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Adverse health effects of air polluion [sic] on primary school children in Tehran

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University of Wollongong

ADVERSE HEALTH EFFECTS OF AIR POLLUION ON PRIMARY SCHOOL CHILDREN IN TEHRAN

A thesis is submitted in partial fulfilment of the
requirements for the award of the degree

DOCTOR OF PHILOSOPHY

From

UNIVERSITY OF WOLLONGONG

by

NARGES BAGHERI LANKARANI, GRAD. DIP (PUBLIC HEALTH) MSC. BSC

School of Health Sciences

2006

Thesis Certification

I, Narges Bagheri Lankarani, hereby declare that this thesis, submitted in the partial fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Health Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualification at any other institution.

Narges Bagheri Lankarani

31 March 2006

Dedication

In the name of God

Most Gracious Most Merciful

To my beloved husband Ali asghar Faramarzian who has supported me all the way since the beginning of my study and who has been a great source of motivation and inspiration and my sons for their patience.

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Glossary

Absenteeism	Daily respiratory illness-related absences from schools when the schools were open.
APHEA	Air Pollution and Health - A European Approach
AQCC	Air Quality Control Company
BS	Black Smoke
CI	Confidence Interval
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COH	Coefficient of Haze or Soiling Index
COPD	Chronic Obstructive Pulmonary Disease
DALYs	Disability Adjusted Life Years
DOE	Department of Environment
EC	Elemental Carbon
EHI	Environmental Health Indicator
EPA	Environmental Protection Department
FEF	Forced Expiratory Flow
FEV_1	Forced Expiratory Volume
FVC	Forced vital Capacity
GAM	Generalized Additive Models
GEE	Generalized Estimating Equations
Hospitalization	Daily diagnoses on discharge data, describing emergency room visits were recorded using the International Classification of Disease version 10 (ICD_{10}).
ICD	International Classification for Disease
IRIMO	Islamic Republic of Iran Meteorological Organization
ISAAC	International Study of Asthma & Allergies in Childhood
JICA	Japan International Co-operation Agency
L/m	Litres per minute
Log	Natural logarithm
Lung function	Peak expiratory flow rate measured by mini Wright
MA	Moving Average
MEF_{25}	Maximum Expiratory Flow at 25% vital capacity
NO_2	Nitrogen dioxide
NO_X	Nitrate Oxides
O_3	Ozone
OECD	Organisation for Economic Co-operation and Development
OR	Odds ratio
PEF	Peak expiratory flow
PEFR	Peak expiratory flow rate measured by mini Wright
PHREG	Proportional Hazard Regression
PM_{10}	Particulate matter smaller than 10 microns per cubic metre

Poor Lung function /airway obstruction	Daily decrease in peak expiratory flow rate (PEFR) of 50 percent of expected values' and having respiratory Symptoms such as recent wheeze (in the 12 months prior to study) or whistling in the chest and coughing**.**
ppm	Part per million
PSI	Pollutant Standards Index
RR	Relative Risk
SAS	Statistical Analysis Software
SCI	Statistical Centre of Iran
SO_2	Sulphur dioxide
Std Dev/SD	Standard deviation
TSP	Total Suspended Particles
USEPA	U.S. Environmental Protection Department
VOCs	Volatile Organic compounds
WHO	World Health Organization

Abstract

Health effects caused by air pollutants may range from subtle biochemical or physiological signs, such as mildly reduced lung function, to difficult breathing, wheezing, coughing and exacerbation of existing respiratory conditions such as asthma, and chronic obstructive pulmonary disease (COPD). These effects can lead to school absenteeism, increased medication use, increased doctor or emergency room visits and more hospital admissions.

Lung function and respiratory symptoms have been the primary focus of most studies addressing the respiratory health effects of air pollution among children. Peak expiratory flow (PEF) has been found to be significantly lower in children exposed to air pollution. These studies have also reported higher prevalence of asthma and respiratory symptoms such as cough, phlegm and wheezing.

Most of the data collected in this study are in the form of time-series. The focus of this thesis is on relationships between time-series, but explicit 'time-series' methods for the analysis of univariate series have not been adopted. The case-crossover method is used to examine short-term effects of air pollution. In a symmetric bi-directional design, two control times are selected, e.g. two weeks before and two weeks after phenomena of interest, so as to reduce auto-correlation effects in the exposure series. In this study, dates of high respiratory related hospital admission rate, respiratory related school absenteeism rate on two consecutive days, or the occurrence in individuals of worst lung function are defined as 'case days' and two weeks after or before each date defined as 'control'. In the case definitions, either a case date or case window was used with the corresponding two control dates or windows.

Two statistical methods were used for investigating the effects of air pollution on school absenteeism, hospital admission and lung function. Poisson regression is commonly used to model responses that are counts. In this study, the response was the absenteeism or hospital admissions per day, the predictors were air pollutants concentrations, weather parameters and other related factors. Time-series methods provide a traditional analytical approach in epidemiology studies but could not be used here because of the existence of too many missing values.

For the case-crossover approach, conditional logistic regression and hazard ratios were used to investigate the relationship between absenteeism, hospital admission, poor lung function or airway obstruction and daily temperature, air pollutant concentration and other covariates such as gender and teaching shift. For both methods, SAS statistical package version 9.1 was used.

The population was potentially exposed to ambient air concentrations of SO_2 in excess of the WHO limit for 304 days in 2000, for the entire year of 2001, and for 241 days in 2002. Since, there is no limit for PM_{10} in WHO air quality standards it is compared to World Bank and other countries' limits. In the period 2000-2002, the population of Tehran was also potentially exposed to ambient air concentrations of PM_{10} in excess of the World Bank limit for 25 days in 2002 and some courtiers such as Australia, Canada, EU, Philippines and Hong Kong limits for 327 days in 2000, 352 days in 2001 and 296 days in 2002. Exposure to ambient air concentration of NO_2 was also potentially in excess of WHO standards for 132 days in 2000, 0 days in 2001 and 142 days in 2002. Potentially exposure to ambient air concentration of O_3 was also there in excess of WHO standards just for 3 days in 2002. Likewise, ambient air concentrations of CO exceeded the WHO limit for 314 days in 2000, 277 days of 2001 and 272 days in 2002.

Absenteeism data over 295 days were obtained from two schools in Tehran, and was found to be associated with some pollutants using both Poisson and case-crossover analyses. Specifically, the strongest association found in this study was equivalent to an increase in daily absenteeism of 0.8 for the Poisson model, and an odds ratio of 10 for the probability of daily absenteeism for case-crossover analysis. However, absenteeism was also negatively associated with concentration of seven-day moving average of PM_{10}, NO_2 and O_3. Such associations are not consistent with the literature.

Hospital admission data were obtained from two hospitals in Tehran over a 2-year period. After using both Poisson regression, addressing the full data set of hospital admissions, and a case-crossover analysis of the reduced set of cases and controls, the following results were found. Temperature and O_3 (same day) were the only statistically significant predictors. However, the association between ozone and hospital admission was negative, which is not consistent with the literature.

This study also assessed the results of a survey using a standard questionnaire on students at two elementary schools. This demonstrated that some respiratory prevalence rates are higher in males than females. Around 22% of students have current wheeze, and 38% of the students who have current wheeze are passive smokers. In general, the level of exposure to known risk factors, with the exception of number of smokers at home, does not seem to be extraordinarily high in this population.

The overall prevalence rate of poor lung function (percentage of students whose lung function was less than 50% of their predicted value or best blow) found in this study is 12% using predicted value and 30% using best blow.

Lung functions of students were measured for six weeks. The lung function data were analysed using the case-crossover method, and it was found that a change between mean and maximum concentration of seven-day moving average of NO is predicted to lead an increases the probability of poor lung function (OR = 19 and OR = 80 using predicted value and personal best blow respectively. The concentrations of seven-day moving average of PM_{10} and CO were negatively associated with the probability of poor lung function, which is not consistent with the literature.

Overall, some significant negative effects of air pollution level on respiratory health were found in this study. Case-crossover analysis tended to confirm the general pattern indicated using Poisson regression. Some puzzling positive effects were found, and these are inconsistent with the literature. While there were some limitations in the quantity of data available (eg. lung function measurements which were only available for a six week period) the major limitation was of the quality of air pollution data, with many missing values as well as problematic measurements.

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Chapter 1: Introduction

High ambient concentrations of air pollutants are common in Tehran, the capital of Iran [Hastaie, 2000; World Bank, 2003]. In Tehran, the pollution levels of total suspended particles, sulphur dioxide, carbon monoxide and oxides of nitrogen often exceed the World Health Organization's (WHO) safety threshold by a factor of well over two [Iran Green Pen, 2004a]. Few studies have been conducted to systemically examine adverse impacts of air pollution on children's respiratory systems from long-term exposure at high levels of multiple pollutants [Gauderman et al., 2000]. The extent to which exposure to ambient air pollutant mixtures affects children's respiratory health is not yet clearly understood.

Air pollution, both indoor and outdoor, is a major environmental health problem affecting developed and developing countries alike. In cities, air may be severely polluted not only by emission from transportation but also by the burning of fossil fuels (oil and coal) in power generating stations, factories, office buildings, homes and by the incineration of garbage. According to the WHO [2000a], major air pollutants associated with the combustion of fossil fuels are particulates, sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) Since these contaminants enter the body via inhalation, it is to be expected that their main effects would be on the respiratory tract. Thus, the most commonly reported health effects from exposure to air pollution are in the respiratory tract (bronchitis, asthma, pneumonia, etc.). Each pollutant affects the health of those exposed to it in special ways. Small particles penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory diseases, such as emphysema and bronchitis, and can intensify existing heart disease [World Health Organization, 2000b]. Sulphur dioxide affects people quickly, usually within the first few minutes of exposure. Studies indicate that SO_2 exposure can lead to acute health effects [World Health Organization Regional Office for Europe, 2000]. Exposure is linked to an increase in hospitalisations [Lin et al., 2002; 2003; Masjedi et al., 2003] and deaths from respiratory [World Health Organization Regional Office for Europe, 2000] and cardiovascular [Neas et al., 1999] causes, especially among asthmatics and those with pre-existing respiratory diseases [World Health Organization Regional Office for Europe, 2000]. In cases where people are exposed to pollutants for long periods, NO_2 has effects on breathing and the respiratory system, and can also cause damage to lung tissue [Peters, 2004], as well as premature death.

A preliminary study by the World Bank in Iran [Rostamihozori, 2002] showed a high correlation between ambient air concentration levels of Total Suspended Particles (TSP) and SO_2 and headaches and bronchitis in school children in Tehran. Another study indicated annual premature deaths because of air pollution in Iran were forecast around 13,200. Estimated new cases of chronic bronchitis in adults were about 12,500 per year. Annual hospitalizations due to air pollution are estimated at 28,600 and emergency room visits at 560,300 [Shafie-Pour and Ardestani, 2007]. This information was presented as the main concern of WHO and the reason for many Iranian environmental departments to initiate some measures to decrease air pollution. Hence on 08/04/03, the World Bank signed a $20 million loan to support the Government of Iran in reducing the impact of water and air pollution in major cities across five provinces in the country [World Bank Group, 2003].

1.1 Air pollution in Tehran: current situation

Air pollution in Tehran is increasing due to the rapid increase in population and the development of industry. Urban expansion over the past two decades in Tehran resulted from high population growth rate, increased rural to urban migration, and a strong tradition of centralization in the capital. Another problem is that in Tehran there is a social gap between the north and the south of the city. When the royal family left their residence in the centre in 1940 and moved to the north of Tehran, the problem was strengthened. Moving the royal family and many others of the upper socioeconomic echelons caused a socioeconomic separation in the capital. In addition, the south of the city is more crowded than the north. For example, District 10, which is located in the south-west, has the highest population density, 55,556 per Km^2 area, compared to other districts in which densities range from 51,429 per Km^2 in District 17 to 2,222 per Km^2 in District 18 [Islamic Republic of Iran Broadcast, 2005]. According to the Statistical Centre of Iran (SCI) the population of the province of Tehran in 2004 was almost twelve million, while the population of the city of Tehran as the capital of province was estimated to be just over seven million (see Figure 1.1) [Statistical Centre of Iran, 2005].

The city is divided into 22 districts, one of which (District 12) is the focus of much of this thesis.

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Figure 1.1 Population of the city of Tehran 1956-2004 [Statistical Centre of Iran, 2006]

As indicated in Figure 1.2 District 12, has an area of 16.7 km^2 with a total population of around 500,000 [Islamic Republic of Iran Broadcast, 2005] and is located in the south-east part of the centre of Tehran which is one of the most polluted districts in Tehran [Shams, 1990]. District 12 is the oldest part of the city, with the Bazaar (old Market), parks, governmental organizations, embassies and two underground railway lines. It consists of 5 regions and 31 neighbourhoods and 100,000 households [Islamic Republic of Iran Broadcast, 2005]. This area was built in the late eighteenth century. One of the oldest markets in Iran is located in the centre of the district. There are ten old squares and many historical buildings, including a palace that was built around 200 years ago [Islamic Republic of Iran Broadcast, 2005]. The two lines of the underground railway cross the district. Line 1 runs from North to South and Line 2 from East to West. In District 12, both lines are operational [Tehran Metro, 2008].

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Figure 1.2 Maps showing (in progressive detail) Iran, Tehran (metheorology stations) and District 12 [Air Quality Control Company, 2002]

There are major traffic problems in the area. As the Bazaar is the oldest and main market of Tehran and attracts many people from all over Iran to shop and to do business, their activities create a lot of solid waste. Fardi [2001b] stated 'they also bring in a lot of private cars and use the public transport at an average rate of 1,620 buses with 1,367,000 passengers daily'. The consistent traffic jams around the Bazaar and the increasing air pollution are a result of these comings and goings.

The population of primary school students in Tehran in 2001 was 530,855 [Iranian Education Ministry, 2005]. At that time, nine percent of the population of the city of

Tehran were children in the age group 6-11 years. This population decreased to 499,935 in 2004. In District 12, there were reported to be 72,556 students in 396 schools in 2004. Of this total, 22,909 were elementary students in 104 schools. In Tehran, the supply of school buildings is insufficient for the number of students. To meet this problem, the Ministry of Education has allowed some schools to work in two shifts. District 12 has two elementary schools which work in two shifts [Iranian Ministry of Education, 2005].

As shown in Table 1.1.1, there were approximately 500,000 primary school aged children (6-11) living in Tehran in 2002-2003 [Iranian Education Ministry, 2005].

Table 1.1.1 The student population of Tehran [Iranian Education Ministry, 2005]

Educational Year	Students	Male	Female
1998-1999	648,323	331,853	316,470
1999-2000	609,389	312,068	297,321
2000-2001	568,546	291,449	277,097
2001-2002	530,855	272,257	258,598
2002-2003	503,513	257,840	245,673
2003-2004	499,935	255,457	244,478

In Iran, various influences, including traditional thinking, lead to different behaviours of girls and boys. One effect is that girls tend to be at home more than boys. Thus, girls are typically confronted with more indoor air pollution and less outdoor air pollution than are boys. Because, some schools work in different shifts students in those different shifts face different air pollution exposure, as some will play (and/or travel) in the afternoon and others in the morning. The gender difference and the school shifts create a unique environment for this research, quite different to that under which research has been done elsewhere.

1.1.1 Geographical location and climatological condition of the city

The Tehran province covers an area of 18,909 square kilometres and is located to the north of the central plateau of Iran. The province of Tehran has over 12 million inhabitants and is Iran’s most densely populated region. Approximately 84.15% live in urban areas and 15.85% in rural areas of the province [Islamic Republic of Iran

Broadcast, 2005]. Mountain ranges such as the Alborz surrounded the north; Savad Kooh and Firooz Kooh are located in the north east; Lavasanat, Qarah Daq, Shemiranat, Hassan Abad and Namak Mountains are in the southern areas; Bibi Shahr Banoo and Alqadr are situated in the south east and the heights of Qasr-e-Firoozeh (see Figure 1.3) are located to the east of the province [Islamic Republic of Iran Broadcast, 2005].

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Figure 1.3 Topography of Tehran [Municipality of Tehran, 2003]

The city of Tehran is not only the capital city of the province, but has also been the capital of Iran since 1778. As of June 2005, this province includes 13 townships, 43 municipalities, and 1358 villages. Tehran is 733.8 Km^2 and is located at latitude 35º 36́- 35º 44́ north and at longitude 51º 17΄- 51º 33́ east. The altitude of Tehran is 900-1800 meter [Islamic Republic of Iran Broadcast, 2005]. It is characterized by gentle upward slopes from the south to the north and from the west to the east formed by the 3,500 to 4,000 m high Alborz Mountains in the north and east [Hastaie, 2000]. The difference in altitude between the southern area of Tehran, Imam Khomeini Airport (990m), and the northern part of Tajrish district (1,548 m) is 558 metres [Islamic Republic of Iran Broadcast, 2005].

Tehran has a steppe climate. The northern part, which is located in the mountain skirt of Alborz, has a moderate and humid climate, while the rest of Tehran has a dry and hot summer and moderate (and sometimes cold) winter.

Because Tehran is located at quite high altitude and covers a broad area, three synoptic stations record the climate of Tehran. The stations are located in north of Tehran: Geophysics, Mehrabad airport and Imam Khomeini airport (see Figure 1.2). The climatology data of Tehran was obtained from Islamic Republic of Iran Meteorological Organization (IRIMO) through a 40-year study from year 1961 to year 2000[1]. The annual mean rainfall in Tehran is about 238 mm. Average monthly rainfall ranges from 1 mm in September to 46.6 mm in March. Figure 1.4 is an example of annual rainfall in Tehran. The hottest months of the year are from mid-July to mid-September, when temperatures typically range from 30° - 35° C and the coldest months experience temperatures as low as -4.6 - 0.6° C around December-February. The number of freezing days was around 18, the first being early November and the last being mid April [Islamic Republic of Iran Meteorological Organization, 2006]. Thus, Tehran as mentioned before has warm summers especially in the area to the south of city centre; and moderate temperatures in the northern area. In winter, the central and southern parts are moderate and northern part of the city has cold weather. The temperature decreases to below zero many times. Tehran in the cold seasons is under the effect of high pressure that comes from the north, from Siberia that leads to the cold, dry, and generally polluted winter. In contrast, in warm seasons the climate is affected by low pressure systems coming from the central desert, located to the south east of Tehran; this leads to dry and warm summers [Islamic Republic of Iran Broadcast, 2005].

In Tehran, on average, there are about 250 days of temperature inversion annually [Hastaie, 2000]. Temperature inversion functions like a cap, which prevents the air from moving vertically. When winds are weak, pollution tends to gather above the city, trapped by the mountains and the warm air rising from the south.

One situation in which a low level or surface inversion might take place is on clear nights, when the earth's surface radiates heat away rapidly. If the air is clear, the ground and the air directly above it can be cooler than the air at higher altitudes. This type of

[1] The data is obtained for the geophysics station which is located in district 6 of Tehran at latitude 35º 44′ N, longitude 51º 23′ E and has an elevation of 1360 meter.

situation commonly occurs on winter nights in Tehran. Another type of surface inversion takes place in valleys at night, when cold dense air flows down a slope under the influence of gravity, draining off slopes and uplands, and into valleys. The air in the bottom of the valley is colder than the air above.

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Figure 1.4 Average monthly precipitation in year 2002 [Islamic Republic of Iran Meteorological Organization, 2006]

In winter, inversion layers can develop on evenings and mornings. These trap pollution near the ground and pollution concentrations can build up to levels that affect people's health. As the sun rises, warming the air in the morning, inversion layers usually should break down, and pollutants are dispersed. However, in Tehran inversion layers often continue for some days.

On sunny days in summer when there is little wind, certain volatile organic compounds (VOCs) and nitrogen oxides (NO_2, NO_X) react in sunlight to form photochemical smog and ozone (O_3). This type of air pollution is common in large cities like Tehran. The prevailing wind direction on an annual basis is westerly as indicated in Figure 1.3 [Islamic Republic of Iran Meteorological Organization, 2006]. The annual mean wind speed is 5.3 knots. The largest monthly mean is 7.2 knots in April and May and the smallest is 3.5 knots in November [Islamic Republic of Iran Meteorological Organization, 2006].

In conclusion, geographical location, the weak winds, frequent temperature inversions, low rainfall and an estimated one million cars, which most of them lack exhaust filter result in a situation in which pollutants from any source have substantial opportunity to accumulate.

1.1.2 Factors influencing air pollution levels

Air pollutants come from both natural (e.g. volcanoes) and human made sources, the latter being the predominant cause of air pollution in Tehran. There are three broad sources of air pollution from human activities: stationary sources, mobile sources and indoor sources [World Health Organization, 1999]. Fixed or stationary sources includes industrial complexes, power plants etc. and mobile sources include vehicles, jet, etc. Air pollutants can be classified by the way that they enter the atmosphere. They are divided into two categories. Primary pollutants, such as CO, enter the atmosphere directly. Secondary pollutants form through chemical reactions with primary pollutants such as ozone.

The biggest single source of air pollution in Tehran is motor vehicles [Iran Green Pen, 2004c], which are categorized as mobile sources of air pollution. Next comes industries and power plants, which are categorized as stationary sources, then other sources such as cooking (two tonnes of green house gases per family annually) [Iran Green Pen, 2005c], cleaning chemicals, paint fumes, and even furniture and carpets. Both outdoor and indoor air pollution affect human health, especially that of children [Ostro et al., 1998; Romieu et al., 2002; Aekplakorn et al., 2003; Delfino et al., 2003; Simoni et al., 2003]. The massive combustion produces tons of ash, soot, and other particulates responsible for the grey smog of cities like Tehran, along with enormous quantities of sulphur dioxide. Tehran experiences the highest levels of air pollution during December each year due to vehicle emissions and use of heaters. In some districts such as District 10, the CO level has reached very unhealthy and hazardous levels (>200 PSI[2]). The PSI 24, reported 282 'unhealthy' days in 2000. On 02/01/05, PSI reached 168 or close to 'very unhealthy' levels. As a result, schools were closed and children, the elderly, and the sick were advised to stay indoors. By comparison, the PSI in New York City was 52 and in Bangkok 57 [Esfandiari, 2005].

[2] Pollutant Standards Index

Tehran is most severely polluted by transportation emissions. Research conducted in 1997 by the Tehran Municipality involved the cooperation of two international organizations: the World Bank (providing $20 million in aid) [World Bank Group, 2003] and Japan's International Cooperation Agency. The research provided the pollutant sources and their levels of responsibility for Tehran's poor air quality. A broad plan to reduce pollution in Tehran was provided by using the data and results, and department of environment has begun programming and using countermeasures to control levels. In that study, the factors which worsened the air pollution were identified. Following is a summary of the specific factors influencing air pollution levels in Tehran.

Transportation and age of vehicle: Motor vehicles are dominant as sources of air pollution in the Tehran metropolitan area [Islamic Republic of Iran Broadcast, 2005]. More than 80% of vehicles are locally made and 26% of these vehicles are more than twenty years old, with poor fuel efficiency and no catalytic converters. Based on expert assessments, wrecks account for almost half of the pollutants emitted into the environment by all vehicles. The Japan International Co-operation Agency (JICA) estimated that about 71% of air pollution in Tehran is produced from mobile emission sources. For example, each Iranian old car uses 5.3% more petrol than the new version of it [Iran Green Pen, 2004a]. So 26% of cars in Tehran use 43% of total fuel consumption. In total, 13 million litres of petrol were used daily in Tehran in 2003, which produces CO as a byproduct of burning fuels, especially during incomplete combustion [Lew, 1998].

To remove cars from the road that are potentially harmful for the environment, the car wreckage age was determined to be 30 years by the Iranian cabinet in year 2004. Under this rule, private vehicles aged 30, four wheel drive vehicles aged 25 and other plate vehicles aged 15 which can not get their technical slip (certificate to say that the car is road-worthy) are considered wrecks. The number of cars aged 20 or more is estimated to be around 800,000. According to the rule, 3,000 old cars were to be removed from streets of Tehran on 21/03/05 [Iran Green Pen, 2004a]. However, the government's efforts to remove these cars from the traffic cycle have so far failed. It has been estimated that by removing them from the transport cycle, Carbon Monoxide (CO) will be reduced by 23% [Air Quality Control Company, 2002]. However, large numbers of cars, minibuses, buses, vans, trucks and motorbikes continue to emit 120,000 tons of CO annually [Air Quality Control Company, 2002].

According to data collected by the Air Quality Control Company (AQCC) and the Department of Environment (DOE), Tehran is one of the worst cities in the world in terms of air pollution. Considering green house gas emissions, about five million tons of CO_2 is released by urban transport operations consuming an estimated two million tons of gasoline/diesel fuel per year [Hastaie, 2000]. On the other hand, according to Iran Green Pen (Iranian sustainable development pathfinder) [2004d], the rate of emission of carbon monoxide was 6.6 million tons in year 2002 while only 163 tons was produced by the industrial sector (stationary sources). The increase of urbanization in Tehran will increase energy consumption, which will increase air pollution relating to stationary emission in future [Japan International Cooperation Agency, 1997].

Increase in number of vehicles: There are more than three million cars in Tehran. Not withstanding the high number of old cars [Shokri, F, 2005], new cars are added to the fleet without considering any space need for the new cars. Each day 1,400 new cars receive license plates. Iran Green Pen [2005d] maintains that to service so many cars, there should be five kilometres of roads built every day. In the absence of road building, the pollution levels keep increasing as the traffic stagnate.

Estimates from the Optimal Fuel Consumption Organization came to around 4 or 5 million daily trips in Tehran. Surveys show traffic jams have been reducing the average car speed by around 1 - 1.5 km/hr [Iran Green Pen, 2005b].

Moreover, Ministry of Industries and Mines statistics showed 3 million motorbikes are used in Iran. This figure has considerably increased in the last few years. The surveys show 1600 new motor bikes per day are registered in Tehran [Saki, 2005]. Non-standard motorbikes per day spread more pollutants into the atmosphere than the emission set standards. Motor bikes consume 33% of the whole country's gasoline consumption. Adopting stricter emission standards and switching to more fuel-efficient motorbikes can considerably decrease air pollution.

Industries: More than 30% of all industries in the country are located in Tehran. Fifteen percent of air pollution is emitted from industries and power plants and 15% of that is emitted from heaters and air conditioning appliances. There are 450,000 industrial units and workshops in Tehran. There are 207 industrial units for each hectare while based on the global standards it should be 17 per hectare [Iranian Department of Environment, 2006]. It can be concluded that 14% of air pollution is emitted from households due to the usage of natural gas in the kitchen and heating systems.

Fuel prices and quality: The government causing little incentive for fuel conservation subsidizes fuel prices. Since 2004, the price of petrol per litre has been $A 0.133 while it costs the government $A 0.57. Although unleaded gasoline was introduced in Iran in 1990, only 2.6% of total fuel consumption was composed of this type in 1995 [Japan International Cooperation Agency, 1997]. In the news of 12/03 /04 Dr. Ebtekar, head of the Department of Environment stated 'lead was removed totally from the air of Tehran' [Iran Green Pen, 2004a]. However, high sulphur content diesel fuel is still in use there.

Lack of adequate public transportation system: In Tehran, as in many cities in the world, trips within the city are generally made mainly by public transport. According to Iran Green Pen [2005a] 5.5% out of 13 million within city trips are work related. Currently more than 56% of these trips by people are conducted by public transport. The main means of transportation in Tehran mainly consists of motorbikes, taxis (33,000), private cars (700,000) minibuses (40,100), buses (5,000), and trolley buses. Also two subway lines, cover 6% of the within city trips [Islamic Republic of Iran Broadcast, 2005]. The number of daily trips of private cars in the peak of the morning traffic was about 900,000 and the total trips in 24 hours of Tehran inhabitants was 10,700,000. The mix of transport modes is very different in China, where less than 10% of total trips were made by taxis and private cars, except in Beijing and a few other cities where the car density is high. A large portion, about 60%, of all trips, is made by foot or by bicycles [Lee and Ng, 2004].

Low proportion of green areas: According to Iran Green Pen, there were few trees and green areas in Tehran [Iran Green Pen, 2004b]. In 1993, there were 480 parks with a total area of 12,509.759 hectares in Tehran. In addition, there were 15 forest parks in the suburbs of Tehran with an area of 7,000 hectares, which were increased by 2,500 hectares. The green space per person ratio has increased from 2.5 m^2 in 1989 to 6 m^2 in

1993 and to more than 10.5 m^2 in 2005, but according to Iran DOE it will be 15 m^2 in future.

In conclusion, it is obvious that the air pollution in Tehran is an environmental problem and there are various contributing factors. Those factors fall broadly into two groups: geographic (including low winds, low rainfall, and scarcity of green areas) and human including the use of obsolete technology, excessive use of private cars, heavy traffic jams, and inadequate public transport.

1.2 Aim

The study described in this thesis aims to examine the relation between daily concentrations of air pollutants and health effects on elementary school age children in Tehran. The relationships between exposure to elevated air pollution levels and each of school absenteeism, hospital admission, and reduced lung function are of particular interest.

1.3 Structure of thesis

This Chapter provides a general introduction to the study. A detailed literature review of health effects associated with air pollution episodes on children is presented in Chapter two. In Chapter three, general overviews of the study design, study population, measurement methods, and data management or in other words a general methodology are given.

In Chapter four, the level of air pollution in Tehran in the period of study are discussed and compared with all known standards. Meteorological data and their relationships with air pollution are presented.

In Chapter five, routine data such as respiratory related school absenteeism and air pollution for the same time are presented. The association between air pollution and school absenteeism is assessed.

In Chapter six, the association between respiratory hospital admissions, based on discharge diagnosis data and air pollution, for children of primary school age will be used.

In Chapter seven, eight and nine, results from purpose collected data on lung function of primary school children in Tehran are discussed. Chapter seven contains a description of the study population for confounders and other determinants as well as response rates.

Chapter eight presents the prevalence of poor lung function or airway obstruction as asthma indicator in school children of Tehran, as measured by questionnaire and lung function measurement, compared to various criteria.

Chapter nine presents statistical analysis of the relation between lung functions and air pollution.

Finally, in Chapter ten, a discussion of the most important findings and conclusions is presented.

The appendices are organized in relation to the Chapters. In Appendix 1 the additional information about Iran is presented. In Appendix 2, the searching strategy and the table of all the references which are mentioned in Chapter two are presented. In Appendix 3 the letter of approval from ethics committee, the consent forms and letters, questionnaire used in data collection and the codebook used to enter the responds in computer are presented. In Appendix 4 the program used for cleaning air pollution data and the hourly air pollution graphs for two years are presented.

Chapter 2: Literature review

The focus of this chapter is on respiratory effects of pollutants which are observed in epidemiological studies of children. Children are considered as a vulnerable group of the population. Schwartz [2004] stated that 'the lung is not well formed at birth, and development of full functionality does not occur until approximately 6 years of age. Children also have a relatively larger lung surface area (per kilogram of body weight) than adults and, under normal breathing, breathe 50% more air per kilogram of body weight than adults'. This demonstrates that children's exposure to air pollution may affect their respiratory health. Another major factor that influences the relative impact of air pollution on children in comparison with adult is exposure. Children are more active, so they take in more air per unit body weight. Children also spend more time outside. Children are in the growth phase, during which time cells in the lung may be especially vulnerable to damage from air pollution [Kleinman, 2000]. Both indoor and outdoor air pollution affect children's health negatively [Lewis et al., 1998; Nikic, 1999; Mishra, 2003].

Air pollution and its negative health effects are not new issues. In ancient Rome, the famous writer, Seneca was advised by his doctor to leave his residence to get cured of asthma [Lomborg, 2001]. Indeed, air pollution has been a problem at least since 900 BC when an Egyptian King, Tukulti, visited a town near Babylon called Hit, and reported a strange smell in the air generated by the ulmeta rocks. These rocks are high in sulphur dioxide and hydrogen sulphide [Anonymous, 1998]. In the 1300s, coal burning caused air pollution in England as early as the reign of King Henry II. Coal burning was prohibited in England in 1306. Then wood began to replace coal as a source of fire fuel and air pollution during the late 1500s [Anonymous, 2005].

Air pollution caused by industrialization combined with household heating, created several air pollution disasters recorded during the 20th century. During 1930, in the Meuse Valley of Belgium, industrial pollution led to thousands of cases of acute pulmonary attacks resulting in a death toll of 60 [Roholm, 1937]. Another 600 residents of the valley became ill with breathing problems and respiratory infections. In the United States of America, 20 people died and another 6,000 became ill because of air pollution in Donora, Pennsylvania during winter in 1948. The combination of pollutants from fireplaces and industries condensed in the air forming a dense fog which led to nearly 4,000 deaths in London during 1952 [Ministry of Health, 1954].

Air pollution standards are based on research conducted all over the world to determine acceptable levels of air pollution [World Health Organization, 2000a]. Concentrations of air pollution that exceed the standard levels may lead to chronic or acute effects on human health, especially on the respiratory system [Alves and Ferraz, 2005]. Air pollution is reduced considerably by using emission reduction technologies and using less polluting fossil fuels, e.g. natural gas instead of coal. The pollutants of epidemiological interest are the same five pollutants which are indicated by WHO air quality guidelines as 'classical pollutants' [World Health Organization, 2000a]. These five pollutants are described in the following sections.

2.1 The classical pollutants

Sulphur dioxide (SO_2) is the classical pollutant associated with sulphur in fossil fuels. It is a colourless and acidic gas. It is mainly generated through transportation (oil fuel, diesel oil) and using natural gas in industrial (70%) [Air Quality Control Company, 2002], residential or commercial sectors.

Particulate matter with diameter less than 10 μm (PM_{10}), as illustrated in Figure 2.1, is formed from most reactions involving combustion [Rostamihozori, 2002]. This is a heterogeneous classification of liquid and solid aerosols including anthropogenic emissions from fuel combustion (coal, oil, and biomass), transportation, and high temperature industrial processes. Size is a critical determinant of deposition site, with smaller particles (less than PM_{10}) penetrating deeper into the lungs.

Nitrogen dioxide (NO_2) is under the chemical category of nitrogen oxides (NO_X), formed by oxidation of atmospheric nitrogen during combustion. The largest portion originates from transport sectors, refineries, industries and electricity sectors, and hydrocarbons from vehicle exhausts, is emitted in the form of the non-toxic nitric oxide (NO), which is subsequently oxidised in the atmosphere to the secondary 'real' pollutant NO_2 [Fenger, 2002]. Nitrogen dioxide is soluble in water, reddish-brown in colour, and a strong oxidant. Ambient air NO_2 is a gaseous air pollutant, which derived, in large part from the oxidation of nitrogen oxide, the major source of which is combustion emissions, mainly from vehicles. NO_2 is therefore a clear indicator for road traffic [World Health Organization, 2000a]. Nitrogen dioxide has a variety of environmental and health impacts. Due to its low solubility, nitrogen dioxide penetrates to the lung periphery where greater than 60% is deposited [American Thoracic Society, 1996]. It is a respiratory irritant, and may exacerbate asthma and possibly increase susceptibility to infections [Timonen et al., 2002]. In the presence of sunlight, it reacts with hydrocarbons to produce photochemical pollutants such as ozone [Crutzen, 1979].

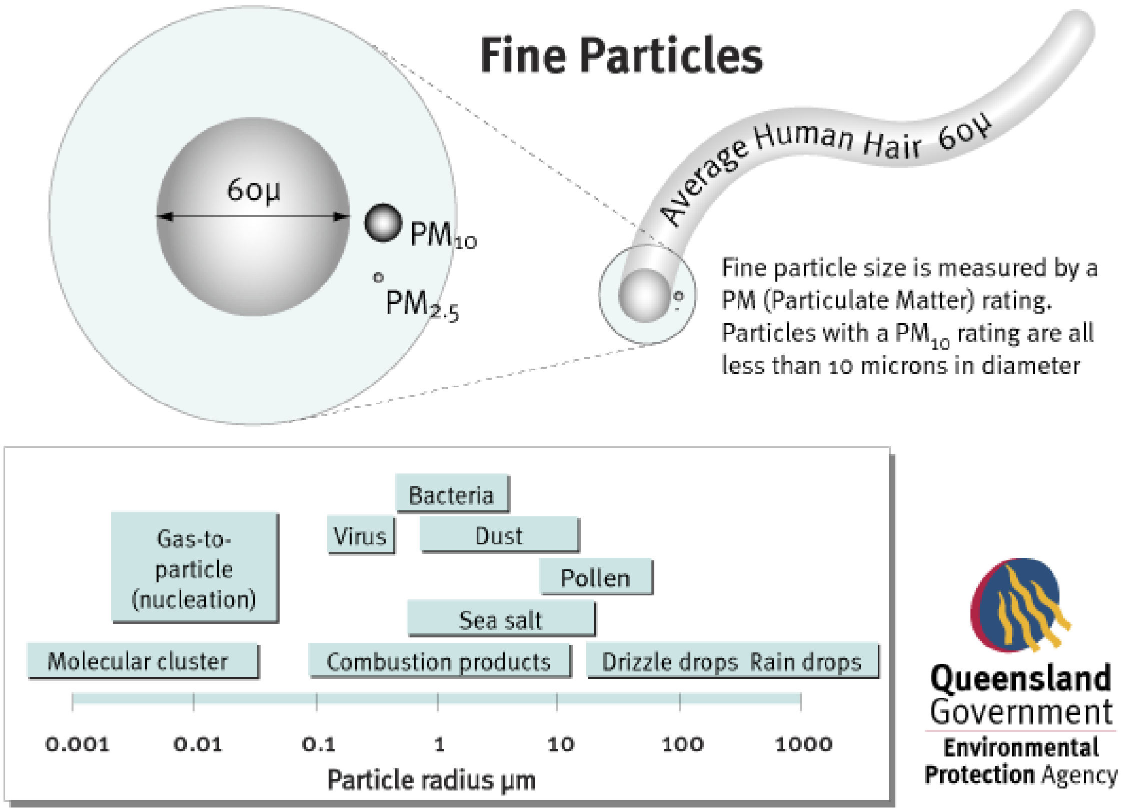

Figure 2.1 Particular matter rating

Ozone (O_3) is an unstable, poisonous allotrope of oxygen and also a gas formed from other pollutants [Columbia University Press, 2003]. A strong oxidizing agent, it is generated when oxides of nitrogen and hydrocarbon compounds react in the presence of sunlight. Variations in O_3 concentrations may occur through seasonal changes, meteorological processes [World Health Organization Regional Office for Europe, 2000] and impact of the built environment. For example, the highest levels of O_3 typically are in the summer. Concentrations are often low in busy urban centres and higher in suburban and adjacent rural areas, particularly on sunny days in summer [Liu et al., 1987]. Exposure to ozone mainly affects the lungs, but it can also affect the eyes and increase susceptibility to inhaled allergens [Hazucha et al., 1989].

Carbon monoxide (CO) is a colourless, odourless and tasteless gas that is weakly soluble in water. It is a by-product of combustion and formed through the oxidation of hydrocarbons and other organic compounds [Columbia University Press, 2003]. It has an atmospheric lifetime of approximately two months when further oxidation will form carbon dioxide [Heald et al., 2003]. In the human body, it reacts with haemoglobin to form carboxyhemoglobin, preventing uptake and transport of oxygen. Because carbon monoxide readily and firmly attaches to haemoglobin, it stays in the blood for a relatively long time. Thus, during an exposure, carbon monoxide concentrations in blood can rise in a matter of minutes, then stay high for long periods [Kleinman, 2000]. The major source of atmospheric carbon monoxide is road transport [Stewart, 1975]. Smaller contributions come from processes involving the combustion of organic matter, for example in power stations and waste incineration [Stewart, 1975]. In various indoor environments, space heaters fuelled with oil or gas, gas stoves and some other appliances and tobacco smoking cause significant emissions of carbon monoxide. The ambient concentrations measured in urban areas depend greatly on the density of combustion powered vehicles, and are influenced by topography and weather conditions [World Health Organization, 2000a].

2.2 Indoor air pollution

Over 90% of our time is spent in indoor environments [EPA, 1994] and, according to a WHO health report [World Health Organization, 2005a] illustrated in Figure 2.2, indoor air pollution is the 8th most common risk factor for the second biggest environmental contributor to ill health, and is responsible for 2.7% of the global burden of disease (in Disability-Adjusted Life Years or DALYs). Also, solid fuel use is responsible for over 1.6 million deaths annually [World Health Organization, 2005a].

By using the data for cardiopulmonary and lung cancer death for 2002 from Iranian Ministry of Health and DALYs coefficients as incidence data in Iran, [Shafie-Pour and Ardestani, 2007] estimated the urban air pollution impacts which is presented in Table 2.1.

Table 2.1 Estimated health impacts of urban air pollution, 2003 [Shafie-Pour and Ardestani, 2007]

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There are numerous sources for indoor air pollution including: outside contaminated air, moisture or standing water, mould and mould spores, pets and their body wastes, cockroaches, dust mites and their droppings, heating and air conditioning, personal care products, smoking, cooking, house cleaning products, chemicals released from building products like carpet, and remodelling a home [Maertens et al., 2004; Viegi et al., 2004; Halios et al., 2005; Jedrychowski et al., 2005]. The details of their studies were presented in Appendix A2.1.

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Figure 2.2 Disease burden (DALYs) due to indoor air pollution by level of development-2002
Source: [World Health Organization, 2005a]

2.3 Outdoor air pollution

Outdoor air pollution is generally caused by combustion processes. This includes motor vehicle emissions, solid fuel burning and industrial processes. In cities, children are exposed to outdoor air pollution from industries and traffic exhausts on their way to and from school, during outdoor play and other activities. In addition, outdoor air pollutants may enter the buildings in which they live or study.

2.4 Adverse health effects of air pollution on children

Air pollution is a global threat for children's health. Air pollutants are associated with a wide range of adverse health effects in children, including: aggravation or causation of asthma, increased respiratory symptoms [Dockery et al., 1989], and increased sickness rates (as indicated by kindergarten and school absences); and decreases in lung function [Gauderman, 2002].

Regarding lung function, studies have shown that increases in particulate pollution are associated with temporary declines in peak expiratory flow rate (PEFR) and/or lung growth rates in children [Chestnut et al., 1991; Gauderman et al., 2004]. Those declines were greater in symptomatic children, i.e. those already displaying symptoms [Dockery et al., 1989].

According to the World Health Organization (WHO) guidelines, millions of children living in the world's largest cities, particularly in developing countries, are exposed to life-threatening air pollution two to eight times above the maximum. In the developing world cities, it is estimated that air pollution is responsible for at least 50 million cases of chronic coughing in children aged below 14 [Davis and Saldiva, 1999b]. Urbanization is positively associated with more children being exposed to hazardous pollutants which means the proportion of results corresponding serious respiratory illness is increasing as well [Davis and Saldiva, 1999a].

Davis and Saldiva [1999b] developed an Environmental Health Indicator (EHI) to discover and categorize cities with the most threatened children. This EHI reveals that some of the highest risks to children occur in countries such as Mexico, India, China, Brazil, and Iran. As mentioned in Chapter one, the air pollution in Tehran is often 2.8 times the World Health Organization standards [Iran Green Pen, 2004a].

According to WHO [2005b] the single most common cause of death in children under five years of age globally is pneumonia and other acute lower respiratory infections. Exposure to indoor air pollution doubles the risk of chronic respiratory diseases and consequently is responsible for almost half of 2 million annual deaths from pneumonia. A significant body of evidence supports the explanation that much of the morbidity and mortality related to air pollution in children occurs via interactions with respiratory infections, which are very frequent among children. Evidence suggests a causal relationship between exposure to ambient air pollution and increased incidence of upper and lower respiratory symptoms (much of which are likely to be symptoms of infections) [Gehring et al., 2002; Frye et al., 2003; Finkelstein et al., 2004].

Before explaining the adverse effects of air pollution, it is necessary, to describe lung function and respiratory symptoms measurement tools used in epidemiological studies.

2.4.1 Lung function

The development of full functionality of lungs does not occur until approximately the age of six. Lung function increases with age. Normally, children's lung function grows gradually as they grow up. Lung function continues to grow until height growth stops [Xuan et al., 2000]. Lung function is decreased at both extremes of weight. Females reach their greatest potential lung function by the age of 18 years, while males reach their maximum lung function when they are in their early twenties. After that, lung function stays at an approximately constant level for a while, before slowly declining as a person ages [Knudson, 1991; Gauderman et al., 2004]. To evaluate lung function, clinicians and researchers use various tests, which measure forced expiration.

Tests of forced expiration were introduced on a practical basis by clinicians; however, later research showed that these tests reflect the mechanical properties of the lungs, providing a sound physiological basis for their use [American Lung Association, 1991].

2.4.1.1 Physiological basis

As illustrated in Figure 2.3, the respiratory system consists of the required elements to take air from the atmosphere down to the alveoli, exchange oxygen and carbon dioxide in the blood circulation through the pulmonary capillaries and then move carbon dioxide back to the atmosphere [Schwartzstein and Parker, 2006]. Components of the respiratory systems include respiratory controller, ventilatory pump, and gas exchange. The mechanism of breathing consists of accessory muscles, compliance and air way resistance [Crisp and Taylor, 2001].

In obstructive lung conditions such as asthma, the airways are narrowed, usually causing an increase in the time that it takes to empty the lungs. The response of lungs to environmental agents is acute or chronic airflow obstruction. Airway obstruction may be a result of increased mucus secretion, airway inflammation followed by swelling and narrowing of the passages, smooth muscle contraction, oedema, inflammatory cell infiltration and epithelial desquamation [National Asthma Council, 2002]. During an acute asthma attack, the already inflamed airways narrow further due to bronchospasm, resulting in increased airway resistance. Because of an increase in the smooth muscle tone during an asthma attack, the airways also tend to close at abnormally high lung volumes, trapping air behind closed or narrowed small airways [Beckett, 1999].

2.4.1.2 The tests

Literature suggests that various tools can be used to study lung function and respiratory symptoms in epidemiological research. Some of these are discussed below.

Self-reported respiratory symptoms are often collected through a structured questionnaire, which has also been commonly used to investigate the prevalence of environmental effects on children in epidemiological studies [Hosein et al., 1989; Brunekreef, 1992; Cuijpers et al., 1994; Cuijpers et al., 1995; Yang et al., 1997a; Yang et al., 1997b; Chen et al., 1998; Ronmark et al., 1998; Berglund et al., 1999; Goren et al., 1999; Mungan et al., 2003; Hong et al., 2004; Saijo et al., 2004; Lewis et al., 2005].

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Figure 2.3 Diagram of human respiratory system

Questionnaires developed by the International Study of Asthma and Allergies in Childhood (ISAAC) are used in many epidemiological studies in different countries. One benefit of using this questionnaire is the consistency of questions; this assists comparison of results across different studies.

There is a broad range of pulmonary function tests. These tests are usually done in a health care provider's office or in a specialized facility. Spirometry is used to measure the volume of air entering and leaving the lungs. The efficiency of the lungs while inhaling and exhaling is measured by spirometer [Blaivas, 2005]. Spirometers are most useful in assessing obstructive lung diseases, especially asthma and chronic obstructive pulmonary disease (COPD) [Blaivas, 2005]. The two main measurements recorded using spirometers are:

- Forced Expiratory Volume in one second (FEV_1), which is the amount of air that a person can exhale in one second.
- Forced Vital Capacity (FVC), which is the total amount of air that a person can exhale in one breath.

Spirometry provides an indication of how well lungs are functioning by measuring the degree of impairment of lung function. However, spirometers are heavy and expensive and thus used primarily in clinical and hospital settings for long-term monitoring of asthma. Cost, weight and availability precluded the use of a spirometer in this study. A peak flow meter was used instead.

A peak flow meter records the peak expiratory flow rate (PEFR), or the fastest rate at which air can move through the airways during a forced expiration, starting with fully inflated lungs. A strong positive correlation ($r = 0.74\text{-}0.87$) has been reported between PEFR and FEV_1 [Nowak et al., 1982; Vaughan et al., 1989; Diagnosis, 2002]. Mini Wright peak flow meters are small, portable, convenient and inexpensive devices, which can be used with minimal training [American Lung Association, 2002]. They are commonly used, not only in hospital and clinical settings, but also in home and office settings to help diagnose asthma [National Asthma Council, 2005], assess its severity, and evaluate response to therapy [American Lung Association, 2002].

While peak expiratory flow (PEF) may be associated with achieving flow limitation in the trachea, the value of flow depends on the rapidity with which expiratory pressure is increased; the more rapidly this is generated, the larger the lung volume at which peak flow is achieved, and the higher the value of peak flow. A reduced PEF can be a sign of poor expiratory effort in a normal person or of airflow limitation in an ill person. PEF normally increase with increasing height and decline with age after reaching a peak in young adults [Xuan et al., 2000]. PEF results are normally compared with normal predicted value of subjects without disease but with similar personal characteristics such as age, height, sex and possibly, race since lung function is influenced by these characteristics [American Lung Association, 1991]. After correcting for (standing) height, girls appear to have higher expiratory flows than do boys, whereas adult men have larger volumes and flows than do women [American Lung Association, 1991].

2.4.2 Air pollution and changes in lung function in children

Children breathe faster and the amount of time spent (playing) outdoors is more than that for adults; therefore they have greater exposure to air pollution [American Lung Association, 2005]. As well as aggravating wheezing and coughing, air pollution is responsible for temporary deficits in lung function [Asgari et al., 1998; Gauderman, 2002; Frye et al., 2003]. Gauderman et al. [2000] have studied more than 3,000 children in Southern Californian communities since 1993, and found that some air pollutants such as microscopic particles, NO_2, and acid vapours affect children's lungs, but that O_3 did not show any effects.

Air pollution retards lung function increase in growing children. Various studies have shown that lung function growth in children is negatively associated with exposure to PM_{10} [Gauderman et al., 2000; Timonen et al., 2002]. Other studies examining effects of air pollutants such as SO_2 and PM_{10} in children have found significant decrements in lung function, as measured by PEF [Wanner, 1990; Pope III, 1991; Schwartz et al., 1994; Peters et al., 1997; Hoek et al., 1998; Jedrychowski et al., 1998; Gauderman et al., 2000; Koenig and Mar, 2000; Horak et al., 2002; Neuberger et al., 2002; Frye et al., 2003; Simons and Wood, 2003; Gauderman et al., 2004; Tatum and Shapiro, 2005]. However, others have not found any effects [Jalaludin et al., 2000; Chhabra et al., 2001].

Several epidemiological studies indicate that children are susceptible to ambient air pollution. Increasing levels of ambient O_3 levels have been shown to be associated with a decrease in lung function in children [Hoek et al., 1993a; Hoek et al., 1993b; Braun-Fahrlander et al., 1994; Cuijpers et al., 1994; Chen et al., 1999; Just et al., 2002; McConnell et al., 2002] whereas, others did not get the same result [Linn and Gong 1999; Gauderman et al., 2000].

Deterioration of lung function among children has been reported to be associated with O_3 levels, which exceed the local air quality standards for more than four hours per day, as well as with small particles of solids, or particulate matter (PM_{10}) levels exceeding USA standards [Calderon-Garciduenas and Fordham, 2001; Horak et al., 2002].

In Mexico City, Gold et al. [1999] also found significant associations between both PM_{10} as well as O_3 levels with reduction in PEF in school children (aged 8 to 11 years).

The researchers suggested that both O_3 and fine particles impair the lung function of children. The peak flow of forty children living in Southwest Mexico City declined about 7% after exposure to fine particles (7 day mean 17,000 $\mu g/m^3$) and to O_3 (7 day mean 53.5 $\mu g/m^3$). The effects of these two pollutants, both characteristic of summer haze episodes, were additive but had different induction periods. Ozone exposures were associated with a rapid decline in peak flow (0 to 4 days later) while fine particle effects were delayed (4 to 7 days later).

Horak et al. [2002] in Austria studied almost a thousand school children from 8 communities for 3 years. The lung function measurements were taken twice a year. Higher summertime PM_{10} concentrations were associated with a slower increase in FEV_1, for each 10 $\mu g/m^3$ increment, 84 ml/yr in FEV_1 was observed. Exposure to NO_2 and O_3 also reduced lung-function growth, confirming earlier work. Further evidence for a long-term effect of PM_{10} on the development of pulmonary function in elementary schoolchildren was provided by this study. In addition, this study provides strong evidence for a further effect of O_3 and NO_2 on the development of forced vital capacity and forced expiratory volume in one second. Similarly, in the same country Frischer et al. [1999] followed a cohort of 1,150 children for 3 years to investigate the adverse effect of O_3 with ozone exposure at a level of ≥ 128 $\mu g/m^3$, which is far less than the current ambient standard of 182 $\mu g/m^3$. The results showed summertime O_3 was associated with increase in FEV_1 and forced vital capacity (FVC). However, they did not find any consistent association for lung function and SO_2, PM_{10} and NO_2. The authors concluded, 'Long-term ambient O_3 exposure might negatively influence lung function growth. This is the first study that suggests chronic effects of O_3 on lung function growth in children. Thus, O_3 would constitute a risk factor for premature respiratory morbidity during later life' [Frischer et al., 1999:396].

Under the California Children's Health Study, Peters et al. [1999] followed 3,300 school children who lived in 12 Southern California Communities for a period of 10 years. The children's lung functions were tested four times during the 10-year period. The result indicated that diminished lung function was associated with O_3 in female children with asthma and among males who spent more times outdoors.

In three cohort studies of Southern California children over a 4 year period, Gauderman et al. [2000] found that significant deficit in growth of lung function was associated with exposure to particles such as PM_{10} and NO_2. No significant association was observed with O_3. The study concluded that 'exposure to air pollution may lead to a reduction in maximal attained lung function, which occurs early in adult life, and ultimately to increase risk of chronic respiratory illness in adulthood.' Even in eight years study, Gauderman et al. [2004] did not find any significant correlation between O_3 level and other study pollutants which is not consistent with other studies.

In a study by Krzyzanowski et al. [1992] children in the age group 5-15 together with asthmatics and adults spending long time outdoors were identified as having the most significant temporary decline in lung function in relation to O_3 exposure. Studies on Taiwanese children also confirmed that lung function decreases during exposure to ambient air pollution. However, in this study ozone was found to be the most significant factor [Chen et al., 1999].

2.4.3 Air pollution and asthma in children

According to the National Heart, Lung and Blood Institute [1997] 'asthma is a chronic inflammatory disorder of the airways in which many cells and cellular elements play a role, in particular, mast cells, eosinophils, T lymphocytes, macrophages, neutrophils, and epithelial cells. In susceptible individuals, this inflammation causes recurrent episodes of wheezing, breathlessness, chest tightness, and coughing, particularly at night or in the early morning. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment. The inflammation also causes an associated increase in the existing bronchial hyper responsiveness to a variety of stimuli'.

Over the past four decades, asthma prevalence has risen in both developed and developing countries [Beasley et al., 1997; Woolcock and Peat, 1997; Shima and Adachi, 2000; Tamburlini, 2002; Crane, 2004; Gryparis et al., 2004; Lewis et al., 2004]. According to WHO, between 100 and 150 million people globally suffer from asthma and this number is rising [2000b]. For example, the number of individuals with asthma in USA increased two folds from 1980 to 1995 [Storey et al., 2003] and India has an estimated 15-20 million asthmatics, rough estimates indicate a prevalence of 10 to 15% in the age group 5-11 years [World Health Organization, 2000b].

It has been known for many years that the prevalence of childhood asthma varies from place to place. Recently the International Study of Asthma and Allergy in Childhood (ISAAC) has developed a standardized methodology that contributes significantly to describing the prevalence and severity of asthma throughout the world [Pearce et al., 2000]. The ISAAC project consists of three phases. ISAAC phase one used simple core written questionnaires for both 6-7 and 13-14 age groups. It was completed in 156 collaborating centres in 56 countries, with 721,601 children participating [ISAAC, 2005]. The ISAAC phases two and three questionnaires are not directly relevant to the research in this thesis, and will not be discussed here.

Information regarding cough, phlegm, episodes of cough and phlegm, wheezing, breathlessness, chest tightness, flu, tobacco smoking and home environment is collected in the questionnaires. The prevalence of asthma worldwide is shown in Figure 2.4, based on use of the ISAAC questionnaire in 56 countries. The highest prevalence (20-35%) was observed in UK and the lowest (2.5%) was observed in Indonesia [ISAAC, 1998]. In Figure 2.4 there are multiple measures for some countries, based on multiple studies using the ISAAC questionnaire. According to these findings, the prevalence in Iran is about a third of that in the countries with the highest prevalence.

The prevalence and incidence of asthma have increased over the past few decades [Tamburlini, 2002; Arif et al., 2003] as presented in Figure 2.5 the highest prevalence of asthma (35.6%) was observed in New Zealand and the lowest (2.5%) was observed in Estonia. There is some doubt that changes in definition of asthma and possibly higher diagnosis rates may explain the increase [Rumchev, 2001; Tennant and Szuster, 2003]. Even using the same definition of asthma as used in ISAAC questionnaire, the asthma rate shows significant increase [Woolcock 1991; Beasley et al., 1997; Borenstein, 2002]. As presented in Table 2.2, asthma prevalence in Tehran has increased by 0.4% in the 6-7 year-old children over a 5-year period.

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Figure 2.4 Prevalence of asthma related symptoms from written questionnaires [ISAAC, 1998]

Country	Center	12-mo Prevalence: Wheeze	12-mo Prevalence: ≥ 4 Asthma Attacks	12-mo Prevalence: Severe Wheeze Limiting Speech	Asthma Ever
Albania	Tirana	4.4 (3.1 to 5.6)	0.5 (0.1 to 0.9)	0.5 (0.1 to 0.9)	2.7 (1.7 to 3.7)
Brazil	Uruguaiana	25.6 (23.7 to 27.5)	6.5 (5.4 to 7.6)	5.9 (4.8 to 6.9)	12.7 (11.2 to 14.1)
China	Beijing	3.7 (3.2 to 4.3)	0.8 (0.5 to 1.1)	0.5 (0.2 to 0.7)	6.4 (5.7 to 7.2)
	Guangzhou	3.2 (2.6 to 3.8)	0.5 (0.3 to 0.7)	0.2 (0.1 to 0.4)	4.4 (3.7 to 5.0)
	Hong Kong	5.5 (4.7 to 6.3)	1.3 (0.9 to 1.7)	0.5 (0.2 to 0.7)	7.9 (6.9 to 8.8)
Ecuador	Pichincha	0.8 (0.2 to 1.4)	0.2 (−0.1 to 0.5)	0.2 (−0.1 to 0.5)	—
Estonia	Tallinn	8.4 (6.7 to 10.2)	1.5 (0.7 to 2.2)	1.1 (0.5 to 1.8)	2.5 (1.5 to 3.5)
France	Creteil	7.6 (6.2 to 9.0)	1.8 (1.1 to 2.4)	0.9 (0.4 to 1.5)	9.2 (7.6 to 10.7)
Georgia	Tbilisi	9.2 (7.4 to 11.1)	1.7 (0.9 to 2.6)	1.1 (0.5 to 1.8)	3.2 (2.1 to 4.3)
Germany	Dresden	7.9 (6.9 to 8.8)	1.6 (1.2 to 2.1)	1.9 (1.4 to 2.4)	3.6 (3.0 to 4.3)
	Munich	8.3 (7.3 to 9.2)	2.1 (1.6 to 2.6)	2.5 (2.0 to 3.1)	4.8 (4.0 to 5.5)
Ghana	Kintampo	6.4 (5.1 to 7.7)	2.5 (1.7 to 3.4)	2.4 (1.6 to 3.3)	15.8 (13.9 to 17.8)
Greece	Athens	5.6 (4.2 to 7.1)	1.0 (0.4 to 1.7)	0.6 (0.1 to 1.1)	7.5 (5.9 to 9.2)
	Thessaloniki	8.4 (6.7 to 10.1)	0.7 (0.2 to 1.2)	1.6 (0.8 to 2.3)	11.6 (9.6 to 13.5)
Iceland	Reykjavik	9.2‖	3.5‖	1.7‖	22.9‖
India	Mumbai	6.1 (4.9 to 7.3)	0.8 (0.4 to 1.2)	1.6 (1.0 to 2.2)	4.8 (3.8 to 5.8)
Italy	Rome	7.9 (6.5 to 9.4)	1.5 (0.9 to 2.2)	1.2 (0.6 to 1.8)	14.3 (12.5 to 16.2)
Latvia	Riga	6.9 (5.3 to 8.6)	1.0 (0.4 to 1.7)	0.7 (0.1 to 1.2)	3.2 (2.1 to 4.4)
The Netherlands	The Netherlands	8.7 (7.8 to 9.6)	2.7 (2.1 to 3.2)	1.6 (1.2 to 2.0)	7.8 (6.9 to 8.7)
New Zealand	Hawkes Bay	21.9 (19.7 to 24.1)	6.8 (5.5 to 8.2)	4.6 (3.5 to 5.8)	35.6 (33.0 to 38.2)
Norway	Tromsø	14.0 (12.9 to −15.2)	6.3 (5.5 to 7.1)	1.8 (1.3 to 2.2)	10.3 (9.3 to 11.3)
Spain	Almeria	15.5‖	3.5‖	2.8‖	14.6‖
	Cartagena	11.9‖	2.1‖	1.6‖	10.9‖
	Madrid	11.6‖	3.6‖	2.8‖	11.4‖
	Valencia	9.1‖	1.7‖	1.0‖	9.8‖
Sweden	Linköping	7.9 (6.2 to 9.7)	2.3 (1.3 to 3.3)	1.0 (0.3 to 1.6)	9.6 (7.7 to 11.5)
	Östersund	10.2 (8.5 to 12.0)	4.4 (3.2 to 5.5)	1.5 (0.8 to 2.2)	10.9 (9.1 to 12.7)
Turkey	Ankara	10.9 (9.8 to 12.0)	2.0 (1.5 to 2.6)	2.2 (1.6 to 2.7)	—
United Kingdom	West Sussex	16.2 (13.9 to 18.4)	6.5 (5.0 to 8.0)	2.4 (1.5 to 3.3)	20.3 (17.9 to 22.8)
West Bank	Ramallah	8.8 (7.6 to 9.9)	1.5 (1.0 to 2.0)	2.0 (1.4 to 2.6)	9.4 (8.2 to 10.6)

Prevalence values are in % with 95% confidence intervals in parentheses. Em dashes (—) = not performed/question not asked.

‖ The reported frequencies should not be interpreted as prevalence estimates because participation was <60% (*see* METHODS).

Figure 2.5 Prevalence of asthma related symptoms

Table 2.2 Asthma prevalence in Iran using ISAAC questionnaire [Tabatabaie et al., 1995a; Masjedi et al., 2004]

Please see print copy for image

Many factors including air pollution, may be involved in increased asthma prevalence, [Friedman et al., 2001]. Exposure to outdoor air pollution has been specifically identified as a potential risk factor for the development [McConnell et al., 2002] or exacerbation of asthma [Just et al., 2002].

Ozone exposure cannot only aggravate existing childhood asthma, but may actually cause it. McConnell and colleagues [2002] monitored the development of asthma in 3,535 children with no history of asthma who engaged in outdoor team sports in communities of California where concentrations of ambient O_3 and other air pollutants were known to exist. The results of the study showed that in communities with high O_3 concentrations, the relative risk of developing asthma in children playing three or more outdoor sports was three times higher than in children not participating in outdoor sports. In low-ozone communities, playing outdoor sports had no effect on the development of asthma. This indicates that time spent outside was associated with higher incidence of asthma in high ozone areas but not in areas of low ozone. Overall, the risk was similar in boys and girls; however, of those who played three or more outdoor sports in high-ozone communities, the risk was somewhat greater in girls (relative risk: 4.7 in girls compared with 2.5 in boys). The authors concluded that in communities with high ozone levels, participation in strenuous outdoor exercise is associated with the development of childhood asthma. This effect does not occur when O_3 levels are low. The results suggest that asthma may be caused by a combination of factors and that air pollution and outdoor exercise could contribute to the development of asthma in children [Simons and Wood, 2003].

2.4.4 Association of air pollution with children's health, especially lung function in asthmatic children

Asthma makes children's lungs more vulnerable to air pollution impacts. This section discusses the effects of particulate air pollution on decreasing lung function of children with asthma.

Increased particulate concentrations have been associated with acute reduction in lung function, including in children with asthma [He et al., 1993; Peters et al., 1997; Hoek et al., 1998; Strand et al., 1998; Aekplakorn et al., 2003]. Some of the studies compared the effects of air pollution on children with and without asthma and found that exposure to elevated levels of air pollution was associated with decreased peak expiratory flow rates [He et al., 1993; Peters et al., 1997; Strand et al., 1998; Jedrychowski et al., 1999; Aekplakorn et al., 2003], increased respiratory symptoms [Romieu et al., 1996; Romieu et al., 1997; Van der Zee et al., 1999], increased prevalence of school absenteeism [Ponka, 1990; Romieu et al., 1992; Chen et al., 2000; Gilliland et al., 2001; Park et al., 2002], and increased medication use [Van der Zee et al., 1999]. Declines in pulmonary function among asthmatic children were associated with increases in particulate air pollution, rather than with increases in SO_2 [He et al., 1993; Strand et al., 1998; Aekplakorn et al., 2003].

To investigate the short-term effects of air pollution on respiratory morbidity in children with asthma, Peters et al. [1997] recruited 89 children with asthma in the age group 6-14 years from Sokolov, Czech Republic. They were asked to record their daily peak expiratory flow measurements, symptoms, and medication use in a diary for a period of 7 months during the winter of 1991-1992. Linear and logistic regression analyses estimated the impact of air pollutants adjusted for trend, temperature and weekend and auto correlated errors. The children showed a stronger association between decreases in mean deviation of PEF in the evening and air pollution. Thus in this study, a group of children with mild asthma experienced small decreases in PEF in association with fine particles formed during air pollution episodes.

A study carried out by Aekplakorn et al. [2003] investigated the association of short-term exposure to increased ambient SO_2 and daily pulmonary function changes among children with and without asthma in Thailand by recruiting 175 children aged 6-14 years. Each child performed daily pulmonary function tests during the 61-day study period. General linear mixed models were used to estimate the association of air pollution and pulmonary function controlling for time, temperature, co-pollutants, and autocorrelation. In asthmatic children, a 10-$\mu g/m^3$ increase in PM_{10} level was associated with changes in forced vital capacity (FVC) (-6.3 ml, 95% CI: -9.8, -2.8), FEV_1 (-6.0 ml, 95% CI: -9.2, 2.7), peak expiratory flow rate (PEFR) (-18.9 $ml.sec^{-1}$, 95% CI: -28.5, -9.3) and forced expiratory flow 25% to 75% of the FVC ($FEF_{25-75\%}$) (-3.7 $ml.sec^{-1}$, 95% CI: -10.9, 3.5). The results showed that there were no consistent associations between air pollution and pulmonary function for non-asthmatic children. The authors concluded that increases in particulate matter were associated with declines in pulmonary function among asthmatic children. This result confirms the Hoek et al. [1998] study results.

To investigate the association between PM_{10} and decrements in pulmonary function measured in PEF rates in children, Hoek et al. [1998] reported the results of a reanalysis of data from five panel studies. The decrement in the mean PEF for increases of $10\mu g/m^3$ in PM_{10} concentration in the same day was 0.07%, averaged of all panels. A significance relative increase of 2.7% in the prevalence of PEF decrement greater than 10% was associated with the same exposure.

To address whether asthmatic children are more likely to experience the adverse effects of air pollution than children without asthma, Vedal et al. [1998] studied a group of 2,200 elementary school children (6-13 years old) in a pulp mill community of Vancouver Island. The children were followed for 18 months. PEF measurements were taken twice daily and symptom diary recordings were kept and collected daily. The result showed that in the entire sample of children, increases in PM_{10} were associated with reduction in PEF. Children with asthma were found to be more susceptible to effects of PM_{10} than other children. It means PEF fell by an estimated 0.55 L/min (95% CI: 0.06, 1.05) for a 10 $\mu g/m^3$ PM_{10} increase above the mean daily concentration of 27.3 $\mu g/m^3$. There was no consistent correlation between PM_{10} concentration increases and PEF decline in non-asthmatic children. This result supports those of Aekplakorn et al. [2003] results, which was mentioned before.

In the Netherlands, Van der Zee et al. [1999] looked at winter air pollution. The researcher followed panels of children in the age group 7-11 years with and without asthma. A stronger association was found between particle pollution and PEF decrement in children with asthma symptoms, particularly those on regular medication, than with non-symptomatic children. There was an 80% increase in decrements in PEF for a 100 $\mu g/m^3$ increase in the 5-day mean PM_{10} concentration. The authors concluded that children with symptoms are more susceptible to the effects of particulate air pollution than children without symptoms, and that use of medication for asthma does not prevent the adverse effects of particulate air pollution in children with symptoms. This study was very similar to Vedal's study [1998]; a difference was that Vedal's study participants were in the age group 6-13 years. The other difference relates to seasonal effects. Vedal's study included all seasons, whereas that of Van der Zee et al [1999] concentrated on winter only.

With the purpose of investigating the effects of moderately high levels of winter air pollution on the symptoms and lung function of asthmatic children, Just et al [2002] followed 82 medically diagnosed asthmatic children in Paris for 3 months during spring and early summer. The results showed that O_3 was associated with an increase in PEF variability and a decrease in PEF. Daily PEF variability increased by 2.6% with an increase of 10µg/m^3 of 0-2 mean O_3 concentration ($p = 0.05$) and 3.3% with an increase of 10µg/m^3 of 0-4 mean O_3 concentration ($p = 0.09$). Morning PEF correlated with O_3 concentration (mean 0-2, $p = 0.006$; mean 0-4, $p = 0.009$) only if a significant interaction between O_3 and temperature was introduced in the models. No relationship was found between PEF variables and levels of the other three pollutants. This study was carried out in summer when the O_3 concentration is high. If lung function for the entire year was considered, the result would be different.

To investigate how daily variations in ambient air pollution, especially in particles, during the cold days of winter affect repeated measurements of baseline lung function and exercise induced bronchial responsiveness among primary school children with chronic respiratory symptoms, Timonen et al [2002] followed 33 children during alternate school weeks (maximum five) from February to April 1994. The students took part in exercise challenge tests (n = 141 tests) which were conducted outdoors in a schoolyard in the centre of Kuopio, Finland. Spirometric lung functions were measured indoors before the exercise, again 3 and 10 minutes after. Daily mean concentrations of SO_2, PM_{10}, black smoke (BS), NO_2, CO, and particle size and numbers were monitored at a nearby fixed monitoring site. The researchers found increased concentrations of PM_{10}, BS; particle numbers, NO_2, and CO were consistently associated with an impairment of baseline lung functions. The reductions in FVC and FEV_1 were 0.5% and 0.6%, respectively, for each 10 µm/m^3 increase in BS (lag 2). The authors concluded that '…particles derived from combustion affect baseline lung function rather than bronchial responsiveness among children with chronic respiratory symptoms' [Timonen et al., 2002:134].

2.4.4.1 Association between diesel emissions and lung function

Diesel exhaust is a mixture containing over 450 different components, including vapours and fine particles [American Lung Association, 2000]. For the same load and engine conditions, diesel engines exhaust 100 times more sooty particles than gasoline engines. Thus, diesel engines account for an estimated 26% of the total hazardous PM_{10}

from fuel combustion sources in the air, and 66% of the PM_{10} from on-road sources. Diesel engines also exhaust almost 20% of the NO_X in outdoor air and 26% of the total NO_X from on-road sources. NO_X are contributor to O_3 production and smog [American Lung Association, 2000].

Exposure to this mixture may result in exacerbation of asthma and other health problems. Various studies focusing on air pollution effects from diesel emissions and lung functions in children are enlightening in that such emissions strongly affect PM_{10} levels. For example, the authors of an epidemiological study of children in the Netherlands [Brunekreef et al., 1997] stated that there are large amounts of elemental carbon (EC) in diesel exhaust particles, which contributes much to the 'blackness' of particles as measured by Organization for Economic Cooperation and Development (OECD) method for BS. A side-by-side comparison of BS and EC near a busy road in Berlin, Germany, in 1991 showed a close relation (R^2 = 0.96). Apparently, BS measurements represent diesel exhaust particles (as opposed to tire abrasion, which results in organic carbon) well in such situations. The same situation is present in Iran as the news site for Iranian Green Party reported in Tehran diesel vehicles is the main producer of suspended particulate particles [Iran Green Pen, 2004a].

Tehran is one of the major cities that relies heavily on diesel powered public transport vehicles including buses and mini-buses. A new policy of DOE, implemented in March 2004, which stipulates that no more licence plates will be given to diesel-fuel buses. All buses in polluted cities must be converted to Compressed Natural Gas (CNG) within two years and all public transport should be converted to CNG fuel base by 2007 [DOE, 2005].

To evaluate the extent to which lung function in 1,213 children living near freeways is related to air pollution generated on the motorways, Brunekreef et al. [1997] studied children aged 7 to 12 years. They were from 13 schools where their lung functions were measured. In addition, in 12 of 13 participating schools, indoor measurements of PM_{10} were conducted during school hours. Truck traffic (heavily diesel) density was also monitored by the researchers. It is important to note that the study showed that, for all children living within 1000 meters of the freeways, truck traffic density was related to a decrease of 8% for PEF per 10,000 trucks; these effects increased in the group of children living within 300 meters of freeways. The results also showed that the association was stronger in girls than boys were. The result of this study confirms the earlier study carried out by Wjst et al. [1993] who investigated effects of air pollution caused by excessive road traffic on children's respiratory function. They followed 4,320 children in the age group 9-11 years old living in Munich. The children's parents were asked to complete questionnaires about the child's health, including whether the child had ever been diagnosed with asthma and how often the child caught colds. Their lung functions were evaluated with an electronic spirometer. Results indicated that PEF rates dropped almost 1% for each increase of 25,000 cars on the main road through the school district. Episodes of wheezing and shortness of breath also increased. However, the proportion of children who had asthma or recurrent bronchitis did not increase.

