HOSPITAL ADMISSION PATTERNS OF CHILDHOOD RESPIRATORY ILLNESS IN CAPE TOWN AND THEIR ASSOCIATION WITH AIR POLLUTION AND METEOROLOGICAL FACTORS

by

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ABSTRACT

The aims of this study were (a) to examine the profile of hospital admissions for selected respiratory illnesses for two major hospitals in Cape Town, and (b) to analyse the association of such admissions with air pollution indicators and meteorological variables.

The first part of the study investigated the admission patterns of coloured and African children under twelve years of age who were diagnosed as suffering from asthma or acute respiratory infections at two major teaching hospitals in Cape Town. Computerized hospital admission records covering the years 1988-1990 from the overnight holding wards of the Red Cross War Memorial Children's Hospital and Tygerberg Hospital were used to determine patterns with respect to diagnosis, gender, race, age and date of admission.

During the three year study period, respiratory admissions at both hospitals accounted for 15 078 (47.3%) out of a total of 31 887 admissions. Acute respiratory infections accounted for 63.6% and asthma 37.4 % of these respiratory admissions.

Two factors of interest were noted: (1) Considerably more males than females were admitted with both asthma and acute respiratory infections. (2) Asthma admissions to Red Cross Hospital among African children were proportionally much less than those of coloured children when compared to the proportions of admissions for acute respiratory infections.

After removal of the seasonal effect, a multiple linear regression model was fitted to the data to determine the individual associations between admissions and ambient environmental variables. Significant associations were found between: (1) acute respiratory infections and oxides of nitrogen, soiling index, and temperature; (2) asthma and oxides of nitrogen (3) total admissions and soiling index, average temperature and minimum temperature (negative).

The study concluded that despite generally low levels of air pollution in Cape Town, childhood respiratory admissions to Red Cross War Memorial Children's Hospital and Tygerberg Hospital were statistically significantly associated with some ambient air pollutants as well as temperature.

However, given the nature of both the exposure and admissions databases, these results should be treated with caution. More representative site selections for air pollution monitors, as well as searching and controlling for possible confounding factors (ie. indoor air pollution, parental smoking, overcrowding), would allow a better understanding of the current air pollution problem and the possible effects on the respiratory health of children in metropolitan Cape Town.

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ABBREVIATIONS

ARI	Acute respiratory infections
CCC	Cape Town City Council
ICD	International Classification of Diseases, 9th Revision
NO	Nitric oxide
NO_x	Oxides of nitrogen
O_3	Ozone
Red Cross Hospital	Red Cross War Memorial Children's Hospital
RSC	Western Cape Regional Services Council
SD	Standard Deviation
SO_2	Sulphur dioxide
TA	Total admissions to the overnight holding wards
°C	Degrees centigrade
$\mu g/m^3$	Micrograms per cubic metre

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Respiratory illness, which includes acute respiratory infections (ARI) and asthma, is one of the major causes of ill health amongst children in both developed and developing countries around the world (Graham 1990). Apart from the more obvious effects of ill health on the individual, the economic costs of childhood respiratory illness to both the families and the state are significant. Children with respiratory illnesses use expensive medical resources and personnel; and their demands on the health delivery system are considerable (Mak et al 1982).

Respiratory illness not only results in lost hours at work when the parents have to care for the child and transport him to hospital or clinic, but also significantly affects the child's well-being and school attendance (Mak et al 1982). Furthermore the chronically ill child could be socially stigmatised and have inappropriate restrictions placed on her activity (Bonner 1984).

Early respiratory illness may also affect the child's health later in life by making him more susceptible to other respiratory illnesses, or by causing chronic respiratory impairment (Holland et al 1969). For example, studies in Adelaide (Australia) suggest that children under five years of age experience a mean of seven episodes of respiratory illness per year, resulting in three doctor visits a year, ingestion of pharmaceutical agents on 15 days per year, and experience 52 days of respiratory symptomatology a year (Graham 1990).

The costs to the community, family and individuals of respiratory illness necessitate that steps be taken to identify and rectify this major health problem (Mitchell and Elliot 1981).

In developed countries, many epidemiological studies have been undertaken to determine the aetiology and nature of childhood respiratory illness. In developing countries the results and findings of these studies have limited applicability; and respiratory illness remains an under-researched urban health problem in these countries (Stephens and Harpham 1992).

Owing to the lack of funding, and an infrastructure incapable of supporting large multidimensional epidemiological studies in the developing countries, very few projects have been undertaken to determine the causes, risk factors and nature of respiratory illness in these countries (Graham 1990). Moreover, objective data on respiratory illness in children are scarce and a great deal of what is available is anecdotal, which could lead to inaccurate assumptions regarding the true nature of the illnesses (Kuzemko 1976).

To begin to redress this problem in South Africa, computerised hospital admission records of two major teaching hospitals in Cape Town were examined to determine the patterns of respiratory admissions.

The two hospitals are: Red Cross War Memorial Children's Hospital (hereafter referred to as Red Cross Hospital), a large paediatric hospital in Rondebosch, and Tygerberg Hospital in Parow, which has large paediatric wards (see Figure 1.1 for location and study area). Both offer the advantages of similar computerised data recording systems and both serve large, predominantly poor communities, in a rapidly growing city.

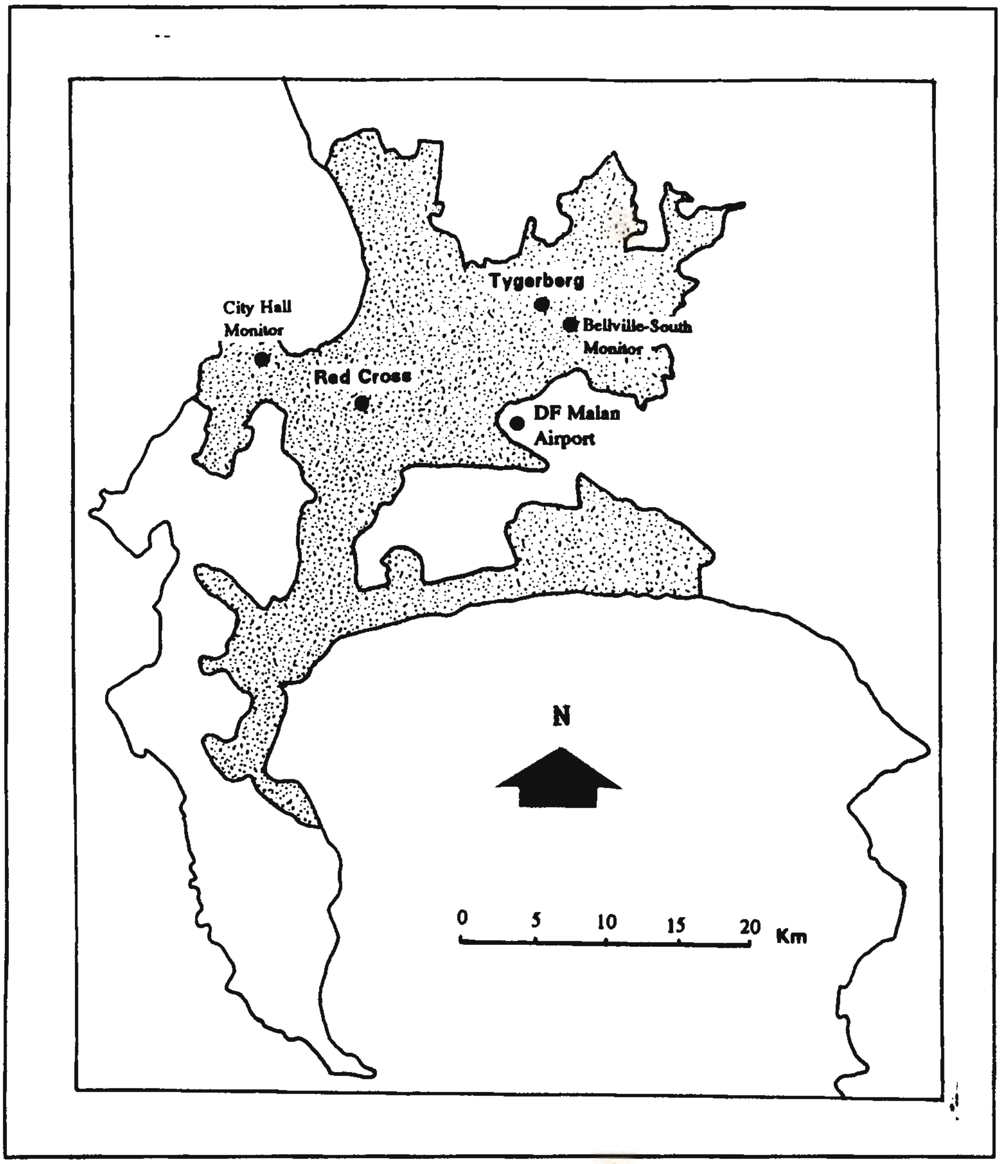

Figure 1.1 MAP OF THE STUDY AREA SHOWING THE LOCALITIES OF THE HOSPITALS AND MONITORS USED IN THIS STUDY.

The first part of the study involves an investigation based on the assumption that the patterns derived from an analysis of these computerised hospital data can be used to determine usage of the hospital. Furthermore clues as to the aetiology of childhood respiratory illnesses in Cape Town as a basis for future research will be provided.

The second part will use the data derived from the analysis of the hospital admissions to investigate possible associations with air pollution and meterological variables.

It has long been thought that one group of causes and precipitants of respiratory illness could be attributed to various ambient environmental factors such as air pollution and meteorological features (Ware et al 1986; Goldstein and Goldstein 1978).

Both indoor and outdoor (ambient) air pollutants can affect the health of children. Before the implementation of air pollution control measures in the 1950s and 1960s in most developed countries, air pollution levels were usually high, so that the health effects of air pollution on the respiratory system of exposed population was fairly easy to demonstrate (Thurston et al 1989).

However, the introduction of the air quality control measures meant that the levels of ambient air pollution began to decline. Thus the focus of air quality control and abatement shifted from the problem of protecting the community from the acute health effects of protracted periods of severely elevated levels, to the long-term consequences of exposure to lower levels (Pengelly et al 1984; Thielebeule and Pelach 1985).

Furthermore, as the hazards posed by ambient air pollution decreased in these countries, the relevance of indoor air quality for health has become increasingly apparent (Samet et al 1987). Indoor pollutants includes exposures to formaldehyde, tobacco smoke, radon and radon daughters, NO_2 from gas-fuelled cooking stoves and smoke from wood-burning fireplaces (Graham 1990; Samet et al 1987). Indoor values may have greater temporal peaks, with concomitant effect on health. Indoor exposures to pollutants may be less than outdoor levels for some pollutants (ie. SO_x, O_3) and may be greater than outdoor levels for others (ie. NO_x, CO, particulate matter) (Lebowitz 1983).

However, information on exposure levels to indoor air pollutants in the Western Cape is non-existent and is beyond the scope of this investigation. Thus only the ambient air pollutants currently being measured as part of the Cape Town City

Council and Western Cape regional Services Council monitoring system will be used in this study.

In Cape Town, the levels of ambient air pollution have been reduced since the introduction of regulatory controls in the early 1960s. However, there are periods of elevated levels of air pollution, especially with regard to photochemical pollution. These periods may also be increasing in severity and frequency (Smith 1984; Baillie et al 1993).

Air pollution, however, is integrally related to the weather, which itself may have an effect on the onset and exacerbation of respiratory illnesses in children.

Therefore, the second section of this aim of this study is to enquire whether air pollution levels and meteorological variables have any respiratory health effects on children living in Cape Town.

1.2 GOAL, AIM AND OBJECTIVES OF THE STUDY

The specific goal, aim and objectives of this study are:

Goal

To contribute to knowledge about the patterns and causes of childrens' respiratory illness in Cape Town using routinely collected data.

Aim

To establish the profile of admissions for selected respiratory illnesses to two Cape Town teaching hospitals, and the association of such admissions with air pollution indicators and meteorological variables.

Objectives:

1) To collect routinely captured computerised hospital data for children under twelve years of age with asthma and acute respiratory infections who were admitted to the overnight holding wards at Red Cross Hospital and Tygerberg Hospital for the period 1988-1990.

2) To examine the admission data with respect to temporal patterns, age, gender and race.

3) To examine for any concordance between high pollution episodes and increases in admissions for respiratory illness.

4) To examine the correlations between admissions and air pollution indicators (sulphur dioxide and oxides of nitrogen) as well as meteorological variables (rainfall, average temperature, minimum temperature and relative humidity).

1.3 PRESENTATION OF THE DISSERTATION

Chapter 2 of this dissertation reviews the literature on respiratory illness in children, while Chapter 3 reviews the literature on the adverse respiratory health effects of the environmental factors mentioned above. Chapter 4 outlines the methodology used in this study. The following chapters present the results and discussion: Chapter 5, the patterns of respiratory hospital admissions, and Chapter 6, the association of environmental factors with these hospital admissions. Chapter 7 concludes with a consideration of the validity of the results as well as making recommendations for further research.

CHAPTER 2

REVIEW OF HOSPITAL-BASED STUDIES

2.1 INTRODUCTION

This chapter will outline why hospital-based studies can serve as an important source of routine epidemiological information. Thereafter, a review of the literature on the use of hospital-based data in furthering our understanding of childhood respiratory illnesses is presented.

2.2 THE USE OF ROUTINELY COLLECTED DATA FOR EPIDEMIOLOGICAL STUDIES

There are distinct advantages to using routinely collected and archival data from hospitals. People who are admitted to a hospital tend to be suffering from more serious illnesses. They will be suffering from specific ailments and illnesses. The data obtained from such studies will thus usually exclude minor ailments and trivial chest complaints.

Expensive data gathering specifically for research projects can be avoided, as the cost of retrieving the required information is usually low. Such information can literally be taken off the shelf or from a computer database (Jones and Moon 1987). Furthermore the data are often already in a format which is easy to manipulate and, in the case of computerised data, have often been entered by staff working for the organisation supplying the data. This leads to greater accuracy and efficiency when retrieving the data.

There are, however, problems associated with utilising such data. There is little control over how the data are collected, stored and published, and how they are obtained and processed. In particular, there may be problems of precision and accuracy, as the data may be biased, under-reported or misclassified (Frisch et al 1990). A further problem is that the data are usually collected for legal and administrative needs and not for research purposes; certain key components may thus not be recorded.

The information obtained from using routinely collected hospital data is often biased towards the sectors of population that use the specific health service. Factors such as availability and access to transport, socio-economic status, access to medical health plans would filter and preclude certain sectors of the population (Lachman and Zwarenstein 1990).

Furthermore, information covering non-medical factors such as housing, overcrowding, education, and other socio-economic factors may not be collected or be available when using routinely collected sources of data.

Despite these problems sources of routinely collected hospital data have been extensively used. When used in descriptive and routine studies, disease frequency can be examined over time, geographically and in relation to any demographic and social variables that have been collected. While absolute rates of disease occurrence may be difficult to determine, relative changes over time are useful in determining seasonal and temporal relationships (Jones and Moon 1987). Furthermore, these databases can sometimes provide an indication of individual human exposure, which is useful when data on exposure of individuals are not available, are expensive to collect, or when data relating to a specific exposure is not well defined (Frisch et al 1990).

Hospital-based studies are usually preliminary investigations which are designed to assess the feasibility of pursuing, in greater depth, a relationship between an environmental agent and a disease (Gross et al 1984; Frisch et al 1990). Such studies are thus an important and relatively accessible source of routine information for assessing the demands being made on health services (Ehrlich 1992).

2.3 USE OF CHILDREN IN STUDYING RESPIRATORY ILLNESSES

Shy (1989) noted that the analysis of morbidity indicators should be subdivided into broad age groups such as children, working adults and the elderly, as this would allow for better comparison with other studies. Of all these population subsets, children have proved to be especially useful indicators of the possible health effects of air pollution and other environmental factors (Holland et al 1979).

In the case of respiratory illness it is thought that the growing lung may be more sensitive to insult than the adult lung, and therefore children are more at risk from adverse air quality and other environmental factors than teenagers or adults (Pengelly et al 1984). Children also have a high reactivity to environmental insult as their respiratory tracts have not yet fully developed (Thielebeule and Pelach 1985). Furthermore, children under the age of twelve are unlikely to smoke as many cigarettes as adults or teenagers, and usually have not been exposed to occupational pollutants (Holland et al 1979).

Children also tend to have an unvaried residential history which ensures a much better characterisation of the environmental conditions in which they live (Pengelly et al 1984). It is also easier to select comparable groups of children than adults (Thielebeule and Pelach 1985).

Children, therefore offer the researcher a good opportunity to investigate the health effects of air pollution and other environmental indicators.

2.4 THE IMPORTANCE OF CHILDHOOD ACUTE RESPIRATORY INFECTIONS AND ASTHMA

ARI and asthma are both important causes of childhood morbidity. In a community-based study in Mitchells Plain, Cape Town, it was found that the most commonly reported acute illness was respiratory infection, and that the most commonly reported chronic illness was asthma (Lachman and Zwarenstein 1990). Furthermore, respiratory diseases accounted for 33% of all attendances in a survey of children that attended Red Cross Hospital (Strebel et al 1990).

Attacks of ARI and asthma early in a child's life may make it more susceptible to further respiratory insult in later years and may be the beginnings of a lifetime of chronic respiratory illness (Leeder and Pengelly 1977; Cooreman et al 1990).

Holland et al (1978), in a study conducted in England, showed that bronchitis, pneumonia and asthma in the first five years of life were associated with excessive respiratory symptoms at the age of eleven and fourteen years, with similar relative risks at each age.

From the above it is clear that the study of childhood respiratory disease is important. However, ARI and asthma are different from each other and their health effects need to be separately investigated.

2.5 ACUTE RESPIRATORY INFECTIONS

The category ARI is used as an umbrella term which incorporates a wide variety of clinical syndromes (see Table 4.2 for a list of illnesses incorporated in ARI in this study).

Graham (1990) noted that lower respiratory tract illness (bronchitis, bronchiolitis and pneumonia) was an important cause of morbidity that affected approximately 25% and 18% of children under 1 year and between 1 and 4 years of age respectively in developing countries.

Von Schirnding et al (1991) found that 29% of children living in urban and peri-urban areas in South Africa had experienced coughing and breathing problems. In Singaporean children, ARI has been one of the leading causes of morbidity, accounting for about one third of total attendances in government clinics (Goh et al 1986). Lopez de Romana et al (1989) found, that in a cohort of 153 infants aged 0-1 years in Peru, 64% of children had had at least one episode of lower respiratory infection. ARI is therefore an important cause of morbidity among children, especially in Third World countries.

2.6 ASTHMA

As asthma is the most common chronic childhood illness in many countries (Lane and Storr 1987), it is not surprising to find that the majority of hospital-based respiratory studies are concerned with the health effects of asthma. Asthma is not equally common in all parts of the world - in Papua New Guinea asthma is so rare that the local population has no word for it, while on Tristan da Cunha almost half the islanders have a history of asthma (Lane and Storr 1987).

Asthma has always been a difficult illness to define (Gordis 1973; Van Niekerk 1980) and this has always caused some confusion when attempting to study this complaint (Ford 1974). The epidemiological study of asthma is plagued by many of the methodological problems which characterise investigations of poorly defined chronic conditions which have low case-fatality rates and have a tendency to intermittency and spontaneous remissions (Gordis 1973). This often leads to problems of comparability between various studies and makes a review of the literature a difficult process (Van Niekerk 1980). However, as asthma is a major component of childhood respiratory disease, it is important to attempt to quantify the problem by looking at other studies.

Although the precise cause of asthma is unknown, it commonly starts in early childhood and improves spontaneously in early adult life (Van Niekerk 1980; Peat et al 1980; Woolcock 1987). Once asthma has been acquired, a variety of provoking stimuli including exercise, airway drying, respiratory infections, allergens, SO_2, and emotional upsets can trigger attacks (Woolcock 1987).

Burney (1988) noted that epidemiological studies indicate that asthma is usually an acquired disease primarily determined by the environment. The most striking evidence that asthma is environmentally acquired is the large variation in asthma prevalence between similar populations living in different environments.

Lee et al (1983) state that asthma is the most common chronic illness of childhood in England, affecting about 10% of schoolchildren. They also found in a study involving seven year old schoolchildren in North Tyneside (England), that 11% of the children studied exhibited symptoms of asthma. Leeder et al (1976B) ascertained that in the United Kingdom, by the age of five years, one or more episodes of asthma had been reported in 3.4% of boys and 2.9% of girls.

Mitchell and Cutler (1984) state that asthma admissions in Auckland (New Zealand) accounted for 20% of paediatric admissions to local hospitals. Asthma represents a major paediatric problem in New Zealand, affecting 5-9% of all children (Mitchell and Elliott 1981). They note that 46% of asthma patients of school age had missed four weeks or more every school year in Auckland (New Zealand). There is also evidence that asthma is increasing in prevalence in Lower Hutt (New Zealand); the prevalence of reported asthma in children aged 11-13 years of age increased from 7.1% in 1969 to 13.5% in 1981 (Mitchell 1983).

Carrasco (1987) reported that the prevalence of asthma in Latin American school children varied from 7.5% in Uruguay to 2.7% in Chile. Nevertheless, Cookson (1987) noted low prevalence rates for asthma among children in developing countries. This is especially so in Africa: no asthmatic subject was found in a survey in the Gambia; and in other hospital surveys few asthmatic children were identified in Nigeria, Kenya, Ethiopia and Zimbabwe, the exception being Tanzania (7.8%) (Cookson 1987).

With respect to proportions of admissions, Joubert et al (1988) noted that during a six-month period, 15.2% of non-white medical admissions to Tygerberg Hospital were due to acute asthma.

Bates et al (1990) stated that the increase in asthma morbidity that seems to be occurring in different parts of the world necessitates a close examination of the factors that cause worsening of the condition in different regions.

There appears to be a strong synergistic relationship between ARI and asthma as respiratory infections appear to be among the most common stimuli of asthmatic attacks (Potter et al 1984; Kerrebijn 1986; Lopez and Salvaggio 1987) It is also thought that asthma is common in children who have had severe viral infections before the age of two years (Woolcock 1987). Joubert et al (1988) found that frequent attacks of bronchitis in asthmatics were a contributory factor in inducing asthma attacks. Viral infections may thus herald the onset of asthma or exacerbate the condition if it pre-exists (Spector 1991).

Acute exacerbations of asthma are often thought to be linked to both air pollutants and meteorological variables (Derrick 1973; Mak et al 1982; Hendrick 1989; Spector 1991). Most asthmatics have hyper-responsive airways which make them more sensitive than non-asthmatics to bronchoconstricting environmental exposures, which may, in turn, enhance responsiveness (Kerrebijn 1986).

2.7 CONCLUSION

This chapter has shown that both ARI and asthma are important causes of childhood morbidity. It is suggested that hospital-based studies utilising routinely collected data can be successfully used to investigate the disease profile of these illnesses. The next step is to determine the environmental causes and precipitants of asthma and ARI; and the following chapter will review the effects of ambient air pollution on respiratory health.

CHAPTER 3

REVIEW OF THE EFFECTS OF AMBIENT AIR POLLUTION AND ENVIRONMENTAL VARIABLES ON THE RESPIRATORY HEALTH OF CHILDREN

"Epidemiological studies regarding the effects of atmospheric pollution are ... a social necessity because the chronic inhalation experiment that, in the final analysis, all people take part in, from birth to death cannot be performed with laboratory animals." (Thielebeule and Pelach 1985, 355)

3.1 INTRODUCTION

In the previous chapter it was demonstrated that both ARI and asthma are important causes of childhood morbidity. This chapter will show that, despite some contradictory results, there is evidence that ambient air pollutants, often in combination with meteorological and other environmental factors, affect and can sometimes severely exacerbate, the symptoms of childhood respiratory illness.

There are many risk factors for childhood respiratory illnesses (see Table 3.1). This study, however, will concentrate on those risk factors found in the outdoor environment of the children living in Cape Town.

Table 3.1 RISK FACTORS OF ACUTE RESPIRATORY INFECTIONS AND ASTHMA.

