospital and does not have the three speciality units found at Mubarak Al Kabir.

Tertiary Care

Tertiary care, or the third level, is provided through a number of specialty hospitals and clinics. The following are noteworthy in this respect:

Maternity Hospital

The first Maternity hospital was established in 1961. However, it was replaced in 1968 by the present Maternity hospital in a new building, which was needed to meet the increasing service needs and has a capacity of 441 beds.

Hospital for Psychiatric Medicine

A small hospital for psychiatric cases was built in Kuwait in 1955. Three years later the present psychiatric hospital was established to meet the increased patient load. By 1983, the capacity had risen to 540 beds.

Chest Diseases Hospital

The original hospital was built in 1952. However in 1959 the present hospital was built to replace the older and smaller one. By 1983, the capacity was 294 beds. The hospital is equipped to perform chest and heart surgery in addition to the provision of treatment for chest diseases.

Ibn Sina Hospital for Specialist Surgery

This hospital started functioning in 1981. It has 263 beds, which are allocated as following:

Paediatric surgery	76 beds
Ophthalmic surgery	94 beds
Neuro and Brain surgery	62 beds
Burns	25 beds
Intensive care	6 beds

The hospital has been operating theatres, as well as an out-patient department to provide all the services mentioned above on an outpatient basis.

Al Razi Orthopaedic Hospital

This hospital provides specialized care for orthopaedics cases. Besides having highly qualified and competent staff, it has the latest state of the art equipment. At present the hospital has 290 beds, which are considered adequate to meet the patient load.

Infectious Diseases Hospital

This hospital is also called "Fever hospital". It provides specialized care for the treatment of acute infections. It has a capacity of 207 beds, which is considered adequate to serve the needs of all acute patients referred from the general hospitals.

Sulabikhat Hospital for Physical Medicine and Rehabilitation

This hospital, provides specialized physiotherapy services. While general hospitals have physiotherapy units that cater to the needs of their patients, specialized physiotherapy care is provided at this hospital. It has both outpatient and in-patient care facilities, including 117 beds.

In addition to these seven specialty hospitals, the following specialty centres and clinics also cater to tertiary care needs:

Chest Diseases Clinic and Tuberculosis Prevention Unit

The tuberculosis screening programme has been existence since 1956. However, as it operates at present, the unit is a relatively recent development. The unit is attached to the Sabah General Centre for medical Specialties and is responsible for the implementation of the national TB control programme. Specifically, it carries out the following activates: (i) receiving referrals from various hospitals, (ii) early detection of TB cases, (iii) treatment of TB cases, and (iv) referring cases to the Chest Diseases Hospital for hospitalization.

Kuwait Centre for Cancer Control

Although the centre was officially inaugurated in 1982, radiotherapy services for cancer control have been available since 1969. At present the centre is organized into two major sections: Radiotherapy Section, and Hussain Makki Al Jum'a Surgical Centre.

The radiotherapy unit has the following sections to provide appropriate treatments to patients:

1. Radiotherapy section.
2. Radiophysics section.
3. Chemotherapy and pharmacy section.
4. Nuclear medicine section.
5. Cancer epidemiology and registry section.
6. Laboratories for tissue culture and chromosome testing.
7. Medical registration.

The Radiotherapy services offer 62 beds, of which 15 are for males and 15 for females. Besides, it has 16 private rooms for males and the same number for females.

The surgical section has both inpatient and outpatient departments. Of its 45 beds, 12 are for males and 12 for females. The facility also has 16 private rooms and 5 rooms for intensive care. It is served by 3 operating theatres.

Another unit in the Centre that deserves a special mention is the Diagnostic X-rays Division, which serves the needs of all patients in both the radiotherapy and the surgical sections.

Kuwait Centre for Allergic Diseases

Established in 1984, the centre has 36 beds. It provides specialized treatment for bronchial asthma, skin allergies, eye allergies, and low immunity cases. Being a tertiary care facility, the centre accepts cases on referral from various hospitals.

Kidney Centre

The Kidney centre started working in 1978 and was initially housed in the Chest Diseases hospital. However, in 1982 it moved to its premises in the Mubarak Al Kabir hospital. The centre has 18 beds. The kidney transplant programme of the centre is rated as one of the most successful professional programmes by international standards.

A new building for the Kidney Centre is under construction and expected to be completed during the current planning period. Once the centre is housed in the new building, additional services will be made available to the population.