Most recently, Gauderman et al. [2004] conducted a cohort study over a period of 8 years on 1,759 school children aged between 10 to 18 years old in 12 Southern Californian communities, and determined the effect of air pollution on lung development. Linear regression was used to find relationships between air pollution and FEV_1 and other spirometric measures. The result showed that a deficit in the growth of FEV_1 was associated with $PM_{2.5}$ ($p = 0.004$), NO_2 ($p = 0.005$), acid vapour ($p = 0.004$), and elemental carbon ($p = 0.007$). The authors concluded that current levels of air pollution have chronic, adverse effects on lung development in children from the age of 10 to 18 years, leading to clinically significant deficits in attained FEV_1 as children reach adulthood.

To investigate the association between air pollution and lung function Peled et al. [2005] followed panels of children with asthma in Israel. There were 285 children in the age group 7-10 years old. The negative association of lung function of asthmatic children with air pollution by $PM_{2.5}$ was found.

Important studies have been carried out in Mexico City where air pollution levels were high. Romieu et al. [1996], studied a panel of 71 children aged 5-7 years with mild asthma. The PEFR in schoolchildren was strongly associated with PM_{10} levels. It means an increase of 20µg/m^3 daily average PM_{10} was associated with a 1.92 litre per minute decrease in the evening PEFR. Romieu et al in another study [1997] studied a panel of children within the age group 5-13 years old with mild asthma. An increase of 107µg/m^3 in 1-hour maximum O_3 level was associated with a decline in the mean deviation in the evening PEFR of -2.32 l/min (95% CI: -4.17, -0.47).

2.4.4.2 Association between air pollution and lung function in inner city children

Some studies investigating the adverse health effects of air pollution compare urban and suburban environment and found urban ambient air contribute to growth lung function retardation [He et al., 1993; Asgari et al., 1998; Chen et al., 1998; Yu et al., 2001].

To compare the lung function of children living in urban area with lung function of children living in suburb, Qing-Ci et al. [1993] evaluated the spirometric lung function of 604 children, who were in age group 7-13 years and who were free of chronic respiratory conditions. The children's lung function was measured in both areas of Wuhan, China. During 1981-1988, ambient total suspended particulate (TSP) levels averaged 481µg/m^3 in the urban area and 167µg/m^3 in the suburb. In 1988, TSP levels, were measured within 500 metres of the children's homes, and showed an average of 251µg/m^3 in the urban area and 110µg/m^3 in the suburb. Levels of SO_2 and NO_2 were also higher in the urban area. The results showed both FVC and FEV_1 were consistently lower in urban than suburban children. Difference between suburban and urban in slopes of lung function growth curves were statistically significant for FVC but not for FEV_1. Rates of clinical upper respiratory irritation were also generally elevated in urban children. The authors concluded, '…these results strongly suggest that urban ambient air pollution exposure in China contributes to retardation in the growth of children's lung function' [He et al., 1993:392].

Another study in China, Qian et al. [2004] studied long-term effects of air pollution on 7,058 school children 5-16 years of age living in the four Chinese cities: Lanzhou, Chongqing, Wuhan, and Guangzhou. Ambient levels of PM, SO_2 and NO_X were measured from 1993 to 1996. They found monotonic, positive relationships of exposure to the pollutant mixture with prevalence rates of cough with phlegm and wheeze. They confirmed that evidence of exposure to the pollutant mixtures had adverse effects on children living in the four Chinese cities.

Studies have shown adverse health effects of long-term exposure even in relatively low-level air pollution. Yu et al. [2001] studied school children aged 8 to 12 years from two districts in Hong Kong with different air quality. In the first phase, parents of 1,660 children were asked to complete questionnaires on respiratory symptoms. In the second phase, 1,294 children whose parents had agreed to participate in the study had their pulmonary function tested with a Spirometer. Children living in the more polluted district were found to have increased odds ratios for frequent cough (1.74), frequent sputum (1.87), chronic sputum (1.84), and doctor-diagnosed asthma (1.98). Children without considering their gender, had significantly poorer lung function in the more polluted district, and with considering their gender, the differences among girls were more noticeable.

To investigate long term effects of ambient O_3, Frischer et al. [1999] carried out a cohort study on 1,150 children for 3 years. The result showed summertime O_3 was positively associated with lung function. No consistent effects of SO_2, PM_{10} and NO_2 on lung function were present. This was the first study that confirmed chronic exposure to ambient O_3 might negatively influence lung function growth.

To assess the effect of low concentrations of ambient air pollution on lung function growth in preadolescent children, Jedrychowski et al. [1999] followed a cohort of 1,129 children living in two different air quality areas in Poland. Two panels of children were compared for their growth in lung function over time. Significant slower growth rate was found in boys compared to girls. However, growth rate in boys living in highly polluted area was significantly lower compared to boys from the area with the lower air pollution level. The proportion of boys with slow growth rates was approximately twice as high in more polluted area as in the low polluted area. For girls, a similar difference did not reach the level of significance. The authors suggested that air pollution might lead to retardation in pulmonary function growth during the pre-adolescent years.

2.4.4.3 Association between decreases in air pollution and children's lung function

To investigate the relationship between air pollution and lung function in Austria, Neuberger et al. [2002] examined 3,451 elementary school children by spirometry over a 5-year period. The research areas were categorized as the area where NO_2 declined during this period (by at least $30 \mu g/m^3$ measured as half year means) and the second area with less or no decline in ambient NO_2. In both districts, SO_2 and TSP fell uniformly over this period. A marked improvement of maximum expiratory flow rate at

25% vital capacity (MEF_{25}) was found in children living in districts with low NO_2. The authors concluded [2002:1733], '…the present study provides the first evidence that improvements in the outdoor air quality during the 1980s are correlated with health benefits, and suggest that adverse effects on lung function related to ambient air pollution are reversible before adulthood. Improvement of small airway functions appeared to be more dependent on reductions of NO_2 than reduction in SO_2 and TSP'.

In another study to investigate the effect of air pollution on lung function, Gauderman et al. [2004] studied 1,759 children in 12 communities of California since 1992 over an 8 year period. They used a base line questionnaire, confirmation of absence of asthma by a doctor and annual testing of lung function. Linear regression was used to find the effect of air pollution on FEV_1 and other lung function measures.

- There was no significant gender effect found for the relationship between lung function growth and air pollution.
- Growth of FEV_1 and FVC declined with increased pollution for all pollutants in the study.
- Exposure to particulate matter, NO_2, and acid vapour were found positively correlated to clinical low FEV_1. This decreased lung development may have permanent adverse effects in adulthood.

In a study in Germany, Frye et al. [2003] investigated the association of lung function with declining ambient air pollution**.** They carried out three repeated cross-sectional surveys of schoolchildren aged 11-14 years from three communities in East Germany in 1992-1993, 1995-1996, and 1998-1999. Lung function tests of 2,493 children were provided. The annual mean of total suspended particulates (TSP) declined from 79 to 25 $\mu g/m^3$. Both FVC and FEV_1 increased from 1992-1993 to 1998-1999. For each 50$\mu g/m^3$ decrease of TSP ($p = 0.043$) and a 100 $\mu g/m^3$ decrease of SO_2 ($p = 0.029$) FVC were 4.7% and 4.9%, respectively. Effects on FEV_1 were negligible to be finding statistically significant. This study showed that the deficit in lung function is reversible. Improvement of lung function seemed related to reduction of air pollution level in a short time period.

To investigate the changes in air pollution levels on lung function, Avol et al. [2001] studied 110 children. The age of the population at the time of recruitment was 10 years old and at the time for follow up was 15 years old. For every 10 $\mu g/m^3$ increase in the annual 24 hourly average PM_{10}, annual lung function growth was estimated to decrease by 34.9 ml/s for PEFR. Subjects who had moved to areas of lower PM_{10} level, increased growth in lung function were found and vice versa. The authors concluded that 'changes in air pollution exposure level during adolescent years may have measurable effects on long term lung function outcomes' [Avol et al., 2001:2071].

2.4.5 Association between air pollution and absenteeism in elementary school children

Given the significant adverse health effects on children resulting from air pollution described above, it is not at all surprising that air pollution has been shown to result in increased school absenteeism [Ponka, 1990; Ransom and Pope III, 1992; Romieu et al., 1992; Chen et al., 2000; Makito, 2000; Gilliland et al., 2001; Park et al., 2002]. However, there are limited numbers of studies in this area compared to hospital admissions.

School absenteeism is a good indicator for health of school-aged children reflecting the overall health condition of children; however, it is not as specific as other indicators, like emergency room visits or hospital admissions. In the absenteeism studies, data were collected to evaluate the association between air pollution and absenteeism [Chen et al., 2000; Park et al., 2002].

In a study carried out in the Czech Republic, Peters and colleagues [1997] found that upper and lower airways were affected by air pollution and prevalence of school absenteeism was associated with elevated levels of SO_2.

To investigate the association between air pollution and school absenteeism, Ransom and Pope [1992] assessed the association between school absenteeism and SO_2, PM_{10}, NO_2 and ozone levels in the Utah Valley for the six school years of 1985 to 1990. In both data sets, the association between absenteeism and PM_{10} pollution was found significantly positive. An increase in 28-day moving average of each 100 $\mu g/m^3$ of PM_{10} was associated with an increase of 2% in the absence rate, or an increase of 40% in overall absenteeism.

To investigate the relation between air pollution and absenteeism, Gilliland et al. [2001] studied a group of 1,933 fourth graders from 12 southern California communities during the first six months of 1996. The pollutants were respirable PM_{10}, NO_2, and O_3.

The reasons for absenteeism were collected via telephone interviews. To examine the effects of air pollution data on absenteeism rate, a two-stage time-series model was fitted to the absence count data. Short-term change in O_3, but not NO_2 or PM_{10}, was strongly associated with a substantial increase in school absences from both upper and lower respiratory illness. The results indicated that an increase of 42.8 $\mu g/m^3$ of O_3 was associated with an increase of 62.9% (95% CI: 18.4, 124.1%) for illness-related absence rates, 82.9% (95% CI: 3.9, 222.0%) for respiratory illnesses, 45.1% (95% CI: 21.3, 73.7%) for upper respiratory illnesses, and 173.9% (95% CI: 91.3, 292.3%) for lower respiratory illnesses with wet cough. Ozone related increases in total absenteeism and especially illness-related absenteeism were larger in communities with lower level of NO_2 or PM_{10} than in communities with high levels of NO_2 or PM_{10}. Daily (24-hour) PM_{10} was also associated with all absences. An increase of 10$\mu g/m^3$ in PM_{10} was associated with a 22.8% increase in all types of school absenteeism combined with a 97.7% increase in non-illness-related absences, but a 5.7% increase in illness-related absences. These results are consistent with those of Ransom and Pope. However, acute effects of NO_2 on school absenteeism were not observed by the study. Gilliand et al. concluded that respiratory illness related school absenteeism from O_3 exposure in children documents an important adverse effect of O_3 on children's health and well-being.

To investigate the acute effects of O_3 exposure on children, Romieu et al. [1992] studied air pollution and absenteeism among children in a private kindergarten in Mexico City. The researchers conducted a short follow up study (3 months) of respiratory illness in a population of 111 preschool children frequently exposed to O_3 levels that exceed 256.8$\mu g/m^3$. Parents completed questionnaire on demographic data, medical history, and the potential sources of indoor air pollution. The respiratory illness related absenteeism was used in analysis. The authors used a logistic regression model for longitudinal data to determine the relation of O_3 and respiratory illness related school absenteeism. The results indicated that 50% of children had at least one respiratory-related absenteeism period, and 11.7% of them had two or more. Children exposed to high ozone level for two consecutive days had a 20% increment in the risk of respiratory illness. Children exposed to low temperature for previous day in combination with the exposure to high ozone level, showed a 40% risk of respiratory illness. This study suggested 'ozone exposure might be positively associated with the risk of respiratory illness in children and it may have an interactive effect with low temperature exposure' [1992:1531].

Similarly, to assess the association of air pollution and school absenteeism, Park et al. [2002] assessed 1,264 elementary school students. Absenteeism records for the four-year period were collected from student attendance reports of one elementary school in Seoul, Korea. Illness related absenteeism was collected from teacher records, which reported by parents. Air pollutants such as SO_2, PM_{10}, NO_2, O_3 and CO were measured. To determine the effect of air pollution on absenteeism, time-series analysis of air pollution and school absenteeism data with controlling for long-term trends, seasonality, day of the week, and holiday as well as meteorological variables were used. Exposure to air pollutants such as SO_2, PM_{10}, and O_3, was found associated with illness-related absenteeism. In this study, the absenteeism classified as illness related and non-illness related absenteeism. The estimated relative risks were 1.09 (95% CI: 1.07, 1.12) per 16.24 $\mu g/m^3$ increases in SO_2, 1.06 (95% CI: 1.04, 1.09) per 42.1 $\mu g/m^3$ increases in PM_{10}, and 1.08 (95% CI: 1.06, 1.11) per 34.11 $\mu g/m^3$ increases in O_3. There was no significant association between NO_2 level and illness-related absenteeism. This result is consistent with that of Gilliland et al [2001]. The results concluded that air pollution is associated with illness-related absences among elementary students. This conclusion suggests that air pollution is closely related to daily activities, especially in school-aged children.

A study by Chen et al. [2000] examined the association between ambient air pollution and daily elementary school absenteeism in Washoe County, Nevada, for a two year period. All the 57 elementary schools in the area were recruited for the study. The students were counted as 27,793 student enrolments during this study period. The daily average absence rate was 5.09% (±1.54%). PM_{10}, O_3, and CO concentrations were obtained from seven air-monitoring stations. Meteorologic data were collected from 5-7 stations. The daily average levels of $PM_{10,}$ O_3 and CO were 32.44$\mu g/m^3$, 80.14$\mu g/m^3$ and 3412.5$\mu g/m^3$, respectively. Correlation analysis was used for statistical design. O_3 and CO were found statistically significant predictors of daily absenteeism in elementary schools. For every 107 $\mu g/m^3$ and 1250 $\mu g/m^3$ increase in CO and O_3, the absence rate would increase 13.01% (95% CI: 3.41, 22.61%) and 3.79% (95% CI: 1.04, 6.55%), respectively. However, PM_{10} values were negatively correlated with school absenteeism. For an increase of every 1250 $\mu g/m^3$ and 107 $\mu g/m^3$ in CO and O_3, the daily absenteeism decreased 3.79% and 13.01%, respectively, whereas, the negative association is not meaningful.

2.4.6 Association between air pollution and hospital admissions and emergency room visits

There is an increasing interest in the use of hospital admission data in studies of short-term effects of air pollution on health. This reflects the improved availability of admission data from routine systems and the possibility that, as a health outcome, admissions offer some advantages including the likelihood that the diagnosis will be more accurate, the possibility that admission may be a more sensitive indicator of pollution effects, and the availability (for respiratory disease) of information on children. However, studies concerning the relationship between air pollution and hospital admission in children are few.

Numerous studies associate air pollution with acute changes in lung function and respiratory illness [Dockery et al., 1996; U.S. Environmental Protection Agency (USEPA), 1996], resulting in increased hospital admissions for respiratory disease and school absences from respiratory infections, or aggravation of chronic conditions such as asthma and bronchitis [Shprentz, 1996].

To investigate the association of daily consultations of general practitioners (GPs) for upper respiratory diseases with air pollution, Hajat et al. [2002] studied the effect of air pollution on hospital admission for upper respiratory diseases in London, United Kingdom. Air pollutants such as SO_2, BS, NO_2, O_3 and CO measures, were obtained from three stations. To determine the effect of air pollution on daily consultations of GPs, time-series analyses were used. In children, a 10^{th}-90^{th} percentile change (13-31μg/m^3) in SO_2 levels was associated with a 3.5% increase in consultations (95% CI: 1.4-5.8). The association was weak and was found during cold months. The study suggests that air pollutants such as SO_2 and PM_{10} have some effects on upper respiratory related GPs' consultation but this effect was relatively small.

Similarly, to investigate the association of increase in certain pollutants and weather phenomenon with increase in respiratory related emergency room (ER) visits, Wilson and co-workers [2005] compared daily ER visits for all respiratory and asthma among all age groups with daily SO_2, O_3 and weather variables. The study was done over the period 1998-2000 in Portland, Maine, and Manchester, New Hampshire during 1996-2000. Seasonality was removed from all variables. For statistical analysis, general additive models were used to estimate the effect of elevated levels of pollutants on ER visits. Seasonal variation was marked in ER visits in both cities, with 20-30% fewer admissions in the summer than in the winter in both cities. Positive association was found between elevated levels of SO_2 and O_3 elevated respiratory and asthmatic ER visits.

To find the effect of air pollution and meteorological parameters on respiratory morbidity during the summer, Goncalves et al. [2005] collected the records of respiratory admissions of children under 13 years old in 80 hospitals in Sao Paulo City, Brazil in two consecutive summers: from 22/12/92 to 20/03/93 and 22/12/93 to 20/03/94. Daily concentrations of SO_2, PM_{10}, and O_3 were collected. The results showed during the 1992/1993 summer, there was a positive association between O_3 and morbidity. No clear association was found with other variables such as temperature and water vapour density. However, in the 1993/1994 summer, there were clear, independent and distinct patterns associating respiratory morbidity with temperature and water vapour density. The authors [2005] concluded that: 'under significant contrast of synoptic conditions, a stronger relationship between weather variables and respiratory morbidity can occur and the role of pollutants is minimized or unclear'.

In a study investigating the impact of air pollution in Australia, Jalaludin and others [2004] studied respiratory symptoms, asthma medication use and doctor visits for asthma in primary school children in association with ambient air pollution. Daily PM_{10}, NO_2 and O_3, meteorologic and pollen data were obtained. The authors used generalized estimating equations (GEE) logistic regression models to determine associations between air pollution variables and respiratory symptoms, medication use and any doctor visits for asthma. One hundred and forty eight children were enrolled. No associations were found between ambient O_3 concentration and respiratory symptoms, asthma medication use, and doctor visit for asthma. However, an association between PM_{10} levels and doctor visits for asthma (RR = 1.11, 95% CI: 1.04, 1.19) and between NO_2 levels and wet cough (RR = 1.05, 95% CI: 1.003, 1.10) in single pollutant models was observed.

Likewise, in Australia Erbas et al. [2005] assessed the associations of ambient air pollution on Emergency Room (ER) childhood asthma presentations in Melbourne for the years 2000 and 2001. The study population was children in the age group 1-15 years old. Generalized Additive Models (GAM) were used to describe the association. Consistent associations was found between childhood ER asthma presentations and regional concentration of PM_{10}, with a strongest association of RR = 1.17 (95% CI: 1.05, 1.31) in the central district of Melbourne. NO_2 and O_3 were associated with increased childhood asthma ER presentations in the Western districts. The authors concluded the findings suggest a consistent positive association of PM_{10} with childhood asthma ER presentations. Possible local variation in O_3 levels may also have contributed to intra-city variations in association with childhood asthma related ER admissions.

To investigate the association between air pollution and the rate of childhood admissions for asthma, Wong et al. [2001] collected any admissions with the International Classification of Diseases, 9th revision (ICD_9) code 493 in Hong Kong. Daily SO_2, PM_{10}, and NO in combination of weather data were collected from 9 monitoring stations for the period 1993-1994. Using Poisson regression, the association between three pollutants and hospital admission were calculated. A total of 1,217 children less than 15 years old were admitted for asthma during the study period. The ratio of male to female was 1.7:1. The calculated annual hospitalisation rates were 283 boys and 178 girls per 100,000. Daily admission for asthma increased significantly with increasing ambient level of SO_2 (RR = 1.06), respirable particles (RR = 1.03) and NO_2 (RR = 1.08 per 10 $\mu g/m^3$). No association was found between hospital admission and weather parameters.

Similarly, to examine the relationship between air pollution and ER admission for asthma in children, Migliaretti and Cavallo [2004] conducted a case control study in Turin, Italy in the period of 1997-1999. The number of cases was 1,060 and other children with other respiratory and heart diseases diagnoses who were admitted in hospital defined as control (25,523). Using simple and multiple logistic regression models, the association between ER admission for asthma and exposure to each pollutant were found. For each increase of 10 $\mu g/m^3$ in NO_2 and TSP, the ER admission for asthma increased 2.8% (95% CI: 0.7, 4.9%) and 1.8% (95% CI: 0.3, 3.2%), respectively.

2.5 Analysis methods used to assess adverse health effects of air pollution

The case-crossover design was first introduced in 1991 as a new epidemiological method of analysis to examine the transient effects of a brief exposure on the onset of an acute outcome [Maclure, 1991]. The design has the important advantage of eliminating most confounding variables, allowing a stronger causality inference. Unfortunately, it seems there are limited studies on the effect of air pollution on children using case-crossover design. Therefore, some of the studies using this design are presented in this section in combination with other studies, which have used this method, but not specifically on children.

To evaluate the relation between daily indicators of air quality and hospitalizations for acute myocardial infarctions, or heart attacks, D'Ippoliti et al. [2003] used a case-crossover design in Rome, Italy. Individual data on patients was considered as possible effect modifiers. The study period was over two years and included over 6,000 patients. The strongest and most consistent positive effects were found for total suspended particulates, with positive associations also reported for NO_2 and CO. The study suggests that traffic-derived air pollutants increase the risk of heart attacks, especially during the warm season, among the elderly, and in people with heart conduction disturbances. Increases in carbon monoxide were also associated with more severe asthma attacks, but researchers believe that this pollutant is a marker for exposure to combustion by products [Slaughter et al., 2003].

To investigate the air pollution effects on asthma hospitalization for children, Livingston [2002] used both time series and case crossover designs. The sample was the air pollution data and hospital admission data for asthma patients aged 6 to 12 in Toronto area from 01/01/81 to 31/12/93. The study showed that asthma hospitalizations are more prevalent during warm season than during cool season. Of all pollutants, NO_2 and CO indicated the most significant association with hospital admission. The odds ratios and confidence intervals averaging were 1.017 (0.980, 1.056) and 1.026 (0.979, 1.050), respectively. For example, for an increase of 11 units in NO_2 concentration, hospital admissions were likely to increase by 1.017 times.

To investigate transient effects of intermittent exposure on acute onset of disease occurring shortly after exposure, Boutin-Forzano et al. [2004] used a case-crossover design. The study was carried out to evaluate the relationships between emergency room visits for asthma attacks and gaseous air pollution changes. The population in this study consisted of 549 individuals, 3-49 years old, visiting the ER during one-year period. Exposure to gaseous air pollutants (SO_2, NO_2, and O_3) on the same day and up to 4 days before was computed according to the patient's address. The statistical analysis included meteorological data as potential confounding variables. No association could be shown between ER visits and SO_2 or NO_2 levels. In contrast, there was a statistically significant association between ER visits and mean O_3 levels, on the day of admission and on D-2 and D-3. For an increase of 10 $\mu g/m^3$, the risk of requiring an ER admission increased by 6-10%. This study confirmed that ozone changes lead to a moderate increase in risk of requiring an ER admission in asthmatic subjects.

Other studies of emergency room visits for respiratory diseases in the United States and in Spain [Sunyer et al., 1991; Sunyer et al., 1993] using different statistical design such as time-series [Samet et al., 1981; Schwartz et al., 1993] have shown similar findings. The study considers that the health effects of air pollution may be delayed from 1 to 5 days.

To investigate the association between ambient air pollution levels and the number of daily hospital admissions, Burnett et al. [1994] studied 168 hospitals in Ontario, Canada, which serviced 8.1 million people. Summer respiratory admissions were found to be closely related to ozone levels, and children were found to be especially affected, as 15% of the admissions for children were associated with ambient air pollution compared with 4% for the elderly population.

In another study to examine the association between O_3 and hospitalization for respiratory diseases, Burnett et al. [1997] studied the hospitalization in 16 Canadian cities, which represented approximately half of the country's population for the period 1981 to 1991. The respiratory diseases related admission records were obtained from a central registry at Statistics Canada. During the 3927-day period from 01/04/81, to 31/12/91, there were 720,519 admissions for which the principle diagnosis was a respiratory disease. Daily measures of SO_2, COH (soiling index which is correlated to airborne particles), together with NO_2, O_3 and CO were obtained from all monitoring stations. To determine the effect of ozone level on hospital admission the regression after controlling for SO_2, NO_2, CO, soiling index, and dew point temperature was used. The results indicated that the daily high hour concentration of O_3 recorded 1 day before the date of admission was positively associated with respiratory admissions in the April to December period but not during the coldest months. No association was obtained between ozone levels and non-related air pollution admission records. Positive association for CO and particulate matter as measured by soiling index were observed. These results suggest that 'ambient air pollution at the relatively low concentrations observed in this study, including troposphere O_3, is associated with excess admissions to hospital for respiratory diseases in populations experiencing diverse climates and air pollution profiles' [1997:24].

To explore the relationship between PM_{10} and hospital admission with cardio-respiratory illnesses, McGowan et al. [2002] found winter air pollution in Christchurch, New Zealand is dominated by particulate from solid fuel domestic heating. Particulate air pollution statistics were obtained from the Canterbury Regional Council monitoring station in the city. A significant association between particulate air pollution levels and cardio-respiratory admissions was observed using time-series analysis controlling for weather variables. There is evidence in Christchurch of a relationship between ambient particulate levels and admissions with cardiac and respiratory illnesses, which was consistent with other studies. Associations between various health indicators and PM_{10} pollution were observed even for levels below the national 24-hour standard of 150µg/m^3. There was a 3.37% increase in respiratory admissions for every inter-quartile rise in PM_{10} (IQR = 14.8µg/m^3) for all ages.

Several studies specific to the Utah Valley in the United States, have evaluated the association between various indicators of health and respirable PM_{10}. These studies found substantial associations between PM_{10} and respiratory hospital admissions [Pope III, 1989; 1991]; and reported respiratory symptoms and lung function as measured by PEFR [Pope III, 1991; Pope III and Dockery, 1992]. In each of these studies, associations between compromised health and elevated PM_{10} levels were below the federal ambient air quality standard (24-hour average 150µg/m^3).

Studies from North America have documented that during months with peak particulate pollution, average admissions for respiratory illness rise by 300% for children, and 44% for adults [Bates and Sizto, 1987; Pope III, 1991].

To examine the relationship between the level of air pollution and incidence of respiratory disease admission, Cho et al. [2000] studied the relationship between the level of air pollution in three areas of Korea and the incidence of respiratory diseases. They found respiratory disease admissions were related to TSP, NO_2 and CO, concentrations below the current environmental standard.

To investigate the effects of ambient air pollution, Petroeschevsky et al. [2001] used air pollution and health**:** a European approach (APHEA) to examine the effects of air pollutants on daily hospital admissions for asthma and respiratory, cardiovascular, and digestive disorders (control diagnosis) that occurred during the period 1987-1994 in the Australian city of Brisbane. Daily hospital admissions to public hospitals in Brisbane were obtained. Daily SO_2, NO_2, O_3 with combination of meteorological data were obtained. Association of O_3 with admissions of asthma and respiratory disease was found using linear regression. Particulate pollution was associated positively with admissions for respiratory disease and admission for asthma in summer, whereas a negative association was observed for cardiovascular admissions. Although SO_2 was significantly associated with admissions for respiratory and cardiovascular disorders, a significant association was also found for the control diagnosis of digestive disorders. No significant associations were found for NO_2 over the study period, although significantly positive seasonal interactions were found for asthma and respiratory disease in autumn, winter, and spring. The authors concluded that '…current ambient levels of air pollution exacerbate pre-existing respiratory conditions, particularly in asthmatics and the elderly' [2001:51].

To investigate correlations between air pollutants, weather conditions, airborne allergens, and the incidence of ER visits of children with acute asthma attacks in Israel, Garty et al. [1998] studied 1,076 asthmatic children in the age group 1-18 years old who attended the Paediatric ER between January 1 and December 31, 1993. Positive correlation of ER visits with concentrations of SO_2 ($r = 0.64$), NO_X ($r = 0.74$), and with high barometric pressure ($r = 0.65$) were explored using multiple regression analysis. It was found that ER visits was negatively correlated to O_3 concentration ($r = -0.52$) and minimal ($r = -0.45$) and maximal ($r = -0.41$) temperatures. No significant correlations were observed with concentrations of particulates, humidity, or airborne pollen and spores. However, the effect of air pollutants was stronger than weather components. An exceptionally high incidence of ER visits of asthmatic children was observed during

September. This peak coincided with the beginning of the school year and the Jewish holidays. The authors concluded that ‘high concentrations of certain air pollutants, in combination with weather parameters, are highly correlated with outbreaks of acute wheezing in children’ [1998:568].

To explore the association between air pollution level and hospital admission for respiratory symptoms, Gouveia and Fletcher [2000] studied daily public hospital records in Sao Paulo, Brazil for children less than 5 years of age for pneumonia and asthma. An elevated air pollution level in Sao Paulo on the same day or on the previous day was confirmed to be associated with an increase in children’s hospital admissions using linear regression. The admissions for total respiratory and pneumonia were found to be positively associated with O_3, NO_2, and PM_{10}, with greater effects for pneumonia than for all respiratory diseases.

To observe the association between concentration of air pollutants and the ER visits for asthma, Tolbert et al. [2000] studied 130,000 visits of which nearly 6,000 were for asthma. They evaluated the association between air quality indices and paediatric emergency room visits for asthma in the major emergency centre in Atlanta, Georgia. By using logistic regression, they found the estimated relative risk per 42.815$\mu g/m^3$ increase in the 8-hour O_3 level was 1.04 and the estimated relative risk for PM_{10} was 1.042 per 15$\mu g/m^3$ increase in 24-hour PM_{10}. Findings from this study are consistent with other studies on relation of PM_{10} pollution to childhood asthma exacerbation.

Some studies have linked both traffic-related pollutants (including PM_{10}) and traffic density with increased hospital admissions for asthma and increased asthma symptoms in children [English et al., 1999; Gehring et al., 2002; Neuberger et al., 2004]. For example, in a study on the relationship between living near the busy roads and hospitalization rate for asthma, Lin et al.[2002] found that children living in a county of New York City in neighbourhoods with heavy truck traffic within 200 meters of their homes had increased risks of asthma hospitalization. The study examined hospital admission for asthma amongst children ages 0-14, and residential proximity to roads with heavy traffic.

According to the WHO, India is estimated to have a 10-15% prevalence of bronchial asthma among children aged 5-11 [World Health Organization, 2000b]. Studies performed in developing countries suggest that urban air pollution may have a tremendous impact on health. Another example in Jakarta, estimated that some 1,400 deaths, 49,000 emergency room visits, and 600,000 asthma attacks could be avoided each year if particulate levels were brought down to WHO standards [Ostro, 1994].

Sulphate particles, PM_{10} and O_3 are each associated with hospital admissions for asthma and other respiratory diseases independently [Gouveia and Fletcher, 2000; McGowan et al., 2002; Peel et al., 2005], the higher the levels of these pollutants, the higher the number of hospital admissions. The relationship between PM_{10} and hospital admissions for all respiratory diagnoses or asthma is a linear one [Wong et al., 2001; Peel et al., 2005].

To observe the rates of acute asthma admissions, Thompson et al. [2001] studied the hospital admissions in Belfast's major children's emergency department for the 3-year period between 01/01/93, and 31/12/95. Daily levels of SO_2, PM_{10}, NO_2, nitric oxide (NO), NO_X, O_3, CO in combination of temperature, and rainfall for the same period were obtained from the meteorological office.

Small associations were found for thoracic particulate matter (RR = 1.10), SO_2 (relative risk = 1.09), NO_2 (RR = 1.11), NO (RR = 1.07), NO_X (RR = 1.10), and CO (RR = 1.07) using linear regression. Emergency department admissions for asthma correlated positively with all pollutants except O_3.

More recently, Luginaah and colleagues [2005] carried out research in Canada to assess the association between air pollution and daily respiratory hospitalisation (ICD_9 460-519) for different age groups. Daily hourly of SO_2, PM_{10}, NO_2, O_3 and CO were obtained from Ontario Ministry of Environment. However, the highest reading for each day was used for the analysis to catch the effects of exposure. Daily weather data were obtained from the Environment Canada. The 4,214 overall admissions due to respiratory disease were obtained. Significant association of respiratory admission among females was explored with NO_2 with two days delay using case-crossover analysis. A significant current-day effect of SO_2 on respiratory admission among females 0-14 years of age was observed using time-series approach. Significant association of respiratory admission among males 15-64 years of age was found with PM_{10} with two days delay using time-series analysis.

No significant association was found between O_3 and respiratory admission for either females or males. Time series studies showed a significant association between respiratory admissions of females 0-14 years of age with CO, whereas case-crossover results showed that CO had both immediate and delayed effects on respiratory admission of females 0-14 years of age.

The results of both analyses were consistent. In conclusion, both time series and case-crossover analysis showed females in age groups 0-14 years old were more likely to be admitted for air pollution induced respiratory diseases than were males.

2.6 Air pollution studies in Iran

Iranian studies related to air pollution are indicated in Table 2.3.

To describe trends in ambient air quality in Tehran Shirazi and Harding studied the levels of air pollution in Tehran from 1988 to 1993. Daily SO_2, total suspended particulate (TSM), NO_2, CO and hydrocarbons (HC) were obtained from five monitoring stations. Lead and O_3 were not monitored. There was a statistically significant upward trend in air pollution levels for all pollutants except NO_2. SO_2 levels were found to exceed the WHO guidelines of 100-150 $\mu g/m^3$ through the entire period by using regression. The authors concluded that: 'Much of the upward trend is likely due to unfavourable pollutants dispersion conditions and the continuing increase in population growth and vehicle numbers and congested traffic' [2001:526].

Kermani et al. [2003] investigated the composition of TSP and PM_{10} in Tehran, as well as their relations to weather parameters. The study area was selected in a district, which is located in central part of Tehran and is highly congested with traffic. TSP and PM_{10} were collected from a 3-meter high monitoring station from 22/12/01 to 20/04/02. Sixty-one samples of each were collected. Significant correlation was found between TSP and PM_{10}. The maximum mean concentration of lead in TSP and PM_{10} occurred from 22/12/01 to 20/01/02. Lead free petrol was distributed in Tehran from 21/01/02. TSP and PM_{10} contained 24% and 32% organic substances, and 76% and 68% inorganic substance, respectively. It was found that when the relative humidity and temperature were in the range of 50% and 5-10°C, respectively, especially on Saturdays, the first working day, in winter and under inversion conditions, the highest concentration of TSP and PM_{10} would be expected.

All asthma prevalence studies, which are mentioned below, used the Persian version of the ISAAC questionnaires.

Table 2.3 Air pollution related studies in Iran

Topic	Reference
Air pollution data and hospitalization for angina pectoris	[Hosseinpoor et al., 2005]
Ambient air quality levels in Tehran, Iran, from 1988 to 1993	[Shirazi and Harding, 2001]
Association of ambient air quality with children's lung function	[Asgari et al., 1998]
Asthma prevalence in primary school children in Isfahan	[Golshan et al., 2002b]
Asthma prevalence in primary school children in Birjand	[Golkari et al., 1996]
Asthma prevalence in primary school children in Broujerd	[Chegeni et al., 1991]
Asthma prevalence in primary school children in Ghazvin	[Lashgari and Zohal, 2002]
Asthma prevalence in primary school children in Isfahan	[Golshan et al., 1998]
Asthma prevalence in primary school children in Zanjan	[Najafi Zadeh et al., 1996]
Chemical composition of TSP and PM_{10} and their relations to meteorological parameters in ambient air of Shariati hospital district	[Kermani et al., 2003]
Distribution of volatile organic compounds in ambient air of Tehran	[Bahrami, 2001]
Environmental Damage Costs in Iran by Energy Sector.	[Shafie-Pour and Ardestani, 2007]
Integrated master plan for air pollution control in Tehran	[Japan International Cooperation Agency, 1997]
Knowledge of residents of district 20 of Tehran about air pollution	[Farzinfard, 1989]
Passive smoker and prevalence of asthma in a junior high school in Ghazvin.	[Lashgari and Zohal, 2002]
Prevalence of Asthma Symptoms among Secondary School Students (Aged 11-16 Years) In the City Of Mashad (Northeast Of Iran).	[Boskabady and Karimian, 1999]
Prevalence of respiratory diseases among primary school students	[Shams, 1990]
Prevalence of self-reported respiratory symptoms in rural areas of Isfahan.	[Golshan et al., 2002a]
Prevalence and severity of asthma symptoms in children of Tehran: ISAAC study	[Masjedi et al., 2004]
The effect of age and gender on prevalence of wheezing and asthma	[Tabatabaie et al., 1995b]
The effect of air pollution on emergency room visits in Tehran for asthma and COPD.	[Masjedi et al., 2003]
The effects of air pollution on acute respiratory conditions.	[Masjedi et al., 2003; Masjedi et al., 2004]
The Assessment of Tehran Air Pollution.	[Abadi et al., 1992]

By using the ISAAC questionnaire to measure asthma prevalence in Iran, Chegeni et al. [1991] measured asthma prevalence in primary school children in Broujerd. The prevalence of diagnosed asthma history, asthma attack ever in life, active asthma, and night cough were 1.5%, 21.1%, 5.7% and 16.6%, respectively. They used cross-sectional methods and tested for differences by comparing the means. Also Golkari et al. [1996] measured asthma prevalence in two age groups of students in another city of Iran called Birjand. The prevalence of 'wheeze ever' among 13-14 and 6-7 year-old children was 12.3% and 8.1%, respectively. Najafizadeh [1996] measured the prevalence of 'wheeze ever' in Zanjan, 'wheeze in last 12 months' and 'asthma ever' were 12.8%, 8.5% and 4.1% in children 6-7 years old and 13.2%, 8.1% and 2.6% in children 12-14 years old, respectively. Golshan et al. [1998] measured prevalence of asthma and related symptoms in primary school children of Isfahan. The prevalence rates for previously diagnosed asthma, dyspnea and wheezing ever, dyspnea and wheezing in the last 12 months, and frequently recurring dyspneal attacks were 0.71%, 7.6%, 3.9%, and 1.6%, respectively. In another study, Golshan et al [2002b] measured prevalence of asthma and related symptoms in junior high school children in Isfahan. The prevalence of 'asthma ever in life' was 9.5% with male to female ratio of 2:1. Also in another study Golshan et al. [2002a] measured the prevalence of self-reported respiratory symptoms in rural communities of Isfahan, Iran, between June - September 2000. Nine hundred ninety four individuals in all age groups were recruited. Previous history of bronchitis and true chronic bronchitis were found to be strongly associated with smoking and age. No significant association was found between asthma and smoking history or age. The authors concluded that frequency of chronic bronchitis, asthma, and related symptoms was high for a rural area and suggested it might be related to the condition of housing, nearby farm practices and indoor jobs such as baking and rug weaving.

To inspect the effect of age and gender on prevalence of wheezing and asthma, Tabatabaie [1995b] studied two age groups of students 6-7 and 13-14 years old in Tehran. Five thousand one hundred sixty one ISAAC questionnaires were completed by students in Tehran. The risk of having asthma in older students was 1.6 times higher than younger students. The older students experienced 'wheeze ever' 2.4 times higher than younger students. Boys experienced 'wheeze ever' 1.3 times higher than girls. It was concluded that the prevalence of asthma and 'wheeze ever' in Tehran were higher in boys and older students compared to girls and younger students.

To observe the prevalence of asthma and related symptoms, Masjedi et al. [2004] measured the prevalence of asthma and related symptoms in two groups of age 6-7 and 13-14 years old. Results showed that 15% and 17% of the 6-7 and 13-14 years old children had positive history of wheezing, respectively. The prevalence of asthma diagnosed children were 2.1% of younger students and 2.6% among the older students. Golshan et al. [2002a] measured prevalence of self-reported respiratory symptoms in rural areas of Isfahan. The self-reported prevalence rates for current asthma, chronic bronchitis, non-specific exercise-induced cough and night cough were 6.1%, 4.4%, 13.3% and 11.3%, respectively.

Lashgari [2002] carried out a study on prevalence of asthma in children as passive smokers in Ghazvin. She measured the PEFR of 707 students in age group 12-15 years old by peak flow meter. The prevalence of students with diagnosed asthma and exercise-induced asthma were 1.7% and 13.9%, respectively. Significant associations were found between the smoking habits of the parents, prevalence of asthma, and the quantity of smoking.

To investigate air pollution and its relation with prevalence of respiratory diseases among primary schools, Shams [1990] studied the absenteeism reasons of 10,720 students in three districts within the city of Tehran-Iran that had different levels of air pollutants. He identified a positive correlation between the frequency of respiratory symptoms reported by students in a respiratory questionnaire and SO_2 and the amount of total suspended particulates (TSPs) in the ambient air.

Masjedi et al.[2003] assessed the effect of air pollution on emergency room visits in Tehran for asthma and COPD in adults in 5 hospitals. A correlation was observed between the number of hospital admissions for asthma and the weekly mean concentration of nitrogen dioxide ($P<0.05$). The 3-day and 10-day mean concentrations of SO_2 were also found to be directly associated with the number of asthma admissions during this period ($P<0.05$). No direct correlation was observed for other variables.

The latest article was focused on air pollution and hospitalization for angina pectoris [Hosseinpoor et al., 2005], which is a retrospective time-series study. Air pollution data and hospitalization for angina pectoris rate were measured for a 5-year period (1996-2001). The association of CO and related hospital admission was significant. For each mg/m^3 for CO a 1.01 increase in number of angina pectoris admission was observed (95% CI: 1.00359, 1.01512).

To assess how levels of air pollutants affect pulmonary function and respiratory symptoms of children in Tehran-Iran, Asgari et al. [1998] conducted a cross-sectional study in summer time, in which the pulmonary function of children in the city was compared with pulmonary function of children in a rural area. The sample included 400 children aged 5-11 years old. Higher pollutant concentrations were found to be associated with reduced lung function.

2.7 Conclusion

Worldwide, more than a billion people live in areas where air pollution exceeds acceptable levels. In general, air pollution in Tehran exceeds the standard level of WHO. Air pollution is a major problem associated with urban areas [World Bank Group, 2004], which is harmful for human being especially for vulnerable population like children. Air pollution is increasing in big cities especially in developing countries [World Bank Group, 2004], which may endanger the residents. However, few studies were carried out in developing countries addressing this issue.

According to United Nations Environment Program [2002] air pollution is much worse in developing countries. On the other hand, of the 15 cities in the world with the highest levels of particulate matter, 12 are located in Asia [United Nations Environment Program, 2002]. Air pollution in the developing world is responsible for at least 50 million cases of chronic cough in those under age 14 [Davis and Saldiva, 1999b]. Although the air pollution standard is lower in developed countries compared to developing countries, most of the research regarding air pollution health effects is carried out within developed western nations.

Air pollution can affect respiratory system. The health effects of air pollution can be seen as a pyramid, with the mildest but most common effects at the bottom of the pyramid, and the least common but more severe at the top of the pyramid (see Figure 2.6).

Health effects caused by air pollutants may range from subtle biochemical and physiological signs such as reduced lung function to difficult breathing, wheezing, coughing, and exacerbation of existing respiratory conditions such as asthma and COPD. These effects can lead to school absenteeism and increased medication use, increased doctor or emergency room visits and more hospital admissions, or based on Gauderman et al. results [2004] air pollution may cause delay in lung development which may produce long term problem.

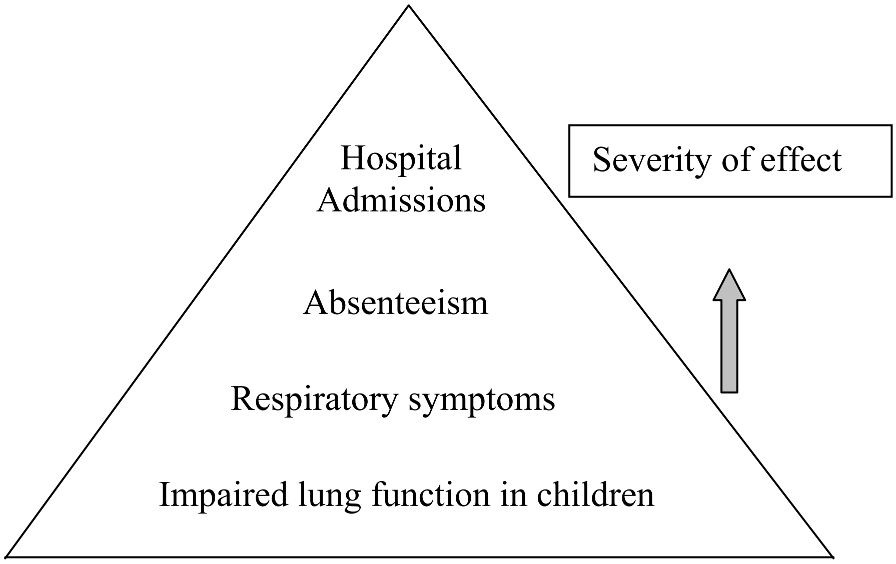

Figure 2.6 Air pollution health effects pyramid used in this study

According to the American Thoracic Society 'morbidity indicators can be at the level of physiological function (e.g. lung function), symptoms, or consequences for daily living'[World Health Organization European Centre for Environment and Health, 2001]. Most studies have concentrated on short-term effects of air pollution on children. The health indicators, which were used in these studies, included lung function decrement, school absenteeism and hospital admission for asthma and respiratory symptoms.

Lung function and respiratory symptoms among children have been the primary focus of most studies, which addressed the respiratory health effects of air pollution. PEFR has been found to be significantly lower in children exposed to air pollution. These studies have also been reporting higher prevalence of asthma and respiratory symptoms such as cough, phlegm and wheezing.

Lung function has been the concern of the studies, which addressed the respiratory health effects of vehicle emissions. Lower lung function indices have been reported to be associated with exposure to vehicle emissions. Indices such as FEV_1 and PEFR have been found to be significantly lower in children exposed to transportation emission. Children have also been reported to have higher prevalence of asthma symptoms.

Most of these studies were carried out in geographical locations very different from Tehran where air pollution was much less than that of the capital.

More wealthy, developed countries have more studies with relatively less pollution than poor, less developed countries. For example, the concentrations of some pollutants (especially CO and PM_{10}) in Tehran are much higher than the WHO standards. This may lead to several adverse health effects and it is reasonable to expect an increase in the negative impact of pollutants on the respiratory systems of children. Moreover, despite Tehran being a crowded city and one of the most polluted cities in the world, there are limited studies addressing the direct adverse effects of air pollution on children, for example the effect of air pollution on lung function or hospital admission. The studies were concentrated on respiratory symptoms collected by questionnaire or absenteeism.

Chapter 3: Overview of methods

As mentioned in Chapter one, it is the aim of the study described in this thesis to examine the relationship between concentrations of daily air pollutants and the air pollution's adverse health effects on children of elementary school age in Tehran. The relationships between exposure to elevated air pollution levels and the indicators of school absenteeism, hospital admission and reduced lung function are of particular interest. The focus of this chapter is on the study questions and the methods used to address these questions. It will also address practical applications for the research.

Studies, which measure different aspects of health effects of air pollution in Iran, are rare. This study might provide reliable evidence on adverse health effects of air pollution on children. Prevalence of asthma and its determinants are also investigated in this study.

3.1 Study Questions

1. What are the air pollution levels in Tehran in relation to meteorology parameters, and guideline levels locally and around the world?
2. What is the association between elevated concentrations of air pollution and respiratory disease related school absenteeism?
3. What is the association between elevated concentrations of air pollution and hospital admissions of children in Tehran?
4. What is the prevalence of poor lung function and asthma in Tehran and what are the patterns of recognized determinants of asthma?
5. What is the association between the occurrences of poor lung function or asthma episodes in relation to air pollution levels?

3.2 Study Design

This study was conducted in two parts; one was conducted over a period of two years and a shorter one, over a period of seven weeks. The first part will address study questions 1 to 3, and questions 4 and 5 will be addressed in the second part. The study as a whole was submitted to the human Ethics Committee of the University of Wollongong for evaluation and the approval letter was copied in Appendix A3.1.

3.2.1 Part one

Part one data were collected over a two-year period. The data consisted of:

- Daily measurements of air pollution from two monitoring stations (Bazaar and Fatemi) which are located in commercial business area by the Air Quality Control Corporation;
- Daily measurements of temperature, humidity, wind speed and direction and sun shine;
- School absenteeism recorded for two schools in District 12, which were also the subject of the second part of this study;
- Hospital admissions: Only hospital admissions for children in the age group of 6-11 years old were recorded. Recording was further restricted to admission for respiratory symptoms and diseases. Two hospitals around or near District 12 were judged to be suitable sources for collecting this information.

3.2.2 Part two

Part two of the study was conducted over a seven-week window towards the end of the two-year period of part one. During this phase of the study, additional respiratory data were collected. The Peak Expiratory Flow Rate (PEFR) of each student was measured on a daily basis, six days a week. The questionnaire and diaries were distributed and collected during this period.

To examine the environmental effects on schoolchildren, a cohort study of children at two single sex schools in District 12 of Tehran was carried out. In the context of epidemiology, a cohort study typically examines multiple health effects of exposure. A questionnaire was used to assess exposure characteristics on an individual (household oriented) basis. Other foci of part two were the daily measurement of PEFR (6 days a week, as schools in Iran are closed on Fridays) and collection of symptom data via a daily diary. The diaries were completed by the children, with assistance from their parents, and with overall supervision by the author in order to ensure that the diaries were completed accurately or properly.

3.3 Materials

The following data were gathered for this thesis.

3.3.1 Data on air quality and meteorology in Tehran

Air pollution data were collected from the database available from the Air Quality Control Company (AQCC) described in the introduction. Data on the hourly concentration of five pollutants were gathered continuously at four ambient air-monitoring stations in Tehran which are under AQCC administration. The monitoring (sampling and analysis) is carried out continuously and the data for each day covers a 24-hour period ending at 10 am on each day [AQCC, 2002].

The period covered in this study was from 01/01/00 to 31/12/03. To date there are 13 monitoring stations in Tehran which are administered by various governmental bodies such as DOE, Ministry of Health and AQCC. Bazaar and Fatemi stations are under AQCC administration and were selected for the study based upon the following criteria (see Figure 3.2):

The monitoring station had to be located near or in the area of interest for this study (Bazaar area, District 12). The Bazaar and Fatemi stations, which are located in the Bazaar area (District 12) and in the centre of Tehran (District 6), respectively (see Figure 3.2), were selected, as satisfying the additional criteria:

- The station was fixed and measured pollutants on a daily basis;
- All five classic pollutants including sulphur dioxide (SO_2), respirable particles (PM_{10}), nitrogen dioxide (NO_2), ozone (O_3) and carbon monoxide (CO) were measured (see Figure 3.1).

Figure 3.1 Public air quality condition board located on Fatemi street close to air pollution monitoring station

Meteorological data on minimum, maximum and mean temperature, humidity, wind speed and sunshine were obtained from the Islamic Republic of Iran Meteorological Organization (IRIMO). They are collected at a meteorologic centre located at Tehran Mehrabad Airport.

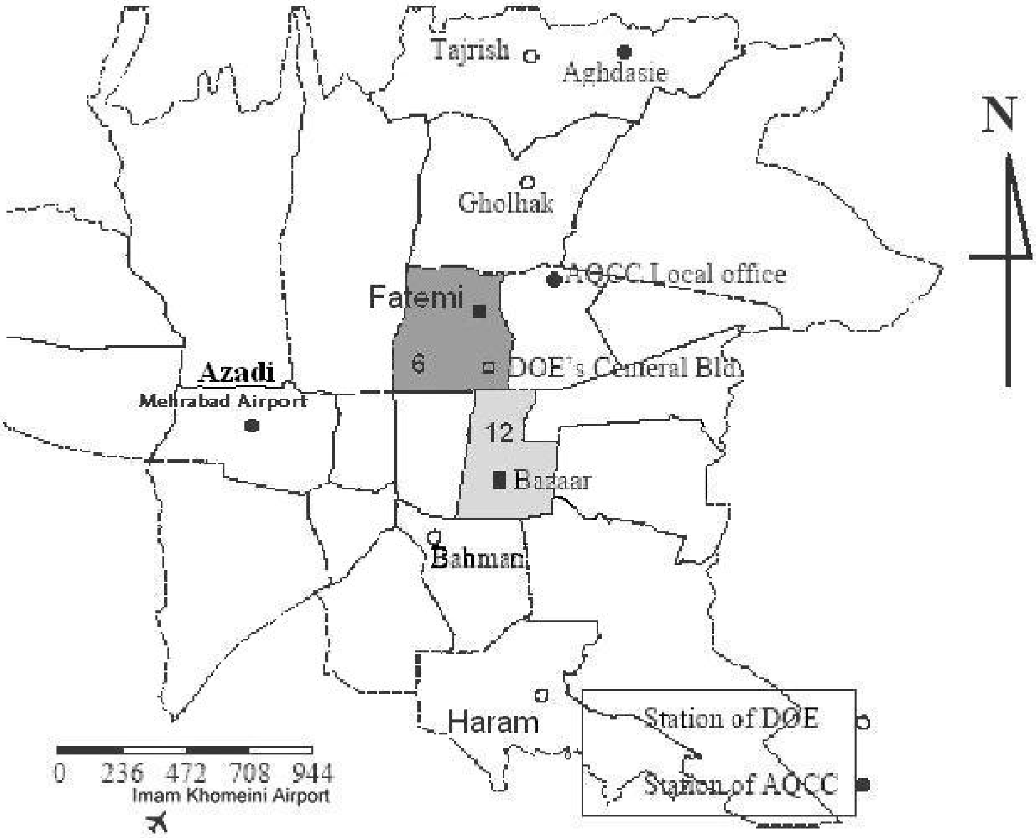

Figure 3.2 Locations of air pollution monitoring stations in Tehran

3.3.2 Daily school absenteeism

The population of primary school students in Tehran in 2001 was almost 531,000 [Iranian Education Ministry, 2005]. Two single sex primary schools (boys and girls), which work in two shifts (8:00-12:30 and 13:00-17:30) were selected out of a total of 99 [Iranian Education Ministry, 2005] primary schools in Tehran District 12. The selection was based on the following criteria:

- Situated in District 12;
- Established no later than 1999;
- Have five grades of primary school (1-5);
- Complete archive of absenteeism records;
- Two shift teaching program.

The daily absenteeism records of the students of these two single sex primary schools in Tehran were obtained between the 01/01/01 and the 31/12/02. There were 608 male students in Shahid Shasavari primary school, with 306 attending the morning shift and 302 attending in the afternoon shift. There were 430 female students in Haghighat primary school. The girls' school had 220 students in the morning and 210 in the afternoon in year 2002. The rate and the cause of absenteeism were collected for two years for each class per grade per school.

School absenteeism was collected through school absenteeism records and medical diagnosis in the medical certificates that each student presented when they were absent from each school. The locations of the schools are indicated in Figure 3.3.

3.3.3 Daily hospital admissions data

Of the 140 hospitals in Tehran [Ministry of Health and Medical Education, 2004], two hospitals were chosen for this study (see Figure 3.3). The two hospitals, Imam Hussein (District 7) and Loghman (District 11), were chosen based on the following criteria:

- General or paediatric hospital;
- Have a complete archive system for the past 2 years;
- Public hospital not private;
- Have an emergency department that is open 24 hours, 7 days a week;
- Preferably located in or near District 12

From these hospitals, admission records on children within the age range of 6 to 11 who were admitted between 01/01/01 and 31/12/02 were collected. Only emergency admissions were considered and all scheduled admissions, transfers from other hospitals, were excluded.

The information available on each patient included:

- Date of admission;
- Age (6-11years old);
- Gender.

Diagnoses on discharge for all diseases based on ICD_{10} for all ages were collected from the statistics unit of each hospital. The collected data were in a computerized format that captured by gender, age (6-11 years old when they were referred to the hospital), date of admission, and diagnosis on discharge (ICD_{10}). Diseases of the respiratory system that were used included acute upper respiratory infections (ICD_{10}: J00-J02), influenza and pneumonia (ICD_{10}: J10-J18), other acute lower respiratory infections (ICD_{10}: J20-J22), nasal polyp (ICD_{10}: J33), other diseases of upper respiratory tract (ICD_{10}: J39), chronic lower respiratory diseases (ICD_{10}: J40-J47), and lung diseases due to external agents (ICD_{10}: J60-J68).

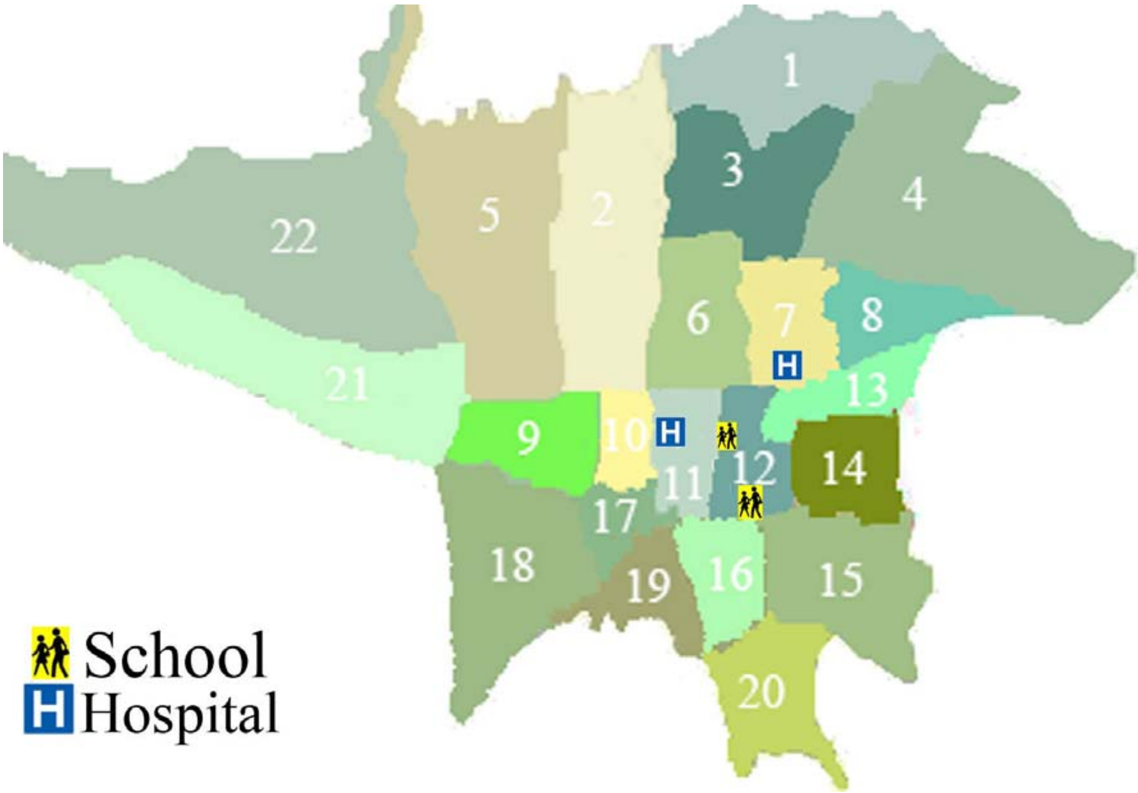

Figure 3.3 Locations of schools and hospitals in Tehran

3.3.4 *Data on general health of students*

Two single-sex primary schools (boys and girls), which work in two shifts (8:00-12:30 and 13:00 -17:30) were selected to assess the adverse effects of air pollution on children by gender and different times of exposure. There are only single sex schools in Iran. There are only two schools in District 12 that work in two shifts [Iranian Ministry of Education, 2005]. For the first step of data collection, a survey was used.

After getting permission from the Ministry of Education and the principals of the schools, the questionnaires were distributed with a consent sheet to all students in the two schools on 01/11/02. The students were asked to fill out the questionnaires with the help of their parents.

The filled-in questionnaires were checked against the names of students after ten days. The students who did not return their questionnaires were reminded to do so by the researcher and the class teacher.

3.3.4.1 Questionnaire

The purposes of the family questionnaires were to collect data about the home environment as potential risk factors for some symptoms of respiratory diseases and to obtain information about respiratory data of individual students. To be comparable with the international literature, it was decided to use internationally standardised questionnaires as much as possible. Thus, the ISAAC modules and Childhood Asthma Questionnaire form B were used. The questionnaires in both English and Persian form are presented in Appendix A3.3.

3.3.4.2 Diary

The diary format was a one page weekly table, consisting of eight columns, which had to be filled out daily and was collected weekly. The diary provided information on the following:

- Date
- Wheeze
- Cough
- Activity
- Sleep
- Duration of playing outside (hours)
- Use of medication
- Comments

At the bottom of the table, a guideline was provided for students, which explained how they should rate their wheezing or sleeping. Each child was asked to fill out the asthma diaries by themselves or with the help of their parents. These asthma diaries were designed for a week. Every Saturday, which is the first day of week in Iran; these diaries were distributed to all the students and were collected the next Saturday. For further information, see the asthma diary in Appendix A3.4.

3.3.5 Daily lung function

The lung function of the students was measured daily using a standard range Mini-Wright Peak Flow Meter during their school shifts for approximately 30 minutes over a seven-week period from 01/11/02 to 21/12/02. Each child was asked to perform three tests, and the ‘best test’ based on the highest of the three readings for each student per day was used for analyses, in accordance with ATS instruction [Samet, 2003]. All measurements were recorded on a flow chart, which is presented in Appendix A3.5. This flow chart has the school’s name, date, and class. A table was designed to record the time of the measurements, student’s code and names, three peak flow measures and the last time and date they used the puffer. This flow chart was filled out daily and could not be anonymous because of the need to follow-up individuals for a 7-week period.

The parents of each participant were given a copy of their child’s records at the end of the study.

3.4 Data management

A spreadsheet was designed for entering the questionnaire data by using the coding system specified on the ISAAC site, as detailed in Appendix A3.3.2. The coded data were entered in the spreadsheet by the name of the students. The data were checked by the author for inconsistencies and inaccuracies. The cleaning processes included checking out the inconsistencies of responses codes. For example, when a response to a question has only two choices, then code three indicated an error. Therefore, any deviation from expected was checked out with the related questions to find out the problem. Then, the spreadsheet data were rechecked and edited against the returned questionnaires.

3.5 Ethical issues

This study was approved by the Ethics Committee of University of Wollongong (see Appendix A3.1). The Committee is responsible for monitoring the ethical aspects of this study.

When the subjects were recruited for the study of lung function, they were informed that they had the freedom to join in or leave the study any time. This study analysed data obtained from students' health situation. Therefore, individual consent was sought to use those data.

To protect the privacy of each student, personal information relevant to this study was kept confidential and an anonymous database was created for use in this thesis. The study summarises and analyses the questionnaire and lung function data statistically. The reports focus on presenting population-based information. Identifiable individual information is reported neither in this thesis nor in any papers.

All relevant information about the lung function performance of the participants was reported back to students' parents'. The guidelines for the interpretation were those of the American Lung Association [American Lung Association, 1991] .

3.6 Methods of Analysis

Most of the data collected in this study are in the form of time-series. A time-series is a collection of observations made on the same units sequentially in time [Chatfield, 1996]. These data can be analysed in a variety of ways. The focus of this thesis is on relationships between time-series and explicit 'time-series' methods for the analysis of univariate series have not been adopted.

- Air pollution, weather, and questionnaire variables were analysed using Pearson correlation to assess the association between variables.
- Three methods were used for investigating the effects of air pollution on school absenteeism, hospital admission, and lung function. Poisson regression and logistic regression were used for investigating the association between air pollution and absenteeism and hospital admission. Linear regression and logistic regression were used for investigating the effects of air pollution on lung function.

3.6.1 Case-crossover analysis

The case-crossover design, introduced by Maclure [1991] is a method devised to examine the short-term effects of air pollution. In the case-crossover design, each person who had an event is matched with him or herself on a nearby period when that person did not have the event. This design enables estimation of the effect of day-to-day variation in pollution on morbidity. For example, when a person's lung function is abnormal compared to his or her best blow or expected lung function in this study, the day is taken as an event day. A one-week period before onset is defined as a hazard period (non-failure time) [Schwartz, 2005]. In a symmetric bi-directional design, two control times are selected, e.g. two to three weeks before and two to three weeks after failure. To avoid the auto correlation in the exposure series, selections of sampling referents too close to the index day e.g. one week before or after were not selected otherwise it leads to loss of power [Janes et al., 2004]. In this study, the period of worst period respiratory related hospital admission, the period of worst respiratory related school absenteeism, or of worst lung function were defined a 'case' and equivalent period of two weeks after or before each occurrence defined a 'control'. The association between elevated air pollution concentration and absenteeism or hospital admission or reduced lung function risk was measured with the odds ratio in conditional logistic regression by means of SAS statistical package version 9.1. These analyses have been extended also by Poisson regression and linear regressions.

Several control selection methods have been addressed for the case crossover design in air pollution studies. For this study, bi-directional control sampling was used, with an interval of 2 weeks between case and control periods to minimize autocorrelation between case and control exposures and to control for seasonal effects.

This approach was applied to all data collections in this study of air pollution and morbidity in Tehran. The detailed definitions of event and control are presented in the individual results chapters.

Review of the literature showed that traditionally air pollution effects research uses time series [Lin et al., 2002; Jaakkola, 2003]. However, there were many missing dates in the air pollution data from the two mentioned stations in Tehran (see Chapter four) and time series design needs reasonably complete datasets for analysis, with at least 30 continuous observations. Therefore, it was decided to use an alternative statistical analysis, which has the same or approximately same statistical power. The case-crossover design was considered most suitable, given the circumstances.

3.7 Confounding and bias

The major confounders were seasonality; calendar effects (e.g., day of the week, holidays, and day after holiday); meteorology (i.e., temperature, wind speed, and humidity) and drought. (There was a drought in Iran during 2001 and 2002). By using case-crossover analysis these confounders should have minimal or, at least, substantially reduced effects on the study. The reason is that the controls were selected from the same subject, so they are matched. However, in other analysis designs by using dummy variable, the effect of those confounders could be met.

Some personal characteristics such as gender and age are measured as confounders too. For anatomical reasons, the airways in boys are smaller than in girls of this age range, and age is positively associated with lung function. Using dummy variables in analyses can help to address this problem.

One of the variables is medication use, information on which was collected through diaries. During the study period, the participants recorded their medication use details including the name of medication and time of taking it. Although medication can modify the effect of air pollution on lung function, this has not been evaluated in the current study. Ignoring the modifying effect of medication would tend to reduce the observed effects of air pollution.

3.8 Conclusion

The effects of air pollution on children were analysed through measuring school absenteeism, hospital admission, and lung function. The air pollution data were collected from two monitoring stations Bazaar and Fatemi one of them is located in District 6 and the other in District 12. The meteorological data was collected from IRIMO. For measuring school absenteeism and lung function two schools were selected from District 12 in Tehran. The period of collection data for each part is indicated in Table 3.1. For hospital admission, two general hospitals were selected near District 12. The principle methods of analysis for the whole of study were Poisson regression (for counts) and case-crossover, which used logistic in modelling the dichotomous response case/control. Other statistical techniques used in the thesis included simple linear regression, Pearson correlation and t-test.

Table 3.1 Period of collection for each data component

Variables	1/01/2000	1/02/2000	1/03/2000	1/04/2000	1/05/2000	1/06/2000	1/07/2000	1/08/2000	1/09/2000	1/10/2000	1/11/2000	1/12/2000	1/01/2001	1/02/2001	1/03/2001	1/04/2001	1/05/2001	1/06/2001	1/07/2001	1/08/2001	1/09/2001	1/10/2001	1/11/2001	1/12/2001	1/01/2002	1/02/2002	1/03/2002	1/04/2002	1/05/2002	1/06/2002	1/07/2002	1/08/2002	1/09/2002	1/10/2002	1/11/2002	1/12/2002	1/01/2003	1/02/2003	1/03/2003	1/04/2003	1/05/2003	1/06/2003	1/07/2003	1/08/2003	1/09/2003	1/10/2003	1/11/2003	1/12/2003
Meteorological parameters																																																
Air pollution																																																
Absenteeism																																																
Hospital admission																																																
Lung function measurement																																																

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Chapter 4: Air Pollution in Tehran

Tehran has been recognized by WHO as one of the most polluted cities in the world [Shirazi and Harding, 2001]. This chapter addresses the first study question on the air pollution levels in Tehran in relation to meteorology parameters and guideline levels locally and around the world (Chapter three). This chapter presents a description of data on air pollution for a period of almost four years supplied by the Iranian authorities. Air pollution levels are compared to other cities and standards around the world. They are also related to potential determinants, in particular meteorological factors. The final part of this chapter addresses the usefulness and validity for research into health effects of air pollution in Tehran.

4.1 Definitions

Air quality, by definition, refers to ambient concentrations of air pollutants, in reference to an Air Quality Standard for each pollutant. There are hundreds of air pollutants in the atmosphere with six ubiquitous pollutants which present potential health hazards identified internationally as criteria pollutants [World Health Organization Regional Office for Europe, 2000]. The air quality data for five of these six criteria pollutants, namely sulphur dioxide, particulates, nitrogen dioxide, ozone and carbon monoxide are presented in this chapter. The sixth criterion pollutant is lead. However, Tehran does not have continuos monitoring methods for this pollutant.

4.2 Standards and/or guidelines in different countries

In general, air quality standards are based on scientific and technical data on public health and environmental effects and on other aspects such as cost-benefit or cost-effectiveness and political choices. Because ambient levels of air pollutants, cultural backgrounds and level of health status vary from country to country, it is to be expected that national regulatory authorities would recommend different standards [World Health Organization, 2000a]. The World Health Organization provided the air quality guidelines for Europe. These have recently been made internationally applicable as starting points from which individual countries could drive their own standards depending on their own circumstances [World Health Organization, 2000a].

According to WHO [2000a], choosing the criteria for selection of averaging times for each pollutant is difficult, because the development of toxicity depends on the interaction between concentration of a pollutant and duration of exposure. The effect of a chemical substance may be acute and damaging after peak exposure for a short period, and/or irreversible or weakening after prolonged exposure to lower concentrations. It is recommended that a short-term averaging time be used when short-term exposures lead to adverse effects.

Australia's method of determining national air quality standards serves as one example. Australia considered scientific studies of air quality and human health from all over the world as well as standards set by other organizations such as the World Health Organization. Australian conditions, eg climate, geography, and demographics, were taken into account in estimating the likely exposure of Australians to these major air pollutants. Each air quality standard has two elements: the maximum acceptable concentration and the period of time over which the concentration is averaged [Department of the Environment and Heritage-Australian Government, 2005].

4.3 Methods

Data were obtained from Air Quality Control Company (AQCC) for two sites, which are located in major streets in the districts of Fatemi and Bazaar, as shown in Figure 4.1-Figure 4.4.

The particular station type is used for monitoring of air pollution from road traffic. The streets are wide. In 2004, car ownership was 3.08 and 1.40 per Km^2 in District 6 (Fatemi) and District 12 (Bazaar) respectively [Tehran Comprehensive Transportation and Traffic Studies Company, 2004]. The traffic volume in Fatemi was higher than in Bazaar because the movement of private cars in District 12 is heavily restricted. Both Districts 6 and 12 are classified as urban, but Fatemi is predominantly residential while Bazaar is a mixed commercial/residential zone, and exclusively commercial in the immediate neighbourhood of the monitoring site.

Figure 4.1 Fatemi location

Figure 4.2 Fatemi station

Figure 4.3 Bazaar location


Figure 4.4 Bazaar station

Figure 4.5 Entering filter for gaseous air pollutants

The equipment and instrumentation for each monitoring station are housed in a shelter with approximate dimensions of 3m $\times$2m $\times$2.5m (L$\times$W$\times$H). The sampling inlet for the continuous particulate monitor was installed two (2) meters above the shelter roof, passing through the roof directly to the monitor (PM_{10}), Continuous Ambient Particulate. The other pollutants were Sulphur Dioxide (SO_2), Ozone (O_3), Nitrogen Oxides (NO_X), and Carbon Monoxide (CO). These were collected through a different inlet. The inlets are shown on the top of roof of both stations in Figure 4.2 and Figure 4.4.

All analysers are located in the monitoring stations and connected to the station's data processing system. All analysers (see Figure 4.6) use USEPA Federal Reference Methods or equivalents. More detailed technical specifications for each analyser have been provided by the World Bank [World Bank, 2004].

Sulphur Dioxide (SO_2) is analysed by pulsed UV fluorescent (Rotork Model 477). This analyser measures SO_2 (with the option of H_2S) in the range 0-100/200/500/1000ppb or 0-2/3/5 ppm[1]. Continuous Ambient Particulate (PM_{10}) is analysed by True Micro Weighing, which is a real time analyser capable of measuring $PM_{10}/_{2.5}$ with calibration facility (The TEOM Series 1400a monitor USEPA PM_{10}

[1] Part per million

equivalency approval EQPM-1090-079). Ozone (O_3) is analysed by UV Photometry, which is a microprocessor-controlled analyser with automatic calibration using an external gas dilution calibrator and calibration gas standards (Thermo Environmental U.V. Model 49). Nitrogen Oxides are analysed by Chemiluminescence (Thermo Environmental Instruments Model 42C). It is a microprocessor-controlled analyser with automatic calibration using an external gas dilution calibrator and calibration gas standards. Carbon Monoxide (CO) is analysed by Non-Dispersive Infrared Photometry - Gas Filter Correlation, which is a microprocessor, controlled analyser with automatic calibration using an external gas dilution calibrator and calibration gas standards (Thermo Environmental Instruments Model 48).

Figure 4.6 Air quality analysers located in AQCC stations

The stations have data loggers (Odesa DSM-3260) and collect, process and send data to the central office via telephone line. It is a microprocessor-controlled analyser with automatic calibration using an external gas dilution calibrator and calibration gas standards. The data gathering, services and maintenance (calibration and routine checks) in all stations are done by AQCC responsible staff [World Bank, 2004] (see Figure 4.7).

All the measurements are obtained on line from the stations continuously. Every morning, the stations are checked by AQCC staff.