ACUTE RESPIRATORY INFECTIONS (Graham 1990)

Demographic factors (age and sex)
Outdoor air pollution
Indoor air pollution
Smoking (passive and active)
Crowding (housing, day care, family size)
Nutrition
Lower respiratory tract infection in early infancy
Psychosocial factors
Socio-economic status
Meteorologic
Human immunodeficiency virus infection
Low birth weight

ASTHMA (Spector 1991)

Changes in weather
Exercise
Allergens
Additives to drink and food (yeast, metabisulphites, monosodium glutamate, tartrazine)
Aspirin and nonsteroidal anti-inflammatory drug
Nonspecific irritants (SO_2, O_3, NO_2, particulate matter, perfumes)
Viral infections
Sinusitis
Gastroesophageal reflux
Hormonal factors
Psychological factors

3.2 AIR POLLUTION STUDIES

Air pollution has been associated with an increase in both mortality and morbidity during severe episodes of smog. Individuals who are exposed to high levels of air pollution may suffer impairment of lung function and insult to the respiratory system (Holland et al 1979). This was most clearly observed in the years preceding the early 1960s. It was during dramatic cases of extreme pollution, such as in

London (England) during 1952 and Yokkaichi (Japan) between 1960-1969, that it was possible to demonstrate the effects of air pollution in exacerbating respiratory illnesses and, ultimately, death (Holland and Reid 1965; Kitagawa 1984; Thurston et al 1989).

Following these severe air pollution incidents many countries legislated to reduce levels of atmospheric pollution (Holland et al 1979; Abramson and Voigt 1991). Due to the increasingly stringent environmental regulations, falling pollution levels over the past three decades have made it more difficult to ascribe ill health to air pollution (Melia et al 1981).

The focus of air quality control and abatement has consequently begun to shift from the problem of protecting the community from the acute health effects of protracted periods of severely elevated levels, to the long-term consequences of exposure to lower levels that very infrequently reach dangerously high concentrations (Pengelly et al 1984; Thielebeule and Pelach 1985).

These lower levels of air pollution make it difficult to link adverse respiratory health effects to specific pollutants (Ferris 1978). The significant effects of the constituents of the ambient air pollutants are much more difficult to unravel at lower levels because the health effects are not clearly defined. Furthermore, it is difficult to determine whether short-term change in morbidity is related to pollution, rather than to changes in weather or to epidemics of infectious diseases (Holland et al 1979). Factors other than air pollution, such as tobacco smoke, airborne allergens, occupational, genetic and social factors, also play an important part in any increase in respiratory mortality and morbidity (Holland et al 1979).

The epidemiologist is faced with the necessity of determining what, and exactly how much, environmental control is necessary to achieve some optimal condition of health (Leeder and Pengelly 1977). Furthermore, particulate and gaseous ambient pollutants are rarely if ever found in isolation. Unless the effect sought is highly specific, the use of epidemiological techniques will seldom result in the attribution, with any degree of certainty, of an observed effect to a specific pollutant (Cassell et al 1972).

Thus in modern epidemiological studies, cause and effect cannot usually be readily identified in a single study. Rather causality is inferred, based on such criteria as the strength of association, the consistency with other studies, the specificity of the association, the temporality of the relationship, the demonstration of a biological gradient of effect, and the plausibility and coherence of the results (Ferris 1978).

The remainder of this chapter reviews the various types of studies that have been used to determine the health effects of air pollution and other ambient environmental factors.

3.3 LABORATORY STUDIES ON THE HEALTH EFFECTS OF AIR POLLUTION

Laboratory studies of animals are an important source of information regarding the health effects of air pollutants at different levels and concentrations. In particular, considerable information has been obtained on the effects of long-term low level air pollution (Ferris 1978). The fundamental problem of these experiments is the extrapolation of their results to humans, and more specifically, to children.

Laboratory studies using human subjects avoid the problem of extrapolation, but raise problems such as the ethics of the research and the practical aspects of long-term exposures (Ferris 1978). However, to a limited extent, controlled human studies - on both the healthy and the diseased - can be performed, and have been used to establish various acceptable exposure standards.

The results and findings of controlled human studies are usually relevant only to the sub-groups of populations, for example young adults or asthmatics, which are selected for study (Ozkaynak and Spengler 1985). These sub-groups are studied as they are important in determining the health effects of specific air pollutants. Often it is the reaction of these sensitive sub-groups of exposed persons, rather than that of the mean of the exposed populations, that is of greatest concern for the health protection decision process.

Avol et al (1988B) noted that when young adult asthmatics were exposed to light fogs containing various concentrations of sulphuric acid in an environmental control chamber, they experienced an adverse respiratory effect after exercise under all exposure conditions. Furthermore, despite the absence of substantial lung function changes, modest statistically significant increases in respiratory symptoms occurred with increasing acid concentrations.

Lippman (1989) noted that the combined exposures to acid aerosols and other air pollutants such as NO_2 and SO_2 produced greater effects in both humans and animals than exposures to each agent separately. Moreover, some of the effects are cumulative with increasing duration of daily exposure and number of repetitive exposures. Raizenne et al (1989) found that chamber studies have provided evidence that adolescent children, particularly asthmatics, may be especially sensitive to levels of air pollution periodically observed in various ambient settings. However, Huang et al (1991) 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 to allergens of selected asthmatic children.

Despite experimental findings that pollutants may be related to asthma, the extent to which air pollution worsens asthma remains obscure (Richards et al 1981). Laboratory studies of the human effects of air pollutants are most useful in defining acute or short-term effects, but cannot identify subtle long-term effects - for these one has to utilise epidemiological studies which can control for confounding variables (Ferris 1978; Avol et al 1987A). It is impossible to assess truly chronic effects in clinical studies or to use any simulated exposures that have even a remote possibility of serious or irreversible effects on the subjects (Knelson 1978). Furthermore the results of epidemiological studies cannot be predicted from the results of clinical or physiological studies as they contain different information and pose different questions (Burney 1988).

Although it may seem more desirable to rely solely on controlled exposure studies to study pollutant combinations, it is unlikely that the complex mixture of ambient air pollution can be reproduced in the laboratory (Shy 1989). Lippman (1985) stresses that the absence of direct measurement data on the specific constituents of air pollution in population studies and the reliance on surrogate indices preclude firm conclusions about exposure-response relationships. Information on many of the complex air pollution compounds is lacking from these studies and, most importantly, the frequency and duration of exposures are not representative of most short- or long-term ambient exposures to pollutants (Ozkaynak and Spengler 1985). Ford (1974) stressed that asthma produced under laboratory conditions by provocation studies may not be the same in any one individual as that occurring in his natural surroundings.

To redress these deficiencies in laboratory studies and to study the health effects of air pollution in a more realistic setting the researcher has to turn to various epidemiological methods. As Shy (1989, 190) states: "Nature provides the exposure conditions for us; we need to take advantage of these situations by studying groups of people exposed to variable ambient mixtures."

3.4 EPIDEMIOLOGICAL STUDIES OF THE HEALTH EFFECTS OF AIR POLLUTION

The objective of epidemiological studies into the health effects of air pollution is to establish relationships between degrees of respiratory health (or illness) and levels of pollutants in the ambient air (Pengelly et al 1984). Studies of this kind seek an answer to such questions as: how harmful to health is a specific pollutant and what regulatory measures are desirable as a result of the study (Goldstein and Goldstein 1978).

Out of the controlled laboratory environment, the health effects of air pollution are confounded by other environmental factors. However, the results of several studies exhibit strong evidence that air pollution does have a negative effect on respiratory health, especially in children.

Ware et al (1986) concluded that preadolescent children, when exposed to moderately elevated levels of ambient sulphur oxides (annual mean of 60.2 $\mu g/m^3$) and suspended particulates (annual mean of 114.1 $\mu g/m^3$), suffered an increased risk of bronchitis and other lower respiratory disorders. Berciano et al (1989) showed a significantly higher frequency of wheezing episodes in children with asthma living in polluted areas (concentration of sedimentary material was greater than 300 mg/m^3/day) than in non-polluted ones. Whittemore and Korn (1980) established that asthmatics in Los Angeles, USA tended to have increased attacks on days with high oxidant (daily average greater than 526 $\mu g/m^3$) and particulate (daily average greater than 200 $\mu g/m^3$) pollution.

Charpin et al (1988) found that moderate daily changes in SO_2 levels (average winter high of 93 $\mu g/m^3$) induced a significant but transient increase in the prevalence of respiratory symptoms in children. Pope (1991) noted that bronchitis and asthma admissions for preschool children were approximately twice as frequent in Utah Valley (USA) when a steel mill producing particulate matter (mean winter average of 95 $\mu g/m^3$) was in operation than when it was closed. Braun-Fahrlander et al (1990) concluded that the duration of respiratory symptom episodes of preschool children was associated with particulate concentrations, and possibly with NO_2. Kreis et al (1990) found a relationship between absenteeism and air pollution, with a delay of one to two weeks and a clear relationship between SO_2 and influenza attendances recorded by general practitioners.

However, Schenker et al (1986), in a study involving rural children in the USA, concluded that the levels of air pollution were not high enough to facilitate detection of respiratory outcomes associated with ambient pollution (annual average of 91 $\mu g/m^3$). Goren et al (1988) found that the effects of age, epidemics and background variables rather than ambient air pollution were responsible for the observed differences noted in a follow-up study of children living near a coal-fired power plant. Goldstein and Weinstein (1986) could detect no association between short-term SO_2 peaks (daily averages greater than 790 $\mu g/m^3$) in ambient air and children.

In South Africa there have been relatively few studies investigating the effects of air pollution on childhood respiratory health. Of those conducted, most are in areas such as the Transvaal Highveld where air pollution, meteorological, population and socio-economic conditions are different to those found in the Western Cape (Zwi et al 1990; Coetzee et al 1986).

Due to the varied nature of both epidemiological studies and their subjects, many of the results are confusing at best and contradictory at worst. However, some of the epidemiological studies did detect an adverse health effect of air pollution, especially on groups with a heightened susceptibility (such as asthmatics). Clearly even relatively low levels of ambient air pollution can under certain conditions lead to environmental insult. The long-term effects of low levels of air pollution as well as the particular mixture of pollutants that cause ill health in specific areas need to be addressed. There is a need for long-term, and ideally, standardised studies to be conducted so that comparable results may be obtained.

3.5 THE EFFECT OF METEOROLOGICAL COMPONENTS ON RESPIRATORY ILLNESS

The negative health effects of ambient air pollution are often dependent on the weather. Goldstein and Goldstein (1978, 1125), noted that "few researchers have recognized the importance of weather and the complex nature of its relation to the other variables in their studies". The various meteorological components that make up the weather such as temperature, rainfall, humidity, wind, temperature inversions as well as the macro- and meso-scale patterns, often determine whether various air pollutants are going to be concentrated or dispersed by the atmosphere. It is important to investigate the effects of these meteorological components on the respiratory health of children.

Asthmatics seem to be most affected by changes in weather and meteorological variables. Asthmatics have often recognised that their lungs are sensitive to weather conditions (Lane and Storr 1987). Some of the major asthma triggers have been attributed to weather components such as changes in relative humidity (Stebbings 1978), temperature (Lebowitz et al 1974), the onset of rain, and stormy weather (Wagner et al 1983). When parents of asthmatic children living in Lewes (England) were asked what precipitated their child's asthma, changes in the weather was given as the third most frequent cause (Storr et al 1987).

It is not clear whether meteorological conditions influence the spread of infection, or whether sudden weather changes themselves are liable to induce asthma attacks. It may be that the true association between weather and asthma lies with seasonal change itself (Dawson et al 1983). Weather may affect asthma either by direct action on the patient or indirectly by influencing the spread of infections or the concentration of allergens or irritants (Derrick 1973). Furthermore, the effects may be immediate or delayed, and sudden changes are particularly liable to induce attacks (Derrick 1973). Thus, an editorial in <u>The Lancet</u> concluded that

"Since the conducting airways of the respiratory tract are continuously exposed to the gas phase of the environment, it is not surprising that patients with asthma, with their low threshold for bronchial hyperreactivity, should experience changes in their symptoms with variations in the weather." (Anon, 1985, 1079)

The components that make up "the weather" are varied and the studies conducted to investigate the relationship between respiratory illness and meteorological components are just as diverse. Packe et al (1983) noted that there had been a widespread peak in asthma admissions at the height of violent thunderstorms and that meterological data indicated that there had been a notable change in several climatic factors either before, or during the increase in asthma admissions. In a study on asthmatic children in Auckland (New Zealand), Mitchell and Cutler (1984) found that weather was the precipitating factor in 70% of asthmatic children admissions (see Table 3.1). Whittemore and Korn (1980) found that asthmatics tended to have increased attacks on cool days and that males were significantly more affected by dry weather than were females.

The relationship between weather changes and asthma appears to be neither simple nor constant (Wagner et al 1983). Where documented, the increase in asthmatic symptoms has occurred only with abrupt changes from warm to cold in early autumn and not with similar weather changes one or two months later (Wagner et al 1983). It is also important to distinguish between information obtained from short unexpected asthma outbreaks due to sudden meteorological events and those pertaining to the influence of the more continuous meteorologic variations on the acute exacerbations of asthma (Beer et al 1991).

Graham (1990, 153) noted that the seasonality of epidemics of ARI "has long been established, seeming to correlate best with low temperature, humidity, and/or precipitation". These factors usually result in higher rates of infection as more time is spent indoors either at home or at school. One factor that has been closely studied IS the effects of low temperature or chilling on host susceptibility (Graham

1990). Humidity might also play a role as rhinoviruses may tend to survive better at high humidity, and high humidity levels might favour increased transmission of these rhinoviruses (Graham 1990).

Table 3.2 MAJOR PRECIPITANTS OF ASTHMA ATTACKS.

Factor	Percentage
Weather	70
Infection	61
Stress/excitement	25
Dust	24
Pollen	17
Food	13
Running out of medicines	11
Animals	10
Exercise	4
Other	4

(n = 83)

(Mitchell and Cutler 1981, 332)

Beer et al (1991) found that the absolute outside air temperature per se did not have any effect on asthma admissions. Of more importance was the role played by certain changes in meteorological variables, especially in the afternoon. They postulate that it could be due to the fact that most children are relatively sheltered against changes during the night and in the morning by staying indoors at home or at school. In the afternoon they spend more time outdoors.

Richards et al (1981) found that levels of certain pollutants were highly associated with relative humidity (negatively) and with dry and hot wind conditions. The possible importance of reduced relative humidity as a factor in worsening asthma is supported by experimental evidence that exercise-induced bronchoconstriction is more pronounced in dry than warm humid air (Richards et al 1981). Bethel et al (1984) in a clinical study on seven asthmatic volunteers, found that airway cooling and/or drying increased the bronchoconstriction induced by inhaled SO_2. Thus it may be that persons who have asthma may be more sensitive to the bronchoconstrictor effects of ambient SO_2 in cold dry environments than in warm moist environments. Khan (1977) found that different air pollutants as well as meteorological conditions, when combined, played a minor role in the complex aetiology of asthma (5-15% of the total variance).

There may be a direct effect of one or more climatic parameters which act as direct irritants on the respiratory tract of asthmatics (Hobday and Stewart 1973). These may be relative humidity, barometric pressure, atmospheric electric charge or temperature. However, the effect of alteration in the climate may be mediated by their effect on plant or fungal growth or the release of aerial spores (Hobday and Stewart 1973).

It is rare for meteorological components to affect respiratory illness by themselves. Normally these components act on and with other environmental factors which in turn have an effect on susceptible persons. Atmospheric changes may affect asthma by direct effects on the airways, such as cooling or irritation, and indirectly by influencing the atmospheric levels of aero-allergens such as pollens and fungal spores and air pollutants (Anon 1985).

3.6 AEROALLERGENS AND RESPIRATORY HEALTH OF CHILDREN

Lane and Storr (1987) recognised that asthma attacks may be due to allergies. They define allergy as "an unusual sensitivity possessed by some people and not others" (Lane and Storr 1987, 58). They may be sensitive to particles commonly encountered in the atmosphere, to substances only met in industry, to food eaten, or medications given. In asthmatics, the unusual sensitivity or allergy shows itself in the lungs as coughing and wheezing.

In a sensitised person, tiny amounts of antigen can provoke a reaction. There is an initial early reaction, which usually subsides within an hour and is sometimes, but not always followed by a late reaction which may develop into a long-term period of symptoms (Kerrebijn 1986). This increased responsiveness may last for a considerable time and makes the patient more vulnerable to antigens, resulting in a vicious circle (Kerrebijn 1986).

Allergens are among the more important factors that provoke asthma attacks (Reed and Swanson 1987). However, patients in whom allergens provoke attacks of asthma, frequently have asthma for other reasons as well. Reed and Swanson (1987) estimate that 60 to 80% of persons of all ages with asthma have had at least some antigen-induced episodes, and that 5 to 15% of patients with asthma severe enough to require hospital admission have had an allergic component.

Geographical, seasonal and climatic factors are important in determining the allergens present in both indoor and outdoor air; while cultural and socio-economic factors determine the kind and amount of antigen indoors (Reed and Swanson 1987).

Allergens such as house dust, moulds, pollens and animal dander (small particles of hair or feathers) induce, in susceptible persons, specific immunoglobulin (IgE) antibodies that provoke symptoms of allergy such as rhinitis, conjunctivitis and asthma (Stankus and Lehrer 1987). One of the major triggers for asthma attacks is the inhalation of an antigen to which a subject has made specific IgE antibodies (Kerrebijn 1986). Specific IgE responses to environmental allergens are not random and depend not only upon the genetically determined immune responsiveness of the individual, but are also subject to the dose and intensity of the environmental allergen exposure (Potter et al 1991). Potter et al (1991) found that one-third of 1 372 children aged between 0-12 years attending the Red Cross Hospital out-patients department with symptoms involving the upper and lower respiratory tract, had specific IgE responses to environmental allergens. Van Niekerk et al (1977A) listed the environmental allergens that affect susceptible children in Cape Town; the most important being house-dust mites and the mites *Dermatophagoides pteronyssinus* and *D. farinae* (see Table 3.3).

The inhalation of pollen may cause direct synergistic effects as well as indirect multiplication effects where upper respiratory irritation caused by pollen allergies forces people to practice breathing through their mouths. Thus the filter mechanisms of the upper airways are bypassed and will increase exposure to the lower airways and lungs (Dr. A.P.L. Terblanche, personal communication).

In Cape Town, poaceae (grass) pollens are the dominant atmospheric pollen and basidiospores are the most dominant fungal spore or mould in Cape Town (Hawke 1989). Generally sporès outnumber pollens 4 to 1. Atmospheric pollen has distinct seasonal fluctuations, while the seasonality of fungal spores is less distinct (Hawke 1989).

Table 3.3 RESULTS OF POSITIVE SKIN TESTS IN 103 ASTHMATIC CHILDREN IN CAPE TOWN (Van Niekerk et al 1977, 75)

Allergens	Positive Skin Tests
D. farinae	25.3%
D. pteronyssinus	23.5%
House-dust	16.7%
Cat Dander	9.8%
Grass	6.9%
Ascaris	6.3%
Feathers	2.9%
Botrytis	1.1%
Egg White	1.1%
Other	6.3%

(Total number of skin tests = 174; mean per patient 1.7)

Ordman (1964) noted that almost all the seasonal respiratory allergy patients in South Africa develop symptoms in the summer. This is due to the flowering of grasses and consequently grass pollens abound during this season. Certain species of exotic trees (planes, oaks and poplar in particular) are responsible for allergies during spring (Ordman 1964). During late summer, certain weeds can affect allergic individuals (Ordman 1964).

Van Niekerk et al (1977A) noted that despite the Cape Town coastal climate and winter season, very few asthmatic children were found to be sensitive to moulds. They concluded that moulds play a minor role in asthmatic children living in the Cape Peninsula.

Often airborne allergens are related to both the climate and air pollution. Both SO_2 and NO_2 were shown by Kagamimori et al (1986) to be associated with the prevalence of respiratory symptoms in children who had positive skin reactions to household dust extract. Changes in the weather, particularly rainfall and humidity, may produce an antigen-rich aerosol that leads to acute bronchospasm in sensitive subjects (Anon 1985). If this is true then it may account for some of the difficulties experienced in relating sensitivities in asthmatics to larger antigen particles and asthma exacerbations to whole pollen and spore counts (Anon 1985). If changes in weather cause fragmentation of pollen and spores, generating antigen-laden aerosols, as well as governing their release, then the link between the weather and asthma becomes one of great importance (Anon 1985).

3.7 CONCLUSION

The above discussion has indicated the complex nature of the many ambient environmental factors that may have some effect, either individually or synergistically, on the health of children who live in an urban environment. After determining the hospital admission patterns of childhood respiratory illness in the following chapter, this study will investigate various environmental factors present in Cape Town to ascertain whether or not they have any relationship to these patterns.

CHAPTER 4
MATERIALS AND METHODS

4.1 HOSPITAL ADMISSION DATA

4.1.1 Nature of the data

The two hospitals selected for this study were the Red Cross War Memorial Children's Hospital in Rondebosch and Tygerberg Hospital in Tygerberg, Cape Town. Both are Provincial (public-sector) hospitals and were chosen because of their size, function and utilization of an almost identical computerised system handling patient records. Both are large teaching and referral hospitals. Red Cross is a major children's hospital, while Tygerberg Hospital has a large paediatric ward. Both offer secondary and tertiary care, although they have been increasingly utilised as primary care institutions for the poorer section of Cape Town's population (Lachman 1989; Lachman and Zwarenstein 1990; Horler 1990).

Hospital admission data were provided by the Medical Informatics Departments at both hospitals for the period 1985-1990. The wards surveyed were the overnight holding wards, A8 at Red Cross Hospital and C11B at Tygerberg Hospital. These wards are for children (usually under 13 years of age) whose illnesses do not warrant immediate admission into the main wards, but are serious enough to be held overnight for observation. The following morning the children are transferred to available hospital wards either at the same hospital or elsewhere, or are discharged.

The computerisation of records at both hospitals began in 1985. It reportedly took some time to solve problems in the system and to train staff:

only data from 1988 onwards at both hospitals is regarded as reliable (Drs. M. Power and S. Skaafe, personal communication). As the two hospitals operate an almost identical computerised system, the data obtained have approximately the same content (Table 4.1).

Table 4.1 HOSPITAL DATA.

CRITERIA	RED CROSS	TYGERBERG
Date of Admission	Yes	Yes
Name	Yes	Yes
File Number	Yes	Yes
Date of Birth	Yes	Yes
ICD Code	Yes	Yes
Gender	Yes	Yes
Race	Yes	Yes
Postal Code	Yes	Yes
Street Address	No	Yes
Discharge Code	Yes	No

When there was more than one diagnosis per child, only the first recorded was chosen (1100 and 631 children were admitted aith more than one diagnosis at Red Cross and Tygerberg Hospitals respectively). Readmissions were not investigated or deleted as the study considers individual admissions on a daily basis; and no special consideration was given to children who presented several times during the study period.

4.1.2 Patient Profile

The overnight holding wards, or low-maintenance wards, are usually occupied by patients using the hospital for primary health care purposes. Traditionally these patients come from the coloured and African low-income areas situated in the Cape Flats (Rip and Hunter 1990). Children brought to the out-patient departments of both hospitals are examined by clinicians. If the medical staff consider the child too ill to be treated and released, but not sick enough to be admitted directly into the wards, the child is admitted into the respective holding wards for observation. Children are also kept in these wards if it is felt that the parents might not be able to return the child for further treatment or if the paediatric wards are full.

These low-maintenance wards where parents are expected to help with the care of the child are not ideal. The "'partial' nursing allocation is based on the seemingly incorrect premise that a tired, anxious often uneducated... [parent] ... is in some way a substitute for a nurse" (Red Cross War Memorial Children's Hospital 1987/88, 11). The level of care in the wards, especially during the busy winter months, is often not as high as it could be (Red Cross War Memorial Children's Hospital 1987/88).

Children from higher income areas usually have access to a group or company medical aid scheme. The pattern typically seen in white children is a high proportion of specialist consultations (Strebel et al 1990). White children tend to use private hospitals, clinics and private physicians (Rip and Hunter 1990). Only in the more serious cases would they make use of the out-patient services at the two hospitals, and would then be more likely to be admitted directly into the hospital wards (Drs. L. Whitelock-Jones and S. Skaafe, personal communication).

There are very few persons of direct Asian descent resident in Cape Town: due to their socio-economic status it is also likely that they would use private hospitals and private physicians. From the data very few Asian patients presented to either of the holding wards: they were consequently not included in this study.

This study is therefore restricted to the poorer stratum of coloured and African population groups living in the Cape Flats area of Cape Town (see Figure 4.1).

4.1.3 Diagnosis

Both hospitals use the International Classification of Diseases Ninth Revision (ICD)[1].

Patients are examined by clinicians at both hospitals. The patient's diagnosis is written into the hospital folder. A diagnostic form in the folder is completed by a ward nurse and then captured onto a computer by trained data-entry clerks (see Table 4.2 for a list of relevant diagnostic codes used at both hospitals).