Kuwait Dermatology Centre

The need for specialized unit to provide dermatology services was expressed by policy planners in the seventies, but the Dermatology centre was not established until 1981. The centre receives referral patients from all six general hospitals.

Genetic Centre.

Scientific advances in genetics have found a deserving application through the establishment of the genetics centre, which was founded in 1979. The centre offers counselling and treatment to its patients. The services offered at the centre are comparable to those available from leading centres in the field in the developed countries.

Speech and Hearing Treatment Centre

As its name suggests, this centre caters to patients in need of speech and hearing services. During 1988, 14,276 patients were examined and treated in the centre.

The Centre of Islamic Medicine

Among the various achievements of the Ministry of public health, one notable contribution is the development of the Centre of Islamic Medicine. The following four spheres identified and that various scientific works be commissioned on each of them:

1. Medical jurisprudence.
2. Herbal medicine.
3. Al Tib al Nabawi (Prophetic medicine).
4. Islamic medicine heritage.

Emergency Medical Services

Emergency medical services are provided through the appropriate facilities in relation to the primary, secondary, or tertiary care. Any emergency patient in need of specialized care is given a prompt referral to the tertiary care facilities. The ambulance network, which effectively covers all the tertiary care of Kuwait, facilitates timely referral, transportation and provision of emergency medical services.

APPENDIX D

SPECIFICATION OF INSTRUMENTS

SPECIFICATION OF INSTRUMENTS

Ambient Sulphur Compounds Monitoring System

Measuring Object	:	H_2S, SO_2
Measuring Principle	:	Flame Photometry (FPD)
Range	:	0 0.1 0 0.5 0 1 ppm(Auto Range Selection incorporated)
Repeatability	:	Within ± 2% of full scale
Response Time	:	Within 60 sec. of 90% response
Noise	:	Within 2% of full scale
Drift Zero	:	Within ± 2% of full scale per day
Span	:	Within ± 2% of full scale per day
Temperature	:	0 40°C
Humidity	:	Less than 85% R.H.
Calibration	:	Automatic zero/span calibrator incorporated
Power	:	AC 100v ± 10V 50Hz ± 1Hz
External Dimension	:	150(W) x 540(D) x 1350(H) mm
Colour	:	Blue (Munsell 10B 4.5/5)

Ambient NH_3 Monitoring System

Measuring Object	:	NH_3
Measuring Principle	:	Pressure Reduction Chemiluminescence (CLD)
Range	:	0 0.5 0 2.0 5 ppm

		(Auto Range Selection incorporated)
Repeatability	:	Within ± 2% of full scale
Response Time	:	Within 60 sec. of 90% response
Noise	:	Within 2% of full scale
Drift Zero	:	Within ± 2% of full scale per day
Span	:	Within ± 2% of full scale per day
Temperature	:	0 40°C
Humidity	:	Less than 85% R.H.
Calibration	:	Automatic Zero/span calibrator incorporated
Power	:	AC 100V = 10C 50Hz = 1Hz
External Dimensions	:	450(W) x 540(D) x 1350(H) mm for Analyzer Unit
	:	450(W) x 500(D) x 1000(H) mm for Converter Unit
Color	:	Blue (Munsell 10B 4.5/5)

Ambient N0x Monitoring System

Measuring Object	:	N0, $N0_2$
Measuring Principle	:	Pressure Reduction Chemiluminescence (CLD)
Range	:	0 0.1 0 -1 0 1 ppm
		(Auto Range Selection incorporated)
Repeatability	:	Within ± 2% of full scale
Response Time	:	Within 30 sec. of 90% response

Noise :	Within 2% of full scale	
Drift Zero	:	Within ± 2% of full scale per day
Span	:	Within ± 2% of full scale per day
Temperature	:	0 40°C
Humidity	:	Less than 85% R.H.
Calibration	:	Automatic Zero/span calibrator incorporated
Power	:	AC 100V ± 10V 50Hz ± 1Hz
External Dimensions	:	450(W) x 540(D) x 1350(H) mm
Colour	:	Blue (Munsell 10B 4.5/5)