The data received from AQCC contained all classic air pollutants except for SO_2 and covered the period of 01/01/00 to 31/07/03. A second request for data was made and a completely new data set was received, this time including SO_2. However, after comparing both versions of data it was realized that some values for PM_{10} for Bazaar 2002 were missing. In addition, the PM_{10} values for 2003 were replaced by values for another pollutant, which was of no interest for this thesis. Therefore, the original data set was used, with the addition of SO_2 values from the second data set. The units of all pollutants were converted to $\mu g/m^3$ for zero ºC temperature to make data consistent. Note that PM_{10} was already presented using this as the measurement unit.

Figure 4.7 Stations' tools

All data received from AQCC had already been summarized. Hourly averages for each pollutant had been calculated, and the original ‘continuous’ measurement data were not made available for the research undertaken in this thesis. Further manipulation of the data was required. The intention was, for various purposes, to calculate 24-hour (daily) averages and averages based on teaching shift windows chosen to best assess the effect of level of pollution and exposure of children to this pollution.

Before these further manipulations, it became clear that it was necessary to clean the hourly data. A comprehensive cleaning process was undertaken. Data screening involved graphing as well as flagging missing values and ‘out of range’ values. Outliers, or ‘out of range’ values were determined in several ways. Individual extreme hourly values that were highly inconsistent with adjacent observations and sequences of ‘zero’ or extremely low values constituted the first group of observations to be deleted.

Further scrutiny was given to every observation, which had a missing value in either the immediately preceding or the following hour. Using this criterion, less extreme but inconsistent observations were also removed from the data prior to analysis.

In order to gain a better understanding of why such substantial data cleaning was necessary, the process of data collection was reviewed in detail. While not necessarily explaining all data problems, hypotheses were generated concerning the principle sources of data contamination.

Firstly, there clearly were periods when data collection was not operating effectively. Sequences of very high values and of very low (or zero) values occurred under these circumstances. Secondly, the filters needed to be changed periodically. It seems that around the times of these filter changes (typically about once a month, usually on the 11^{th} /12^{th} of each month) there is an increase in the incidence of problematic data. Therefore, the hourly data were polished.

For each pollutant, the initial (received) data set and the cleaned data set are presented and summarized in the following sections of this chapter. The SAS program, which was used for cleaning up data, is presented in Appendix A4.1.

4.4 Results

The data on individual pollutants will be described separately. Pre and post cleaning data and comparison with standards and with other cities will be presented in Table 4.1-Table 4.17. All pollutants will be assessed for their association with various meteorological factors.

Limit values for ambient concentration of air quality of some countries are presented in this chapter. Comparing these standards and the number of days of exceedance for each pollutant per year provides a yardstick for the air pollution situation of Tehran in relation to other countries (see Table 4.2).

4.4.1 SO_2

The SO_2 data provided by AQCC covered a period of nearly three and half years, as presented in Figure 4.8, which shows that SO_2 levels at Fatemi's monitoring station were much higher than Bazaar's. As indicated in Table 4.1, the SO_2 average at Fatemi was 215 $\mu g/m^3$, while at Bazaar it was 49 $\mu g/m^3$. In addition, from 28/10/02, a very sharp drop happened at Fatemi and following that, in early November 2002 at Bazaar, a very sharp increase happened. The reasons for these sudden changes are not known. To prepare SO_2 data for further analysis a cleaning process was undertaken.

After removing two clusters as the outliers, the remaining data are presented in Figure 4.9. As indicated in Table 4.1 the SO_2 average at Fatemi and Bazaar were changed to 241 $\mu g/m^3$ and 44.1 $\mu g/m^3$ respectively.

Table 4.1 Summary statistics for 24 hourly averages of SO_2 levels for four years in Tehran before and after cleaning up (µg/m^3)

Stations	Fatemi		Bazaar	
	Before	After	Before	After
Min	1.2	108.5	-0.8	1.1
10%	3.4	157.9	8.8	12.9
25%	177.5	197.7	22.0	22.5
50%	253.5	260.1	35.8	34.9
75%	280.8	283.0	57.9	51.1
90%	296.1	297.0	124.1	117.8
Max	315.4	315.4	395.2	123.0
Mean	212.9	241.0	55.7	44.1
Std Dev	91.7	53.1	59.8	33.7
Number of missing values	536.0	627.0	186.0	343.0
Number of observations	772.0	681.0	1122.0	965.0

The graph shows maximum values of just under 400 µg/m^3 for both stations. It also shows several peculiar features, along with a general trend, which indicated seasonality, some short-term trend effects, and an overall long-term increase in SO_2 levels. The peculiarities indicate:

- Individual outliers
- Inconsistent clusters

As noted in Section 4.3, extreme outliers were deleted and they were defined as missing values. For example, observations on 9/02/02, 20/02/02, 21/02/02, 4/09/02, and 27/10/02-29/12/02 at Fatemi; and from 15/02/02 until 2/11/02 at Bazaar were excluded using this criterion. In all, 91 outliers were removed from the Fatemi data set and 157 outliers from the Bazaar data set.

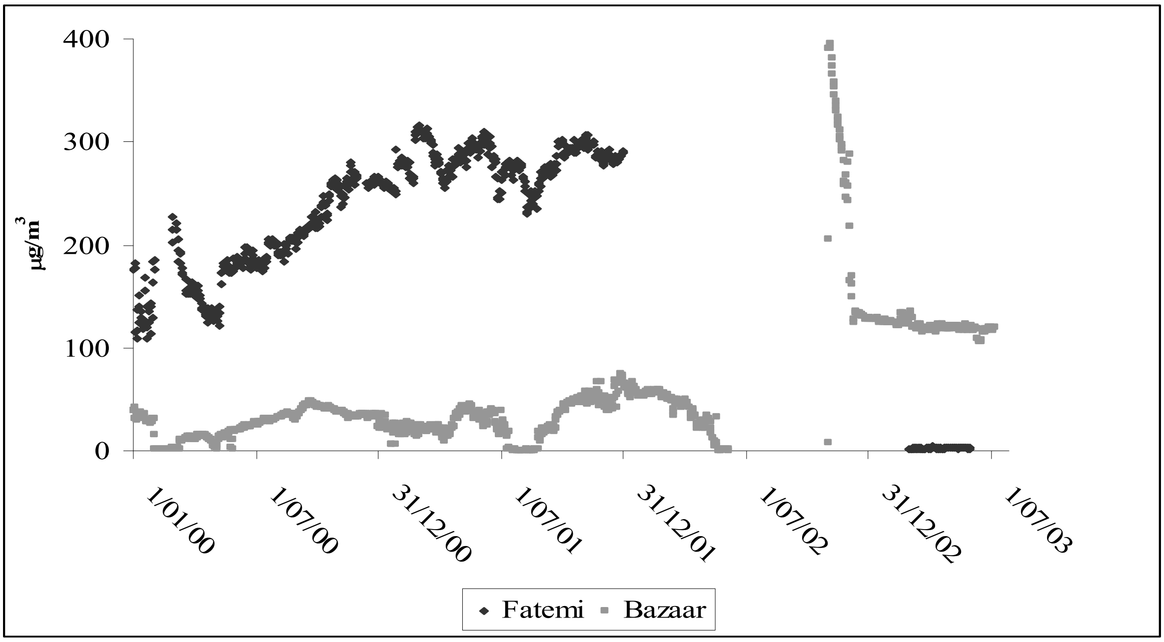

Figure 4.8 Daily SO_2 levels for 3.5 years in Tehran before cleaning up

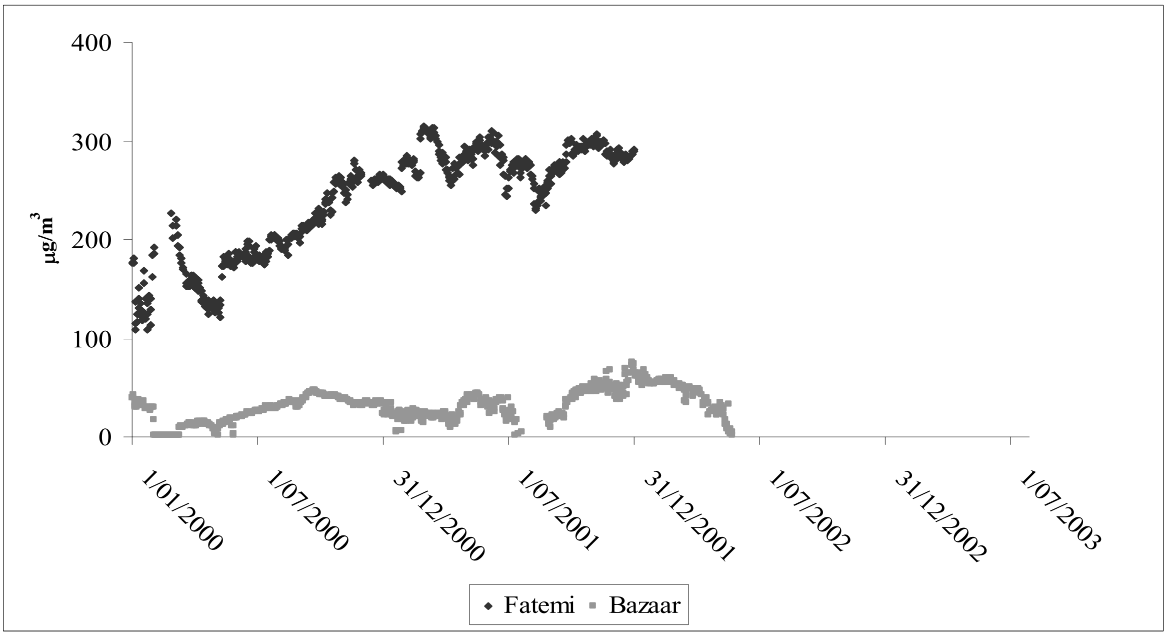

Figure 4.9 Daily SO2 levels for 3.5 years in Tehran after cleaning up

In Tehran, the population has been potentially exposed to ambient air concentrations of SO_2 in excess of the Iranian limit value set for the protection of human health (365 $\mu g/m^3$ 24 hourly mean). Seven days during 2002 showed the worst period of polluted air. However, using the WHO limit, the population has been potentially exposed for 304 days in 2000; for the entire year of 2001 and during 241 days in 2002 (see Table 4.3). The annual SO_2 pollutions of other cities are presented in Table 4.4. Tehran's situation in comparison with other cities and international standards shows that the population has been exposed to polluted air most days of a year (see Table 4.4).

Table 4.2 Standards for SO_2 levels of some countries around the world (units in µg/m^3)

Country	Annual	24 hours	1 hour	15 minutes	10 minutes
Australia [National Environment Protection Council, 2008]	57.2	228.8	572	-	-
Canada [EPEQ, 2000]	30	150	450	-	-
China [World Bank, 1995]	60	150	-	-	-
EU [World Bank, 1995]	20	125	350	-	-
Germany [World Bank, 1995]	140	400	-	-	-
Hong Kong [Environmental Protection Department, 2005]	80	350	800	-	-
Indonesia [Syafruddin et al., 2002]	60	260	900	-	-
Iran [AQCC, 2002]	-	365	-	-	-
Japan [World Bank, 1995]	260	110	286	-	-
Nepal [Ministry of Population and Environment, 2005]	50	70	-	-	-
NZ [Ministry for the Environment]	-	120	350	-	-
Philippines [World Bank, 1995]	-	-	370	-	-
Poland [World Bank, 1995]	32	-	200	-	-
Thailand [World Bank, 1995]	100	-	300	-	-
UK [Environment agency, 2000]	20	125	350	266	-
US [California Air Resources Board, 2005]	80	365	-	-	-
WHO [World Health Organization, 2000a]	50	125	-	-	500
World Bank [World Bank, 1995]	100	1000	-	-	-

Note: there were no standards for 8 and 4 hours averaging time.
- Not available

Table 4.3 Frequency of SO_2 exceedance in comparison with standards for 24 hours at both stations

Years	2000	2001	2002
WHO	304	365	241
Iran	0	0	7

Table 4.4 Annual concentration of SO_2 in 2 stations of Tehran and in other cities

Years	2000	2001	2002
Tehran (Fatemi)	195.2	280.7	195.2
Tehran (Bazaar)	25.8	29.3	25.8
Athens [APHEIS, 2005]	34.0	67.8	-
Barcelona [Quijano et al., 2005]	-	11.0	-
Copenhagen [National Environmental Research Institute, 2001; APHEIS, 2005]	3.3	3.1	3.8
Hong Kong [Yau, 2000; 2001; 2002]	18.0	22.0	27.0
Lisbon [APHEIS, 2005]	8.0	-	-
Los Angeles [EPA, 2003]	5.7	5.7	5.7
Madrid [Carrasco and Torras, 2005]	24.0	-	-
Paris [Le Franc and Chardon, 2005]	14.0	-	-

- Not available

Overall, the SO_2 data set has many missing values and often shows normal hourly fluctuations as illustrated in (see Figure 4.10) [Ferrari and Salisbury, 1999]. In addition, the machines used are very old, so may not function reliably within expected ranges.

Therefore, it has been decided that this data will not be used in the analysis of this thesis.

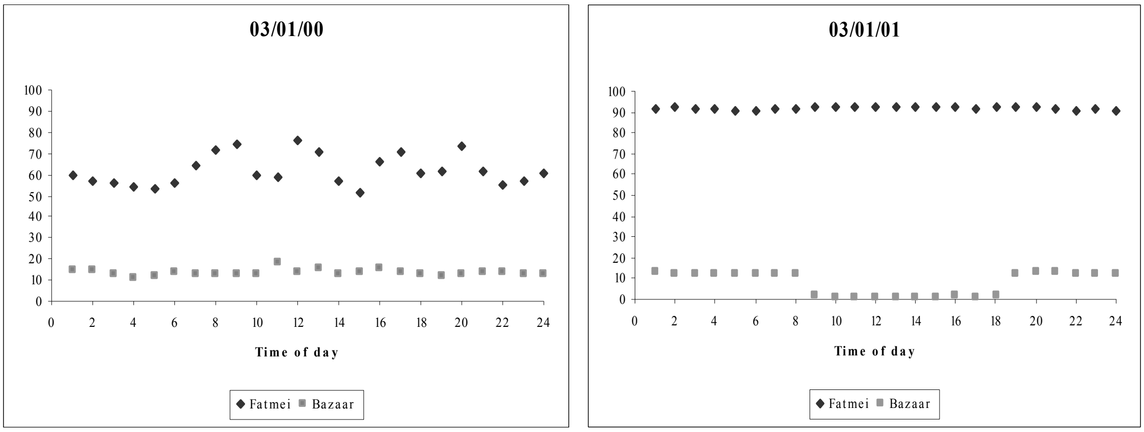

Figure 4.10 SO_2 fluctuations on two selected days (units in µg/m^3)

4.4.2 PM_{10}

Summary statistics for daily PM_{10} data and comparisons with standards and other cities are presented here. The PM_{10} data as received from AQCC are presented in Table 4.5 and Table 4.9. After removing outliers, the following changes were observed. The maximum concentration of PM_{10} at Bazaar was reduced from 5000 units to 1850. The mean and the standard deviation were decreased. It should be mentioned that an unexpected increase which can be seen for PM_{10} at Bazaar was most likely due to a fire which occurred on 14/06/02 during which 4,000 tyres were burned [Nejad, 2002]. The values in this period were not considered outliers as they occurred as an 'outlier' cluster with a plausible cause.

Table 4.5 Summary statistics for 24 hourly averages of PM_{10} levels for 3.5 years in Tehran before and after cleaning up

	Fatemi		Bazaar	
Stations	Before	After	Before	After
Min	3.8	3.8	8.8	8.8
10%	49.3	49.4	36.1	36.1
25%	68.1	68.4	49.3	49.2
50%	89.8	89.8	72.6	72.3
75%	115.4	115.5	108.2	107.7
90%	139.2	139.2	178.8	173.0
Max	462.6	462.6	5000.0	1850.0
Mean	94.2	94.3	138.2	122.9
Std Dev	41.7	41.6	340.2	217.2
Number of missing values	138.0	138.0	603.0	605.0
Number of observations	1170.0	1170.0	705.0	703.0

Figure 4.11shows maximum values of 463µg/m^3 and 5000 µg/m^3 for Fatemi and Bazaar stations respectively. It also shows several peculiar features, along with a general trend, which indicated seasonality, some short-term trend effects, and an overall long-term increase in PM_{10} levels. The peculiarities indicate a cluster. As noted in Section 4.3, extreme outliers were deleted and they were defined as missing values. In all, no outliers were removed from the Fatemi data set but two outliers from the Bazaar data set. Figure 4.12 is drawn on a different scale to Figure 4.11, to better show variation.

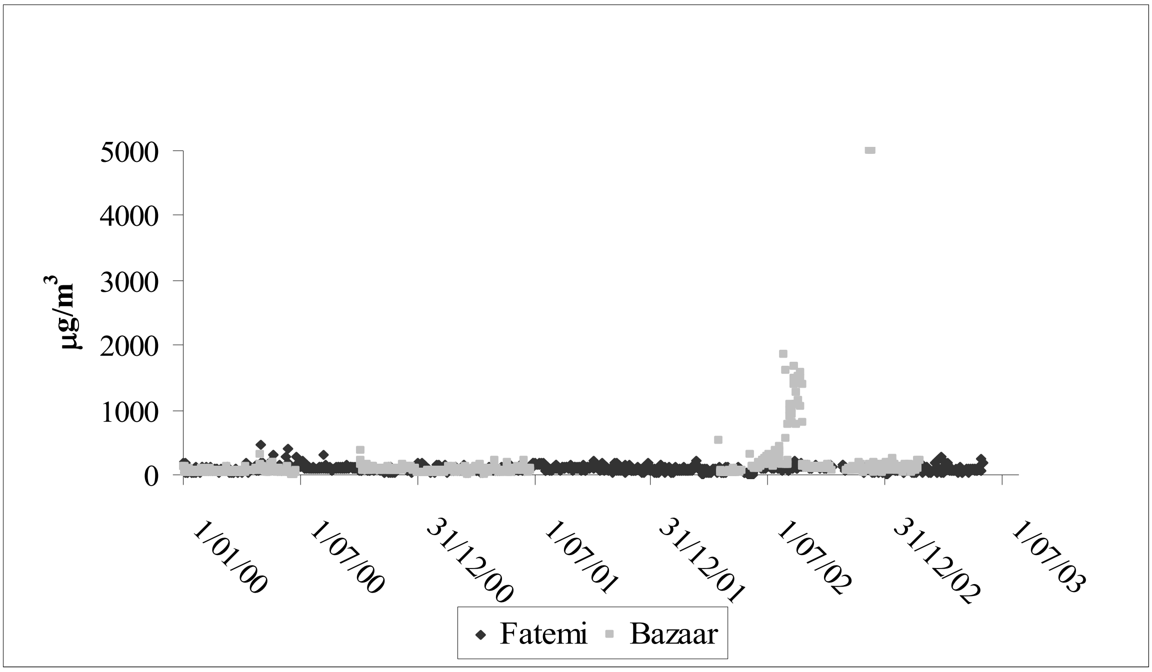

Figure 4.11 Daily PM_{10} levels for 3.5 years in Tehran before cleaning up

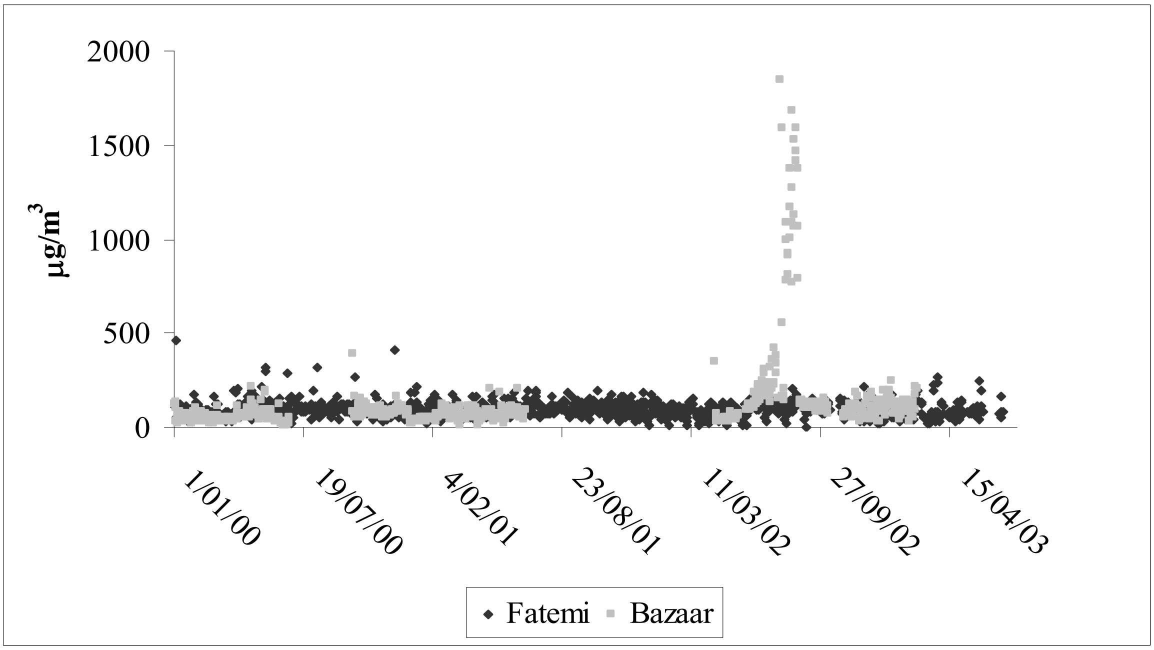

Figure 4.12 Daily PM_{10} levels for 3.5 years in Tehran after cleaning up

There are no 24 hourly standards for WHO and Iran. The number of polluted days per year was compared to the highest and lowest levels standards in Table 4.6 . In the period 2000-2002, the population of Tehran has been potentially exposed to ambient air concentrations of PM_{10} in excess of the Iranian limit value set for the protection of human health (500 µg/m^3 24 hourly mean) (see Table 4.6). Twenty-five days during 2002 showed the worst period of polluted air in Bazaar. Compared to the cities' 24 hourly standard (see Table 4.6) pollution on these days was nearly 12 times more than the World Bank standard (see Table 4.7). However, compared to other cites, pollution in all years was higher than annual levels in other cities except for Hong Kong in 2001 and 2002 (see Table 4.8).

Table 4.6 Standard PM_{10} levels of some countries around the world (units in µg/m^3)

Country	Annual	24 hours	1 hour
Australia [National Environment Protection Council, 2008]	-	50*	-
Canada [EPEQ]	-	50	-
China [World Bank, 1995]	100	300	-
EU [World Bank, 1995]	40	50	-
Germany [World Bank, 1995]	100	200	77
Hong Kong [Environmental Protection Department, 2005]	80	260	-
Indonesia [Syafruddin et al., 2002]	-	150	-
Iran [AQCC, 2002]	150	-	-
Japan [World Bank, 1995]	-	260	-
Nepal [Ministry of Population and Environment, 2005]	-	100	-
NZ [Ministry for the Environment]	-	120	-
Philippines [World Bank, 1995]	20	50	-
Poland [World Bank, 1995]	-	150	-
Thailand [World Bank, 1995]	50	120	-
UK [Environment agency, 2000]	100	330	-
Hong Kong [Environmental Protection Department, 2005]	40	50**	-
US [California Air Resources Board, 2005]	50	-	150
WHO [World Health Organization, 2000a]	-	-	-
World Bank [World Bank, 1995]	100	500	-

* Not to be exceeded more than 5 days per year
** Not to be exceeded more than 7 days per year
Note: there were no standards for 8 and 4 hours averaging time.

Table 4.7 Frequency of PM_{10} exceedance in comparison with standards for 24 hours at both stations

Years	2000	2001	2002
World Bank	0	0	25
Australia, Canada, EU, Philippines and Hong Kong	327	352	296

Table 4.8 Annual concentration of PM_{10} in 2 stations of Tehran and in other cities (units in µg/m^3)

Years	2000	2001	2002
Tehran (Fatemi)	96.3	96.1	94.0
Tehran (Bazaar)	67.1	62.7	240.7
Barcelona [Quijano et al., 2005]	-	-	39.7
Brussels [APHEIS, 2005]	-	24.9	-
Budapest [APHEIS, 2005]	29.0	22.0	-
Copenhagen [National Environmental Research Institute, 2001; APHEIS, 2005]	49.0	34.0	36.0
Dublin [APHEIS, 2005]	-	-	24.0
Hong Kong [Yau, 2000; 2001; 2002]	77.0	120.0	106.0
Lisbon [APHEIS, 2005]	-	-	32.0
Los Angeles [EPA, 2003]	42.7	43.1	41.8
Madrid [Carrasco and Torras, 2005]	37.0	-	33.3
Paris [Le Franc and Chardon, 2005]	-	22.0	22.0
Rome [APHEIS, 2005]	51.4	47.2	48.1

- Not available

4.4.3 Nitrogen oxides (NO and NO_2)

Summary statistics for daily NO and NO_2 data and comparison with standards and other cities data are presented here. The NO and NO_2 data as received from AQCC are presented in Table 4.9. The NO and NO_2 shows similar patterns at Fatemi and Bazaar. However, at Bazaar, NO_2 had many missing values compared to NO. To clean the data, the extreme outliers were removed and they were defined as missing values.

Table 4.9 Summary statistics for 24 hourly averages of NO and NO_2 levels for 3.5 years in Tehran before and after cleaning up (units in µg/m^3)

	NO				NO_2			
Stations	Fatemi		Bazaar		Fatemi		Bazaar	
	Before	After	Before	After	Before	After	Before	After
Min	0.4	20.1	2.4	6.0	0.6	25.2	0.6	20.9
10%	48.2	51.7	30.4	30.5	75.4	76.2	31.3	31.3
25%	66.5	71.2	45.4	45.6	102.2	102.5	37.6	37.7
50%	109.9	110.6	67.2	67.5	147.6	148.6	52.9	52.6
75%	184.7	184.5	96.7	96.7	214.8	215.4	80.9	79.9
90%	231.0	229.7	123.2	123.2	262.8	262.8	101.3	100.8
Max	669.4	451.9	236.1	236.1	665.8	658.8	322.5	196.3
Mean	129.9	130.3	73.5	73.6	160.7	161.5	61.4	60.8
Std Dev	80.9	73.4	37.6	37.5	76.4	75.7	30.4	28.8
Number of missing values	185.0	190.0	329.0	330.0	184.0	188.0	529.0	531.0
Number of observations	1123.0	1118.0	979.0	978.0	1124.0	1120.0	779.0	777.0

Figure 4.13 shows maximum values of just under 670 µg/m^3 at Fatemi and 236 µg/m^3 on Bazaar stations. It also shows several peculiar features, along with a general trend, which indicated seasonality, some short-term trend effects, and an overall long-term increase in NO levels. The peculiarities indicate individual outliers. As noted in Section

4.3, extreme outliers were deleted and they were defined as missing values. For example observations on 25/06/01 to 29/06/01 and any hourly observation lesser than 12 or higher than 394 at Fatemi; and data from 08/03/02 and 09/03/02 at Bazaar were excluded using this criterion. In all, five outliers for NO were removed from the Fatemi data set and one outlier for NO from the Bazaar data set (Appendix 4).

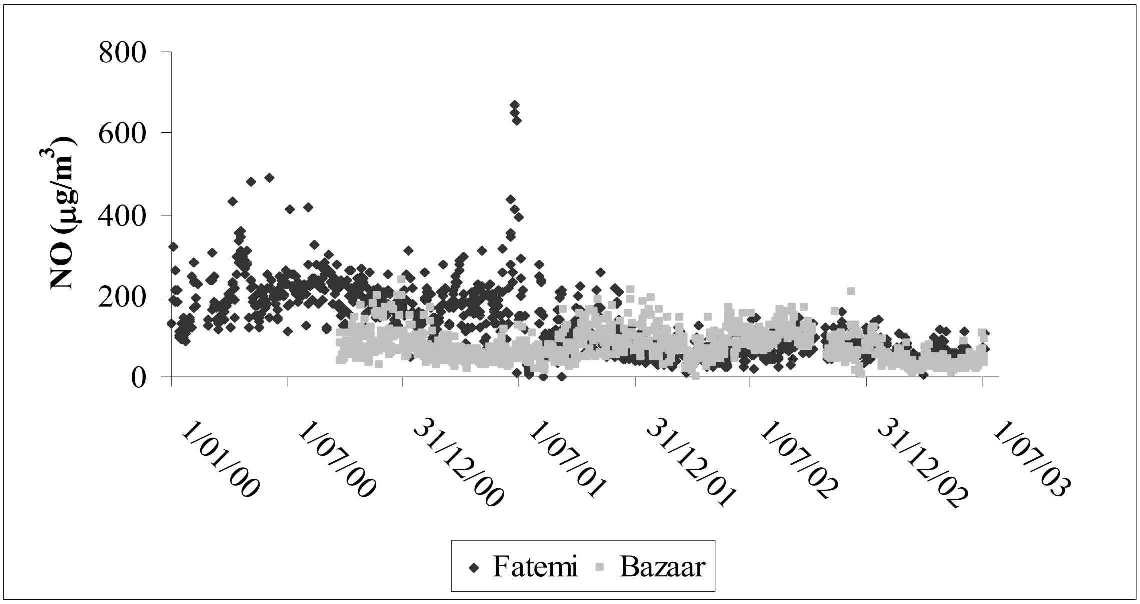

Figure 4.13 Daily NO levels for 3.5 years in Tehran before cleaning up

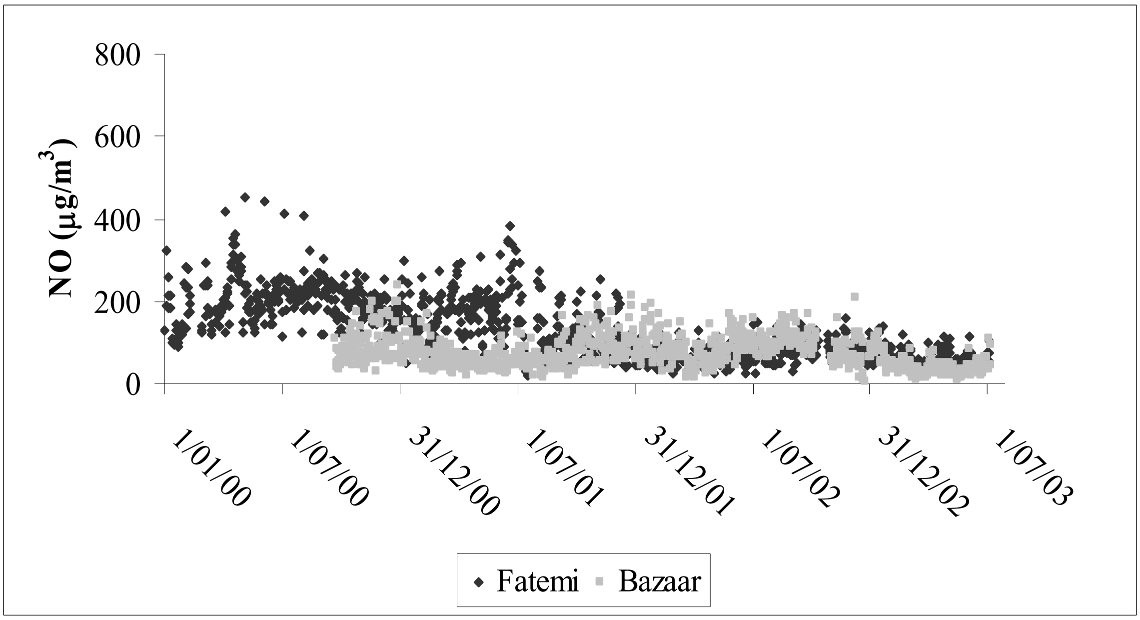

Figure 4.14 Daily NO levels for 3.5 years in Tehran after cleaning up

Figure 4.15 shows maximum values of just under 666 µg/m^3 at Fatemi and 323 µg/m^3 at Bazaar station. It also shows several peculiar features, along with a general trend, which indicated seasonality, some short-term trend effects, and an overall long-term increase in NO_2 levels. The peculiarities indicate individual outliers. As noted in Section 4.3, extreme outliers were deleted and they were therefore defined as missing values. For example, observations on 25/06/01 to 29/06/01, any hourly observation less than nine or higher than 400 at Fatemi; and any hourly observation less than one or higher than 43 on the same dates at Bazaar were excluded using this criterion. In all, four outliers for NO_2 were removed from the Fatemi data set and two outliers for NO_2 from the Bazaar data set. The details were presented in Appendix 4.

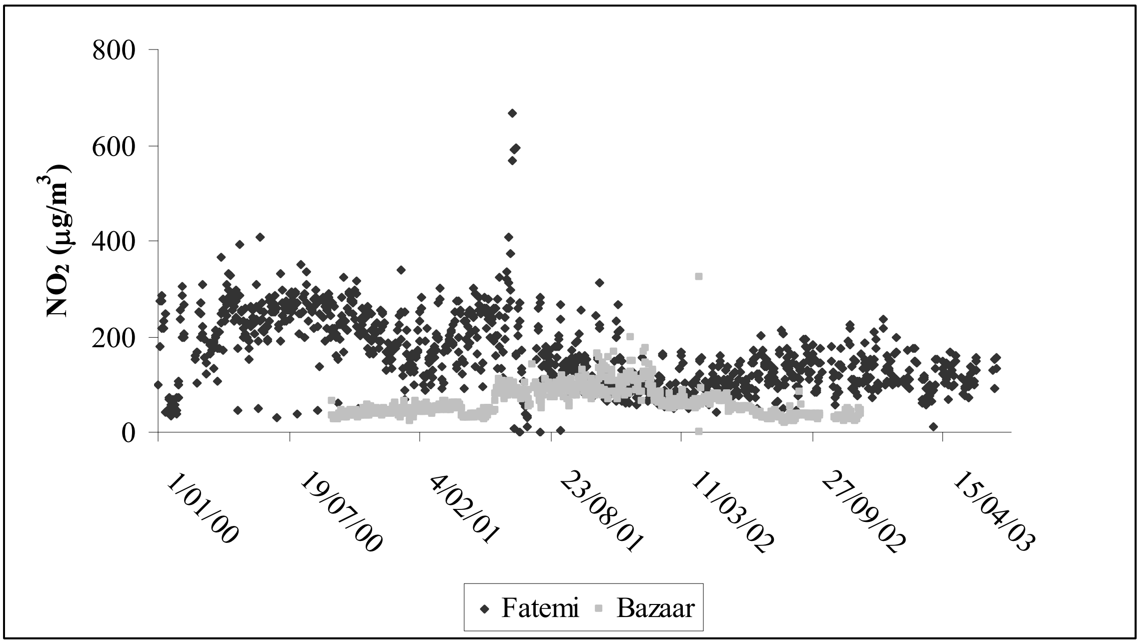

Figure 4.15 Daily NO_2 levels for 3.5 years in Tehran before cleaning up

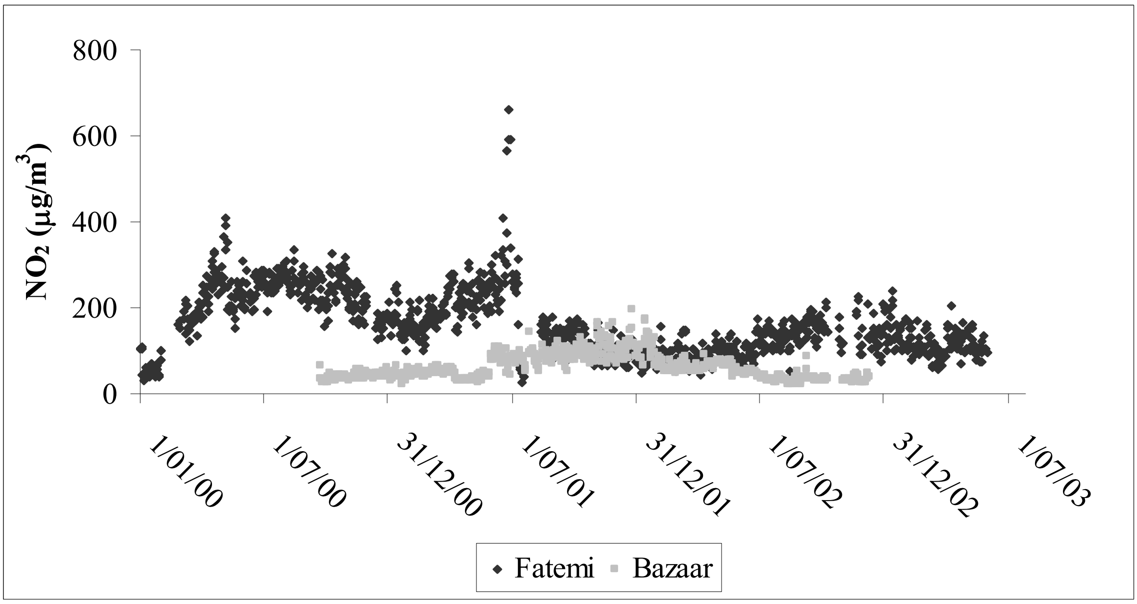

Figure 4.16 Daily NO_2 levels for 3.5 years in Tehran after cleaning up

During the period 2000-2002, the population of Tehran has been potentially exposed to ambient air concentration of NO_2 in excess of both WHO standards (annual 40-50 μg/m3, hourly 200 μg/m3) and Iranian annual standards (100 μg/m3) each year. Most days during 2001 were polluted in comparison with 24 hourly standards, although there were no days that hourly pollution levels were too high. In both 2000 and 2002, there were over 100 days with hourly exceedances. In comparison with other cities during 2001, Tehran had the most polluted days and it was 2-4 times WHO annual standard (see Table 4.10 -Table 4.12).

Table 4.10 Standard for NO_2 levels of some countries around the world (units in μg/m^3)

Country	Annual	24 hours	1 hour
Australia [National Environment Protection Council, 2008]	61.5	-	246
Canada [EPEQ]	100	200	402
EU [World Bank, 1995]	200	-	-
Hong Kong [Environmental Protection Department, 2005]	80	150	300
Indonesia [Syafruddin et al., 2002]	60	92.5	400
Iran [AQCC, 2002]	100	-	-
Japan [World Bank, 1995]	-	-	82
Nepal [Ministry of Population and Environment, 2005]	40	80	-
NZ [Ministry for the Environment]	40	100	200*
UK [Environment agency, 2000]	40	-	200
US [California Air Resources Board, 2005]	100	-	-
WHO [World Health Organization, 2000a]	40-50	-	200

*Not to be exceeded more than 9 days per year.
Note: there were no standards for 8 and 4 hours averaging time.
- Not available

Table 4.11 Frequency of NO_2 exceedance compared to WHO hourly standard

Year	2000	2001	2002
WHO hourly Standard	132	0	142

Table 4.12 Annual NO and NO_2 levels in 2 stations of Tehran and in other cities (units in μg/m^3)

	NO			NO_2		
Years	2000	2001	2002	2000	2001	2002
Tehran (Fatemi)	201.8	143.6	75.6	218.2	172.4	112
Tehran (Bazaar)	92.9	71.1	87.1	40.0	73.1	53.7
Athens [APHEIS, 2005]	-	-	-	64.0	-	-
Barcelona [Quijano et al., 2005]	-	-	-	34.0	-	-
Copenhagen [National Environmental Research Institute, 2001; APHEIS, 2005]	46.0	39.0	-	42.0	40.0	-
Hong Kong [Yau, 2000; 2001; 2002]	-	-	-	61.0	105.0	91.0
Lisbon [APHEIS, 2005]	-	-	-	52.0	-	-
Los Angeles [EPA, 2003]	-	-	-	80.0	75.9	71.8
Madrid [Carrasco and Torras, 2005]	-	-	-	66.0	-	-
Paris [Le Franc and Chardon, 2005]	-	-	-	57.0	-	44.0

- Not available

4.4.4 O_3

Summary statistics for daily O_3 data and comparison with standards and other cities are presented here. The O_3 data as received from AQCC are presented in Table 4.13, Figure 4.17. After removing the outliers from the data, the most obvious change can be seen in Bazaar where the maximum value changed from 422 to 145 μg/m^3. It should be mentioned that the standard deviation was changed from 32 to 18 μg/m^3.

Table 4.13 Summary statistics for 24 hourly averages of O_3 levels for 3.5 years in Tehran before and after cleaning up (units in μg/m^3)

	Fatemi		Bazaar	
Stations	Before	After	Before	After
Min	1.5	2.4	3.4	3.4
10%	4.4	4.4	4.8	4.8
25%	7.2	7.2	5.3	5.3
50%	13.4	13.4	18.9	18.7
75%	21.9	21.9	36.1	35.6
90%	33.9	33.9	47.1	46.5
Max	92.9	92.9	422.4	144.7
Mean	16.5	16.5	24.4	22.2
Std Dev	12.1	12.1	31.7	18.0
Number of missing values	208.0	208.0	138.0	140.0
Number of observations	1100.0	1100.0	1170.0	1168.0

Figure 4.17 shows maximum values of just under 93 μg/m^3 at Fatemi and 422 μg/m^3 at Bazaar station. It also shows several peculiar features, along with a general trend, which indicated seasonality, some short-term trend effects, and an overall long-term increase in O_3 levels. The peculiarities indicate individual outliers. As noted in Section 4.3, extreme outliers were deleted and they were defined as missing values. For example, observations on 27/01/01, any hourly value less than 0.4 at Fatemi; and on 19/05/02 to 01/07/03 any observation higher than 145 at Bazaar were excluded using this criterion as presented in Appendix 4. In all, no outlier for daily O_3 levels was removed from the Fatemi data set but two outliers from the Bazaar daily data set.

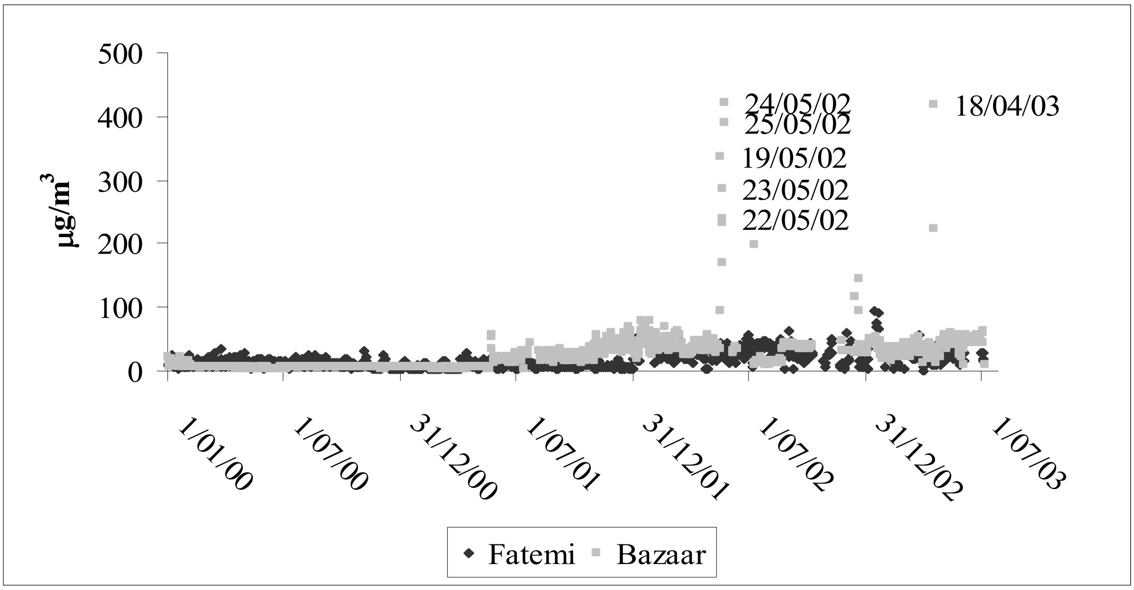

Figure 4.17 Daily O_3 levels for 3.5 years in Tehran before cleaning up

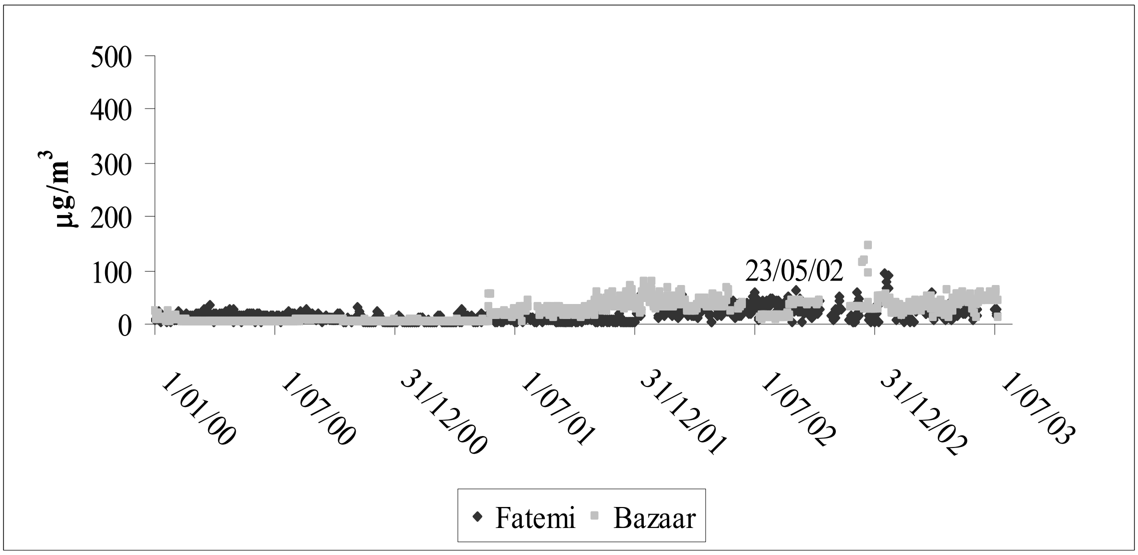

Figure 4.18 Daily O_3 levels for 3.5 years in Tehran after cleaning up

In the period 2000-2002, the population of Tehran has been potentially exposed to ambient air concentrations of O_3 in excess of the WHO limit value set for the protection of human health (120 $\mu g/m^3$ 8 hourly mean) (see Table 4.14). Specifically, only 3 days during 2002 showed the worst polluted air (see Table 4.15). Comparing with other cities' annual data, each year's annual total of both stations in Tehran was not out of range (see Table 4.16).

Table 4.14 Standards for O_3 levels of some countries around the world (units in μg/m^3)

Country	Annual	24 hours	8 hours	4 hours	1 hour
Australia [National Environment Protection Council, 2008]	-	-	-	171.2	214
Canada [EPEQ]	20	30	-	-	100
Hong Kong [Environmental Protection Department, 2005]	-	-	-	-	240
Indonesia [Syafruddin et al., 2002]	30		-		200
NZ [Ministry for the Environment]	-	-	100	-	150
UK [Environment agency, 2000]	-	-	100	-	-
US [California Air Resources Board, 2005]	-	-	157	-	235
WHO [World Health Organization Regional Office for Europe, 2000]	-	-	120	-	-

-Not available

Table 4.15 Frequency of annualy exceedance of O_3 compared to WHO standard

Year	2000	2001	2002
WHO 8 hourly Standard	0	0	3

Table 4.16 Annual O_3 level in 2 stations of Tehran and in other cities (units in μg/m^3)

Years	2000	2001	2002
Tehran (Fatemi)	12.2	8.6	28.2
Tehran (Bazaar)	6.0	19.4	36.2
Athens [APHEIS, 2005]	-	109.0	-
Barcelona [Quijano et al., 2005]	-	-	40.7
Brussels [APHEIS, 2005]	-	74.0	-
Budapest [APHEIS, 2005]	-	74.0	-
Copenhagen [National Environmental Research Institute, 2001; APHEIS, 2005]	-	68.0	29
Dublin [APHEIS, 2005]	-	60.0	-
Hong Kong [Yau, 2001; 2002]	32.0	267.0	-
Lisbon [APHEIS, 2005]	-	79.0	-
Los Angeles [EPA, 2003]	94.2	-	-
Madrid [Carrasco and Torras, 2005]	-	-	70.1
Paris [Le Franc and Chardon, 2005]	-	78.0	-

-Not available

4.4.5 CO

For CO effect, usually eight hourly averages are used. Graphs of daily hourly air pollutants levels (Appendix A4.1) were used to assess the most influential for 8 hours interval. It was realized that CO peaks usually happened in the second and third 8-hour section of the day. However, to be consistent it was decided to use 24 hourly average of CO base on the teaching shift for any calculation in this thesis.

Summary statistics for description of daily CO data comparison with standards and other cities are presented here. The CO data as received from AQCC is presented in Figure 4.19. Nothing was removed from these data, which are presented in Table 4.17.

Table 4.17 Summary statistics for 24 hourly averages of CO levels for 3.5 years in Tehran before and after cleaning up(units in μg/m^3)

	Fatemi		Bazaar	
Stations	Before	After	Before	After
Min	515.6	2474.0	2375.0	2375.0
10%	7567.7	7588.5	4760.4	4760.4
25%	9817.7	9817.7	5994.8	5994.8
50%	13020.8	13010.4	7682.3	7682.3
75%	17265.6	17182.3	10349.0	10349.0
90%	21343.8	21286.5	13984.4	13979.2
Max	81937.5	81937.5	72205.9	72205.9
Mean	13923.2	13923.2	8726.7	8724.7
Std Dev	6023.6	6008.6	4625.2	4622.8
Number of missing values	141.0	142.0	57.0	57.0
Number of observations	1167.0	1166.0	1251.0	1251.0

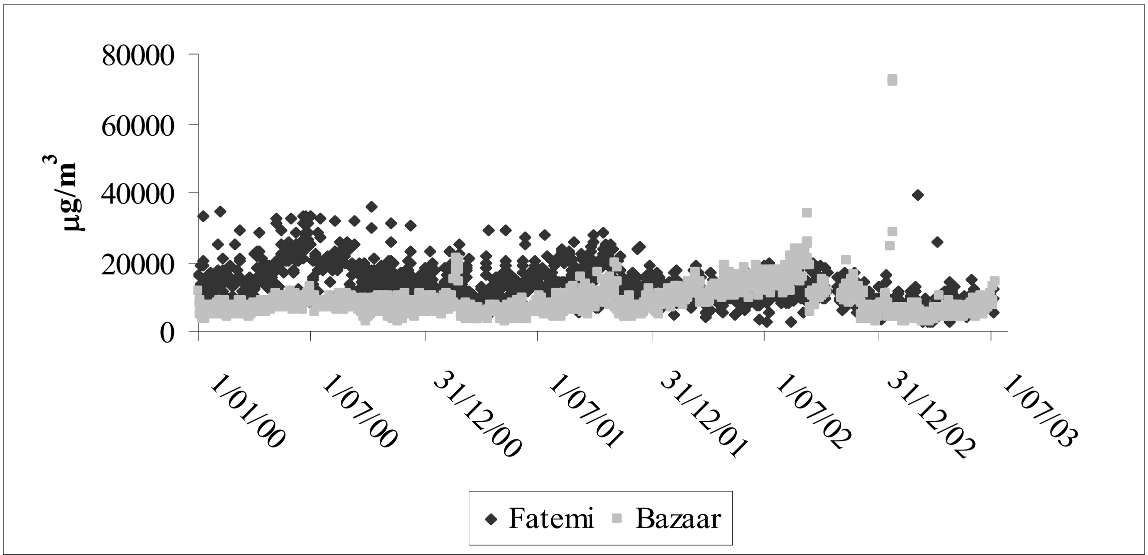

Figure 4.19 Daily CO levels for 3.5 years in Tehran before cleaning up

In the period of 2000-2002, the population of Tehran has been potentially exposed to ambient air concentrations of CO in excess of the Iranian limit value set for the protection of human health (11, 250 μg/m^3 8 hourly mean) (see Table 4.18). The worst year of polluted air occurred during 2000 and included 298 days (81%), or by using WHO standard 314 days (87%) (see Table 4.19). However, comparing with other cities annual data, Tehran was the most polluted city in all three years (see Table 4.20).

Table 4.18 Standards for CO of some countries around the world (units in $\mu g/m^3$)

Country	Annual	24 hours	8 hours	1 hour	30 minute	15 minute
Australia [National Environment Protection Council, 2008]	-	-	11,250	-	-	-
Canada [EPEQ]	-	-	6,000	15,000	-	-
Hong Kong [Environmental Protection Department, 2005]	-	-	10,000	30,000	-	-
India [World Bank, 1995]	1,000-5,000	-	-	-	-	-
Indonesia [Syafruddin et al., 2002]	-	9,000	-	26,000	-	-
Iran [AQCC, 2002]	-	-	11,250	-	-	-
Japan [World Bank, 1995]	-	-	25,000	12,500	-	-
Nepal [Ministry of Population and Environment, 2005]	-	-	10,000	-	-	100,000
NZ [Ministry for the Environment]	-	-	10,000	30,000	-	-
Thailand [Pollution Control Department, 2003]			11,250	37,500		
UK [Environment agency, 2000]	-	-	11,600	-	-	-
US [California Air Resources Board, 2005]	-	-	10,000	40,000	-	-
WHO [World Health Organization Regional Office for Europe, 2000]	-	-	10,000	30,000	60,000	100,000

Note: there were no standards for 4 hours averaging time.

Table 4.19 Frequency of exceedance of CO in Tehran compared to WHO standards and other cities

Year	2000	2001	2002
WHO 8 hourly Standard	314	277	272
Iranian 8 hourly Standard	298	251	221
WHO hourly Standard	6	1	5
Copenhagen	361	365	349
Hong Kong	327	365	348
Los Angeles	-	-	282

- Not available

Table 4.20 Annual levels for CO in 2 stations in Tehran and in other cities (units in $\mu g/m^3$)

Years	2000	2001	2002
Tehran (Fatemi)	17,588	14,590	11,597
Tehran (Bazaar)	7,396	7,650	12,226
Athens [APHEIS, 2005]	-	-	-
Barcelona [Quijano et al., 2005]	-	-	-
Brussels [APHEIS, 2005]	-	-	-
Budapest [APHEIS, 2005]	-	-	-
Copenhagen [National Environmental Research Institute, 2001; APHEIS, 2005]	1,099	1,018	1,037
Dublin [APHEIS, 2005]	-	-	-
Hong Kong [Yau, 2000; 2001; 2002]	10,000	4,098	3,739
Lisbon [APHEIS, 2005]	-	-	-
Los Angeles [EPA, 2003]	-	-	-
Madrid [Carrasco and Torras, 2005]	-	-	-
Paris [Le Franc and Chardon, 2005]	-	-	-
Rome [APHEIS, 2005]	-	-	-

- Not available

4.4.6 Determinants of air pollution levels

A summary of descriptive data for meteorologic parameters over the three years of study is presented in Table 4.21. The year 2002 was drier and warmer than other years.

Table 4.21 Summary statistics for meteorological variables, from 01/01/00 through 31/12/02

Year 2000	Minimum	Mean	Median	Maximum	Std Dev
Daily temperature	0.6	18.5	20.0	35.2	10.0
Minimum temperature	-4.8	13.8	14.7	30.6	9.3
Maximum temperature	3.0	23.3	25.0	40.6	10.9
Winds mean	0	4.9	4.0	17.1	3.3
Winds speed (max)(knots)	0	11.2	10.0	39.0	5.7
Humidity mean	25.1	55.3	51.0	97.5	17.1
Sun Shine	0	8.6	9.8	13.5	3.9
Year 2001					
Daily temperature	-2.3	19.3	20.2	35.4	9.2
Minimum temperature	-6.6	14.2	15.2	30.0	8.4
Maximum temperature	0	24.3	25.6	40.8	10.2
Winds mean	0	4.8	4.3	17.6	3.2
Winds speed (max)(knots)	0	11.3	10.0	31.0	5.6
Humidity mean	8.9	45.2	39.8	96.8	20.8
Sun Shine	0	8.7	9.6	13.8	3.6
Year 2002					
Daily temperature	-1.3	18.9	18.7	35.8	9.9
Minimum temperature	-4.6	14.1	14.6	32.0	9.2
Maximum temperature	2.0	23.6	24.0	41.0	10.7
Winds mean	0	5.5	4.8	18.4	3.6
Winds speed (max)(knots)	0	12.3	10.0	39.0	5.9
Humidity mean	11.4	37.4	33.1	93.5	18.2
Sun Shine	0	9.1	10	13.5	3.4

Pearson correlation was used to assess linearity and strength of the relationship between weather parameters and concentrations of each pollutant as well as correlation among air pollution measurements. The results are summarized in Table 4.22. In this table, the values that are significant (at the 5% level) are shaded. Note that p values here are not strictly valid, but are still indicative. Although over-estimating significance the assumption of independent pairs of observations (on eg. CO) is not valid, since the time-series for each pollutant has non-zero auto-correlation.

All pollutants concentrations were positively correlated with daily temperature except for SO_2 at Fatemi. However, it was positively correlated with PM_{10} and CO and it was negatively correlated with SO_2, NO_2, and O_3 at Bazaar. In addition, minimum temperature was positively correlated with all pollutants except for SO_2 at Fatemi. However, it was negatively correlated with all except for PM_{10} at Bazaar.

Wind (maximum speed) was positively correlated with O_3 and with the other Fatemi's pollutants. However, at Bazaar, it was negatively correlated with all pollutants except for O_3 and CO.

Daily humidity was positively correlated with NO, NO_X. However, it was negatively correlated with PM_{10} and O_3 at Fatemi. It was negatively correlated with PM_{10}, NO_2, NO_X, O_3 and CO at Bazaar.

Sunshine was positively correlated with PM_{10}, NO_2, NO_X, O_3 and CO at Fatemi. However, it was negatively correlated with SO_2 and O_3 and positively correlated with PM_{10} and CO at Bazaar.

Also the concentrations of the same pollutants as PM_{10} and O_3 between two sites were positively correlated and for NO, NO_2 and NO_X they were negatively correlated. Therefore, whenever the levels of PM_{10} and O_3 were high at Fatemi, the levels of those parameters were high at Bazaar too. However, whenever the levels of NO, NO_2 and NO_X were high at Fatemi, the levels of those parameters were low at Bazaar or vice versa. As can be seen in Table 4.22, CO levels and NO_X levels were positively correlated which is expected as CO is a product of incomplete combustion and NO_X are caused by sunlight reacting with combustion products. Oxygen will combine with nitrogen, forming oxides of nitrogen (NO_X; NO_1, NO_2, etc) [Trzupek, 2002]. The CO and NO_X levels were higher in Fatemi station because Fatemi was not a restricted area for traffic and cars were allowed to enter this area.

Table 4.22 Pearson correlation coefficient of weather parameters and air pollutants concentrations over 3 years

	Fatemi							Bazaar						
	SO_2	PM_{10}	NO	NO_2	NO_X	O_3	CO	SO_2	PM_{10}	NO	NO_2	NO_X	O_3	CO
Daily T	-0.06	0.20	0.17	0.29	0.22	0.25	0.25	-0.21	0.35	-0.06	-0.07	-0.07	-0.15	0.31
p-value	0.059	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.104	0.048	0.061	<.0001	<.0001
Min T	-0.08	0.19	0.16	0.27	0.21	0.24	0.24	-0.19	0.35	-0.08	-0.09	-0.09	-0.15	0.30
p-value	0.025	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.033	0.018	0.015	<.0001	<.0001
Max T	-0.05	0.21	0.18	0.29	0.23	0.25	0.25	-0.23	0.34	-0.04	-0.06	-0.05	-0.15	0.32
p-value	0.117	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.237	0.105	0.167	<.0001	<.0001
Winds mean	0.02	-0.13	-0.13	-0.14	-0.14	0.12	-0.09	-0.15	0.001	-0.24	-0.12	-0.24	-0.05	0.003
p-value	0.479	<.0001	<.0001	<.0001	<.0001	0.000	0.002	<.0001	0.989	<.0001	0.001	<.0001	0.090	0.934
Wind Speed max	0.04	-0.12	-0.10	-0.12	-0.11	0.08	-0.09	-0.12	-0.06	-0.22	-0.08	-0.19	-0.05	0.01
p-value	0.237	<.0001	0.002	0.0001	0.0004	0.013	0.006	0.0003	0.131	<.0001	0.030	<.0001	0.155	0.853
Hum mean	-0.18	-0.11	0.15	0.01	0.09	-0.39	-0.05	0.05	-0.26	-0.02	-0.10	-0.08	-0.22	-0.43
p-value	<.0001	0.0004	<.0001	0.787	0.003	<.0001	0.091	0.117	<.0001	0.491	0.004	0.032	<.0001	<.0001
Sun shine	0.01	0.07	0.06	0.18	0.11	0.21	0.10	-0.11	0.18	0.01	-0.04	-0.01	-0.06	0.22
P-value	0.723	0.033	0.065	<.0001	0.001	<.0001	0.001	0.001	<.0001	0.790	0.289	0.762	0.047	<.0001
Bazaar														
SO_2	0.36	0.02	-0.26	-0.19	-0.23	0.14	-0.16							
p-value	<.0001	0.540	<.0001	<.0001	<.0001	<.0001	<.0001							
PM_{10}	0.06	0.17	-0.24	-0.15	-0.21	0.41	-0.06							
p-value	0.152	<.0001	<.0001	0.000	<.0001	<.0001	0.112							
NO	-0.03	0.22	-0.08	-0.09	-0.08	0.20	0.06							
p-value	0.507	<.0001	0.032	0.018	0.030	<.0001	0.129							
NO_2	0.18	0.08	-0.10	-0.14	-0.12	-0.23	0.13							
p-value	<.0001	0.028	0.006	0.0001	0.002	<.0001	0.001							
NO_X	0.06	0.22	-0.10	-0.14	-0.12	0.09	0.10							
p-value	0.156	<.0001	0.006	0.0001	0.002	0.021	0.005							
O_3	0.49	-0.004	-0.56	-0.47	-0.54	0.33	-0.25							
p-value	<.0001	0.896	<.0001	<.0001	<.0001	<.0001	<.0001							
CO	0.25	0.11	-0.34	-0.24	-0.30	0.53	0.01							
p-value	<.0001	0.0003	<.0001	<.0001	<.0001	<.0001	0.814							

The high lighted cells are statistically significant p = 0.05
Max = Maximum
Min = Minimum
Hum = Humidity
T = temperature

The descriptive characteristics of pollutants levels on Thursdays, Fridays and other days are presented in Table 4.23. According to Table 4.23, the mean concentration of PM_{10} at Fatemi is higher on other days than on Thursdays.

Table 4.23 Summary statistics for air pollution levels on Thursdays, other days and Fridays.

	Other days				Thursday				Friday			
Variable	N	N Miss	Mean	Std Dev	N	N Miss	Mean	Std Dev	N	N Miss	Mean	Std Dev
Fatemi												
PM_{10}	736	48	98	42	143	13	90	31	145	11	88	40
NO	701	83	142	75	135	21	134	68	137	19	134	76
NO_2	703	81	171	81	135	21	160	69	137	19	156	73
NO_X	703	81	189	95	135	21	177	84	137	19	174	93
O_3	706	78	15	11	136	20	15	11	138	18	15	11
CO	733	51	14921	5426	143	13	14355	5237	145	11	13919	8013
Bazaar												
PM_{10}	466	318	130	241	92	64	113	204	92	64	101	156
NO	566	218	83	37	112	44	79	32	113	43	73	37
NO_2	556	228	62	30	110	46	60	27	111	45	57	26
NO_X	566	218	91	35	112	44	87	30	113	43	81	32
O_3	704	80	20	18	140	16	19	17	138	18	17	14
CO	761	23	9353	3923	151	5	9091	3691	152	4	7408	3403

The reason for the day of week differences effect on air pollution has to do with the workweek in Iran and other Islamic countries. Saturday through Wednesday is workweek while in this study, they were classified as other days; and Thursday and Friday are singled out. In Iran nearly all government offices, except the Ministry of Education are closed on Thursday. On Fridays, government offices, businesses and schools are closed, and thus this day is considered the weekend.

The mean differences in pollutant levels between Thursdays and other days, Fridays and other days and Thursdays and Fridays in the three-year period are presented in Table 4.24. To assess the effect of days of the week on air pollution levels, t-tests were used. As illustrated in Table 4.24, the data for PM_{10}, NO and NO_2 between Thursday and other days were different and these differences are significant. In addition, another test was applied to see the effect of Fridays on level of pollutants. As indicated in Table 4.23 the pollution levels are lower on Fridays than on other days. Significance of mean differences was assessed using a t-test, as presented in Table 4.24. The difference between the effect of Fridays and other days for $PM_{10,}$ NO_2 at Fatemi and NO, NO_X and CO at Bazaar station were significant. The result showed the days of the week has some effects on the pollution level and this difference was not caused by chance. It should be mentioned that CO levels at Bazaar on Thursdays were higher than Fridays and Fridays than other days (see Table 4.23). As indicated in Table 4.24 mean difference of CO level was significant ($p \leq 0001$) which means this difference is caused by a weekday's effect.

Although, according to traffic rules, private cars can pass through down town only on Thursdays and Fridays, the air pollution in other days was at the highest level followed by Thursday and then Friday. On Thursdays and Fridays, the offices are usually closed so any car passed there because of some other reasons except official jobs.

Table 4.24 Comparison of pollution levels: other days vs Thursday vs Friday

Pollutants	Thursday and other days		Fridays and other days		Thursdays and Fridays	
	Mean difference	Pr > |t|	Mean difference	Pr > |t|	Mean difference	Pr > |t|
Fatemi						
PM_{10}	9*	0.002	10*	0.012	2	0.721
NO	8	0.134	8	0.256	0	0.994
NO_2	13*	0.021	15*	0.041	5	0.596
NOX	13*	0.046	15	0.097	3	0.795
O_3	0	0.908	-0.1	0.956	-0.3	0.824
CO	786	0.053	1003	0.063	373	0.641
Bazaar						
PM_{10}	23	0.239	30	0.259	13	0.635
NO	7	0.015	10*	0.008	6	0.169
NO_2	3	0.150	4	0.149	2	0.554
NOX	7	0.007	10*	0.005	6	0.179
O_3	2	0.115	3	0.059	2	0.220
CO	1107	<.0001	1946*	<.0001	1683*	<.0001

* Statistically significant p = 0.05

In 1996, AQCC carried out research with the aim of measuring CO concentration in high traffic regions of Tehran. The result showed eight hourly concentrations were higher than the eight hourly standard levels in the city. In addition, it showed the concentration of CO was at eight hourly standard levels in any days of the week and it was higher than one hourly standard on the start and end of the week. Traffic was one of the important factors in the concentration of CO [Air Quality Control Company, 1996]. It is confirmed that the concentration of CO was positively associated with traffic density. This is the reason that CO mean concentration on workdays was higher than

Thursdays. The same result can be seen for CO at Bazaar where the traffic restriction was ruled.

4.5 Discussion

Tehran was recognized by WHO as one of the most polluted cities in the world [Shirazi and Harding, 2001]. In Iran, like any other Islamic countries, Friday is the official weekend. However, on Thursday all the governmental offices except Ministry of Education are already closed. Therefore, in this study the days of the week Saturday through Wednesday are defined as ‘other days’, Thursday and Friday as weekend. According to traffic rules, private cars can pass through downtown only on Thursdays and Fridays. However, on weekdays, the air pollution was at the highest level followed by Thursday and then Friday; this is according to expectations given working patterns.

CO is the main pollutant in Tehran as indicated in Table 4.17 and Figure 4.19. As mentioned in the introduction chapter there were more than 700,000 cars, most of them with poor fuel efficiency and lacking modern exhaust filters. This is believed to be the major reason for the high pollution levels. In early December 2005, Tehran experienced a condition with extreme smog situation [Harrison, 2005]. CO was measured from space. As it is indicated in Figure 4.20, CO concentration at 700 millibars (about 3 kilometres altitude) averaged over the week from 5-10/12/05. High CO levels, coded in crossed squares in Figure 4.20, which is evident over the region of Tehran.

In a study on measurement of air pollution concentration in 22 districts in Tehran in 2003, CO emitted from transportation contributed to 98% of total CO level in the whole country. CO emission in Tehran was 147,345 tons in year 1998 due to transportation (65%), industries (25%) and household (10%) [Changani and Baniardalani, 2003]. The impact of Tehran’s urban environment on CO emissions is evident in the hourly levels of CO concentration as shown in Appendix A4.2. The pattern shows that the highest concentration of CO usually happens in the late night when emissions are condensed due to the lack of strong winds to disperse them.

Geography, climate and urban design are all important factors contributing to pollution and smog in Tehran. The south of Tehran has lower altitude and narrower streets, and is lined with buildings of at least four stories in height on both sides of streets. In addition, very heavy traffic throughout the day results in vehicles, buses and cars, running their engines while stopped in traffic jams and the region's elevation makes fuel combustion inefficient, further adding to the problem [Atieh Bahar Consulting Co, 2002]. The physical aspects of the city, combined with the heavy traffic patterns as well as the fact that catalytic converters are not used, lead to high emission of CO. The height of city buildings combined with the surrounding mountain chain creates a wall, which traps pollution within Tehran. The situation in northern Tehran is somewhat different. While the population density is lower and streets become wider, there are, more highways and the buildings generally increase in height.

This situation is called 'street canyon'. Street canyons can have a significant influence on the dispersion of the pollutants near the sources, as most automotive emissions take place at ground zero. There are two general ways that canyons affect the dispersion. First, by enhancing vertical mixing above the canyons and second, by trapping the pollutants into their physical boundaries through preventing existing wind and delaying pollutant transport to the freely moving air above the canyons. Therefore, the effect of canyons is obvious; the higher the local pollutant concentrations, the higher the impacts will be.

The data on air pollution is based on reports from urban monitoring sites. It should be mentioned that the concentrations are sensitive to local conditions and even within the same city, different monitoring sites may register different concentrations as indicated in Table 4.9. Thus, these data should be considered only as a general indication of air quality in each city; a cross-country comparison should be made with caution.

Compared with other cities and for all three years, Tehran had the highest air pollution concentration except for O_3. Some experts believed that the machines in Tehran were too old to be sensitive to evaluate an air pollutant like ozone.

It is estimated that up to 5,000 people died every year from air pollution [Harrison, 2005]. However, there is no official confirmation of any smog-related deaths. Ambient concentration of hazardous pollutants is relatively high to detect the adverse health effect of air pollution and the analytic methods are important concern as well.

Shafie Pour and Ardestani used data for cardiopulmonary and lung cancer death for 2002 from the Iranian Ministry of Health to estimate the urban air pollution impacts which is presented in Table 2.1 [Shafie-Pour and Ardestani, 2007]. In this study, it was assumed that 90% of Tehran's population is exposed to air pollution. This assumption was confirmed by air pollution experts' advice used to establish the population exposed to air pollution in each city in Iran for that study. Urban air pollution is estimated to cause around 13,200 premature deaths annually. In addition, it was estimated that the air pollution causes about 12,500 new cases of chronic bronchitis per year.

Please see print copy for image

Figure 4.20 Satelite image of CO pollution in Tehran in December 2005

4.6 Conclusion

Although, air pollution is main environmental problem in Tehran, the monitoring machines did not work well as many missing value were seen in the data collected for this study. The main source of these is motor vehicle exhaust and house heating. The wind speed is often not strong enough to remove it from the streets combined with buildings and mountains blocking airflow. Most of the days of the year the air pollutant concentration were exceeded for the 24 hourly World Bank standard level. In addition, the concentration of pollutants was at the highest level on workdays and decreased gradually on weekends. With a population of about 12 million people, the Iranian capital, Tehran, frequently experiences severe air pollution events (see Table 4.3, Table 4.7, Table 4.11, Table 4.15 and Table 4.19). An estimated 1 million cars, most of them lacking exhaust filters, are believed to be a major cause for the high pollution levels. Tehran is surrounded by mountains, and if there is no wind or rain, the pollution gets trapped and can cause extreme smog situations, such as the conditions that the region experienced in early December 2005 (see Figure 4.20).

The analysis of air pollution data is useful for health risk assessment of the population within the study area, to assist in establishing and monitoring air quality standards if it is systematically monitored. The consistency of data availability is limited and may require adaptations in health effect studies. Particularly the SO_2 data are very inconsistently collected and widely different between the stations different to what was expected. Meteorological parameters like wind speed; temperature, humidity, and altitude affect pollutant dispersion and need to be taken into account.

Chapter 5: Air pollution and school absenteeism due to respiratory illness

Ambient air pollutants including ozone (O_3), nitrogen dioxide (NO_2), and respirable particles less than 10 µm in diameter (PM_{10}) contribute to the occurrence of respiratory symptoms, which may lead to school absenteeism. Previous studies indicated that increased school absenteeism was associated with PM_{10} concentration and that effects persisted for up to 3 to 4 weeks [Ransom and Pope III, 1992]. In another study, absences were increased two to three days after exposure to high ozone concentration and reached a peak on day five after exposure [Gilliland et al., 2001]. Yet another study [Park et al., 2002] found that increased PM_{10}, SO_2 and O_3 levels were associated with the number of illness-related absences. This chapter addresses the study question about the association between respiratory disease related school absenteeism and air pollution levels in Tehran.

5.1 Methods

Attendance records and medical certificate reports of the students at two elementary schools in District 12 of Tehran were collected by the school administration. Only respiratory illness-related absences (as determined by a medical certificate and/or parent report) or any absenteeism noted by the school assistants as respiratory illness-related was deemed relevant to the purpose of this study. An absence was defined as occurring when a student did not attend the school on a day when the school was open.

The air pollution values used here were 24 hourly air pollution levels, derived from hourly air pollution levels, as mentioned in Chapter four. Further derived air pollution variables, for each pollutant, are the 24 hourly averages immediately preceding and appropriate to the particular school shift. Thus, the period over which these averages are calculated ends six hours earlier for the morning shift than for the afternoon shift. The morning air pollution average is based on 24 hourly values from 7:00 in the morning to 6:00 the next morning. However, the afternoon average was based on data from 13:00 each day to 12:00 of the next day. In the analysis tables, these variables are designated using ‘comb’ as a suffix. Air pollution variables with a ‘comb’ suffix were those calculated for the 24-hour average for the relevant shift (morning or afternoon). Derived from these air pollution variables was a seven-day moving average which is indicated in Table 5.2-Table 5.5 as MA.