At Red Cross Hospital a simplified version of the ICD codes on one A4 sheet of paper is used by staff in the holding ward to classify illnesses. This makes the coding a fairly simple process.

At Tygerberg Hospital a large booklet with all the ICD codes in numerical order, in Afrikaans, is used by medical staff to classify illness. The booklet has not been simplified and contains many codes which are not used. This booklet is difficult to print and distribute, and is often in short supply. There is also a two month turnover of clinicians as the ward is used as part of the in-house training programme. Several of these clinicians do not speak Afrikaans and often have difficulty in using the code booklet.

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[1] "*The International Classification of Diseases is a list of all known diseases and syndromes published by the World Health Organization every ten years (approximately). ... each is allocated a three-digit number for computerization and hence comparison of mortality and morbidity rates, both regionally and nationally.*" (Concise Medical Dictionary (2nd Ed). Oxford University Press:Oxford, 1988, p 361)

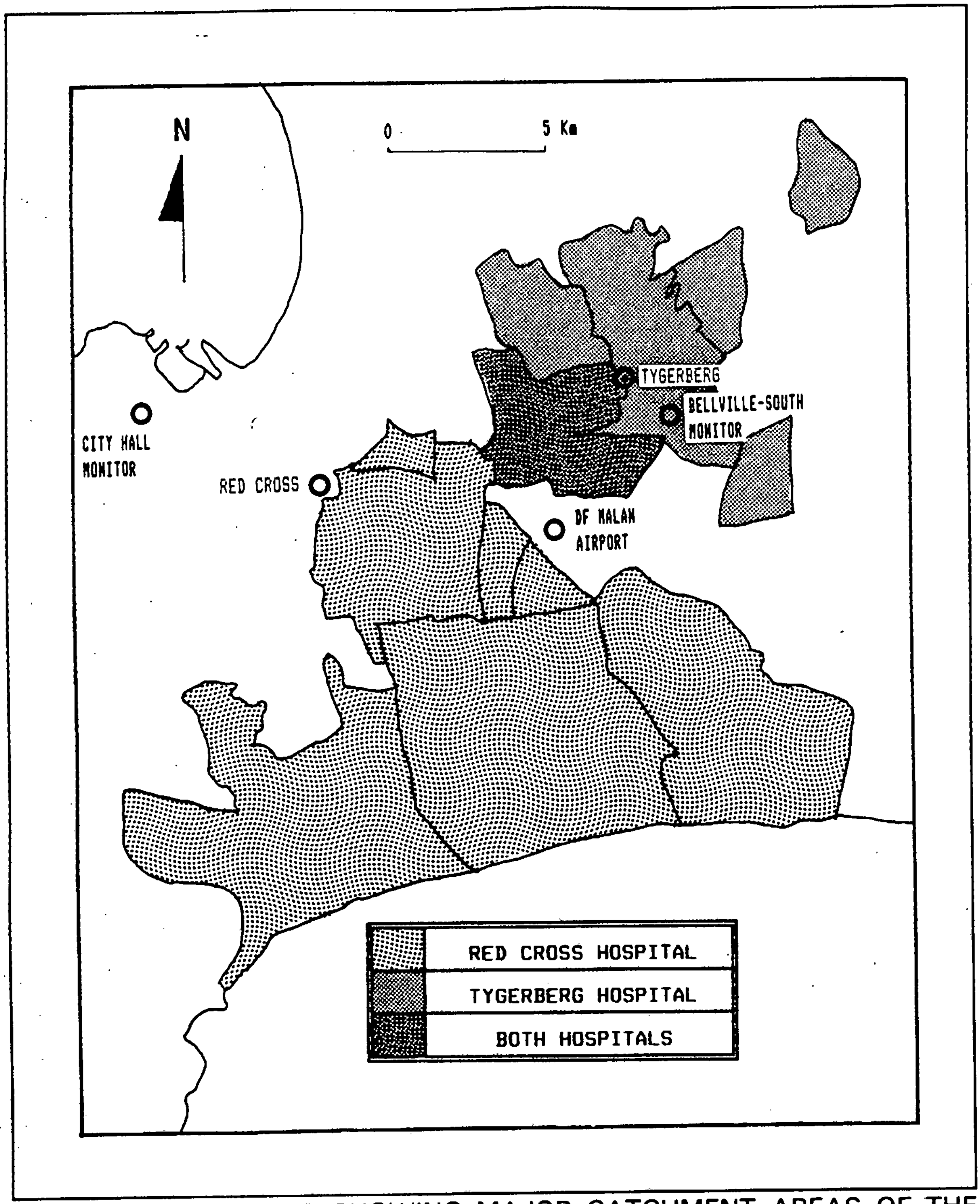

Figure 4.1 MAP SHOWING MAJOR CATCHMENT AREAS OF THE RED CROSS AND TYGERBERG HOSPITALS.

Table 4.2 ICD CODES UTILISED.

RED CROSS		TYGERBERG	
Code	Description	Code	Description
A)	ACUTE RESPIRATORY INFECTION		
462	Pharyngitis	4620	Pharyngitis
463	Tonsillitis	4630	Tonsillitis
464.2	Laryngotracheo-bronchitis (LTB)	4644	Stridor-Croup
465.9	Upper Respiratory Tract Infection	4659	Upper Respiratory Tract Infection
466.1	Bronchiolitis	4661	Bronchiolitis
481	Pneumonia-Lobar	4829	Pneumonia-Lobar
485	Bronchopneumonia	4850	Bronchopneumonia
507	Pneumonia-Aspiration	5070	Pneumonia-Aspiration
339	Whooping Cough	4660	Bronchitis-Acute
480.9	Pneumonia-Viral	4824	Pneumonia-Staphyloccus
486	Pneumonia-?cause	4900	Stridor-Acute LTB
B)	ASTHMA		
493	Asthma	4930	Asthma
		4912	Bronchitis-Asthma
		5199	Bronchospasm
C)	BOTH ARI AND ASTHMA		
786.09	Wheezing - ? Cause		

NOTE: Each Hospital has slightly changed the format of the ICD Codes to allow for the computerisation of the records.

The difference in approach to ICD codes could lead to differences in diagnosis. However the head of the holding ward at Tygerberg Hospital supposedly checks and codes the diagnosis on each folder on a weekly basis. If any anomalies are found, they are corrected by consultation with the medical staff who originally examined the patient (Dr. S. Skaafe, personal communication).

Overcrowding in the overnight holding wards is sometimes very severe (Red Cross War Memorial Children's Hospital Annual Report 1989/1990; Dr. S. Skaafe, personal communication) and thus initial diagnoses may be inaccurate. However, the discharge diagnoses are cross-checked against the admission diagnoses and are updated by hospital staff.

At Red Cross Hospital a significant number of asthma and bronchitis admissions are often classified as "786.09 wheezing - cause not specified" by less experienced staff (Red Cross War Memorial Children's Hospital 1988/89). Data recorded under this code were examined to determine whether patterns were similar to asthma or bronchiolitis.

Figure 4.2 shows that the race and gender breakdown of code 786.09 is dissimilar to asthma as well as to bronchiolitis. Admissions classified as 786.09 were thus not included in this study

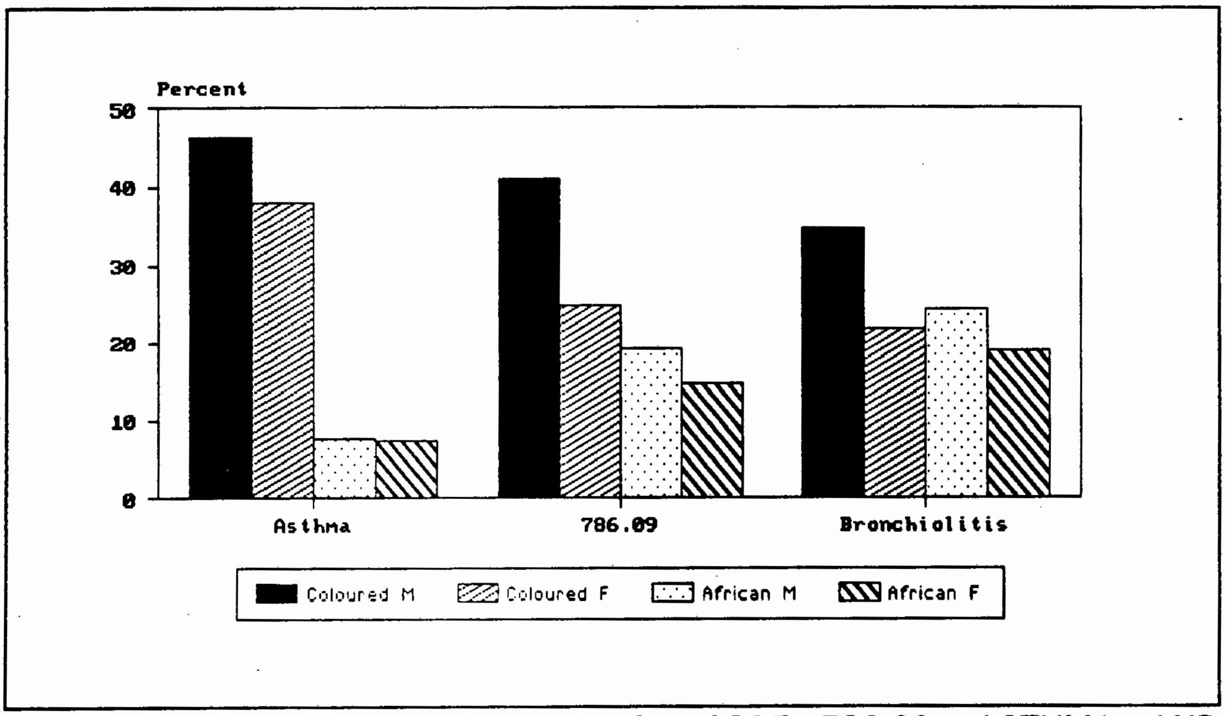

Figure 4.2 COMPARISON OF ICD CODE 786.09, ASTHMA AND BRONCHIOLITIS, RED CROSS HOSPITAL, 1988-1990.

4.1.4 Postal Codes

The only indication of residential area available from the computerised records at both hospitals is a four digit code denoting the postal area in which the patients live (see Table 4.3).

Table 4.3 MAJOR POSTAL CODES IN CAPE TOWN.

CODE	SUBURB	CODE	SUBURB
7405	MAITLAND	7750	GUGULETU
7441	MILNERTON	7755	NYANGA
7455	LANGA	7764	GATESVILLE
7460	GOODWOOD	7784	KHAYELITSHA
7490	MATROOSFONTEIN	7785	MITCHELLS PLAIN
7500	PAROW	7800	PLUMSTEAD
7530	BELLVILLE	7925	SALT RIVER
7550	DURBANVILLE	7945	RETREAT
7560	BRACKENFELL	7975	FISH HOEK
7570	KRAAIFONTEIN	7995	SIMONSTOWN
7581	BLACKHEATH	8001	CENTRAL CAPE TOWN
7700	RONDEBOSCH		

The use of postal codes for spatial analysis of hospital admission data is not recommended as the code often amalgamates several suburbs into a larger area that is not representative of the patient's residential location. This is especially evident with codes such as Matroosfontein (7390), Gatesville (7764) and Plumstead (7800) - these codes cover large and seemingly diverse areas which have low and high socio-economic and income inequality indexes (as defined by Riley et al 1984). Even with a postal code that supposedly represents one "suburb", for instance Mitchells Plain (Code 7785), there still remains a socio-economic gradient within the suburb which would not be accommodated.

The amalgamation of various suburbs also leads to problems in determining the extent of hospital use in various areas. The estimation of numbers of residents present in the Cape Flats, especially those in the informal housing areas, is difficult even when concentrating on one suburb. Thus hospital admission rates for the different suburbs could not be calculated from the data used in this study.

4.2 EXPOSURE DATA

4.2.1 Air Pollution Data

Air pollution measurements are conducted in Cape Town by the Cape Town City Council (the principal Municipal Authority, hereafter referred to as CCC) and the Western Cape Regional Services Council (District Authority, hereafter referred to as RSC).

An air pollution monitoring programme in Cape Town commenced in 1959. The initial monitors were SO_2 bubblers (measuring the amount of SO_2 in $\mu g/m^3$) which also draw air over a filter paper to record the particulate level (Soiling Index) in the air (Kemeny and Halliday 1964; 1968). Over the intervening years there have been several additions to, and deletions of, air pollution monitors from the programme. The CCC and RSC currently operate ten fixed SO2 bubbler sites within the Cape Town metropolitan area.

Of these monitors, only the Bellville-South monitor is situated near a coloured residential area and could be utilised in the study. The other monitors were located outside the catchment areas of the two hospitals[2].

[2]. City Hall, Heerengracht, Parow, Vasco, Pinelands, Edgemead, Epping Market and Paarden Eiland.

The samples from the SO_2 bubblers are collected and analysed twice a week (on Mondays and Fridays) - thus each data point represents a three or four day average. The equipment is old and unreliable (Mr. G. Ravenscroft, personal communication) and is not being replaced when it breaks down.

During the study period, the CCC operated one further air pollution monitor at the City Hall in the Cape Town Central Business District. It monitors a more comprehensive set of air pollutants recorded on magnetic tape on an hourly basis. Pollutants monitored are: sulphur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2), oxides of nitrogen (NO_x) and ozone (O_3) (all in $\mu g/m^3$).

Data recorded by the City Hall monitor are generally reliable, but are representative of only the Central Business District - an area with very high levels of vehicular traffic. This data is not strictly representative of the pollution levels experienced in the study area on the Cape Flats. However, it is the best set of reliable pollution data that is available for use in Cape Town Metropolitan area, and it is thus utilised in this study as an indicator of metropolitan-wide air pollution levels.

The RSC operates a mobile air pollution monitor which was positioned at three different sites during the study period (see Table 4.4) none of which was representative of the air pollution experienced on the Cape Flats. It measured the same pollutants using the same instruments as the CCC's City Hall monitor. The electronic data logger was unreliable; and there are considerable gaps in the data. The data from this monitor were not utilised in this study.

Table 4.4 LOCATION OF RSC MOBILE MONITOR 1988-1990.

Period	Location
Jan 1988	Bothasig
Feb 1988 - Aug 1989	Tygerberg Reserve
Sep 1989 - Dec 1990	Labiance, Bellville

4.2.2 Meteorological Data

Daily levels of meteorological variables (rainfall, maximum and minimum temperature, and relative humidity) were obtained from the D.F. Malan Airport Weather Office. Because of its location on the Cape Flats, data from this source is regarded as being representative of the areas pertinent to this study.

Further data concerning still days and wind direction were obtained from the CCC and RSC as part of their air pollution monitoring programme. This data also relates to the D.F. Malan Airport Weather Office.

4.2.3 Airborne Allergens Data

As grasses, weeds, trees and moulds are important sources of airborne allergens which could induce allergic respiratory disease (Ordman 1958; Ordman 1964; Van Niekerk et al 1977A; Stankus and Lehrer 1987), it was decided to investigate data pertaining to pollens and mould counts.

Data on moulds and pollens were investigated from Red Cross Hospital. The collection of pollen and mould data at the Red Cross Hospital is routinely conducted as part of a pollen study. However, after 1987, collection and analysis of data was sporadic as it is only a part of the duties of the staff delegated to collection and analysis of the data. Whenever a more pressing project was being undertaken, pollen and mould collection and analysis went into abeyance.

For the years 1988-90 there are consequently very few data pertaining to daily levels of airborne allergens available; and it was decided not to use these data.

However, reliable data collected between 1984-1987 were used as an indication of which pollens and moulds are likely to be present during the year.

4.3 DATA ANALYSIS

4.3.1 Admission Data

Due to the size of the data set (approximately 3 000 admissions per year) and the time and manpower available, only computerised hospital records were used in this study.

All admissions for all respiratory illnesses to both wards were selected for analysis. Only those codes pertaining to ARI and asthma were eventually used. Others such as tuberculosis were disregarded. Furthermore daily totals for all admissions to the overnight holding wards and all paediatric admissions to both hospitals by gender were extracted.

All data supplied by the respective Medical Informatics Departments were downloaded onto high density floppy disks and restored directly onto a personal computer.

After initial editing and sorting, data from the two hospitals were checked to remove admissions of children over twelve years of age and admissions with postal codes from outside the study area.

Some admission data had been captured twice; these duplicated entries were removed. Where children had been admitted with more than one diagnosis, the first was chosen.

4.3.2 Concordance Between Asthma Peaks and Environmental Data

During the study period there were several occurrences when hourly and daily concentrations on NO_x were very high, including seven times. The Department of Health Acceptable Limits for 24-hour concentrations of NO_x were exceeded during the study period.[3] Five of these occurred in May and June 1990. Twice-weekly averages were calculated for NO_x and hospital admissions to determine whether these peaks were matched by a similar rise in admissions for respiratory illness.

A visual inspection of the admission data showed that there was a particularly high asthma peak between December 1989 and March 1990. These four months were consequently examined to determine whether any environmental variables influenced hospital admissions.

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[3]. The Department of Health National Levels for air pollutants are not based on a cause and effect type relationship supported by science.

4.3.3 The Relationship Between Hospital Admissions and Environmental Variables on a Metropolitan Scale

An analysis to determine whether there was any correlation between air pollutants and meteorological variables was attempted for the whole study period.

To highlight the effects of autocorrelation (seasonality), unadjusted as well as "deseasonalised" averages of patients admitted were separately calculated and correlated with the corresponding concentrations of NO_x, SO_2, soiling index, average temperature, minimum temperature, relative humidity and rainfall.

The distribution of the deseasonalised data was then checked for normality and a multiple regression model was fitted to the data to determine the relative importance of the individual environmental variables on hospital admissions.

The results of these analyses are presented in Chapter Six.

CHAPTER 5

RESULTS AND DISCUSSION OF PATTERNS OF RESPIRATORY ILLNESS

5.1 ADMISSION PATTERNS

Table 5.1 presents the results summarised by year and admission category to the overnight holding wards at both hospitals of children under twelve years of age.

Table 5.1 HOSPITAL VISITS BY YEAR AND ILLNESS.

	RED CROSS HOSPITAL				TYGERBERG HOSPITAL			
	1988	1989	1990	Total	1988	1989	1990	Total
TA	7313	7519	6882	21714	3195	3784	3254	10233
ARI	2473	2429	2242	7144	1263	1635	1203	4101
(% Total)	(33.8)	(32.3)	(32.6)	(32.9)	(39.5)	(43.2)	(37.0)	(40.1)
ASTHMA	737	892	711	2340	508	565	420	1493
(% Total)	(10.1)	(11.9)	(10.3)	(10.8)	(15.9)	(14.9)	(12.9)	(14.6)
ALL RESPIRATORY	3210	3321	2953	9484	1771	2200	1623	5594
(% Total)	(43.9)	(44.2)	(42.9)	(43.7)	(55.4)	(58.1)	(49.9)	(54.7)

During the three year study period, respiratory admissions at both hospitals accounted for 15 078 (47.3%) out of a total of 31 887 admissions. Red Cross Hospital had more admissions for respiratory illnesses (9 484) than Tygerberg Hospital (5 594). Admissions for ARI accounted for the majority of respiratory illnesses; 32.9% at Red Cross Hospital and 40.1% at Tygerberg Hospital. Asthma admissions comprised only 10.8% and 14.6% of admissions to both hospitals. At both hospitals ARI, asthma and TA peaked or stabilised in 1989 before dropping below the 1988 levels.

Average daily attendances varied from 19.8 for TA at Red Cross Hospital to 1.4 for asthma admissions at Tygerberg Hospital (Table 5.2).

Table 5.2 MEAN VALUES OF ADMISSIONS TO THE OVERNIGHT HOLDING WARDS AT RED CROSS AND TYGERBERG HOSPITALS, 1988-1990.

ADMISSION CATEGORY	MEAN	RANGE	SD
TA:			
Red Cross Hospital	19.8	3-38	5.0
Tygerberg Hospital	8.8	0-26	4.2
ARI:			
Red Cross Hospital	6.5	0-21	3.1
Tygerberg Hospital	3.7	0-20	2.5
Asthma:			
Red Cross Hospital	2.1	0-10	1.6
Tygerberg Hospital	1.4	0-8	1.4

5.2 MALE EXCESS IN RESPIRATORY ADMISSIONS

The onset, prevalence and severity of respiratory illnesses is often determined by the age and gender of the child. To ignore these differences could have a detrimental effect on the treatment and management of pre-adolescent children who are especially susceptible to respiratory illnesses.

In young children, management may be more difficult; and they may have more severe respiratory attacks than older children (O'Halloran and Heaf 1989). McKenzie et al (1979) found that young children admitted to hospital were more seriously ill than older ones. Peat et al (1980) noted that there was a larger proportion of chronic asthmatics among boys than girls after the age of twelve, and that boys are more likely to experience wheezing which required treatment at an earlier age than girls. Ordman (1958) noted that with patients suffering from bronchial asthma, symptoms began largely before the age of one year and more than 60% had developed symptoms by the age of four years.

It is thus important to investigate the age and gender patterns of illness of pre-adolescent children as information gained may be used in improved methods of treatment. Preventative measures may then be taken to immunise or protect children from illnesses at different times of their lives.

5.2.1 Asthma

It is well known that more male asthmatics present with asthma during the first decade of life than females (Bonner 1984). This male dominance typically declines until the initiation of puberty (about 14 years); and a change to a female dominance emerges by the late teens and early twenties (Crawford and Beedham 1976).

Although a common phenomenon, the magnitude of the male excess varies according to location. Hardes et al (1979) noted that the childhood male:female ratio of asthma discharges was 1.6:1 in the Hunter Health Region (Australia). Mak et al (1982) found a preponderance of asthmatic boys with a male to female ratio of 1.6:1 among those in the first grade (about five years of age), dropping to 1.3:1 for the sixth grade (11-12 years of age). Mitchell and Elliott (1981) noted that the male to female ratio for asthma in New Zealand children aged between 3-14 years was 1.9:1. Sears et al (1982) found in a study of seven year old children in Dunedin (New Zealand) that the male to female ratio was 1.6:1.

Table 5.3 shows the breakdown in admissions by age, gender and race per hospital during the three-year study period. In nearly all cases there was an overall male excess for asthma admissions. The exception being asthma admissions of African children between >4-12 years of age. The male excess for African children, it seems, reverted to a female excess earlier than for coloured children.

Table 5.3 ADMISSIONS BY GENDER, AGE GROUP AND RACE, 1988-1990.

	ARI				ASTHMA			
	0-1	>1-4	>4-12	Total	0-1	>1-4	>4-12	Total
RED CROSS HOSPITAL								
Coloured								
Males	1118	842	129	2089	36	615	432	1083
Females	757	653	117	1527	18	490	382	890
Total	**1875**	**1495**	**246**	**3616**	**54**	**1105**	**814**	**1973**
% of Total	52%	41%	7%		3%	56%	41%	
Males:1 Female	1.48	1.29	1.10	1.37	2.00	1.26	1.13	1.22
African								
Males	1056	757	118	1931	8	114	55	177
Females	803	672	99	1574	7	104	61	172
Total	**1859**	**1429**	**227**	**3505**	**15**	**218**	**116**	**349**
% of Total	53%	41%	7%		4%	63%	33%	
Males:Females	1.32	1.13	1.19	1.23	1.14	1.10	0.90	1.03
TYGERBERG HOSPITAL								
	ARI				ASTHMA			
	0-1	>1-4	>4-12	Total	0-1	>1-4	>4-12	Total
Coloured								
Males	754	1066	264	2084	86	478	245	809
Females	607	839	242	1688	55	367	214	636
Total	**1361**	**1905**	**506**	**3772**	**141**	**845**	**459**	**1445**
% of Total	36%	51%	13%		10%	58%	32%	
Males:1 Female	1.24	1.27	1.09	1.23	1.56	1.30	1.14	1.27
African								
Males	64	97	23	184	7	12	9	28
Females	61	53	18	132	1	6	7	14
Total	**125**	**150**	**41**	**316**	**8**	**18**	**16**	**42**
% of Total	40%	47%	13%		19%	43%	38%	
Males:Females	1.05	1.83	1.28	1.39	7.00	2.00	1.29	2.00

There was a steady overall decline in the male excess as the age of admission increased. This seems to match the expected pattern found elsewhere.

The excess in male admissions varied between both hospitals and between race. Rates for coloured children at both hospitals were similar, except that there were more males being admitted in the 0-1 year age group at Red

Cross Hospital. The male excess in African admissions to Red Cross Hospital was much lower than that of coloured admissions at both hospitals. The total of 42 African admissions to Tygerberg Hospital was too low to draw any conclusions.