Ambient HC Monitoring System

Measuring Object	:	Non-CH_4
Measuring Principle	:	FID + Selective Combustion
Range	:	0 5, 0 10, 0 50 ppmC
		(Auto Range Selection incorporated)
Repeatability	:	Within ± 2% of full scale
Response Time	:	Within 30 sec. of 90% response
Noise :	Within 2% of full scale	
Drift Zero	:	Within ± 2% of full scale per day
Span	:	Within ± 2% of full scale per day
Temperature	:	0 40°C
Humidity	:	Less than 85% R.H.
Calibration	:	Automatic zero/span calibrator incorporated

Power	: AC 100V = 10V 50Hz = 1Hz
External Dimensions	: 450(W) x 540(D) x 1350(H) mm
Colour	: Blue (Munsell 10B 4.5/5)
Additional Equipment	: H_2 Generator (Model OPGU-800) with water tank (water supply interval: Approx. 30 days)

Ambient Co Monitoring System

Measuring Object	: CO
Measuring Principle	: Non-Dispersive Infrared Ray Absorptiometry (NDIR)
Range	: 0 20, 0 50, 0 100 ppm (Auto Range Selection incorporated)
Repeatability	: Within ± 2% of full scale
Response Time	: Within 150 sec. of 90% response
Noise	: Within 2% of full scale
Drift Zero	: Within ± 2% of full scale per day
Span	: Within ± 2% of full scale per day
Temperature	: 0 40°C
Humidity	: Less than 85% R.H.
Calibration	: Automatic zero/span calibrator incorporated
Power	: AC 100V ± 10V 50Hz ± 0.25Hz
External Dimensions	: 450(W) x 540(D) x 1350(H) mm
Colour	: Blue (Munsell 10B 4.5/5)

APPENDIX E

SURVEY QUESTIONNAIRE

Dear Sir

I am conducting a health survey of the State of Kuwait, in association work with London School of Hygiene and Tropical Medicine. I would be extremely grateful if you could help me by completing the accompanying questionnaire. Rather than send the questionnaire to you by post, I have decided that it would be wiser to deliver it to you personally, so that I can advise you about its successful completion.

I must emphasize that the information obtained in the questionnaire will be used for research and not for commercial or political purposes. All the information you provide will be treated with complete confidentiality.

I shall be most grateful for your assistance and the time that you can give me.

Yours faithfully

Mariam Al-Kandari

To start, it would be very helpful if you can answer a few general questions about yourself.

1. Name :
2. Sex :
3. Age :
4. Nationality :
5. Family size :

Name	Age	Sex	Relationship to head of household

6. Servant:

Name	Age	Sex

Housing Conditions

7. Tenure:

( )	Own
( )	Rent

8. Type of house:

( )	Traditional house
( )	Flat
( )	Villa

9. Address:

10. Occupation:

( )	Employed
( )	Unemployed
( )	Student
( )	Housewife
( )	Retired

11. What is/was your job?

12. What do/did you actually do in this job?

13. Address of place of work:

14. Type of work in the present employment. (Description of job and length of time in the job.)

15. What type of school or college did you last attend full time?

( ) None
( ) Elementary/primary school
( ) Intermediate school
( ) Secondary school
( ) Technical school
( ) Technical college
( ) Commercial college
( ) College of Education
( ) Training college
( ) University

16. How much of the year are you away from your house, <u>in weeks</u>?

( ) None
( ) One week
( ) Two weeks
( ) Three weeks
( ) Four weeks
( ) Five weeks
( ) Six weeks
( ) Seven weeks
( ) Eight weeks
( ) More than 10

I would like to ask you some questions about

		Most of the time	Sometimes	Never

In the last week:

		Most of the time	Sometimes	Never
1.	I feel tired.	( )	( )	( )
2.	I find it annoying to walk outdoors.	( )	( )	( )
3.	It takes me a long time to get to sleep.	( )	( )	( )
4.	I lose my temper easily.	( )	( )	( )
5.	I soon run out of energy.	( )	( )	( )
6.	I sleep badly at night.	( )	( )	( )
7.	I wake up in the early hours of the morning.	( )	( )	( )
8.	I wake up feeling depressed.	( )	( )	( )
9.	I take tablets to help me to sleep.	( )	( )	( )

10.	I have some itching in my skin.	( )	( )	( )
11.	I am losing my smell sensation.	( )	( )	( )
12.	I have lost my appetite.	( )	( )	( )
13.	I lie awake for most of the night.	( )	( )	( )
14.	I am anxious.	( )	( )	( )
15.	I am underweight.	( )	( )	( )
16.	I feel distressed and on the edge of tears.	( )	( )	( )

Listed below are some problems people may have in their duty life.