5.1.1 Statistical Analysis

Two methods were used to assess the association between air pollution levels and absenteeism. Poisson regression was used to assess the relationship over the whole study period between daily absences as response: (a count variable) and air pollution. Poisson regression assumes that absenteeism data follow a Poisson distribution, a distribution that is frequently encountered when counting a number of events. In epidemiological studies, one often encounters situations where the outcome variable is numeric, and in the form of a count. The aim of the regression analysis is to model the response variable Y using various explanatory variables such as NO level. The basic (so called 'canonical') model formulation in Poisson regression is that the mean of the Poisson random variable is a function of predictor information, such as E(Y) = exp $(\beta_0+\beta_1X_1+\beta_2X_2)$. Because the logarithm of this function produces a linear combination of predictors, this model is said to have a logarithmic link function.

At first, air pollutant concentrations and temperature with lags of zero to seven days (to the day of absenteeism) were chosen as potential explanatory variables. In preliminary model evaluation, one lag length was used for all pollutants together with temperature on the day of absenteeism. The 'best' lag was chosen using standard model evaluation techniques. In addition, a seven-day moving average was calculated. Using the resultant full model as a base, stepwise elimination was used to produce a model in which only significant pollution variables were used, along with forced terms for temperature, school, shift and so on.

Secondly, using the method of case-crossover design, conditional logistic regression was used to model a dichotomous response variable, which is assigned the value '1' for a case and '0' for a control. A case was defined as two consecutive days of respiratory related absence for a student. If the days straddled a holiday or Friday, they were considered as consecutive too. Therefore, air pollution levels on the first day of substantial (two or more days of respiratory illness related) absenteeism were compared with air pollution levels two weeks before and two weeks after that date [Levy et al., 2001]. A backwards stepwise method was used to reduce and refine the models.

5.2 Results

The relevant data for this section of the study covered 906 children (541 boys and 365 girls) over an intended period of two years, and included children from first to fifth grade in each school (see Table 5.1).

Table 5.1 Students according to gender and teaching shift of their school

	Gender			
Shift	Female	Male	Total	%
AM	180	259	439	48.5
PM	185	282	467	51.5
Total	365	541	906	
%	40.3	59.7		

The data eventually collected only spanned a period of 1.3 years (464 days), not the planned 2 years. A summary of air pollution data over this period is given in Table 5.2 The average number of daily absences due to respiratory illness per shift per school was 1.1 to 1.9 as shown in Table 5.3. The effective period of study was further reduced to 464 days, since 79 days were summer holidays; 24 days were additional public holidays and 66 additional days Fridays. In the end, 295 days ($=464-79-24-66$) were defined as school days used to measure absenteeism (Table 5.2 and Table 5.3). As there are two different shifts and two different schools, the effective total number of observations for this part of the study was $1180 (= 295 \times 4)$.

Time-series of absenteeism in combination with air pollution levels graphs are presented in Figure 5.1 to Figure 5.13. Some missing individual points and intervals of missing values can be seen in the graphs. The reason is that the school year for primary students started on 23 September of the year and ended on 4 June of the next year. The other long holiday covers the Iranian New Year, which was from 21 March to 2 April. Furthermore, since Friday is the ‘weekend’ in Iran, all Fridays are missing. A summary of daily absenteeism data is presented in Table 5.3.

As SO_2 data showed many missing values and limited changes in range (Table 5.2, Figure 5.2 and Figure 5.3) [Ferrari and Salisbury, 1999], it was decided that this variable would not be used in any analysis for this chapter. For PM_{10}, the data for Fatemi were used as they had fewer missing values, for all other pollution variables, only Bazaar data were used (Table 5.2), since these are regarded as most reliable. Also included in this table are those pollution variables, which turned out to be significant predictors. For each site, these are included below the dotted lines. The number of days of data on pollutant variables varied according to pollutant, with SO_2 most noticeable in terms of missing values. Further, the seven-day moving averages were calculated whenever there was at least one day of data, hence fewer missing observations. Finally, because case-crossover data included some control dates outside range for case dates Poisson analysis, this led to extra data days for case-crossover analysis.

Table 5.2 Summery statistic of daily air pollution over 1.3 years

Variables	N	N Miss	Minimum	Median	Mean	Maximum	Std Dev
Fatemi							
SO_2	99	365	277	291	291	307	7.1
PM_{10}	419	45	4	95	95	213	38.3
NO	420	44	20	77	78	160	26.5
NO_2	420	44	43	106	111	224	34.5
NO_X	420	44	34	108	111	229	36
O_3	375	89	2	22	23	63	13.5
CO	414	50	2734	11807	12481	81938	5477.8
MA PM_{10}comb for Poisson	441	23	12	93	93	154	28.5
MA PM_{10}comb for Case-crossover	584	58	19	89	88	149	21.2
MA NO comb	584	58	17	78	78	134	18.8
MA O_3 comb	447	195	1	13	17	43.8	11.1
Bazaar							
SO_2	239	225	2	50	47	75	13.6
PM_{10}	216	248	26	112	238	1850	361.8
NO	431	33	6	87	90	215	35.4
NO_2	417	47	21	58	65	196	32.5
NO_X	431	33	5	92	98	271	35.2
O_3	374	90	8	35	36	145	15.7
CO	438	26	2375	11232	11485	34125	4295.9
MA NO comb	446	18	6	89	88	143	24.9
MA NO_2comb	433	31	9	59	64	141	30.1

Table 5.3 Statistical summary of daily absenteeism over 1.3 years

Variables	N	N Miss	Minimum	Median	Mean	Maximum	Std Dev
Morning shift/Girls' school	295	169	0	0	1.1	26	2.3
Afternoon shift/Girls' school	295	169	0	1	1.4	12	1.8
Morning shift/Boys' school	295	169	0	0	1.9	13	2.8
Afternoon shift/Boys' school	295	169	0	1	1.3	14	2

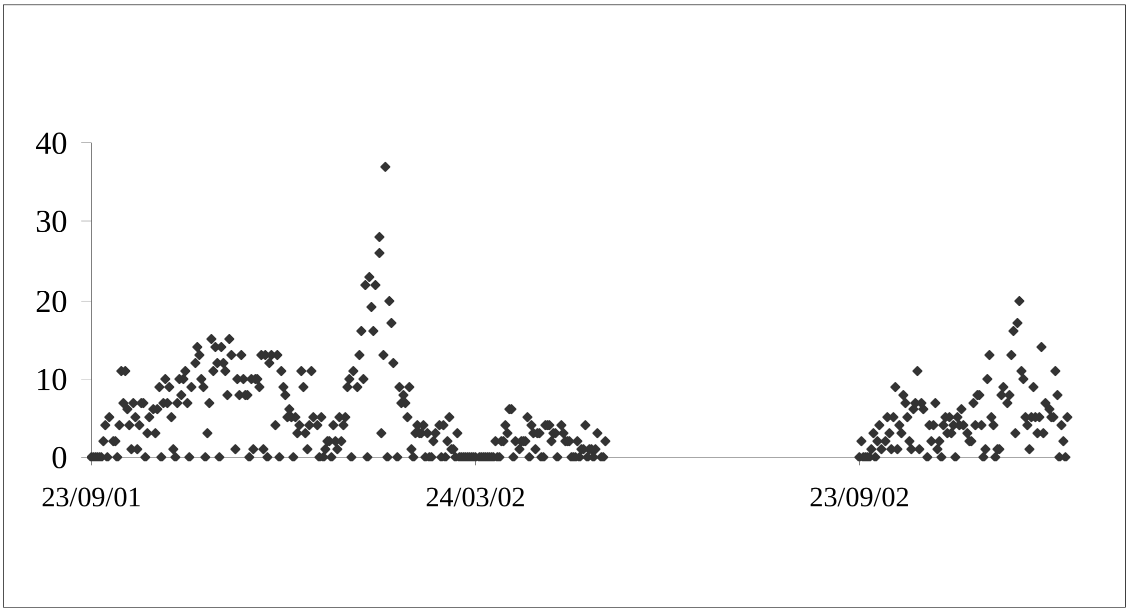

Figure 5.1 Daily absenteeism over 1.3 years

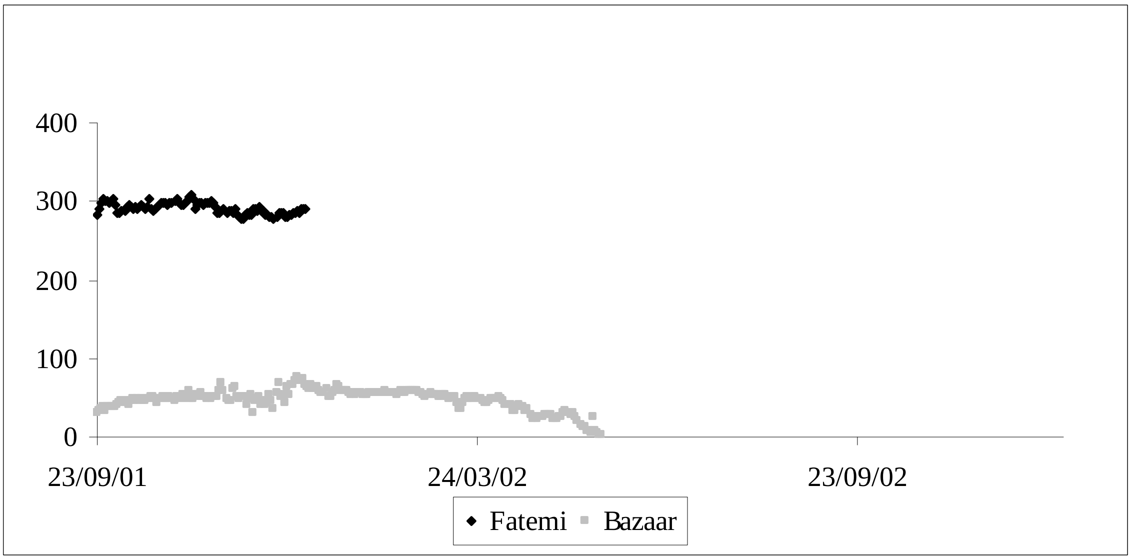

Figure 5.2 Daily SO_2 levels over 1.3 years, units in μg/m^3 for morning shift

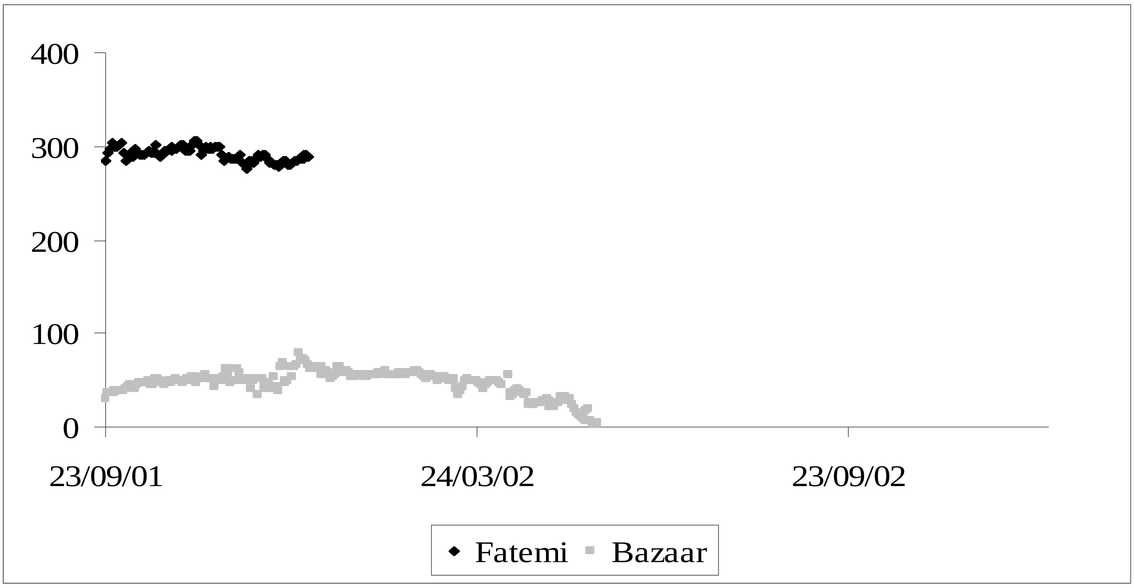

Figure 5.3 Daily SO_2 levels over 1.3 years, units in μg /m^3 for afternoon shift

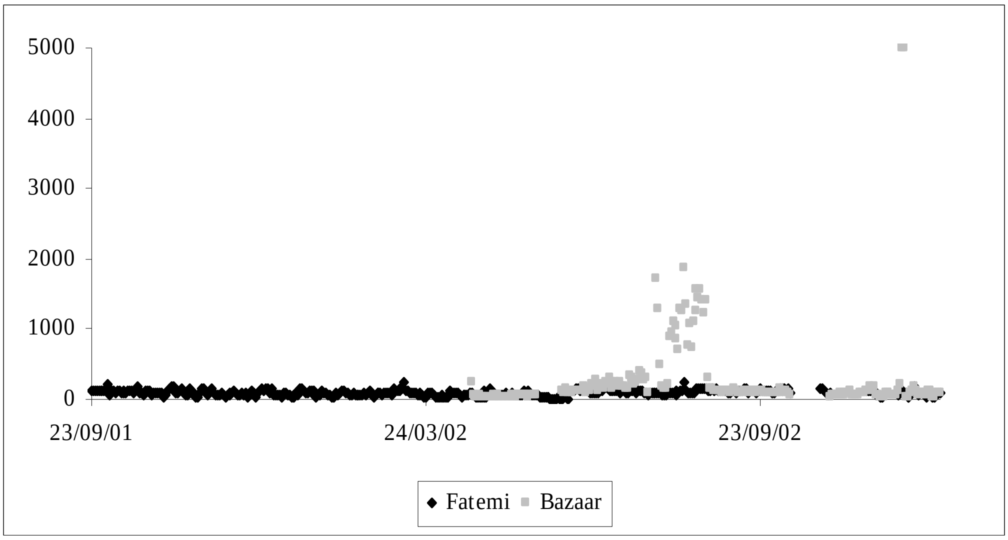

Figure 5.4 Daily PM_{10} levels over 1.3 years, units in $\mu g/m^3$ for morning shift

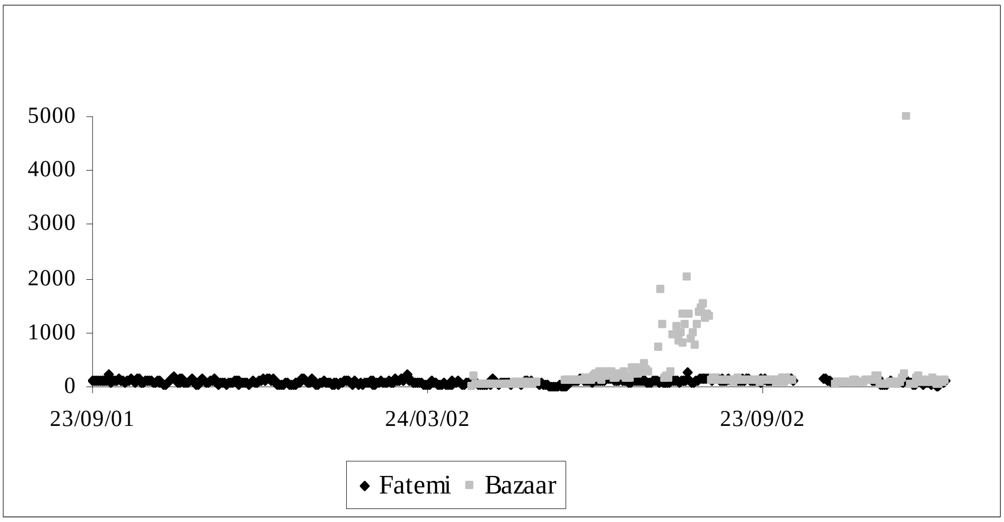

Figure 5.5 Daily PM_{10} levels over 1.3 years, units in $\mu g/m^3$ for afternoon shift

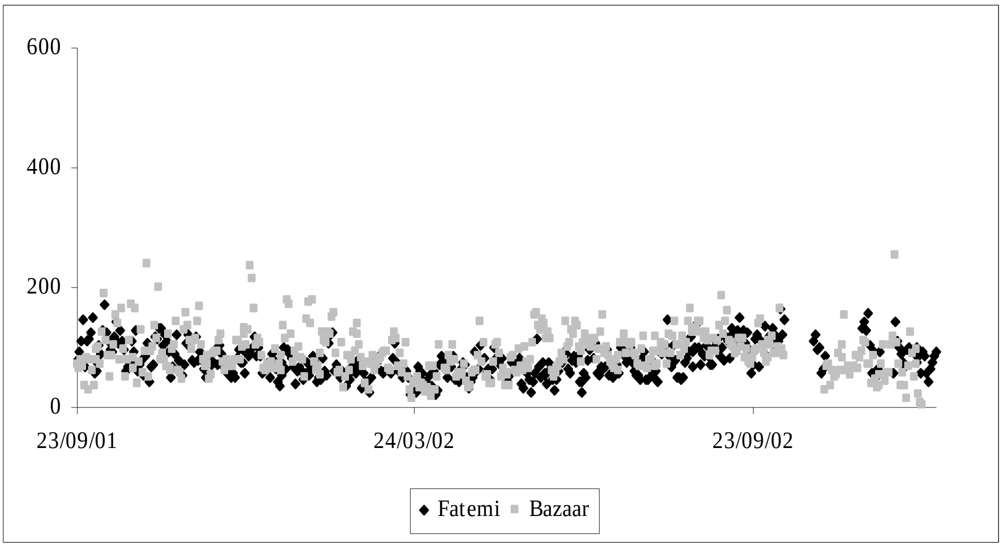

Figure 5.6 Daily NO levels over 1.3 years, units in $\mu g/m^3$ for morning shift

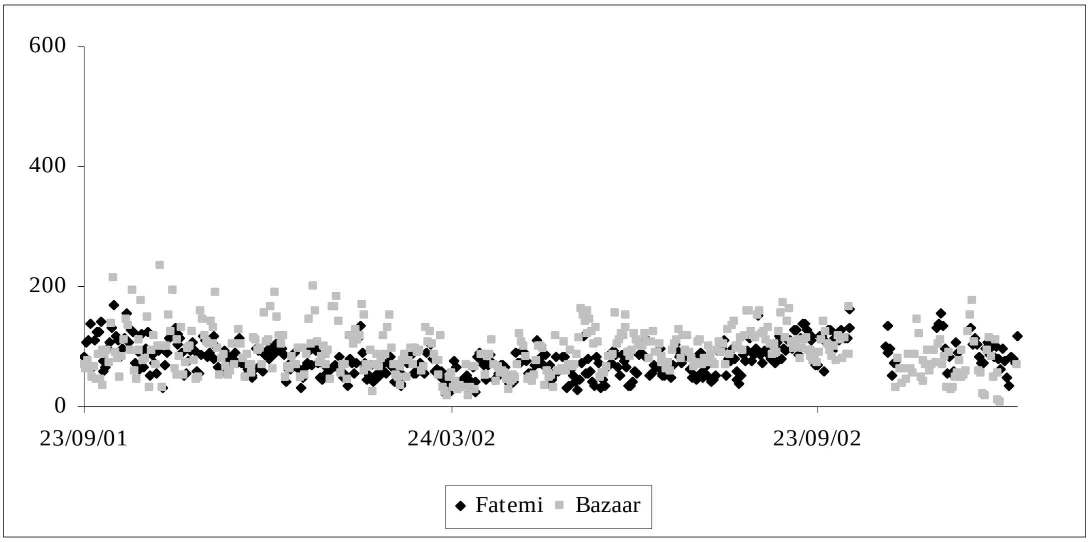

Figure 5.7 Daily NO levels over 1.3 years, units in μg/m^3 for afternoon shift

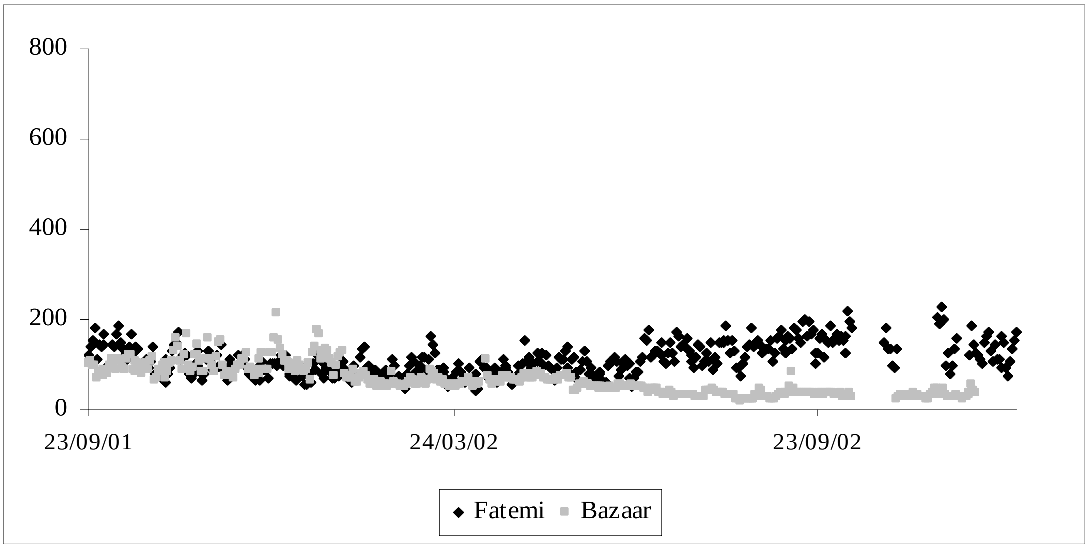

Figure 5.8 Daily NO_2 levels over 1.3 years, units in μg/m^3 for morning shift

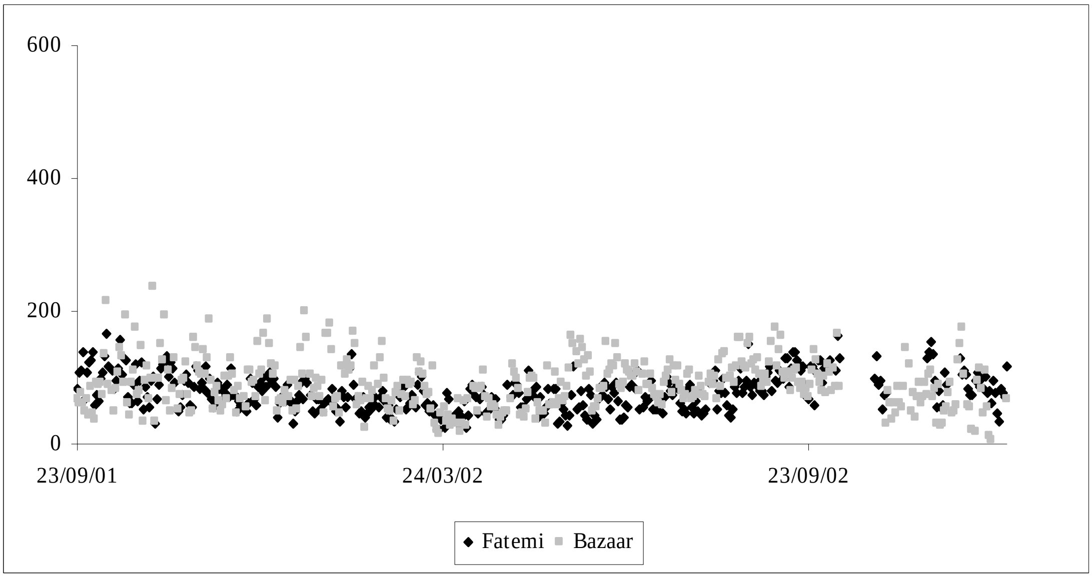

Figure 5.9 Daily NO_2 levels over 1.3 years, units in μg/m^3 for afternoon shift

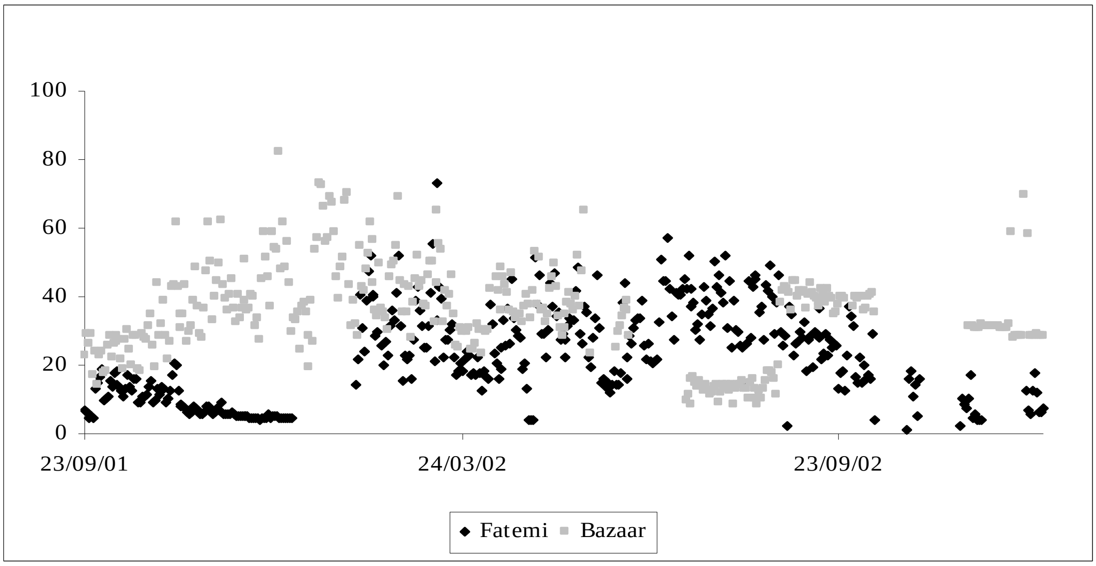

Figure 5.10 Daily O_3 levels over 1.3 years, units in μg/m^3 for morning shift

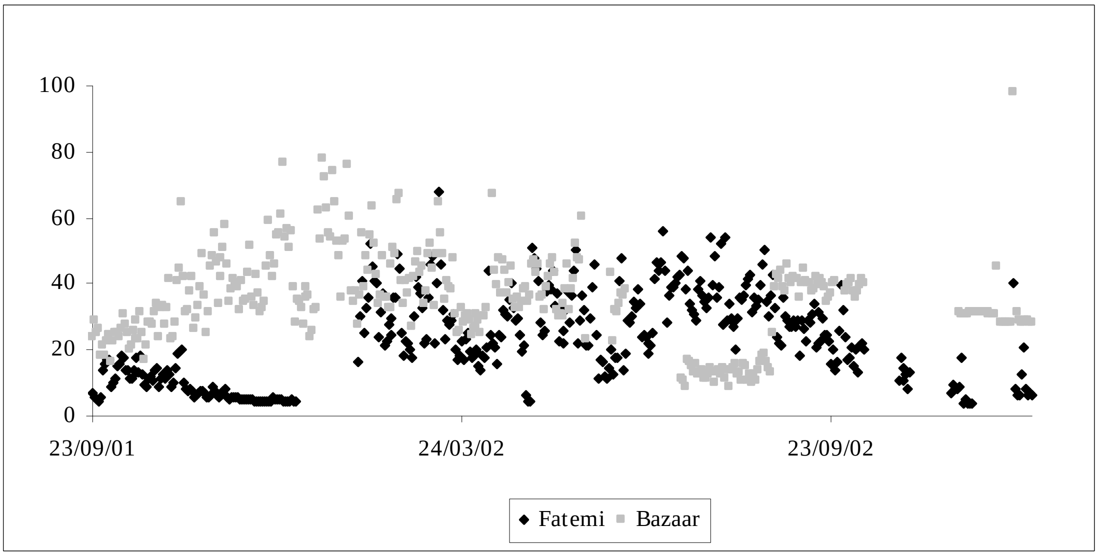

Figure 5.11 Daily O_3 levels over 1.3 years, units in μg/m^3 for afternoon shift

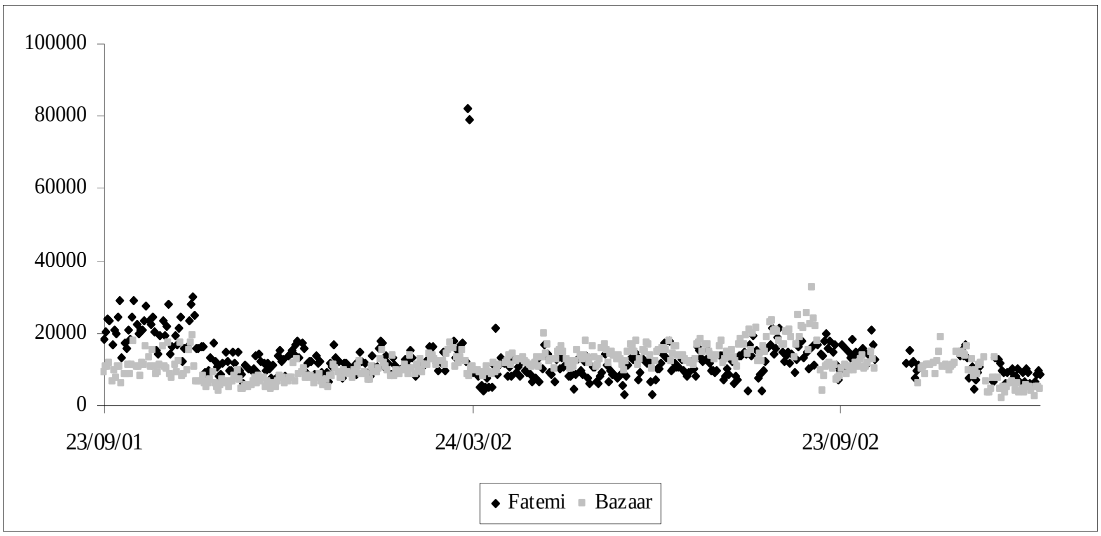

Figure 5.12 Daily CO levels over 1.3 years, units in μg/m^3 for morning shift

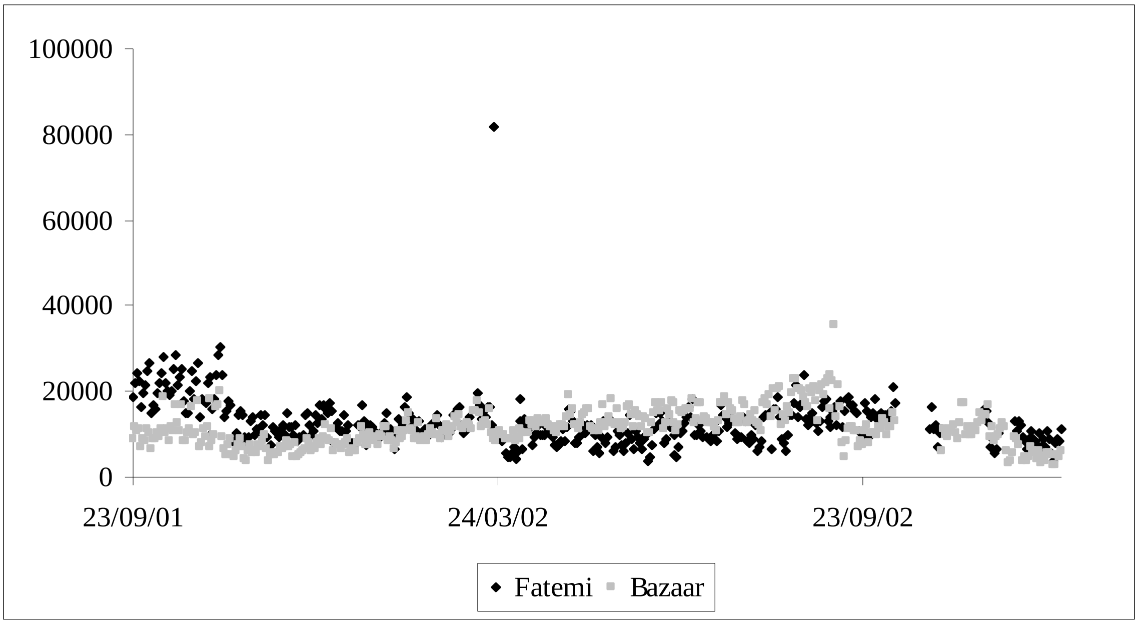

Figure 5.13 Daily CO levels over 1.3 years, units in μg/m^3 for afternoon shift

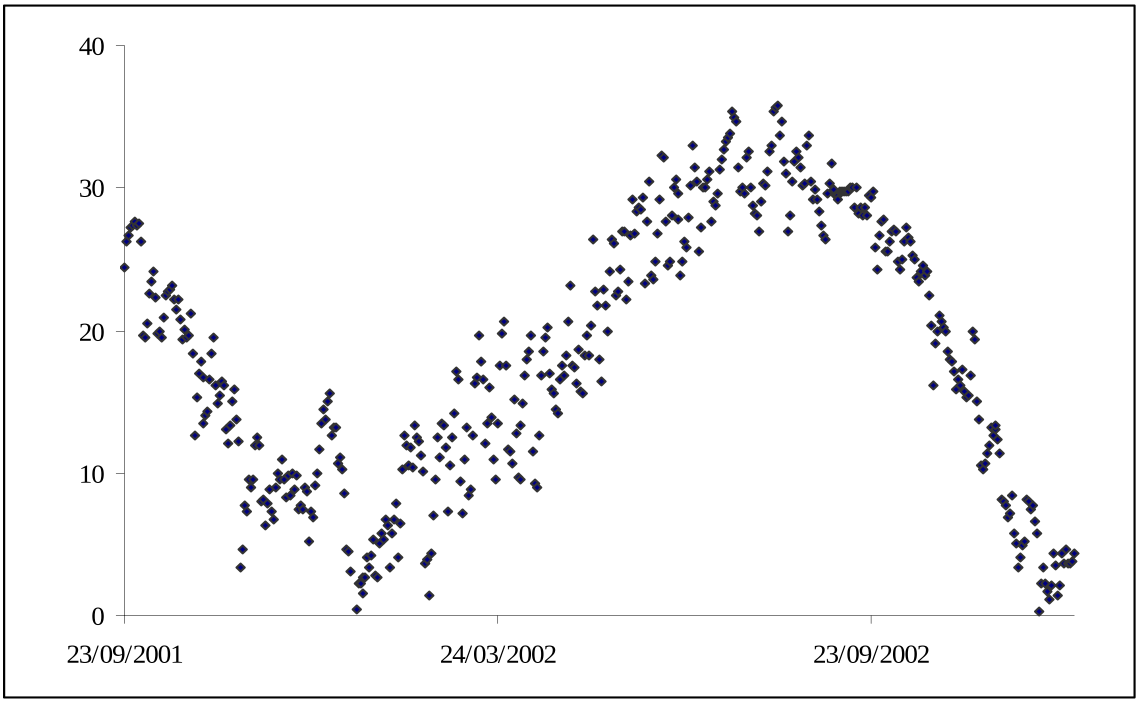

Figure 5.14 Daily temperature over 1.3 years, units in °C

5.2.1 Poisson regression

The Poisson regression model chosen using backward stepwise selection is presented in Table 5.4. For eighty-five students, the teaching shift for the second year was changed. Therefore, an additional dichotomous dummy variable was created for year as well as dummies for interaction between year, shift and school. The chosen model used daily temperature and squared temperature as ancillary predictors along with dummy variables for shift, school, year and their interactions as well as the concentrations of selected pollutant variables.

In the best Poisson regression model for absenteeism, temperature and squared temperature were significant predictors, as presented in Table 5.4. While temperature is an indicator of seasonal effects and is potentially a useful predictor in its own right, a linear term in temperature is insufficient to cover the substantial seasonal variation in temperature, its effect or long function and its role as a surrogate 'seasonal' variable. Accordingly, a quadratic temperature term, using T^2 as a predictor, is added in these subsequent chapters. Absenteeism was also negatively associated with the seven-day moving average of PM_{10} at Fatemi and with the seven-day moving averages of NO_2 comb at Bazaar, but positively associated with the seven-day moving average of NO comb at Bazaar. Using the difference between mean (93) and maximum (154) concentration of PM_{10} in this period to judge the size of the effect, such an increase in PM_{10} is predicted to lead to a decrease of 0.4 in daily absenteeism. Using the difference between mean (88) and maximum (143) concentration of NO in this period to judge the size of the effect, such an increase in NO is predicted to lead to an increase of 0.8 in daily absenteeism. Using the difference between mean (64) and maximum (141) concentration of NO_2 in this period to judge the size of the effect, such an increase in NO_2 is predicted to lead to a decrease of 0.7 in daily absenteeism.

Table 5.4 Poisson regression for the effect of air pollutant concentrations on daily absenteeism

Parameter	Estimate	Standard Error	Wald 95% Confidence Limits Lower	Upper	Chi-Square	Pr > Chi-Sq
Intercept	1.4836	0.3729	0.753	2.215	15.83	<.0001
Daily Temperature (T)	-0.0027	0.0211	-0.044	0.039	0.02	0.8990
T^{2*}	-0.0006	0.0008	-0.002	0.001	0.72	0.3978
Shift	0.407	0.2954	-0.172	0.986	1.9	0.1682
School	-1.6661	0.9251	-3.479	0.147	3.24	0.0717
Year	-0.3241	0.197	-0.710	0.062	2.71	0.1000
Shift × School	0.947	0.9661	-0.947	2.841	0.96	0.3270
Shift × Year	-0.3159	0.2334	-0.773	0.142	1.83	0.1758
School × Year*	0.9976	0.4846	0.048	1.947	4.24	0.0395
School × School × Year	-0.4022	0.5349	-1.451	0.646	0.57	0.4521
MA[1] PM_{10} comb(F)*	-0.0073	0.0023	-0.012	-0.003	9.69	0.0019
MA NO comb(B)*	0.0124	0.002	0.008	0.016	36.98	<.0001
MA NO_2 comb(B)*	-0.0095	0.0023	-0.014	-0.005	16.56	<.0001
Observation used	412		DF	399		
Missing values	1444		Log likelihood	-182.0		

* Statistically significant p = 0.05
1-Moving average

5.3 Case crossover

Based on the case window, any respiratory related absenteeism records for at least two consecutive days defined a case date as the first of any such group of successive days. A matched conditional logistic regression analysis was carried out to investigate the relationship between an outcome and a set of prognostic factors in matched case-control studies. Out of 2671 absence occasions, 214 observations became cases under the consecutive day definition. Thirty-three students have more than one ‘case’ among these 214 observations. The controls were the same students two weeks before and after the case dates provided that these did not occur on another case date. If they did so, they were removed from control dates. Conditional logistic regression using the PHREG procedure in SAS was performed. For this analysis, a stratum was set up for each matched set. All the risk factors such as daily temperature, school, teaching shift, educational year, their interactions, daily air pollution and seven-day moving averages for air pollution variables were included in the initial model. As noted in Section 5.2.1, for Poisson regression, Bazaar pollution variables were selected along with PM_{10} from Fatemi since there were many missing values for PM_{10} at Bazaar. For case-crossover analysis, since Bazaar data did not show any significant results it was decided to assess the predictive values of Fatemi pollution data instead. Stepwise backward elimination was used to choose a final model in which the seven-day moving averages for PM_{10} NO and O_3 in a model at Fatemi station were the only pollution variables significantly associated with absenteeism.

The results of case-crossover analysis are presented in Table 5.5. As presented in Table 5.5 absenteeism is significantly associated with moving average of PM_{10}, NO and O_3 comb. In addition, using the difference between mean (88) and maximum (149) concentration of moving average of PM_{10} in this period to judge the size of the effect, such an increase in PM_{10} is predicted to lead to a decrease in the probability of daily absenteeism (OR = 0.2). Using the difference between mean (78) and maximum (134) concentration of moving average of NO in this period to judge the size of the effect, such an increase in NO is predicted to lead to an increase in the probability of daily absenteeism (OR = 10). Using the difference between mean (17) and maximum (44) concentration of moving average of O_3 in this period to judge the size of the effect, such an increase in O_3 is predicted to lead to a decrease in the probability of daily absenteeism (OR = 0.1).

Table 5.5 Conditional logistic regression and daily absenteeism

Variable	Parameter Estimate	Standard Error	Chi-Square	Pr > Chi-Square	Hazard ratio	(95%CI) Lower	upper
Daily Temperature (T)	0.07	0.04	3.388	0.0657	1.07	1.00	1.15
Shift	-0.04	0.35	0.013	0.9077	0.96	0.49	1.89
School	-0.27	0.77	0.119	0.7306	0.77	0.17	3.50
Educational year	-0.53	0.54	0.978	0.3227	0.59	0.20	1.69
Shift × School	0.06	0.72	0.007	0.9321	1.06	0.26	4.33
Shift × educational year	0.21	0.66	0.096	0.7562	1.23	0.34	4.49
School × educational year	0.65	0.56	1.362	0.2433	1.92	0.64	5.76
MA PM_{10} comb(F)*	-0.02	0.01	5.280	0.0216	0.98	0.96	1.00
MA NO comb(F)*	0.04	0.01	12.536	0.0004	1.04	1.02	1.07
MA O_3 comb(F)*	-0.08	0.03	6.585	0.0103	0.93	0.88	0.98

*Statistically significant p = 0.05
MA: seven-day moving average

5.4 Discussion

This section of the study examined the association between air pollutants and elementary school absenteeism in District 12 of Tehran for 1.3 years commencing on 23/09/01, not 01/01/01 as had been the intention for the 2-year study. In total, two elementary schools with 906 students were studied over 295 school days on 214 of which, there was absenteeism for respiratory reasons. This study has shown a statistically significant relationship between outdoor air pollution and respiratory related absenteeism. Although Poisson regression and case-crossover analysis use the data quite differently, and they use pollution data, other than PM_{10}, from different stations, the strongest association for both was between seven-day moving average of NO and school absenteeism.

These data suggest an acute effect of high air pollution exposure on the occurrence of absenteeism due to respiratory illness among children. The effect of pollutant changes from mean to maximum levels for NO led to significant rises in absenteeism. In this study, 24 hourly moving averages based on school's teaching shifts were used to define exposure.

When studying the health effect of hazardous exposures, children are often considered as if they were small adults. However, this does not produce an accurate picture when investigating effect of exposure on respiratory health. Children represent the largest sub-population susceptible to the adverse health effects of air pollution [Kleinman, 2000]. As children grow, their organ systems are still developing and their normal growth may be affected when exposed to pollutants at critical periods. Children also typically spend more time outdoors than adults [Kleinman, 2000], and concentrations of pollutants of ambient origin are higher outdoors than indoors. Children playing outdoors also engage in exercise that increases ventilation. This is particularly true in afternoons, when photochemical pollutant concentrations (nitrogen oxides, ozone and particulate) are highest. In this study, an association with respiratory related absenteeism was found in the 6-11 year age group and particulate matter, nitrogen oxides, ozone and CO exposures. This study showed only association and could not be used to ascribe causes, but other studies have reviewed air pollution effects on human respiratory disease [Bernstein et al., 2004]. The Bernstein et al study found that diesel exhaust particles increase airway inflammation and exacerbate asthma and chronic obstructive pulmonary disease and also reported the inflammatory impacts of ozone on respiratory disease [2004]. Ponka studied the effect of air pollution on hospital admission. In a model containing temperature, SO_2, TSP, NO, NO_2, O_3 and CO simultaneously, NO, ozone and CO alone were significant predictors for asthma visits [1990]. In another study, PM_{10} and NO decreased PEF by 3-9% in urban children [Steerenberg et al., 2001]. Carbon monoxide which is a by product of incomplete combustion of fuel such as natural gas, coal or wood, [EPA, 2006] is mostly outdoor air pollution in Tehran [Changani and Baniardalani, 2003; Hosseinpoor et al., 2005]. Emissions from motor vehicles increase the concentrations of all the pollutants under study, making it difficult to separate differing impacts.

The results of this study seem to be compatible with other studies. Results from a study among students in Taiwan suggested short-term exposure to NO_2 and nitrogen oxides were positively correlated with illness-absence frequency [Hwang et al., 2000]. The result of another study, carried out in USA, also O_3 showed to be statistically significant predictors of daily absenteeism in elementary schools [Chen et al., 2000]. In that study, for every 50 ppb increase in O_3, the absence rate would increase 4% (95% CI: 1.0, 6.6%) and 13% (95% CI: 3.4, 22.6%), respectively. However, in this study, PM_{10} values were negatively correlated with school absenteeism.

The accuracy of the data in this study needs to be addressed. Absenteeism was recorded by the schools' administration and was therefore presumed accurate because all teachers kept daily records of school attendance for their class and then the detail of it was followed by schools assistants. Although no effort was made to validate these records, there is no reason to suspect that GPs or parents misreport the reason for absenteeism of the child. For this study in 2001, none of the parents was made aware of the possible relationship of the air pollution concentration and absenteeism. Even though they were aware of the possible aim of the data collection in 2002 (Chapters seven, eight and nine), there seems no inconsistency with the data collection for 2001.

In the Poisson regressions presented in this chapter, the ratio of residual deviance to the degrees of freedom is substantially higher than one, indicating that there are unattributed sources of variation which are not allowed for in the fitted model. An effect on the interpretation of the model is to overestimate significance of individual fitted parameters.

For this study, one to two weeks were used as control period (one-week exposure window for the Poisson analysis, two weeks for the case-crossover). Given the literature [Ransom and Pope III, 1992], this may underestimate the size of the effect for particulate matter. However, given the number of missing values for the air pollution data, it was considered that a longer window would give too many missing values to be of any worth.

5.5 Conclusion

This study has shown consistent associations between respiratory related daily absenteeism and outdoor air pollutants such as NO comb in District 12 of Tehran. The strongest association found in this study was equivalent to an increase in daily absenteeism of 0.8 for the Poisson model, and an odds ratio of 10 for the probability of daily absenteeism for case-crossover analysis, daily school absenteeism due to an increase from mean to maximum in seven-day moving average of NO comb.

There were many missing values in the air pollution data and there was a low level of absenteeism. The positive associations of the level of some air pollutants such as NO with various delayed effects with daily absenteeism are consistent with the literature. The power of the study was not as strong as would have been possible with data that are more reliable and fewer missing observations.

Chapter 6: Air pollution and hospital admissions

Daily air pollution has been found to be associated with increased hospital admissions for respiratory diseases in several countries [Masjedi et al., 2003; Barnett et al., 2005]. This chapter addresses the possible association between hospital admissions of children of primary school age and air pollution in Tehran during 2000-2003.

6.1 Methods

Diagnosis on discharge data, describing emergency room visits, were recorded using the International Classification of Disease version 10 (ICD_{10}) [World Health Organisation, 2003]. These data were collected from two hospitals located in or near District 12 of Tehran. The hospital data were available for all age groups but only data for children aged 6-11 were used in this analysis. Only hospital admissions related to specific ICD_{10} codes were selected: J00-J70 (acute upper respiratory infections, influenza and pneumonia, other acute lower respiratory infections, other disease of upper respiratory tract, chronic lower respiratory diseases and lung disease due to external agents). Also, code J96.9 (respiratory failure and unspecified), and H65-H66.9 (disease of external ear, otitis media and unspecified).

For air pollution: the 24 hourly air pollution adjusted for morning shift was used for either the same day or a seven-day moving average.

6.1.1 Statistical analysis

Two methods were used to assess the association between air pollution levels and admissions. In a manner analogous to that of Chapter five, Poisson regression was used to assess the association between daily hospital admissions and air pollution for the whole study period. The daily number of respiratory related admissions was the chosen response variable. In epidemiological studies, one often encounters situations where the outcome variable is numeric, and in the form of a count. For example, here a hospital admission is a count. The aim of the regression analysis is to model the response variable Y using various explanatory variables such as O_3 level. The basic (so called 'canonical') model formulation in Poisson regression is that the mean of the Poisson random variable is a function of predictor information, such as E(Y) = exp $(\beta_0 + \beta_1 X_1 + \beta_2 X_2)$. Because the logarithm of this function produces a linear combination of predictors, this model is said to have a logarithmic link function.

In addition to analysis of the whole data set, a case-crossover analysis was undertaken for a subset of the data. Reflection on the data led to a case-crossover design which focuses on the days (case-dates) when the related respiratory illness hospital admissions in children were more than two per day.

To gain some insight into case and control definition for a case-crossover analysis, two-week moving averages of hospital admissions were calculated. As can be seen in Figure 6.1 these demonstrate strong seasonality. This supported a choice of control dates relatively close, but not too close, to case-dates.

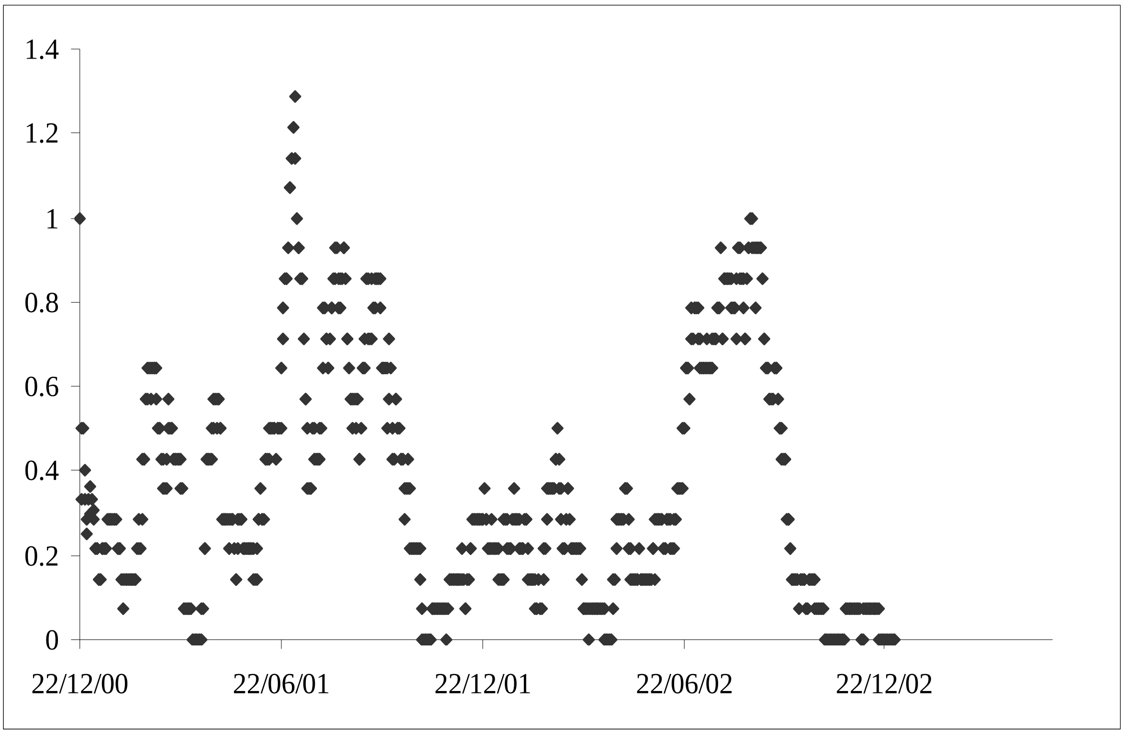

Figure 6.1 Seven-day moving average of daily hospital admissions

Data for the dates of high rates of hospital admissions were compared with data two weeks before and two weeks after these dates [Levy et al., 2001]. The control periods were taken as the same weekdays two weeks before and after the case-date. A matched conditional logistic regression analysis was carried out to investigate the relationship between an outcome and a set of prognostic factors in matched case-control studies.

6.2 Results

The air pollution data for all pollution variables along with the concentration of ozone used in case-crossover analysis is presented in Table 6.1. All pollution variables except SO_2 (too many missing values) were considered as candidate predictor in regression models. There were 52 case days and thus, potentially 156 days for cases/controls. Eliminating controls which were the same as cases, and allowing for missing values, 110 observations remained for case-crossover analysis. As only one pollutant emerged as significant predictor in the case-crossover analysis, summery data on that pollutant (O_3 at Bazaar station) is also included in Table 6.1.

The data cover 740 days in two hospitals, presented in Figure 6.2. The hospital admissions data consisted of 6,472 observations, but only 256 of these were for children (124 females and 132 males) in the age range of 6-12 years due to respiratory disease or otitis media. One or more of these 256 children were admitted on each of 196 days in two hospitals over two years. Graphs of time-series of admissions, air pollution levels and daily temperature are presented in Figure 6.2 - Figure 6.9.

Table 6.1 Summary statistics for daily air pollution (morning shift)

Variables	N	N Miss	Minimum	Median	Mean	Maximum	Std Dev
Fatemi							
SO_2	375	365	184.4	281	280	316	18.1
PM_{10}	698	42	2.5	92	94	249	37.0
NO	670	70	6.1	92	108	414	59.1
NO_2	672	68	11.6	129	143	646	69.0
NO_X	671	69	9.9	130	148	590	76.1
O_3	654	86	0.6	13	17	73	12.8
CO	694	46	1932.3	12492	13152	79250	5289.8
Bazaar							
SO_2	475	265	0.1	35	36	76	15.8
PM_{10}	405	335	9.5	75	149	1593	270
NO	705	35	5.3	74	80	252	36.4
NO_2	692	48	10.7	55	63	214	29.7
NO_X	705	35	4.7	85	89	319	34.9
O_3	633	107	0.5	27	27	172	18.5
CO	716	24	1656.3	9008	9762	32708	1656.3
O_3 for Case-crossover	110	20	4	18	21	62	12.3

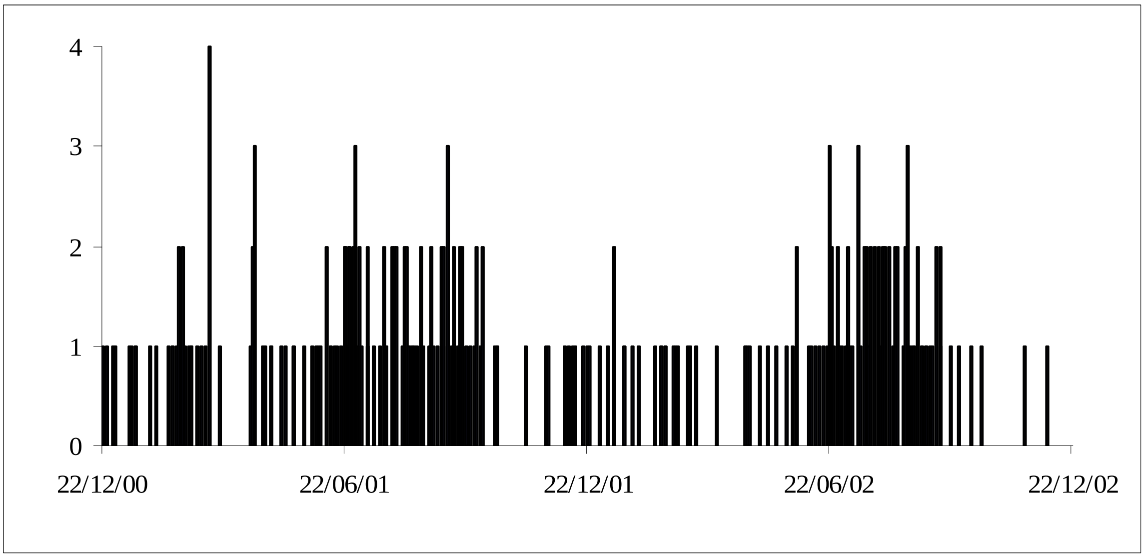

Figure 6.2 Daily hospital admissions for respiratory related illnesses in children over two years

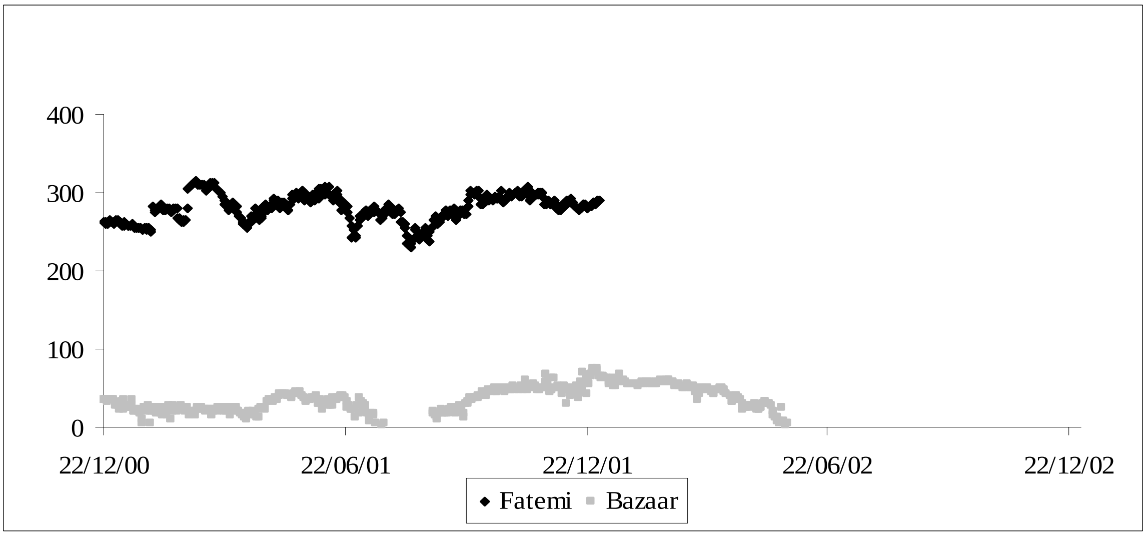

Figure 6.3 Daily SO_2 levels over two years, units in μg/m^{3}for morning shift

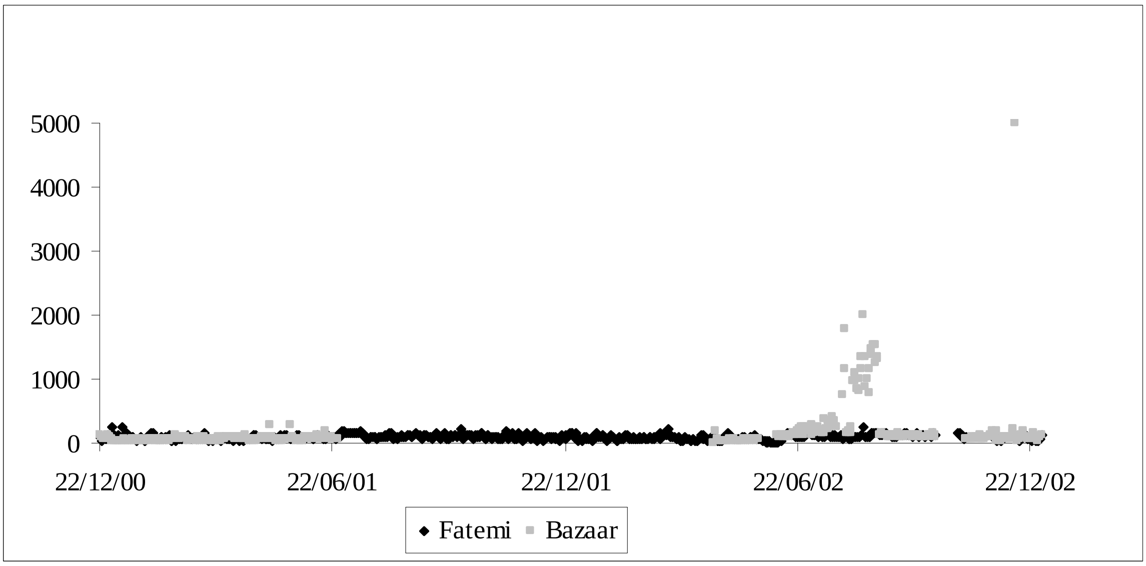

Figure 6.4 Daily PM_{10} levels over two years, units in μg/m^3 for morning shift

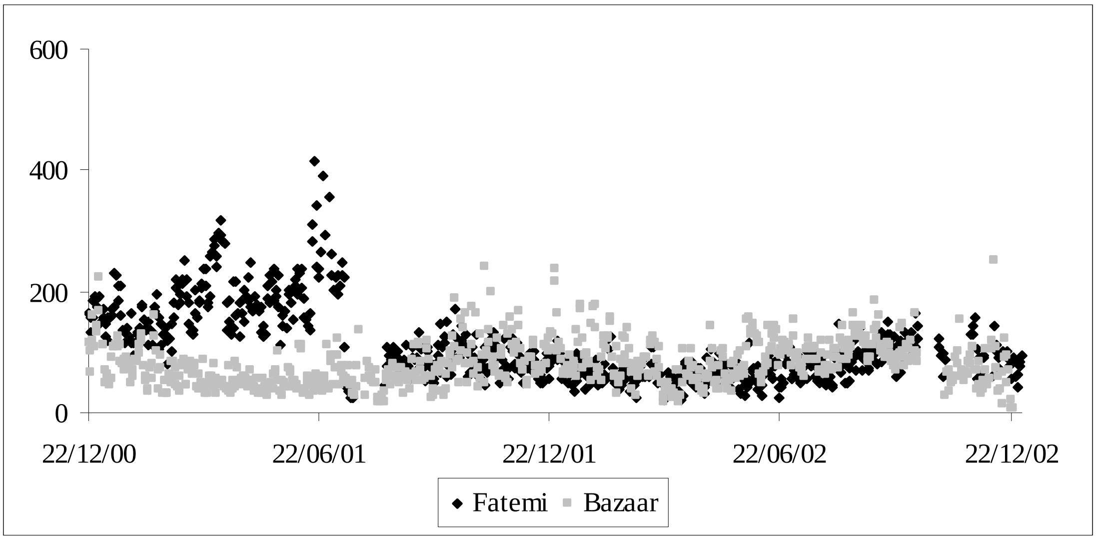

Figure 6.5 Daily NO levels over two years, units in μg/m^3 for morning shift

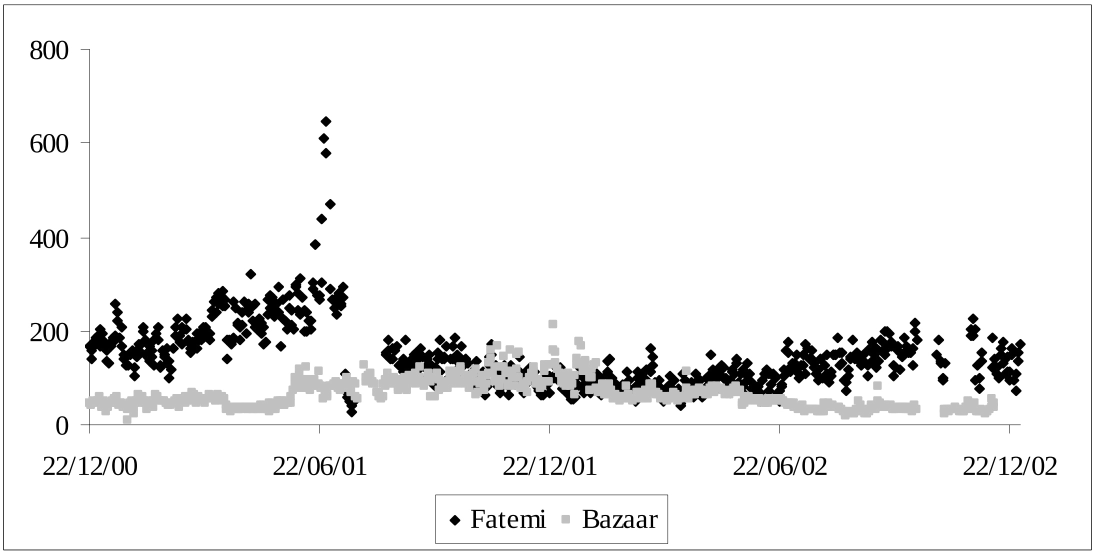

Figure 6.6 Daily NO_2 levels over two years, units in μg/m^3 for morning shift

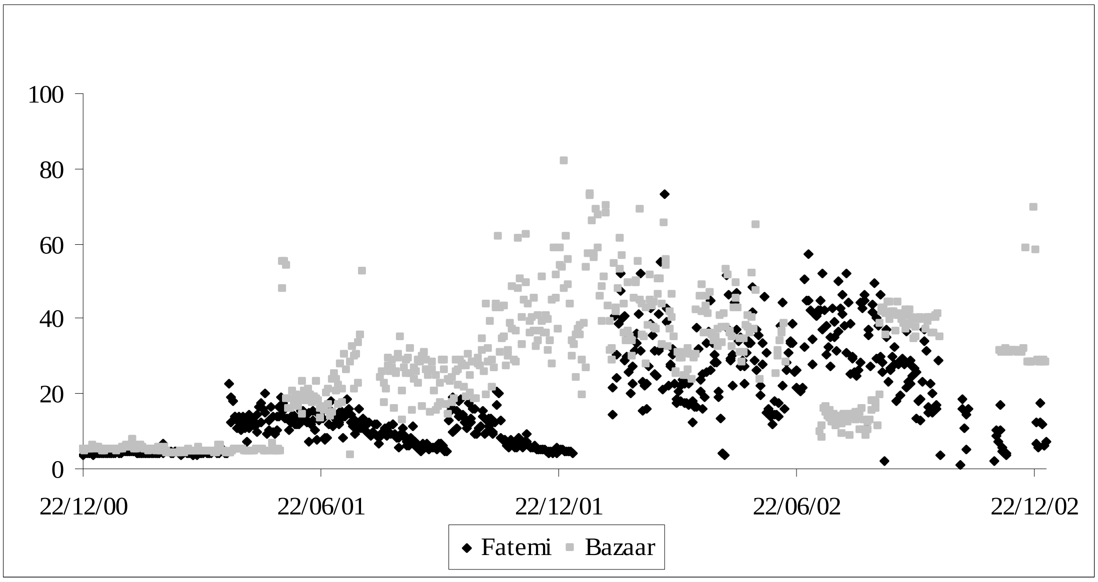

Figure 6.7 Daily O_3 levels over two years, units in μg/m^3 for morning shift

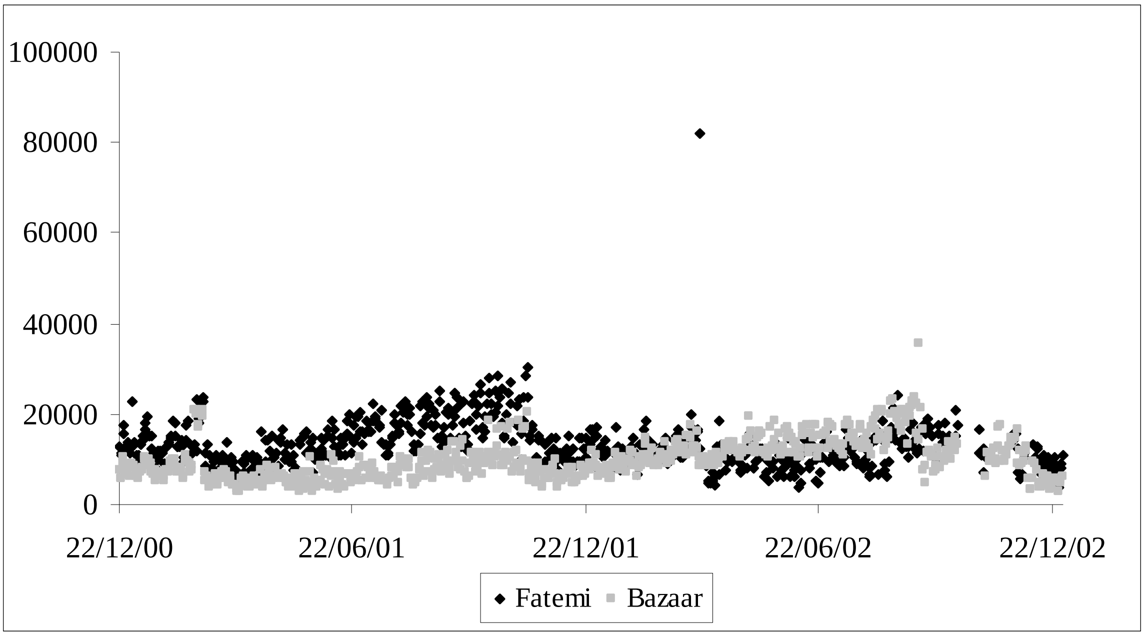

Figure 6.8 Daily CO levels over two years, units in μg/m^3 for morning shift

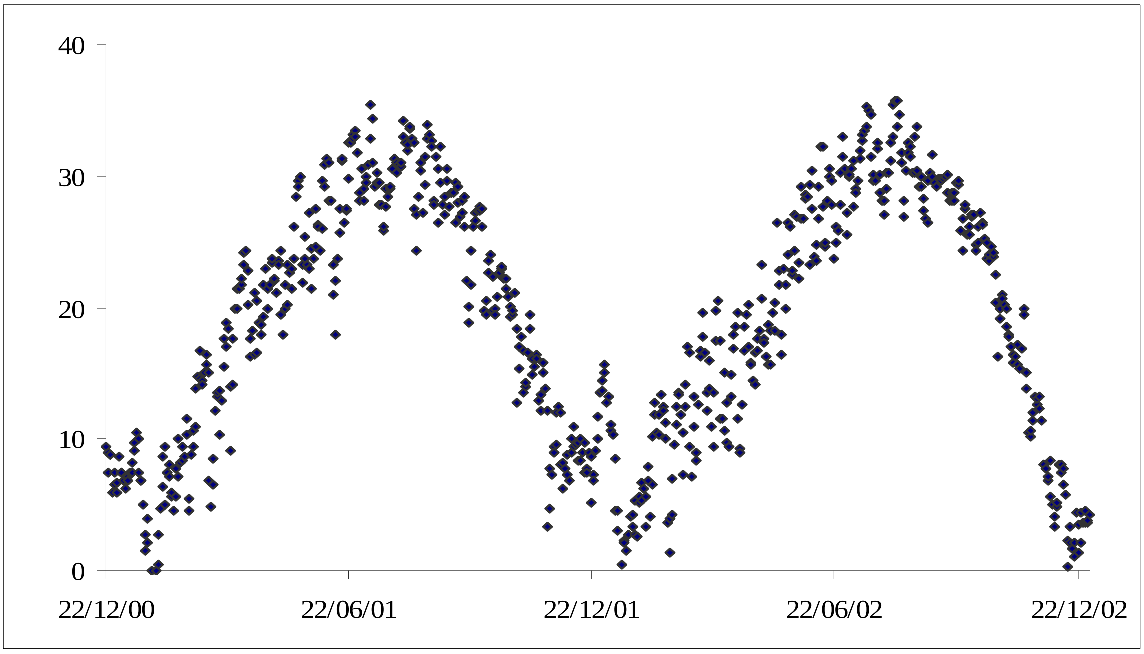

Figure 6.9 Daily temperature over two years, units in °C

6.2.1 Poisson regression

Pollutant concentrations at both stations were analysed. The results of Poisson regression after backward stepwise selection of the regression models are presented in Table 6.2. Daily temperature, squared temperature and O_3 (morning) were the only statistically significant predictors.

Table 6.2 Poisson regression for the effect of daily air pollutant concentrations on daily hospital admissions

	Parameter Estimate	Standard Error	Wald 95% Confidence Limits Lower	Upper	Chi-Square	Pr > Chi-Sq
Intercept	-1.021	0.2894	-1.5885	-0.454	12.45	0.0004
Daily Temperature(T)	-0.048	0.0315	-0.1100	0.014	2.33	0.1266
T^2*	0.003	0.0008	0.0009	0.004	9.53	0.0020
O_3 morning (B)*	-0.014	0.0047	-0.0230	-0.005	8.68	0.0032
Observation used	633		DF	629		
Missing values	107		Log likelihood	-416.7		

*Statistically significant p = 0.05
B: Bazaar station

The results show O_3 at the same day at Bazaar was the only pollutant that significantly contributed to this model. As in other chapters, both temperature and squared temperature were used as predictors to capture non-linearity in the effects of seasonal variation. Using the difference between mean (27) and maximum (172) concentration of O_3 in this period to judge the size of the effect, such an increase in O_3 is predicted to lead to a decrease of 2 in daily hospital admissions.

6.2.2 Case-crossover

Based on the case window, any dates with more than two respiratory related hospital admissions for 6-11 years old children were defined as case dates. A matched conditional logistic regression was carried out to investigate the relationship between an outcome and a set of prognostic factors in matched case-control studies. The control dates were two weeks before and after the case-dates unless they were the same as another case-date, in which case they were removed from the list of control dates, as highlighted (in light grey) in Table 6.3. Conditional logistic regression using the PHREG procedure in SAS was performed. This used the discrete logistic model with a stratum for each match set. After entering all the risk factors such as daily air pollution and seven-day moving average of each pollutant, only O_3 at Bazaar showed to be a significant predictor of hospital admissions.