Table 5.4 shows the gender breakdown for admissions to both hospitals by disease category including total paediatric admissions. The overall male to female ratio for total asthma admissions was 1.36:1 at Red Cross Hospital and 1.09:1 at Tygerberg Hospital. The ratio for asthma admissions at Red Cross Hospital was 1.19:1, while that of Tygerberg Hospital was higher at 1.29:1.

Table 5.4 TOTAL PAEDIATRIC AND RESPIRATORY ADMISSIONS BY GENDER, 1988-1990.

	RED CROSS HOSPITAL		TYGERBERG HOSPITAL	
	MALE	FEMALE	MALE	FEMALE
TOTAL PAEDIATRIC	42925	31643	23787	21828
RATIO	**1:1.36**		**1:1.09**	
ARI	4020	3101	2268	1820
RATIO	**1:1.30**		**1:1.25**	
ASTHMA	1260	1062	837	650
RATIO	**1:1.19**		**1:1.29**	

Thus, at Red Cross Hospital, the male predominance in asthma admissions may have been a reflection of the overall male excess in total paediatric admissions. However, at Tygerberg Hospital the male excess was larger than that of total paediatric admissions, and was probably specific to respiratory disease and not derived from the overall male excess.

Despite the overall male excess at both hospitals, there is clear evidence from other studies which does support the contention of an excess in male admissions specific to asthma.

The reasons for the male excess in asthma admissions during the first decade of life are not clear. There may be a genetic component in the development of asthma which allows more male children to suffer from asthma than females (Woolcock 1987).

Orren (1974) noted a gender difference in allergy levels in young children in Cape Town, but not in young adults. However, raised levels of serum IgE were found in both children and young adults. She maintained that the clinical manifestations of allergy in young adults had been obscured by environmental or other factors, while remaining detectable by the tendency for IgE levels to be higher in males than females. This may be one reason for the male excess in asthmatics during the first decade of life.

5.2.2 Acute Respiratory Infections

For coloured and African ARI admissions at Red Cross Hospital (See Figures 5.1 - 5.4), there were more admissions in the first year of life compared to Tygerberg Hospital. Admissions to Tygerberg Hospital gradually declined with an increase in age of admission.

From Table 5.3 it is clear that there was a male excess in all age and race groups of ARI admissions at both hospitals. At Red Cross Hospital, however, the excess diminished with age for both coloured and African admissions.

At Tygerberg Hospital there was a marginal increase in coloured admissions in the >1-4 years age group. African ARI admissions however, showed a drastic increase from 1.05:1 to 1.83:1 male to females. The ratio dropped to 1.28:1 in the >4-12 years age group. This was the only case where the male:female ratio in the older age group was higher than in the previous two age groups.

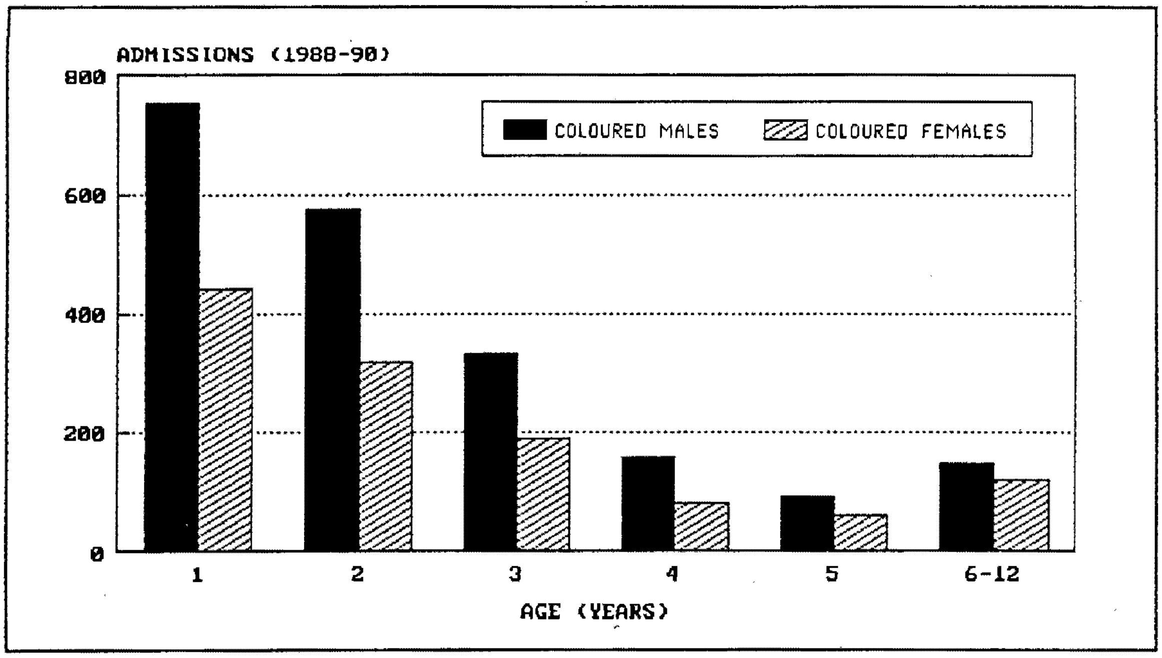

Figure 5.1 COLOURED ARI ADMISSIONS BY GENDER AND AGE, TYGERBERG HOSPITAL.

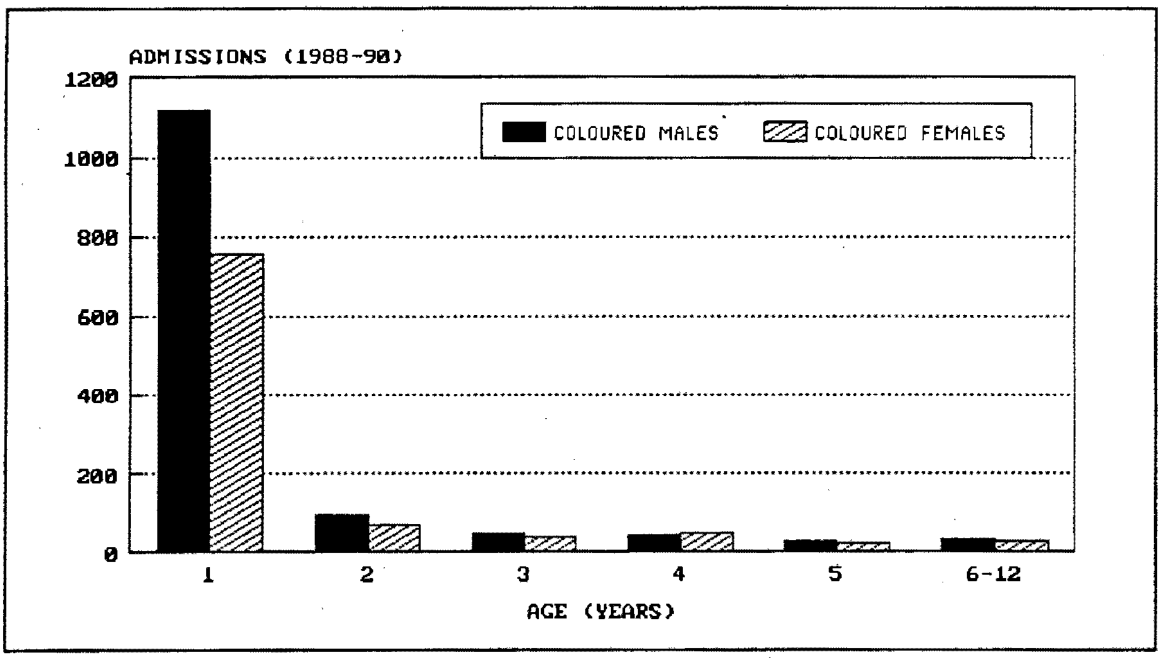

Figure 5.2 COLOURED ARI ADMISSIONS BY GENDER AND AGE, RED CROSS HOSPITAL.

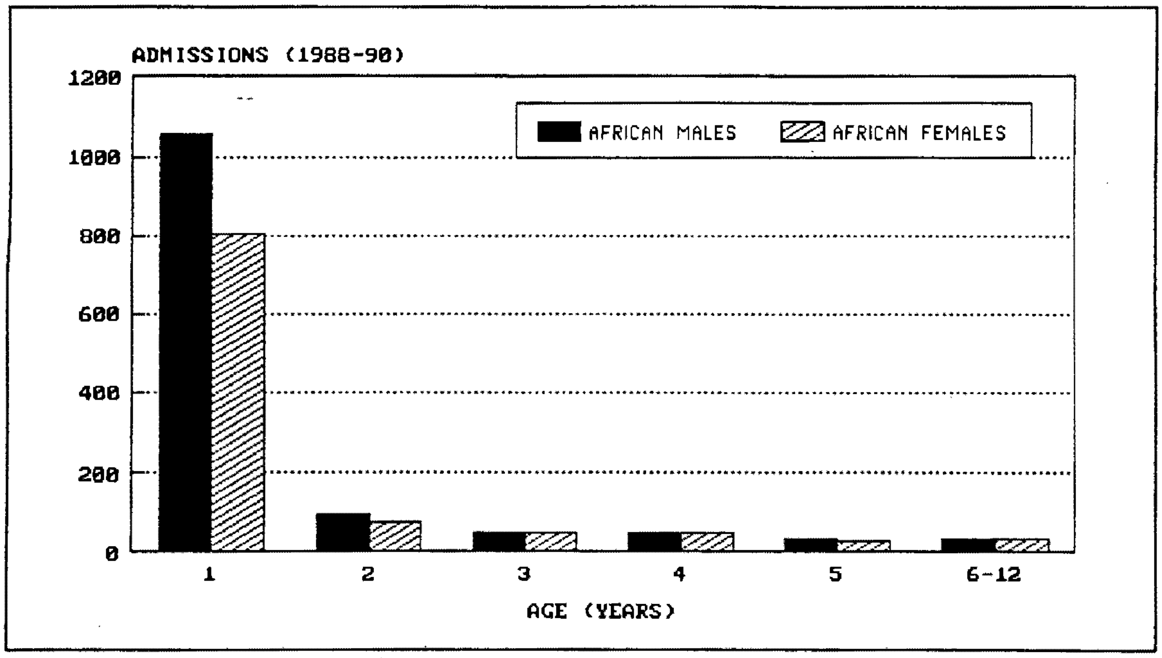

Figure 5.3 AFRICAN ARI ADMISSIONS BY GENDER AND AGE, RED CROSS HOSPITAL.

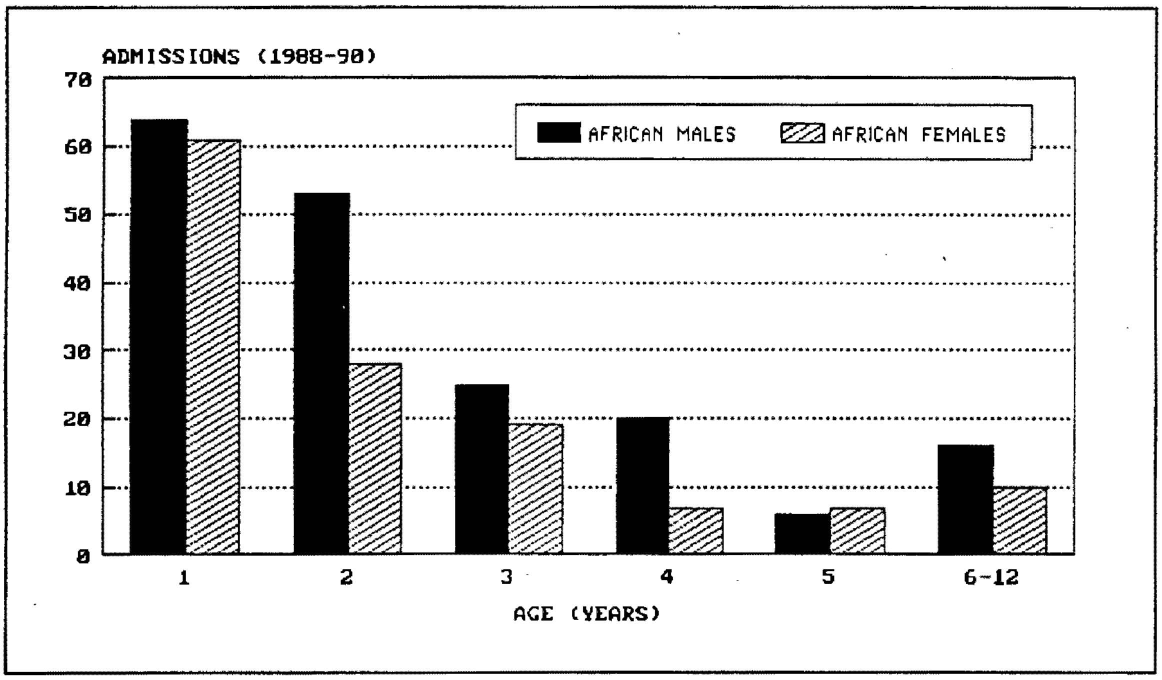

Figure 5.4 AFRICAN ARI ADMISSIONS BY GENDER AND AGE, TYGERBERG HOSPITAL.

The male excess in ARI admissions was an unusual occurrence. Ehrlich and Weinberg (1993) also noted a male predominance in pneumonia and bronchitis/bronchiolitis admissions to Red Cross Hospital. The male excess does not seem to be an established epidemiological feature of ARI (Graham 1990). It would seem that in Cape Town, preadolescent girls appear less prone to develop severe acute respiratory infections, or perhaps, were less likely to be admitted to hospital if they do suffer such illness (Ehrlich and Weinberg 1993).

Table 5.4 shows the male predominance in total paediatric admissions to both hospitals. The ratio for ARI admissions to both hospitals was similar. However, the male to female ratio at Red Cross Hospital was also slightly less than total paediatric admissions. It thus seems that the male excess in ARI admissions at Red Cross could have been the result of the overall male excess. The male excess in ARI admissions at Tygerberg Hospital, was much higher than total paediatric admissions, and was probably an expression of the true admission pattern and not due to the male excess in total paediatric admissions.

5.3 RACIAL PATTERNS

Differences in admission patterns by race may yield important clues as to the effects of respiratory illnesses on children often living in impoverished or disadvantaged circumstances. Many of the poorer communities in Cape Town are from the coloured and African residential areas. The great differences in distribution of health services across the metropolitan areas of Cape Town reflect the other legacies of apartheid (Eichhorn 1992); and the results of the apartheid era will take many years to diminish or ameliorate.

These communities have been subjected to a large variety of changes in lifestyle; and thus influences on respiratory health are likely to be multifactorial (Cookson 1987). Furthermore, an insight into the socio-economic and cultural factors which influence the mechanisms of respiratory illness for individuals and population groups could enhance the ability of doctors to recognise and eliminate causative factors and minimise symptomatic treatment (Joubert et al 1988). It is thus useful to investigate differing patterns of admissions by race.

5.3.1 Acute Respiratory Infections

At Red Cross Hospital, the number of both African and coloured children admissions for ARI was almost identical (Figure 5.5). At Tygerberg Hospital, though, relatively few African children were admitted for ARI when compared to coloured children (Figure 5.6).

The differences in age of admission between the two hospitals is interesting. The top sections of Figure 5.7 show the different proportions of admissions for ARI by age and race at both hospitals. At Red Cross Hospital just over 50% of the coloured and 75% of African admissions were presenting in the 0-1 year age group, while at Tygerberg Hospital both race groups had similar admission patterns.

5.3.2 Asthma

The racial breakdown for asthma admissions is presented in Table 5.3. Very few African children were admitted to both hospitals for asthma; at Red Cross Hospital there were 5.7 times more coloured than African admissions, while at Tygerberg Hospital there were 34.4 times more coloured asthmatics. Figures 5.5 and 5.6 graphically illustrates the paucity of African admissions for asthma and ARI at both hospitals.

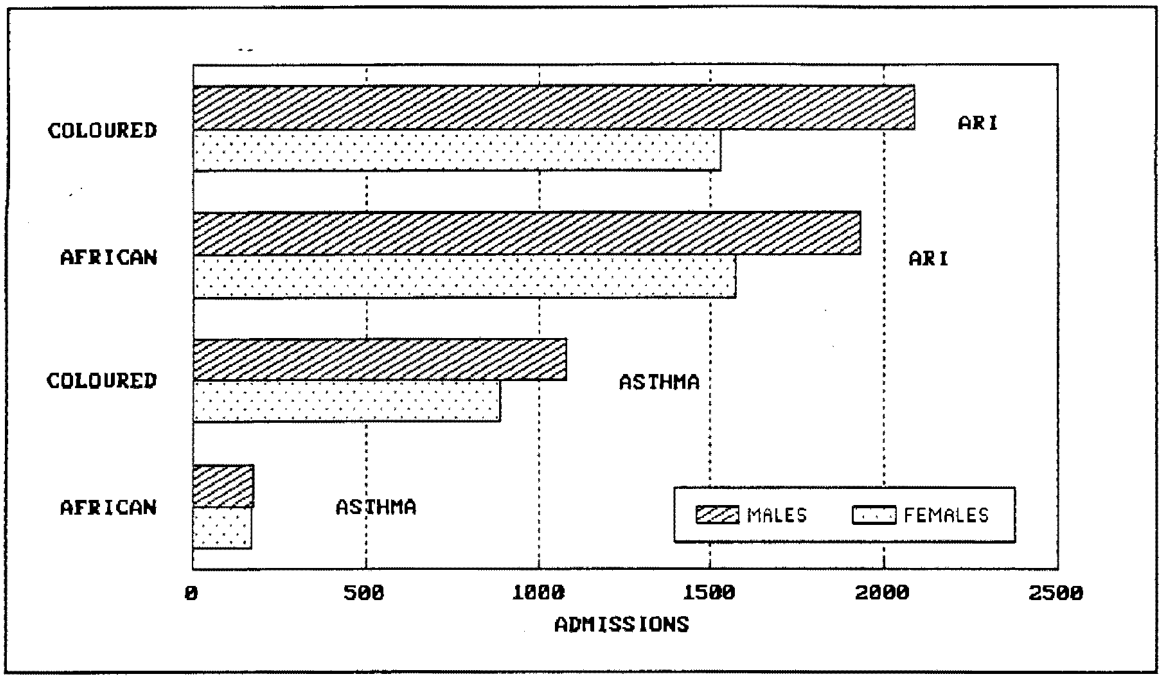

Figure 5.5 ARI AND ASTHMA ADMISSIONS BY RACE AND GENDER, RED CROSS HOSPITAL, 1988-1990.

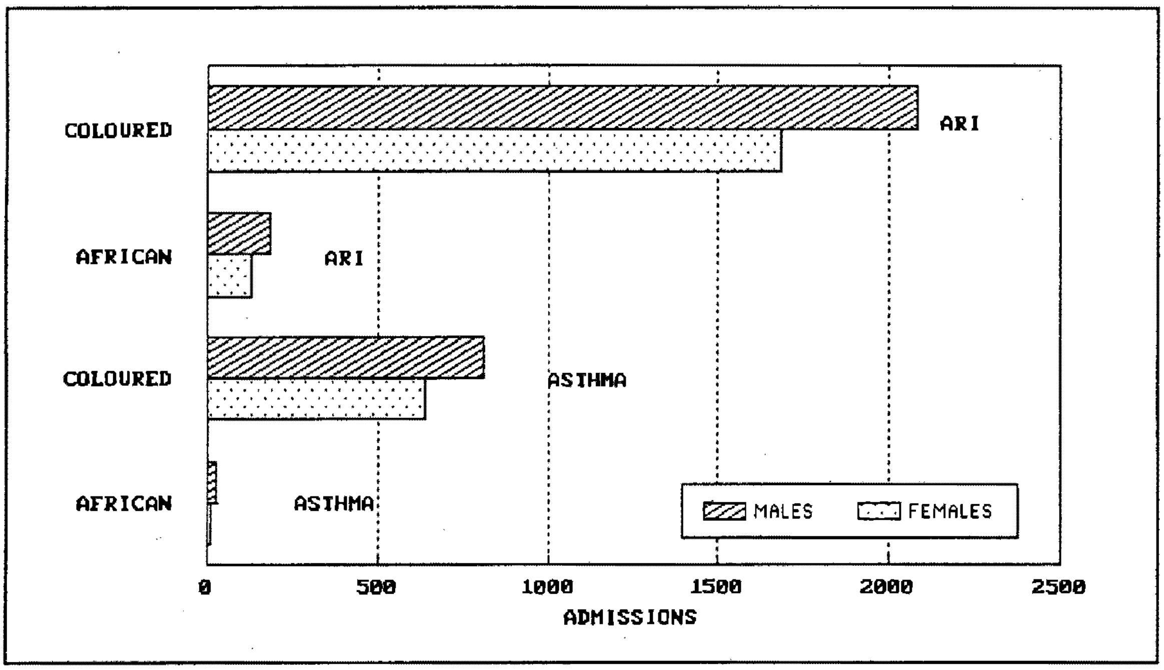

Figure 5.6 ARI AND ASTHMA ADMISSIONS BY RACE AND GENDER, TYGERBERG HOSPITAL, 1988-1990.

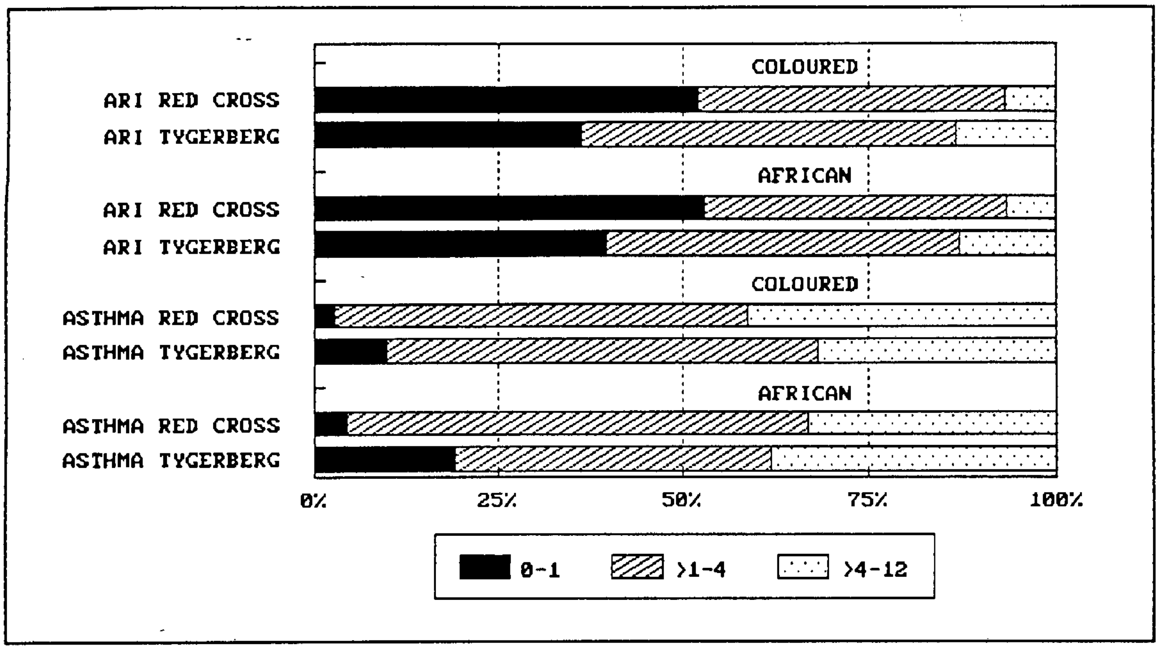

Figure 5.7 PROPORTION OF ADMISSIONS BY AGE AND RACE, 1988-1990.

The lack of African admissions to Tygerberg Hospital seem to stem from its situation from the African residential areas. An inadequate public transport system does not readily serve the hospital (Prof. P. Donald, personal communication) (see Figure 5.8).

Figure 5.9 indicates that Tygerberg Hospital seemed to draw many patients from the surrounding suburbs. The majority of admissions were from Matroosfontein (7490) which is comprised of former coloured residential suburbs in the area close to the hospital. The only African township to feature in Figure 5.9 is Khayelitsha (7784).

Tygerberg Hospital is located in an Afrikaans speaking area and is the major teaching hospital for an Afrikaans speaking university. African patients may thus have avoided attending Tygerberg Hospital as they may have preferred English to Afrikaans. African patients may also have associated Tygerberg Hospital with the Afrikaner people and chief proponents of the Apartheid bureaucracy which had kept them from the cities for many years.