Look down the list and put a tick in ( ) for any problem you had in the last week.

Please answer every question. If you are not sure what to say, tick whichever answer you think is nearest to the truth for you. Please answer all the questions by ticking ONE box only.

1. In the last week, I had a cough:

   ( ) 4 days or more
   ( ) 2 - 3 days
   ( ) one day
   ( ) not at all

2. In the last week, I have had attacks of shortness of breath:

   ( ) 4 days or more
   ( ) 2 - 3 days
   ( ) one day
   ( ) not at all

3. In the last week, I have had a sore throat:

   ( ) 4 days or more
   ( ) 2 - 3 days
   ( ) one day
   ( ) not at all

4. In the last week, I have had dryness of the throat:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

5. In the last week, I have had mucous membrane of the nose:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

6. In the last week, I have had a headache:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

7. In the last week, I have had nausea:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

8. In the last week, I have felt faint or dizzy:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

9. In the last week, I had irritation of my nose and throat:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

10. In the last week, I have had wheezing or whistling:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

11. In the last week, I have had irritation in my eyes:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

12. In the last week, I have had tears in my eyes:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

13. In the last week, I have had irritation of my skin:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

14. In the last week, I have had bronchitis:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

15. In the last week, I have had severe chest infection:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

16. In the last week, I have had episodes of loss of vision:

( ) 4 days or more
( ) 2 - 3 days
( ) one day
( ) not at all

I would now ask you about your smoking habits:

1. Have you smoke:

( ) have never smoked

( ) ex-smoker - age of starting:
- age of stopping:

( ) occupational and regular pipe, *nargila smokers*

( ) occupational and regular cigarette smoker

2. How many cigarettes/day do you smoke:

I would like to ask you a few questions about your past health. Please answer all the questions by ticking ONE ( ) only.

1. Over the last 12 months would you say your health has on the whole been:

   ( ) good
   ( ) fairly good
   ( ) not good

2. In the last week, how many times have you visited your general practitioner:

   ( ) not at all
   ( ) once
   ( ) twice or three times
   ( ) 4 or more times

3. In the last 3 months, have you been to the hospital out-patient departments? If once or more, please state the hospital attended:

   ( ) yes.
   ( ) no.

4. In the last 12 months, have you been admitted into the hospital:

   ( ) not at all
   ( ) once
   ( ) twice
   ( ) 3 or more times

5. Please state the hospital attended:

6. What was your sickness?

In the list below, tick ONE ( ) only for each activity in your life explaining your feeling about these activities in the last three months.

Are you satisfied with your:

	Very satis fied	Satis fied	Indif- ferent	Dissat isfied	Very satis fied
1) Job	( )	( )	( )	( )	( )
2) School	( )	( )	( )	( )	( )
3) Social Life (e.g. going out, seeing friends, shopping	( )	( )	( )	( )	( )
4) Family social life (that is: relationships with other people in your home)	( )	( )	( )	( )	( )
5) Interests and hobbies (e.g. sports, do-it-yourself gardening)	( )	( )	( )	( )	( )

Here is a list of problems which some people say they have experienced in and around their homes. In the *list below please tick* ONE ( ) only for each problem.

		Very Worrying	Rather Worrying	Not Worrying
1.	Overcrowding.	( )	( )	( )
2.	Dampness.	( )	( )	( )
3.	Smells.	( )	( )	( )
4.	Noise.	( )	( )	( )
5.	Needing major repairs.	( )	( )	( )
6.	Litter/dirt.	( )	( )	( )
7.	Lack of leisure facilities.	( )	( )	( )
8.	Transportation problems.	( )	( )	( )
9.	Lack of children's play area.	( )	( )	( )
10.	Health care problems.	( )	( )	( )
11.	Education facilities.	( )	( )	( )
12.	Dust.	( )	( )	( )
13.	Insects/mice.	( )	( )	( )

In the next group of questions, answer by ticking ONE ( ) only.