Table 6.3 Frequency of case and control for daily hospital admissions

2 weeks before	Date	2 weeks after	absenteeism
3/02/01	17/02/01	3/03/01	2
6/02/01	20/02/01	6/03/01	2
26/02/01	12/03/01	26/03/01	4
31/03/01	14/04/01	28/04/01	2
2/04/01	16/04/01	30/04/01	3
25/05/01	8/06/01	22/06/01	2
8/06/01	22/06/01	6/07/01	2
9/06/01	23/06/01	7/07/01	2
11/06/01	25/06/01	9/07/01	2
12/06/01	26/06/01	10/07/01	2
15/06/01	29/06/01	13/07/01	2
16/06/01	30/06/01	14/07/01	3
19/06/01	3/07/01	17/07/01	2
25/06/01	9/07/01	23/07/01	2
7/07/01	21/07/01	4/08/01	2
14/07/01	28/07/01	11/08/01	2
16/07/01	30/07/01	13/08/01	2
17/07/01	31/07/01	14/08/01	2
23/07/01	6/08/01	20/08/01	2
24/07/01	7/08/01	21/08/01	2
4/08/01	18/08/01	1/09/01	2
13/08/01	27/08/01	10/09/01	2
20/08/01	3/09/01	17/09/01	2
21/08/01	4/09/01	18/09/01	2
25/08/01	8/09/01	22/09/01	3
30/08/01	13/09/01	27/09/01	2
3/09/01	17/09/01	1/10/01	2
4/09/01	18/09/01	2/10/01	2
15/09/01	29/09/01	13/10/01	2
20/09/01	4/10/01	18/10/01	2
28/12/01	11/01/02	25/01/02	2
14/05/02	28/05/02	11/06/02	2
8/06/02	22/06/02	6/07/02	3
10/06/02	24/06/02	8/07/02	2
15/06/02	29/06/02	13/07/02	2
22/06/02	6/07/02	20/07/02	2
29/06/02	13/07/02	27/07/02	3
5/07/02	19/07/02	2/08/02	2
6/07/02	20/07/02	3/08/02	2
9/07/02	23/07/02	6/08/02	2
12/07/02	26/07/02	9/08/02	2
15/07/02	29/07/02	12/08/02	2
19/07/02	2/08/02	16/08/02	2
20/07/02	3/08/02	17/08/02	2
23/07/02	6/08/02	20/08/02	2
27/07/02	10/08/02	24/08/02	2
29/07/02	12/08/02	26/08/02	2
5/08/02	19/08/02	2/09/02	2
6/08/02	20/08/02	3/09/02	3
13/08/02	27/08/02	10/09/02	2
27/08/02	10/09/02	24/09/02	2
30/08/02	13/09/02	27/09/02	2

Light grey cells = control day removed as identical to dark grey case-days

The result of case-crossover analysis is presented in Table 6.4. As Table 6.4 shows Hospital admissions, are significantly associated with ozone in the morning. Using the difference between mean (21) and maximum (62) concentration of O_3 in this period to judge the size of the effect, such an increase in O_3 is predicted to lead to a decrease in the probability of daily hospital admissions (OR = 0.1).

Table 6.4 Conditional logistic regression of daily hospital admissions

Variable	Parameter Estimate	Standard Error	Chi-Square	Pr > Chi-Square	Hazard Ratio
Daily Temperature (T)	-0.51	0.33	2.37	0.12	0.603
T^{2*}	0.01	0.01	3.96	0.05	1.013
O_3 for morning(B)*	-0.06	0.03	4.25	0.04	0.946

* Statistically significant p = 0.05

6.3 Discussion

Poisson regression and conditional logistic regression showed significant association between O_3 and hospital admissions for respiratory illness in 6-11 years old children. With both methods, daily concentration levels of this air pollutant were negatively associated with daily hospital admissions. Daily hospital admissions are high in summer, as presented in Figure 6.1. In another study, summertime haze air pollution was associated ‘with roughly half’ of all respiratory admissions (21% with O_3, 3% with H+) [Thurston et al., 1994] too. In this study, $O_{3,}$ levels were high in winter, although ozone level should be normally high in summer [Green Facts, 2008]. In winter, there were some days the weather was clear. This may explain why, using both statistical methods, an increment in daily ozone level was associated with decrement in daily hospital admission.

In this study, daily hospital admission was negatively associated with daily ozone level. The measure of pollutant exposure, being based on only one monitoring station, was not necessarily precise because ambient concentrations probably vary throughout the city due to the varying nature of emission sources, topography, air mixing, and dispersal and removal processes. Furthermore, outdoor levels, which comprise the main exposure indicator, do not necessarily reflect indoor levels. However, the residents of this area of Tehran do not belong to high socio-economic levels. Therefore, they do not have enough space in their house area for physical activity of their children. The children need to play outside where they are exposed to highly polluted air. In addition, it may not be concluded that all the respiratory related admissions are necessarily from District 12. The summer effects of daily hospital admissions could also be related to indoor air pollution such as environmental tobacco smoke. Particularly given the high temperature during the day, children may often remain indoors during summer.

6.4 Conclusion

Associations between daily hospital admissions for respiratory related illnesses among children of primary school age and some air pollutants were seen. However, all were inconsistent with the literature. Daily hospital admissions covered a period which daily school absenteeism could not. Admissions were higher in summer.

Statistical power was severely limited by the incomplete air pollution data and the limited number of admissions among children. However, this study showed daily hospital admission was significantly associated with daily air pollutant level such as O_3. Further research is required to examine the interaction between indoor and outdoor air pollutants, exposure response relationships and health impacts. For the present, this study indicates that current daily levels of air pollution are likely to be harmful to children and policies to future reduce air pollution should be continued.

Chapter 7: Prevalence of self-reported determinants and symptoms

There are differences between countries and regions in exposure to hazards that are known to provoke higher prevalence of respiratory disorders [Burr et al., 2003]. Children are especially vulnerable to respiratory hazards. Changes in home building and furnishing, such as the size of the building, the existence of sealed windows and unvented combustion appliances, decreased ventilation rates in houses and increased indoor humidity, lead to increased concentrations of indoor environment pollutants and exposure to them for children [Shendell et al., 2004; Blakely et al., 2005; Bobbitt et al., 2005; Pike-Paris, 2005]. Common indoor pollutants are environmental tobacco smoke, dust and biological allergens. Allergens in the homes are established risk factors for asthma. Asthma prevalence is generally higher in families with pets than those without. Small children tend to have a higher prevalence of respiratory disorders the more time they spend with pets [Mungan et al., 2003; Bener et al., 2004].

Currently there is very limited information about precise prevalence of determinants of asthma in Iran, especially for children [Golshan et al., 2002a]. As mentioned in the literature review, studies addressing this have been undertaken in different cities. The questionnaire which was most commonly used is based on the International Study of Asthma and Allergies in childhood (ISAAC) questionnaire, which was also used in this study for a survey of a population of the students at two elementary schools in Tehran.

The focus of this chapter is to provide an overview of risk factors for respiratory symptoms in this population. The information about respiratory symptoms and home environment of these students was provided by both parents and students. This chapter addresses the following general questions:

- Are there any risk factors in the home?
- Do the students show any symptoms of respiratory ill health?
- What do parents say about the home environment and the existence of respiratory symptoms of ill health?

7.1 Methods

To examine the environmental effects on schoolchildren, a cohort study was carried out on students from two single sex schools in District 12 of Tehran. To define the subjects according to their exposure levels, a questionnaire was used.

7.1.1 Statistical analysis

Chi-squared tests were used to assess association between categorical variables in this study. In particular, gender differences were investigated in this way.

7.1.2 Population and data collection

Two single sex primary schools (boys and girls), which work in two shifts (8:00-12:30 and 13:00 -17:30) were selected. After getting permission from the Ministry of Education and the principals of the schools, the questionnaires, with a consent sheet, were distributed to all 893 students in the two schools on 01/11/02. The students were asked to fill out the questionnaires with the help of their parents. Completed questionnaires were checked against the names of students after ten days. Students who did not return their questionnaires were reminded to do so by the researcher and the class teacher.

7.1.3 Questionnaire construction

The ISAAC questionnaire developed a standard protocol for the investigations of asthma and its determinants in children. This protocol and its questions have been widely used, and are used here. The ISAAC project used simple core written questionnaires for two age groups, children within the age groups 6-7 and 11-13 years. In particular, of considerable importance to this study from phase I, ISAAC module 1.1 (core questions on wheezing), phase II, supplementary modules (module 2.2: Indoor environmental risk factors and module 2.3: other respiratory symptoms) were selected.

A childhood asthma questionnaire designed by French [1996] was issued by the American Thoracic Society in three forms: A B C [American Thoracic Society, 1999].

The focus of this questionnaire is to measure the quality of life of asthmatic children. The standard asthma questionnaire form B is designed for children in the age group 7 to 11, whereas, the ISAAC questionnaire focus was on those aged 7 and younger. Therefore, some questions about quality of life were selected from form B and added to the questionnaire used here.

This collated questionnaire was translated and interpreted into Farsi. Then it was translated back into English again by an independent translator, and the resulting differences were analysed. Finally, it was printed as a booklet 20 cm × 15 cm, with some animation under each page to entertain the students. The font of the printed questionnaire was selected as the font that is used in their elementary school books, published by the Ministry of Education. The questionnaire (both English and Farsi versions) is presented in Appendix A3.3.

7.2 Results

Here a general overview is accompanied by the presentation of details of important components of the response data and analysis.

7.2.1 Response rate

As presented in Table 7.1 and Table 7.2, 782 (87%) of the 893 questionnaires distributed to the students in two schools were returned.

Table 7.1 Population characteristics after cleaning the data

Population	Female		Male		Total
	N	%	N	%	N
No response	24	6.5	92	17.5	116
Response	343	93.5	434	82.5	777
Total number of questionnaires distributed	367	100	526	100	893
Removed	1	0.3	4	0.8	5

Table 7.2 Response rate

Population	N	%
Total number of questionnaires distributed	893	
Number of questionnaires returned	782	87.5
Number of girls	344	44.2
Number of boys	438	56.0

The 782 returned questionnaires were split fairly evenly between boys, girls, morning and afternoon teaching shifts (see Table 7.3). Initially children aged 6 to 11 were to be included in the population. However, as Table 7.4 shows, five returned questionnaires were not considered because they were out of the age range, thus reducing the effective population size to 777 of which 434 (56%) were boys and 343 (44%) were girls. The data regarding age are summarized in Table 7.4, which shows that the age distributions of males and females are more or less the same. The final response rate was 93% for girls and 83% for boys. The response rate was significantly higher ($p \leq 0.0001$) in girls than boys. However, as both had response rates exceeding 80%, this is not a potential major source of bias in the survey results.

Table 7.3 Students according to sex and the teaching shift of their schools

School shift	Female	Male	Total	%
AM	170	230	400	51.2
PM	174	207	381	48.7
Total	344	438	782	
%	44.0	56.0		

Table 7.4 Students according to age

	Female		Male		Total	
Age	N	%	N	%	N	%
6	46	5.9	79	10.2	125	16.1
7	59	7.6	81	10.4	140	18.0
8	68	8.8	74	9.5	142	18.3
9	76	9.8	100	12.9	176	22.7
10	75	9.7	75	9.7	150	19.3
11	19	2.5	25	3.2	44	5.7
12	1	0.3	4	0.9	5	0.6
Total	344		438		782	

7.2.2 Respiratory health of respondents

Thirty seven percent of females and 33% of males reported coughing on weekdays, decreasing to 21% and 18%, respectively, on weekends (see Table 7.5). However, those are not significant gender differences.

Many asthmatics have their asthma symptoms triggered by perfumes and colognes. Often other strong smells such as paints, stains, and varnishes are triggers as well. As Table 7.5 shows, 27% and 32% of female and male students, respectively, reported that they experienced chemical smells like detergents or perfumes.

Table 7.5 Self-reporting of some allergy symptoms

		Female		Male		Total		p-value
		N	%	N	%	N	%	
Coughing on weekends	Yes	54	20.6	61	18.2	115	19.3	0.46
	No	208	79.4	274	81.8	482	80.7	
	Missing	81		99		180		
Coughing on workdays	Yes	124	37.1	139	33.3	263	35.0	0.941
	No	210	62.9	279	66.8	489	65.0	
	Missing	9		16		25		
Coughing all days	Yes	33	14.9	34	12.6	67	13.6	0.455
	No	184	85.1	237	87.5	421	86.4	
	Missing	126		163		289		
Eyes irritation	Yes	24	7.4	28	6.7	52	7.0	0.738
	No	302	92.6	388	93.3	690	93.0	
	Missing	17		18		35		
Class mates eyes irritation	Yes	52	21.7	64	21.4	116	21.5	0.941
	No	188	78.3	235	78.6	423	78.5	
	Missing	103		135		238		
Contact with other smells or fumes	Yes	200	27.0	235	31.7	435	58.7	0.14
	No	124	16.7	182	24.6	306	41.3	
	Missing	19		17		36		

Table 7.6 shows that 64% of the students (both female and male) who ‘cough on workdays’ also ‘cough on weekends’ (with one missing male who had ‘cough on weekends’ but did not respond to the cough on weekdays question). From the opposite perspective, 80% of females and 75% of males who ‘cough on weekends’ also ‘cough on workdays. The proportion of students who did not ‘cough on weekends’ among those who have no ‘cough on workdays’ is 94% (both female or male) whereas the proportion to who have no ‘cough on weekends’ with no ‘cough on workdays’ was 90% (88% for females and 91% for males). There was strong association ($p < 0.0001$) between coughing at weekends and on the workdays. The odds ratio for any student

reporting ‘coughing on weekends’ for having ‘cough on workdays’ is 30 (CI:13.6, 65.5) for females and also 30 (CI:14.4, 60.3) for males.

Table 7.6 Coughing on weekends and on workdays

Coughing on workdays	Coughing on weekends						
	Female			Male			
	Yes	No	Total	Yes	No	Total	p-value
Yes	43	24	67	45	25	70	<.0001
%	16.5	9.2	25.7	13.6	7.6	21.2	
Row %	64.2	35.8		64.3	35.7		
Col %	79.6	11.6		75.0	9.2		
No	11	183	194	15	246	261	
%	4.2	70.1	74.3	4.5	74.3	78.9	
Row %	5.7	94.3		5.7	94.3		
Col %	20.4	88.4		25.0	90.8		
Total	54	207	261	60	271	331	
%	20.7	79.3	100	18.1	81.9	100	
Missing			82			103	

Table 7.7 shows the prevalence of asthma symptoms and self-reported asthma diagnosis ‘ever had asthma’ (3%) which was 1% for females and 4% for males. The estimated prevalence of asthma is significantly higher (p = 0.03) in male students than females. As measured by other questions indicative of asthma, prevalence ranged from 6% to 22%, with no significant differences between boys and girls.

It should be noted that two questions on asthma indicators in the ISAAC questionnaire were wrongly translated in the Farsi version. The first one was question number 31, about ‘coughing, wheezing and shortness of breath at night in past 4 weeks’ and the next was question number 32, about ‘wheezing, coughing or shortness of breath after using certain food’. The word ‘wheeze’ was inadvertently translated to ‘sneeze’ in both questions.

Table 7.7 shows that the prevalence of ‘current wheeze’ or ‘having wheeze for last 12 months’ is 22%, substantially more than that of ‘ever wheeze’ (14%). If responses to these questions are treated literally, this is impossible and suggests some misreporting, although non-responses (missing values) are substantially more common (386 vs. 130 out of 777) students for the ‘current wheeze’ question. Further exploration of the data for students who answered both questions (Table 7.8) revealed that 23 (13+10) students responded yes to ‘current wheeze’ and no to ‘ever wheeze’. This represents a misreporting rate of 8% among those (289) that responded to both questions and answered no to ‘ever wheeze’ question. It may be that this anomaly was due to students misunderstanding the questions.

Table 7.7 Self-reported asthma symptoms and diagnosis

		Female		Male		Total		p-value
		N	%	N	%	N	%	
Ever had asthma*	Yes	4	1.2	16	3.8	20	2.7	0.033
	No	318	98.8	404	96.2	722	97.3	
	Missing	21		14		35		
Ever had wheeze	Yes	33	11.3	55	15.5	88	13.6	0.122
	No	259	88.7	300	84.5	559	86.4	
	Missing	51		79		130		
12-month prevalence of:								
Any wheeze	Yes	36	21.1	51	23.2	87	22.3	0.616
	No	135	95.7	169	76.8	304	77.8	
	Missing	172		214		386		
Exercise wheeze	Yes	22	6.9	20	5.0	42	5.8	
	No	299	93.1	384	95.0	683	94.2	
	Missing	22		30		52		
Wheeze limiting speech	Yes	7	4.8	13	6.2	20	5.6	0.574
	No	139	95.2	197	93.8	336	94.4	
	Missing	197		224		421		
Wheeze disturbs sleep:								0.071
Never woken up with wheezing		113	36.5	33.6	48.7	82.1	85.2	
Less than one night in a week		6	1.9	4.8	7.4	12.5	9.4	
Once a week		7	2.0	10	5.4	17	5.5	
	Missing	217		250		467		
Number of wheeze attack in last 12 months:								0.098
None	41.0	154	41.0	198	90.8	352	93.6	
1–3	1.6	6	1.6	10	4.6	16	4.3	
4–12	0	0	0	6	2.8	6	1.6	
More than 12	0	0	0	2	0.9	2	0.5	
				216		401		
Night cough	13.8	45	13.8	65	15.6	110	14.8	0.497
	86.2	281	81.9	352	84.4	633	85.2	
		17		17		34		
Asthma medication	2.5	5	1.5	5	1.9	10	2.2	0.698
	97.5	199	58.0	255	98.1	454	97.8	
		139		174		313		
Sneeze/cough/ shortness of breath in the night for last 4 weeks (Q31)	26.9	88	25.7	124	29.9	212	28.6	0.375
	73.1	239	69.7	291	70.1	530	71.4	
		16		19		35		
Sneeze/cough/ shortness of breath after eating certain food (Q32)	7.7	25	7.3	42	10.0	67	9.0	0.274
	92.3	301	87.8	379	90.0	680	91.0	
	Missing	17		13		30		

* Statistically significant p=0.05

Table 7.8 Prevalence of any wheeze and current wheeze

Ever had wheeze	12-month prevalence of any wheeze						
	Female			Male			
	Yes	No	Total	Yes	No	Total	p-value
Yes	21	10	31	37	15	52	<.0001
%	12.8	6.1	18.9	17.8	7.2	25	
Row %	67.7	32.3		71.2	28.9		
Col %	61.8	7.7		78.7	9.3		
No	13	120	133	10	146	156	
%	7.9	73.2	81.1	4.8	70.2	75	
Row %	9.8	90.2		6.4	93.6		
Col %	38.2	92.3		21.3	90.7		
Total	34	130	164	47	161	208	
%	20.73	79.27	100	22.6	77.4	100	
Missing			179			226	

Table 7.9 shows the rates of reported parameters related to quality of life of students with asthma. There was low prevalence of use of relief inhaler 3% (2% females, 4% of males) and missing school because of asthma which was 1.5% for females and 0.3% for males, but 2% for females and 5% for males (ever). The estimated prevalence of ‘missing school (a lot) because of asthma’ is significantly higher (p = 0.004) in males students than females. There was high prevalence of coughing (a lot) because of asthma. This was almost equal (3%) for females and males, which was consistent with the percentage (3%) of ‘ever had asthma’ (see Table 7.7) although ‘ever had asthma’ was different for female (1%) and male (4%). However, the 30% positive response rate to ‘sometimes coughing because of asthma’ (see Table 7.9) is not consistent with the responded 3% of students who ‘ever had asthma’ (see Table 7.7).

Table 7.9 Self-reported quality of life questions

	Female		Male		Total		p-value
	N	%	N	%	N	%	
Coughing recently because of asthma							0.957
Not at all	92	28.5	125	30.3	217	29.5	
Hardly ever	125	38.7	154	37.3	279	37.9	
Sometimes	97	30.0	122	29.5	219	29.8	
A lot	9	2.8	12	2.9	21	2.9	
Missing					41		
Missed school because of asthma*							0.004
Not at all	267	98.1	338	94.9	605	96.3	
Hardly ever	1	0.4	9	2.5	10	1.6	
Sometimes	0	0	8	2.2	8	1.3	
A lot	4	1.5	1	0.3	5	0.8	
Missing					149		
Relief inhaler because of asthma:							0.096
Not at all	276	98.2	346	95.8	622	96.9	
Hardly ever	0	0	8	2.2	8	1.2	
Sometimes	3	1.1	4	1.1	7	1.1	
A lot	2	0.7	3	0.8	5	0.8	
Missing					135		

*Statistically significant p = 0.05

Table 7.10 is concerned with the responses of the parents section of the questionnaire. This table shows the prevalence of asthma symptoms, self-reported asthma diagnosis, and the quality of life of a child with asthma. The estimated prevalence of asthma symptoms 'tightness in the chest' was for 6% or 'phlegm in particular season' was for 18%. These estimated prevalences are significantly higher (p = 0.029 and 0.004 respectively) in males (8%, 23%) than females (4%, 12%) respectively. According to the parents, there was no significant difference between the groups in the 'rated children's asthma', 'ever had shortness of breath' or 'coughing' categories. The reported responses to the question 'how asthma controlled' and 'missed schools because of asthma' show no significant gender differences.

Table 7.10 Parents reports on children's respiratory symptoms and gender difference

		Female		Male		Total		p-value
		N	%	N	%	N	%	
Parents reported:								
Rated children's asthma								0.08
Mild		23	69.7	39	61.9	62	64.6	
Medium		6	18.2	22	34.9	28	29.2	
Severe		4	12.1	2	3.2	6	6.3	
	Missing	310		371		681		
Cough with phlegm with cold	Yes	136	43.6	181	45.9	317	44.9	0.533
	No	176	56.4	213	54.1	389	55.1	
	Missing	31		65		96		
Cough with phlegm without cold	Yes	67	22.3	94	24.7	161	23.6	0.476
	No	233	77.7	287	75.3	520	76.4	
	Missing	43		53		96		
Ever had shortness of breath	Yes	20	5.8	32	8.1	52	7.3	0.391
	No	293	85.4	364	91.9	657	92.7	
	Missing	36		40		76		
Phlegm in particular season*	Yes	19	11.7	53	23.2	72	18.5	0.004
	No	143	88.3	175	76.8	318	81.5	
	Missing	181		206		387		
Ever had tightness in the chest*	Yes	13	4.1	32	8.1	45	6.3	0.029
	No	305	95.9	363	91.9	668	93.7	
	Missing	25		39		64		
Asthma controlled								0.638
Very well		19	52.8	29	46.8	48	49.0	
Quite well		10	27.8	23	37.1	33	33.7	
Not at all		7	19.4	10	16.1	17	17.3	
	Missing	307		372		679		
Missed school								0.689
> 10 days		2	0.7	1	0.3	3	0.5	
3-5 days		0	0.0	1	0.3	1	0.2	
1-2 days		5	1.8	6	1.6	11	1.7	
None		278	97.5	371	97.9	649	97.7	
	Missing	58		55		113		

*Statistically significant p = 0.05

Table 7.11 shows the prevalence of asthma symptoms according to the parents' reports. The prevalence of 'wheeze with flu' was 27% (27% for both females and males).

However, the prevalence of 'wheeze without flu' was 5% (6% females, 5% of males). Wheeze related to exercise was 7% (6% for females and 7% for males) and 'wheeze not related to exercise' was 5% (5% females, 6% of males). There were no significant differences between the responses of female and male children to questions regarding 'wheeze disturbing sleep' and 'wheeze with or without flu'. Wheezing during or after exercise was not related to gender. The highest prevalence of wheeze worsened by cold or flu (18% females, 21% of males) was 20% followed by cigarette smoke (10% females, 12% of males) 11% then weather (6% females, 9% of males) 8%. The lowest prevalence of 'wheeze worsened by' was dust, running, cooler, and swimming pool (0.1%) (see Table 7.11).

Table 7.11 Self-reported wheeze in students

		Female		Male		Total		p-value
		N	%	N	%	N	%	
Parents reported:								
Wheeze disturbs sleep								0.565
Never woken with wheezing		275	97.5	365	97.6	640	97.6	
Less than one night in a week		4	1.4	3	0.8	7	1.1	
Once a week		0	0.0	3	0.8	3	0.5	
Several nights a week		1	0.4	1	0.3	2	0.3	
Almost every night		2	0.7	2	0.5	4	0.6	
	Missing	61		60		121		
Wheeze with flu	Yes	84	26.7	108	27.1	192	27.0	0.966
	No	228	72.4	291	72.9	519	73.0	
	Missing	31		35		113		
Wheeze during or after exercise	Yes	20	6.5	27	6.9	47	6.7	0.957
	No	287	93.5	367	93.1	654	93.3	
	Missing	36		40		76		
Wheeze without flu	Yes	18	5.8	19	4.8	37	5.2	0.561
	No	292	94.2	376	95.2	668	94.8	
	Missing	33		39		72		
Wheeze not related to exercise	Yes	14	4.6	22	5.6	36	5.2	0.522
	No	293	95.4	368	94.4	661	94.8	
	Missing	36		44		80		
Wheeze worsened by:								0.130
Colds or flu		61	17.8	92	21.2	153	19.7	
Cigarette smoke		34	9.9	51	11.8	85	10.9	
Weather		21	6.1	40	9.2	61	7.9	
Foods & drinks		12	3.5	25	5.8	37	4.8	
Fumes		14	4.1	22	5.1	36	4.6	
Soaps, sprays or detergent		14	4.1	10	2.3	24	3.1	
Pollen		7	2.0	17	3.9	24	3.1	
Emotion		11	3.2	12	2.8	23	3.0	
Wool clothing		5	1.5	12	2.8	17	2.2	
None		7	2.0	2	0.5	9	1.2	
Pet		0	0	4	0.9	4	0.5	
Running		1	0.3	0	0	1	0.1	
Dust		1	0.3	0	0	1	0.1	
Cooler		0	0	1	0.2	1	0.1	
Swimming pool		0	0	1	0.2	1	0.1	

7.2.3 Home environment of the questionnaire respondents

The second part of the questionnaire contained questions about the home environment as shown in Table 7.12 to Table 7.20.

7.2.3.1 Pets

According to Table 7.12, almost 14% of the students had pets and 89% of those pets were birds. Of those students who had pets, 18% of pets stayed in the student's bedroom. Further, 73% of students were exposed to cats outside their home at least once a week. Only 6% of the students had allergic reactions when they came into contact with animals. There is no significant relationship between the gender of students and reported pet ownership. As presented in Table 7.13 children reported have pet at home were less likely to have wheeze for last 12 months (OR, 1.0; 95% CI: 0.5, 1.9).

7.2.3.2 Bedroom

According to Table 7.14, only 0.8 percent of students had dusty beds and mite-proof beddings covered 85% of their beds. Forty one percent used feather pillows. Twenty two percent and 64% of the students used cotton quilts and mattresses, respectively. It should be mentioned that students might tick two or more kinds of bedding. In addition, the bedding of 75% of students' was washed in warm water two times a month. Sixty three percent of students did not have a bedroom for themselves and sleep in shared bedrooms twenty-nine percent of these rooms had sealed windows.

Table 7.12 Self-reported of pets exposure

		Female		Male		Total		p-value
		N	%	N	%	N	%	
Pet ownership	Yes	42	12.6	62	14.3	104	13.6	0.484
	No	292	87.4	371	85.7	663	86.4	
	Missing	9		1		10		
Pet kind:								0.684
Bird		36	90.0	38	88.4	74	89.2	
Cat		2	5.0	2	4.7	4	4.8	
Dog		1	2.5	0	0	1	1.2	
Fish		1	2.5	2	4.7	3	3.6	
Rabbit		0	0	1	2.3	1	1.2	
	Missing	303		395		696		
Number of pets:								0.666
1		8	22.9	14	28.0	22	25.9	
2		11	31.4	11	22.0	22	25.9	
3		5	14.3	9	18.0	14	16.5	
4		1	2.9	5	10.0	6	7.1	
5		3	8.6	3	6.0	6	7.1	
6		1	2.9	1	2.0	2	2.4	
7		2	5.7	0	0	2	2.4	
8		1	2.9	2	4.0	3	3.5	
9		0	0	1	2.0	1	1.2	
10		2	5.7	2	4.0	4	4.7	
11		0	0	1	2.0	1	1.2	
60**		0	0	1	2.0	1	1.2	
100*		1	2.9	0	0	1	1.2	
	Missing	30		38		69		
Pets in bedroom	Yes	8	20.0	10	16.4	18	17.8	0.643
	No	32	80.0	51	83.6	83	82.2	
	Missing	30		373		676		
Came into contact with animals:								0.786
Cat		69	71.9	85	73.3	154	72.6	
Farm animals		18	18.8	18	15.5	36	17.0	
Dog		6	6.3	9	7.8	15	7.1	
Mouse		2	2.1	1	0.9	3	1.4	
Pigeon		1	1.0	3	2.6	4	1.9	
	Missing	27		318		565		
Allergy to pets	Yes	18	6.1	20	5.7	38	5.9	0.827
	No	276	93.9	330	94.3	606	94.1	
	Missing	49		84		133		

*This case is a boy and his pets were pigeons which the person usually kept in some cages in the yard or on the roof.

**This case is a girl, who mentioned those birds were canaries which were kept in different rooms. Usually people grow them as a business.

Table 7.13 Wheeze prevalence for students who have pets

Pet ownership	Wheeze for last 12 months									
	Yes		NO		Total		p-value	95% CI		
	N	%	N	%	N	%		OR	lower	upper
Yes	13	15.1	47	15.5	60	15.4	0.008	1.0	0.5	1.9
No	73	84.9	256	84.5	329	84.6				
Total	86	22.1	303	389	78	100				
Missing					387					

Table 7.14 Self-reported of bedding detailes

		Female		Male		Total		p-value
		N=343	%	N=434	%	N	%	
Had dusty beds	Yes	2	0.6	4	0.9	6	0.8	0.596
	No	330	99.4	418	99.1	748	99.2	
	Missing	11		12		22		
Covered with mite proof	Yes	281	84.9	362	85.2	643	85.1	0.914
	No	50	15.1	63	14.8	113	14.9	
	Missing	12		9		21		
Type of pillow :*								<0.0001
Feather		122	35.6	194	44.7	316	40.7	
Cotton		120	35.0	50	11.5	170	21.9	
Synthetic fibre		67	19.5	93	21.4	160	20.6	
Foam		38	11.1	47	10.8	86	11.1	
Cotton fibres		19	5.5	24	5.5	43	5.5	
Woollen		7	2.0	32	7.4	39	5.0	
Do not know		4	1.2	11	2.5	15	1.9	
Cloth pieces		4	1.2	1	0.2	5	0.6	
No pillow use		0	0	7	1.6	7	0.9	
Blanket		0	0	1	0.2	1	0.1	
	Missing					1489		
Type of quilt:*								<0.0001
Blanket		243	60.8	270	4.6	513	52.2	
Cotton		110	27.5	104	1.8	214	21.8	
Woollen		26	6.5	148	2.5	174	17.7	
Feather		11	2.8	36	0.6	47	4.8	
Synthetic		9	2.3	24	0.4	33	3.4	
Cotton strands		1	0.3	1	0	2	0.2	
	Missing					2902		
Type of Mattress:*								<0.0001
Cotton		221	82.2	172	49.9	393	64.0	
Woollen		24	8.9	131	38.0	155	25.2	
Manufactured		7	2.6	16	4.6	23	3.7	
Synthetic		6	2.2	22	6.4	28	4.6	
Blanket		5	1.9	2	0.6	7	1.1	
Foam		4	1.5	0	0	4	0.7	
Cotton strands		1	0.4	2	0.6	3	0.5	
No mattress use		1	0.4	0	0	1	0.2	
	Missing					940		
Shared bedroom	Yes	212	63.5	267	61.9	479	62.6	0.666
	No	122	36.5	164	38.1	286	37.4	
	Missing	9		3		12		
Child's bedroom window type								0.570
Single glazing		148	45.5	214	49.5	362	47.8	
Sealed		95	29.2	125	28.9	221	29.2	
Secondary window		40	12.3	52	12.0	92	12.2	
Double glazing		23	7.1	22	5.1	45	5.9	
No windows		19	5.8	18	4.2	37	4.9	
	Missing					1577		

*Statistically significant p = 0.05

7.2.3.3 Passive smoking

Thirty percent of the students in this population were passive smokers; 88% of these indirect smokers had one smoker at home and 29% of their parents or other adults smoked ≥10 cigarettes at home daily (see Table 7.15). There is no association between passive smoking and gender in this study. As presented in Table 7.16 children reported have smoker at home were 38% more likely to have wheeze for last 12 months (OR, 1.3; 95% CI: 0.8, 2.1).

Table 7.15 Self-reported smoking rate

		Female		Male		Total		p-value
		N	%	N	%	N	%	
Smoke	Yes	84	26.5	133	32.9	217	30.1	0.062
	No	233	73.5	271	67.1	504	69.9	
	Missing	26		30		56		
Place to smoke:								0.556
Home		13	65.0	20	69.0	33	67.3	
Toilet		6	30.0	7	24.1	13	26.5	
Outside		1	5.0	0	0	1	2.0	
At the window		0	0	1	3.4	1	2.0	
Kitchen		0	0	1	3.4	1	2.0	
	Missing					385		
Number of smokers:								0.189
1		71	93.4	96	85.0	167	88.4	
2		4	5.3	15	13.3	19	10.1	
3		1	1.3	2	1.8	3	1.6	
	Missing				28			
Smoke per day								0.740
<10		48	70.6	85	71.4	133	71.1	
10-20		16	23.5	24	20.2	40	21.4	
>20		4	5.9	10	8.4	14	7.5	
	Missing					30		

Table 7.16 Wheeze prevalence for passive smokers

Smoke	Wheeze for last 12 months					
	Yes		NO		Total	
	N	%	N	%	N	%
Yes	30	38.0	96	32.8	126	33.9
No	49	62.0	197	67.2	246	66.1
Total	79	21.2	293	78.8	372	100
Missing					404	

7.2.3.4 Dampness and pests

In the homes, 19% reported moisture or dampness with only 4% who reported mould in their homes. Sixty nine percent of the students have seen cockroaches but only nine percent have seen mice in their homes in the last month. However, moisture and the existence of cockroaches show significant association with gender of students. Males reported more moisture and cockroaches in their homes than females (see Table 7.17).

Table 7.17 Self-reported dampness and pests

		Female		Male		Total		p-value
		N	%	N	%	N	%	
Mice seen in last month	Yes	29	8.7	37	8.7	66	8.7	0.983
	No	305	91.3	388	91.3	693	91.3	
	Missing	9		9		18		
Cockroaches seen in last month*	Yes	209	62.8	317	73.4	526	68.8	0.002
	No	124	37.2	115	26.6	239	31.2	
	Missing	10		2		12		
Mould	Yes	11	3.4	21	5.1	32	4.4	0.272
	No	310	96.6	392	94.9	702	95.6	
	Missing					43		
Moisture*	Yes	51	15.5	93	21.9	144	19.1	0.025
	No	279	84.5	332	78.1	611	80.9	
	Missing	13		9		22		

*Statistically significant p = 0.05

7.2.3.5 Air conditioning and carpets

As Table 7.18 shows, 88% of students use water coolers to cool their homes. Eighty one percent and 84% of students use loose carpet (rugs) as floor covering in the rest of the house and bedrooms, respectively. The estimated frequencies of any kind of floor covering in the bedroom and the rest of the house were significantly higher for female students 85% and 87% than for males 77% and 82% using loose carpet for floor cover and bed room floor cover, respectively.

Table 7.18 Self-reported gender difference in the rate of temperature control

	Female		Male		Total		p-value
	N	%	N	%	N	%	
Cooling system:							0.397
Water cooler	320	88.4	404	87.8	724	88.1	
Fan	30	8.3	44	9.6	74	9.0	
Air conditioning	7	1.9	3	0.7	10	1.2	
Gas cooler	5	1.4	8	1.7	13	1.6	
Package	0	0.0	1	0.2	1	0.1	
Missing					150		
Floor cover:*							0.017
Loose carpets	306	85.2	362	77.5	668	80.9	
Fitted carpets	46	12.8	94	20.1	140	16.9	
Bare floor	7	1.9	11	2.4	18	2.2	
Missing					72		
Bed room floor cover:*							0.046
Loose carpets	286	86.9	354	81.6	640	83.9	
Fitted carpets	36	10.9	74	17.1	110	14.4	
Bare floor	7	2.1	6	1.4	13	1.7	
Missing					79		

*Statistically significant p = 0.05

7.2.3.6 Cooking

Eighty three percent of kitchens were near the living room and 97% of the students' houses used natural gas for cooking, while 43% reported there were no chimneys for the stove in the kitchen (see Table 7.19).

Table 7.19 Self-reported cooking factors

		Female		Male		Total		p-value
		N	%	N	%	N	%	
Kitchen location near living room	Yes	277	83.7	351	83.2	628	83.4	0.840
	No	54	16.3	71	16.8	125	16.6	
	Missing	12		12		24		
Cooking fuel:								0.520
Gas		329	97.6	426	97.3	755	97.4	
Electricity		6	1.8	6	1.4	12	1.5	
Oil		2	0.6	6	1.4	8	1.0	
	Missing					13		
Chimney for stove	Yes	196	59.2	237	55.8	433	57.3	0.360
	No	135	40.8	188	44.2	323	42.7	
	Missing	12		9		21		

7.2.3.7 Heating system

As shown in Table 7.20 while 68% of students did not use a central heating system, 72% of them used one heater for warming their houses. Ninety percent of them use natural gas for heating and 6% of them had fireplaces in their homes. Table 7.20 shows that the estimated rate of reported central heating was significantly higher in males (36%) than females (26%).

Table 7.20 Self- reported for heating system.

		Female		Male		Total		p-value
		N	%	N	%	N	%	
Central heating*	Yes	74	26.1	137	36.3	211	32.0	0.01
	No	209	73.9	240	63.7	449	68.0	
	Missing	60		57		117		
Heater number								0.27
1		150	76.5	147	68.1	297	72.1	
2		42	21.4	60	27.8	102	24.8	
3		4	2.0	7	3.2	11	2.7	
4		0	0	1	0.5	1	0.2	
7		0	0	1	0.5	1	0.2	
	Missing					37		
Heating fuel:*								<.0001
Gas		321	95.3	377	86.1	698	90.1	
Electricity		4	1.2	10	2.3	14	1.8	
Wood		4	1.2	4	0.9	8	1.0	
Oil		2	0.6	37	8.4	39	5.0	
Coal		1	0.3	1	0.2	2	0.3	
Diesel		0	0	1	0.2	1	0.1	
	Missing					157		
Fire place	Yes	25	7.6	19	4.6	44	5.9	0.09
	No	304	92.4	394	95.4	698	94.1	
	Missing					35		

*Statistically significant p = 0.05

7.2.3.8 Concordance and discrepancy between parental and children's answers

As shown in Table 7.21 students and parents answers to number of 'missed school' because of asthma and 'ever had asthma' were highly associated. As the table shows, 21/600 (4%) of the students had missed school while 96% had not missed school at all.

Table 7.21 Self-reported questions by parents and students

	Parents										
	None		1-2 days		3-5 days		> 10 days		Total		p-value
Students	N	%	N	%	N	%	N	%	N	%	
Missed school*											<.0001
A lot	2	0.3	1	0.2	0	0	2	0.3	5	0.83	
Sometimes	4	0.7	1	0.2	1	0.2	0	0	6	1.00	
Hardly ever	7	1.2	3	0.5	0	0	0	0	10	1.67	
Not at all	573	95.5	5	0.8	0	0	1	0.2	579	96.5	
Total	586	97.7	10	1.7	1	0.2	3	0.5	600	100	

*Statistically significant p = 0.05

7.3 Discussion

The response rate of 87% in this study implies that, while the survey only provides limited information, the results can be regarded as strongly representative of the student populations in the two schools, except for the very small proportion of children not in the age group 6-11 years old.

The results show that asthma (ever had asthma) was more prevalent in males (4%) than females (1%) in this age group (see Table 7.7). As shown in Table 7.22 the prevalence of asthma by gender is consistent with international literature review [SIDRIA, 1997; Shamssian and Shamsian, 1999; Al-Riyami et al., 2001; Maziak et al., 2003; Robertson et al., 2004]. Our study is also consistent with local literature for respiratory symptoms [Tabatabaie et al., 1995a]. For example, the prevalence of tightness in the chest and phlegm (see Table 7.10) were notably higher in male than female students, which is consistent with some international studies [Burr et al., 1999; Galizia and Kinney, 1999]. Such differences in early childhood may be attributable to mechanical factors, such as smaller size of bronchi in pre-adolescent males. Hormonal factors may influence airway inflammation in girls who typically have greater growth between 8 and 12 years than boys for both air ways and air spaces [Hibbert et al., 1984].

Using our questionnaire, in which most questions were based on ISAAC, the rates of reported risk factors such as type of bedding (see Table 7.14), moisture (see Table 7.17), cockroaches (see Table 7.17), the type of floor covering (see Table 7.18) using central heating and the type of the heating fuel [Behrens et al., 2005] (see Table 7.20) were significantly higher in males. One study showed 43% of asthma attacks could be prevented by not cooking with gas [Jarvis et al., 1996], which seems unlikely given the generally low socioeconomic status of the people in this region. Other studies confirm these as risk factors for asthma. Considering the higher prevalence of asthma in males in this study, the positive association between these risk factors and asthma in male students is probable.

In Table 7.14 covered bedding with mite proof was reported for 85% of students. This report might not be right because the definition of this question in Farsi might not truly define the properties of mite proof covering. Therefore, the response to this question might not be reliable or comparable to the literature.

Moisture and cockroaches tend to be linked [Jarratt, J H, 1999]. In some studies it was confirmed that evidence of cockroaches in a child’s bedroom was linked to asthma and respiratory symptoms [Yang, C-Y et al., 1997a; Eggleston, P A and Arruda, L K, 2001; Amr, S et al., 2003; O'Connor, G T et al., 2004]. The source of the cockroach allergen is thought to be cockroach faeces, saliva or body parts, or other sources on the body [Department of Environment Protection of Maryland, 2002].

Although, the results do not show any significant association between number of pets and respiratory symptoms, 18% of children kept their pets in their bedroom (see Table 7.12) while the number of pets in their bedroom was high. It was known that, animals with a proven effect on sensitisation rates are pets such as cats and dogs [Mungan et al., 2003].There is no significant association between asthma indicator questions and pet ownership (see Table 7.13). The reason might be the cats and dogs' ownership was low or the questionnaire does not measure the amount of time that children spent indoors or outdoors.

In this study, as shown in Table 7.18 floor covering report was significantly higher in females than in males. Literature showed that allergen linked to asthma is produced in poorly maintained housing [Breysse et al., 2005]. Dust mites nest in carpets just like any dust-collecting fabric [Yiin et al., 2003]. In this study while 83% of the students reported the use of loose carpets in their homes, 51% (highest rate) of them washed their carpets once a year and smaller proportions washed their carpets more frequently. Some studies showed the association between floor covering and asthma prevalence [Rudolph and Cohen, 1932; Norback and Torgen, 1989].

In this study, the prevalence of self-reported cooking fuel is significantly higher in females (see Table 7.19). In the literature cooking with gas was positively associated with respiratory symptoms but not current asthma exclusively in girls, [Behrens et al., 2005]. Although, Behrens et al.[2005] did not focus on the prevalence of reported risk factors and gender; their study showed an association between respiratory symptoms, development of asthma and some risk factors such as cooking fuel and mould.

This study showed central heating was reported more by females than males, which is highly significant (see Table 7.19). Although the use of central heating provides suitable environment for cockroaches to live [Children's Hospital Boston, 2005] and the studies have confirmed the association between cockroaches and asthma prevalence [Jones, 1998; Eggleston and Arruda, 2001; Amr et al., 2003], the questionnaire did not measure this item.

The third general question of this chapter addressed what parents say about the home environment and the existence of respiratory symptoms. The only significant reports of parents were about symptoms such as ‘ever had tightness in the chest’ and ‘brought up phlegm in particular season’, both of which were higher in males than females. Further, the estimated rating of children’s asthma and the school absenteeism for asthma were higher in males than females (see Table 7.10).

7.4 Conclusion

Overall, this study demonstrates that some respiratory prevalence rates are higher in males than females, as are some reported risk factors (see Table 7.22). In general, the level of exposure to known risk factors, with the exception of number of smokers at home, does not seem to be extraordinarily high in this population. Further analysis of the prevalence is discussed in Chapter eight. This study showed positive response rate students in diagnosed asthma and missed school was higher for males than females. In addition, positive response rate of parents for the existence of phlegm in particular season and tightness in the chest was higher in males than females. Although a questionnaire cannot provide a perfect scale to show the real prevalence, since it is a self-reported scale, it can show risk factors associated with prevalence of any illnesses.

Table 7.22 Prevalence of asthma, asthma symptoms, and other allergic disorders in this study and other studies

Researches	Our Study		UK[1]		Germany[2]		Iran/1995[3]		Iran/2004[4]		Oman[5]		Au[6]	
Symptoms	F	M	F	M	F	M	F	M	F	M	F	M	F	M
Ever wheezed	5.1	8.5	18.3	27.7	-	-	8.2	12.6	8.1	7.5	11.3	15.8	35.3	44.8
Current wheeze	9.2	13	15.4	21.5	12.7	13.6	2.6	7.2	29.6	28	5.3	8.5	19	25.6
Exercise induced wheezing	2.8	3.0	11.1	16.4	6.0	7.8	1.2	2.5	1.5	5.9	6.0	7.7	-	-
Current night time cough	6.1	8.8	26	28.6	15.4	16.3	5.6	7.1	3.4	4.1	18.7	20.3	-	-
Ever had asthma	0.5	2.2	18.3	27.7	3.6	5.2	1.5	1.9	1.2	1.0	8.0	12.4	23.3	32.7
Current number of wheezing episodes														
1-3	1.6	2.7	8.8	13.4	-	-	-	-	-	-	-	-	-	-
4-12	0	1.6	4.5	5.6	-	-	-	-	-	-	-	-	-	-
>12	0	0.5	1.7	2.4	-	-	-	-	-	-	-	-	-	-
Woken by wheeze past year														
<1 per week	1.9	7.4	5.4	9.4	-	-	-	-	14.3	12.4	-	-	-	-
>1 per week	2.3	3.2	5.3	6.3	-	-	-	-	9.8	8.6	-	-	-	-
Current limitation of speech	2.0	3.7	3.1	4.2	1.9	2.9	-	-	7.1	9.4	3.0	3.4	-	-

[1] [Burr et al., 1999]
[2] [Maziak et al., 2003]
[3] [Asher et al., 1998]
[4] [Masjedi et al., 2004]
[5] [Al-Riyami et al., 2001]
[6] [Robertson et al., 2004]

Chapter 8: Asthma prevalence in primary school students

There is increasing evidence of a worldwide rise in the prevalence of asthma [Boskabady and Karimian, 1999; Mallol et al., 1999; World Resources Institute, 1999] and of morbidity and mortality due to asthma [Woolcock, 1991]. Although changes in medical practice, diagnostic labelling, and public awareness could have influenced this trend, it is suggested that the increase is real [Woolcock, 1991; Williams, 1998; Willers et al., 2000; Burr et al., 2006]. The cause of this apparent increase in prevalence is unclear, but environmental factors such as air pollution due to sulphur dioxide, nitrogen oxide, ozone, or vehicle exhausts are contributing factors [Shima and Adachi, 2000]. Thus, there is considerable interest in the comparison of the prevalence of asthma internationally. Prevalence of asthma has been measured by several standard methods. Prevalence data have been used as a basis for testing hypotheses relating to the nature and causes of asthma. However, there are many problems associated with the definition of asthma. The definition of ‘asthma’ is often confusing. Assessing that someone is asthmatic is problematic. In general, two methods have been used to assess the prevalence of asthma. Historically this has been done most often by asking questions about a diagnosis of asthma or about any history of asthma symptoms, especially wheezing [Samet, 1987]. However, questionnaire responses are both subjective and influenced by a wide variety of cultural, psycho-sociologic factors and having access to and use of health care facilities [Tennant and Szuster, 2003]. For these and other reasons, the responses to questionnaires may not be accurate. It is therefore recommended that questions with high specificity be used; these include questions about ‘self-reported asthma’ and ‘physician-diagnosed asthma’.

Another method used in measuring asthma prevalence is peak flow measurement. A ‘normal’ peak flow rate is based on a person’s age, height, sex and race. A ‘standardized normal’ flow measurement may be obtained from a chart comparing the patient with a demographically matching population without breathing problems. A problem with comparing readings to predicted values, is that the person can fall quite a long way above or below his or her predicted peak flow (which is based on a population average) and still be normal. This is why it is considered better to compare a person’s readings to his/her personal best peak flow [American Academy of Allergy-Asthma and Immunology, 2006].

Although lung function tests have not always been used for diagnosis in the past, the National Institute of Health, National Heart, Lung, and Blood Institute (NHLBI) Guidelines for the Diagnosis and Management of Asthma [1997] state that 'Pulmonary function studies are essential for diagnosing asthma and for assessing the severity of asthma in order to make appropriate therapeutic recommendations. The use of objective measures of lung function is particularly important because subjective measures, such as patient symptom reports and physicians' physical examination findings, often do not correlate with variability and severity of airflow obstruction' [National Heart Lung and Blood Institute, 1997:28].

Wide variation in the prevalence of asthma has been reported between different countries and also between different regions within the same country [Golkari et al., 1996; Najafi Zadeh et al., 1996; Ertle and London, 1998; Boskabady and Karimian, 1999; Amra and Masjedi, 2001; Kubic, 2003; Akinbami et al., 2005; Hertzen and Haahtela, 2005]. The International Study of Asthma & Allergies in Childhood (ISAAC)[1] was developed to provide a standardized tool and methodology to ascertain the prevalence of asthma and allergies in different regions as well as the major determinants such as environmental factors, demographic factors and medication use [Mallol et al., 1999; Hong et al., 2004; Galassi et al., 2005].

Currently there is very limited information about precise asthma prevalence in Iran, especially for children [Golshan et al., 2002a]. As mentioned in the literature review, asthma prevalence is recorded differently in different studies. The questionnaire, which was mostly based on the ISAAC questionnaire was used in a survey of a population of the students at two elementary schools in Tehran, as, described in Chapter three.

The aim of this chapter is:

- to determine the prevalence of poor lung function or asthma in elementary students in Tehran using a standard questionnaire;
- to determine an alternative prevalence measure by measuring the students' lung function over a six week period and using the American Thoracic Society guidelines determine asthmatic status;

[1] ISAAC was formed in 1991 to facilitate research into asthma, allergic rhinitis and eczema by promoting a standardized methodology.

- to assess the association of known and suspected risk factors with the prevalence of poor lung function; and
- to compare questionnaire responses with data on the measurement of the students' lung function over a six-week period.

8.1 Methods

This chapter describes a cohort study. As mentioned in Chapter seven, a survey was carried out using a standard questionnaire. From that survey, the required respiratory data on individual students were obtained. Then, as mentioned in Chapter three, the lung function of students was measured in two schools, after obtaining permission from the two principals and signed parents' consent forms.

Lung function was measured as peak expiratory flow rate (PEFR) using a mini-Wright flow meter. Each child was asked to perform three tests in a standing position as indicated in Figure 8.1 and Figure 8.2. The highest of the three readings for each student each day was used for analyses, in accordance with guidelines from the American Thoracic Society (ATS) [Samet, 2003]. All measurements were recorded on a flow sheet, which is presented in Appendix A3.4. This flow sheet has the school's name, date and class. A table was designed to record the time of the measurements, student's code and names, three peak flow measures and the last time and date they used the puffer. This flow sheet was filled out daily and could not be anonymous because of the need to follow-up individuals for a 7-week period. The recorded lung function for the first week was removed from the database, because it was treated as a learning period. Then, the recorded measurements for the remaining six weeks period were analysed. It should be noted that there is no standard epidemiological definition of asthma [Pekkanen and Pearce, 1999; Tennant and Szuster, 2003].

There are several alternative ways to define poor lung function, itself a strong indicators of asthma. One mode of analysis of lung function makes use of a traffic light system, adapted from the NHLBI [The Centre for Children with Special Needs, 2001; American Academy of Allergy-Asthma and Immunology, 2006]. In this system, for example, a high score (80 to 100 percent of personal best) indicates no asthma) symptoms are present or all clear or good control for an asthmatic child; a medium score (50 to less than 80 percent of lung function test) signals the need for caution, and a low score (below 50 percent of lung function test) signals a medical alert. Traffic light colour codes were used in reporting results to families, with red, yellow and green corresponding to high, medium and low respectively. The cut-off methods of traffic light systems have been applied to both predicted value and best blow and then used as a basis for defining poor lung function.

Figure 8.1 Measuring lung function using a mini-Wright peak flow meter

Figure 8.2 Measuring lung function using a mini-Wright peak flow meter

Using predicted value, poor lung function corresponds to those with one or more peak flow measurements less than or equal to 50% of their predicted value or below the 'lower limit' of predicted normal (i.e. less than two standard deviations below the predicted normal for their age, height and gender, according to the chosen prediction equation).

In this study, results from Gharagozlo et al. [2003] have been used to generate predicted values for Iranian children. The Peak Expiratory Flow Rate (PEFR) values of the Iranian children in that study were similar to those of some Europeans, Americans and Asians, but lower than those of Australian and Srilankans [Gharagozlo et al., 2003] persons who are at risk for adverse respiratory conditions [Gauderman et al., 2004]. To determine the predicted PEFR for each subject, the predicted peak expiratory flow rate was computed based on the student's heights and age. For girls, PEFR= $(2.2 \times \text{height}) + (11.6 \times \text{age}) - 147$, and for boys, PEFR= $(1.9 \times \text{height}) + (10 \times \text{age}) - 142$ [Gharagozlo et al., 2003].

No standard deviation of prediction was available from the study reported here since prediction equations from a different study were used to predicted lung function of students. The Iranian literature was searched. Most studies could not be used because their reported population standard deviation was not the standard deviation of the predicted values based on age, height and gender [Mohammadzadeh et al., 2006]. The study used to 'measure' standard deviation was one that produced spirometry reference values for middle eastern populations under 21 years old and also the standard deviation of predicted values [Golshan et al., 2003].

Another baseline to gauge asthma control is comparing daily peak flow recordings with the 'personal best' reading, that is the highest measurement for each student during the six week period, an approach suggested by Radoes and Camargo [2004].

A further method of assessing poor lung function is based on questionnaire responses, specifically a positive answer to the question 'have you had wheezing or whistling in the chest in the past 12 months?' A positive response to this question in combination with at least one lung function value below 50% of predicted value (or of best blow) indicates persistent or current asthma. In combination with no such lung function values, the positive response is an indicator of intermittent asthma.

To assess comparability of all the definitions used, the results are compared to each other. There is no golden definition available, especially since access to health practitioners was limited in this population, and asthma self-diagnosis of students was not expected to be reliable.

8.2 Results

From the 893 children eligible for study, 574 students were allowed to participate after the lung function consents were returned. Eleven[2] of these 574 did not participate or were absent all the time. Another student was out of the age range and was removed from the study. Thus, the study ended up with 562 students (63%). The main reason for non-participation was that the boys' school principal did not allow 302 (34%) students to participate. The students who were not allowed to participate in the study were weak in a mathematics subject and the principal thought the lung function tests might distract them from concentrating on mathematics. This selection was from all classes so is unlikely to be an important source of bias in the study. The remaining 17 (2%) non-participants were students whose parents disagreed with their children's participation. A description of the study population is presented in Table 8.1. The lung function data are summarized in Table 8.2. The outcomes data consisted of the results of lung function tests for 356 female and 206 male students over the six-week period.

Table 8.1 Population characteristics of lung functions study

Participated in lung function tests		
	Number of girls	356
	Number of boys	206
	Total	562
Non-participants		331
Population size		893
Mean age	8.4 years	
Std Dev	1.4 years	

Table 8.2 Statistical summary data for lung function

Variables	N	N Miss	Minimum	Median	Mean	Maximum	Std Dev
Lung function (PEFR)	17927	6239	60	250	250	530	65.1
Personal best (PEFR)	17927	6239	170	300	311	530	59.5
Height	24080	86	105	132	132	161	10.0
Age	24166	0	6	8	8	11	1.4
PEFR (Predicted)	17927	6239	119	223	225	325	41.9

8.2.1 Poor lung function prevalence using predicted value

Using the traffic light system showed 48% of students had clear airways while 39% had moderate lung function and 12% had poor lung function. Combining these latter categories, (100 - 48 = 52%) of the students appear to have some airways obstruction

[2] The absents here are the same students who were absent in Chapter 5.

but, when broken down by gender, it is clear that of obstruction is much more prevalent in girls (100 - 24 = 76%) than in boys (100 - 89 = 11%) (see Table 8.3).

Using a PEFR measurement less than or equal to 50% of predicted value as an indicator, 12% of the students showed poor lung function, while the percentages for females and males were 19% and 1% respectively.

Table 8.3 The proportion of poor lung function based on traffic light system

	Female		Male		Total	
Predicted value	N	%	N	%	N	%
≥ 80% of their predicted value	87	24	184	89	271	48
Between 50% and 80% of their predicted value	202	57	19	9	221	39
≤ 50% of their predicted value	67	19	3	1	70	12
Total	356	100	206	100	562	100

Alternative cut-offs for assessing lung function, as occasionally used by clinicians, are presented in Table 8.4. Using the detailed scale of low and the combination of medium and high scores, showed 52% of the students had moderate or poor lung function, but the percentages for females and males were respectively 76% and 11%. Out of 48% of students who had clear airways, the percentages for males (89%) was almost four times that of females (24%). Using this cut off shows that all the students have a degree of poor lung function, which does not seem reasonable.

Table 8.4 The porportion of students classified as 'clear airway'

	Female		Male		Total	
Predicted value	N	%	N	%	N	%
≤ 90% of their predicted value	53	15	174	84	227	40
≤ 85% of their predicted value	34	10	10	5	44	8
≤ 80%of their predicted value	269	76	22	11	291	52
Total	356	100	206	100	562	100

As mentioned in section 8.1, poor lung function was also calculated on the basis of observations more than two standard deviation below the predicted values. As presented in Table 8.5, this indicator of poor lung function led to an overall prevalence estimate of 3%, but 5% for females and zero for males.

Table 8.5 Prevalence of poor lung function based on less than 2SD of normal distribution

	Female		Male		Total	
Poor lung function	N	%	N	%	N	%
Yes	19	5	-	-	19	3
No	337	95	206	100	543	97
Total	356	100	206	100	562	100

8.2.2 Asthma prevalence using students' best blow

Another indicator for prevalence of asthma was calculated according to each student's personal best PEFR in the period of six weeks, as is presented in Table 8.6-Table 8.7. Using the traffic light system definition, 30% of the students in this study have severe airflow obstruction (≤50% of their personal best), while the percentages by gender were, respectively, 37% for females students and 17% for males. Sixty-six percent have moderate airflow obstruction (between 50% and 80% of their personal best) and the rest (4%) had clear airways (80-100% of their personal best). Only 1% of females had clear airways, compared to 10% of males.

Table 8.6 Prevalence of asthma using traffic light system

	Female		Male		Total	
Personal best	N	%	N	%	N	%
≥80% of their personal best	5	1	20	10	25	4
Between 50% and 80%of their personal best	220	62	151	73	371	66
≤50% of their personal best	131	37	35	17	166	30
Total	356	100	206	100	562	100

Some clinicians use alternatives percentages to those presented in Table 8.6. For example, the classification in Table 8.7 uses cut-offs of 90%, 85% and 80%. As shown in Table 8.7, 96% of students have moderate or severe airflow obstruction (≤80% of their personal best), the rates for females and males being respectively 99% and 91%.

Table 8.7 Prevalence of asthma

	Female		Male		Total	
Personal best	N	%	N	%	N	%
≤90% of their personal best	2	1	4	2	6	1
≤85% of their personal best	2	1	14	7	16	3
≤80% of their personal best	352	99	188	91	540	96
Total	356	100	206	100	562	100

8.2.3 Comparison of different definitions

Asthma questionnaire responses are presented in Chapter seven. In Chapter seven, it was noted that 14% of students reported pet ownership and 30% of the students have smokers at home. Three percent of students indicated in their questionnaire responses that they had asthma, while 22% of the students had wheeze episodes for last 12 months or ever wheezed in their life. In addition, male students reported the higher rate (12%) of these items. Odds ratios calculated for the various 'definitions' of asthma were used to indicate inconsistency of definitions. Four sets of circumstances relate to these comparisons, and the results have been grouped accordingly. Given the observed gender differences, all odds ratios were calculated separately for females and males.

- Group 1: ‘0’ cells, so OR not measurable.
- Group 2: OR<1 but confidence interval (CI) includes 1.
- Group 3: OR>1 but CI includes 1.
- Group 4: OR>1 CI does not include 1.
- Group 5: OR<1 CI does not include 1. (there were no cases in this group)

Only the significant odds ratios (Group 4) are presented in Table 8.8 and Table 8.9. Female students whose best blow was more than 80% are at significantly increased risk of ‘ever had asthma’ (OR, 10.7; 95% CI, 1.0, 112). In addition, female students whose predicted value were less than 90% are at significantly increased risk of had asthma were (OR, 32.3; 95% CI, 1.9, 554). Male students whose predicted value were less than 85% are at significantly increased risk of ‘wheeze after or during exercise for last 12 months’ (OR, 15; 95% CI, 2.3, 98.5). Parents reported their female children whose predicted values were less than 90% are at significantly increased risk of ‘have woken up with tightness in chest’ (OR, 19.5; 95% CI, 1.2, 326.2).

It should be noted that while the tabled confidence intervals for odds ratios all excluded the value 1, for two of them the lower limit barely exceeded 1 and for the other two the lower limits were 1.9 and 2.3. However, three of the four significant cases had only one subject in the ‘yes, yes’ category and the other case had just two. Further, in three cases Fisher’s exact test did not show significance at the conventional 5% level.

The overall results provided limited and very weak evidence of significant association between asthma indicators based on lung function (PEFR) and questionnaire responses.

Table 8.8 Canditate associations for significance based on traffic light

		Yes		No		Total		95% confidence interval			Fisher test
		N	%	N	%	N	%	OR	lower	upper	
>80% of their personal best (clear airway) for females											
Ever had asthma	Yes	1	11	8	89	9	3	10.7	1.0	112.1	0.12
	No	1	1	134	99	135	91				
	Missing	1		20		21					

Table 8.9 Canditate associations for significance based on alternative cut-offs

		Yes		No		Total		95% confidence interval			Fisher test
		N	%	N	%	N	%	OR	lower	upper	
<85% of their predicted value (clear airway) for males											
Wheeze after/during exercise for last 12 months	Yes	2	33	4	67	6	3	15	2.3	98.5	0.021
	No	6	3	180	97	186	90				
	Missing	2		12		14					
<90% of their predicted value (clear airway) for females											
Ever had asthma	Yes	1	9	10	91	11	3	32.3	1.9	554.1	0.065
	No	1	-	323		324					
	Missing	0		21		21	6				
Woken up with tightness in chest	Yes	1	6	16	94	17	5	19.5	1.2	326.2	0.101
	No	1		312		313	88				
	Missing	0		26		26					

8.3 Discussion

Using traffic light indicators, the results in this chapter show overall prevalence of poor lung function was 3% and 12% respectively using predicted value and best blow as described earlier. The differences between females and males are substantial. This study is consistent with another study which was carried out by Greavesa et al [2007] in schools in Minneapolis USA on immigrant children. In that study, females had significantly lower FEV_1 (-8.8%) and FVC (-11.0%) than males, and a history of physician-diagnosed asthma was not associated with decreased lung function.

Some clinicians use the proportions of children who recorded any peak flow at less than 80%, less than 85%, and less than 90% of their personal best as indicators. This gives indicators of the prevalence of asthma (defined as variable airflow obstruction) of various levels of severity. Using these indicators, in descending order of severity, the prevalence is 96%, 99% and 100%. Again, there are differences between females and males, with higher prevalence for females. However, this definition was not consistent with the traffic light system, which used as different cut-offs and produced much smaller estimates of ‘prevalence’. As the definitions are different, compatible prevalence estimates can hardly be expected.

A traffic light system showed 12% of students in this study as having poor lung function using predicted value (see Table 8.3) and 30% as having airway obstruction using best blow (see Table 8.6). Airway obstruction or asthma indicator prevalence was 37% for females and 17% for males using best blow (see Table 8.6). Prevalence of 'current wheeze' was lower for females than males, using the ISAAC questionnaire (see Table 7.8). Combining both tools, questionnaire and lung function definitions showed no poor lung function or airway obstruction for females or males (see Table 8.8). In this study, the gender difference in prevalence of 'current wheeze' and 'current asthma' is neither consistent with another study carried out in Tehran [Masjedi et al., 2004] nor with lung function results (see Table 8.3 and Table 8.6). The evidence in Table 8.8 of the association between predicted values and questionnaire responses is based in every case on either one or two students with a positive questionnaire response. This provides rather flimsy support for association, especially since it is possible that some or all of this very small number of students used asthma relief medication before taking lung function tests, as has been reported in ATS standards [Miller et al., 2005]. While there is no agreed definition of asthma, some definition was needed. Asthma prevalence can be measured in terms of self-reported wheeze, doctor-diagnosed asthma, or a combination of symptoms and lung function abnormality [Pekkanen and Pearce, 1999]. Poor lung function and severity of obstruction of airway can be classified in a range from clear to poor. The only classification of airway obstruction, which significantly matched with questionnaire results, was clear airway mostly for females.

Objective measures of lung function combined with asthma symptoms did not allow classification of asthma into persistent and intermittent. Approximately one quarter of Iranian children have wheezed in the past 12 months, and it seems unlikely that they all have intermittent or persistent asthma that requires treatment. At present, there is no way to classify asthma on wheeze alone, although, in many studies, children with more than four wheeze episodes per year are regarded as having 'asthma'. Masjedi et al [2004] found that among 6-7 year olds who report current wheeze 30% reported more than four wheeze episodes (about 11% of the population).

Having doctor diagnosis of asthma is regarded as the gold standard, and is often taken as the mandatory definition. It was not available for this study, because of the low socio-economic class of the students, many of whom would not have 'easy' access to a general practitioner. In this study, as discussed in section 8.1, the chosen measure of students' lung function was PEFR. The accuracy of asthma prevalence estimation could be potentially improved by using both questionnaire scores and PEFR records. However, there are two definitions of lung function abnormality, one using predicted values and the other using personal best blow as a yardstick. These two definitions led to respective prevalence estimates of 12% for poor lung function (based on predicted value) and of 30% for airflow obstruction (based on personal best blow), the latter being an asthma indicator.

These students are from a district of Tehran with low socio-economically situation [University of Sorbonne, 2005]. This district is located in one of the most polluted and condensed area of Tehran. They had poor lung function in autumn when the cold season and school year had started for a month when the lung functions were measured.

This study has determined the prevalence of poor lung function using a standard questionnaire. It has determined the alternative prevalence using lung function (PEFR) readings over a six-week period, and using the American Thoracic Society guidelines. It has also shown statistically significant relationship of known and suspected risk factors with the prevalence of poor lung function. In addition, this study has shown the comparison of questionnaire responses with measured lung function (PEFR) data.

This study compared the prevalence of poor lung function using different definitions. Other studies in Iran using ISAAC questionnaire showed current wheeze prevalence of 8.6% for 6-7 years old children in Tehran [Masjedi et al., 2004]. This study showed 22% since it works on a broad age range. Using three definitions showed children in this study have clearly problematic lung function, which is similar to those found in another Iranian study [MirSaeid Ghazi et al., 2004]. This study confirmed that there is no gold definition for asthma. This study has shown 22 % of students had current wheeze using ISAAC questionnaire, that is, 21% female and 23% male. The prevalence of current wheeze is consistent with that found in an Oceania study, but not with worldwide trends [Pearce et al., 2007; Weinmayr et al., 2007]. In these studies, the mean symptom prevalence of current wheeze in the last 12 months was 11.6%.

The measurement of severity of asthma is difficult. The nature of mild, moderate, or severe asthma depends on the perspective of the observer. Using self-reported wheeze with lung function can show persistent or intermittent asthma. Under the classification of any recorded lung function less than 50%, this study showed that the prevalence of asthma is zero since the significant odds ratios were defined only the clear airway scales with asthma indicator questions.

8.4 Conclusion

This study has shown consistent prevalence of poor lung function in District 12 of Tehran. Prevalence of poor lung function was more in females than males. The largest prevalence estimation of poor lung function was 12% and the largest prevalence estimation for airway obstruction as asthma indicator in this study was 30% using best blow.

The risk factors such as ‘pet ownership’ and having ‘smoker at home’ were assessed but they were not significant. This study showed the percentage of students who have a degree of poor lung function using questionnaire and other definitions were different. However, when the definitions combined then the significant ones could only matched with the clear airway level.

Chapter 9: Air pollution effects on lung function

Epidemiological studies have demonstrated a clear association between air pollution as it occurs in various places around the world and decreased lung function [Brunekreef et al., 1997; Gauderman et al., 2000; Peled et al., 2001; Gauderman, 2002; Neuberger et al., 2002; Timonen et al., 2002; Frye et al., 2003; Neuberger et al., 2004; Jedrychowski et al., 2005]. The question is whether air pollution, as it occurs in Tehran, will show similar association with respiratory health of primary school children.

This chapter addresses the association between air pollution levels and the poor lung function.

9.1 Methods

To assess this association, two different statistical approaches were used. The first approach explored the time series of lung function measurements in each student in relation to pollution measurements. The second approach used case-crossover methods to assess the impact of air pollution on episodes of poor lung function.

9.1.1 Data collection

Lung function data were collected on students in the two schools. Over seven weeks, daily measurements of peak expiratory flow rate (PEFR) were obtained using a mini-Wright flow meter, as detailed in Chapter eight. The recorded lung function (PEFR) for the first week was removed from the database, because it was treated as a learning period. Then, the recorded measurements for the remaining six-week period were analysed.

During the period, six measurements per week were taken on each child, there being no school on Fridays.

9.1.2 Statistical Analysis

To assess this association, two different statistical approaches (a two-stage regression analysis and case-crossover) were used.

9.1.2.1 The relationship between daily lung function and predictors including pollution variables

Time series analysis was not used in determining the relationship between daily lung function measurements of individual students and pollution and other predictors. This was because of the substantial number of missing values among the pollution measurements. Thus, a simple autocorrelation model for the daily lung function measurements on a child (ignoring Fridays and occasional other days of absences when there were no measurements) could be fitted, but could not be extended to also include the relationship with pollution variables.

Therefore, a two-stage strategy was developed for the analysis. The first stage was a multiple regression analysis for each child. In this first stage of model fitting, both daily and seven-day moving averages of pollution predictors were used along with temperature, shift, gender and related variables. Because any autocorrelation structure was ignored, this would render unreliable any calculation of significance or precision. This did not matter, as a statistically significant pattern would not be necessarily expected for an individual with only six-week data.

The second stage was to carry out separate univariate analyses of the stage regression coefficients for each predictor. This analysis relies only on the validity and lack of bias in the stage one analysis and does not rely on precision estimates from stage one.

9.1.2.2 Case-crossover design

Case-crossover analysis of the data used worst lung function definitions [Schwartz, 2005].

The presence of poor lung function is more complex than often presented. As discussed in detail in Chapter eight, based on PEFR data were introduced. Cases would be any date which lung function measured less than 50% the predicted value or the personal best blow. These are the basis of case definition for case-crossover analysis two definitions of poor lung function for using in the analyses.

<u>Case definition one: predicted value</u>

Using a definition of poor lung function based on PEFR less than 50% of predicted value, the case date for each student identified as having poor lung function was the date of worst lung function.

<u>Case definition two: best blow</u>

This used a different definition of poor lung function but then an identical method of defining a case and case date. For each subject, the best PEFR of the students produced during the six-week data collection period was identified. Subjects were deemed eligible to be a case if any observed PEFR was below 50% of the student's best PEFR (best blow). Each such student was identified as a case on the day of his or her worst lung function.

<u>Control definition for either case definition</u>

The case date is defined as the date of worst lung function for each person according to either definition one or two. The control dates are two weeks before and after each case date. Therefore, by definition, a student is his or her own control on a day of better lung function. However, that day's lung function may measurement (by either definition).

<u>Statistical model</u>

Conditional logistic regression was used to analyse case-crossover data, with the response variable taking the value 1 for a case and 0 for a control.

Variables used as putative predictors in the regression model were daily average of air pollution based on the teaching shift, seven-day moving averages of air pollutants, daily temperature and squared temperature.

9.2 Results

The air pollution and lung function data are summarized in Table 9.1 and Figure 9.1-Figure 9.10. The lung function data consisted of the results of 4,088 lung function tests on 356 girls and 3,112 tests on 206 boys. The pollution data are a temporal subset of the values described and presented in Chapter four.