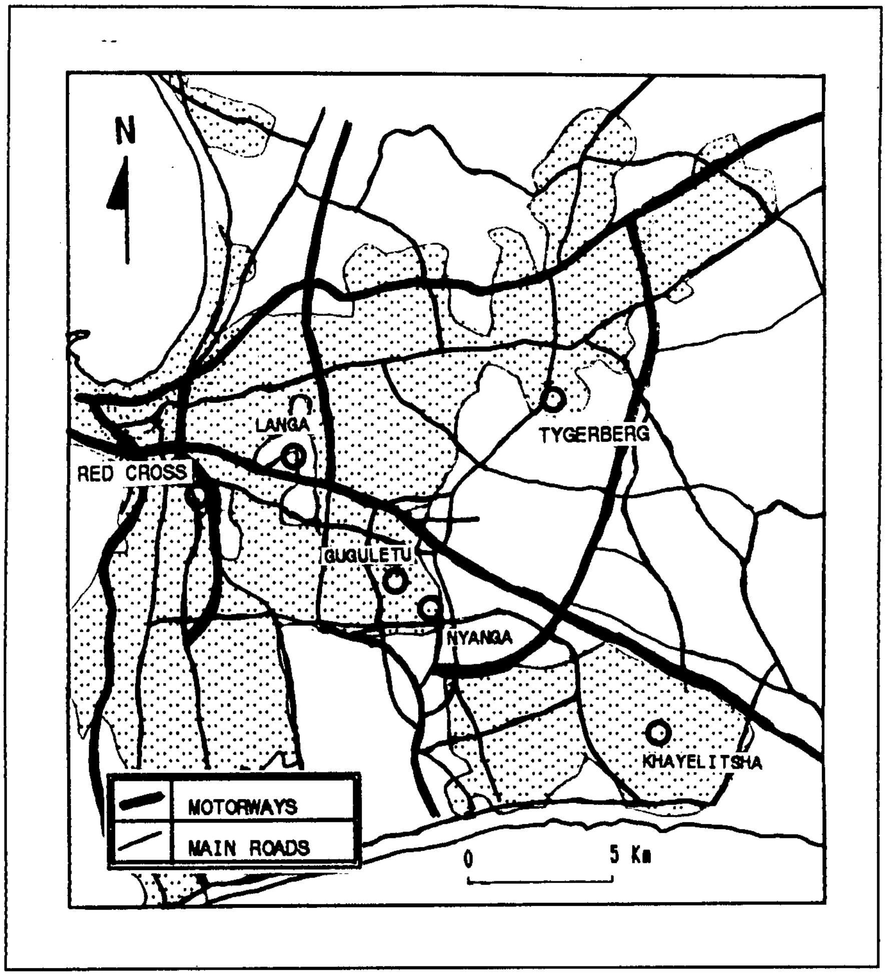

Figure 5.8 MAP SHOWING THE MAJOR ROADS IN CAPE TOWN IN RELATION TO RED CROSS AND TYGERBERG HOSPITALS.

The lack of admissions to Red Cross Hospital however cannot be solely explained by the difficulty of access and language problems. The hospital is situated on a major arterial road as well as near to many other roads leading to and from the Cape Flats townships (Walls and Ordman 1983) (see Figure 5.8). The public transport system (predominantly buses and mini-bus taxis) along the road is very efficient and regular.

Judging by the number of admissions for ARI, the African population had little difficulty in attending the hospital. Figure 5.5 shows admissions to Red Cross Hospital for ARI were almost equally divided between coloured and African children. From Figure 5.10 it can be seen that the hospital was clearly attracting patients from the African townships of Langa (7455), Guguletu (7750), Nyanga (7755) and Khayelitsha (7784).

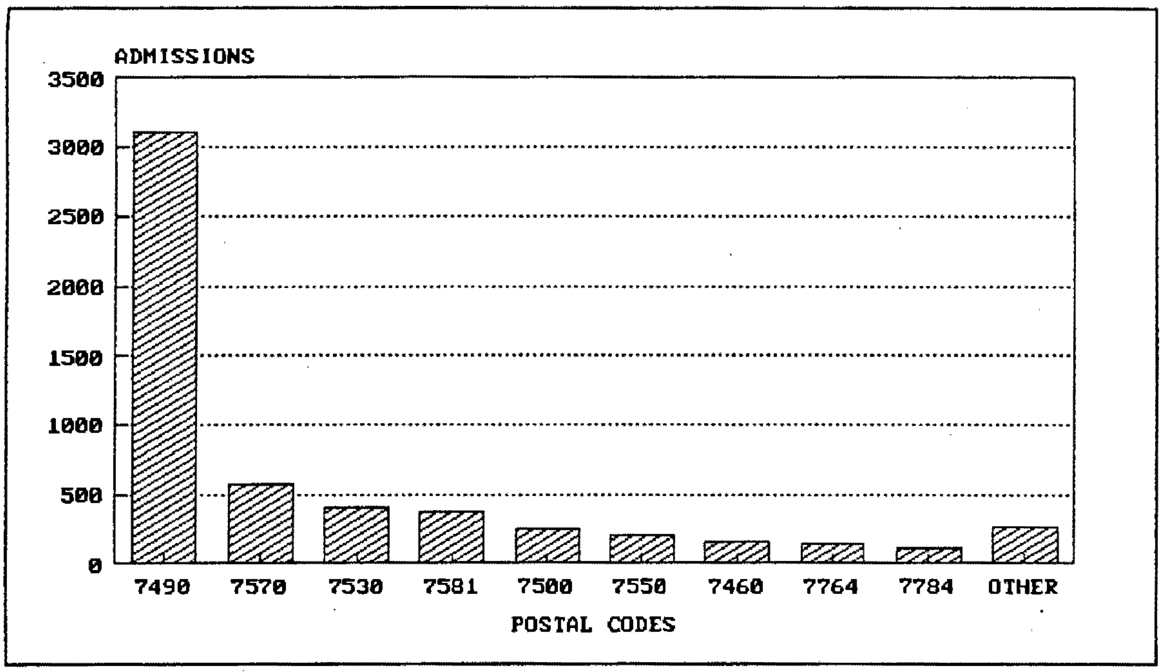

Figure 5.9 TOTAL RESPIRATORY ADMISSIONS BY POSTAL CODE, TYGERBERG HOSPITAL, 1988-1990.

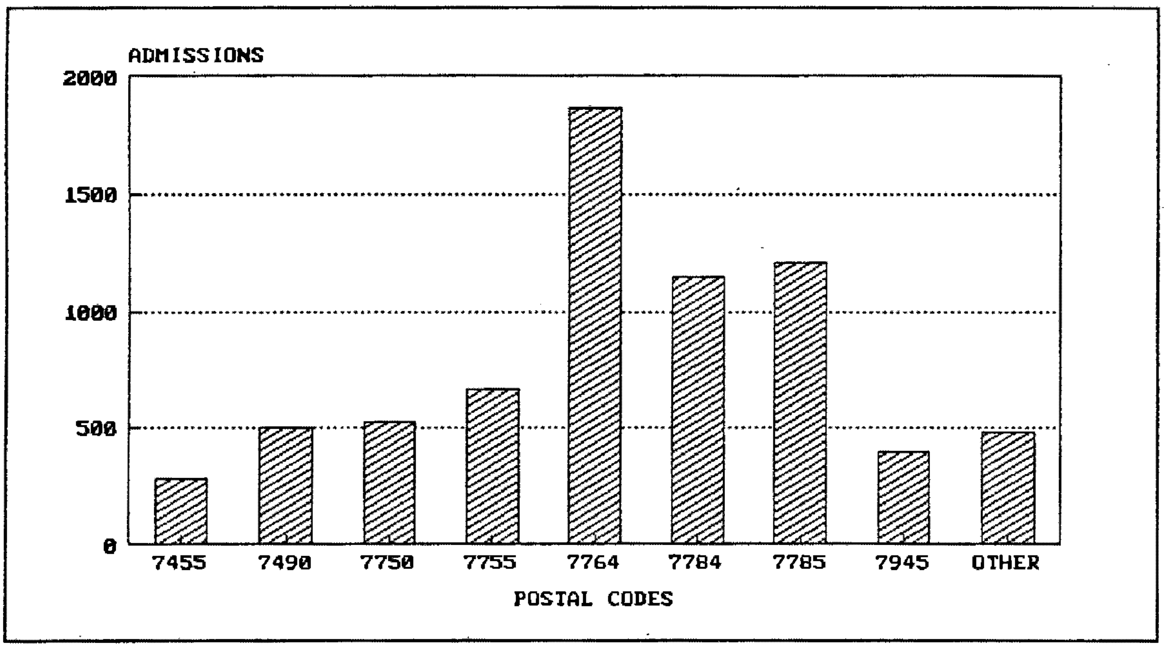

Figure 5.10 TOTAL RESPIRATORY ADMISSIONS BY POSTAL CODE, RED CROSS HOSPITAL, 1988-1990.

There were clearly many African patients attending Red Cross Hospital. Therefore difficulty of access to the hospital could not be cited as a sole reason for the relative paucity of African asthma admissions.

Underdiagnosis may have been one reason why there were fewer asthma admissions for African children; if the child was under two years of age, it would have been difficult to diagnose whether she had asthma or not. At Red Cross Hospital, there were proportionally more African than coloured children being admitted for ARI in the 0-1 age group (see Table 5.3 on p. 49). Some of these children may have been mis-diagnosed as having ARI as the clinician may have been unwilling to confirm a diagnosis for asthma in such a young child. However, it was unlikely that underdiagnosis would account for such a dearth of African asthma admissions.

Evidence suggested by the high levels of asthma found on Tristan da Cunha points to genetic factors being important in the distribution of asthma (Lane and Storr 1987). Lane and Storr (1987) reason that climatic and socio-economic circumstances cannot alone induce asthma to those not inherently predisposed.

Several studies have indicated that the onset of asthma among various races occurs at different ages. Walls and Ordman (1983) noted that asthma started later in whites than in coloureds; 62% of allergic whites had developed asthma in the first decade of life compared with only 42% of coloureds. Two other studies, Louw (1967) and Lewis et al (1976), found that the mean age of onset for African asthmatics was found to be 32.5 years and 32.8 years respectively. Figure 5.11 shows the mean age of onset extracted from information supplied from the above two studies. The age of onset is highest from the 21-30 years age group onwards. Perhaps, asthma manifests itself only in the African population later in life.

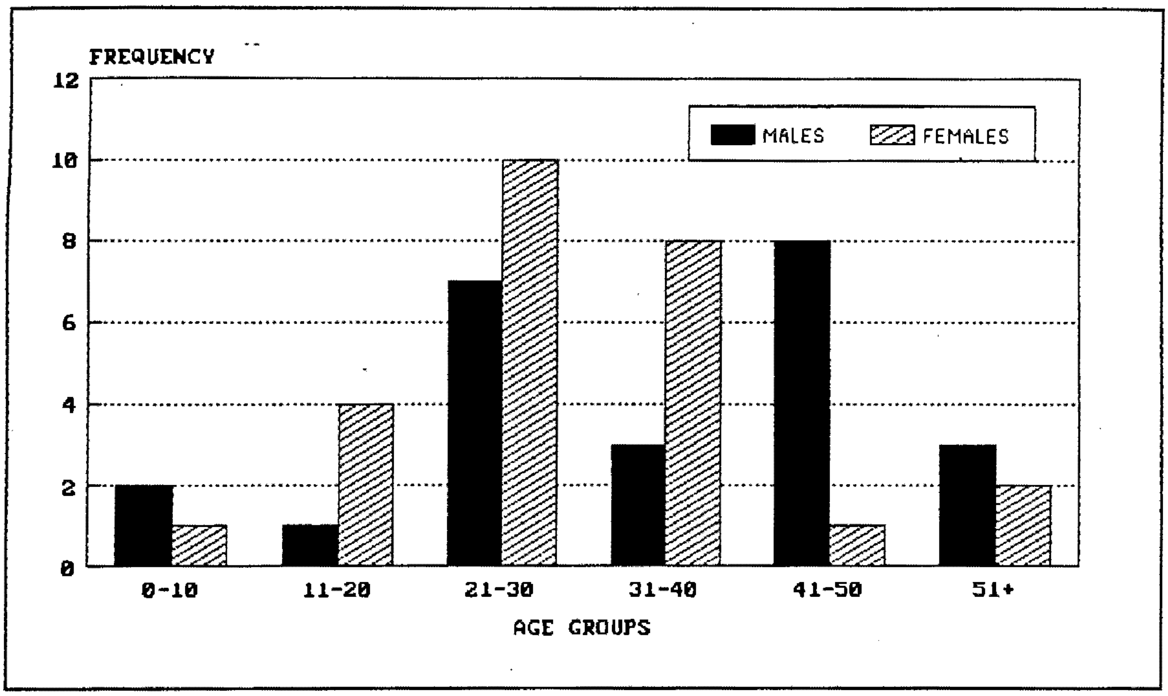

Figure 5.11 AGE OF ONSET FOR AFRICAN ASTHMATICS (Louw 1967; Lewis et al 1976)

In developed countries, several studies have shown that asthma is less prevalent among whites than among other races (Mak 1982; Bonner 1984; Evans et al 1987). The reasons for this racial difference were unclear. However, these studies were conducted on stable and well-established communities. Other studies have indicated that immigrant populations often had a higher incidence of asthma (Mitchell and Cutler 1984; Ayres 1986B). Several reasons for the higher levels of asthma were presented.

Ayres (1986B) thought the excess was mainly due to multifactorial reasons. Poor asthma education due to language problems and poor compliance with medication may have also been significant causes. Mitchell and Cutler (1984) argued that the excess could have been associated with environmental factors such as poor living conditions and lower socio-economic status. Environmental factors that are new to the recently immigrated population may predispose the child to contract asthma. However, in developing countries, it seems that the opposite is true, namely that the indigenous and often rural population experiences a low prevalence of asthma.

There have been several studies investigating the prevalence of asthma among African children in South Africa. Nearly all note the low levels of asthma among African children, especially those in the rural areas. For instance Van Niekerk et al (1977B) in a preliminary study of 700 rural and 700 urban African schoolchildren, noted that there was a low prevalence of asthma, especially in the rural children. Van Niekerk (1980), in an epidemiological study on the prevalence of asthma in children who had lived for over four years in a rural and an urban area, established that the point prevalence of childhood asthma from Guguletu (Cape Town) was much higher than in the rural district of Tsolo (Transkei).

Wesley et al (1969) found that the hospital incidence of asthma in African children in Durban was extremely low when compared with white and Asian children (only 5 cases in 5 years) (see Table 5.5). These African children came from comparatively "well-to-do" families with at least one parent of the professional class; all had been domiciled in the townships - none were from the rural areas.

Since the mid 1980s Cape Town has experienced a rapid influx of rural African migrants attracted to the city. Cookson (1987) argued that recent migrants to an urban environment may not be susceptible to the allergens present in the city which could have caused the child to suffer an asthma attack. Thus if their natural predisposition to asthma was low then it could be why so few African asthmatics presented to Red Cross Hospital.

It is likely that as the African population becomes established in the urban areas and children are born in the city, the incidence of asthma will rise. Wesley et al (1969) in a study on Durban asthmatics, speculated that as African children became exposed to socio-economic environments similar to their white and Asian contemporaries, more will present with asthma. It is clear that urbanisation plays a vital role in the spread of asthma (Lane and Storr 1987); and before this occurs it is important that the factors causing asthma in Cape Town be found.

Table 5.5 FEATURES OF CHILDHOOD ASTHMATICS ADMITTED TO TWO HOSPITALS IN DURBAN, SOUTH AFRICA, 1963-1967 (Wesley et al 1969).

	African	Indian	White
Total Number	11	73	62
Age of Onset:			
< 3 Years	5	40	40
> 3 Years	4	28	15
Unknown	2	5	7
Hospital Incidence (%)	0.02	0.77	0.79

Furthermore Joubert et al (1988, 150) speculated that "causative agents and complicating factors for allergic asthma could differ considerably between population groups, the recognition of which could influence therapeutic decision-making in patients of the Third World among whom little is known concerning etiological factors."

Asthma is a multifactorial disorder; and it is the summation of the effects of inheritance and environment that determines whether asthma will or will not be experienced (Lane and Storr 1987).

5.4 CONCLUSION

The use of hospital admission data in investigating patterns of respiratory illness is a good opportunity to expand the current knowledge of these illnesses.

Demographic patterns may be relatively easily determined; and in a changing society such as South Africa, information of this kind is becoming increasingly valuable. The chance of documenting racial differences and inequalities in the health care sector will become more and more difficult as racial classification of patients admitted to hospitals is no longer collected.

Furthermore, this section has highlighted certain areas that warrant further investigation: the male excess in asthma and ARI admissions, and the paucity of African asthmatics at Red Cross Hospital.

CHAPTER 6
RESULTS AND DISCUSSION OF RESPIRATORY ADMISSIONS AND ENVIRONMENTAL VARIABLES

6.1 INTRODUCTION

This chapter will present first the seasonal patterns of hospital admissions for childhood respiratory illness, air pollution, meteorological variables and aeroallergens. An analysis to determine whether there is a relationship between the hospital admission data and the various environmental variables follows.

6.2 THE IMPORTANCE OF SEASONALITY

Among the factors essential to an epidemiological investigation and understanding of any disease or condition is its temporal variation or seasonality (Goldstein and Currie 1984).

Seasonality, whether daily, weekly, monthly or yearly, warrants further research and often reveals an otherwise obscure disease aetiology (Goldstein and Currie 1984). For example, the onset of cold weather often brings with it a concomitant increase in ARI and chronic chest complaints. Pollens usually released by plants and trees during spring may trigger allergic reactions that could precipitate asthma attacks.

A wide variety of infectious and non-infectious diseases exhibits marked seasonality, and the determinants responsible for these distributions include natural and artificial components of the environment, and human behaviour (Goldstein and Currie 1984).

The seasonal increase in certain respiratory illnesses during the year, especially in autumn, have important implications in primary health care planning. More staff, beds and equipment may be needed to cope with the expected increase. Similarly, an understanding of the seasonality of various illnesses can forewarn susceptible individuals, and precautions taken to minimise the threat.

The attempt to compare seasonal patterns of respiratory admissions between countries is complicated as the majority of studies are conducted in the mid-latitudes of the northern hemisphere. These results are not often transferable to more temperate areas.

This is especially so in tropical areas where winters are milder than those in Europe or north America. These milder temperatures coupled with the need to burn less fuel may be one determining factor of why asthma patterns are different in various parts of the world.

For example Ayres (1986A) found that the attack rates for acute bronchitis in the United Kingdom show a consistent January-February (winter) peak and an August (summer) trough. If six months are added or subtracted to make the data comparable to the southern-hemisphere seasons a July-August (winter) peak and a February (summer) trough should occur.

Results of studies investigating the seasonality of respiratory illness are thus place specific, are not easily transferable and cannot be effectively used to predict patterns elsewhere. It is therefore important to study the unique patterns found in each region and city.

6.3 SEASONALITY OF RESPIRATORY ILLNESS

6.3.1 Asthma Admissions

While asthma is generally regarded as a seasonal disease, it can occur at any time during the year. Walls and Ordman (1983) in a study of asthmatics of all ages in Cape Town found that 52% of allergic asthmatics had perennial symptoms and 37% of them had symptoms all year round with seasonal exacerbations. However, it was the perennial allergic symptoms which predominated; and seasonal allergic symptoms were uncommon, despite the wealth of local flora and high levels of pollen in spring, with the worst seasons being from August to October (spring) and May to July (early winter). In New York (USA) Goldstein and Currie (1984) noted that the autumnal increase in asthma hospitals was due to a gradual increase in the total number of daily asthma emergency room visits, rather than an episodic increase in asthma epidemic days. Thus, although asthma has a seasonal pattern, it is also common throughout the year.

Figure 6.1 presents the monthly admission patterns for asthma at Red Cross Hospital and Tygerberg Hospital. The patterns between each hospital are remarkably similar to each other. Between 1988-1990 there was an inconsistent peak in the autumn (May). A number of factors could account for the autumn peak. Autumn usually heralds a change in weather patterns as well as an increase in air pollution associated with increased episodes of atmospheric stagnation which may precipitate and/or exacerbate asthma attacks. Respiratory infections increase in autumn, and coupled with renewed school attendance after the mid-term holiday, could account for an increase in infection-induced asthma (Gordis 1973). Furthermore, a summer of sensitisation by pollens, dust and warm weather may leave asthmatic patients more susceptible to the effects of the autumnal viral infections (Ayres 1986B). Other possible factors include changes in pollen count, resuspension in air of settled allergens in the home with the beginning of the heating season and increased prevalence of mould spores (Gordis 1973).

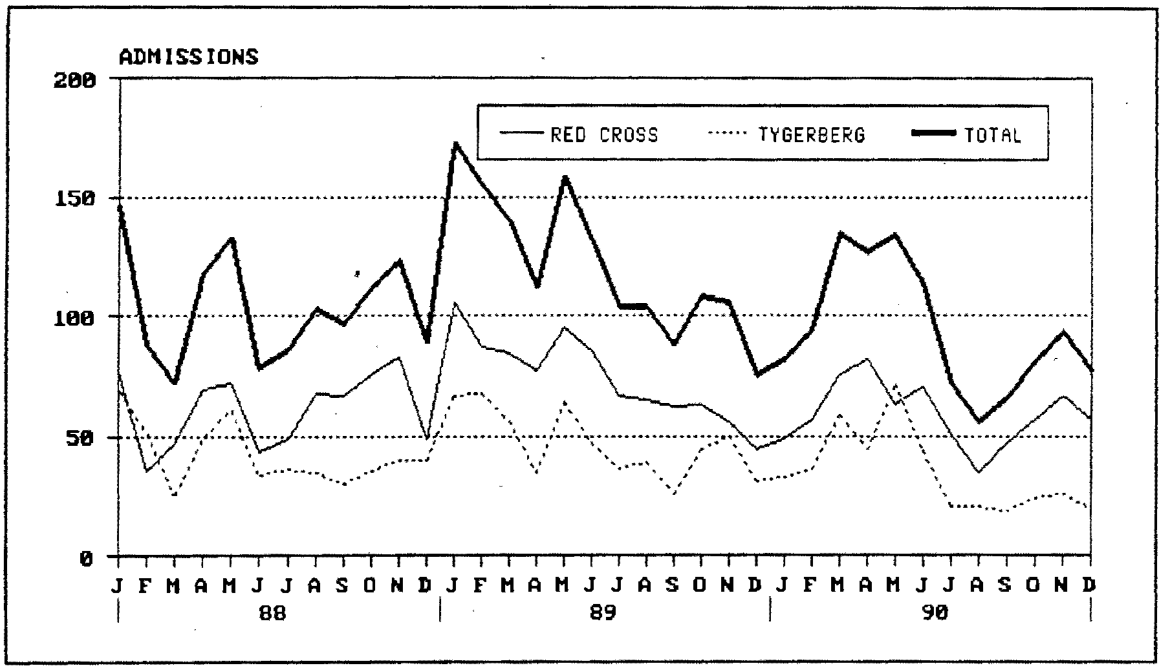

Figure 6.1 MONTHLY ASTHMA ADMISSIONS.

Figures 6.1 and 6.12 show that a second peak occurred later in the year during the spring months of October and November. It is believed that raised levels of aeroallergens in spring, especially pollens, may be the precipitant of asthma attacks (Ordman 1964).

These peaks were predicted by medical staff consulted during this study, as well as in the literature examining the seasonality of asthma attacks and admissions (Ehrlich 1992; Drs. L. Whitelock-Jones, M. Power and M. Klein, personal communication).

During January and February of 1988 and 1989, however, there was a further peak at both hospitals. The 1989 peak at Red Cross Hospital was the highest of any asthma peak during the study period. In 1990 this peak was absent from both hospitals. Figure 6.2 shows the monthly averages: and this peak may clearly be observed.