		Yes	No
1.	Noise:		
	(a) Traffic.	( )	( )
	(b) A/C.	( )	( )
	(c) Industrial.	( )	( )
	(d) Others, specify.	( )	( )
2.	Smells & Fumes:		
	(a) Garbage.	( )	( )
	(b) Sewage.	( )	( )
	(c) Traffic.	( )	( )
	(d) Industrial.	( )	( )
	(e) Fire.	( )	( )
	(f) Others, specify.	( )	( )
3.	Damage of property:		
	(a) Plumbing.	( )	( )
	(b) Corrosion of metal.	( )	( )
	(c) Paint removal.	( )	( )
	(d) Others, specify.	( )	( )
4.	Infections:		
	(a) Mice.	( )	( )
	(b) Cockroach.	( )	( )
	(c) Others, specify.	( )	( )
5.	Dust:		
	(a) Sandstorms.	( )	( )
	(b) Industrial.	( )	( )
	(c) Others, specify.	( )	( )

Please place a tick in the correct answer:

1. Do you notice the presence of air pollution in the area:

   ( ) yes.
   ( ) no.
   ( ) sometimes.

2. If yes or sometimes, specify the source:

   ( ) sewage.
   ( ) industrial.
   ( ) garbage.
   ( ) others.

3. Can you identify the source of air pollution:

   ( ) yes.
   ( ) no.

4. If yes, is it:

   ( ) one source.
   ( ) more than one source.

5. From where did you get this information:

   ( ) personal.
   ( ) from others.

   If so, where is it:

6. Dose the air pollution come from any particular direction:

( ) yes.
( ) no.

If yes, specify:

	Yes	No
City	( )	( )
Industrial	( )	( )
Sea	( )	( )
Desert	( )	( )

7. Have you notice any variation to the level of air pollution in any time during the day:

( ) yes.
( ) no.

If yes, specify:

	Yes	No
Morning	( )	( )
Afternoon	( )	( )
Nights	( )	( )

8. Does it vary seasonally during the year:

( ) yes.
( ) no.

If yes, specify:

	Yes	No
Winter	( )	( )
Spring	( )	( )
Summer	( )	( )
Autumn	( )	( )

9. Does it increase in:

	Yes	No
Higher temperature	( )	( )
Higher humidity	( )	( )
Calm days	( )	( )

10. In general has the level of air pollution changed while you have lived in the area:

( ) yes.
( ) no.

Is it :

	Yes	No
increasing	( )	( )
decreasing	( )	( )

11. How long in years you lived in this area:

12. How many hours per-day do you spend in the open air:

( ) less than 5 hours.
( ) 5 - 9 hours.
( ) 10 - 19 hours.

13. Have you ever thought of leaving home because of the pollution in your area:

( ) yes.
( ) no.

14. Have you ever complained to the authorities about this problem:

( ) never.
( ) once.
( ) twice.
( ) more than twice.

15. Are there any complaints from your neighbours concerning this problem:

( ) yes.
( ) no.
( ) don't know.

16. In order to reduce the level of air pollution in the area what are your suggestions:

Date: ---/---/---.

APPENDIX F

SAMPLING

SAMPLING

First

Fahaheel Residential Area:

Located 3 km north to Shuaiba Industrial Area.

A.

1. Season: Spring 1989.
2. Date of distribution: 15.3.1989.
3. Date of collection: 24.3.1989 / 1.4.1989.
4. Number of questionnaire distributed: 108.
5. Number of questionnaire collected: 86.
6. Houses selected:

Block no.	Ave	Home
7,	3,	2.
9,	12,	7.
8,	39,	8.
11,	13,	9.
9,	16,	10.
8,	7,	11.
10,	64,	13.
11,	7,	15.
10,	125,	16.
10,	38,	17.
9,	2,	21.

11,	45,	22.
8,	11,	25.
10,	55,	26.
7,	9,	27.
8,	16,	30.
7,	10,	34.
9,	17,	39.
7,	18,	41.
11,	29,	44.

B.

1. Season: Summer 1989.
2. Date of distribution: 17.7.1989.
3. Date of collection: 25.7.1989 / 1.8.1989.
4. Number of questionnaire distributed: 120.
5. Number of questionnaire collected: 93.
6. Houses selected:

Block no.	Ave	Home
7,	3,	2.
9,	12,	7.
8,	39,	8.
11,	13,	9.
9,	16,	10.
8,	7,	11.
10,	64,	13.
11,	7,	15.

16.	10,	125,
17.	10,	38,
21.	9,	2,
22.	11,	45,
25.	8,	11,
26.	10,	55,
27.	7,	9,
30.	8,	16,
34.	7,	10,
39.	9,	17,
41.	7,	18,
44.	11,	29,

B.