Table 9.1 Summary statistics for air polluion data

Variables	N	N Miss	Minimum	Median	Mean	Maximum	Std Dev
Fatemi							
SO_2	-	43	-	-	-	-	-
PM_{10}	24	19	35	86	90	165	39.3
NO	24	19	58	92	97	160	24.6
NO_2	24	19	91	133	142	224	39.0
NO_X	24	19	86	132	137	229	37.6
O_3	10	33	4	8	7	14	3.2
CO	24	19	5703	9219	10167	16828	2874.9
Bazaar							
SO_2	-	43	-	-	-	-	-
PM_{10}	42	1	30	84	324	5000	1046.4
NO	42	1	14	68	76	207	36.2
NO_2	32	11	24	30	33	48	7.0
NO_X	42	1	10	66	73	178	29.9
O_3	27	16	28	31	37	117	22.4
CO	42	1	3078	10589	9466	20172	4109.2

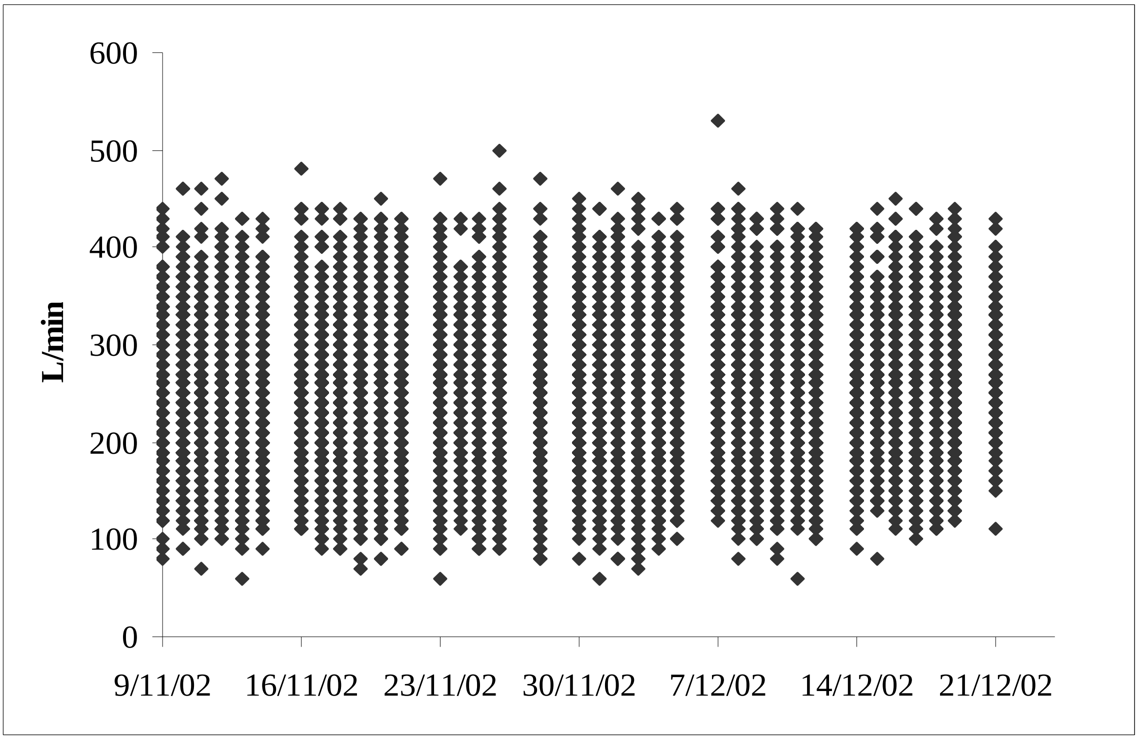

Figure 9.1 Daily lung function of all students during a six-week period

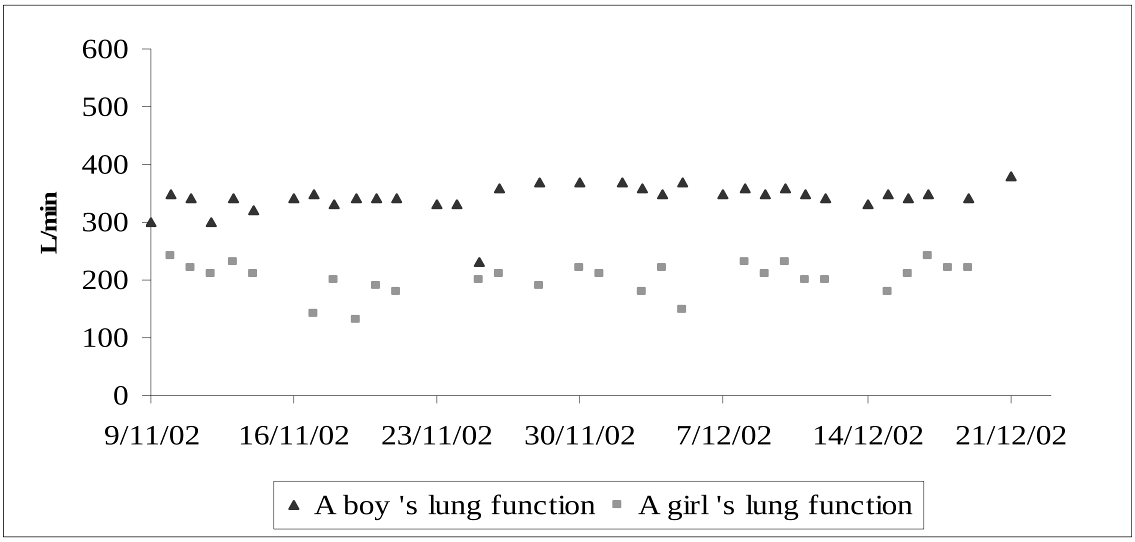

Figure 9.2 An example of daily lung functions of two students during six-week period

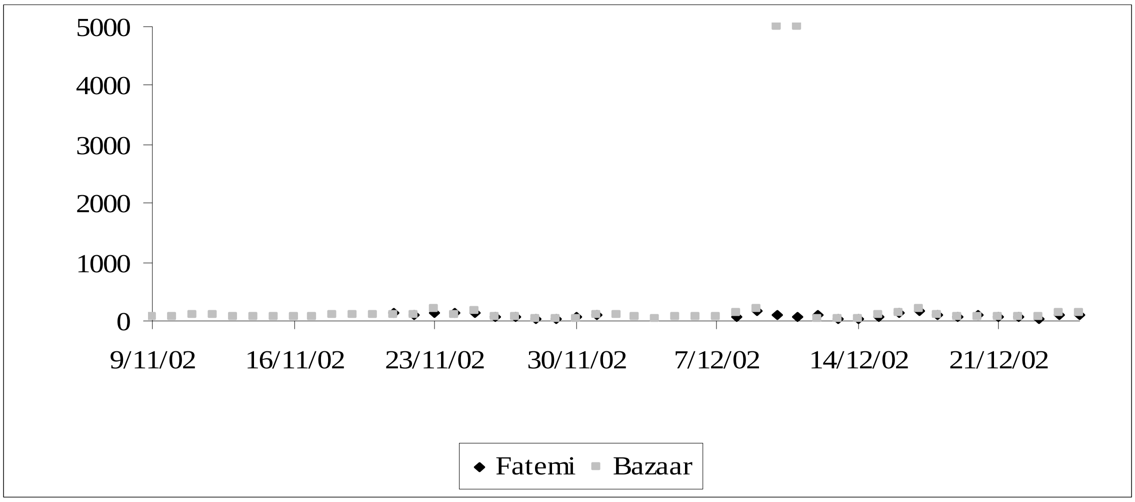

Figure 9.3 Daily PM_{10} levels over six-week, units in $\mu g/m^3$ for the morning teaching shift

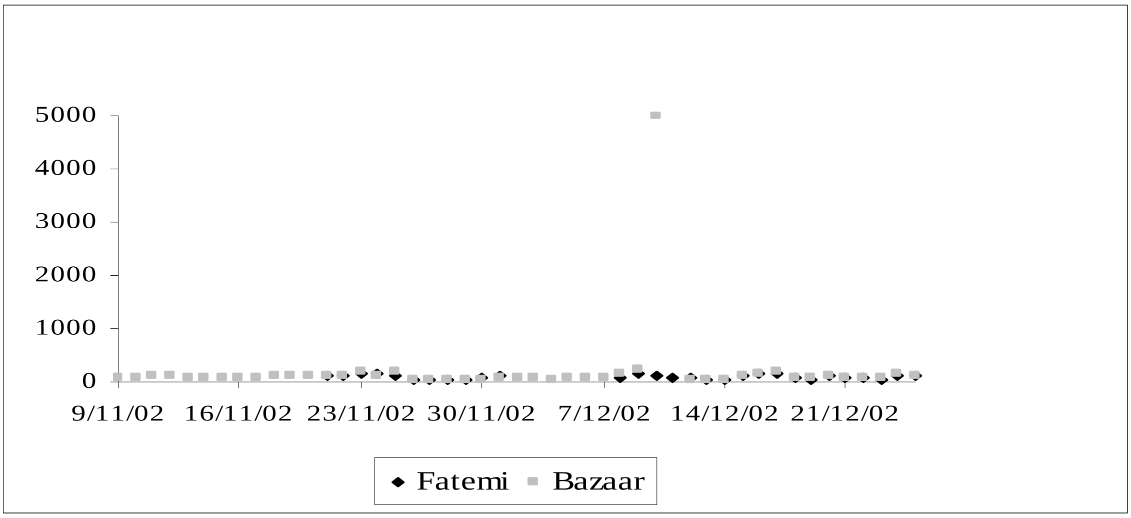

Figure 9.3 Daily PM_{10} levels over six-week, units in $\mu g/m^3$ for the afternoon teaching shift

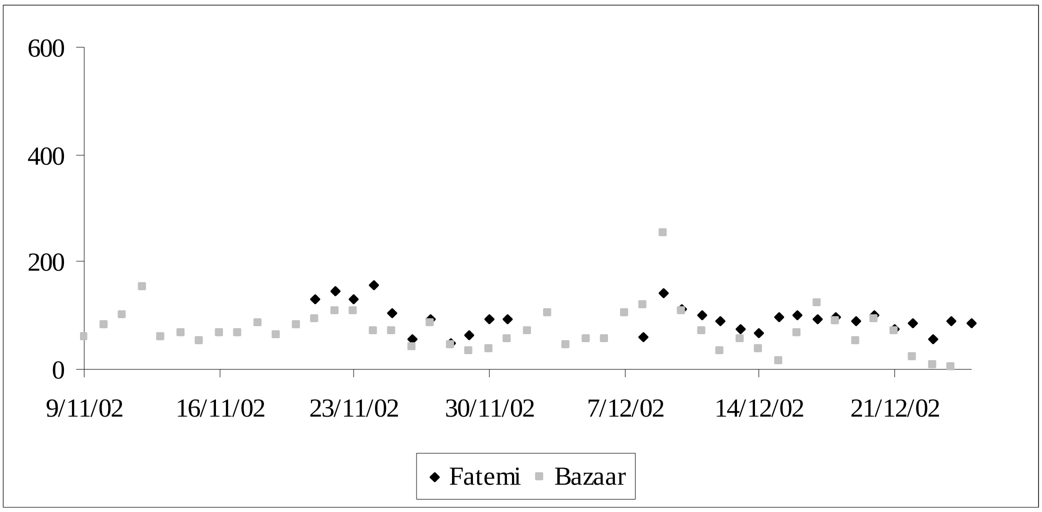

Figure 9.2 Daily NO levels over six-week, units in μg/m^3 for the morning teaching shift

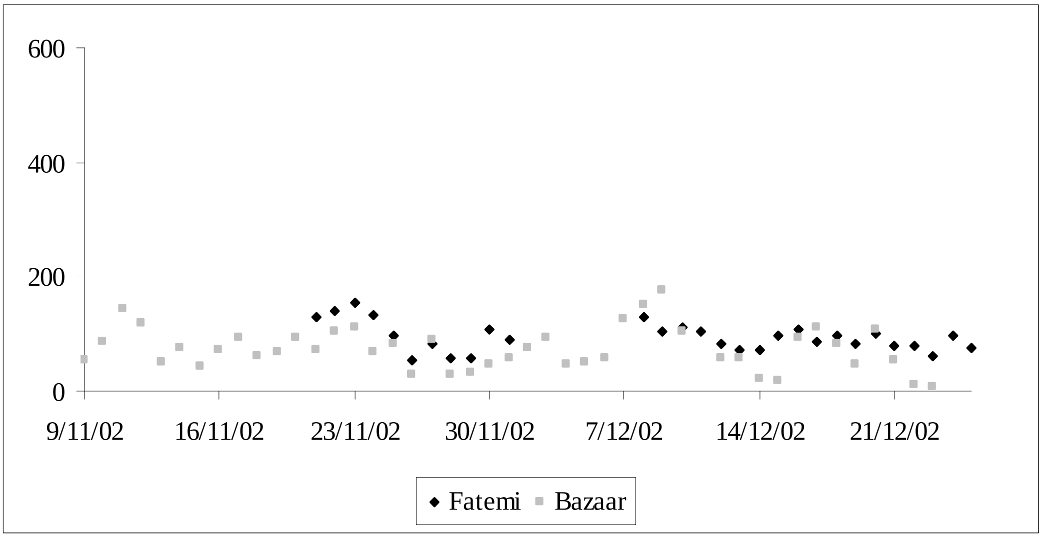

Figure 9.3 Daily NO levels over six-week, units in μg/m^3 for the afternoon teaching shift

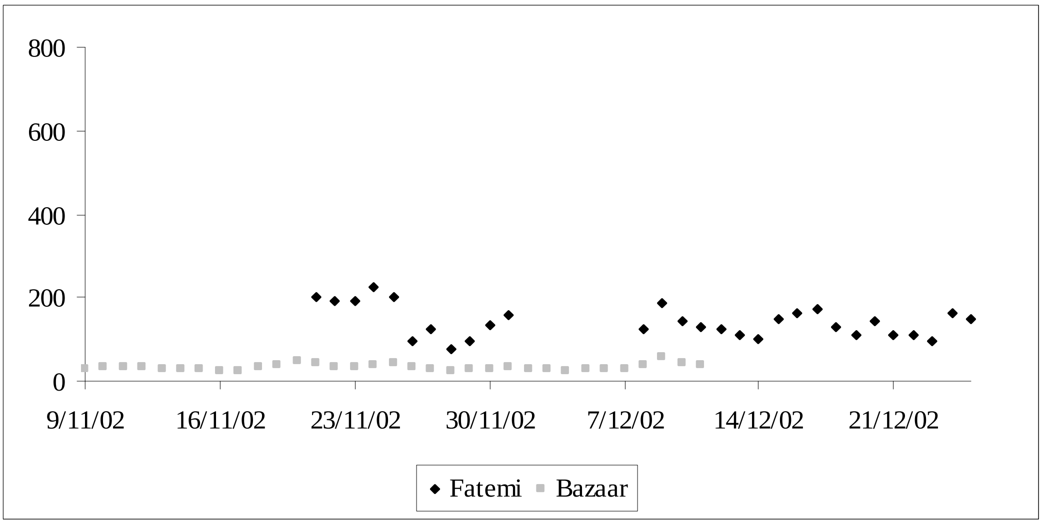

Figure 9.4 Daily NO_2 levels over six-week, units in μg/m^3 for the morning teaching shift

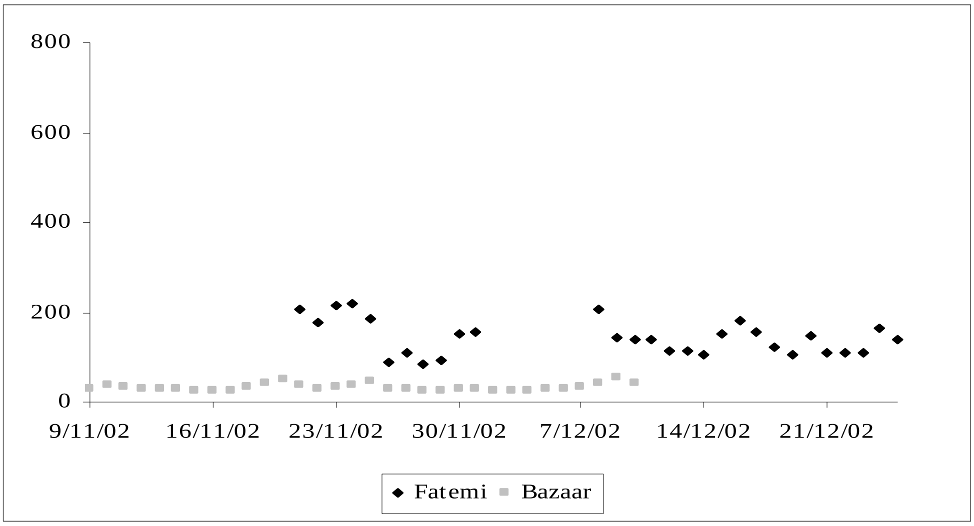

Figure 9.5 Daily NO_2 levels over six-week, units in $\mu g/m^3$ for the afternoon teaching shift

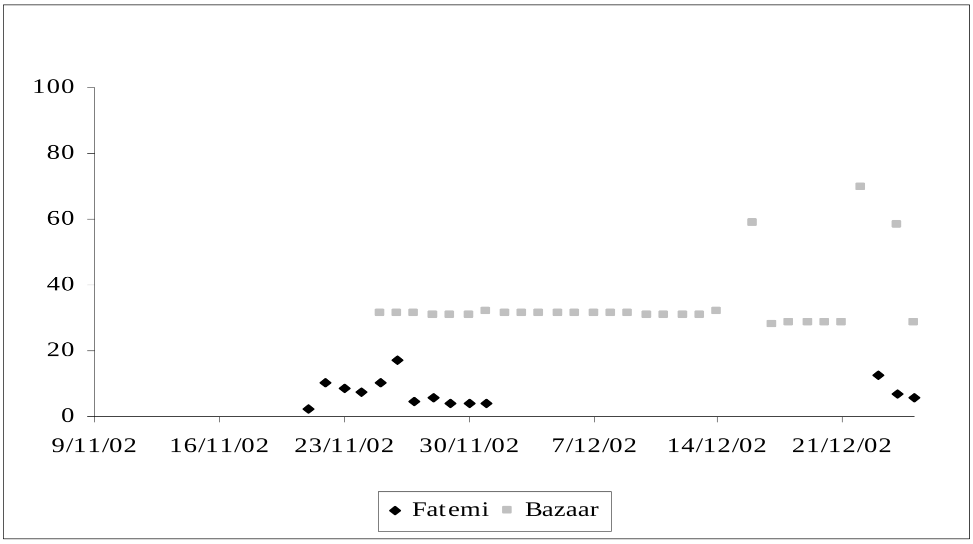

Figure 9.6 Daily O_3 levels over six-week, units in $\mu g/m^3$ for the morning teaching shift

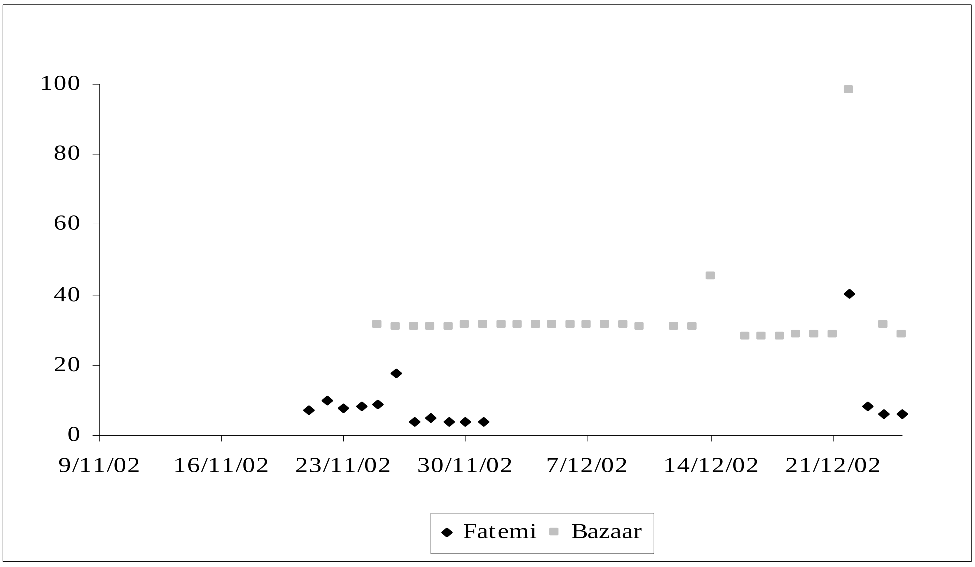

Figure 9.7 Daily O_3 levels over six-week, units in $\mu g/m^3$ for the afternoon teaching shift

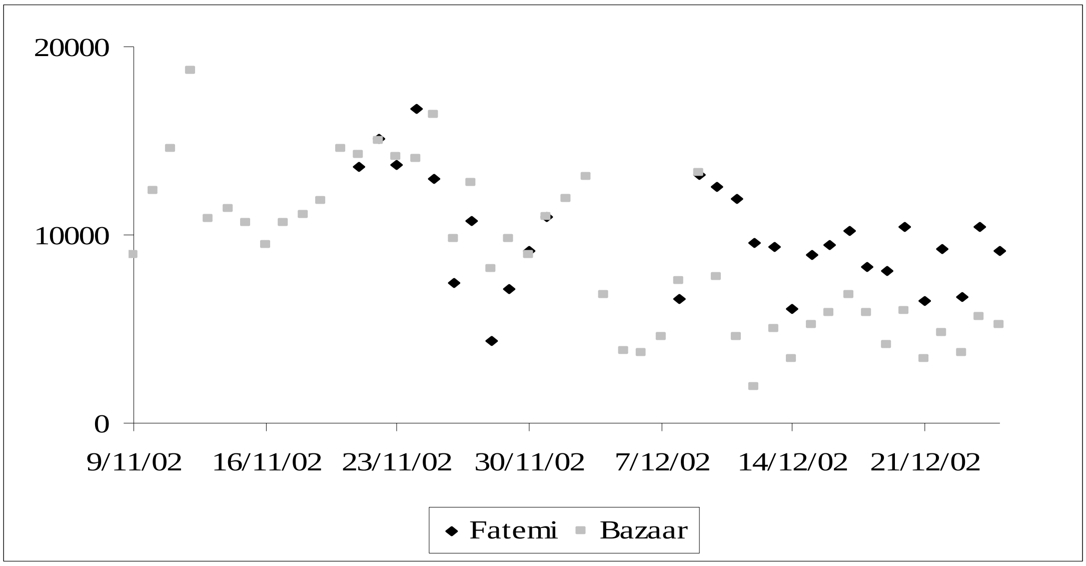

Figure 9.8 Daily CO levels over six-week, units in μg/m^3 for the morning teaching shift

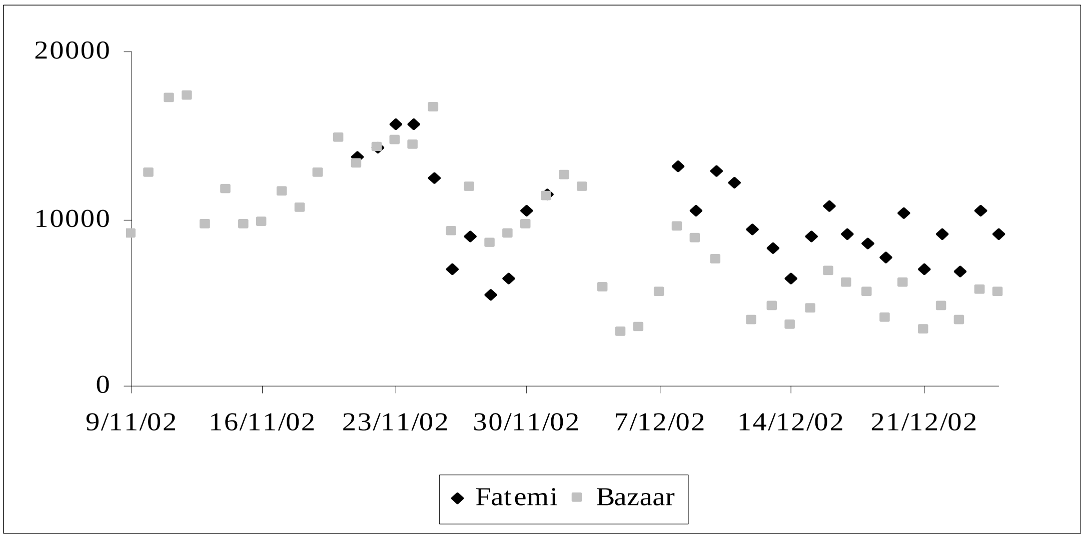

Figure 9.9 Daily CO levels over six-week, units in μg/m^3 for the afternoon teaching shift

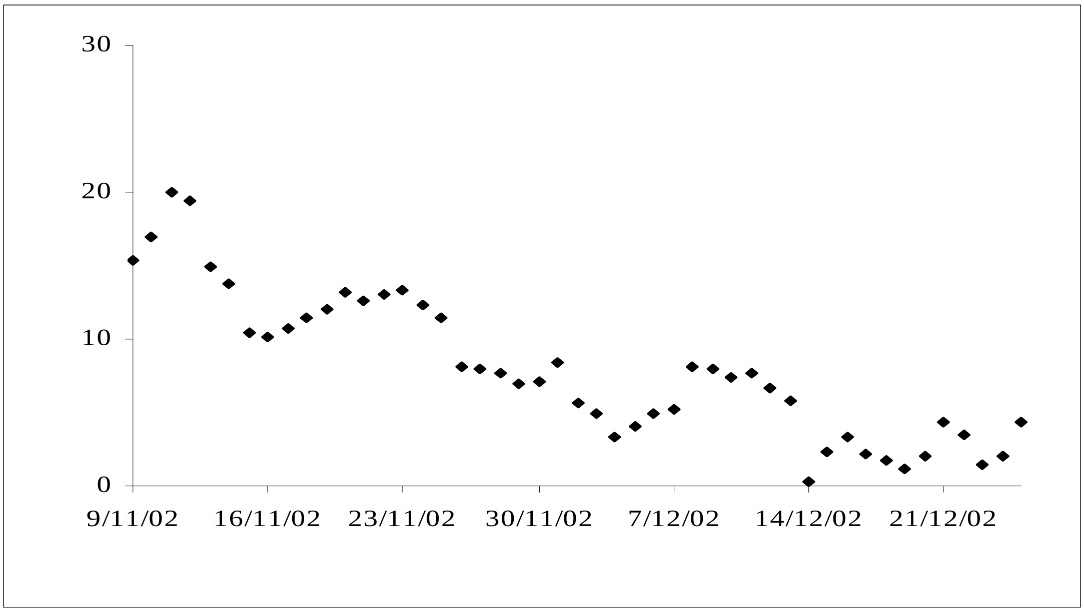

Figure 9.10 Daily temprature levels over six-week, units in °C

As indicated in Table 9.1 and Figure 9.9, the air pollution data for Fatemi look insufficient to analyse. However, since case-crossover analysis just needs the case dates, air pollution data for Fatemi were used in this study. In addition, there were no SO_2 data for either station.

9.2.1 Two-stage analysis of lung function time series data

The regression analyses for individual students produced distributions of estimated predictor coefficients which included both negative and positive values. This is not at all surprising, given the limited data on each student and the fact that multiple regressions were used. These would be expected to produce imprecise estimates for an individual student, even when variation in any one of the predictors might be highly predictive of variation in lung function. Nevertheless, the distribution of coefficients for each predictor provides a basis for assessment of significance for that predictor. For only three predictor pollutant variables was the 'centre' of the distribution of coefficients significantly different from zero. These were the seven-day moving averages of PM_{10}, NO and CO.

Summaries of the distributions for the various significant predictors are presented in Table 9.2. Depending on the 'shapes' of these distributions, significance can be assessed by student's t test or the more robust Signed rank and sign test. Each of these can be used to carry out a significance test or produce a confidence interval for the centre of the distribution (over students) for a particular coefficient.

Table 9.2 Summary of distribution of coefficients for significant air pollutants at Fatemi station

	MA PM_{10}	MA NO	MA CO
100% (Max)	4	9.2	78.8
75% (Q3)	0.8	1	4.2
50% (Median)	0.3	0.2	-6.9
25% (Q1)	-0.2	-0.6	-18.6
0% (Min)	-4.7	-8.6	-80.9

The results of these analyses for significant predictors are presented in Table 9.3 in the form of point estimates and 95% confidence intervals. The sign test is the most robust and least powerful of the three tests. For the seven-day moving average of NO, the confidence interval based on the sign test (just) includes 0 but all other confidence intervals for the three pollutants do not. Indeed, for each pollutant the confidence intervals are broadly the same for all three methods.

Table 9.3 Point estiamtes and confidence intervals for pollutants regression coefficints at Fatemi station

	MA PM_{10}			MA NO			MA CO		
		95% CI			95% CI			95% CI	
Tests	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
Student's t	0.83	0.033	0.113	0.17	0.043	0.297	-7.57	-9.2	-5.93
Sign |	0.85	0.43	0.117	0.15	-0.001	0.281	-6.93	-9.41	-5.6
Signed Rank	0.92	0.51	0.136	0.159	0.51	0.268	-7.35	-8.87	-5.86

9.2.2 Case-crossover analysis

Case-crossover analysis was carried out based on both definitions to find the effect of air pollution on lung function.

9.2.2.1 Lung function based on predicted value

The descriptive data of worst lung function based on the predicted value (case definition one) are summarized in Table 9.4 Pollutants exposures used were the average of the current and seven-day moving average based on the teaching shift. Estimates of the increase in prevalence are shown using the hazard ratio. As indicated in Table 9.4, there were 70 cases of worst lung function using predicted value and 140 control observations which is 2 controls per case. The average lung function was 101 L/min. A matched conditional logistic regression was carried out to investigate the relationship between an outcome and a set of prognostic factors in matched case-control studies. This analysis used the PHREG procedure in SAS, with a conditional logistic model and a stratum for each matched set.

Table 9.4 Summary statistics for lung function data based on case definition 1 and corresponding air pollution data over six weeks

Variable	N	N Miss	Minimum	Median	Mean	Maximum	Std Dev
Lung function	210	0	60	100	101	140	20.8
Height	210	0	113	129	131	151	9.7
Age	210	0	6	8	8	11	1.3
Fatemi							
SO_2	0	210	-	-	-	-	-
PM_{10}	102	108	36	72	76	146	49.1
NO	102	108	66	90	91	160	26.6
NO_2	102	108	91	125	130	224	41.2
NO_X	102	108	86	116	126	229	39.9
O_3	54	156	4	6	7	14	3.3
CO	102	108	5	7	8	13	2.3
MA PM_{10}comb	158	52	39	81	81	133	18.2
MA NO comb	158	52	23	88	87	121	13.8
Bazaar							
SO_2	0	210	-	-	-	-	-
PM_{10}	198	12	30	78	81	157	30.3
NO	204	6	14	64	69	161	28.0
NO_2	168	42	25	30	33	48	7.3
NO_X	204	6	10	63	67	137	23.4
O_3	138	72	28	31	38	117	24.1
CO	204	6	2	9	8	16	3.3

- Not available

The results of case-crossover analysis are presented in Table 9.5. Stepwise backward elimination was used to choose the final model in which the seven-day moving average of PM_{10} and NO from Fatemi were the pollution variables significantly associated with poor lung function (see Table 9.5). In addition, using the difference between mean (81) and maximum (133) concentration of moving average of PM_{10} in this period to judge the size of the effect, such an increase in PM_{10} is predicted to lead to a decrease in the probability of poor lung function (OR = 0.1). Using the difference between mean (87) and maximum (121) concentration of moving average of NO in this period to judge the size of the effect, such an increase in NO is predicted to lead to an increase in the probability of poor lung function (OR = 19).

Table 9.5 Conditional logistic regression for lung function based on predicted value

Variable	Parameter Estimate	Standard Error	Chi-Square	Pr > Chi-Square	Hazard ratio	(95%CI) Lower	upper
Daily Temperature (T)	0.34	0.18	3.4486	0.06	1.4	1.0	2.0
T^2	-0.02	0.01	1.9721	0.16	1.0	1.0	1.0
School	-15.49	1312.00	0.0001	0.99	0	0	-
Shift	0.15	0.38	0.1491	0.70	1.2	0.5	2.5
MA PM_{10} comb(F)*	-0.05	0.02	5.0308	0.02	0.9	0.9	1.0
MA NO comb(F)*	0.09	0.03	6.5257	0.01	1.1	1.0	1.2

* Statistically significant p = 0.05

9.2.2.2 Lung function based on best blow

The descriptive data of worst lung function based on best blow (case definition two) are presented in Table 9.6. As indicated in Table 9.6, there were 166 cases of worst lung function using personal best blow and 332 control observations (two weeks before and after case dates). The average lung function was 125 L/min.

Table 9.6 Descriptive data of lung function based on definition 2 and air pollution

Variable	N	N Miss	Minimum	Median	Mean	Maximum	Std Dev
Lung function (BB)	498	0	60	120	125	220	31.0
Fatemi							
SO_2	0	498	-	-	-	-	-
PM_{10}	260	238	24	89	91	165	39.1
NO	260	238	43	92	94	160	25.3
NO_2	260	238	74	133	140	224	38.5
NO_X	260	238	62	132	134	229	37.4
O_3	156	342	4	8	8	17	3.7
CO	260	238	4	8	8	13	2.2
MA PM_{10} comb	375	123	19	84	83	140	20.6
MA NO comb	375	123	17	87	88	125	16.5
MA CO comb(ppm)	375	123	2	8	8	11	1.4
Bazaar							
SO_2	0	498	-	-	-	-	-
PM_{10}	443	55	30	87	91	184	35.2
NO	449	49	6	67	75	207	31.8
NO_2	361	137	25	30	33	48	6.6
NO_X	449	49	5	66	72	178	26.2
O_3	296	202	28	31	37	145	23.0
CO	469	29	2	9	8	16	3.2

- Not available

Conditional logistic regression using the PHREG procedure in SAS was performed, and used a conditional logistic model with a stratum for each matched set.

The results of case crossover analysis are presented in Table 9.7. All risk factors such as daily temperature, squared temperature, school, teaching shift, their interactions, seven-day moving average of daily air pollution PM_{10} from Fatemi, NO, NO_2, O_3 and CO comb at both stations (see Table 9.7) were included in the initial model. Stepwise backward elimination was used to choose the final model in which the seven-day moving average of PM_{10}, NO and CO at Fatemi station were the pollution variables significantly associated with poor lung function. From Fatemi station, using the difference between mean (83) and maximum (140) concentration of moving average of PM_{10} in this period to judge the size of the effect, such an increase in PM_{10} is predicted to lead to a decrease in the probability of airway obstruction (OR = 0.1). Using the difference between mean (88) and maximum (125) concentration of moving average of

NO in this period to judge the size of the effect, such an increase in NO is predicted to lead to an increase in the probability of airway obstruction (OR = 80). Using the difference between mean (8) and maximum (11) concentration of moving average of CO in this period to judge the size of the effect, such an increase in CO is predicted to lead to a decrease in the probability of airway obstruction (OR = 0.1).

Table 9.7 Conditional logistic regression for lung function at Fatemi

Variable	Parameter Estimate	Standard Error	Chi-Square	Pr > Chi-Square	Hazard ratio	(95%CI) Lower	upper
Daily Temperature (T)*	0.41	0.13	9.48	0.0021	1.5	1.2	2.0
T^{2*}	-0.02	0.01	6.22	0.0126	1.0	1.0	1.0
Shift	0.20	0.28	0.54	0.4606	1.2	0.7	2.1
School	-0.29	0.41	0.50	0.478	0.8	0.3	1.7
Shift × School	0.15	0.62	0.05	0.8156	1.2	0.3	3.9
MA PM_{10} comb(F)*	-0.04	0.01	6.99	0.0082	1.0	0.9	1.0
MA NO comb(F)*	0.12	0.04	11.09	0.0009	1.1	1.1	1.2
MA CO comb(ppm)(F)*	-1.02	0.36	7.89	0.005	0.4	0.2	0.7

*Statistically significant p = 0.05
MA: seven-day moving average

9.3 Discussion

This section of the study examined the association between air pollutants and poor lung function in elementary school children in District 12 of Tehran over six-week. In total, 562 students from two schools participated in the lung function study.

This study has shown a statistically significant relationship between outdoor air pollution and child's poor lung function. In this study, associations of seven-day moving averages of PM_{10}, NO and CO with poor lung function were found. While the frequency of poor lung function was high in December, this study showed the effect of NO concentration could increase the number of days with poor lung function. In other hand, higher concentration of NO is associated with higher rate poor lung function.

Nitric oxide (NO) is the most common form of nitrogen directly emitted into the atmosphere [Brunekreef et al., 1997]. In ambient outdoor air, nitric oxide (NO), which is emitted by motor vehicles, combines with oxygen in the atmosphere under the action of sunlight, producing nitrogen dioxide (NO_2) a major air pollutant and other NO_X. The previous studies showed nitric oxide does not significantly affect human health. On the other hand, elevated levels of NO_2 cause damage to the mechanism that protect the human respiratory tract and can increase a person's susceptibility to, respiratory infections [Hwang et al., 2000; Gilliland et al., 2001].

This is why it concerns in particular populations living near busy roads. At levels currently observed in Europe, exposure to NO_2 may decrease lung function [Peters et al., 1999] and increase the risk of respiratory problems, particularly in children [Neuberger and Moshammer, 2004]. Short-term exposure to peak levels can increase respiratory allergic reactions.

Overall, the study had good response rates with a response of 72%. Therefore, it can be considered representative for the busier areas of Tehran at least. To assure consistency in the measurements of lung function, the researcher used competition between students to get their best PEFR. The students were blinded to the hypothesis investigated in this study. One reason was that they could not check out the air pollution level every day as it is not available everywhere. It is presented every day on an electronic screen on Fatemi station only at the time were the data were collected and it is available online but the number of students who had access to internet was limited. Another reason was that the population does not express much concern about the level of air pollution. A possible confounder that was not controlled for in the analysis was the use of asthma medication. However, as seen in Chapter seven, only 10 students in that sample used this medication. The effect of this confounder would be to limit our ability to detect an effect, as it would potentially mask the effect of air pollution on lung function. Therefore, it is expected that selection and respondents bias have not substantially influenced the results of this study.

As a form of case-control was used in the analysis, a selection bias might be of concern in the selection of the controls. To prevent this, a symmetric bidirectional method was used; this was described as providing adequate control [Bateson and Schwartz, 2001].

9.4 Conclusion

This study has shown strong and consistent associations between children's poor lung function and outdoor air pollutants in District 12 of Tehran for some pollutants. The strong association found in this study was an increase in seven-day moving average of NO using both definitions. These impacts also appeared to be distinct from any temperature effects. PM_{10} and CO are not consistent with the literature. To answer the study question whether there is an association between air pollution levels and poor lung function, the study showed there is association between lung function changes or airway obstruction with air pollution levels. These data indicate that in circumstances in which NO level are chronically elevated, the level of exposure to NO in the previous seven-day can influence the level of lung function in children. Interestingly, other study in this thesis on absenteeism also showed the positive association between the concentration of NO and respiratory related absenteeism from school. This study adds the effect and positive association of NO on lung function to the literature.

Chapter 10: General discussion and conclusion

Previous chapters have reported analysis of respiratory illness related school absenteeism, hospital admissions, prevalence of asthma and poor lung function of primary school children in Tehran. It was found that exposure to air pollution had adverse impacts on absenteeism, hospital admissions, the presence of respiratory symptoms and measured lung function. The focus of this chapter is to bring together the various parts of this study and to provide a general overview.

The study was restricted to students at two primary schools and children of primary school age who were admitted to either of two hospitals over a two-year period. The study focused on primary students, as they are one of the vulnerable groups for adverse health effects of air pollution and they were located in the most polluted parts of the city.

This was a mixed method study. It was felt that a greater understanding could be provided if various possible effects of air pollution were assessed. A survey of general health of students provided a more detailed picture of students' health status, while measuring respiratory disease related absenteeism among the same children and hospital admissions of children of the same age range admitted to two hospitals, covering broadly the same area could provide additional knowledge about their health.

In this chapter, the strengths and limitations of the research will be addressed. Then, each study question is considered in turn, and the major findings are presented, and related to each other.

10.1 Strengths and limitations of the study

There were several strengths in this study. This study worked on four indices of air pollution: adverse health effects including school absenteeism, hospital admission, poor lung function prevalence and poor lung function. Literature shows that children living in more polluted areas have increased frequent cough, frequent sputum, chronic sputum, and doctor-diagnosed asthma. Such children also have significantly poorer lung function [Pearce et al., 2007].

This study has used three main statistical methods, Poisson, linear and logistic regression, to examine the association of air pollution levels and absenteeism, hospital admission and poor lung function. In addition, standardized international data instruments were used for this study, thus, allowing for easier comparisons with the literature.

A major limitation of this study was the great number of missing values in air pollution data. This caused substantial difficulties in using and interpreting traditional statistical analysis. However, this limitation could not be controlled by the researcher. A good way to deal with this issue is to use the case-crossover method, which is potentially less sensitive to the problem than more traditional methods, especially time-series models which do not easily adapt to missing values.

Another limitation was the difficulty in online accessibility of Persian sources. Electronic searching and even getting basic facts from Iran was often difficult, or even impossible. As much as possible, details on issues such as major fires affecting air pollution were sought, but it remains uncertain how complete this information was.

A final limitation was sample size. If for example, there had been any possibility of collecting more data from several hospitals and schools then the power of the study would have been enhanced. However, one lone researcher was not able to collect data from several areas in the limited time available for the study.

10.2 Air pollution levels in Tehran

From this study, air pollution levels in Tehran were high compared to WHO standards (see Chapter four). The population has been potentially exposed to ambient air concentrations in excess of the limit value set for the protection of human health (annual, 24 hourly and hourly mean) for most days of the year or even the whole year. Compared to some other cities in the world and depending on the air pollutants, the pollution was at least four times the annual level. As mentioned in the introductory chapter, likely reasons for the high level of air pollution are, firstly, vehicle emissions followed by industry and households.

The results showed significant association between meteorological factors and most measured air pollutants. This made it especially important to include one key relating a meteorological factor, temperature, in statistic models relating health outcomes, to air pollution as described earlier.

One major problem was the consistency and availability of data. Particularly, the SO_2 data had many missing values (including long sequences) and values that were widely different between stations; these differences sometimes far exceeded expectations of variability. The problem of missing values was also present in some other variables, especially PM_{10} measurements at the Bazaar station. It is possible that if there were not such missing values, association between PM_{10} levels and lung function would be statistically stronger.

Another observation seen in Chapter four was the effect of day of week on air pollution levels. The result shows air pollution levels were highest from Saturday to Wednesday, decreased on Thursdays and decreased further on Fridays. The reason was that Iran is an Islamic country. Therefore, the working week starts on Saturday and the day of rest is Friday. In addition, most government offices are closed on Thursdays. Therefore, less vehicle movement is expected on these two days.

In Tehran, the population has been potentially exposed to ambient air concentrations of SO_2 in excess of the Iranian limit value set for the protection of human health (365 $\mu g/m^3$ 24 hourly mean). The extreme of this exposure was a seven-day period in 2002 when pollution exceeded the Iranian limit by at least 375 $\mu g/m^3$ on each day. Using the WHO limit (125), the population was potentially exposed to excess air pollution for 304 days in 2000, for the entire year of 2001, and for 241 days in 2002.

In the period 2000-2002, the population of Tehran has also been potentially exposed to ambient air concentrations of PM_{10} in excess of the Iranian limit set for the protection of human health (150 $\mu g/m^3$ annual mean). In 2002, the measurement of PM_{10} concentration Bazaar showed exceedances resulting in the worst year of polluted air with PM_{10}. Compared to other cites, pollution was higher than the annual levels in the other cities for all years except for Hong Kong in 2001 and 2002. There are no recognized 24 hourly standards for WHO and Iran for PM_{10}.

During the period 2000-2002, the population of Tehran has been potentially exposed to ambient air concentration of NO_2 in excess of both WHO standards (annual 40-50$\mu g/m^3$, hourly 200$\mu g/m^3$) and Iranian annual standards (100$\mu g/m^3$) each year. Most days during 2001 were polluted, although there were no days that showed excess hourly pollution levels. In both 2000 and 2002, there were over 100 days with hourly exceedances. In comparison with other cities during 2001, Tehran had the most polluted days (see Table 4.10 – Table 4.12).and annual standard was 2-4 times the WHO.

In the period 2000-2002, the population of Tehran has been potentially exposed to ambient air concentrations of O_3 in excess of the WHO limit value set for the protection of human health (120 μg/m^3 8 hourly mean). Specifically, three days during 2002 showed the worst polluted air. Compared to other cities, Tehran was heavily polluted for the annual whole year 2001. There are no recognized 24 hourly standards for Iran for O_3.

In the period 2000-2002, the population of Tehran has been potentially exposed to ambient air concentrations of CO in excess of the Iranian limit value set for the protection of human health (11,250 μg/m^3 8 hourly mean). The worst year of polluted air occurred during 2000 and included 298 days (81%), or 314 days (87%) using WHO standard (10,000 μg/m^3 8 hourly mean).

10.3 The association between elevated concentrations of air pollution and respiratory disease related school absenteeism

Exposure to air pollution is one of the main determinants of respiratory disease in children. This effect of air pollution may increase school absenteeism. Park et al. [2002] found that PM_{10} and O_3 were positively associated with illness-related absenteeism and they did not find any effect of NO_2 on absenteeism. Chen et al. found that CO and O_3 in a time-delayed effect had statistically significant positive relationships with absenteeism, while PM_{10} was negatively associated with absenteeism. Gilliland et al.[2001] found that O_3, but not NO_2 nor $PM_{10,}$ was associated with increase in respiratory illness related school absenteeism. Hwang et al. [2000] found that school children's risks of illness absenteeism were associated (statistically significant) with acute exposure to NO_2 with a 1-day delay at levels below the WHO's guideline.

When studying the health effect of hazardous exposures, children are often considered as if they were small adults. However, children represent the largest sub-population susceptible to the adverse health effects of air pollution [Kleinman, 2000]. As children grow, their organ systems are still developing and their normal growth may be affected when exposed to pollutants at critical periods. Children also spend more time outdoors than adults [Kleinman, 2000], and concentrations of pollutants of an ambient origin are higher outdoors than indoors. Children playing outdoors also engage in exercise that increases ventilation. This is particularly true in afternoons, when photochemical pollutant concentrations (nitrogen oxides, ozone, and particulate) are highest. In this study, an association with respiratory related absenteeism was found in the 6-11 year age group and particulate, nitric oxide, and ozone exposures. However, it was found that NO was the only pollutant associated with increase in respiratory illness related school absenteeism. This study showed only association here, not causes. Other studies have reviewed the air pollution affects on human respiratory disease, and looked at possible cause effects. Bernstein [2004] found that diesel exhaust particles increase airway inflammation and exacerbate asthma and chronic obstructive pulmonary disease, and there have been other studies on the inflammatory impacts of ozone on respiratory disease [World Health Organisation, 2004; Mikerov et al., 2008].

One of the problems in this study was the existence of many missing values in the air pollution data and a low level of absenteeism. The power of the study was not as strong as would have been possible with data that were more reliable and with fewer missing observations.

In the Poisson regressions presented in chapter five, the ratio of residual deviance to the degrees of freedom was substantially higher than one, indicating that there were unattributed sources of variation which were not allowed for in the fitted model. An effect on the interpretation of the model was to overestimate significance of individual fitted parameters.

For this study, one to two weeks were used as control period (one-week exposure window for the Poisson analysis, two weeks for the case-crossover). Given the literature [Ransom and Pope III, 1992], this may underestimate the size of the effect for particulate matter. However, given the number of missing values for the air pollution data, it was considered that a longer window would give too many missing values to be of any worth.

10.4 The association between elevated concentrations of air pollution and hospital admissions in Tehran

Associations were found between daily hospital admissions for respiratory related illnesses among children of primary school age and some air pollutants, especially O_3, but also particulate matter. However, all were inconsistent with the literature. Daily hospital admission covered a period which daily school absenteeism could not since normally schools are closed in summer in Iran. In this study, hospital admissions were higher in summer. The summer effects of daily hospital admissions could be related to indoor air pollution such as environmental tobacco smoke. Particularly given the high temperature during the day, children may often remain indoors during summer.

Statistical power was severely limited by the incomplete air pollution data and the limited number of admissions among children. The highest number of missing values was for SO_2 (365 days at Fatemi) and the lowest was for CO (24 days at Bazaar station). The hospital admission data was for 256 children admitted on 196 days in two hospitals over two years. The range of daily hospital admissions was from zero to four. If data on admissions for more hospitals were available, this might have demonstrated stronger association between air pollution and hospital admissions. Further research is required to examine the interaction between indoor and outdoor air pollutants, exposure response relationships and health impacts. For the present, this study indicates that current daily levels of air pollution are likely to be harmful to children and policies to future reduce air pollution should be continued.

10.5 Prevalence of poor lung function or asthma and patterns of recognized determinants of asthma in Tehran

Although a questionnaire cannot provide a perfect scale to show the real prevalence, since it was a self-reported scale, it can show risk factors associated with prevalence of any illnesses. Using traffic light indicators, the results in this chapter show that overall prevalence of poor lung function was 3% and 12% respectively using predicted value and best blow as described earlier. The differences between females and males are substantial. This study is consistent with another study carried out by Greavesa et al [2007] in schools in Minneapolis (USA) on immigrant children. In that study, females had significantly lower FEV_1 (-8.8%) and FVC (-11.0%) than males, and a history of physician-diagnosed asthma was not associated with decreased lung function.

Some clinicians use the proportion of children who recorded one or more peak flows at less than 80%, less than 85%, and less than 90% of their personal best as indicators. This gives indicators of the prevalence of asthma (defined as variable airflow obstruction) of various levels of severity. Using these indicators, in descending order of severity, the prevalence is 96%, 99% and 100%. Again, there are differences between females and males, with higher prevalence for females. However, this definition was not consistent with the traffic light system, which used as different cut-offs and produced much smaller estimates of ‘prevalence’. As the definitions are different, compatible prevalence estimates can hardly be expected.

A traffic light system showed 12% of students in this study as having poor lung function using predicted value (see Table 8.3) and 30% as having airway obstruction using best blow (see Table 8.6). Airway obstruction or asthma indicator prevalence was 37% for females and 17% for males using best blow (see Table 8.6). Prevalence of ‘current wheeze’ was lower for females than males, using the ISAAC questionnaire (see Table 7.8). Combining both tools, questionnaire and lung function definitions showed no poor lung function or airway obstruction for females or males (see Table 8.8). In this study, the gender difference in prevalence of ‘current wheeze’ and ‘current asthma’ is neither consistent with another study carried out in Tehran [Masjedi et al., 2004] nor with lung function results (see Table 8.3 and Table 8.6). The evidence in Table 8.8 of the association between predicted values and questionnaire responses is based in every case on either one or two students with a positive questionnaire response. This provides rather flimsy support for association, especially since it is possible that some or all of this very small number of students used asthma relief medication before taking lung function tests, as has been reported in ATS standards [Miller et al., 2005]. While there is no agreed definition of asthma, some definition was needed. Asthma prevalence can be measured in terms of self-reported wheeze, doctor-diagnosed asthma, or a combination of symptoms and lung function abnormality [Pekkanen and Pearce, 1999]. Poor lung function and severity of obstruction of airway can be classified in a range from clear to poor. The only classification of airway obstruction, which significantly matched with questionnaire results, was clear airway mostly for females.

Objective measures of lung function combined with asthma symptoms did not allow classification of asthma into persistent and intermittent. Approximately quarter of Iranian children have wheezed in the past 12 months, and it seems unlikely that they all have intermittent or persistent asthma that requires treatment. At present, there is no way to classify asthma on wheeze alone, although, in many studies, children with more than four wheeze episodes per year are regarded as having ‘asthma’. Masjedi et al [2004] found that among 6-7 year olds who report current wheeze 30% reported more than four wheeze episodes (about 11% of the population).

Having doctor diagnosis of asthma is regarded as the gold standard, and is often taken as the mandatory definition. It was not available for this study, because of the low socio-economic class of the students, many of whom would not have ‘easy’ access to general practitioner. The accuracy of asthma prevalence could be provided by using both questionnaire scores and lung function records. However, there are calculation of lung function abnormality was detected by using two definitions normal predicted and personal best blow. Two indicators derived from those definitions as prevalence of poor lung function for 12% and prevalence of airflow obstruction for 30%, which obviously is asthma indicator.

This study has determined the prevalence of poor lung function using a standard questionnaire. It has also determined an alternative prevalence estimation using lung function readings over the six weeks, and using American Thoracic Society guidelines. It has also shown statistically significant relationship of known and suspected risk factors with the prevalence of poor lung function. In addition, this study has compared of questionnaire responses with measured lung function data, and the prevalence of poor lung function using different definitions. Other studies in Iran using ISAAC questionnaire showed current wheeze prevalence of 8.6% for 6-7 years old children in Tehran [Masjedi et al., 2004]. This study showed 22% for primary school children in a broader age range. Using three alternative definitions children in this study have been shown to present clearly problematic lung function, similar to findings in another Iranian study [MirSaeid Ghazi et al., 2004]. This study confirmed that there is no gold definition for asthma. This study has shown 22 % of students had current wheeze using ISAAC questionnaire, that is, 21% female and 23% male. The prevalence of current wheeze is consistent with that found in an Oceania study, but not with worldwide trends [Pearce et al., 2007; Weinmayr et al., 2007]. In these studies, the mean symptom prevalence of current wheeze in the last 12 months was 11.6%.

The measurement of severity of asthma is difficult. The nature of mild, moderate, or severe asthma depends on the perspective of the observer. Using self-reported wheeze with lung function can show persistent or intermittent asthma. Under the classification of any recorded lung function less than 50%, this study showed that the prevalence of asthma is zero.

10.6 Association between the occurrence of asthma episodes or poor lung function in relation to air pollution levels

This study has shown a statistically significant relationship between outdoor air pollution and child's poor lung function. In this study, associations of seven-day moving averages of PM_{10}, NO and CO with poor lung function were found. While the frequency of poor lung function was high in December, this study showed the effect of NO concentration could increase the probability of poor lung function. In other hand, higher concentration of NO is associated with higher poor lung function probability.

Nitric oxide (NO) is the most common form of nitrogen directly emitted into the atmosphere [Brunekreef et al., 1997]. In ambient outdoor air, nitric oxide (NO), which is emitted by motor vehicles, combines with oxygen in the atmosphere under the action of sunlight, producing nitrogen dioxide (NO_2) a major air pollutant and other NO_X. The previous studies showed nitric oxide does not significantly affect human health. On the other hand, elevated levels of NO_2 cause damage to the mechanism that protect the human respiratory tract and can increase a person's susceptibility to, respiratory infections [Hwang et al., 2000; Gilliland et al., 2001].

This is why it concerns in particular populations living near busy roads. At levels currently observed in Europe, exposure to NO_2 may decrease lung function [Peters et al., 1999] and increase the risk of respiratory problems, particularly in children [Neuberger and Moshammer, 2004]. Short-term exposure to peak levels can increase respiratory allergic reactions.

Overall, the study had good response rates with a response of 72%. Therefore, it can be considered representative for the busier areas of Tehran at least. To assure consistency in the measurements of lung function, the researcher used competition between students to get their best PEFR. The students were blinded to the hypothesis investigated in this study. One reason was that they could not check out the air pollution level every day as it is not available everywhere. It is presented every day on an electronic screen on Fatemi station only at the time were the data were collected and it is available online but the number of students who had access to internet was limited. Another reason was that the population does not express much concern about the level of air pollution. A possible confounder that was not controlled for in the analysis was the use of asthma medication. However, as seen in Chapter seven, only 10 students in that sample used this medication. The effect of this confounder would be to limit our ability to detect an effect, as it would potentially mask the effect of air pollution on lung function. Therefore, it is expected that selection and respondents bias have not substantially influenced the results of this study.

As a form of case-control was used in the analysis, a selection bias might be of concern in the selection of the controls. To prevent this symmetric bidirectional method was used, which was describes as being used adequate control [Bateson and Schwartz, 2001].

10.7 The relationship between chapters

The results of chapter four showed the population of Tehran potentially was exposed to adverse health effects of SO_2, PM_{10} and CO particularly as they regularly exceeded WHO standards as well as Iranian standards. Using the difference between of mean and maximum concentration of each pollutant at both stations, allows for a comparison of the magnitude of effect of each of the pollutant within the range of what actually occurs in Tehran. The results are presented in Table 10.1 and those results show a consistent pattern. For school absenteeism, The strongest association found in this study was equivalent to an increase in daily absenteeism of 0.8 for the Poisson model, and an odds ratio of 10 for the probability of daily absenteeism for case-crossover analysis, daily school absenteeism due to an increase from mean to maximum in seven-day moving average of NO. For hospital admissions, associations between daily hospital admissions for respiratory related illnesses among children of primary school age and some air pollutants were seen. However, all were inconsistent with the literature. For lung function, Prevalence of poor lung function was more in females than males. The largest prevalence of poor lung function was 12% and the largest prevalence for airway obstruction as asthma indicator in this study was 30% using best blow. This study has shown strong and consistent association between child's poor lung function and outdoor air pollutants in District 12 of Tehran for some pollutants. The strong association found in this study was an increase in seven-day moving average of NO using both definitions. These impacts also appeared to be distinct from any temperature effects. PM_{10} and CO are not consistent with the literature.

Table 10.1 Comaparing the outcomes of result chapters

Pollutant	Change from mean to maximum level	Measure	Regression / sub dataset	Outcome
Fatemi				
MA PM_{10}	-0.4 daily absenteeism	Count	Poisson regression, full data	School absenteeism
MA PM_{10}	decrease in probability of daily absenteeism (OR = 0.2)	OR	case-crossover	School absenteeism
MA PM_{10}	decrease in probability of daily poor lung function (OR = 0.1)	OR	case-crossover	Lung function (PV)
MA PM_{10}	decrease in probability of daily airway obstruction (OR = 0.1)	OR	case-crossover	Lung function (BB)
MA NO	increase in probability of daily absenteeism (OR = 10)	OR	case-crossover	School absenteeism
MA NO	increase in probability of daily poor lung function (OR = 19)	OR	case-crossover	Lung function (PV)
MA NO	increase in probability daily airway obstruction (OR = 80)	OR	case-crossover	Lung function (BB)
MA O_3	decrease in probability of daily absenteeism (OR = 0.1)	OR	case-crossover	School absenteeism
MA CO	decrease in probability of daily airway obstruction (OR = 0.1)	OR	case crossover	Lung function (BB)
Bazaar				
MA NO	+0.8 daily absenteeism	Count	Poisson regression, full data	School absenteeism
MA NO_2	-0.7 daily absenteeism	Count	Poisson regression, full data	School absenteeism
O_3 (Same day morning)	-2.0 daily hospital admission	Count	Poisson regression, full data	Hospital admission
O_3 (Same day morning)	decrease in probability of daily hospital admission (OR = 0.1)	OR	case-crossover	Hospital admission

BB = Best Blow
PV = Predicted value
OR = Odds Ratio
MA = Seven-day Moving average

10.8 Conclusions

The aim of this study was to examine the relation between concentrations of daily air pollutants and air pollution adverse health effects on children of elementary school age in Tehran as mentioned in Chapter one. The aim of this section is to review study questions and provide conclusions to the study.

- What are the air pollution levels in Tehran in relation to meteorology parameters, and guideline levels locally and around the world?
  When comparing the air pollution levels against Iranian and WHO guidelines, the result showed their population of Tehran was exposed to potentially adverse health effects of air pollution for most days of all years in the 2000-2002 period (Chapter 4).

In particular, massive exceedences occurred frequently for several pollutants, namely SO_2, PM_{10} and CO.

- What is the association between elevated concentrations of air pollution and respiratory disease related school absenteeism?
  The concentration of seven-day moving average of PM_{10}, NO_2 and O_3 was found to be associated negatively and significantly with absenteeism. The concentration of seven-day moving average of NO was found to be associated positively and significantly with absenteeism (Chapter 5).

- What is the association between elevated concentrations of air pollution and hospital admissions of children in Tehran?
  Using two statistical methods, the concentration of morning ozon was found to be associated negatively and significantly with hospital admissions (Chapter 6).

- What is the prevalence of asthma in Tehran and what are the patterns of recognized determinants of asthma?
  Using the ISAAC questionnaire, the reported prevalence current wheeze was 21% and 23% in female and male, respectively. The known environmental factors, which act as risk factors for asthma, were colds or flu for 20%, smoking as 11% and weather for 8%. Any students who have smoker at home have 38% more likely to have current wheeze (Chapter 7).
  Using two lung function based definitions the prevalence of poor lung function or asthma were 3% (<2SD of normal predicted), 12% (<50% of predicted value) and 30% (<50% of their personal best blow). When the questionnaire was combined with those definitions then the significant ones could only matched with the cleat airway.
  The prevalence was related to gender and shift of the schools. The results have shown the prevalence was higher in females than males (Chapter 8).

- What is the association between the occurrence of asthma episodes or poor lung function in relation to air pollution levels?
  Using conditional logistic regression between worst lung functions days and air pollution levels, it was found the seven-day moving average of PM_{10}

concentration was ignorantly and negatively; and the seven-day moving average of NO concentration was significantly and positively associated with worst lung function using predicted value (Chapter 9).

Using conditional logistic regression between worst lung functions days and air pollution levels, it was found that seven-day moving average of PM_{10} and CO concentrations were ignorantly and negatively associated with worst lung function days using best blow. However, worst lung functions days were associated positively significant with seven-day moving average of NO (Chapter 9).

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Appendix I

To have a clear overview of air pollution in Tehran, it is important to have an understanding of the various governmental bodies involved in air pollution regulations as well as an explanation of their responsibilities and functions. An organizational chart and a summarized history of the Iranian government are discussed. Then each environmental body is discussed separately.

A1.1 Organization in Iran

The Islamic Republic of Iran was formed in 1979 through the Islamic Revolution. Since the end of the Iran-Iraq War (1980-1988), the Government of Iran has been engaged in reconstruction and developing intra structure. During the decade after the end of the war, recovery has been underway in all sectors [Japan International Cooperation Agency, 1997:2-7]. The importance of the environmental sector can be seen in the organization of the Government of Iran in Figure A1.1 and Figure A1.2 as the head of the Environment Protection Organization is one of the vice presidents and a member of the president’s administration.

A1.2 Iranian Department of Environment

The history of environmental protection activities in Iran has commenced for three decades. Initially, the Department of Environment did not exist. First, it was created as Iranian Wildlife Association (IWA) in 1956, to protect natural resources from extinction [The Department of the Environment of Iran, 2004].

In 1967, the Hunting and Fishing Organization (HFO) replaced the IWA, which was renamed as the Environmental Protection Organization (EPO) in 1972. The High Council of Hunting and Fishing supervised HFO. This council consists of the Ministers of Agriculture, Treasury and Defence along with six experts. This council was then restructured and called the High Council for Environment Protection [The Department of the Environment of Iran, 2004].

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Figure A1. 1 Governmental organization of Islamic Republic of Iran [Japan International Cooperation Agency, 1997; ParsTimes, 2006]

A1.2

In 1974, the restructured EPO was administered by the High Council of Environmental Protection (HCEP). Currently, the President chairs the Council and head of the DOE is one of the Vice-Presidents. The HCEP consists of the Ministers of Agricultural Jihad, Interior, Foreign Affairs, Industry, Science-Technology and Research, and Health and Medical Education, as well as the Head of the State Management and Programming Organization, and the Institute of Standard and Industrial Research [The Department of the Environment of Iran, 2004].

Air Pollution Reduction Committee is part of the DOE. The members of this Committee are the representatives of the HCE, the ministries of Oil, Telecommunication and IT, Health & Medical Education, Interior, Traffic Police, Meteorological Organization, and Governor General of Tehran Province, Management & Planning Organization, Air Quality Control and the United Bus Companies (affiliated to the Municipality of Tehran) [The Department of the Environment of Iran, 2004].

The Air Pollution Reduction Committee is responsible for formulating policies to address air pollution in Tehran through coordination among relevant ministries and organizations. In addition, it suggests executive programs, secures managerial instruments and approves of the timetable of projects. It also provides consultation about the mobilization of financial resources. The committee determines practical practices such as prevention of registration of diesel based buses and minibuses (unless they were converted to CNG fuel based), prepares progress reports and obtains the necessary approvals of the HCE, the Cabinet and the Parliament [The Department of the Environment of Iran, 2004].

According to Article 50 of the Constitution of the Islamic Republic of Iran (IRI) “Environmental conservation in the IRI is a public duty. Therefore, economic or other activities which cause environmental pollution or other irreversible damages are forbidden.” [International Constitutional Law, 1997] To implement this article some regulations, standards and rules were put into place. For example, air pollution emission standards, consisting of some regulations about automotive emissions were implemented in 1994 [Shahidi, 2004].

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Figure A1. 2 Iranian Department of the Environment [Iranian Department of Environment, 2004]

A1.2.1 Emission regulations

Some of the regulations and laws which are related to air pollution and enacted to protect the environment are:

- Municipality law concerning air pollution, solid waste disposal and reduction of industrial pollution in 1955;
- The Environmental Protection and Development Act (EPEA) in 1974;
- The executive rule of EPEA in 1975;
- The Clean Air Act in 1975;
- Article 50 of the Constitution of the Islamic Republic of Iran (IRI) approved in December 1979;
- Air pollution control law in 1995;
- Industrial location guidelines;
- Environmental impact assessment guidelines and framework in 1995;
- Air pollution emissions standards in 1998.

The emission regulations consist of accreditation of testing agencies, defining emission limits for Type Approval (TA) and Conformity of Production (COP) for new cars as well as for in-use vehicles. In other words, COP sets the standards required to produce the products series which meet the type approval concerning the specification, performance and the other requirements which mentioned in Type approval [Vehicle Certification Agency, 1999].

Under emission regulations, the performance of newly built vehicles should be checked for emission rates and emission factors against the approved standard levels which are shown in Table A1.1 & A2.2.

Table A1. 1 Emission standards for vehicles [Masahiko, 2003; Iran Daily, 2005]

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- Type Approval

Under the DOE regulations, all car manufacturers need to make a prototype of their new product and send it to the centre for Vehicle Research and Innovation at SAIPA[1] Company. All prototypes are tested against the necessary emission standards which were mentioned in Table A1.2. Once it is tested and passes the relevant standard, then it can get the "Type Approval" (TA). This process is under the supervision of DOE. After the prototypes get their TA, then the new product may continue for mass production [Masahiko, 2003].

- Weekly testing of mass produced passenger cars

Randomly selected cars are sent to the reference test centre every week to take part in the TA process. This is to ensure that all in-use vehicles are tested against emission standards.

- Test process for other vehicles

1 It is stand for French sentence of Societe Annonyme Iranienne De Production Automobile

Currently, all heavy vehicles & motorcycles are required to pass the emission standards and get the certificate which is issued by the original manufacturer of their product as presented in Table A1.3 and Table A1.4. From the 21st of March 2005, the opening day of the test centre of DOE, the same process which is used for passenger cars has been applied to other types of vehicles. Thus, under the emission standards, the domestic importers and producers of petrol vehicles shall be charged if they do not meet the necessary standard which is mentioned in Table A1.2. As shown in Table A1.2 for example when a car is examined against the standard ECER-83.00 it should exhaust not more than 6.16-7.40 gram Carbon Monoxide and 1.60 -1.99 gram maximum Hydrocarbons (HC) and NO_X per kilometre to get TA and COP.

Table A1. 2 Pollutants standards for light and heavy duty vehicles [Air pollution Research Bureau, 2005]

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Table A1. 3 Pollutants standards for Diesel Motor Vehicles [Masahiko, 2003]

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Table A1. 4 Permissible limits for reference Weight and Exhaust Emissions for Motorcycles [Masahiko, 2003]

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The Department of the Environment (DOE) is responsible for air monitoring all over Iran, on site inspection of emission of pollutants from industries, environmental

[1] g/test

research, education and other matters. The organization of DOE is shown in Figure A1.2. As shown in Figure A1.1, there are several other ministries with some responsible for environmental matters Health and Medical Education, Industry and Oil.

Ministry of Health (MOHME): MOHME has 10 stations for measuring air pollution of Tehran. Three of them are under international observations [Japan International Cooperation Agency, 1997]. The organizational chart of MOHME is shown in Figure A1.3.

Ministry of Industry (MOI): Under the Iranian law all industries are under the supervision of MOI including the automobile industry. As shown in Table A1.5 the emission standards, which are used in Iran, require Iran Khodro Co., the biggest car manufacturer in Iran and other manufacturers to make an engine which satisfies these emission standards. Thus, MOI is not responsible for maintenance of cars. As mentioned before, industrial emission control is supervised by DOE and is under the authority of MOI.

Ministry of Oil (MOO): The Ministry of Oil supervises and controls all matters concerning oil. These matters include quality of petrol, diesel, and heavy oil and price of oil; all of which are the key elements for environmental problems [Japan International Cooperation Agency, 1997].

Table A1. 5 The emission standards [Masahiko, 2003]

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Figure A1. 3 Organization chart of Ministry of Health and Medical Education [Ministry of Health and Medical Education, 2005]

Islamic Republic of Iran Meteorological Organization (IRIMO): Meteorological observations are being made at two stations in Tehran with one located in the North and another at the Mehrabad International Airport. The IRIMO has four kinds of meteorological observation stations, namely “Synoptic”, “Upper Air”, “Climatology” and “Rain gauge”. The data of the “Synoptic” stations are particularly useful because they are obtained hourly or every 3 hours and cover full items of observation. Observation items include atmospheric pressure, wind direction and speed, temperature, humidity, visibility and so on. In 1947, it established a website so the daily measures could be extracted online from http://www.weather.ir/.

Air Quality Control Company (AQCC)[1] was founded in 1993 by Municipality of Tehran. The relationship of AQCC and Municipality of Tehran is shown in Figure A1.4

AQCC is a research centre, which is involved in presentation of relevant countermeasures to improve air quality in Tehran. The major role of AQCC is carrying out research, studies, consultation, planning and implementation of various projects. It also provides commercial services regarding air and noise pollution of urban and industrial environment, mobile and stationary sources as well as ambient area. It has the following functions [Air Quality Control Company, 2001]:

[1] Control in Persian language means monitoring.

- Operation and managing the system for measurement and monitoring of air and noise pollution;
- Providing consultations and implementation of plans for measurement and control of air and noise pollution;
- Public training and methods for reduction of air and noise pollution;

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Figure A1. 4 Organizational chart of Municipality of Tehran [Fardi, 2001a]

Appendix II: Literature Search Strategy

The principle databases accessed in the literature were Medline, Science Direct and Proquest. Medline was used as the main source for searching literature related to air pollution and health effects of children. Key words such as ‘ air pollution’, ‘lung function’ , ‘pulmonary function’, ‘children’ , ‘respiratory symptoms’, ‘absenteeism’, ‘hospital admission’ and ‘ hospitalization in only English language texts were used. Then suitable results for each section were combined to get the matched results using Boolean operator ‘and’. Science Direct and proquest were used for searching in since the selected references can be directly exported to Endnote. The most general key word such as air pollution was used first. Next, the aforementioned keywords were searched one by one within the results. The only difference between these two database was exporting the marked reference by proquest to Endnote needed further correction. Snow balling method was used for searching literature in the references listed in searched publications. This was also the main strategy to search literature on analysis methods.

Google scholar search engine was used as an efficient search engine. The key words such as ‘air pollution’ ‘delayed effect’ or some guidebooks for using SAS were used Google search engine was used as part of a general back up search strategy, but also to mainly specific institutional and government websites such as http://www.irimo.ir/english/index.asp and organizational chart of government administration or www.thoracic.org , http://www.nationalasthma.org.au/ or http://isaac.auckland.ac.nz/ The UOW library catalogue was also used as a general resource in searching for books, including textbooks and research monographs. The UOW serials were used for finding the non-electronic journals too.

The referenced used in Chapter 2 is presented in Table A2.1.

Table A2.1 References used in literature review

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
Aekplakorn	2003	SO_2, PM_{10}	Lung function	175	Spirometry	General Linear mixed model	2.2, 2.4.3.1	Case-control	Declines in pulmonary function among asthmatic children were associated with increases in particulate air pollution, rather than with increases in SO_2.
Alves and Ferraz	2005	SO_2, PM_{10}	Hospital admission	all age groups		Descriptive	Intro	Meta analysis	The observation of respiratory symptoms for concentrations below the current ambient standards, in agreement with previous studies carried out in the same area and other countries, suggests that it is urgent the process of updating and revision of those values in order to protect in effect the health of populations.
American Lung Association	1991						2.4.1, 2.4.1.2		
American Lung Association	2000						2.4.3.2		
American Lung Association	2005						2.4.2		
Anonymous	1998						Intro		
Anonymous	2005						Intro, 2.4.3		
AQCC	2002						2.1, table2.1-2.5		
Arif et al.	2003						2.4.3		This study observed racial/ethnic differences in the prevalence of asthma and wheezing and identified several important risk factors that may contribute to development and/or exacerbation of asthma and wheezing.