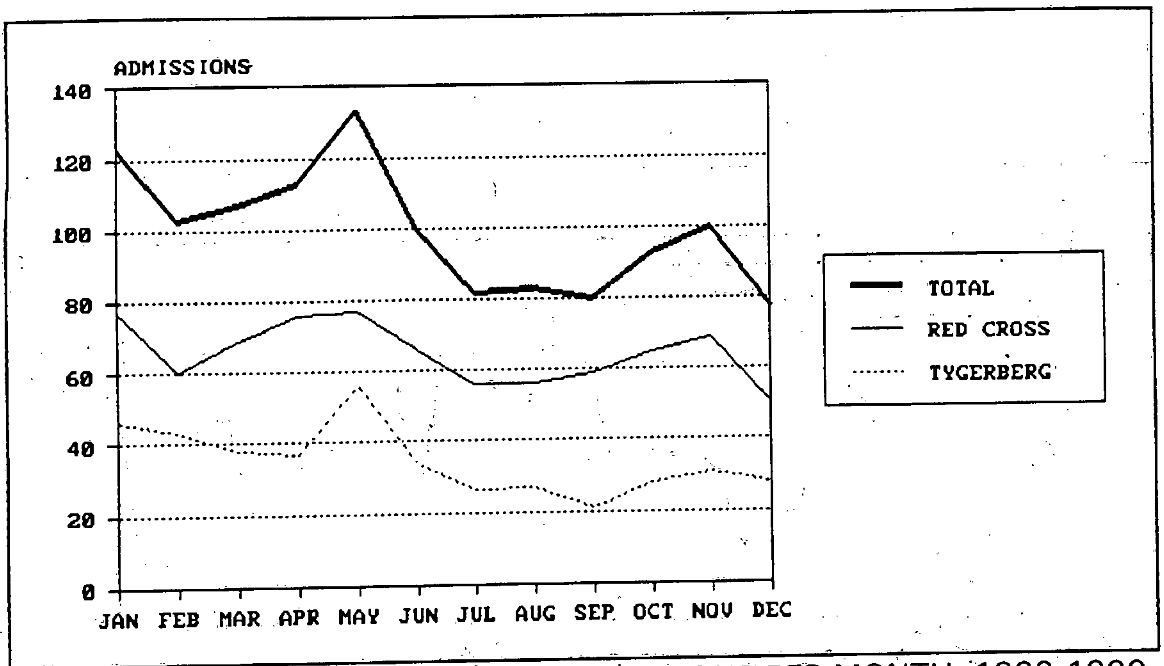

Figure 6.2 MEAN ASTHMA ADMISSIONS PER MONTH, 1988-1990.

Ehrlich (1992), examining admissions from 1984 to 1990, found that there was a more pronounced summer peak among the few African asthmatics that presented at Red Cross Hospital compared to coloured children. Figure 6.3 shows that when African asthmatics were separated from coloured admissions in this study, a discernable January peak in 1988 and 1989 was noted for both groups of children.

It is difficult to ascribe confidently what caused the January/February peak in 1988 and 1989 as the meteorological data does not exhibit any untoward characteristics during this period. However, Figures 6.11 and 6.12 (see p. 75) indicate that the production of the moulds *alternaria* and *cladosporum*, and grass pollens are elevated during January and December. Unfortunately, pollen counts covering this period were not available for this period.

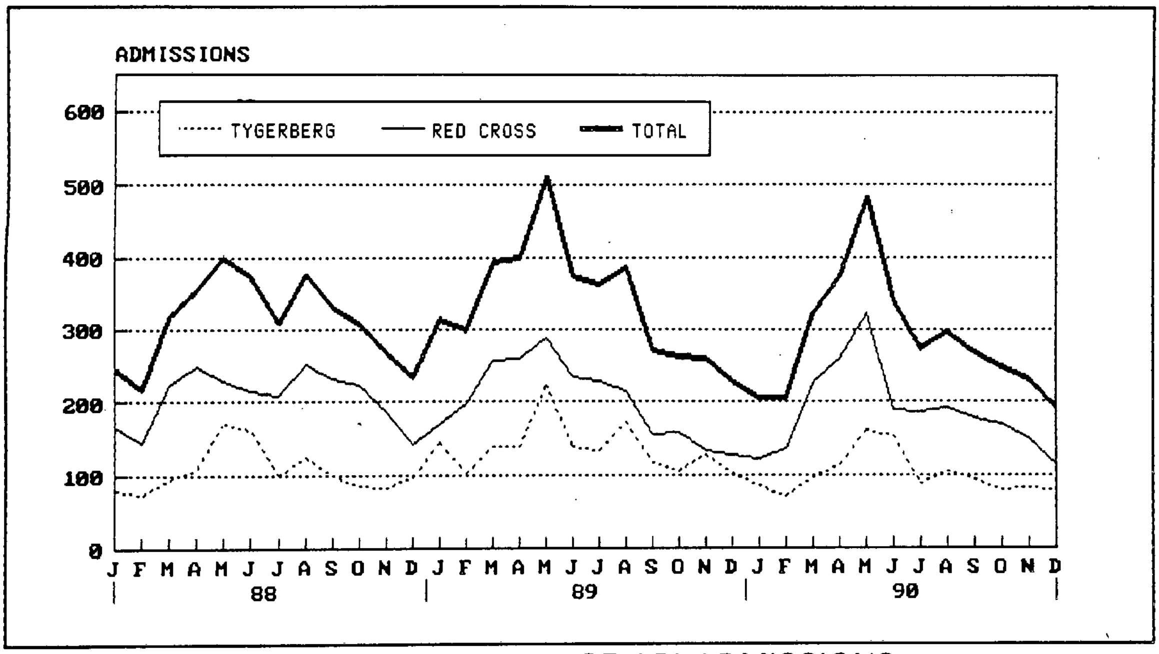

Figure 6.4 MONTHLY AVERAGE ARI ADMISSIONS.

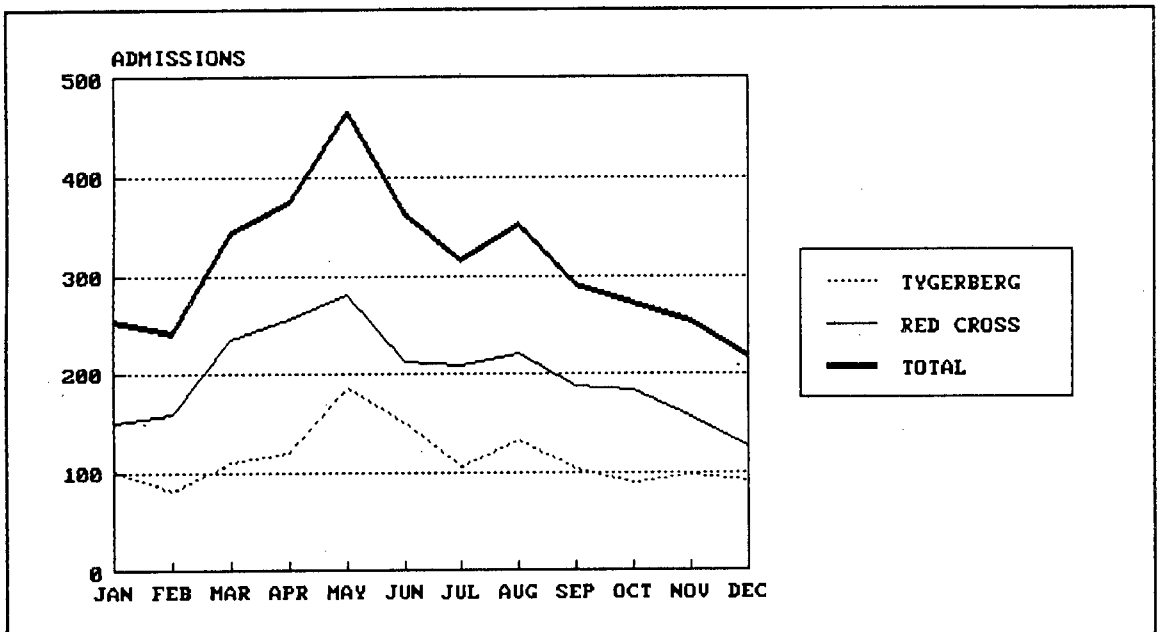

Figure 6.5 MEAN ARI ADMISSIONS PER MONTH, 1988-1990.

There are several possible reasons for the rapid increase in autumnal admissions. The forced intimacy of staying in an often poorly ventilated dwelling during the onset of inclement weather in autumn may facilitate the spreading of ARI more easily. Alternatively the colder weather may have a deleterious effect on the airways and lungs of people who breathe in the cold air, thus making them more prone to respiratory infection. High levels of tobacco smoke inside the dwellings probably also contribute to this increase in respiratory admissions. The increase in rainfall during autumn could also cause an increase of fungal moulds in the dwellings. Children living in damp houses, especially with these moulds present, have been shown to have higher rates of respiratory symptoms than those in drier homes (Platt et al 1989; Strachan 1988; Martin et al 1987).

However, if cold weather and winter conditions are important factors affecting the increase of ARI, then the number of admissions for ARI at both hospitals should continue to rise throughout winter. Figure 6.10 (see p. 74) shows that July is the coldest month and if temperature and/or other factors affect the incidence of ARI then levels should be increasing at least until July. In fact Figure 6.4 and Figure 6.5 show that admissions decrease in July before rising slightly in August.

The onset of the colder and wetter winter weather and related effects may initially have an adverse effect on respiratory health. As winter progresses the child may then become acclimatised to these changed environmental conditions. This suggests that the child is susceptible to *changes* in the environment rather than severity of conditions.

ARI is one of the most important categories of illnesses, not only because of its effects on infant morbidity, but because of the overwhelming effect on hospital admissions every autumn.

6.4 SEASONALITY OF AIR POLLUTANTS

Pollutants in the Cape Town area primarily originate from small industries and vehicular traffic (Jury et al 1989). The levels of air pollution in Cape Town have decreased rapidly since the early 1960s (Kemeny 1980). Thus it was not surprising to find that the concentrations of air pollution levels measured during the study period were relatively low (Table 6.1). The mean annual values for NO_x and SO_2 are well below the Department of Health Acceptable Levels of 376 $\mu g/m^3$ and 79 $\mu g/m^3$ respectively (Cape Town 1988).

Table 6.1 MEAN DAILY CONCENTRATIONS OF AMBIENT AIR POLLUTANTS IN CAPE TOWN, 1988-1990.

VARIABLE	MEAN	RANGE	SD
NO_x (City Hall) ($\mu g/m^3$)	214.9	49-1030	119.0
SO_2 (City Hall) ($\mu g/m^3$)	40.2	8-222	21.1
SO_2 (Bellville-South) ($\mu g/m^3$)	9.5	0-101	12.8
Soiling Index(Bellville-South) ($\mu g/m^3$)	20.6	0-113	18.3

However there are short periods, especially during temperature inversions in winter, where high air pollution levels are experienced. The highest recorded value for 24-hour mean level of NO_x does exceed the acceptable level of 750 $\mu g/m^3$; and there were seven days where these standards were exceeded during the study period.

It is also widely accepted that Cape Town has a photochemical air pollution problem (Dutkiewitz et al 1980; Smith 1984; Cape Town 1989/90, 1990/91, 1991; Eichhorn 1992; Liebenberg and Stander 1990, 1992). The occasional high pollution levels for NO_x during the study period, a constituent of photochemical smog, supports this view.

Instrumentation to record the data on key indicators of photochemical smog has been installed on a limited basis in Cape Town; but much more data are needed from different sites in the Western Cape.

Figure 6.6 shows the monthly averages for NO_x and SO_2 levels recorded at the City Hall fixed site monitor. NO_x displays a distinct seasonal pattern with peaks in May

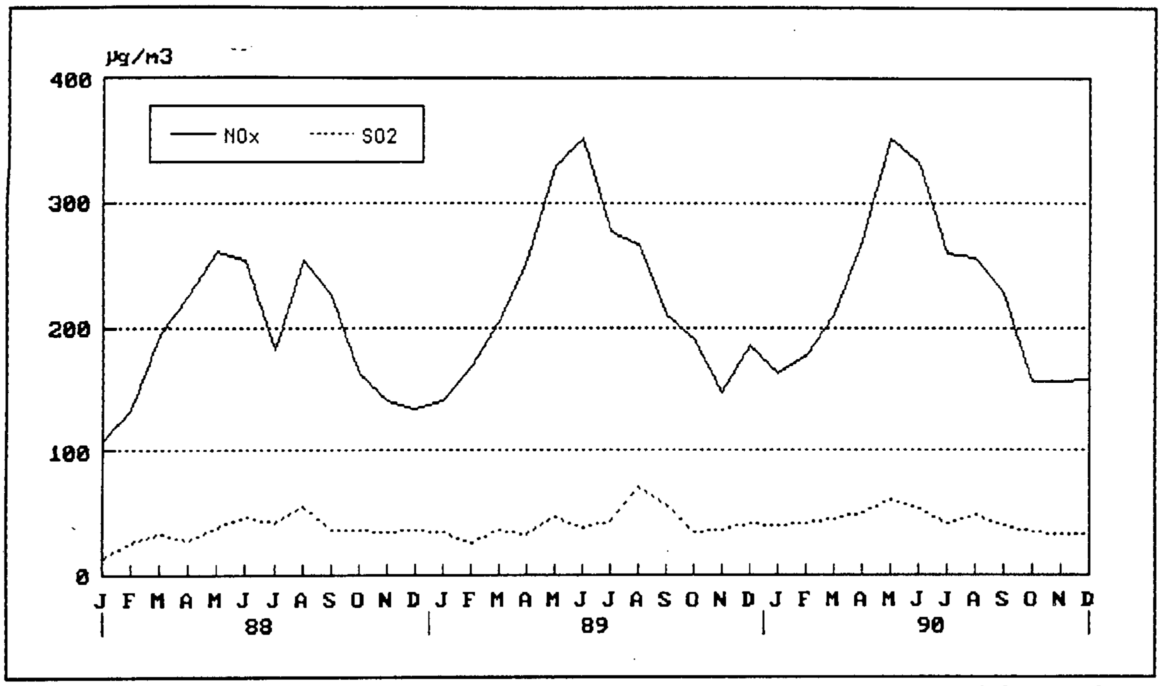

Figure 6.6 AVERAGE MONTHLY LEVELS OF NO_x AND SO_2, (BOTH CITY HALL MONITOR).

and June. 1988 had two peaks in May/June and again in September. The following two years levelled off during September before dropping (with a monthly low during mid-summer between November 1989 and January 1990). Although the graph depicting the monthly averages of SO_2 seems to peak later during August with smaller peaks in May-June, there is much less variation; and the levels are lower during the study period than those of NO_x although the use of one scale may obscure the variability.

Bellville-South is the closest air pollution monitor to the Cape Flats area where most of the children who attend the two hospitals live. Figure 6.7 shows the monthly averages of SO_2 and SI recorded from the Bellville-South fixed site SO_2 bubbler. The overall averages are much lower than the City Hall monitor - this is probably due to the less sensitive instrumentation used by the bubbler method.

Figure 6.7 indicates that the SO_2 peaks at the Bellville-South monitoring site show marked differences from those recorded at the City Hall. The peaks occur during the summer months (December to January). Only in August 1989 was there a small winter peak. The SO_2 levels in Cape Town do not follow the usual

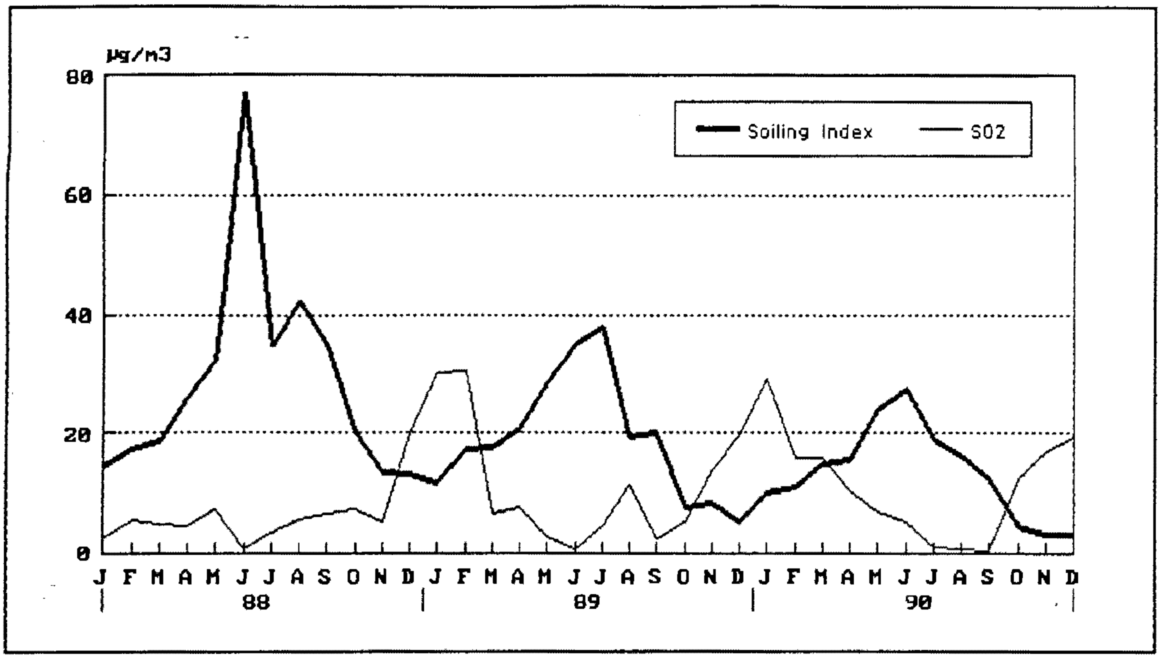

Figure 6.7 MONTHLY AVERAGES OF SO_2 AND SOILING INDEX (BOTH BELLVILLE-SOUTH MONITOR).

countrywide pattern of higher levels during the winter months (April to September) and lowest levels during summer (October to March) (Kemeny 1980). Dutkiewitz (1979, 10) noted that the summer peaks for SO_2 were the "exact opposite of every other city in the world for which SO_2 data is available." He reasons that this anomaly could not be explained by a seasonal change in wind pattern as the strong southerly winds experienced throughout summer would have dispersed any air pollutants. On the other hand, in autumn and winter there were frequent temperature inversions and calm periods, which resulted in air pollutants being trapped which exacerbated the pollution problem. Thus the winter months should have had higher SO_2 levels than during summer.

Dutkiewitz (1979) argues that two factors have a bearing on this phenomenon. Firstly, in most cities elsewhere in the world where air pollution is monitored (especially in the Northern Hemisphere), winter is associated with increased fuel consumption resulting in increased SO_2 production, together with an increase in the strength of inversion layers. He postulates that in Cape Town where winters are not as severe, an increase in fossil fuel consumption is not great and therefore air pollution levels are lower.

Secondly, Dutkiewitz (1979) noted that there is an inverse relationship between rainfall and SO_2 because SO_2 is absorbed by rain droplets to produce sulphurous acid. This, in the presence of dust, could result in sulphate precipitation and decrease the levels of SO_2 in the air. The presence of rain during the winter period could thus be a natural pollution control mechanism.

Soiling index on the other hand exhibits the expected pattern of a high mid-winter peak in June and July which is probably due to the increase in stability of the atmosphere in autumn/winter (Dutkiewitz 1979).

The environmental insults to community populations are thus a complex mix of pollutants and of meteorological conditions (Lebowitz 1983). The next section will present the patterns of the meteorological component of this study.

6.5 SEASONALITY OF METEOROLOGICAL VARIABLES

Jury et al (1989) note that Cape Town, at the south-west tip of the African continent, is located in an exposed coastal environment where pollutants can mix seawards. Although in winter, northwesterly winds and rain cleanse the air, they are followed by anti-cyclones that ridge eastwards over the southern Cape coast. Thus certain climatic conditions coupled with the sheltering effect of Table Mountain lead to the accumulation of atmospheric pollution in the City Centre and presumably in other parts of the Western Cape.

Table 6.2 shows the average values for the meteorological variables during the study period.

Table 6.2 MEAN DAILY VALUES OF METEOROLOGICAL VARIABLES IN CAPE TOWN, 1988-1990.

VARIABLE	MEAN	RANGE	SD
Relative Humidity (%)	75.4	15 - 98.5	10.9
Rainfall (mm)	1.6	0 - 49.8	4.7
Temperature (°C)	16.3	7.6 - 26.2	3.7
Minimum Temperature (°C)	11.4	-0.4 - +20.0	4.4

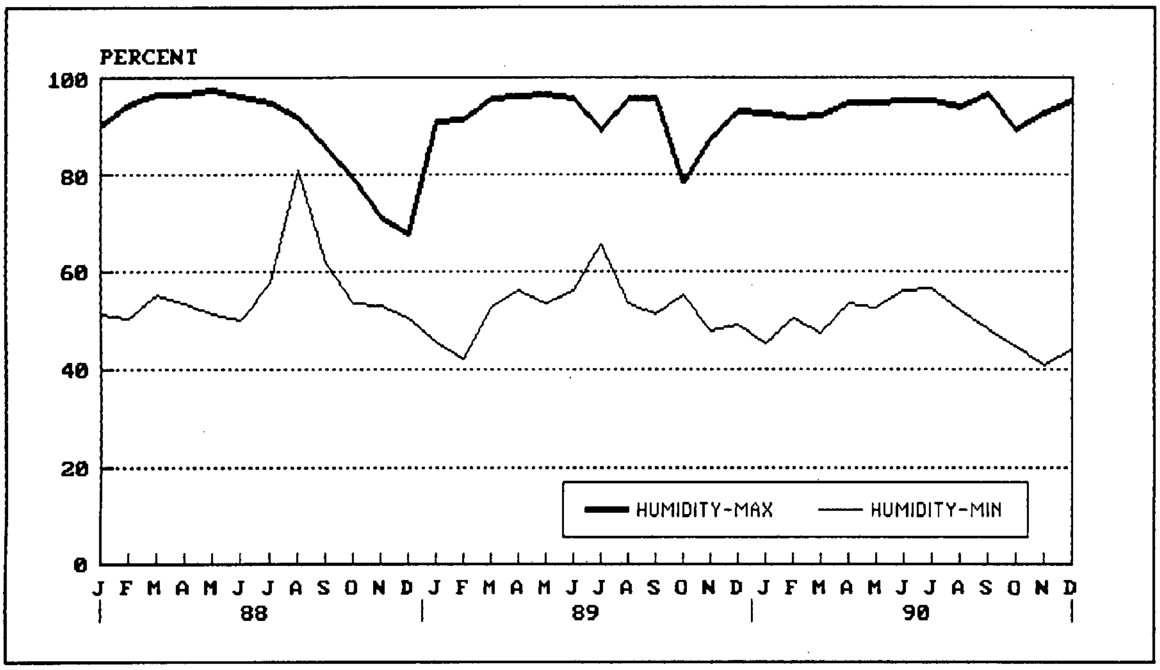

Figure 6.8 MONTHLY AVERAGES OF MAXIMUM AND MINIMUM RELATIVE HUMIDITY (D.F. MALAN AIRPORT WEATHER OFFICE).

Figures 6.8 - 6.10 show the seasonal patterns of selected meteorological variables. The seasonality of the variables shows no unexpected pattern; the winter months are characterised by colder, wetter, higher humidity than the summer ones.

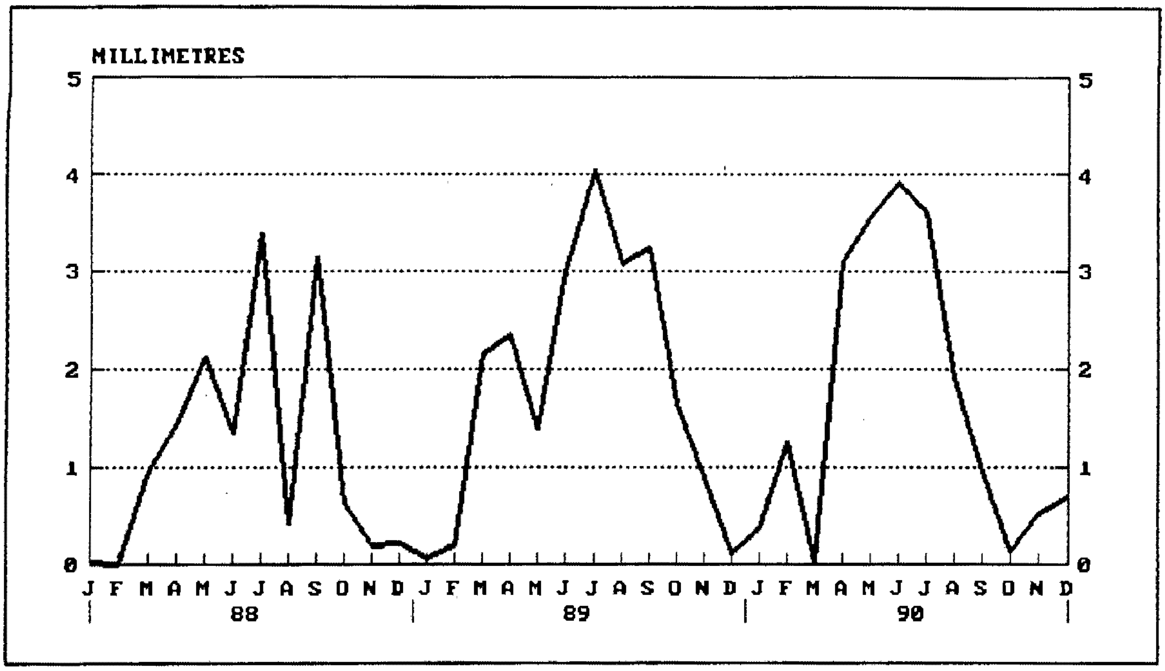

Figure 6.9 TOTAL MONTHLY RAINFALL (D.F. MALAN AIRPORT WEATHER STATION).