1. Season: Summer 1989.

2. Date of distribution: 17.7.1989.

3. Date of collection: 25.7.1989 / 1.8.1989.

4. Number of questionnaire distributed: 120.

5. Number of questionnaire collected: 93.

6. Houses selected:

Block no.	Ave	Home
11,	62,	1.
7,	73,	2.
10,	94,	4.
11,	14,	3.
10,	112,	6.
10,	133,	7.
8,	115,	8.
8,	12,	12.
8,	33,	13.
10,	109,	15.
7,	67,	16.

9,	29,	20.
9,	117,	24.
11,	59,	28.
8,	43,	31.
7,	56,	33.
9,	61,	45.
7,	34,	47.
11,	56,	53.
9,	121,	64.

C.

1. Season: Autumn 1989.

2. Date of distribution: 24.9.1989.

3. Date of collection: 3.10.1989 / 11.10.1989.

4. Number of questionnaire distributed: 112

5. Number of questionnaire collected: 87.

6. Houses selected:

Block no.	Ave	Home
7,	15,	1.
7,	84,	5.
8,	65,	7.
11,	79,	8.
9,	120,	9.
7,	59,	10.
8,	1,	14.
10,	102,	16.
10,	110,	20.
10,	42,	23.
11,	52,	32.
9,	11,	37.
8,	121,	48.
11,	25,	61.
10,	14,	69.
7,	39,	76.
9,	73,	103.
11,	12,	118.
8,	46,	222.
9,	13,	281.

D.

1. Season: Winter 1990

2. Date of distribution: 3.1.1990

3. Date of collection: 11.1.1990.

4. Number of questionnaire distributed: 120.

5. Number of questionnaire collected: 89.

6. Houses selected:

Block no.	10,	Ave	16,	Home	2.
	7,		83,		3.
	8,		34,		9.
	9,		116,		10.
	8,		44,		12.
	9,		116,		14.
	7,		6,		15.
	7,		70,		18.
	9,		9,		20.
	10,		101,		25.
	9,		64,		31.
	8,		13,		38.
	8,		44,		41.
	10,		22,		52.
	11,		66,		58.
	10,		91,		67.
	11,		39,		73.
	7,		16,		96.
	9,		121,		117.
	11,		15,		130.

Second

Rega Residential Area:

Located 10 km north of Shuaiba Industrial Area.

A.

1. Season: Spring 1989.

2. Date of distribution: 16.3.1989.

3. Date of collection: 27.3.1989 / 3.4.1989.

4. Number of questionnaire distributed: 116.

5. Number of questionnaire collected: 101.

6. Houses selected

Block no.	6,	Home	12.
	2,		14.
	4,		28.
	1,		37.
	3,		45.
	7,		51.
	6,		115.
	3,		116.
	3,		121.
	1,		141.
	1,		156.
	7,		161.
	3,		167.
	1,		219.
	4,		254.
	2,		229.
	6,		286.
	6,		302.
	7,		321.
	4,		332.
	4,		348.
	2,		396.
	2,		472.
	2,		484.

B.

1. Season: Summer 1989.
2. Date of distribution: 16.7.1989
3. Date of collection: 23.7.1989 / 5.8.1989.
4. Number of questionnaire distributed 124
5. Number of questionnaire collected 98
6. Houses selected

Block no.	4,	Home	23.
	3,		30.
	6,		32.
	1,		47.
	6,		57.
	7,		61.
	2,		72.
	3,		88.
	7,		104.
	3,		145.
	4,		149.

7,	189.
3,	222.
1,	218.
7,	235.
7,	251.
6,	273.
4,	295.
6,	296.
1,	317.
1,	333.
2,	358.
2,	415.
2,	511.

C.

1. Season: Autumn 1989.

2. Date of distribution: 25.9.1989.

3. Date of collection: 4.10.1989.

4. Number of questionnaire distributed: 115.

5. Number of questionnaire collected: 103.

6. Houses selected:

Block no.	7,	Home	12.
	1,		29.
	3,		58.
	4,		63.
	6,		69.
	1,		81.
	6,		112.
	7,		114.
	4,		119.
	1,		138.
	5,		150.
	3,		172.
	4,		193.
	3,		207.
	4,		212.
	7,		246.
	2,		279.
	3,		291.
	7,		317.
	1,		328.
	6,		330.
	2,		407.
	2,		435.