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
									Contrary to earlier reports, the proxy measures of indoor air pollution used in this study were not found to be associated with increased risk of asthma and wheezing.
Asgari et al.	1998						2.4.2, 2.4.3.3		
Avol et al.	2001	PM_{10}, NO_2, O_3	Lung Function + Questionnaire	110	Spirometry	Linear Regression	2.4.3.4	Prospective, Longitudinal	
Beasley et al.	1997						2.4.3		
Beckett	1999						2.4.1.1		
Bornestein	2002						2.4.3		
Boutin-Forzano et al.	2004	SO_2, NO_2, O_3	Hospital admission	549		Case-crossover	2.4.5	Case-crossover	No association could be shown between ER visits and SO_2 or NO_2 levels. In contrast, there was a statistically significant association between ER visits and mean O3 levels, on the day of admission and on D -2 and D -3. For an increase of 10 microg/m^3, the risk of requiring an ER admission increased by 6-10%.
Braun-Farlander et al.	1994						2.4.2		
Brunekreef	1997	BS	Lung Function	1213			2.4.3.2		Exposure to traffic-related air pollution, in particular diesel exhaust particles, may lead to reduced lung function in children living near major motorways.
Burnett et al.	1994	O_3	Hospital admission	168			2.4.5		Positive and statistically significant associations were found between hospital admissions and both ozone and sulfates recorded on the day of admission and up to 3 days prior to the date of admission. Five percent of daily respiratory admissions in the months of May to August were associated with ozone, with sulfates accounting for an

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
									additional 1% of these admissions. Ozone was a stronger predictor of admissions than sulfates. Positive and statistically significant ($P < 0.05$) associations were observed between the ozone-sulfate pollution mix and admissions for asthma, chronic obstructive pulmonary disease, and infections. Positive associations were also found in all age groups, with the largest impact on infants (15% of admissions associated with the ozone-sulfate pollution mix) and the least effects on the elderly (4%). Temperature had no effect on the air pollution-admission relationship. Ozone (lagged 1 day) and sulfates (lagged 1 day) displayed a positive association with respiratory admissions for 91 and 100% of the 168 acute care hospitals, respectively. Air pollution was not related to a class of non-respiratory admissions, which served as a negative control, nor was it related to admissions in the winter months of December to March, when ozone and sulfate levels are low and when people spend a considerable amount of time indoors.
Burnett et al.	1997	SO_2, COH, NO_2, O_3 and CO	Hospital admission	720519		Regression	2.4.5	Longitudinal	Daily high hourly concentration of ozone recorded 1 day before the date of admission was positively associated with respiratory admissions in the April to December period but not in the winter months. The relative risk for a 30 ppb increase in ozone varied from 1.043 ($P < 0.0001$) to 1.024 ($P = 0.0258$) depending on the selection of covariates in the regression model and subset of cities examined. The association between

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
									O_3 and respiratory hospitalizations varied among cities, with relative risks ranging from 1.000 to 1.088 after simultaneous covariate adjustment. PM_{10} and CO were also positively associated with respiratory hospitalizations.
Caderon-Garciduenas and Fordham	2001						2.4.2		
California Air Resources Board	2005						table2.1-2.5		
Chen et al.	1998	SO_2, PM_{10}, NO_2, O_3, CO, NO_X, NO, THC, and NMHC.	Questionnaire	4072		Multiple Logistic Regression	2.4.3.3	Cross sectional	Only nasal symptoms of children living in the petrochemical communities were more prevalent than in those living in the rural community. Although the association with ambient air pollution is suggestive, the cross-sectional study cannot confirm a causal relationship; thus further studies are needed.
Chen et al.	1999	SO_2, PM_{10}, NO_2, O_3, and CO	Lung function	941	Spirometry	Multivariate linear model analysis	2.4.2	Cross sectional	We found a significantly negative association of peak O3 concentration on the day before spirometry with individual forced vital capacity and forced expiratory volume in 1 sec. The decrease in children's lung function can occur at peak hourly O3 concentrations < 80 ppb. The slope of lung function decrease for Taiwanese children is approximately 1 mL/ppb for peak hourly O3 exposure.
Chen et al.	2000	PM_{10}, O_3CO	Absenteeism	27793		Correlation analysis	2.4.3.1, 2.4.4	Cross sectional	We found that CO and O3 were statistically significant predictors of daily absenteeism in elementary schools. For every 1.0 ppm and 50 ppb increase in CO and O3, the absence

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
									rate would increase 3.79% (95% CI 1.04–6.55%) and 13.01% (95% CI 3.41–22.61%), respectively. However, PM10 values were negatively correlated with school absenteeism.
Chestnut et al.	1991	PM_{10}, TSP	Lung function	23808	Spirometry	Regression	2.4	Cross sectional	CO and O_3 were statistically significant predictors of daily absenteeism in elementary schools. For every 1.25 and 107 $\mu g/m^3$increase in CO and O3, the absence rate would increase 3.79% and 13.01%, respectively. However, PM_{10} values were negatively correlated with school absenteeism.
Chhabura et al.	2001	SO_2, PM_{10}, NO_2, O_3, CO, TSP, PM2.5	Questionnaire + Lung function	4171	Spirometry	Multiple Logistic Regression	2.4.2	Cross sectional	In the comparison of non-smoking residents of lower- and higher-pollution zones stratified according to socioeconomic levels and sex--chronic cough, chronic phlegm, and dyspnea (but not wheezing) were significantly more common in the higher-pollution zone in only some of the strata. Furthermore, prevalence rates of bronchial asthma, chronic obstructive pulmonary disease, and chronic bronchitis among residents in the two pollution zones were not significantly different. Nonetheless, lung function of asymptomatic non-smokers was consistently and significantly better among both male and female residents of the lower-pollution zone.
Cho et al.	2000	SO_2, TSP, NO_2, O_3, and CO	Hospital admission	2151		Time series, Poisson regression	2.4.5	Cross sectional	Respiratory disease admissions were related to NO_2, CO, and TSP concentrations below the environmental standard, but the significance of this relationship was area dependent.

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
Crane	2004						2.4.3		
D'Ippoliti et al.	2003	SO_2, PM_{10}, NO_2, and CO	Hospital admission	6531		Case-crossover	2.4.5	Case-crossover	Air pollution increases the risk of myocardial infarction, especially during the warm season. There was a tendency for a stronger effect among the elderly and people with heart conduction disturbances
Davis and Saldiva	1999						2.4		
Delfino et al.	2003	SO_2, PM_{10}, NO_2, O_3, CO, VOCs, OC	Diary	22		Regression	2.2	Cross sectional	There were no significant associations with PEF. Findings support the view that air toxins in the pollutant mix from traffic and industrial sources may have adverse effects on asthma in children.
Department of the Environment and Heritage	2005						2.3.1		
Dockery et al.	1989	SO_2, PM_{10}, NO_2, O_3, TSP, PM_{15}, $PM_{2.5}$, FSO4			Spirometry		2.4		
DOE	2005						2.4.3		
Education Ministry	2005						2.4		
Environment Agency	2000						table2.1-2.5		
EPA	1994						2.3		
EPA	2003						table2.1-2.5		
EPEQ	2003						table2.1-2.5		
Erbas et al.	2005	PM_{10}, NO_2	Hospital			GAM[1]	2.4.5	Cross	Regional concentrations of PM_{10} may have a

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
		and O_3	admission					sectional	significant effect on childhood asthma morbidity. In addition, ozone may play a role. However, its effect may vary by geographical region.
Fenger	2002						2.1		
Friedman et al.	2001						2.4.3		
Frischer et al.	1999	SO_2, PM_{10}, NO_2, O_3	Lung function	1150	Spirometry	GEE[2]	2.4.3.3	Prospective cohort	No consistent associations were observed for lung function and NO_2, SO_2 and PM_{10}. Long-term ambient ozone exposure might negatively influence lung function growth.
Frye et al.	2003	SO_2, TSP	Lung function	2493	Spirometry	Linear Regression	2.4.2, 2.4.3.4	Cross sectional	The study indicates that a reduction of air pollution in a short time period may improve children's lung function.
Garty et al.	1998	SO_2, PM_{10}, NO_X, O_3	Hospital admission	1076		Multiple Regression	2.4.5	Prospective study	The major factors found to be associated with ER visits of asthmatic children were high NO_X, high SO_2, and high barometric pressure. Negative correlation was found between ER visits of asthmatic children and ozone concentrations. The particularly high number of ER visits at the beginning of the school year and the Jewish holidays was probably associated with an increase in the number of viral infections and/or emotional stress.
Gauderman et al.	2000	PM_{10}, $PM_{2.5}$, NO_2, O_3, HCL and HNO_3	Lung function	3,035	Spirometry	Linear Regression	2.4, 2.4.2	Prospective cohort	The results suggest that significant negative effects on lung function growth in children occur at current ambient concentrations of particles, NO_2, and inorganic acid vapour.
Gauderman et al.	2004	PM_{10}, NO_2 and O_3	Lung function	1759	Spirometry	Linear Regression	2.4, 2.4.2, 2.4.3.2, 2.4.3.4, 2.4.4	Prospective cohort	Current levels of air pollution have chronic, adverse effects on lung development in children from the age of 10 to 18 years, leading to clinically significant deficits in attained FEV1 as children reach adulthood.

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
Gilliand et al.	2001	PM_{10}, NO_2 and O_3	Absenteeism	1933		Time series	2.4.3.1	Prospective cohort	A 15-day lag period provided the best fit for upper and lower respiratory absences for all 3 of the pollutant metrics. The acute effects of O_3 were increased at a 3-daylag, peaked at a 5-day lag, and subsequently showed a slow decrease. Daily 1 hour peak O_3 produced the same overall results as analysis using the 10am-6 pm average O_3. Increased PM_{10} was only associated with increases in non-illness-related absences.
Gold et al.	1999	PM_{10}, O_3	Lung function	40	PEF	Multiple Regression	2.4.2	Prospective cohort	Short-term change in O_3, but not NO_2 or PM_{10}, was associated with increase in school absences for respiratory illness. An increase of 42.8 $\mu g/m^3$ of O_3 was associated with an increase of 62.9% for illness-related absence rates, 82.9% for respiratory illnesses, 45.1% for upper respiratory illnesses, and 173.9% for lower respiratory illnesses with wet cough. The short-term effects of a 42.8 $\mu g/m^3$ change of O_3 on illness-related absenteeism were larger in communities with lower long-term average PM_{10} compared with communities with high average levels. Increased school absenteeism from O_3 exposure in children is an important adverse effect of ambient air pollution worthy of public policy consideration.
Goncolves et al.	2005	SO_2, PM_{10}, O_3	Hospital admission			Principal component analysis (PCA)	2.4.5	Cross sectional	Marked changes in synoptic conditions from the end of January to end of March of the 1993/1994 summer seem to have played an important role in modulating respiratory morbidity. A detailed examination of meteorological conditions in that period indicates that prefrontal (postfrontal), hot

Author (s)	**Year**	**Air Pollutants**	**Variables**	**Sample**	**Lung function**	**Statistics methods**	**Where**	**Epidemiologic design**	**Results**
									(cold) and dry (wet) days favoured the observed decrease (increase) of respiratory morbidity.
Gouveia and Fletcher	2000	SO_2, PM_{10}, NO_2, O_3 and CO	Hospital admission			Poisson regression	2.4.5	Cross sectional	Point estimates for most pollutants were higher for asthma than for other diagnosed admissions. However, these associations were not significant.
Gouveia etal.	2000		Respiratory diseases in children			time series analysis			In general, lagged effects of T. seemed to have a greater effect than measures taken on the same day. For HA from all respiratory causes and from pneumonia the effect of T was larger when lagged by 1 day, and for asthma a lag of 3 days provided the best fit.
Hajat	2002	SO_2, PM_{10}, NO_2, O_3 and CO	Hospital admission			GAM	2.4.5	Cross sectional	air pollution worsens allergic rhinitis symptoms, leading to substantial increases in consultations. SO_2 and O_3 seem particularly responsible, and both seem to contribute independently.
Halios et al.	2005	SO_2, NO_X, CO_2					2.3		he results indicated that when windows are kept closed and smoking takes place NOx, CO_2 and TVOCs concentrations increase by an order of 3, 4 or 10 times, respectively, and decrease returning to initial levels after 1 or 2 h.
Hoek et al.	1993	O_3	Lung function	533	Spirometry	Regression	2.4.2	Prospective cohort	The high correlation between ozone and temperature prevented the evaluation of effects of the maximum ozone concentration of the same day on PEF after training. A small negative association of borderline statistical significance between PEF after training and previous-day maximum ozone was observed.
Hoek et al.	1993	O_3	Lung function	83	Mini Wright	Regression	2.4.2		

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
Hoek et al.	1998	PM_{10}	Lung function	392	Spirometry	Linear Regression	2.4.2, 2.4.3.1	Prospective cohort	Defining the peak expiratory flow response by the prevalence of large decrements provides effect estimates of a comparable magnitude to affect estimates for the prevalence of reports of acute lower respiratory symptoms.
Horak et al.	2002	PM_{10}, O_3	Lung function	975	Spirometry	GEE	2.4.2	Prospective cohort	Long-term exposure to PM_{10} had a significant negative effect on lung-function proxy for the development of large (forced expiratory volume in one second) and small (mid expiratory flow between 25 and 75% of the forced vital capacity) airways, respectively, with strong evidence for a further effect of ozone and nitrogen dioxide on the development of forced vital capacity and forced expiratory volume in one second.
Hosseinpoor etal.,	2004								In single pollutant model, significant associations were found for 24-h NO_2 lag1, 24-h CO lag1 and 8h O_3 lag1. A nearly significant association was found for 24-h pm_{10}, lag1. In multi pollutant model 24h CO lag 1 is the only air pollutant that showed significant association with angina HA.
Hwang et al.	2000								NO_2 and NOx significantly effects on one day lag.SO_2 marginal effect on one day lag.PM_{10} and O_3 had no significant effects. Illness absence increased as ambient T. decreased.
Iran green pen	2004b						2.3		
Iran green pen	2004a						2.4, 2.4.3.2		
Iran green pen	2005						2.3		
ISAAC	1998						2.4.3		

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
ISAAC	2005						2.4.3		
Jalaludin et al.	2000	PM_{10}	Lung function	32	Mini Wright	GEE, Time series	2.4.2	Prospective cohort	The high levels of particulate pollution caused by the Sydney bushfires did not lead to any clinically significant reductions in PEFR in symptomatic children. Our results have implications for community risk communication during future bushfires.
Jalaludin et al.	2004	PM_{10}, NO_2 and O_3	Hospital admission	125		GEE, logistic Regression.	2.4.5	Prospective cohort	There were significant associations between PM10 levels and doctor visits for asthma and an association between NO_2 levels and the prevalence of wet cough. We were, however, unable to demonstrate that current levels of ambient air pollution in western Sydney have a coherent range of adverse health effects on children with a history of wheezing.
Jalaludin etal	2004		Respiratory symptoms, asthma medication use, and doctor visits					cohort	In single pollutant model, significant associations were found between PM_{10} and doctor visits for asthma (sameday,lag1,lag2 and 2day average) and between the dame day mean day time NO_2 and the prevalence of a wet cough in the evening. In multi-pollutant models that all three air pollutants (same day mean day time o3, same day mean daytime PM_{10} and same day mean daytime NO_2), the only significant associations were still between PM_{10} and doctor visits for asthma and between same day mean day time NO_2 and the prevalence of a wet cough in the evening.
Jedrychowski et al.	1998	SO_2, SPM	Lung function	1048	Spirometry		2.4.2	Cross sectional	The results of the study provided the evidence that the current level of communal air pollutants (SPM and SO_2) is not related to an excessive risk of respiratory symptoms

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
									in children, provided it is not combined with other sources of air pollution such as heavy traffic or local low point industrial emission. The risk of obstructive ventilation disorders (FEV1/FVC% 85) was significantly higher in children from the residential areas with higher air pollution (RR = 1.71; 95% CI: 1.19-2.47).
Jedrychowski et al.	1999	SO_2, PM_{10}	Lung function	1129	Spirometry	Multivariate Logistic Regression.	2.4.3.1	Prospective cohort	he association between ambient pollutants and poorer gain of pulmonary volumes in children living in more polluted areas suggests that air pollution in the residence area may be a part of the causal chain of reactions leading to retardation in pulmonary function growth during the preadolescent years.
Jedrychowski et al.	2005	SPM, ETS	Lung function	1036	Spirometry	Multivariate Linear Regression.	2.3	Retrospective cohort	A lower level of lung function in pre-adolescent children can be related to postnatal exposure to indoor emissions in the winter.
Just et al.	2002	SO_2, PM_{13},, NO_2 and O_3	Lung function + Diaries	82	Mini Wright	GEE	2.4.2, 2.4.3	Prospective cohort	This study showed that, although within international air quality standards, the prevailing levels of photo-oxidant and particulate pollution in spring and early summer had measurable short-term effects on children with mild-to-moderate asthma.
Kinney et al.	1996	O_3	Lung function+ Diaries		Spirometry	Linear Regression	2.4.2	Reanalysis	
Kleinman	2001						Intro		
Knudson	1991						2.4.1		
Koenig and Mar	2000	SO_2			Spirometry		2.4.2	Reanalysis	

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
Krzyzanowski et al.	1992	O_3	Lung function + Questionnaire	287 children+ 523 adults	Mini Wright	ANCOVA	2.4.2	Prospective cohort	The respiratory response to low-level ambient O_3 is acute, occurs more in asthmatics, and increases as temperature and PM_{10} increase.
Lewis et al.	1998	SO_2, PM_{10}	Questionnaire	3023		Logistic Regression	Intro	Cross sectional	These results provide evidence of health effects at lower than expected levels of outdoor air pollution in the Australian setting. They also suggest differences in contributions of environmental and hereditary factors to cough and chest colds compared with wheeze.
Lewis et al.	2004		ISAAC Questionnaire	377		Logistic Regression	2.4.3	Cross sectional	Chronic respiratory symptoms are very common among AN children. CPC is an important non-asthmatic respiratory condition in this population. The differing patterns of respiratory illness within this region may help to elucidate the specific risk factors for asthma and chronic bronchitis in children.
Lin et al.	2002	SO_2, NO_2 ,O_3 and CO	Hospital admission			Case-crossover, Time-series(GAM)	2.4.5	-	We did not find significant effects of fine particulate matter $PM_{2.5}$ or of thoracic particulate matter PM $_{10}$ on asthma hospitalizations using either of these two analytic approaches. For the most part, relative risk estimates from the unidirectional case-crossover analysis were more pronounced compared with both bidirectional case-crossover and time-series analyses.
Linn and Gong	1999	SO_2, PM_{10}, NO_2, O_3 and CO					2.4.2		
Livingston	2002	SO_2, PM_{10}, NO_2, O_3	Hospital admission			Time-series, Case-crossover	2.4.5	Longitudinal study	While the time series approach produced fairly accurate results, the bidirectional case-

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
		and CO							crossover using the exact method of approximation was the overall best technique of analysis.
Lomborg	2001						Intro		
Luginaah et al.	2005	SO_2, PM_{10}, COH, NO_2, O_3, CO	Hospital admission			Case-crossover, Time-series	2.4.5	Longitudinal study	Time-series analysis showed that 1-day delayed effect of PM $_{10}$ on respiratory admissions of adult males (15-64 years of age), with an RR of 1.18. COH had significant effects on female respiratory hospitalization, especially for 2-day delayed effects on adult females, with RRs of 1.15 and 1.29 using time-series and case-crossover analysis, respectively. There were no significant associations between O_3 and TRS with respiratory admissions. These findings provide policy makers with current risks estimates of respiratory hospitalization because of poor ambient air quality in a government designated "area of concern."
Maertens et al.	2004						2.3	Review	
Masjedi etal.	2003								By multiple linear regression, only the 3-day mean concentration of SO_2 was found to be positively correlated with the mean asthma admissions for adults.
Masjedi et al.	2004		ISAAC Questionnaire	6127		Chi-Square	2.4.3	Descriptive study	Overall, no significant change in prevalence of asthma symptoms has occurred since 1997 (the last phase of ISAAC) among children of Tehran. The results of our study suggest higher rates of confirmed asthma among 6-7year-old girls' compared to boys. However, more extensive and precisely designed studies are needed to further confirm these findings.
McConnell et	2002	PM_{10}, NO_2	Asthma	3535		Pearson	2.4.2,	Cohort	In communities with high O_3 concentrations,

Author (s)	**Year**	**Air Pollutants**	**Variables**	**Sample**	**Lung function**	**Statistics methods**	**Where**	**Epidemiologic design**	**Results**
al.		and O_3				correlation, RR	2.4.3		the relative risk of developing asthma in children playing three or more sports was 3.3 (95% CI 1.9-5.8), compared with children playing no sports. Sports had no effect in areas of low O_3 concentration (0.8, 0.4-1.6). Time spent outside was associated with a higher incidence of asthma in areas of high O_3 (1.4, 1.0-2.1), but not in areas of low O_3. Exposure to pollutants other than O_3 did not alter the effect of team sports. INTERPRETATION: Incidence of new diagnoses of asthma is associated with heavy exercise in communities with high concentrations of O_3, thus, air pollution and outdoor exercise could contribute to the development of asthma in children.
McGown et al.	2002	PM_{10}	Hospital admission			Time-series	2.4.5	-	These results indicate that measures to control ambient particulate levels have the potential to reduce hospital admissions for cardio-respiratory illnesses.
Migliaretti and Cavallo	2004	NO_2, TSP	Hospital admission	1060		Logistic Regression	2.4.5	case-control	A significant association was found between increased number of hospital emergency admissions for respiratory causes and exposure to principal urban pollutants in Turin. The study confirms the results reported for other Italian and European cities, using a case-control design.
Ministry for the Environment	2005						table2.1-2.5		
Ministry of Health,	1954						Intro		
Mishra,Vinod	2003	PM_{10}, NO_2, CO	Acute respiratory	3559		Logistic Regression	Intro	Cross sectional	children in households using wood, dung, or straw for cooking were more than twice as

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
			Infection						likely to have suffered from ARI as children from households using LPG/natural gas or electricity (OR = 2.20; 95% CI: 1.16, 4.19).
National Asthma Council	2002						2.4.1.1		
Neuberger et al.	2002	SO_2, TSP, NO_2 and O_3	Lung function	3451	Spirometry		2.4.2, 2.4.3.4	Prospective cohort	This study provides the first evidence that improvements in the outdoor air quality during the 1980s are correlated with health benefits, and suggest that adverse effects on lung function related to ambient air pollution are reversible before adulthood. Improvement of small airway functions appeared to be more dependent on reductions of NO_2 than reduction in SO_2 and TSP.
NHLABI	1997						2.4.3		
Nikic, Dragana	1999	SO_2, BS	Respiratory symptoms	663			Intro	Cohort	Passive smoking may be a significant etiologic factor in the occurrence of respiratory symptoms and illness.
Norris et al	1999								Effects of daily average NO_2, lagged 2 days were positive and marginally significant. In multi pollutant models, effect of PM_{10} remained positive and statistically significant, but SO_2 and NO_2 effects did not retained significance.
Ostro et al.	1998	PM_{10} and O_3	Respiratory disease Morbidity			Regression	2.2	-	The estimated relative risks were 1.06 per 42.1- $\mu g/m^3$ increase in PM_{10}, 1.09 per 16.24 - $\mu g/m^3$ increase in SO_2, and 1.08 per 34.11 - $\mu g/m^3$ increase in ozone. There was no significant relationship between nitrogen dioxide level and illness-related absenteeism.

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
Park et al.	2002	SO_2, PM_{10}, NO_2, O_3 and CO	Absenteeism	1264		Time-series	2.4.3.1, 2.4.4	Longitudinal study	Air pollution is associated with illness-related absences among elementary students.
Pearce et al.	2000		ISAAC Questionnaire	8835			2.4.3	Survey	There was a strong correlation between the ISAAC and ECRHS prevalence data, with 64% of the variation at the country level, and 74% of the variation at the centre level, in the prevalence of "wheeze in the last 12 months" in the ECRHS phase I data being explained by the variation in the ISAAC phase I data.
Peled et al.	2001	SO_2, NO_2 ,O_3	Questionnaire+ Lung function	2455	Spirometry	Regression	2.4.3.4	Prospective cohort	No robust association with air pollution was demonstrated.
Peled et al.	2005	PM_{10}, $PM_{2.5}$	Lung Function	285	Teva-Mini Belle	ANOVA, GEE	2.4.3.2	-	Children with asthma are at risk from air pollution and geophysical conditions.
Peters et al.	1997	SO_2, NO_2 ,PSA, TSP	Diary, absenteeism	89	Mini Wright	Linear, Logistic Regression	2.4.2, 2.4.3.1, 2.4.4	Survey +cohort	A panel of children with mild asthma experienced small decreases in peak expiratory flow and increased dyspnoea in association with fine particles formed during air pollution episodes.
Peters et al.	1999	O_3	Lung function	3300	Mini Wright	Linear + Logistic Regression	2.4.2	Prospective cohort	There was a statistically significant association between ozone exposure and decreased FVC and FEV1 in girls with asthma. For boys, significant associations were seen between peak O_3 exposures and lower FVC and FEV1, but only in those spending more time outdoors.
Peters	2004		Epidemiologic Investigation to Identify Chronic Effects of Ambient Air Pollutants in Southern						Absences were significantly increased 2 to 3 days after exposure and reached a peak on day 5 after exposure. The increase in school absenteeism from respiratory illnesses associated with relatively modest day to day changes in O_3 concentration. He used 15 day lag period. For O_3 he used 10am -6 pm daily

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
			California						average.
Petroeschevsky et al.	2001	SO_2, NO_2, O_3	Hospital admission			Regression	2.4.5	-	Current levels of ambient air pollution in Brisbane make a significant contribution to the variation in daily hospital admissions for asthma and respiratory disease.
Ponka	1990	SO_2, NO_2	Absenteeism				2.4.3.1		
Pope III	1991						2.4.2,2.4.5		A significant association was found between levels of SO_2 and absenteeism. After statistical standardization for temperature, no other correlations were observed apart from that between high levels of SO_2 and numbers of upper respiratory tract infections diagnosed at health centres (P = 0.04). When the concentrations of SO_2 were above the mean, the frequency of the upper respiratory tract infections was 15% higher than that during the periods of low concentration. The relative importance of the effects of low-level air pollution and low temperature on health is difficult to assess.
Pope III	1992	PM_{10}	Respiratory symptoms				2.4.5	-	Elevated PM_{10} concentrations are associated with increased school absenteeism.
Pride	1999						2.4.1		
Qian et al.	2004	SO_2, PM, NO_X	Respiratory symptoms	7058		Factor Analysis	2.4.3.3	-	independent respiratory effects of exposure to indoor air pollution, heating coal smoke, and ETS may exist for the studied children.
Qing-Ci et al.	1993	SO_2, TSP, NO_2		604	Spirometry	Linear and logarithmic Regression	2.4.3.1, 2.4.3.3	-	
Ransom and Pop	1992	PM_{10}	Absenteeism			Regression	2.4.4	-	Associations between absenteeism and PM_{10} pollution were observed even for levels below 150µg/m^3.
Roholm	1937		Absenteeism				Intro		An increase in 28-day moving average PM_{10}

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
									equal to 100 $\mu g/m^3$ was associated with an increase in the absence rate equal to approximately two percentage points, or an increase in overall absences equal to approximately 40%. Similar relationships were observed for all grade levels, although the response of absences to air pollution was generally greater for grades 1-3 compared with grades 4-6. Associations between absenteeism and PM_{10} pollution were observed even for levels below 150 $\mu g/m^3$.
Romieu et al.	1992	NO_2, O_3	Absenteeism	111		Logistic Regression	2.4.3.1,2 .4.4	-	Ozone exposure might be positively associated with the risk of respiratory illness in children and that it may have an interactive effect with low temperature exposure.
Romieu et al.	1996	PM_{10}, NO_2, O_3	Lung function	71	Mini Wright	GEE	2.4.3.1,2 .4.3.2	Prospective cohort	During the 3-month follow-up, 50% of children at least 1 respiratory related absenteeism, 11.7% 2 or >2. If exposed for 2 days to >=278 $\mu g/m^3$ leads to 20%increase in the risk of respiratory illness. If T <=5.2°C was added to it the risk increased to 40%.
Romieu et al.	1997	PM_{10}, O_3	Lung function, Respiratory symptoms	67	Mini Wright	GEE	2.4.3.1,2 .4.3.2	Panel study	Children with mild asthma who resided in the south of Mexico City were affected adversely by the high ozone ambient levels observed in this area.
Romieu et al.	2002						2.2	Review	
Rostamhozori	2002						2.1	Thesis	
Rumchev	2001	NO_2, HCHO, VOCs	Questionnaire	192		Multiple Regression	2.4.3	Thesis	
Schildcrout	2006								One-ppm differences in within-subject

Author (s)	**Year**	**Air Pollutants**	**Variables**	**Sample**	**Lung function**	**Statistics methods**	**Where**	**Epidemiologic design**	**Results**
etal									carbon monoxide concentrations were associated with symptom odds ratios for the 0-, 1-, and 2-day lags and the 3-day moving sum, respectively. Although sulfur dioxide lags were positively related to risk of asthma symptoms, only the 3-day moving sum effect would be considered (marginally) statistically significant at the 0.05 level. while 20-ppb shifts in the 0-, 1-, and 2-day lags of nitrogen dioxide and the 3-day moving sum of nitrogen dioxide led to relative rates of rescue inhaler use. Sulfur dioxide was not associated with rescue inhaler use rates. In 2 pollutant models, while all lags in the pairs of pollutants exhibited positive relations with both responses, simultaneous shifts in 2-day lags of pairs of pollutants tended to have the largest impact on asthma aggravation. Among combinations of carbon monoxide, nitrogen dioxide, PM10, and sulfur dioxide, the 2-day lags in all models involving either carbon monoxide or nitrogen dioxide were associated with both responses, with 95 percent confidence intervals excluding 1. Simultaneous standardized shifts in the 2-day lags of these two pollutants led to a 1.09-fold increase in the odds of asthma symptoms and increase in the daily rate of rescue inhaler uses. Simultaneous shifts in 3-day moving sums of two pollutants were also frequently (marginally) related to exacerbations.

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
									Although the relation between the responses and the 0- and 1-day lags in ambient concentrations did not appear to be as strong as the 2-day lags, they were consistent with them (e.g., estimated odds ratios for symptoms and rate ratios for inhaler uses were greater than 1). The strongest among the 0- and 1-day lagged effects was observed with asthma symptoms: Shifts in the 0-day lag of carbon monoxide and PM_{10} resulted in an odds ratio of 1.08 (95 percent CI: 1.01, 1.15).
Schwartz	1994	PM_{10}, O_3	Hospital admission				2.4.2	-	
Schwartz	2004						Intro		
Se´gala et al	2008								The 5-day mean was more consistently associated with bronchiolitis than the 2-day mean for all pollutants, but forSO_2. With consultations, only the 5-day mean of PM_{10} and SO_2 showed a linear effect that can be expressed in terms of relative risk; with hospitalizations, it was the case only with the 5-day mean of SO_2.
Sheppard et al	1999								In single pollutant model, CO lagged 3 days and O_3 lagged 2 days were associated most strongly with asthma admissions. Association of asthma admissions with PM_{10} lagged 1 day, was also positive and strongly associated. The association of admissions with SO_2 (0days) was positive but not significant. in season specific, 2 pollutants models, generally similar effects were observed for CO lagged 3 days .Overall seasons, effects of both pollutants were

Author (s)	Year	Air Pollutants	Variables	Sample	Lung function	Statistics methods	Where	Epidemiologic design	Results
									positive and significant.
Shima and Adachi	2000	NO_2	Prevalence of respiratory symptoms	842		Multiple Logistic Regression	2.4.3	Prospective cohort	Indoor NO_2 concentrations were associated with the prevalence of respiratory symptoms only among girls. Girls may be more susceptible to indoor air pollution than boys.
Simoni et al.	2003						2.2	Review	
Simons and Wood	2003	PM_{10}, NO_2, O_3		3535			2.4.2, 2.4.3	Prospective cohort	
Stern	1994		Respiratory symptoms + lung function		Spirometry		2.4.2	Cross sectional	Children living in south-western Ontario had statistically significant ($P < 0.01$) mean decrements of 1.7% in FVC and 1.3% in FEV1.0 compared with Saskatchewan children, after adjusting for age, sex, weight, standing height, parental smoking, and gas cooking.
Storey et al.	2003		Questionnaire	158		ANOVA	2.4.3	Survey	
Strand et al.	1998	NO_2	Questionnaire + Lung function	16	Spirometry	ANOVA	2.4.3.1	-	
Studnicka et al.	2002						2.4.2		
Tabatabaie et al.	1995						table 2.7		
Tang etal	2007								the evening PEFR changes with an increase in personal PM exposures measured on the same day (lag 0) were less than 5 L/min. stronger lagged effects on morning PEFR were found for $PM_{2.5-10}$ exposures as compared to those for the smaller-size particles ($PM_{1-2.5}$ and PM_1). The decrement in the morning PEFR for asthmatic children, for example, was 20.55 L/min, 10.51 L/min, and 6.00 L/min per increase of IQR for same

Author (s)	**Year**	**Air Pollutants**	**Variables**	**Sample**	**Lung function**	**Statistics methods**	**Where**	**Epidemiologic design**	**Results**
									day (lag 0) exposures to $PM_{2.5-10}$, $PM_{1-2.5}$, and PM_1, respectively.
Tamburlini	2002						2.4.3	Report	
Tatum and Shapiro	2005						2.4.2		Exposure to air contaminants can increase the risk of developing asthma in susceptible persons.
Tennant & Szuster	2003						2.4.3		
Thompson et al.	2001	SO_2, PM_{10}, NO_2, NO, NO_X, O_3, CO	Hospital admission			Linear Regression	2.4.5	-	
Timonen et al.	2002	SO_2, PM_{10}, BS, NO_2, CO	Lung function	33	Spirometry	Linear Regression	2.4.2, 2.4.3.1	Prospective cohort	
Tolbert et al.	2000	PM_{10}, NO_X	Hospital admission			GEE	2.4.5	Time series	
Van der Zee et al.	1999	SO_2, PM_{10}, BS, NO_2, CO	Questionnaire + Lung function	633	Mini Wright	Multiple Regression	2.4.3.1	Panel study	Children with symptoms are more susceptible to the effects of particulate air pollution than children without symptoms, and that use of medication for asthma does not prevent the adverse effects of particulate air pollution in children with symptoms.
Vedal et al.	1998	PM_{10}	Lung Function	2200	Mini Wright	Linear Regression, GEE	2.4.3.1	Prospective cohort	Children experience reductions in PEF and increased symptoms after increases in relatively low ambient PM_{10} concentrations, and that children with diagnosed asthma are more susceptible to these effects than are other children.
Viegi et al.	2004						2.3		Indoor air pollution ranks tenth among preventable risk factors contributing to the global burden of disease.
Wanner	1990						2.4.2		The burden of atmospheric pollution must be reduced to protect human health by an

Author (s)	**Year**	**Air Pollutants**	**Variables**	**Sample**	**Lung function**	**Statistics methods**	**Where**	**Epidemiologic design**	**Results**
									adequate safety margin.
WHO	2000	SO_2, PM_{10}, NO_2, O_3 and CO					2.1, 2.3.1,2.4 .3		
WHO	2005						2.3, 2.4		
WHO Regional Office for Europe	2000						table2.1-2.5, 2.4.3		
Wilson et al.	2005	SO_2, O_3	Hospital admission			GAM/Time-series	2.4.5	Time-series	Elevated SO_2 and O_3 have a significant impact on public health in Portland, Maine.
Wjst	1993		Questionnaire + Lung function	4320	Spirometry	Multiple Regression	2.4.3.2	Prospective cohort	Peak expiratory flow rates dropped almost 1% for each increase of 25,000 cars on the main road through the school district.
Wong et al.	2001	SO_2, $PM_{10}$and NO_2	Hospital admission	1217		Poisson Regression	2.4.5	Time-series	Air pollution contributes to the respiratory morbidity in asthmatic children in Hong Kong.
Woolcock	1991						2.4.3	Review	
Woolcock and Peat	1997						2.4.3	Review	
World Health Organization	2000						Intro		
Xu et al.	1991						2.4.2	Review	
Xuan et al.	2000		Lung function	557	Spirometry	Autoregressive model	2.4.1, 2.4.1.2	Prospective cohort	Asthma influences growth in airway caliber rather than lung size.
Zanobetti and Schwarts	2005	PM_{10}	emergency admissions	300,000		Case-crossover			The PM_{10} effect is mainly associated with the change in risk on the day of hospitalization.

Appendix III: Materials

The materials, which described in Chapter three presented here.

A3.1 Ethics Approval

University of Wollongong

REVIEWED - RESPONSE REQUESTED
In reply please quote: SD:KM HE02/315
Further Information: Karen McRae (42214457)

21 August 2002

Please see print copy for image

Dear Ms Lankarani,

The Human Research Ethics Committee has **REVIEWED** the Human Research Ethics application identified below. The Committee decided that, on receiving satisfactory responses on the following matters, it would grant approval. Please provide written clarification of the matters to the Secretary of the Committee, Office of Research, University of Wollongong.

(i) please provide the qualifications and names of any further assistant researchers when known

(ii) clarify how will the student's in Tehran be recruited? Does the school hand out the information to participants?

(iii) please forward a copy of the Ministry of Tehran's permission when received

(iv) it is requested that a back-translation of the Information Sheets is obtained and forwarded to the Secretary of the HREC as they do not appear accurate

(v) it is suggest that the Chemistry Department at the University of Wollongong collects pollution data and correlates it with data from Wollongong Hospital on Asthma occurrences which the student may wish to investigate

Ethics Number:	HE02/315
Project Title:	Air pollution health effects on primary school children in Tehran
Name of Researcher/s:	Narges Lankarani
Reviewed Date:	13 August 2002

This review letter relates to the research protocol submitted in your application of 26 July 2002. It will be necessary to inform the Committee of any changes to the research protocol and seek clearance in such an event.

Yours sincerely

Please see print

Assoc. Prof. Sue Dodds
Chairperson, Human Research Ethics Committee

Office of Research University of Wollongong NSW 2522 Australia
Telephone: (61 2) 4221 3386 **Facsimile:** (61 2) 4221 4338
office_research@uow.edu.au www.uow.edu.au

FINAL APPROVAL
In reply please quote: SD:KM HE02/315
Further Enquiries: Karen McRae (PH: 42214457)

University of Wollongong

29 August 2002

Please see print copy for image

Dear Ms Bagheri Lankarani,

I am pleased to advise that the following Human Research Ethics application has been finally approved. As a condition of approval, the Human Research Ethics Committee requires that researchers immediately report anything which might warrant review of ethical approval of the protocol, including: serious or unexpected adverse effects on participants, proposed changes to the protocol, unforseen events that might affect continued ethical acceptability of the project and discontinuation of the research project before the expected date of completion.

Ethics Number:	HE02/315
Project Title:	Air pollution health effects on primary school children in Tehran
Name of Researchers:	Bagheri Lankarani, N;
Final Approval Date:	28 August 2002
Date for Renewal:	27 August 2003

This certificate relates to the research protocol submitted in your original application and includes all approved amendments to date.

Please note that research projects of long duration must be reviewed annually by the Committee and it will be necessary for you to apply for renewal of this application if this project is to continue beyond one year.

Yours Sincerely,

Please see print

Assoc. Prof. Sue Dodds
Chairperson
Human Research Ethics Committee

Office of Research University of Wollongong NSW 2522 Australia
Telephone: (61 2) 4221 3386 **Facsimile:** (61 2) 4221 4338
office_research@uow.edu.au www.uow.edu.au

A3.2 Consent forms and letters

A3.2.1 Questionnaire consent form

Dear respondents

The questionnaire, which you are asked to complete it, is part of my study project as a PhD candidate. My research project is about **"Air pollution health effects on children in Tehran"**. Associated Prof. Irene Kreis from the above mentioned University would be supervising me in this research.

The questionnaire asks about yourself and your environment as far as it is related to asthma. Your name is required just for following up of the data, since the data to be collected and analysis will remain anonymous. All information will be confidential and maintained under the Human Research Ethics Committee Standards of the University of Wollongong. Your contribution will also remain in secure storage, strictly confidential and will be used purely for the research purposes. I wish to thank you in advance for your cooperation and assistance in gathering the necessary data for my research.

Moreover, you have the right to accept or refuse to answer the all or some questions. If you do, there will be no consequences to either yourself or your child.

An attempt has been made to use plain language in the wording of the questions in order to be clearly understood. However, if you experience difficulties in understanding the questions please let me know.

Completing the questionnaire will take 30-35 minutes and your participation in this study will greatly be appreciated.

If you would like further discussion about this research, please contact me on 8088417 in Tehran (between November to December 2002) or 0061 2 42215747 in Australia or my e-mail address: nb04@uow.edu.au. If you have any queries regarding the conduct of this research, please contact the Secretary of University of Wollongong Research Ethics Committee:

Please see print copy for image

E-mail address: karen_mcrae@uow.edu.au

Yours truly,
N.Lankarani

-

I agree to participate with my child…………….(please print his/her name) in this project. I will receive a copy of this consent form. I understand that his/her participation is voluntary, (S)he is free to refuse to participate and (S)he is free to withdraw from the research at any time without any consequences. All information obtained will remain confidential.

Signed …………………………….. Date ………/…../…

Name (please print)………………………..

Farsi version of consent letter

پاسخگویان عزیز

پرسشنامه‌ای که جهت تکمیل در اختیار شماست قسمتی از موضوع رساله من برای ارائه به دانشگاه ولونگونگ می‌باشد. این پروژه توسط خانم دکتر آیرین کرایس استاد یار این دانشگاه راهنمائی می‌شود. بدیهی است اطلاعات آن جزئی از تحقیق بوده و جهت بررسی بیشتر کیفیت آلودگی هوا وسلامتی کودکان تهران استفاده خواهد شد.

این پرسشنامه جمع آوری کننده اطلاعاتی در مورد شما و محیط زیستتان است که برای سلامتی کودکان و کنترل آلودگی هوا از اهمیت ویژه‌ای برخوردار خواهد بود.

مشخصات فردی از قبیل نام، آدرس وغیره تنها جهت پی‌گیری بکار گرفته خواهد شد و بعد از جمع آوری اطلاعات تجزیه و تحلیل آنها بدون ذکر نام نگاهداری خواهد شد. بدیهی است این اطلاعات نزد پژوهشگر محفوظ خواهد ماند. قبلا از کمک و همکاری شمار در جمع آوری اطلاعات لازم برای این پژوهش نهایت سپاسگزاری را دارم.

علاوه بر این پاسخ دادن یا ندادن به کل سئوالات یا تعدادی از آنها کاملا به خواست و اراده شما بستگی دارد. این امرجزء حقوق فردی شما محسوب می شود.

تلاش شده است تا سئوالات به زبانی ساده تنظیم گردند تا درک آن آسانتر باشد. با این وجود درصورت مواجهه با مشکل لطفا سئوال فرمائید.

تکمیل این پرسشنامه حدود ۳۵- ۳۰ دقیقه طول می‌کشد. از اینکه در این مورد مرا یاری می‌کنید پیشاپیش و صمیمانه سپاسگزارم.

شماره تماس اینجانب در استرالیا۴۲۲۱۵۷۴۷ ۰۰۶۱۲ یا آدرس پست الکترونیکی nb04@uow.edu.au می‌باشد. همچنین جهت اطلاعات بیشتر در مورد این تحقیق می‌توانید با شماره ۲۱۴۴۵۷ ۴۲ ۰۰۶۱۲ یا آدرسkaren_mcrae@uow.edu.au پست الکترونیکی دبیر کمیته اخلاق پژوهشی دانشگاه ولونگونگ تماس حاصل فرمائید.

با تشکر

نرگس لنکرانی

من با شرکت فرزندم .... (لطفا نام فرزندتان را دراین محل بنویسید)

در این پژوهش موافق هستم. ضمن دریافت قسمت اول این توافقنامه می دانم که شرکت فرزندم دراین تحقیق داوطلبانه بوده و وی مختار است در هرزمان از روند تحقیق از شرکت در آن خودداری نماید.

نام ونام خانوادگی ....

تاریخ .... امضا ....

A3.2.2 *Lung Function Consent Form*

Research Title: **Air pollution health effects on children in Tehran**

Researcher's Name: Narges Lankarani

Student's Name:………………………

By signing this consent form I understand that

1. My child's lung function will be measured by Narges Lankarani from Wollongong University as part of her PhD degree in the Graduate School of Public Health. This research is being supervised by Associated Professor Irene Kreis.

2. Measuring the lung function will be done for 6 weeks; the lung function will be measured 3 times everyday in school for a total of 20-25 minutes.

3. This measurement will not harm my child. It is like any other measurement such as weight or height just the scales are different.

4. My child's name will not be revealed to any one and any information I give, will remain confidential.

5. My child's participation is voluntary. I am free to refuse to permit my child's participation and or withdraw from the lung function measurement at any time without any consequences.

6. I have been given the opportunity to ask questions about the research and my child's participation.

7. I will be given a copy of this consent form.

8. I will be given a copy of the lung function record of my child at the end of the study.

9. If I want further information or have any queries about the research, I can contact N.Lankarani on 8088417 in Tehran (between November to December 2002) or 0061 2 42215747 in Australia or with my e-mail address: nb04@uow.edu.au.

10. If I have any concerns or complaints about the conduct of this research, I can contact the Secretary of University of Wollongong Research Ethics Committee:

Please see print copy for image

E-mail address: karen_mcrae@uow.edu.au

11. I understand that the information collected from my child's participation will be used for part of her Health Research Subject and I consent to this.

Signed ……………………………………..

Name (Please print) ……………………………………….

Date………./……./………

Farsi version of consent letter

فرم مجوز اندازه گیری کارکرد ریوی

عنوان پژوهش: تاثیر آلودگی هوا بر سلامتی کودکان در تهران
نام پژوهشگر: نرگس لنکرانی
نام دانش آموز: ....

اینجانب ....ولی دانش‌آموز با امضای این برگه به پژوهشگر اجازه می‌دهم :

۱- کارکرد ریوی فرزندم توسط نرگس لنکرانی یا همکار وی که بعنوان قسمتی از موضوع رساله دکترای ایشان برای ارائه به دانشگاه ولونگونگ می‌باشد اندازه‌گیری گردد. این پروژه توسط خانم دکتر آیرین کرایس استاد یار این دانشگاه راهنمائی می‌شود.

۲- اندازه گیری کارکرد ریوی دانش آموزان بمدت ۷ هفته و روزانه سه مرتبه در محل مدرسه اندازه‌گیری خواهدشد که در کل ۲۰ تا ۲۵دقیقه به‌طول خواهد انجامید.

۳- این اندازه‌گیری مانند اندازه‌گیری وزن و قد می‌باشد و به فرزندم هیچ صدمه‌ای نخواهد رساند. تنها وسیله اندازه گیری در اینجا متفاوت است.

۴- نام فرزندم ویا هر اطلاعاتی که اینجانب در اختیار خواهم گذاشت نزد پژوهشگر محفوظ خواهد ماند.

۵- شرکت فرزندم در این پژوهش داوطلبانه می‌باشد. من برای اجازه دادن یا ندادن به فرزندم برای شرکت در این پژوهش یا خروج از آن در هر زمان آزاد هستم.

٦-به من فرصتی برای پرسش سئوال درمورد پژوهش وشرکت فرزندم داده شده است.

۷-یک نسخه از این برگه نیز به من داده خواهد شد.

۸-در خاتمه پژوهش یک نسخه از اندازه گیری کارکرد ریوی فرزندم در اختیار من گذاشته خواهد شد.

۹-در صورتی که نیاز به اطلاعات بیشتر در مورد این پژوهش داشته باشم می‌توانم با استرالیا با شماره تماس ۴۲۲۱۵۷۴۷ (۰۰٦۱) یا آدرس پست الکترونیکی nb04@uow.edu.au پژوهشگر تماس بگیرم.

همچنین جهت اطلاعات بیشتر میتوانم با شماره ۴۲۲۱۴۴۵۷ (۰۰٦۱) یا آدرس پست الکترونیکی karen_mcrae@uow.edu.au دبیر کمیته اخلاق پژوهشی دانشگاه ولونگونگ تماس بگیرم.

۱۱- من کاملا متوجه این مساله هستم اطلاعاتی که توسط شرکت فرزندم در این پژوهش جمع آوری می شود جزئی از رساله پژوهشگر می‌باشد.

تاریخ .... امضا ....

A3.2.3 Diary consent form

Dear parents

Collecting asthma diaries is part of my study project as a PhD candidate. This research will be supervising by Associated Professor Irene Kreis the head of Environmental Health Unit of the Graduate School of Public Health at the University of Wollongong.

The purpose of collecting the diaries is to compare the daily changes in your child's asthma symptoms over a period of six weeks and to identify whether these changes are related to air pollution.

Your child name is required only because of follow up needs, since the data will be analysed in an anonymous technique.

You or your child have the right to accept or refuse to co-operate at any time without any consequences.

Each diary will be completed every week and will be collected at school every Saturday. Your child will be given a new diary every Saturday to complete weekly. This process will be continued over a 6 week, and your child's participation in this study will greatly be appreciated.

If you would like further discussion about this research, please contact me on 8088417 in Tehran (between November to December 2002) or 0061 2 42215747 in Australia or my e-mail address: nb04@uow.edu.au. If you have any queries regarding the conduct of this research, please contact the Secretary of University of Wollongong Research Ethics Committee:

Please see print copy for image

E-mail address: karen_mcrae@uow.edu.au

Yours truly,

N.Lankarani

I agree to the participation of my child…………… (please print his/her name) in completing asthma diaries. I will receive a copy of this consent form. I understand that his/her participation is voluntary, (S) he is free to refuse to participate and (S) he is free to withdraw from the research at any time without any consequences.

Signed	Date
……………………………..	………/…../….

Farsi version of consent letter

ولی گرامی

جمع آوری روزنگار فرزند شما درمورد علائم و نشانه های تنفسی وی قسمتی از موضوع رساله دوره دکترای من برای ارائه به دانشگاه ولونگونگ می باشد.

این پروژه توسط خانم آیرین کرایس راهنمائی می‌شود. بدیهی است اطلاعات آن جزئی از این تحقیق بوده و جهت بررسی بیشتر برای پیشبرد کیفیت آلودگی هوا و سلامتی کودکان استفاده خواهد شد.

هدف از این جمع آوری ۷هفته‌ای مقایسه تاثیر میزان تغییرات در کیفیت هوا بر روی علائم تنفسی کودکان است.

نام فرزند شما فقط جهت حضور و غیاب و پیگیری کارکرد ریوی روزانه وی پرسیده خواهد شد.

اطلاعات جمع آوری شده و تجزیه و تحلیل آنها نزد اینجانب کاملا محرمانه خواهد ماند.

علاوه براین شرکت در این تحقیق کاملا بستگی به خواست و اراده شما دارد و این امر جزء حقوق فردی شما محسوب می‌شود.

تکمیل این روزنگار روزانه ۱۰دقیقه طول می‌کشد. ازاینکه در این مورد مرا یاری می‌کنید پیشاپیش و صمیمانه سپاسگزارم.

شماره تماس اینجانب در استرالیا۴۲۲۱۵۷۴۷ ۰۰۶۱۲ یا آدرس پست الکترونیکی nb04@uow.edu.au می‌باشد. همچنین جهت اطلاعات بیشتر در مورد این تحقیق می‌توانید با شماره ۲۱۴۴۵۷ ۴۲ ۰۰۶۱۲ یا آدرس karen_mcrae@uow.edu.au پست الکترونیکی دبیر کمیته اخلاق پژوهشی دانشگاه ولونگونگ تماس حاصل فرمائید.

با تشکر

نرگس لنکرانی

من با شرکت فرزندم .... (لطفا نام فرزندتان را دراین محل بنویسید)

در این پژوهش موافق هستم. ضمن دریافت قسمت اول این توافقنامه می‌دانم که شرکت فرزندم دراین تحقیق داوطلبانه بوده و وی مختار است در هرزمان از روند تحقیق از شرکت در آن خودداری نماید.

نام ونام خانوادگی .... تاریخ ....

امضا ....

A3.2.4 Feed back letter about Peak Flow Rates of students to their parents

School's Name: Date:

Class: Shift: AM PM

Time	Day' Number	attendance	1st FEV1 (L/M)	2nd FEV1 (L/M)	3rd FEV1 (L/M)	Last puffer time & date
:	1					
:	2					
:	3					
:	4					
:	5					
:	6					
:	7					
:	8					
:	9					
:	10					
:	11					
:	12					
:	13					
:	42					

Observer's name:

What do I do with my scores?

Take your scores to your health care provider.

Green zone scores:

Yellow zone scores:

Red zone scores:

Your health care provider will make an asthma management plan with you and your family. This way you will know what to do if you are in the **yellow** or **red** zone. Your health care provider may want you to change how much medicine you take or the type of medicine you take.

Signed………………………………………………

Date……/……/…..

Farsi version of consent letter

ولی گرامی دانش آموز: تاریخ:

نتیجه اندازه گیری ریوی فرزند شما در طول شش هفته اندازه گیری(1381/8/18الی 1381/10/10) از قرار زیر است:

نام مدرسه: شیفت : صبح ☐ ازظهر ☐

کلاس:

زمان	روز	حاضر/غایب	اولین اندازه گیری	دومین اندازه گیری	سومین اندازه گیری	تاریخ وزمان آخرین باری که از آسم یار استفاده کرده است.
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					
	11					
	12					
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	32					
	33					

					34	
					35	
					36	
					37	
					38	
					39	
					40	
					41	
					42	

اکنون شما با این نتایج چه کاری می توانیدانجام دهید؟
این نتایج را به پزشک خانوادگی خود نشان دهید.

امتیازات حیطه سبزفرزند شما در جدول رنگ نشده است.
امتیازات حیطه زرد فرزند شما به رنگ خاکستری روشن نشان داده شده است.
امتیازات حیطه قرمز فرزند شما به رنگ خاکستری تیره نشان داده شده است.
در صورتیکه فرزند شما در حیطه زرد یا قرمز قرار دارد، پزشک خانوادگی شما، باشما یک برنامه منظم برای کنترل آسم فرزندتان تنظیم خواهد کرد. پزشکتان از شما خواهد خواست که در مورد مقدار مصرفی داروی فرزندتان تغییراتی انجام داده یا نوع آنرا عوض کنید.

نرگس باقری لنکرانی

امضا

A3.2.5 Letter to Ministry of Health

Directorate of Public and International Relations, Ministry of Health, Treatment and Medical Education

Dear Sir or Madam:

I am a postgraduate student at the University of Wollongong, Australia. I am undertaking a research project as part of my Doctor of Public Health degree. My research project is about **"Air pollution health effects on children in Tehran"**. Assoc. Prof. Irene Kreis from the above mentioned University will be supervising me in this research. The aim of this research is to examine the relation between concentrations of daily air pollutants and health effects on children of elementary school age in Tehran.

I would like to ask for your permission to allow me to collect data for respiratory hospital admissions of children aged 6-11 years old between 2000 and 2002. I would like to collect this data from the hospitals that are located in district 12. The information they contribute will be an integral part of this research and may ultimately be used to improve the quality of air and children health.

All information will be confidential and maintained under the Human Research Ethics Committee Standards of the University of Wollongong. The hospitals' contribution will also remain in secure storage, strictly confidential, and will be used purely for research purposes. I wish to thank you in advance for your cooperation and assistance in gathering the necessary data for my research.

If you would like further discussion about this research, please contact me on 8088417 in Tehran (between November to December 2002) or 0061 2 42215747 in Australia or my e-mail address nb04@uow.edu.au. If you have any queries regarding the conduct of this research, please contact the Secretary of University of Wollongong Research Ethics

Please see print copy for image

E-mail address: karen_mcrae@uow.edu.au

Best regards,

Narges Lankarani

Farsi version of consent letter

تاریخ: ۱۳۸۷/۶/۲۰

معاونت محترم تحقیقات و فن آوری وزارت بهداشت، درمان و آموزش پزشکی
جناب آقای دکتر ملک افضلی

با سلام و احترام

اینجانب نرگس باقری لنکرانی برای تکمیل بخشی از پروژه دکترای خود نیازمند مجوزی برای اخذ اطلاعات در مورد کودکان ۶ الی ۱۱ ساله مبتلا به بیمارهای تنفسی - قلبی هستم. این کودکان بایستی در سالهای ۱۳۷۹الی ۱۳۸۱ در دو بیمارستانی پذیرش شده باشند که ترجیحا در منطقه ۱۲ یا حوالی آن واقع شده باشد. عنوان این پژوهش تاثیر آلودگی هوا بر سلامتی کودکان در تهران بوده و هدف از این پژوهش بررسی رابطه بین غلظت روزانه آلاینده های هوا و تاثیرات آنها بر سلامتی دانش آموزان مقطع ابتدایی در تهران است. بدیهی است این اطلاعات جزئی از این تحقیق خواهد بود.

اینجانب عضو هیئت علمی دانشکده علوم بهزیستی هستم و هم اکنون در مقطع دکترا در دانشگاه ولنگونگ استرالیا مشغول تحصیل می باشم. این پروژه توسط خانم دکتر آیرین کرایس راهنمائی می شود. شماره تماس اینجانب دراسترالیا ۴۲۲۱۵۷۴۷(۰۰۶۱۲) یا آدرس پست الکترونیکی nb04@uow.edu.au می باشد. همچنین جهت اطلاعات بیشتر در مورد روند این تحقیق می توانید با شماره ۴۲۲۱۴۴۵۷(۰۰۶۱.۲) یا آدرس پست الکترونیکی karen_mcrae@uow.edu.au دبیر کمیته اخلاق پژوهشی دانشگاه ولنگونگ تماس حاصل فرمائید.

بدیهی است همکاری این دو بیمارستان و اطلاعات آن نزد پژوهشگر محفوظ خواهد ماند.
قبلا از کمک و همکاری شما در جمع آوری اطلاعات لازم برای این پژوهش نهایت سپاسگزاری را دارم.

با تشکر و احترام
نرگس باقری لنکرانی

دبیرخانه مرکزی معاونت تحقیقات و فناوری
وزارت بهداشت، درمان و آموزش پزشکی
شماره: ۵۲۱
تاریخ: ۱۳۸۱/۶/۲۲

۶/۲۳

۶/۲۴

English version of reference letter of University of Shihid Beheshti to Hospitals

In the name of God

Chief Executive of Hospitals Imam Hussein and Loghman e Hakim

Dear Dr………….

Mrs Narges Lankarani needs your cooperation in her research project **“Air pollution health effects on children in Tehran”**. Please order to do the required help to do her research.

Dr Latif Gachkar
Research office manager of University

Farsi version of consent letter[1]

تاریخ..................

شماره..................

پیوست..................

دانشگاه علوم پزشکی و خدمات بهداشتی درمانی

شهید بهشتی

بسمه تعالی

ریاست محترم مرکز پزشکی ، آموزشی و درمانی امام حسین (ع) ،
لقمان حکیم

با سلام ،

احتراماً خانم نرگس باقری لنکرانی خواهان همکاری در زمینه پروژه تحقیقاتی خود با عنوان " تاثیرات آلودگی هوا بر سلامت دانش آموزان دبستانی در شهر تهران " می باشند . خواهشمند است دستور فرمایند مساعدت لازم را با ایشان معمول دارند .

دکتر لطیف گچکار
مدیر امور پژوهشی دانشگاه

۵۸۰۴

۸۱/۱۵/ ۱۶

رونوشت : مدیریت امور پژوهشی دانشگاه

تهران: بزرگراه شهید چمران ـ اوین ـ جنب بیمارستان طالقانی

[1] In Iran the researcher usually ask from the related ministry and then they will introduce her to the proper source. Thus there is no need to write a letter to subordinates.

A3.2.6 Letters to Ministry of Education

Directorate of Public Relations, Ministry of Education
Dear Sir or Madam:…………………..

I am a postgraduate student at the University of Wollongong, Australia. I am undertaking a research project as part of my Doctor of Public Health degree. My research project is about **"Air pollution health effects on children in Tehran"**. Assoc. Prof. Irene Kreis from the above mentioned University will be supervising me in this research. The aim of this research is to examine the relation between concentrations of daily air pollutants and health effects on children of elementary school age in Tehran.

I would like to ask for your permission to allow me to collect data for absenteeism records for two years of children aged 6-11 years old grades for the two years between 2000 and 2002. I would like to collect this data from Haghighat and Shahsavari Schools which are located in district 12. The information they contribute will be integral part of this research and may ultimately be used to improve the quality of air pollution and children health.

All information will be confidential and maintained under the Human Research Ethics Committee Standards of the University of Wollongong. The schools' contribution will also remain in secure storage, strictly confidential, and will be used purely for research purposes. I wish to thank you in advance for your cooperation and assistance in gathering the necessary data for my research.

If you would like further discussion about this research, please contact me on 8088417 in Tehran (between November to December 2002) or 0061 2 42215747 in Australia or my e-mail address: nb04@uow.edu.au. If you have any queries regarding the conduct of this research, please contact the Secretary of University of Wollongong Research Ethics Committee:

Please see print copy for image

E-mail address: karen_mcrae@uow.edu.au

Best regards,

Narges Lankarani

Farsi version of letter[1]

تاریخ: ۱۳۸۱/۸/۸

دبیر محترم شورای تحقیقات آموزش و پرورش استان تهران
جناب آقای کسایی

با سلام و احترام
اینجانب نرگس باقری لنکرانی برای تکمیل بخشی از پروژه دکترای خود نیازمند مجوزی برای اخذ اطلاعاتی در مورد محیط زیست، اندازه گیری کارکرد ریوی، علت غیبت و روزنگار علائم ونشانه های تنفسی دانش آموزان ۶ الی ۱۱ ساله مدارس ابتدایی حقیقت و شهید شهسواری در مورد علائم تنفسی آنان واقع در منطقه ۱۲ به مدت ۷ هفته در پاییز سال ۱۳۸۱ هستم. دانش آموزان این دو مدرسه فقط برای بررسی تحقیقات در مورد تاثیر آلودگی هوای تهران بر سلامتی کودکان مورد بررسی قرار می گیرد.

به پیوست پرسشنامه ای ایفاد می گردد که تکمیل آن ۳۰ الی ۳۵ دقیقه بطول خواهد انجامید. اطلاعات این پرسشنامه توسط دانش آموزان این مدارس و به کمک والدین آنها کامل خواهد شد. تکمیل این تحقیق نیازمند اندازه گیری ریوی و جمع روزنگار علائم ونشانه های تنفسی دانش آموزان خواهد بود. شایان ذکر است که اندازه گیری کارکرد ریوی دانش آموزان توسط اینجانب و همکارم صورت می گیرد. صدور مجوز برای همکاری در انجام مراحل این تحقیق موجب تشکر و امتنان خواهد بود.

اینجانب عضو هیت علمی دانشکده علوم بهزیستی و هم اکنون مشغول تحصیل در مقطع دکترا در دانشگاه ولنگونگ استرالیا هستم و پروژه خود را با راهنمائی خانم دکتر آیرین کرایس استاد یار این دانشگاه انجام می دهم. بدیهی است این اطلاعات جزئی از این تحقیق خواهد بود و جهت بررسی بیشتر برای پیشبرد کیفیت الودگی هوا و سلامتی کودکان تهران استفاده خواهد شد.

شماره تماس اینجانب دراسترالیا ۴۲۲۱۵۷۴۷(۰۰۶۱۲) یا آدرس پست الکترونیکی nb04@uow.edu.au می باشد. همچنین جهت اطلاعات بیشتر در مورد روند این تحقیق می توانید با شماره ۴۲۲۱۴۴۵۷ (۰۰۶۱.۲) یا آدرس پست الکترونیکی karen_mcrae@uow.edu.au دبیر کمیته اخلاق پژوهشی دانشگاه ولنگونگ تماس حاصل فرمائید.

بدیهی است همکاری این دو مدرسه و اطلاعات آن نزد پژوهشگر محفوظ خواهد ماند.
قبلا از کمک و همکاری شما در جمع آوری اطلاعات لازم برای این پژوهش نهایت سپاسگزاری را دارم.

با تشکر و احترام
نرگس باقری لنکرانی

۸۱/۸/۱

رونوشت =
بااهداء سلام به دبستانهای شهید شهسواری و دبستان حقیقت جهت همکاری لازم بامشارالیهاارسال میگردد. ۸/۴

رضامددی
مدیر آموزش وپرورش منطقه ۱۲ تهران

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[1] The referral letter from the manager of District 12 of ministry of education was written on the letter.

A3.2.7 Referral letter from Ministry of Education to principals of primary schools

Dear Principals of Shahid Shahsavari and Haghighat

Please do your best to cooperate with the mentioned researcher.

Reza Madady

District 12 Manager
Ministry of Education

A3.2.8 Letter to official body for Air Pollution measurement

6-Aug-02

Managing Director of Air Quality Control Company
Dear Mr. Rashidi

I am a postgraduate student at the University of Wollongong, Australia. I am undertaking a research project as part of my Doctor of Public Health degree. My research project is about "**Air pollution health effects on children in Tehran"**. Assoc. Prof. Irene Kreis from the above mentioned University will be supervising me in this research. The aim of this research is to examine the relation between concentrations of daily air pollutants and health effects on children of elementary school age in Tehran.

I would like to ask for your permission to allow me to collect data for air pollution and meteorological records between 2000 and 2002 in district 12. The information that you contribute will be an integral part of this research and may ultimately be used to improve the quality of air pollution and children health.

All information will be confidential and maintained under the Human Research Ethics Committee Standards of the University of Wollongong. The station' contribution will also remain in secure storage, strictly confidential, and will be used purely for research purposes. I wish to thank you in advance for your cooperation and assistance in gathering the necessary data for my research.

If you would like further discussion about this research, please contact me on 8088417 in Tehran (between November to December 2002) or 0061 2 42215747 in Australia or my e-mail address: nb04@uow.edu.au. If you have any queries regarding the conduct of this research, please contact the Secretary of University of Wollongong Research Ethics Committee:
Telephone number: 0061 2 42214457
E-mail address: karen_mcrae@uow.edu.au

Best regards,
Narges Lankarani

Farsi version of letter

تاریخ :

ریاست محترم شرکت کنترل کیفیت هوا
خانم / آقای ....

با سلام و احترام

اینجانب نرگس باقری لنکرانی برای تکمیل بخشی از پروژه دکترای خود نیازمند مجوزی برای اخذ اطلاعاتی در مورد میزان آلودگی هوا و اطلاعات هواشناسی درمنطقه ۱۲ تهران در سالهای ۱۳۸۰ الی ۱۳۸۱ هستم. این اطلاعات فقط جهت تحقیق درمورد تاثیر آلودگی هوای تهران بر سلامتی کودکان مورد بررسی قرار می گیرد.

اینجانب عضو هیت علمی رسمی دانشکده علوم بهزیستی هستم و هم اکنون در مقطع دکترا در دانشگاه ولنگونگ استرالیا در مورد این موضوع تحقیق می کنم، این پروژه توسط خانم دکتر آیرین کرایس استاد یار این دانشگاه راهنمائی می شود و بدیهی است اطلاعات آن جزئی از تحقیق بوده و جهت بررسی بیشتر برای پیشبرد کیفیت آلودگی هوا و سلامتی کودکان تهران استفاده خواهد شد.

تمام اطلاعات بدست آمده محرمانه بوده و تحت استانداردهای کمیته اخلاق تحقیقات انسانی دانشگاه ولونگونگ محفوظ خواهد ماند. اطلاعات این مرکز نیز در یک صندوق امن نگهداری و به عنوان اطلاعات خیلی محرمانه نگهداری می شود بدیهی است این اطلاعات تنها برای اهداف تحقیقی بکار گرفته خواهد شد. قبلا از کمک و همکاری شما در جمع آوری اطلاعات لازم این پژوهش نهایت سپاسگزاری را دارم.

شماره تماس اینجانب دراسترالیا ۴۲۲۱۵۷۴۷ (۰۰۶۱۲) یا آدرس پست الکترونیکی nb04@uow.edu.au می باشد. همچنین جهت اطلاعات بیشتر در مورد روند این تحقیق می توانید با شماره ۴۲۲۱۴۴۵۷ (۰۰۶۱.۲) یا آدرس پست الکترونیکی karen_mcrae@uow.edu.au دبیر کمیته اخلاق پژوهشی دانشگاه ولنگونگ تماس حاصل فرمائید.

با تشکر و احترام
نرگس باقری لنکرانی

A3.3 General Health Questionnaire

SCHOOL: ☐

TODAY'S DATE: ☐ ☐ ☐

Day Month Year

NAME: ☐

AGE: ☐

Years

DATE OF BIRTH: ☐ ☐ ☐

Day Month Year

(Tick all your answers for the rest of the questionnaire)

Are you a: ☐ ☐

MALE FEMALE

Questions about Home Environment

1. Do you have any pets? YES ☐ NO ☐ If no go to question 3

If yes, what kind? ☐ How many in your home? ☐

2. Do pets stay or sleep in your bedroom? ☐ YES ☐ NO

3. Do you have at least once a week contact with any of the following animals outside your home?

Dog ☐ Cat ☐

Farm animals ☐ other animals (please specify) ☐

4. Do you sneeze, itch, or wheeze or cough around pets? YES ☐ NO ☐

5. Is your bed very dusty? YES ☐ NO ☐

6. Are there mite-proof covers on your pillow and mattress?

YES ☐ NO ☐

7. What kind of pillow do you use? (Tick as many as apply)

Foam ☐ Synthetic fibber ☐ Feather ☐

Other (please specify below) ☐

Do not use a pillow ☐ Do not know ☐

8. What kind of bedding do you use? (tick as many as apply)

Cotton quilt ☐ Woollen quilt ☐

Synthetic quilt ☐ Feathers quilt ☐

Blankets ☐

Other materials (please specify) ☐

Cotton mattress ☐ Synthetic mattress ☐

Woollen mattress ☐ Healthy mattress ☐

Other materials (please specify)

	Cold	Warm	Hot
9. Are the sheets washed in water that is:	☐	☐	☐

How often in a month? ☐

10. Does anybody smoke inside your home? YES ☐ NO ☐

(If no go to question 12)

If yes where? ☐ and how many smokers? ☐☐

11. Is there smoke other places where you regularly go? YES ☐ NO ☐

If yes, where? ☐

12. Do you have moisture or dampness in any room of your home?

(eg. Basement, walls, ceilings) YES ☐ NO ☐

13. Do you have mould visible in any part of your home? YES ☐ NO ☐

14. Have you seen cockroaches in your home in the last month? YES ☐ NO ☐

15. Have you seen mice in your home in the last month? YES ☐ NO ☐

16. Do you share the bedroom with other people (adults or children)?

YES ☐ NO ☐

17. Which cooling system is used in your home?

Water cooler ☐ Gas cooler ☐ Air condition ☐ Fan ☐

18. What kind of floor covering is there in your home?

Fitted carpets ☐ Loose carpets ☐ Bare floor ☐

19. How often are the fitted carpets in your home washed in a year? ☐

20. How often are the loose carpets in your home washed in a year? ☐

21. What kind of floor covering is there in your bedroom?

Fitted carpets ☐ Loose carpets ☐ Bare floor ☐

22. Is the kitchen near the living room? YES ☐ NO ☐

23. Which fuel do you use for cooking? (tick as many as apply)

Electricity ☐ Gas ☐ Oil ☐ Other (please specify) ☐

24. Is there a chimney for the stove in the kitchen? YES ☐ NO ☐

25. Is a central heating system used in your home? YES ☐ NO ☐

If no, how many heaters are used? ☐☐

26. Is a wood-burning stove or fire place used in your home?

YES ☐ NO ☐

27. Do you have contact with other smells or fumes from perfumes, cleaning agents, or sprays in your home? YES ☐ NO ☐

28. Do you cough or wheeze during the week, but not on wee d w away from school? YES NO

29. Do your eyes and nasal passages get irritated soon after arriving at school? YES NO

30. Do your class mates have the same symptoms? YES NO

31. Have you had coughing, wheezing, or shortness of breath at night in the past 4 weeks? YES NO

32. Do you have wheezing, coughing or shortness of breath after eating shrimp, dried fruit, or processed potatoes? YES NO

33. What medication do you use now?

34. Have you ever had symptoms of asthma after taking any of these medications? YES NO

35. How much have you been coughing recently?

A lot hardly ever

Sometimes Not at all

36. How often have you missed school because of your asthma recently?

A lot hardly ever

Sometimes Not at all

37. How often have you missed playing sport at school because of your asthma recently?

A lot ☐ hardly ever ☐
Sometimes ☐ Not at all ☐

38. How often do you use your relief inhaler when you are feeling wheezy?

A lot ☐ hardly ever ☐
Sometimes ☐ Not at all ☐

39. Have you ever had wheezing or whistling in the chest at any time in the past? Yes ☐ No ☐

If you have answered 'No' please skip to question 44

40. Have you had wheezing or whistling in the chest in the last 12 months?
Yes No ☐ ☐

If you have answered 'No' please skip to question 44

41. How many attacks of wheezing have you had in the last 12 months?
None ☐ 1–3 ☐ 4–12 ☐ More than12 ☐

42. In the last 12 months, how often on the average, have your sleep been disturbed due to wheezing?

Never woken with wheezing ☐ less than one night per week ☐
One or more nights per week ☐

43. In the last 12 months, has wheezing ever been severe enough to limit your speech to only one or two words at a time between breaths? Yes ☐ No ☐

44. Have you ever had asthma? Yes ☐ No ☐

45. In the last 12 months, has your chest sounded wheezy during or after exercise? Yes ☐ No ☐

46. In the last 12 months, have you had a dry cough at night apart from a cough associated with a cold or flu?

Yes ☐ No ☐

Information to be completed by parent

47. How many school days has your children lost in the past two months because of his/her asthma?

None at all ☐
1or 2days ☐
3 to 5days ☐
5 to 10 days ☐
More than 10days ☐

48. How often have you been woken at night by your child's asthma in the past two months?

Not at all ☐
Less than one night per week ☐
Once a week ☐
Several nights a week ☐
Almost every night ☐

49. How would you rate the severity of your child's asthma at the moment?

Mild ☐
Moderate ☐
Severe ☐

50. How well controlled is your child's asthma at that moment?

Very well controlled ☐

Quite well controlled ☐

Not at all well controlled ☐

Cough and phlegm

51. In the last 12 months, has your child usually seemed congested in the chest or coughed up phlegm (mucus) with colds?

Yes ☐ No ☐

52. In the last 12 months, has your child usually seemed congested in the chest or coughed up phlegm (mucus) when he/she did not have a cold?

Yes ☐ No ☐

IF YOU HAVE ANSWERED "NO" TO BOTH OF THESE QUESTIONS, PLEASE SKIP QUESTIONS 53a.

53. a- Does your child seem congested in the chest or coughed up phlegm (mucus) on most days (4 or more days a week) for as much as 3 months of the year?

Yes ☐ No ☐

IF YOU HAVE ANSWERED "NO", PLEASE SKIP QUESTION 53-b.

b-For how many years has this happened? _______ years

Wheeze and breathlessness

54. In the last 12 months, has your child's chest sounded wheezy during or after exercise? Yes ☐ No ☐

55. In the last 12 months, has your child's chest sounded wheezy when he or she had not recently taking exercise?

Yes ☐ No ☐

56. In the last 12 months, has your child had wheezing or whistling in the chest when he/she had a cold or the 'flu?

Yes ☐ No ☐

57. In the last 12 months, has your child had wheezing or whistling in the chest when he/she did not have a cold or the 'flu? Yes ☐ No ☐

☐ ☐

58. Has your child woken up with shortness of breath at any time in his or her life? Yes No

59. Has your child woken up with tightness of the chest at any time in his or her life? Yes ☐ No ☐

60. In the last 12 months, what has made your child's wheezing worse? (Tick all that apply)

Weather ☐ Pollen ☐ Emotion ☐

Fumes ☐ Dust ☐ Pet ☐

Wool clothing ☐ Colds or 'flu ☐ Cigarette smoke ☐

Foods or drinks ☐ Soaps, sprays or detergents ☐

Other things (please list below)

Your Home

61. Does anybody, at present, smoke inside your home?

If yes, how many cigarettes in total are smoked per day in the home?