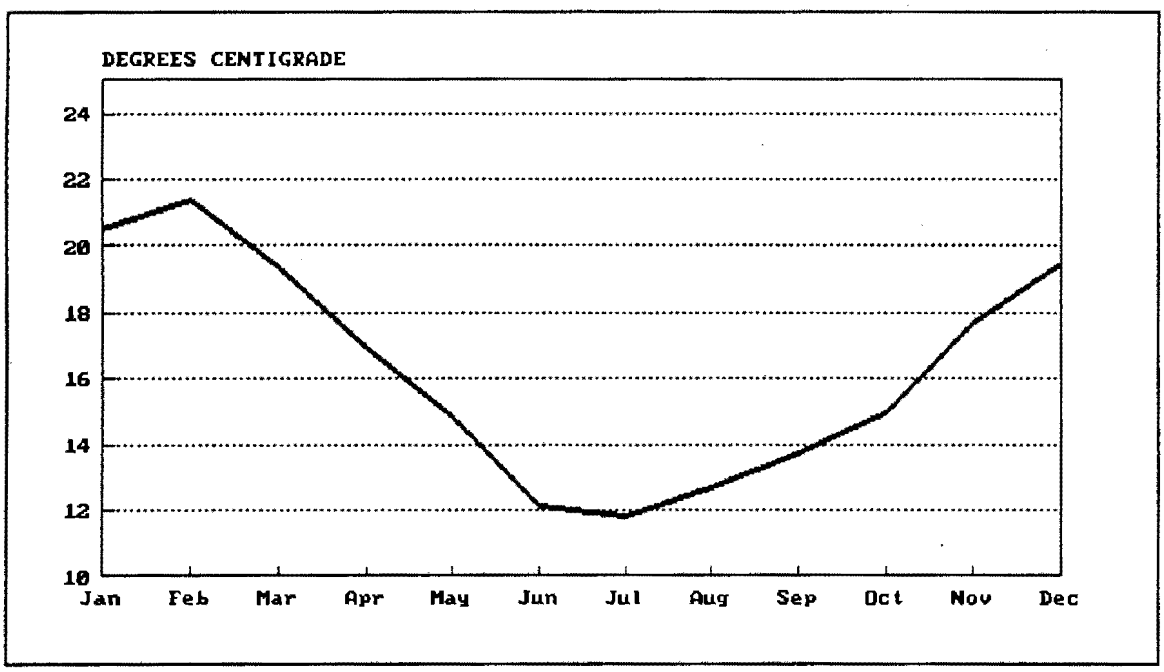

Figure 6.10 MEAN AVERAGE TEMPERATURE PER MONTH (D.F. MALAN AIRPORT WEATHER STATION), 1988-90.

6.6 SEASONALITY OF AEROALLERGENS

Figures 6.11 and 6.12 show the monthly averages for selected moulds and pollens in Cape Town. The moulds (Figure 6.11) seem to have two main peaks; a summer peak during February and March, and a spring peak in October and November. *Alternaria*, however, has a further peak in July. The seasonal pattern of pollens in Figure 6.12 clearly has a high spring peak beginning in September (for plane trees) and continuing until the end of the year for the grasses (peak in November and December) and weeds (peak in October). Furthermore, grasses had a further peak in February and the pollen count of weeds increased in January and February from a December low.

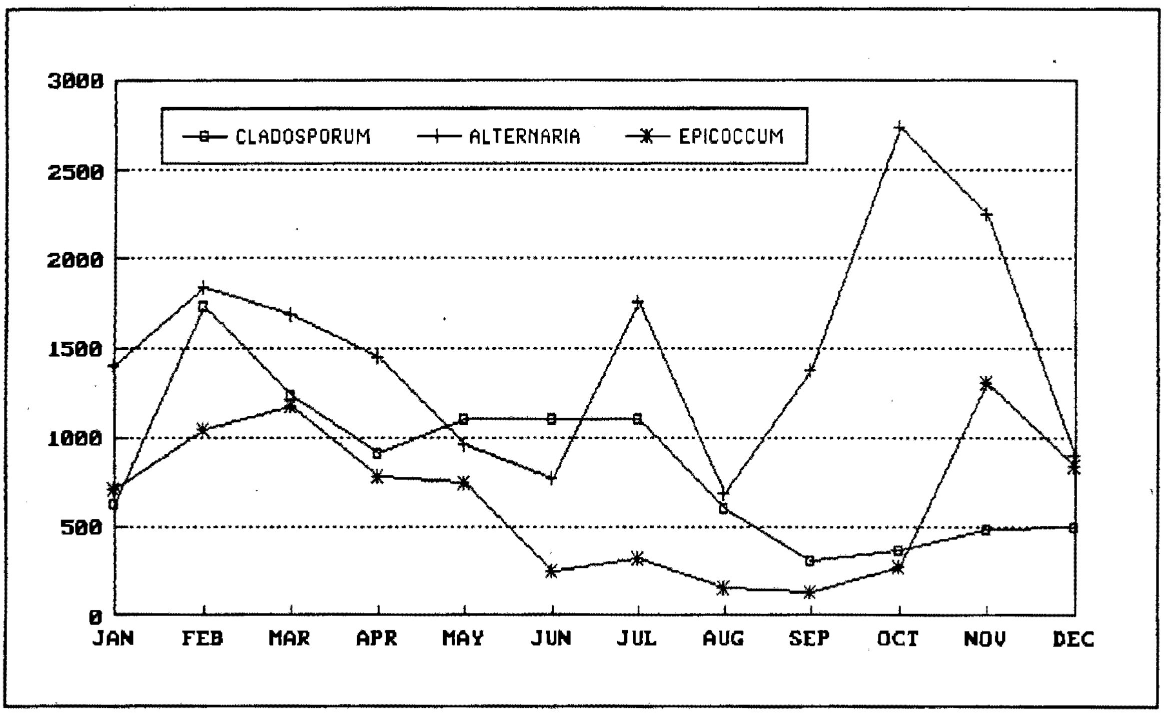

Figure 6.11 MEAN LEVELS FOR SELECTED MOULDS PER MONTH, 1984-1987.

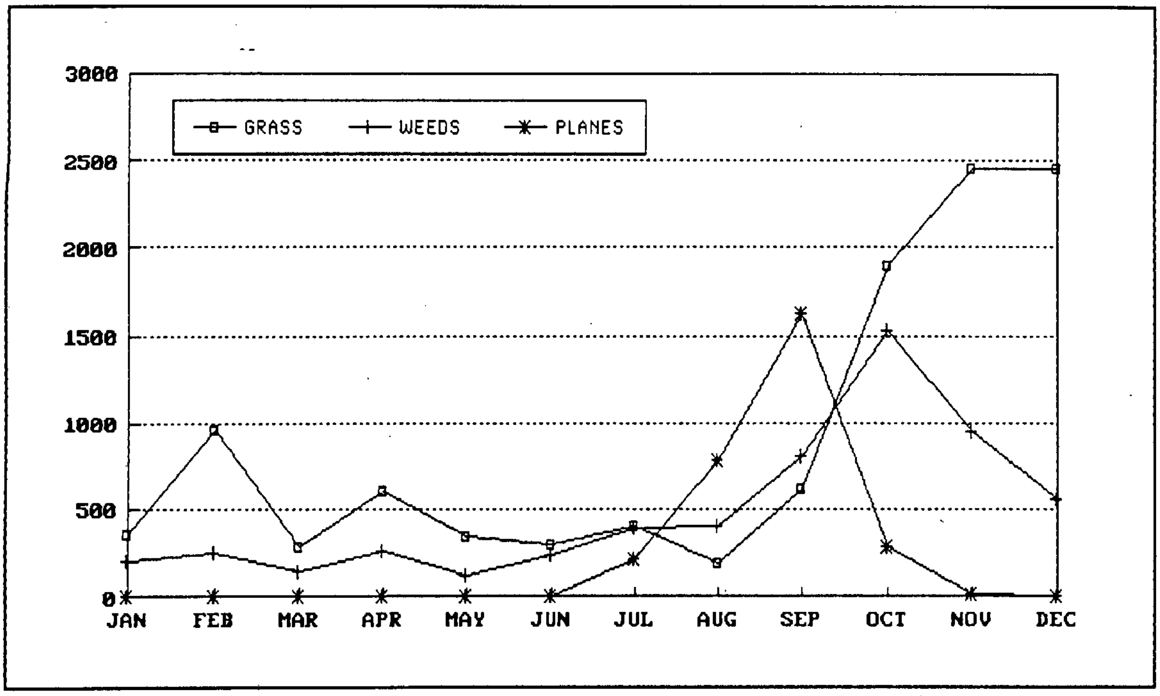

Figure 6.12 MEAN LEVELS FOR SELECTED POLLENS PER MONTH, 1984-1987.

6.7 CONCORDANCE BETWEEN RESPIRATORY ADMISSIONS AND ENVIRONMENTAL DATA

Environmental influences are interconnected; and over a long period it is unlikely given present levels of air pollution in Cape Town, that one specific environmental factor is responsible for any given respiratory disease. However, there are occasions during stagnant winter days when air pollution levels may reach high levels for a short period of time. These raised levels could cause or precipitate observable adverse health effects in susceptible groups.

6.7.1 Elevated NO_x Levels

Examination of the pollution data across the study period showed that there were occasions when air pollution levels were elevated. During these elevated periods there were seven occasions when the Department of Health Acceptable Levels 24-hour limit of 750 $\mu g/m^3$ for NO_x was exceeded during the study period. Of these, three were recorded in May 1990 and two in June 1990. Three and four day averages (ie twice-weekly) were calculated for NO_x and admissions for asthma, ARI and TA for the period 17 April 1990 to 14 July 1990. A plot of NO_x and admission data was made (Figure 6.13).

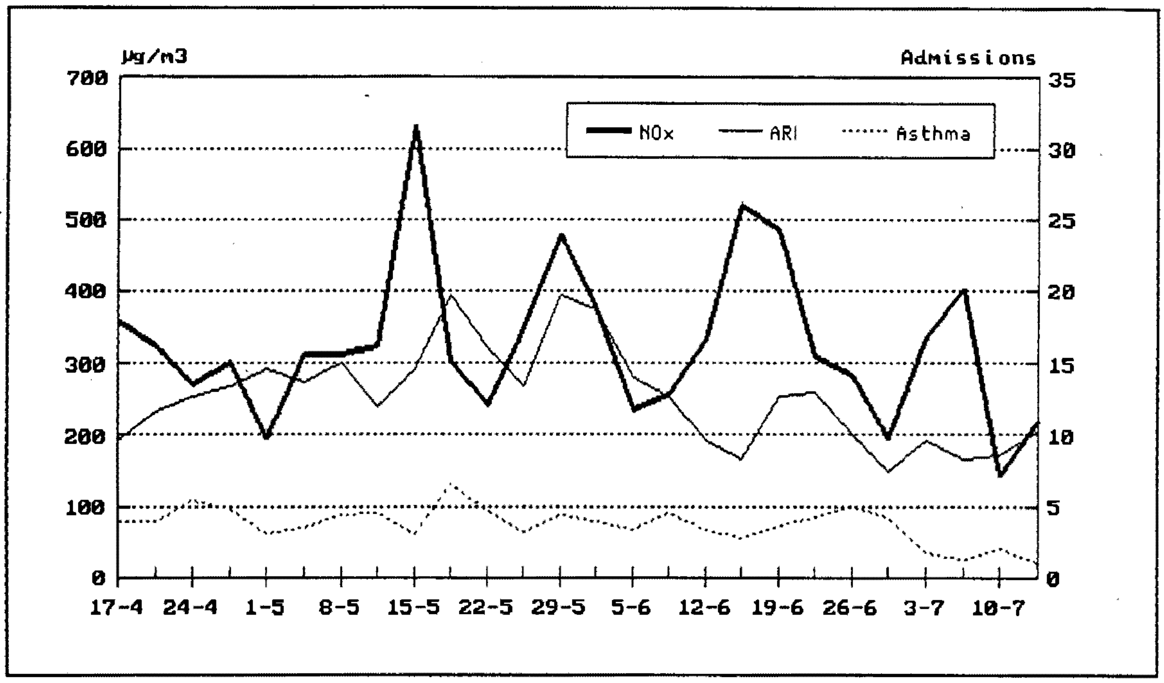

Figure 6.13 BI-WEEKLY PLOT OF NO_X (CITY HALL) AND HOSPITAL ADMISSIONS, 17 APRIL - 14 JULY, 1990.

From Figure 6.13 it can be seen that there were four separate NO_x peaks during this period. The first three peaks were related to the "high" pollution days on 14/15 May, 28 May and 13/19 June; and they clearly precede peaks in ARI admissions.

It thus seems that for periods where levels of NO_x exceed acceptable levels, there is a concomitant increase in hospital admissions for ARI up to three to seven days afterwards.

Conversely, a higher than normal level of hospital attendances for respiratory illness may indicate raised levels of air pollution or other abnormal environmental conditions.

6.7.2 Elevated Asthma Admissions

Between December 1988 and March 1989 both hospitals in this study had higher than normal levels of asthma admissions.

Environmental variables were plotted against the high levels of asthma admissions to determine whether there were any causal effects.

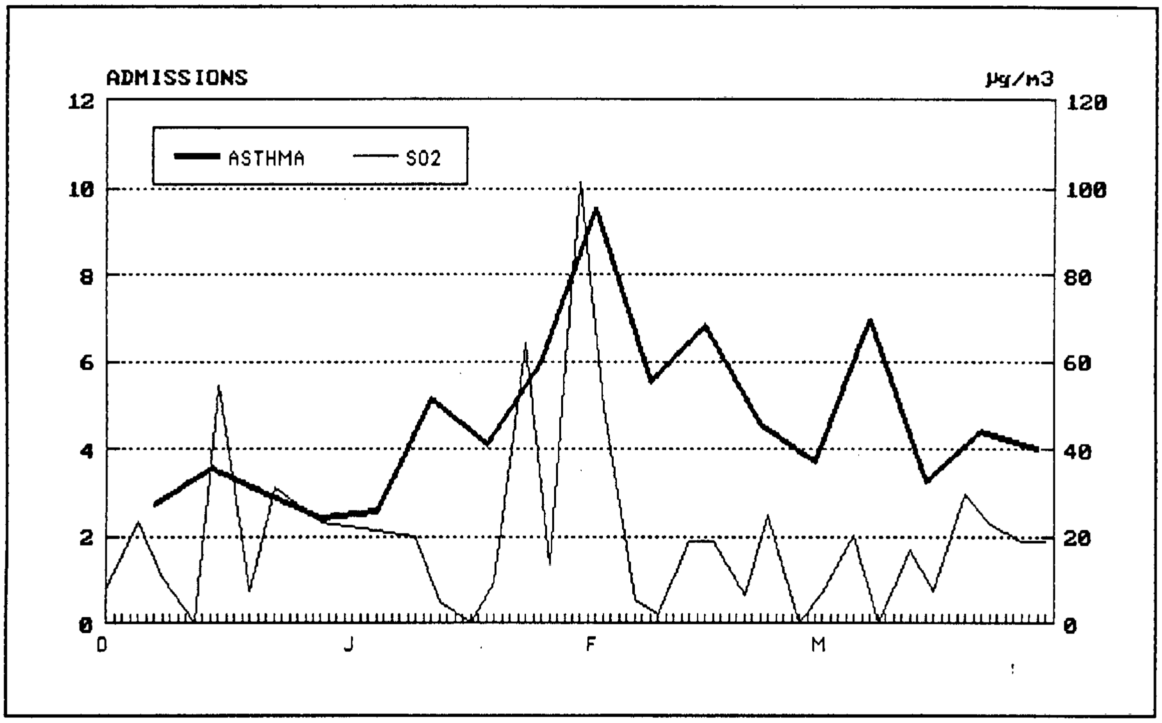

Figure 6.14 WEEKLY PLOT OF AVERAGE ASTHMA ADMISSIONS AND SO_2 (BELLVILLE-SOUTH MONITOR), DECEMBER 1988 TO MARCH 1989.

Three and four day averages were calculated; and a plot of asthma admissions and environmental variables was made for these four months. The only noteworthy result is shown in Figure 6.14. The bi-weekly averages comparing asthma with SO_2 levels measured at Bellville-South show that the high asthma days are preceded by high SO_2 levels three days earlier. This monitor is the only one situated near the catchment areas of the two hospitals.

This method of analysis is however, supplies only a crude visual first approximation of the relationship between hospital admissions and environmental variables over a very short period.

To determine whether there were any systematic relationships between these variables at the metropolitan level during the study period, an analysis using correlation and multiple linear regression was conducted.

6.8 THE RELATIONSHIP BETWEEN HOSPITAL ADMISSIONS AND ENVIRONMENTAL VARIABLES

All the data collected and used in this study were subject to seasonal variations. Such data, called time series, pose specific problems when attempting statistical analysis.

Most time series are subject to time related movements that violate the basic assumptions of regression analysis - the data points are not scattered around the regression line in a random manner, but usually contain a secular trend and cyclical variations (Ben-Horim and Levy 1981). Thus successive data points are not random observations but are related to the previous and following observations, as well as to the data points recorded at the same time in the preceding and following years (in the case of annual cycles). This is called autocorrelation, and precludes the use of simple regression techniques (Robertson and Lebowitz 1984; Stebbings 1978).

There are three main consequences of autocorrelated errors which lead to spurious relationships (Granger and Newbold 1974):

(A) Estimates of the regression coefficients are inaccurate;

(B) Forecasts based on the regression equations are sub-optimal;

(C) The usual significance tests on the coefficients are invalid.

The influence of autocorrelation on the data has to be removed before correlation analysis can be performed.

6.8.1 Correlation Analysis Between Admissions and Environmental Variables

To show the effects of autocorrelation, an initial correlation analysis was conducted on the original data. Simple regression techniques were used to correlate environmental variables with admissions for asthma, ARI and TA (Table 6.3).

Table 6.3 PEARSON PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN UNADJUSTED WEEKLY MEAN HOSPITAL ADMISSIONS AND AMBIENT ENVIRONMENTAL VARIABLES, 1988-1990.

	TA	ARI	Asthma
NO_x (City Hall)	.1225 (.1277)	**.5917** **(.0000)**	.1437 (.0735)
SO_2 (City Hall)	-.0182 (.8217)	**.2846** **(.0003)**	-.0664 (.4105)
SO_2 (Bellville-South)	.0569 (.4835)	**-.2218** **(.0057)**	**.1958** **(.0149)**
Soiling Index (Bellville-South)	**.2230** **(.0054)**	**.4434** **(.0000)**	.0416 (.6081)
Average Temperature	-.0019 (.9809)	**-.3230** **(.0000)**	**.1955** **(.0144)**
Minimum Temperature	-.0696 (.3879)	**-.3614** **(.0000)**	.1518 (.0586)
Relative Humidity	.0673 (.4035)	**.3559** **(.0000)**	-.0432 (.5920)
Rainfall	-.0603 (.4546)	**.1788** **(.0255)**	-.0435 (.5899)

Coefficient
(Significance)

Highly significant and sometimes strong positive and negative correlations were found between ARI and all environmental variables; the strongest being NO_x (City Hall) and SI (Bellville-South). Asthma was correlated with SO_2 (Bellville-South) and average temperature, while TA were correlated with SI (Bellville-South).

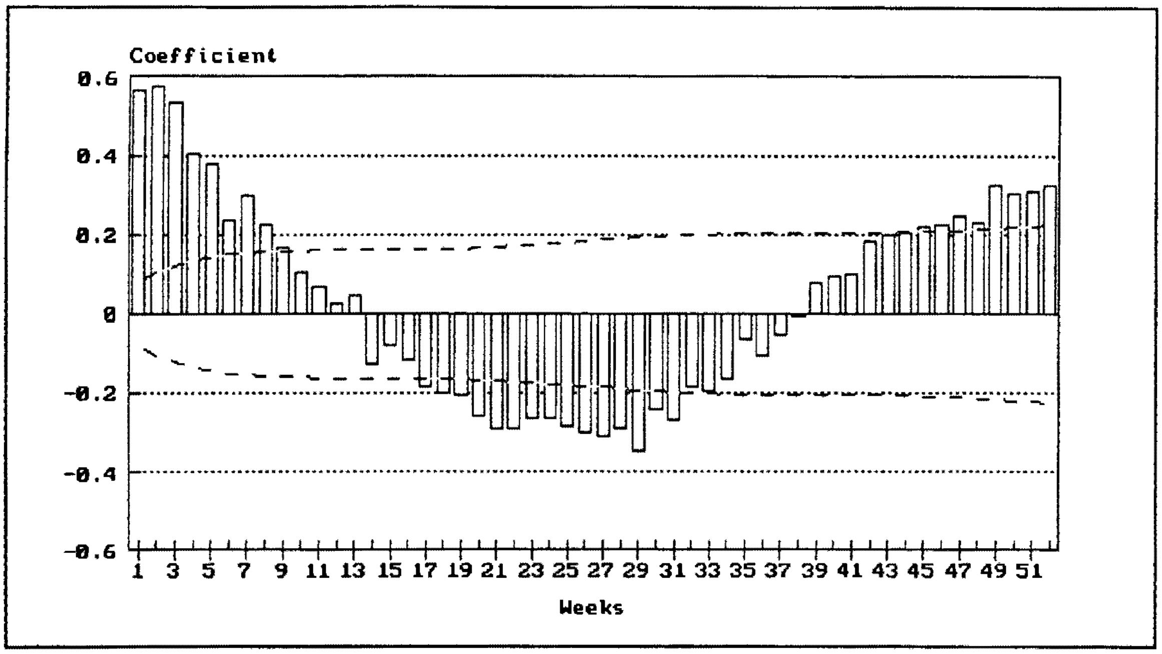

Figure 6.15 CORRELLELOGRAM SHOWING THE SEASONALITY OF NO_x (CITY HALL), 1988-1990.

The data were then adjusted to remove the trend and the effect of auto-correlation. What is left is a type of residual which is the difference between the observed value and the expected value. Figure 6.15 clearly shows the autocorrelation effect on NO_x measured by the City Hall monitor. The seasonality of the data over 52 weeks is clearly evident. If the data were not related to the previous or successive data points then the graph would assume the pattern in Figure 6.16 which has been seasonally adjusted by removal of auto-correlation.

The effect of removing the auto-correlation effect from the data results in a less uniform pattern evident in Figure 6.16. The significant data points protrude beyond the confidence intervals (dotted lines).

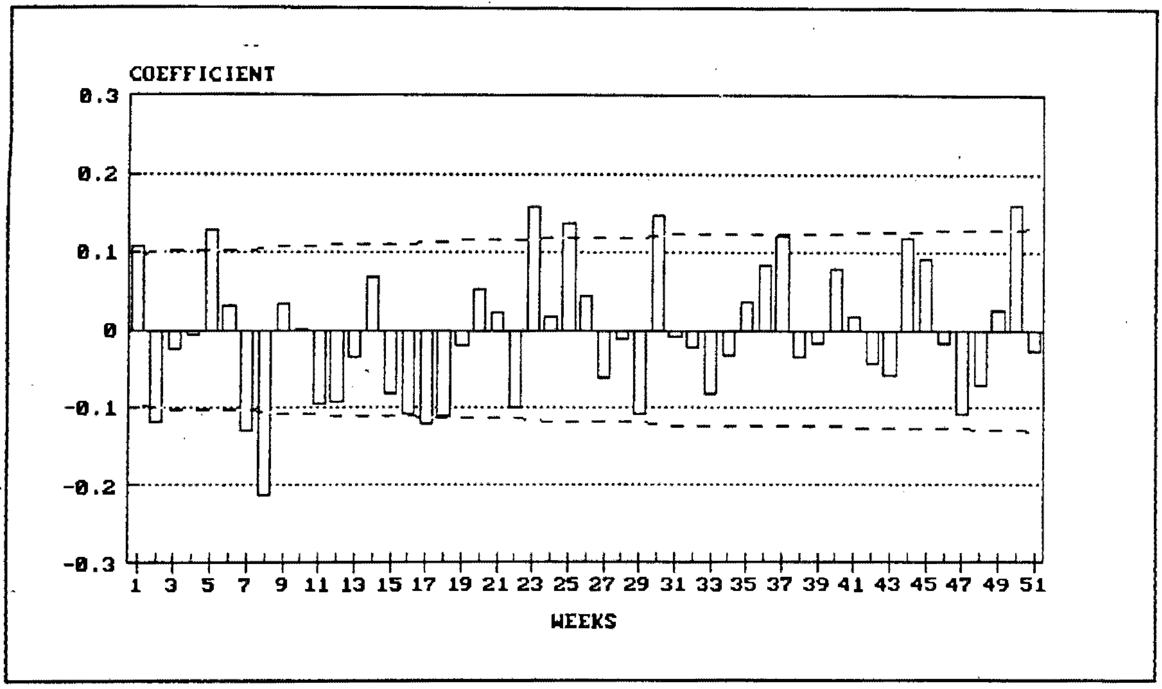

Figure 6.16 CORRELLELOGRAM SHOWING DESEASONALISED NO_x (CITY HALL), 1988-1990.