	2,		577.

D.

1. Season: Winter 1990.
2. Date of distribution: 2.1.1990.
3. Date of collection: 10.1.1990 / 15.1.1990.
4. Number of questionnaire distributed: 122.
5. Number of questionnaire collected: 99.
6. Houses selected:

Block no.	4,	Home	2.
	7,		7.
	6,		10.
	2,		14.
	7,		21.
	7,		60.
	6,		63.
	3,		71.
	3,		112.
	1,		137.
	6,		146.
	7,		168.
	1,		179.
	4,		192.
	1,		209.
	3,		211.
	4,		271.
	3,		292.
	1,		300.
	6,		327.
	6,		362.
	4,		416.
	2,		521.
	2,		553.

Third

Mishrif Residential Area:

Located 27 km north of Shuaiba Industrial Area.

A.

1. Season: Spring 1989.

2. Date of distribution: 17.3.1989.

3. Date of collection: 28.3.1989 / 4.4.1989.

4. Number of questionnaire distributed: 125.

5. Number of questionnaire collected: 96.

6. Houses selected:

Block no.	St.	Home
5,	8,	2.
2,	51,	3.
3,	54,	4.
1,	27,	5.
4,	2,	6.
3,	45,	7.
6,	5,	8.
4,	31,	9.
1,	5,	10.
2,	24,	11.
3,	8,	12.
6,	42,	13.
5,	10,	15.
2,	1,	16.
4,	42,	17.
1,	1,	18.
1,	9,	21.
2,	26,	23.
6,	17,	24.
5,	2,	26.
4,	18,	28.
5,	61,	31.
3,	12,	34.
6,	5,	39.

B.

1. Season: Summer 1989.

2. Date of distribution: 15.7.1989.

3. Date of collection: 24.7.1989 / 30.7.1989.

4. Number of questionnaire distributed: 117.

5. Number of questionnaire collected: 101.

6. Houses selected:

Block no.	2, St.	4,	Home	1.
	6,	9,		2.
	5,	5,		4.
	1,	29,		7.
	6,	24,		8.
	4,	9,		9.
	6,	41,		10.
	3,	4,		11.
	4,	58,		12.
	4,	4,		13.
	5,	28,		14.
	2,	19,		15.
	3,	12,		16.
	3,	7,		18.
	2,	6,		19.
	3,	40,		21.
	4,	8,		23.
	6,	29,		25.
	2,	9,		23.
	4,	29,		28.
	5,	37,		30.
	1,	2,		34.
	1,	16,		37.
	5,	1,		40.

C.

1. Season: Autumn 1989.
2. Date of distribution: 20.9.1989.
3. Date of collection: 27.7.1989 / 2.10.1989.
4. Number of questionnaire distributed: 115.
5. Number of questionnaire collected: 97.
6. Houses selected:

Block no.	2, St.	21,	Home	1.
	5,	39,		4.
	1,	18,		6.
	5,	17,		7.
	3,	7,		8.
	4,	27,		10.
	2,	24,		11.
	3,	33,		12.
	1,	7,		15.
	4,	6,		18.
	2,	4,		20.

1,	23,	21.
1,	48,	23.
2,	7,	24.
1,	9,	25.
6,	12,	30.
4,	5,	35.
4,	1,	36.
5,	48,	37.
5,	1,	40.
6,	32,	42.
5,	52,	45.
3,	2,	46.
6,	8,	51.

D.

1. Season: Winter 1990.

2. Date of distribution: 1.1.1990.

3. Date of collection: 10.1.1990 / 12.1.1990.

4. Number of questionnaire distributed: 106.

5. Number of questionnaire collected: 90.

6. Houses selected:

Block no.	3,	St.	2,	Home	1.
	1,		16,		3.
	1,		1,		4.
	4,		2,		5.
	2,		11,		6.
	1,		22,		8.
	3,		8,		11.
	2,		8,		12.
	5,		16,		13.
	5,		2,		14.
	6,		8,		16.
	1,		5,		17.
	5,		41,		18.
	2,		1,		20.
	3,		48,		21.
	3,		24,		25.
	4,		31,		26.
	2,		17,		29.
	4,		46,		30.
	3,		4,		32.
	6,		31,		35.
	6,		21,		36.
	6,		42,		45.
	5,		35,		49.

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