The correlation coefficients were again calculated (Table 6.4). The weakening effect of removing the autocorrelation and trend is clearly evident. ARI were still significantly positively and negatively correlated with five variables, the strongest being with NO_x. TA were significantly correlated with four variables, the strongest being SI (Bellville-South). Asthma is significantly correlated only with NO_x.

6.8.2 Multivariate Linear Regression Modelling Between Hospital Admissions and Environmental Variables

In order to remove the effect of *inter-correlation* multivariate linear regression modelling was used to determine the strength of each of the individual relationships, after controlling for the other environmental variables. The inter-relationship between the variables is thus removed from the model.

In order to use multivariate linear modelling, which is based on the assumption of normally distributed residuals, the distribution of the

Table 6.4 PEARSON PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN DESEASONALISED WEEKLY MEAN HOSPITAL ADMISSIONS AND AMBIENT ENVIRONMENTAL VARIABLES, 1988-1990.

	TA	ARI	Asthma
NO_x (City Hall)	.1124 (.1622)	.2792 (.0004)	.1824 (.0227)
SO_2 (City Hall)	-.0247 (.7596)	.1833 (.0220)	.0031 (.9698)
SO_2 (Bellville-South)	.1577 (.0493)	.1043 (.1950)	.1397 (.0820)
Soiling Index (Bellville-South)	.2639 (.0009)	.1321 (.1003)	-.0215 (.7895)
Average Temperature	.1891 (.0181)	.1625 (.0426)	.0705 (.3817)
Minimum Temperature	-.1113 (.1666)	-.1222 (.1287)	-.0589 (.4648)
Relative Humidity	-.0346 (.6683)	-.1847 (.0210)	-.1400 (.0814)
Rainfall	-.1978 (.0133)	-.1875 (.0191)	-.0771 (.3385)

Coefficient
(Significance)

deseasonalised data was investigated to determine whether the data followed the normal distribution. The deseasonalised data were compared to the normal distribution using the Kolmogorov-Smirnov One-sample Test (see Table 6.5). The results of this test showed that such data could be regarded as approximating to the normal distribution curve and that multiple linear regression modelling could be used. Multivariate linear regression analysis was thus conducted to determine the individual influences of air pollution and meteorological variables on admission data.

Table 6.5 THE GOODNESS OF FIT BETWEEN THE DISTRIBUTION FOR DESEASONALISED HOSPITAL ADMISSION DATA AND THE NORMAL DISTRIBUTION USING THE KOLMOGOROV-SMIRNOV ONE-SAMPLE TEST.

VARIABLE	SIGNIFICANCE
TA	0.9234
ARI	0.5730
Asthma	0.9087

Note: If the significance falls below 0.05, the two distributions (ie. the normal and the variable) are significantly different at $p<0.05$).

The results are presented in Table 6.6. After controlling for the individual effects of the environmental variables there were some significant (if poorly correlated) relationships.

The environmental variables associated with TA were average temperature, SI (Bellville-South) and minimum temperature. ARI was associated with average temperature, SI (Bellville-South) and NO_x (City Hall). The only significant environmental variable associated with asthma admissions was NO_x (City Hall).

The results of multiple regression analysis show that there were some significant relationships between various environmental variables and hospital admissions for childhood respiratory illnesses. Of especial interest were the effects of NO_x on ARI and asthma admissions; and SI (Bellville-South) on ARI admissions. Average temperature seems to play a role in influencing ARI admissions.

Table 6.7 translates the significant variables in Table 6.5 into useful values. For every increase by the predictive value of the independent variable (say NO_x or SI), so the dependant variable (admissions) increases by one unit per week. For instance an increase of 93.5 $\mu g/m^3$ per week in NO_x will increase ARI admissions by one patient per week. For asthma this increase is 192.3 $\mu g/m^3$ in NO_x. ARI admissions are thus more likely to be more responsive than asthma admissions to increases in NO_x.

Table 6.6 MULTIPLE LINEAR REGRESSION COEFFICIENTS FOR WEEKLY MEAN HOSPITAL ADMISSIONS AND AMBIENT ENVIRONMENTAL VARIABLES, 1988-1990.

	TA	ARI	Asthma
NO_x (City Hall)	.0123 (.1226)	**.0107** **(.0101)**	**.0052** **(.0334)**
SO_2 (City Hall)	-.0585 (.0537)	.0054 (.7293)	-.0145 (.1123)
SO_2 (Bellville-South)	.0352 (.2691)	-.0061 (.7112)	.0119 (.2158)
Soiling Index (Bellville-South)	**.0893** **(.0006)**	**.0293** **(.0279)**	-.0006 (.9376)
Average Temperature	**1.7854** **(.0001)**	**.6372** **(.0046)**	.0999 (.4420)
Minimum Temperature	**-1.0482** **(.0042)**	-.2840 (.1291)	-.0350 (.7485)
Relative Humidity	.0967 (.1107)	-.0286 (.3594)	-.0206 (.2606)
Rainfall	.0465 (.7923)	.0309 (.7349)	.0098 (.8553)
	Coefficient (Significance)		

Table 6.7 INCREMENTAL AVERAGE WEEKLY CHANGE IN INDEPENDENT VARIABLE PRODUCING ONE EXTRA ADMISSION PER WEEK.

	TA	ARI	Asthma
NO_x (City Hall)		93.5 $\mu g/m^3$	192.3 $\mu g/m^3$
Soiling Index (Bellville-South)	11.2 $\mu g/m^3$	34.1 $\mu g/m^3$	
Temperature	0.6 C°	1.0 C°	
Minimum Temperature	-1.0 C°		

6.9 CONCLUSION

The first section of this chapter presented and discussed the seasonal patterns of admissions and the ambient environmental variables that may have some effect on these admissions.

The second section, attempted to discern whether the ambient environmental variables were related to hospital admissions. Initially, "high" days in NO_x and then asthma were visually investigated. Tentative associations were noted between a "high" NO_x period and ARI admissions, and "high" asthma period and SO_2.

After controlling for the seasonal effects, a multivariate linear regression model was fitted to the data to remove the *inter-correlation* effect between the variables. Significant, if weakly correlated, associations were noted for several ambient environmental variables and admissions. The implications of these associations will be discussed in the following chapter.

CHAPTER 7
CONCLUSION

7.1 PATTERNS OF RESPIRATORY ILLNESS

This study has shown that routinely collected data obtained from the computerised records at two major hospitals can add to the knowledge of childhood respiratory illnesses in Cape Town. The admission patterns of these children have revealed some interesting results.

7.1.1 Male Excess in Asthma and Acute Respiratory Infections

A male predominance was found for both asthma and ARI admissions. However, both hospitals had an overall male excess for total paediatric admissions. The overall excess at Tygerberg Hospital was much lower than that at Red Cross Hospital. Thus it seems that the male predominance for asthma and ARI at Tygerberg Hospital was specific to respiratory disease, while at Red Cross Hospital, the male excess could have been due to the overall admission patterns.

Other studies have also noted a male predominance in paediatric male admissions for asthma, and to a lesser extent, ARI (Graham 1990). Thus the male excess in admissions found in this study is probably specific to respiratory disease.

The reasons for gender differences in the prevalence of respiratory illnesses are unclear. It seems likely that there may be a genetic predisposition that makes males more susceptible to respiratory illness (Woolcock 1987).

Gordis (1973) speculates that it is possible that (a) asthma in young girls is much milder and therefore goes unnoticed or at least unrecorded, or (b) asthma in young females may be a continuum of another condition in which known incidence is reduced by mortality - either before birth or early in life.

The suggested male excess in morbidity in childhood respiratory health warrants further investigation to determine whether it is caused by an overall male excess in total admissions, or whether it reflects something specific to respiratory diseases.

7.1.2 The Paucity of African Asthmatics

A paucity of African asthmatics was found at Red Cross Hospital and was discussed at length in Chapter 5. Other studies have detected few African asthmatics in South Africa (Wesley et al 1969; Van Niekerk et al 1977A; Van Niekerk et al 1977B; Van Niekerk 1980; Walls and Ordman 1983) and, indeed, in the rest of Africa (Cookson 1987).

Unlike Tygerberg Hospital, access to Red Cross Hospital by the African population is relatively easy as the hospital is situated near to several major and well serviced transport routes (Walls and Ordman 1983). The large numbers of African children who presented for ARI accord with the fact that the hospital is well utilised by the African population. The under-representation of African asthmatics can therefore be regarded as an accurate reflection of the admission patterns at Red Cross Hospital.

It is suggested that asthma may manifest itself in the African population only later in life. (Louw 1967; Lewis et al 1976; Van Niekerk 1980). This would result in fewer African childhood admissions for asthma.

Furthermore, it seems likely that there is some genetic or environmental factor that protects African children from contracting asthma during the first decade of life (Orren 1973; Van Niekerk 1980). This is especially so in children from rural areas (Wesley et al 1969; Van Niekerk 1980). It might be that the African child who did not grow up in a metropolitan area lacks some exposure that is critical for developing asthma (Wesley 1969; Cookson 1987).

It is likely that in the future, as more African children are born in the metropolitan areas, there may be an increase in asthma which could place a significant demand on the health services in the city. This would have a worsening impact on the services provided by the already overcrowded and under-financed hospitals and clinics which serve the African population.

It is therefore important to pursue this aspect further, for instance, by a study comparing the incidence and prevalence of asthma between African children born in Cape Town and those who have recently migrated from rural areas.

7.2 RELATIONSHIP OF HOSPITAL ADMISSIONS TO AMBIENT ENVIRONMENTAL VARIABLES

7.2.1 Visual Concordance Between Admissions and Ambient Environmental Variables

On inspection of graphed data there seemed to be a relationship between ARI and peak levels of NO_x at the City Hall monitor. Furthermore, an asthma peak seemed to be preceded by SO_2 peaks measured at Bellville-South.

An analysis of this kind seeks to find tentative relationships between admission data and environmental variables by examining short periods where unusually high levels of admissions or environmental variables are detected. After identifying such periods, and plotting the data, it is readily evident whether there is a concomitant rise in admissions for ARI or asthma after high levels of environmental variables; or whether the high asthma peaks are preceded by a peak in an environmental variable.

Unfortunately, the analysis is only visual, and the eye may be selectively mislead by the desire to find a pattern.

Short-term increases in air pollution during winter may be increasing in intensity and frequency (Baillie et al 1993). This method of analysis may be useful in investigating such possible effects of short-term exacerbations of air pollution, or the possible cause of short-term increases in respiratory morbidity.

7.2.2 Correlations between Admissions and Ambient Environmental Variables

An analysis at the metropolitan level demonstrated that the air pollution and meteorological variables investigated in this study were associated with respiratory admissions of children.

In this study, after controlling for autocorrelation, significant, if weakly correlated, relationships were found between hospital admissions and all the variables except minimum temperature. A multiple linear regression model was fitted to the deseasonalised data to determine the independent effects of the environmental variables. Significant values were obtained for NO_x, Soiling Index, and both average and minimum temperature.

i) NO_x

Both ARI and asthma admissions were significantly associated with NO_x. NO_x is comprised of nitrogen dioxide (NO_2) and nitric oxide (NO) (World Health Organisation 1972). NO is emitted by both motor vehicles and stationary combustion sources, while NO_2 originates in chemical and nitration industries and occurs in conjunction with the photochemical oxidant process (World Health Organisation 1972). Most studies have focused on NO_2.

NO_2 is an oxidant gas that contaminates ambient air in many urban locations and indoor air in homes with combustion appliances (Samet 1989). The results of most experimental studies investigating the health effects of NO_2 are negative (Abramson and Voigt 1991). However, exposure to NO_2 in outdoor and indoor air might increase the occurrence of respiratory infection as it reduces the efficacy of lung defense mechanisms (Samet 1989). Furthermore, epidemiological investigations have found associations between elevated levels of NO_2 and acute respiratory symptoms and impaired lung function (Abramson and Voigt 1991).

NO_x data used in this study was measured in the Central Business District of Cape Town. This monitor is approximately 6.5 km from Red Cross Hospital and 14 km from Tygerberg Hospital. The catchment areas of these hospitals, especially Red Cross Hospital, may be situated much further away. The levels of NO_x may thus not be representative of the major catchment areas of both hospitals. Goldstein and Landovitz (1977A) noted that the procedure of using one monitoring station to represent the daily fluctuations of air pollution risks the use of an unreliable or invalid measure of the short-term variation in air pollution. Even if the monitors were to be more significantly placed, one monitor is seldom sufficient to represent the area surrounding it (Goldstein and Landovitz 1977B).

Furthermore, the long-term levels of NO_x in Cape Town are well below the Department of Health Guidelines. However, Shy (1989) has argued that the air pollution levels of the 1980s could produce detrimental health effects in an exposed population even though exposures were usually held below established air quality standards. The adverse health effects may be difficult to detect. Thus, the low levels of air pollution do not mean that there is no adverse health effect on respiratory illness. Furthermore, levels of NO_x seem to be rising in the Cape Town metropolitan area (Baillie et al 1983).

However, there are few studies which indicate that NO2 alone, at the levels of noted in this study, could adversely effect human health. Although a significant association was found, NO_2 may have been acting as a surrogate for other unmeasured pollutants.

Despite the non-representative location of air pollution monitors with respect to the catchment areas of the two hospitals, and despite the fact that levels of NO_x were usually held below the recommended guidelines, this study found that there was a significant relationship between NO_x and both ARI and asthma admissions.

These results suggest that present levels of air pollution may be affecting the respiratory health of young children living on the Cape Flats and the Northern Suburbs. If levels in Cape Town continue to rise, and if short-term air pollution episodes increase in number and severity, there may be further threats posed to the respiratory health of its inhabitants.

ii) Soiling Index

ARI and TA were significantly associated with Soiling Index. Soiling Index is often referred to as "suspended particulates" or "particulate matter" and is often presented in conjunction with data on sulphur oxides in other studies. There are several different forms of particulate matter; and their effects on health are determined not only by dose (concentration) but also by their chemical composition and physical form (World Health Organisation 1972).

Ferris (1978) noted several studies investigating the health effects of suspended particles on children. At levels as low as 93 $\mu g/m^3$ children experience a decrease in lung function; at 180 $\mu g/m^3$, increased respiratory illness and further decreases in lung function were experienced. Ware et al (1986) found that, for children, exposure to moderately elevated concentrations of pollutants believed to be representative of emissions from combustion of fossil fuels (especially fine particle concentrations) increases risk for bronchitis and other respiratory disorders.

It seems that most monitoring sites in Cape Town were often initially selected for regulatory purposes, rather than for estimating the exposure of the population. The Bellville-South monitor is no exception. It is located in a mixed-use area mostly comprised of light industry with a small coloured residential area adjacent, about 5 km from Tygerberg Hospital.

Although it is more favourably sited for this study than other monitors in Cape Town it is still not representative of the catchment area of all but the small residential area adjacent to the site (Goldstein and Landovitz 1977B).

It is also unlikely that the data gathered at this station has been cross-checked by placing a second monitor near the original one. The data recorded from this monitor may not be an accurate reflection of the true levels of air pollution at the site.

The levels of Soiling Index in metropolitan Cape Town are generally low when compared to other studies. High levels may be reached on occasions during winter temperature inversions. However, data is collected only twice per week which could lead to masking of potential short-term periods of high levels of particulate matter. Furthermore, no monitor is located near the informal settlement areas which may have high levels of particulate matter due to the burning of paraffin, wood and refuse.

Shy (1989) notes that the aggregation of data can mask short-term episodes and other major influences on variations in respiratory morbidity, such as season of respiratory epidemics, and can swamp a minor effect of air pollution. Epidemiological methods may lose sensitivity at low levels of exposure; and it may thus be difficult to determine any adverse health effects even among susceptible sub-groups such as asthmatics (Samet 1985).

Despite the above problems, significant associations were found between Soiling Index and both ARI an TA.

iii) Temperature

Mean weekly temperature had a significant *positive* association with TA and ARI, while minimum temperature had a significant negative association with for TA.

Significant positive and negative correlations between temperature and admissions for respiratory illnesses have been found in several studies (Richards et al 1981; Bates and Sizto 1983; Bates et al 1990; Beer et al 1991). However, it is normally asthmatics who are most responsive to temperature variations (Whittemore and Korn 1980; Wagner et al 1983).

The negative association between TA and minimum temperature was expected as admissions are much higher in winter when minimum temperatures are lower. Increases in ARI admissions are generally regarded as the driving force behind the increase in TA as they comprise about 40% of admissions.

The *positive* association between both ARI and TA, and average weekly temperature (ie. when temperature increases, so do ARI and TA) may have been due to high levels of air pollution during inversion periods. Warm air near the ground is trapped by cold air above it, this, coupled with very little wind, means that the temperature would have been warmer. Thus during high pollution days, due to temperature inversions, one might expect a rise in respiratory admissions. Furthermore, on colder days, there may have been some reluctance to attend both hospitals.

Temperature was the only meteorological variable that was significantly associated with admissions. While the meteorological variables should exhibit less variation than air pollution in metropolitan Cape Town, there are different micro-climates, each of which may have an effect on the city's inhabitants and the level of pollutants in the air (Keen 1979). Temperature may be the more consistent variable, better than precipitation, which is dependent on relief, over the metropolitan area. The other meteorological variables such as relative humidity and precipitation may exhibit greater variation with regard to individual micro-climate and should thus be measured closer to the catchment areas of the two hospitals.

The above findings have implications regarding the understanding of respiratory health patterns of children residing in the poorer areas of Cape Town. However, it is useful to evaluate these findings with regard to potential factors which could have effected the results.

7.3 POSSIBLE SOURCES OF BIAS OR ERROR IN THE DATA

7.3.1 Chance

The distinction between medical and statistical significance needs to be stated when discussing whether the results obtained in this study occurred by chance. An investigator uses statistical significance testing to quantify the likelihood that association between exposure and effect occurred by chance alone (Samet 1985). Data from a large study population, analyzed with sophisticated techniques, may yield statistically significant effects of small magnitude that cannot be readily interpreted biologically (Samet 1985). Conversely, large effects of clinical importance may not be statistically significant if the study population is too small.

Given the large sample sizes (7 827 individual admissions), and the fact that after statistical analysis, the results were significant at the $p<0.05$ level, statistical chance can be eliminated from this study.

However, judgements concerning medical significance should be based on the magnitude of the effect and not the level of statistical significance (Samet 1985).

7.3.2 Confounding Variables

Confounding effects occur as a bias resulting from an unbalanced distribution of other causes among the study population. These confounding variables (such as tobacco smoke, allergies and indoor air pollution) may affect the study population and could either increase or diminish the association with ambient environmental variables.

For a factor to be a confounder, it has to operate on both the dependent and independent variables. Thus, in an investigation into the effects on respiratory health of possible confounding factors, there would also have to be a correlation between the potential confounders and both ambient environmental variables and admissions.

For instance, for indoor air pollution to have a confounding effect on the outcome, there would have to be an association with both hospital admissions and ambient environmental factors.

Indoor air pollution, including tobacco smoke, have been found to be one of the most important confounders when investigating the respiratory health of children (Samet et al 1987; Stephens and Harpham 1992). Passive smoking, NO_2 from gas cooking/heating and smoke from biomass fuels have been the subject of extensive epidemiological studies. All have been shown to be significantly associated with ARI (Graham 1990). Nevertheless, it is tobacco smoke that is probably the most important pollutant of human airways (Leeder et al 1976A; Kerrebijn 1986; Murray and Morrison 1988). Kossove (1982) noted, however, that wood smoke was a potent risk factor in the development of severe respiratory tract infections in infants in South Africa.

Overcrowding and poor housing conditions are also important factors in the exacerbation and spread of respiratory illnesses among children (Kossove 1982; Martin et al 1987; Platt et al 1989). As respiratory infections are infectious diseases, general conditions of over-crowding favour their propagation (Graham 1990). Damp housing conditions exacerbate and may cause the onset of asthma attacks (Martin et al 1987; Platt et al 1989).

In this study of coloured and African children living in the Cape Flats area in Cape Town, there is are large differences in the type of housing and urban environments. Most of the coloured children would have come from formally constructed electrified homes. Cooking would have been on an electric stove or gas cooker. The majority of African children, however, would have lived in unelectrified informal settlements. Cooking and heating would have been on paraffin or wood-burning stoves. There is thus no neat homogenous background from which all the children in this study would have emanated.

The home environment may have influenced the child's respiratory health, but given the paucity of studies investigating this problem in the Western Cape, such information could not be included in this study.

Viruses are among the most common stimuli of asthmatic attacks, and have been associated with up to 40% of wheezing episodes (Kerrebijn 1986). Leeder et al (1976A) found that the most important determinant of respiratory illness in infants was an attack of bronchitis or pneumonia in a sibling. Furthermore, overcrowding will have an effect on the spread of viruses between members of the household (Graham 1990).

Allergies caused by the inhalation of an antigen, to which a subject has made specific IgE antibodies, are one of the major trigger factors for asthmatic attacks (Kerrebijn 1986). Viral infections increase the susceptibility of asthmatic sufferers to allergies (Kerrebijn 1986). Antigens may be produced by mould growth in damp houses, house-dust mites, household pets, pollen, as well as certain foods (Stankus and Lehrer 1987).

Controlling for these confounding variables will not be an easy task, and was beyond the scope of this study. However, if a true understanding is to be gained regarding the environmental impacts on the respiratory health of the child, then the above confounding variables have to be measured and controlled (Lebowitz 1985). They may turn out to have a greater impact than the variables investigated in this study.

7.4 CONCLUSION

This first part of this study has shown that hospital admission data can be used to investigate patterns of respiratory illness. Two notable findings, the male excess in asthma and ARI admissions, and the paucity of African asthma admissions, were emphasised. Both these factors require further investigation as they may reveal underlying factors pertinent to the aetiology and prevalence of respiratory illness among different racial groups.

The second part investigated the seasonal patterns of admissions and environmental variables, and the relationship between admissions, and both ambient air pollution and meterological variables. Despite problems of measurement and representativeness of exposure, the latter analysis yielded significant associations between both ARI and TA, and both Soiling Index and NO_x. Significant associations were also noted between admissions and temperature, the only environmental variable that was significantly correlated with admissions.

It seems likely that levels of air pollution will continue to increase in Cape Town. The increase in use of private transport and small mini-bus taxis will increase the level of photo-chemical smog in Cape Town. It is unlikely that this trend will be reversed; indeed it will continue to grow due to the inefficiencies of the public transport system.

The burgeoning informal settlements in metropolitan Cape Town have serious implications for the increase in air pollutants such as SO_2 and particulate matter as more fossil fuels such as wood and paraffin are consumed. However, for a large section of metropolitan Cape Town's population there are no air pollution monitors. It is difficult, if impossible to estimate the level of air pollution in these areas without the placement of adequate monitors, both outside and indoors.

Even without a knowledge of the air pollution levels in many areas of Cape Town, this study has shown that it is important to attempt to reduce further and control the levels of air pollution in Cape Town. If this does not occur then the affect of air pollution on the respiratory health of children may increase in severity, thus further increasing pressure on the already overburdened public health sector.

This study has identified areas for further study that could lead to increasing our knowledge of respiratory illnesses and some of the environmental variables which affect these illnesses in Cape Town, a city that is known for its high prevalence of respiratory morbidity (Klopper et al 1989; 1986).

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