(eg mother smokes 4 + father smokes 5 + other persons smoke 3 = 12 cigarettes)

Less than 10 cigarettes ☐

10-20 cigarettes ☐

More than 20 cigarettes ☐

62. Which fuel do you use for heating?

(Tick as many as apply)

Gas	☐	Electricity	☐	Wood	☐
Oil	☐	Coal or coke	☐	Other (please specify)	

63. What kind of windows are there in your child's bedroom?

(Tick as many as apply)

Single glazing ☐

Secondary window ☐

Sealed unit or Double glazing ☐

No windows ☐

64. Have you made any changes in your home because your child had asthma or allergic problems? (tick as many boxes as apply)

Removed pet

Yes ☐ If yes, at what age of the child? _____ years

No ☐

Stopped or reduced smoking

Yes ☐ If yes, at what age of the child? _____ years

No ☐

Changed pillows

Yes ☐ If yes, at what age of the child? _____ years

No ☐

Changed bedding

Yes ☐ If yes, at what age of the child? _____ years

No ☐

Changed floor Covering

Yes ☐ If yes, at what age of the child? _____ years

No ☐

Other changes

Yes ☐ If yes, at what age of the child? _____ years

No ☐

65. How would you describe the surroundings of your home?

Open spaces or fields nearby ☐

With many parks ☐

With few parks ☐

With no parks or gardens ☐

66. What is the name of your street of residence? ☐

67. What is the postal code of your home? ☐

A3.3.1 Farsi version of questionnaire

پرسشنامه سلامت عمومی

نام دبستان

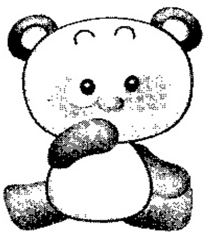
تاریخ روز ۱۳۸۱ / /

نام و نام خانوادگی

سن سال

تاریخ تولد ۱۳ / /

نرگس باقری لنکرانی
Narges Bagheri Lankarani
Email: nb04@uow.edu.au



(لطفا برای پاسخ به سئوالات علامت بزنید)

جنس: پسر ☐ دختر ☐

سئوالاتی درمورد محیط منزل

۱-آیا حیوان خانگی دارید؟ بله ☐ خیر ☐

اگر دارید به سئوال ۲ و اگر ندارید به سئوال ۳ پاسخ دهید .

اگر دارید چه نوع حیوانی؟ ☐ وچند تا؟ ☐☐

۲-آیا حیوانات خانگی شما در اتاق خوابتان می‌مانند یا می‌خوابند؟

بله ☐ خیر ☐

۳-آیا شما با حیواناتی که نام آنها این زیر نوشته شده درخارج ازمنزل دست کم هفته ای یکبارتماس دارید؟

سگ ☐ گربه ☐ حیوانات مزرعه ☐

حیوانات دیگر(لطفا نام انها را بنویسید)

☐

۱

۴-آیا هنگامی که درکنار حیوانات هستید علائمی مانند عطسه سرفه یاخارش دارید؟ بله ☐ خیر ☐

۵-آیا تخت یا رختخواب شما پر گردو غبار است؟
بله ☐ خیر ☐

۶-آیا بالش و تشک شما مجهز به آستری است که با چرخ لبه آن دوخته شده است ؟ بله ☐ خیر ☐

۷- ازچه نوع بالشی استفاده میکنید؟(از هرنوعی که استفاده می کنید علامت بزنید) ابر ☐ الیاف مصنوعی ☐
(اگر غیر از اینهاست نام ببرید) ☐
از بالش استفاده نمی کنم ☐ نمی دانم ☐

۸-از چه نوع رختخوابی استفاده می کنید؟(لطفا هرچندنوعی راکه استفاده میکنید علامت بزنید) لحاف پنبه ای ☐
پشمی ☐ الیاف مصنوعی ☐ پر ☐ پتو ☐
اگر غیر از اینهاست نام ببرید ☐

تشک: پنبه‌ای ☐ الیاف مصنوعی ☐ پشمی ☐ طبی ☐

(اگر غیر از اینهاست نام ببرید) ☐

۹-آیا ملافه‌هایت در آب سرد ☐ گرم ☐ داغ ☐

شسته می‌شوند؟ بله ☐ خیر ☐ چند بار درماه؟ ☐

۱۰-آیا کسی در منزل شما دخانیات استعمال می کند؟

بله ☐ خیر ☐ (اگر نه به سراغ سئوال ۱۲ بروید)

اگر بله کجا؟ ☐ چند نفر؟ ☐

۱۱- آیا درجاهای دیگری که معمولا می‌روید دود وجود دارد؟

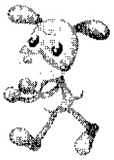
اگر بله کجا؟ ☐

۱۲- آیا درجایی ازاتاق یا منزل شما نم وجود دارد؟

(مثال:زیرزمین،دیوار،سقف) بله ☐ خیر ☐

۱۳- آیا درجایی از منزل شما کفک دیده می‌شود؟

بله ☐ خیر ☐



تشک: پنبه‌ای الیاف مصنوعی پشمی طبی

(اگر غیر از اینهاست نام ببرید)

۹-آیا ملافه‌هایت در آب سرد گرم داغ

شسته می‌شوند؟ بله خیر چند بار درماه؟

۱۰-آیا کسی در منزل شما دخانیات استعمال می کند؟

بله خیر (اگر نه به سراغ سئوال ۱۲ بروید)

اگر بله کجا؟ چند نفر؟

۱۱- آیا درجاهای دیگری که معمولا می‌روید دود وجود دارد؟

اگر بله کجا؟

۱۲- آیا درجایی ازاتاق یا منزل شما نم وجود دارد؟

(مثال:زیرزمین،دیوار،سقف) بله خیر

۱۳- آیا درجایی از منزل شما کفک دیده می‌شود؟

بله خیر

۱۴- آیا در طی ماه گذشته ، درمنزل سوسک دیده اید؟

بله ☐ خیر ☐

۱۵-آیا در طی ماه گذشته، درمنزل موش دیده اید ؟

بله ☐ خیر ☐

۱۶- آیا اتاق خواب شما با سایر افراد خانواده(کودک یا بزرگسال)

مشترک است ؟ بله ☐ خیر ☐

۱۷-از چه سیستمی برای خنک کردن منزل استفاده می کنید؟

کولر آبی ☐ کولر گازی ☐ تهویه مطبوع ☐

پنکه ☐ پکیج ☐

۱۸-از چه کفپوشی در منزل استفاده شده است ؟

موکت به زمین چسبیده ☐ زمین بدون فرش ☐

موکت سیار قالی ماشینی یا فرش ☐

۱۹-چندبار در سال موکت به زمین چسبیده خانه شما شسته

می‌شود؟ ☐

۴

۲۰-چند بار در سال موکت، قالی یا فرش ماشینی شما شسته می‌شود؟ ☐

۲۱- از چه کفپوشی در اتاق خواب شما استفاده شده است ؟

موکت به زمین چسبیده ☐ زمین بدون فرش ☐

موکت سیار قالی ماشینی یا فرش ☐

۲۲-آیا آشپزخانه شما نزدیک هال یا اتاق نشیمن است ؟

بله ☐ خیر ☐

۲۳-در منزل شما برای پختن غذا معمولا از چه سوختی استفاده می‌شود؟ برق ☐ گاز ☐ نفت ☐

سایر موارد (لطفاً نام ببرید)

۲۴-آیا دودکشی برای اجاق آشپزخانه وجود دارد؟

بله ☐ خیر ☐

۲۵-آیا از سیستم گرمای مرکزی درمنزل شما استفاده شده است؟

بله ☐ خیر ☐

اگر نه از چند بخاری در منزل شما استفاده می‌شود؟ ☐

۲۶-آیا در منزل شما از اجاق چوب سوز یا شومینه استفاده می‌شود؟ بله ☐ خیر ☐

۲۷- آیا با بو یا رایحه‌هایی که از عطر،مواد پاک کننده یا اسپری متصاعد می‌شود تماس دارید؟ بله ☐ خیر ☐

۲۸-آیا در روزهایی که به مدرسه می‌روید سرفه یا عطسه می‌کنید؟ بله ☐ خیر ☐

درصورتیکه پاسخ شما به سئوال بالا خیر است آیا در روزهای تعطیل این علائم را دارید؟ بله ☐ خیر ☐

درصورتیکه پاسخ شما به سئوال ۲۸ بله است آیا هرروز دچار این علائم هستید؟ بله ☐ خیر ☐

۲۹-آیا به محض ورود به مدرسه دچار سوزش چشم وبینی می‌شوید؟ بله ☐ خیر ☐

۳۰-آیا همکلا سی های شما هم مانند شما دچار همین علا ئم می شو ند؟ بله ☐ خیر ☐

۳۱-آیا شما درطی ۴ هفته گذشته، سرفه، عطسه یا تنگی نفس شبانه داشته‌اید؟ بله ☐ خیر ☐

۳۲- آیا بعد از خوردن میگو، میوه خشک شده یا سیب زمینی سرخ شده مانند چیپس یا سیب زمینی آماده طبخ دچار سرفه، عطسه یا تنگی نفس می شوید؟ بله ☐ خیر ☐

۳۳-هم اکنون از چه داروهایی استفاده می کنید؟

☐

۳۴-آیا بعد از مصرف این داروها دچار علا ئم آسم شده اید؟ بله ☐ خیر ☐

۳۵- تازگی چند بار سرفه کرده اید؟

خیلی ☐ بعضی او قات ☐ بندرت ☐ هیچوقت ☐

۳۶- تازگی بعلت آسم چند بار مدرسه نرفتید ؟

خیلی ☐ بعضی اوقات ☐ بندرت ☐ هیچوقت ☐

۳۷- تازگی بعلت آسم چند بار ورزش کردن در مدرسه را از دست دادید؟

خیلی ☐ بعضی اوقات ☐ بندرت ☐ هیچوقت ☐

۳۸-چند وقت یکبار، درهنگام خس خس سینه از اسپری تنفسی استفاده می‌کنید؟

خیلی ☐ بعضی اوقات ☐ بندرت ☐ هیچوقت ☐

۳۹-آیا در گذشته خس خس سینه داشته‌اید ؟

بله ☐ خیر ☐ اگر نه به سراغ سئوال ۴۴ بروید.

۴۰-آیا در ۱۲ ماه گذشته، خس خس سینه داشته‌اید؟

بله ☐ خیر ☐ (اگرنه به سراغ سئوال ۴۴بروید)

۴۱- آیا در۱۲ماه گذشته، حمله تنفسی داشته‌اید؟هیچ وقت ☐

۱-۳بار ☐ ۴-۱۲بار ☐ بیش از ۱۲بار ☐

۴۲- آیادر ۱۲ ماه گذشته، بعلت خس خس خوابتان بتعویق

افتاده است؟ هیچوقت با خس خس بیدار نشده‌ام ☐

کمتر از یک شب در هفته ☐ یک یا چند شب در هفته ☐

۴۳- آیا در ۱۲ ماه گذشته، هیچوقت خس خس سینه شما آنقدر

شدید بوده که نتوانید در آن زمان‌بیش از یک یا دو کلمه در

بین هر تنفس صحبت کنید؟ بله ☐ خیر ☐

۴۴- آیا تابحال آسم داشتید؟ بله ☐ خیر ☐

۴۵-آیا در ۱۲ ماه گذشته،درطی زمان ورزش یا بعد از آن سینه

شما صدای خس خس داده است ؟ بله ☐ خیر ☐

۴۶- آیا در ۱۲ ماه گذشته، غیر از سرفه مربوط به‌سرماخوردگی

یا آنفلوآنزا در هنگام شب دچار سرفه خشک شدید؟

بله ☐ خیر ☐

اطلاعات مربوط به والدین :

۴۷- در دو ماه گذشته، فرزند شما بعلت آسم چند روز از مدرسه غیبت داشته است ؟ هیچوقت ☐ ۲- ۱روز ☐

۵-۳روز ☐ ۱۰-۶روز ☐ بیش از ۱۰ روز ☐

۴۸-در دو ماه گذشته، چند بار فرزند شما بعلت آسم در شب بیدار شده است؟ هیچوقت ☐ کمتر از یک شب در هفته ☐

یکبار در هفته ☐ چندبار در هفته ☐ تقریبا هر شب ☐

۴۹- شدت آسم فرزندتان را در آن لحظه چگونه درجه بندی می‌کنید؟ خفیف ☐ متوسط ☐ شدید ☐

۵۰- در آن لحظه آسم فرزندتان خوب کنترل شده است ؟

بسیار خوب ☐ کاملا خوب ☐

اصلا خوب کنترل نشده ☐

۵۱- آیا در ۱۲ ماه گذشته، فرزندشما در صورت ابتلا به سرماخوردگی سینه پرخلطی داشته یا بواسطه سرفه خلط از سینه اش خارج می شده است؟ بله ☐ خیر ☐

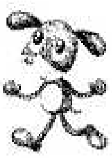
۵۲- آیا در ۱۲ ماه گذشته، فرزندشما در صورت عدم ابتلا به سرماخوردگی سینه پرخلطی داشته یا بواسطه سرفه خلط از سینه اش خارج می شده است؟ بله ☐ خیر ☐

درصورتی که به دوسئوال فوق پاسخ منفی دادید، پاسخ به سئوال ۵۳ ضروری نیست.

۵۳ الف - آیا فرزند شما در اکثر روزهای یک فصل خاص، سینه پر خلطی داشته ، یا در موقع سرفه از دهانش خلط خارج می‌شود؟ بله ☐ خیر ☐

اگر پاسخ شما به سئوال فوق منفی است، پاسخ به سئوال ۵۳ ب ضروری نیست.

۵۳ب - این موارد چند سال است که اتفاق افتاده؟ ☐ سال



خس خس سینه و تنگی نفس

۵۴-آیا در ۱۲ ماه گذشته ، سینه فرزند شما در هنگام ورزش صدای خس خس می داد؟ بله ☐ خیر ☐

۵۵-آیا در ۱۲ ماه گذشته ، سینه فرزند شما در غیرهنگام ورزش صدای خس خس می داد؟ بله ☐ خیر ☐

۵۶-آیا در ۱۲ ماه گذشته سینه فرزند شما در هنگام ابتلا به سرماخوردگی یا آنفلوآنزا صدای خس خس می داد؟

بله ☐ خیر ☐

۵۷-آیا در ۱۲ ماه گذشته ، سینه فرزند شما در غیرهنگام ابتلا به سرماخوردگی یا آنفلوآنزا صدای خس خس می داد؟

بله ☐ خیر ☐

۵۸-آیا فرزند شما در زمانی از عمر خود بعلت تنگی نفس از خواب بیدار شده است؟ بله ☐ خیر ☐

۵۹-آیا فرزند شما در زمانی از عمر خود بعلت احساس فشار در قفسه سینه از خواب بیدار شده است ؟ بله ☐ خیر ☐

۶۰- در ۱۲ ماه گذشته ، چه چیزی باعث بدتر شدن خس خس سینه فرزندتان شده است؟

(درصورتی که همه موارد در زیر در وقوع این امر دخیل بوده، همه را علامت بزنید)

غذا و مایعات آشامیدنی ☐ لباس یا پارچه پشمی ☐

بو ☐ هوا ☐ گرده گیاهان ☐ هیجانات ☐

سرماخوردگی یا آنفلو آنزا ☐ حیوانات خانگی ☐

دود سیگار ☐ صابون، اسپری یا مواد پاک کننده ☐

(سایر مواردلطفا نام ببرید) ☐

منزل شما

۶۱-آیا هم اکنون در منزل شما کسی دخانیات استعمال می‌کند؟

بله ☐ خیر ☐

درصورت پاسخ مثبت ،مجموعا چند نخ سیگار درمنزل شما روزانه استعمال می شود؟

(مثال: مادر ۴ نخ+پدر ۵نخ+سایرین ۳ نخ=۱۲سیگار)

کمتر از ۱۰ نخ ☐ ۱۰-۲۰ نخ ☐ بیش از ۲۰ نخ سیگار ☐

۶۲- برای ایجاد گرما درمنزل چه سوختی‌استفاده می شود؟

گاز ☐ برق ☐ چوب ☐ نفت ☐ زغال ☐

سایر موارد (لطفا نام ببرید) ☐

۶۳-اتاق خواب فرزندتان دارای چه نوع پنجره هایی است؟

(هرموردی که دراین اتاق خواب وجوددارد علامت بزنید)

شیشه یک لایه ☐ شیشه دولایه ☐ پنجره بسته ☐

دوپنجره پشت سرهم ☐ بدون پنجره ☐

۶۴-آیا بواسطه آسم یا مشکلات آلرژی فرزندتان، تغییراتی درمنزل خود ایجاد کرده اید؟

بیرون انداختن حیوانات خانگی بله ☐ خیر ☐

در این صورت فرزندتان درچه سنی بوده است؟ ☐ سال

ترک یا کاهش استعمال دخانیات بله ☐ خیر ☐

۱۴

در این صورت فرزندتان درچه سنی بوده است؟ ☐ سال

تعویض بالش بله ☐ خیر ☐

در این صورت فرزندتان درچه سنی بوده است؟ ☐ سال

تعویض رختخواب بله ☐ خیر ☐

در این صورت فرزندتان درچه سنی بوده است؟ ☐ سال

تعویض کفپوش بله ☐ خیر ☐

در این صورت فرزندتان درچه سنی بوده است؟ ☐ سال

۶۵-چگونه محیط پیرامون منزل خود را توصیف می کنید؟

فضای باز با حیاط ☐ با چند پارک ☐

با پارکهای بسیار ☐ بدون هیچ پارک یا باغچه ☐

۶۶-در صورت تمایل نام خیابان و محل سکونت خود را بنویسید؟

☐

۶۷- درصورت تمایل شماره تلفن و کدپستی خودرا مرقوم فرمائید؟

☐

ALL QUESTIONNAIRE DATA

A3.3.2 Codebook

Question Number	Name	Specification and Codes	width
a	SCHOOL	School identifying number	3-4
b	Shift	am /pm	2
c	DINT	Date of filling out	6
		dd = Day	
		mm = Month	
		yy = Year	
		99 = For an invalid response & any missing value	
d	SERIAL	Serial number of respondent	4
e	AGE	The actual age of the child/respondent	2
		(years)	
		99 = For any invalid response& any missing value	
f	DBIRTH	Date of birth of the child/respondent	6
		dd = Day	
		mm = Month	
		yyyy = Year	
		99 = For any invalid response& any missing value	
g	SEX	Sex of the child/respondent	1
		1 = Male	
		2 = Female	
		9 = any other response	
1	PET		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
1a	PETK		1
		1=birds	
		2= cat	
		3= dog	
		4=fish	
		9 = any other response& any missing value	
1b	NOPET		1
2	PETS		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
3	ANIMALCONTACT		1
		1=Dog	
		2=Cat	
		3=Farm animals	
		9 = any other response& any missing value	
4	PETSALERG		1
		1= Yes	

Question Number	Name	Specification and Codes	width
		2=No	
		9 = any other response& any missing value	
5	BEDSDUST		1
		1= Yes	
		2=No	
		9 = any other response	
6	MITEPROOF		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
7	PILOWK		1
		1 = Foam	
		2 = Synthetic fiber	
		3=Feather	
		4= No pillow use	
		9 = any other response& any missing value	
8	BEDK		1
		1 = Synthetic quilt	
		2 = Feather quilt	
		3= Blankets	
		9 = any other response& any missing value	
9	SHEETSW		1
		1 = cold	
		2 = warm	
		3 = hot	
		9 = any other response& any missing value	
9a	SHEETSWT		1
10	SMOKE		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
10a	SMOKEW		1
10b	SMOKERN		1
11	SMOKEOP		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
11a	SMOKEOPW		1
12	MOIST		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
13	MOLD		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	

Question Number	Name	Specification and Codes	width
14	COACKROCH		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
15	MICE		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
16	BEDROOMS		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
17	COOLSYS		1
		1 = Water	
		2 = Gas	
		3 = Air condition	
		4 = Fan	
		9 = any other response& any missing value	
18	FLOORCOV		1
		1 = Fitted carpet	
		2 = Loose carpet	
		3 = Bare	
		9 = any other response& any missing value	
19	FITCARPW		1
20	LOOSCARPW		1
21	BEDFLOORCOV		1
		1 = Fitted carpet	
		2 = Loose carpet	
		3 = Bare	
		9 = any other response& any missing value	
22	KITCHENLOC		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
23	CFUELTYP		1
		1 = Electricity 1	
		2 = Gas	
		3 = Oil	
		4=Other	
		9 = any other response& any missing value	
24	CHIMNEYSTOV		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
25	CENTRALHEATIN		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	

Question Number	Name	Specification and Codes	width
25a	HEATERSNO		1
26	FIREPLACE		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
27	SMELLSCOTAC		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
28	COUGHWEEKDAYS		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
29	EYESIRRITAT		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
30	CLASSMATE EYESIRRITAT		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
31	WHEZE4		1
		1= Yes	
		2=No	
		9 = Any other response& any missing value	
32	WHEZEF		1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
33	MEDICATION		1
34	ASTHMA MEDICATION		1
35	COUGHQUANT	How much have you been coughing recently?	1
		1 = A lot	
		2 = Sometimes	
		3 = Hardly ever	
		4 = Not at all	
		9 = any other response& any missing value	
36	MISSEDSCHOOL		1
		1 = A lot	
		2 = Sometimes	
		3 = Hardly ever	
		4 = Not at all	
		9 = any other response& any missing value	
37	MISSEDPLAY	How often have you missed school because	
		of your asthma recently?	1
		1 = A lot	

Question Number	Name	Specification and Codes	width
		2 = Sometimes	
		3 = Hardly ever	
		4 = Not at all	
		9 = any other response& any missing value	
38	RELIEFINHALER	How often have you missed playing sport	1
		at school because of your asthma recently?	
		1 = A lot	
		2 = Sometimes	
		3 = Hardly ever	
		4 = Not at all	
		9 = any other response& any missing value	
39	WHEZEV	Have you ever had wheezing or whistling	1
		in the chest at any time in the past?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
40	WHEZ12	Have you had wheezing or whistling in the	1
		chest in the last 12 months?	
		1= Yes	
		2=No	
		9 = Any other response& any missing value	
41	NWHEZ12	How many attacks of wheezing has your	1
		child/ have you had in the last 12 months?	
		1 = None	
		2 = 1 to 3	
		3 = 4 to 12	
		4 = More than 12	
		9 = any other response& any missing value	
42	AWAKE12	In the last 12 months, how often, on	1
		average, has your (child's) sleep been	
		disturbed due to wheezing?	
		1 = Never woken with wheezing	
		2 = Less than one night per week	
		3 = One or more nights per week	
		9 = any other response& any missing value	
43	SPEECH12	In the last 12 months, has wheezing	1
		ever been severe enough to limit your	
		(child's) speech to only one or two words	
		at a time between breaths?	
		1= Yes	
		2=No	
		9 = Any other response& any missing value	
44	ASTHMAEV	Have you ever had asthma?	1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
45	EXWHEZ12	In the last 12 months, has your chest sounded	1
		wheezy during or after exercise?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	

Question Number	Name	Specification and Codes	width
46	COUGH12	In the last 12 months, have you had a dry	1
		cough at night, apart from a cough associated	
		with a cold or chest infection?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
47	MISSEDSCHOOL2	How many school days has your children	1
		lost in the past two months because of his/her	
		asthma?	
		1=None at all	
		2 = 1-2 days	
		3 = 3-5days	
		4 = 5-10days	
		5 = more than 10 days	
		9 = Any other response& any missing value	
48	AWAKE	In the last 2 months, how often, on	1
		average, have you been woken at night by your	
		child's asthma?	
		1=None at all	
		2 = Less than one night per week	
		3 = Once a week	
		4 = several nights a week	
		5 = almost every night	
		9 = any other response& any missing value	
49	ASTHMASEVER	How would you rate the severity of your	1
		child's asthma at the moment?	
		1=Mild	
		2 = Moderate	
		3 = Severe	
		9 = any other response& any missing value	
50	ASTHMACONTROL	How well controlled is your child's asthma	1
		at the moment?	
		1=Very well controlled	
		2=Quite well controlled	
		3=Not at all well controlled	
		9 = any other response& any missing value	
51	COUGHPHLEGMCOLDS	In the last 12 months, has your child usually	1
		seemed congested in the chest or coughed up	
		phlegm (mucus) with colds?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
52	COUGHPHLEGM	In the last 12 months, has your child usually	1
		seemed congested in the chest or coughed up	
		phlegm (mucus) when he/she did not have a	
		cold?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
53	COUGHPHLEGM3	Does your child seem congested in the chest	1
		or cough up phlegm (mucus) on most days	
		(4 or more days a week) for as much as	
		3 months of the year?	

Question Number	Name	Specification and Codes	width
		1= Yes	
		2=No	
		9 = any other response& any missing value	
53a	YEARS	For how many years has this happened?	2
54	WHEZEXERCISE	In the last 12 months, has your child's chest	1
		sounded wheezy during or after exercise?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
55	WHEZNOTEXERCISE	In the last 12 months, has your child's chest	1
		sounded wheezy when he or she had not	
		recently taken exercise?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
56	WHEZFLU	In the last 12 months, has your child had	1
		wheezing or whistling in the chest when he/	
		she had a cold or the 'flu?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
57	WHEZNOTFLU	In the last 12 months, has your child had	1
		wheezing or whistling in the chest when he/	
		she did not have a cold or the 'flu?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
58	SOB	Has your child woken up with shortness of	1
		breath at any time in his or her life?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
59	TIGHTNESS	Has your child woken up with tightness of	1
		chest at any time in his or her life?	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
60	WHEZEWORSE	In the last 12 months, what has made your	2
		child's wheezing worse?	
		1=Weather	
		2=Pollen	
		3=Emotion	
		4=Fumes	
		5=Dust	
		6=Pets	
		7=Wool clothing	
		8=Colds or 'flu	
		9=Cigarette smoke	
		10=Foods or drinks	
		11=Soaps, sprays or detergents	
		12=Other things (please list below)	
		99 = any other response& any missing value	

Question Number	Name	Specification and Codes	width
61	SMOKEPERDAY	Does anybody, at present, smoke inside your	1
		child's home?If yes, how many cigarettes in	
		total are smoked per day in the child's home?	
		1=Less than 10 cigarettes	
		2=10-20 cigarettes	
		3=More than 20 cigarettes	
		9 = any other response& any missing value	
62	HFUEL	Which fuel do you use for heating?	1
		1=Gas	
		2=Electricity	
		3=Wood	
		4=Oil	
		5=Coal or coke	
		6=Other	
		9 = any other response& any missing value	
63	WINDOW	What kind of windows are there in your	1
		child's bedroom?	
		1=Single glazing	
		2=Secondary window	
		3=Sealed unit or double glazing	
		4=No windows	
		9 = any other response& any missing value	
64	REMOVEDPET	Have you made any changes in your home	1
		because your child had asthma or allergic problems?	
		Removed pet	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
64a	SMOKING	Stopped or reduced smoking	1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
64b	PILLOW	Changed pillows	1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
64c	BED	Changed bedding	
		1= Yes	
		2=No	
		9 = any other response& any missing value	
64d	FLOORCOVERING	Changed floor Covering	1
		1= Yes	
		2=No	
		9 = any other response& any missing value	
64e	OTHER	Other changes	1
		1= Yes	
		2=No	
		9 = any other response& any missing value	

Question Number	Name	Specification and Codes	width
65	SURRONDING	How would you describe the surroundings of	1
		your child's home?	
		1=open spaces or fields nearby	
		2=with many parks	
		3=with few parks	
		4=with no parks or gardens	
		9 = any other response& any missing value	
66	STREETNAME	What is the name of your child's street	20
		of residence?	
		9 = any other response	
67	POCODE	What is the postal code of your child's home?	5
		99999 = any other response& any missing value	

A3.4 Diary

Student's Name:

Date	Wheeze	Cough	Activity	Sleep	Duration of playing outside (hours)	Use of medication (Please write the name & time)	**comments**

Wheeze	None=0	Some =1	Medium =2	Sever =3
Cough	None=0	Occasional=1	Frequent=2	Continuous =3
Activity	Normal=0	Can run short distance or climb 3 flights of stairs=1	Can walk only =2	Missed school or stayed indoors=3
Sleep	Fine=0	Slept well, slight wheeze or cough	Awake 2-3 times, wheeze or cough	Bad night, awake most of the time

A3.4.1 Farsi version of diary

روزنگار علائم و نشانه های تنفسی

نام دانش آموز :

ملاحظات	استفاده از دارو نام و زمان (لطفا آنرا بنویسید)	مدت زمان بازی در خارج منزل (برحسب ساعت)	خواب	فعالیت	سرفه	خس خس	تاریخ

شدید: ۳	متوسط: ۲	مقداری: ۱	هیچ: ۰	خس خس
مداوم: ۳	متناوب: ۲	اتفاقی : ۱	هیچ: ۰	سرفه
غیبت از مدرسه و ماندن درمنزل:۳	فقط قادر به راه رفتن:۲	قادر به دو در مسافت کوتاه یا بالا رفتن از سه پله :۱	طبیعی: ۰	فعالیت
داشتن شبی بد در بیشتر اوقات شب:۳	۲تا ۳ مرتبه بیدار شدن خس خس یا سرفه :۲	خواب خوب وکمی خس خس یا سرفه:۱	خوب: ۰	خواب

A3.5 Peak Flow Chart

Researcher's Name: Class:

Date: Shift: AM ☐ PM ☐

Student's Names	Time	Day	Attendance	1st FEV1 (L/M)	2nd FEV1 (L/M)	3rd FEV1 (L/M)	Last puffer time & date
	:	1					
	:	2					
	:	3					
	:	4					
	:	5					
	:	6					
	:	7					
	:	8					
	:	9					
	:	10					
	:	11					
	:	12					
	:	13					
	:	14					
	:	15					
	:	16					
	:	17					
	:	18					
	:	19					
	:	20					
	:	21					
	:	22					
	:	23					
	:	24					
	:	25					
	:	26					
	:	27					
	:	28					
	:	29					
	:	30					
	:	31					
	:	32					
	:	33					
	:	34					
	:	35					
	:	36					
	:	38					
	:	40					
	:	41					
	:	42					

A3.5.1 Farsi version of peak flow chart

چارت کارکرد ریوی

کلاس: ....

تاریخ: ....

نام مشاهده گر: ....

شیفت صبح ☐ بعد از ظهر ☐

تاریخ آخرین بار استفاده از اسپری تنفسی	سومین اندازه گیری	دومین اندازه گیری	اولین اندازه گیری	حضور و غیاب	روز	زمان	نام و نام خانوادگی
					۱		
					۲		
					۳		
					۴		
					۵		
					۶		
					۷		
					۸		
					۹		
					۱۰		
					۱۱		
					۱۲		
					۱۳		
					۱۴		
					۱۵		
					۱۶		
					۱۷		
					۱۸		
					۱۹		
					۲۰		
					۲۱		
					۲۲		
					۲۳		
					۲۴		
					۲۵		
					۲۶		
					۲۷		
					۲۸		
					۲۹		
					۳۰		
					۳۱		
					۳۲		
					۳۳		
					۳۴		
					۳۵		
					۳۶		
					۳۷		
					۳۸		
					۳۹		
					۴۰		
					۴۱		
					۴۲		

Appendix IV: Air Pollution

A4.1 Listing of cleaning up of data

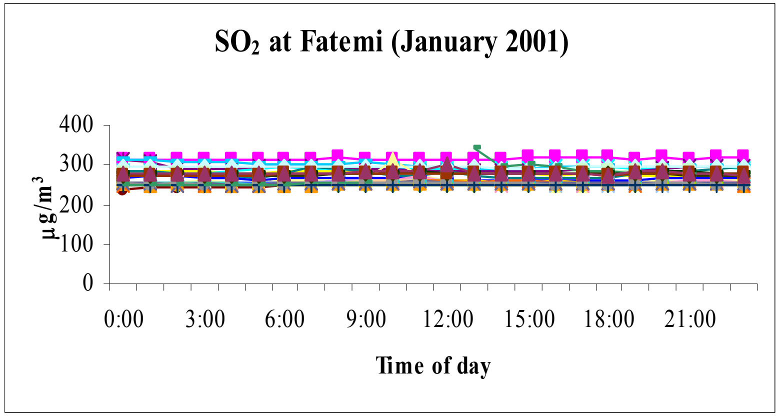
The cleaning up process was applied to hourly air pollution data.

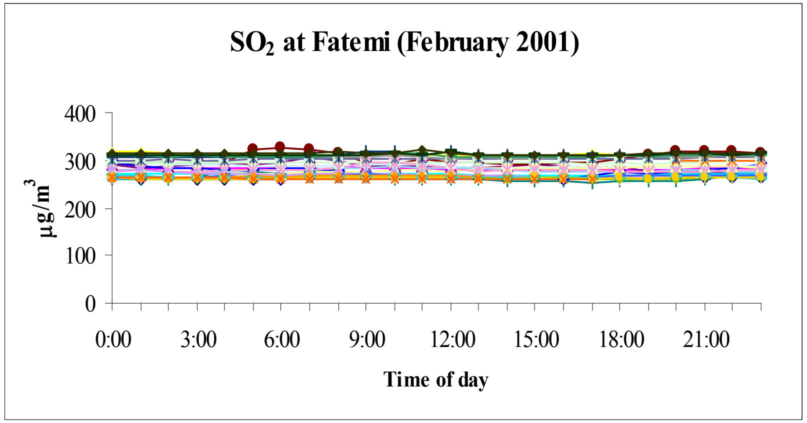
Poll.	Station	Date	Value	Reason
SO_2	Fatemi	>= 09 Feb 02 and <= 21 Feb 02	<210	
		27 Jan 01	>120	
		27 Jan 01	<15	
		20 Feb 01	<86	
		31 May 01	>118	
		17 Sep 01	>116	
		4 Nov 01	>115	
		29 Dec 01	>106	
		26 Feb 02	<41	
		3 Apr 02	<50	
		16 Apr 02	>180	
		22 Feb 01	<23 or >120	
		04 Sep 02	<200	
		11 Jan 02 or 12 Jan 02		seems the day of cleaning up
		12 Mar 02 or 12 Apr02		
		11 May 02 or 12 May 02		
		11 Jun 02 or 12 Jun 02		
		11 Jul 02 or 12 Jul 02		
		11 Aug 02 or 12 Aug 02		
	Bazaar		<0.4 or >131	
			<0	
NO_2	Fatemi	>= 25 Jun 01 and <= 29 Jun 01	>600 or <11	
			>394	

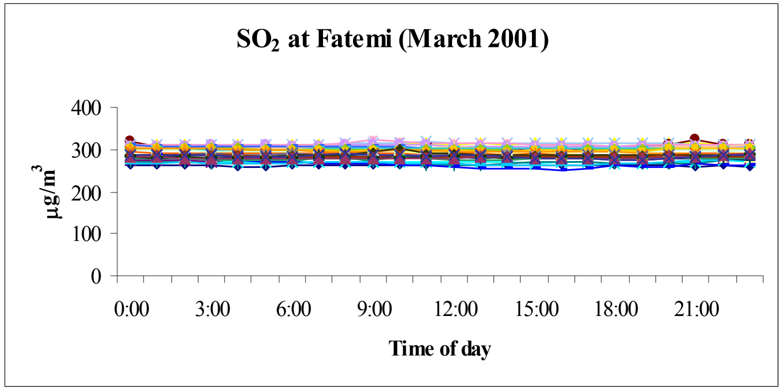
Poll.	Station	Date	Value	Reason
			<12	
		>= 25 Jun 01and <= 29 Jun 01	<9 or >400	
			>410	
		27 Jan 01	<14	
		22 Feb 01	<13	
	Bazaar	>= 08 Apr 02 and <= 09 Apr 02	<60	NOB not NO2 or NOX
		>= 25 Jun 01 and <= 29 Jun 01	<1 or >43	
		30 Jan 01	>52	
		1 Jan 01	>48	
		15 Jan 01	>40	
		25 Jan 01	>44	
		31 May 01	>35	
		1 May 01	>40	
		20 May 01	>30	
		14 Jun 01	<10	
		>=7 Apr 02 and =< 9 Apr 02	>0.5	
		3 Nov 02	<0.5	
			=0	
NO_x	Fatemi	>= 25 Jun 01and <= 29 Jun 01	<12 or >800	
	Bazaar	>= 25 Jun 01 and <= 29 Jun 01	<1 or >90	
CO	Fatemi	>= 29 Oct 01 and >=29 Sep 02	>=20319	
		21 Mar 02 or 21 Mar 02		
			=0	
	Bazaar		=0	
			<1760 and >39000	
		30 Nov 00	>=15625	
		12 Jun 01	>=9916	
		28 Aug 01	>=12527	
		01 Sep 02	>=20000	
		28 Aug 01	>30	
		27 Aug 01	>30	
O_3	Fatemi		=0	

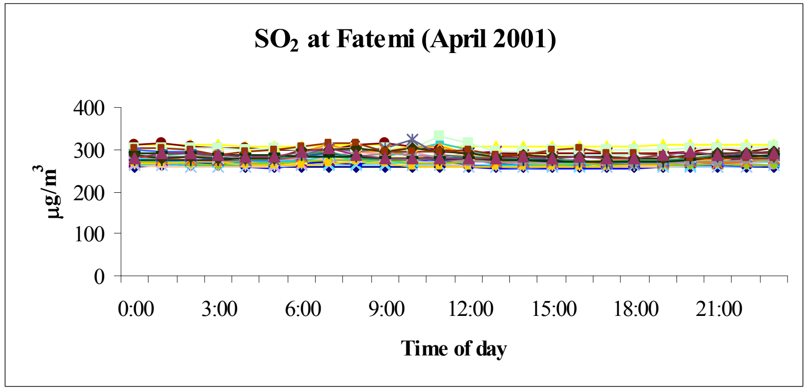
Poll.	Station	Date	Value	Reason
		27 Jan 01	>30	
		15 Jan 01	>5	
		20 Jan 01	>5	
		27 Jan 01	<0.4	
	Bazaar		>120	
		18 Feb 01	>10	
		21 Jul 02	>100	
		22 Jul 02	>20	
		24 Nov 02	>18	
			<0.1	
PM_{10}	Fatemi		<1	
		27 Jan 01	<2	
		15 May 01	>600	
		15 Apr 02	>800	
	Bazaar		>4900	
		18 Apr 02	>500	
		9 Apr 01	>900	
		05 Oct 00	>380	
		01 May 00	>300	
		31 May 01	>1000	
		06 Jun 02	>300	
		>=26 Mar 01 and =<17 Apr 02	135	
			0	

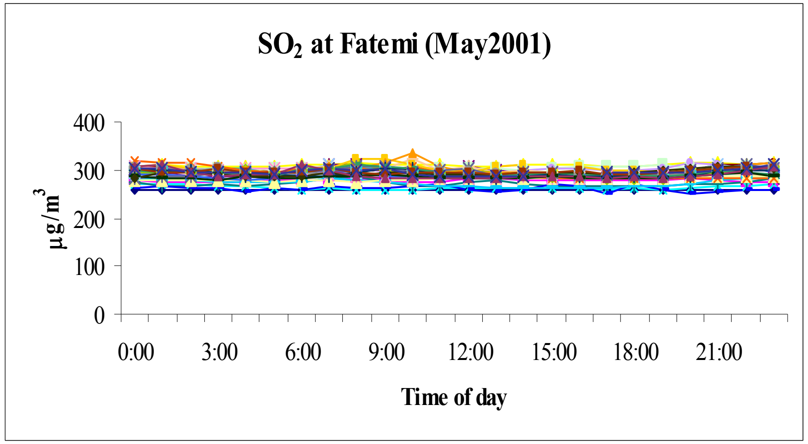
A4.2 Graphs of daily hourly air pollutants levels



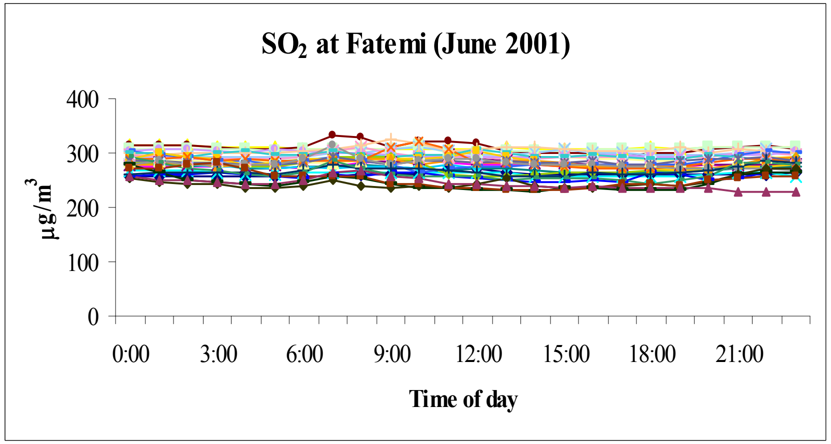




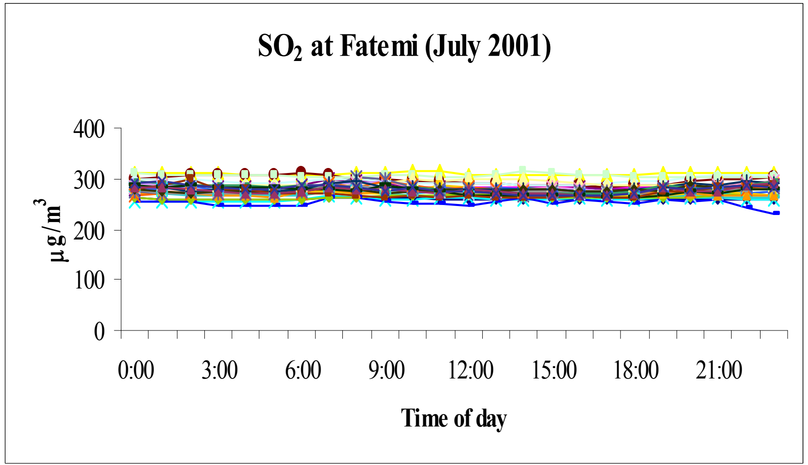




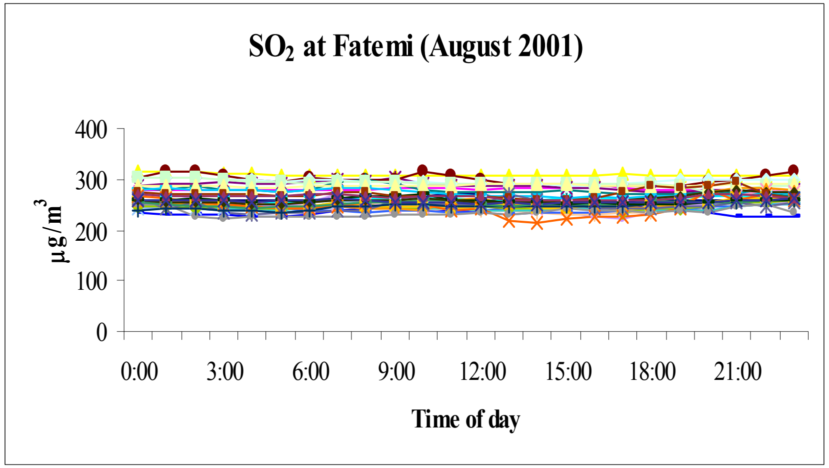
SO2 at Fatemi (May2001)
400
300
200
100
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



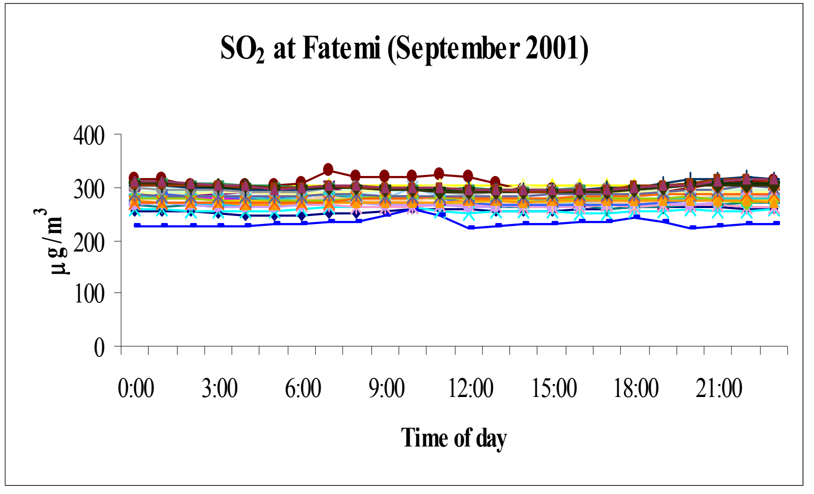
SO2 at Fatemi (June 2001)
400
300
200
100
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



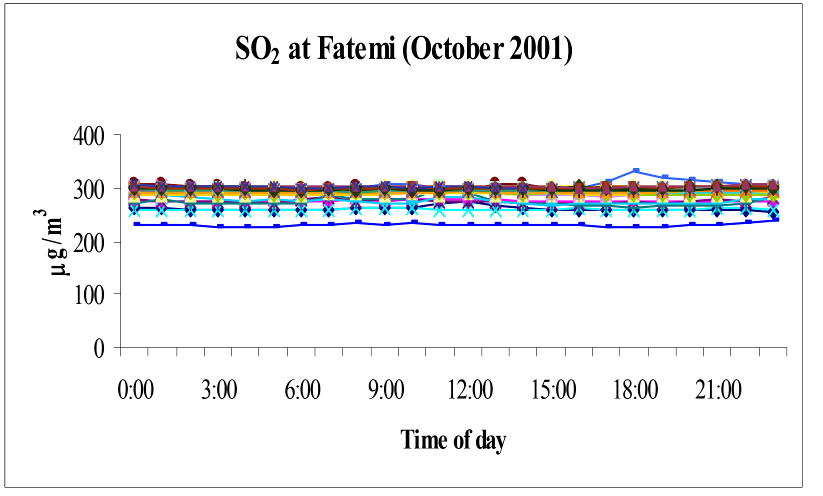
SO2 at Fatemi (July 2001)
400
300
200
100
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



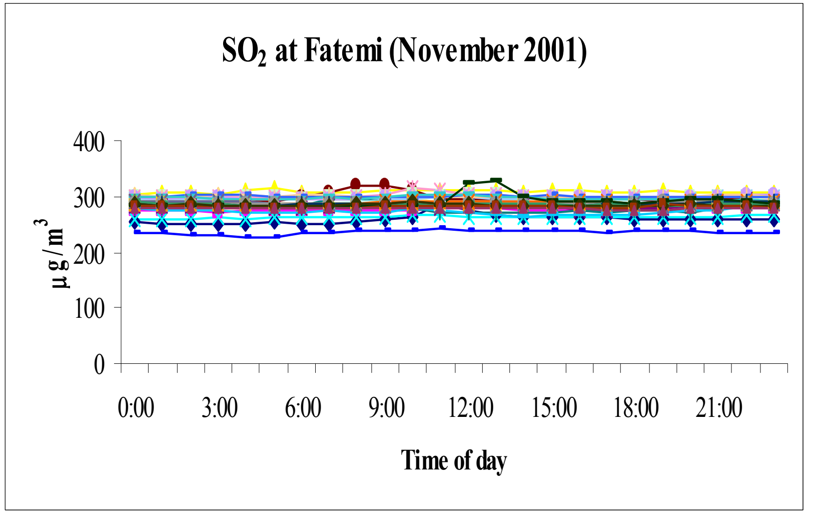
SO2 at Fatemi (August 2001)
400
300
200
100
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



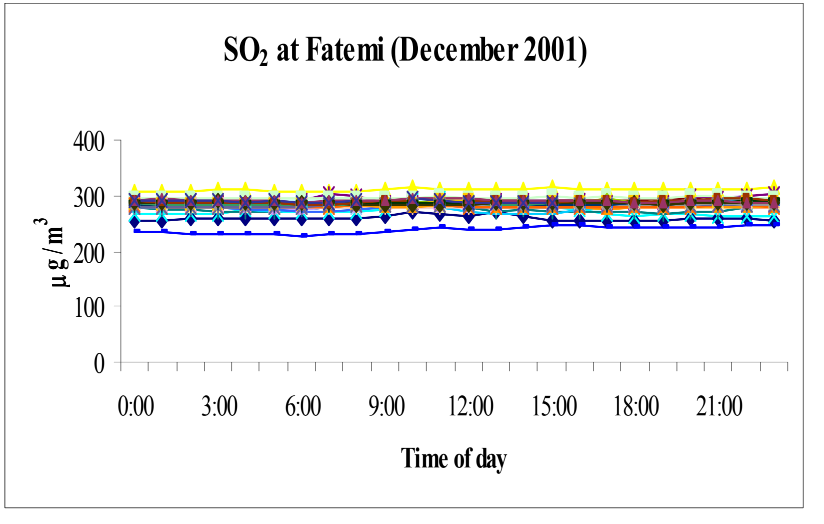
SO$_2$ at Fatemi (September 2001)
400
300
200
100
0
µg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



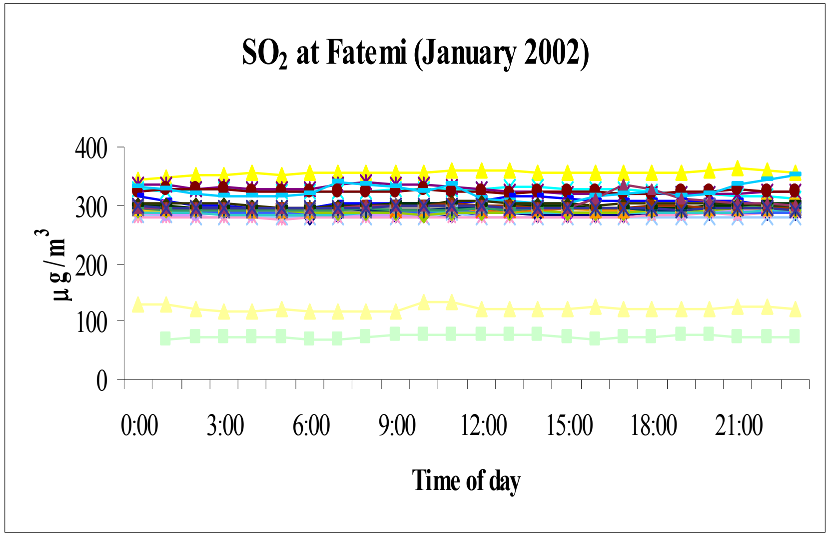
SO$_2$ at Fatemi (October 2001)
400
300
200
100
0
µg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

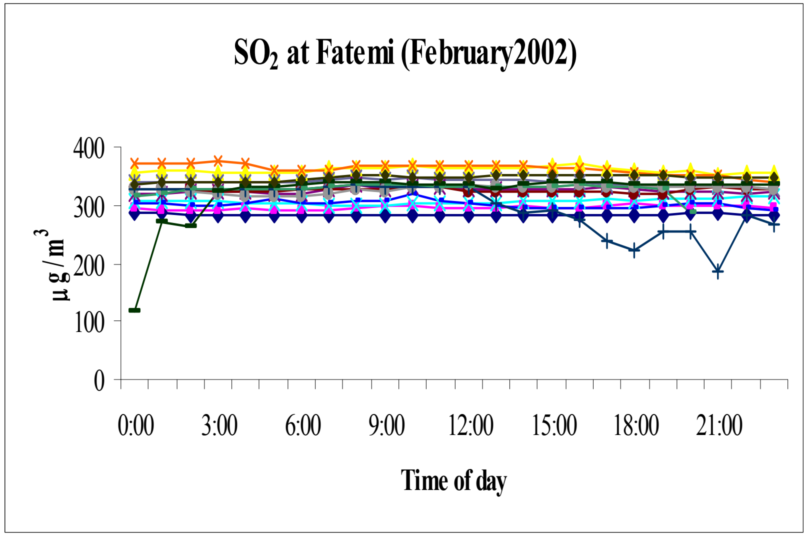


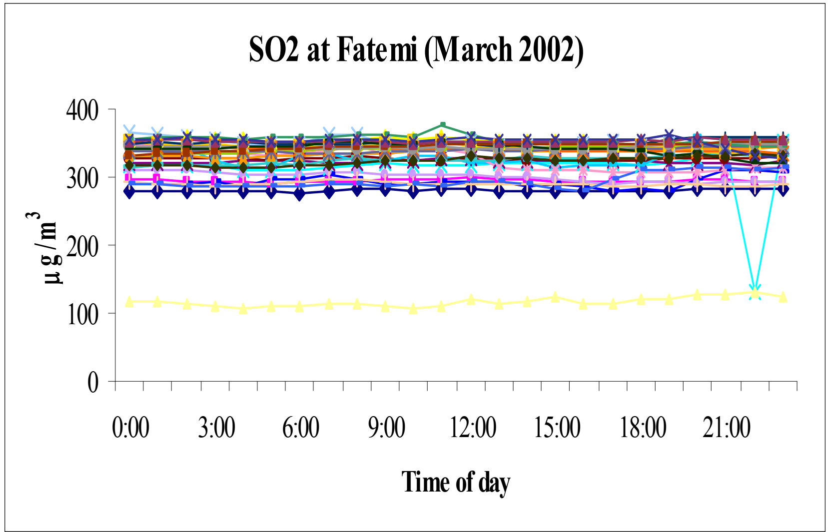
SO$_2$ at Fatemi (November 2001)
400
300
200
100
0
µg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

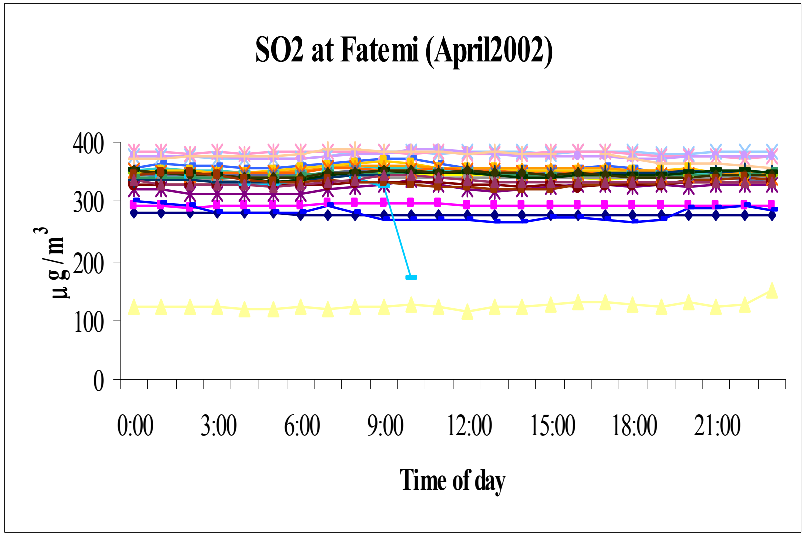


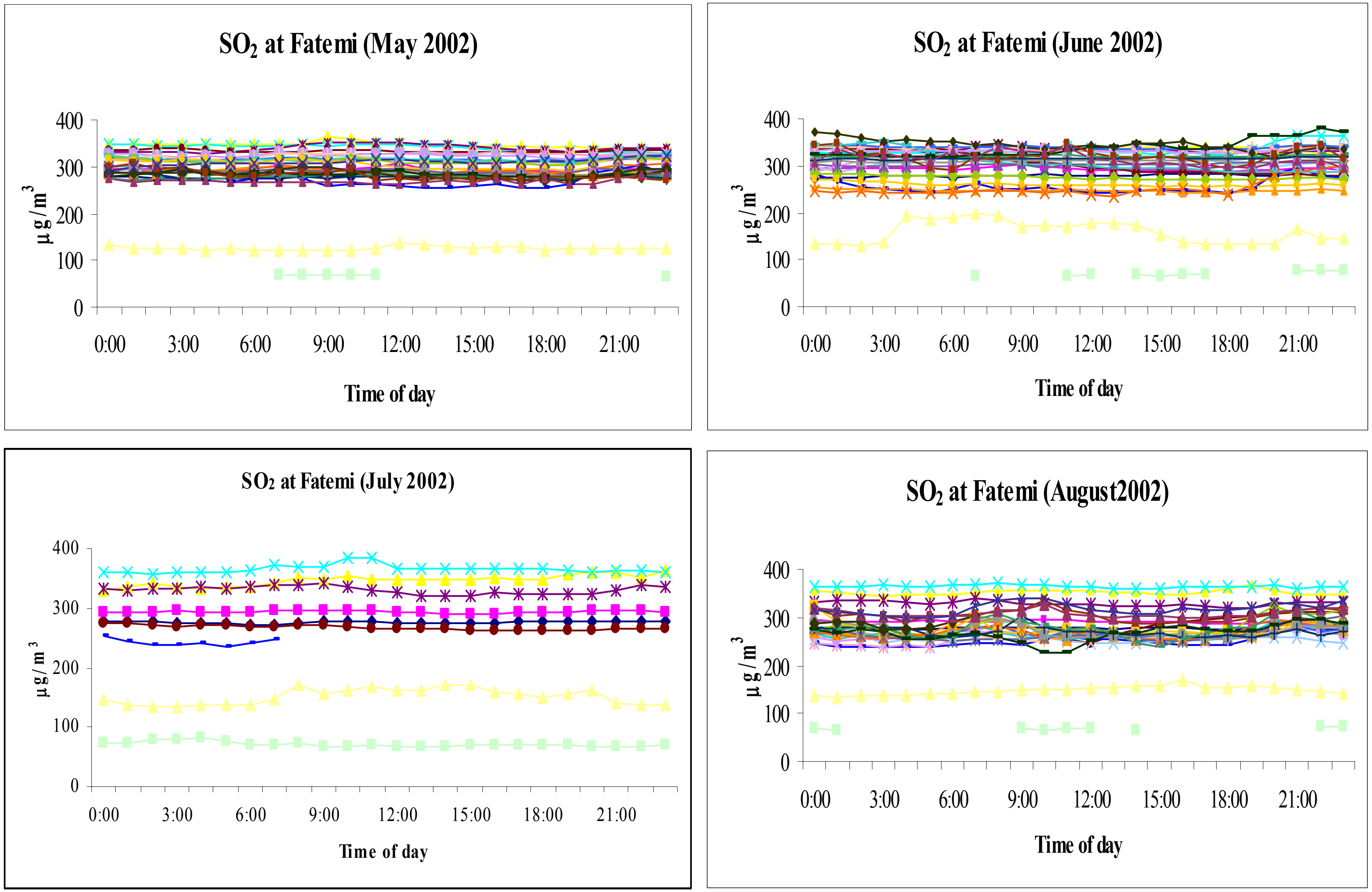
SO$_2$ at Fatemi (December 2001)
400
300
200
100
0
µg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


SO$_2$ at Fatemi (January 2002)
400
300
200
100
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

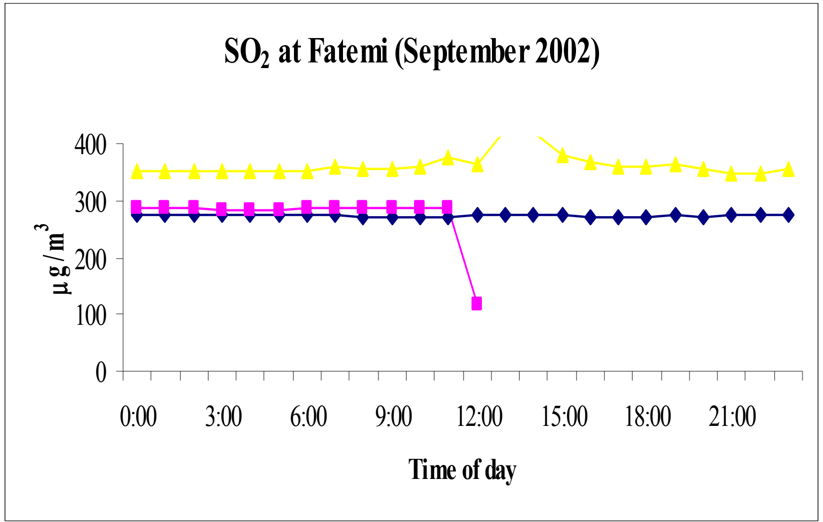

SO$_2$ at Fatemi (February2002)
400
300
200
100
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


SO2 at Fatemi (March 2002)
400
300
200
100
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

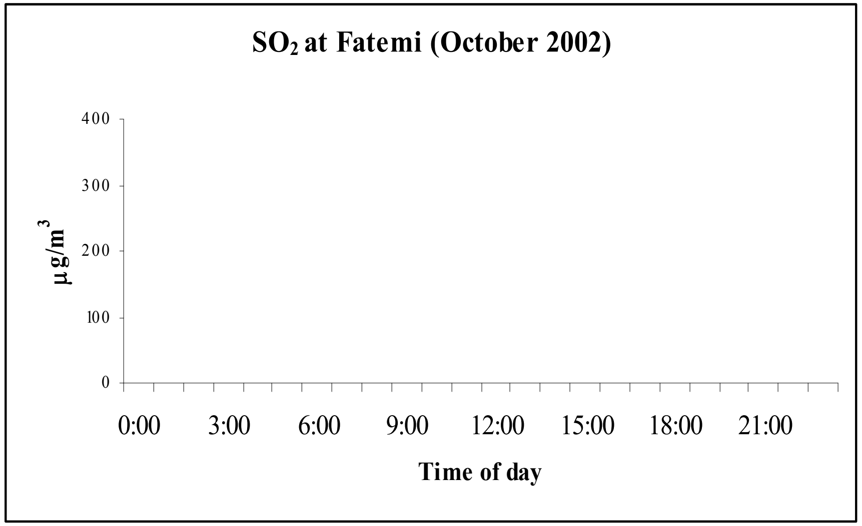

SO2 at Fatemi (April2002)
400
300
200
100
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



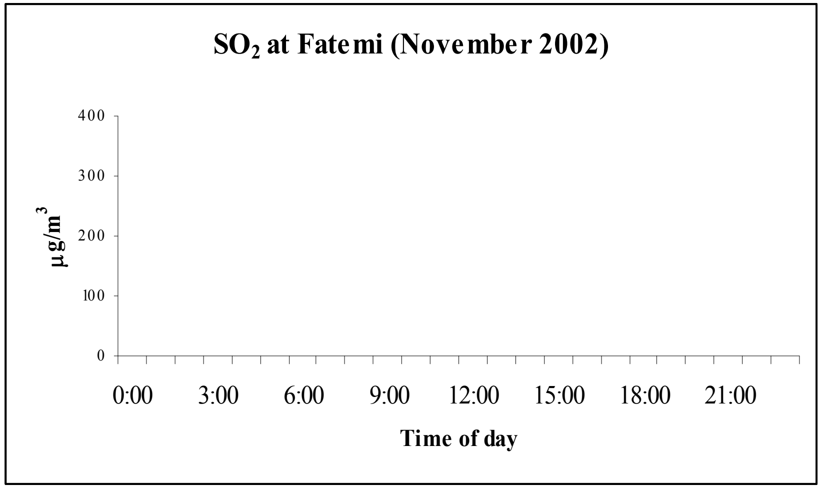
SO$_2$ at Fatemi (May 2002)
μg/m^3
0
100
200
300
400
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
SO$_2$ at Fatemi (June 2002)
μg/m^3
Time of day
SO$_2$ at Fatemi (July 2002)
μg/m^3
Time of day
SO$_2$ at Fatemi (August2002)
μg/m^3
Time of day



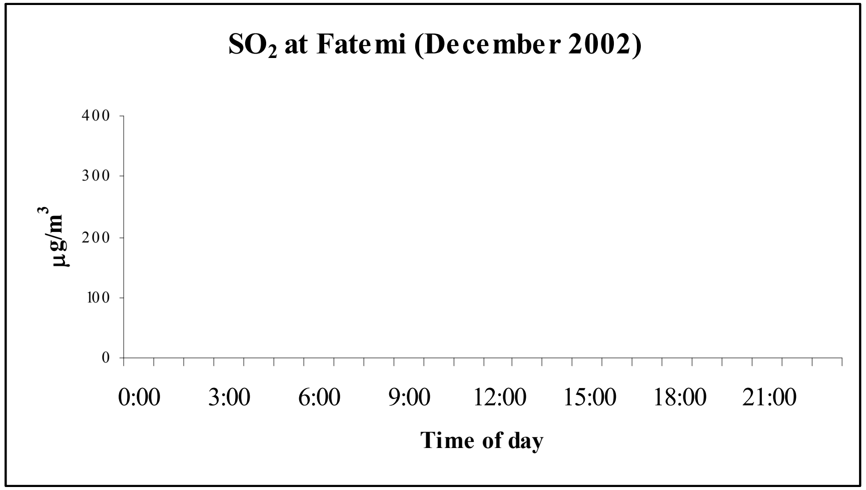
SO_2 at Fatemi (September 2002)
400
300
200
100
0
$\mu g/m^3$
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



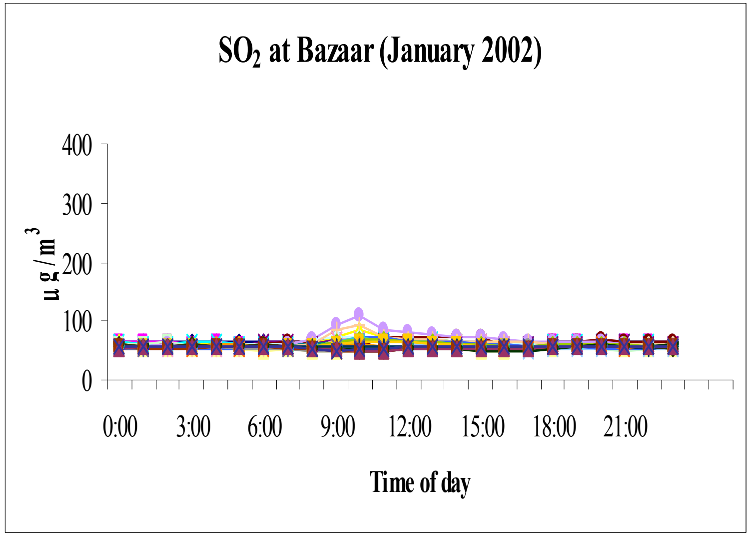
SO_2 at Fatemi (October 2002)
400
300
200
100
0
$\mu g/m^3$
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

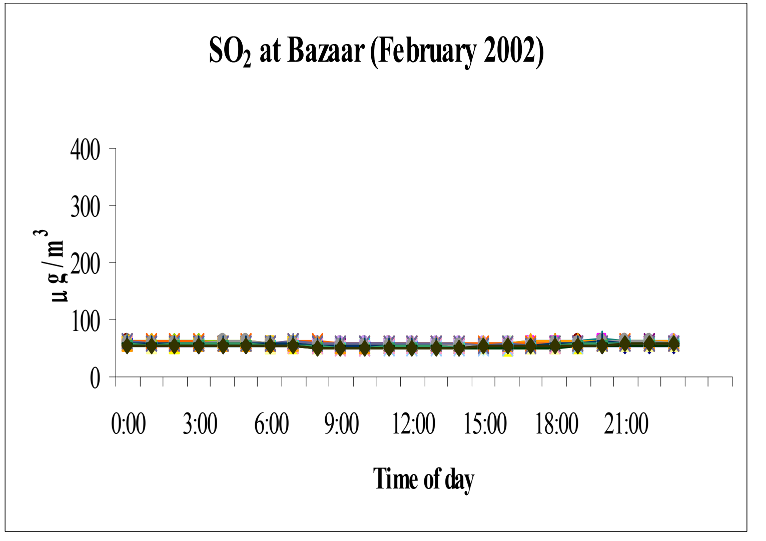


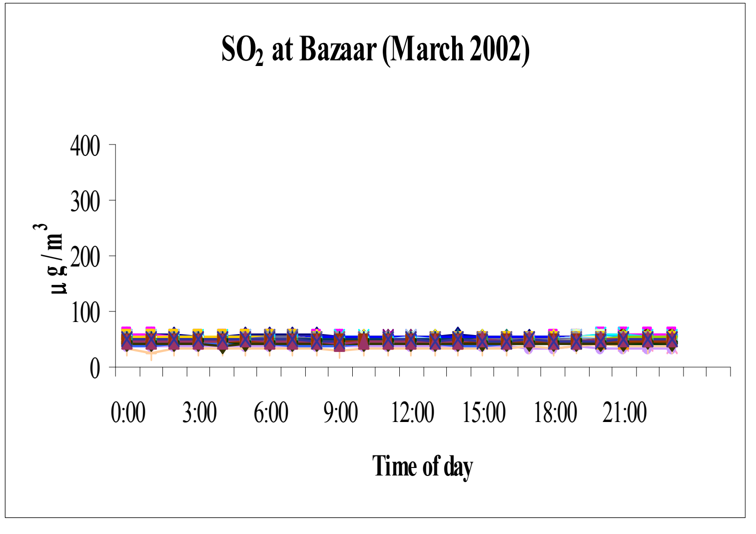
SO_2 at Fatemi (November 2002)
400
300
200
100
0
$\mu g/m^3$
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

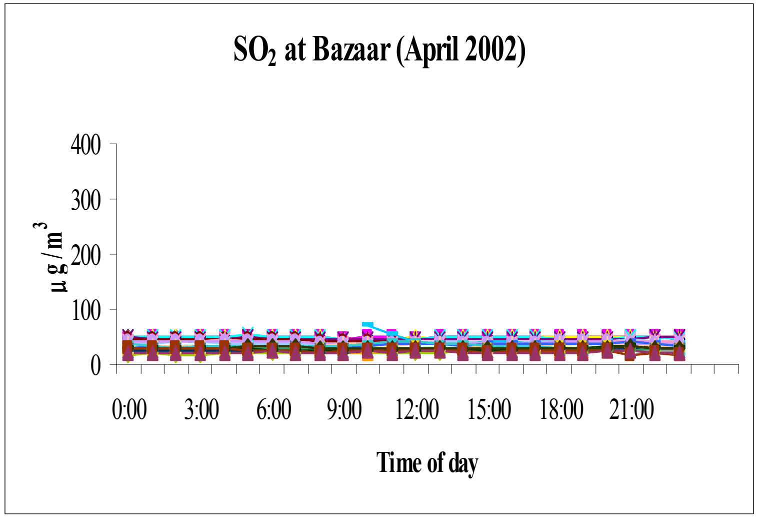


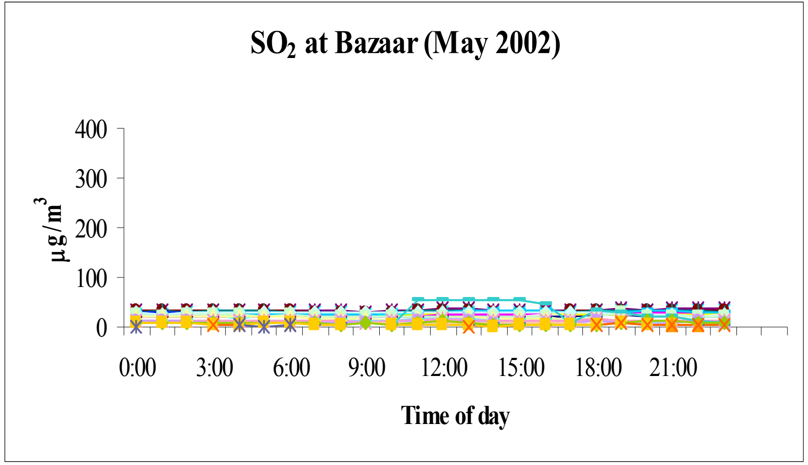
SO_2 at Fatemi (December 2002)
400
300
200
100
0
$\mu g/m^3$
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

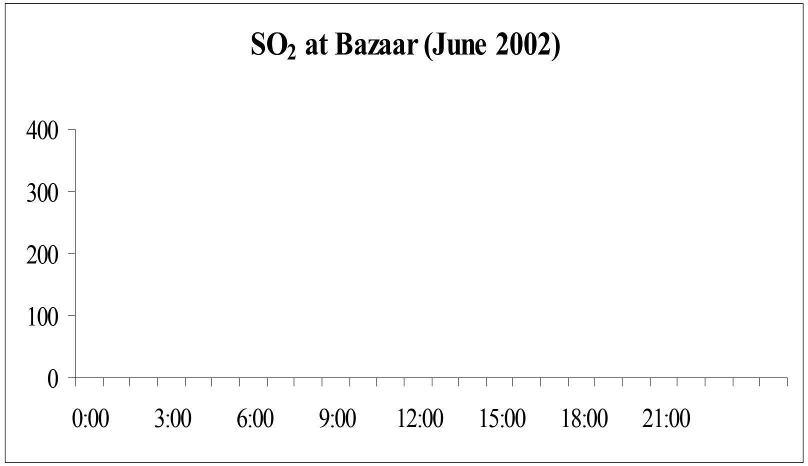

SO2 at Bazaar (January 2002)
400
300
200
100
0
µ g / m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

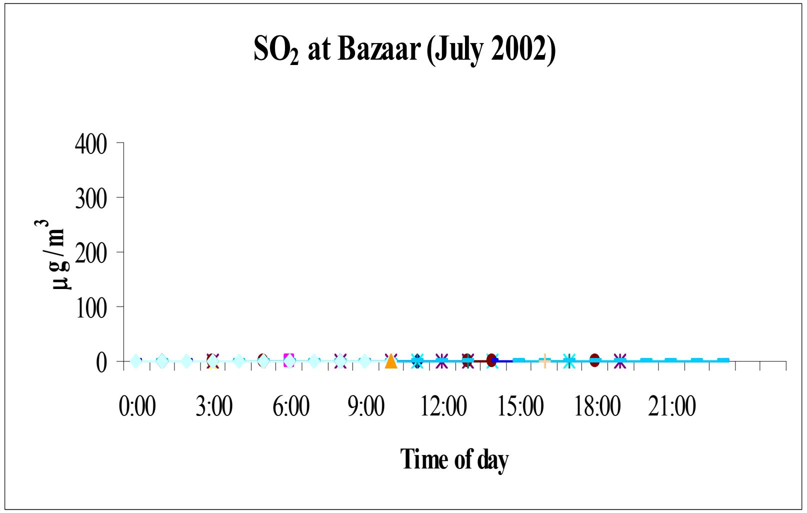

SO2 at Bazaar (February 2002)
400
300
200
100
0
µ g / m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

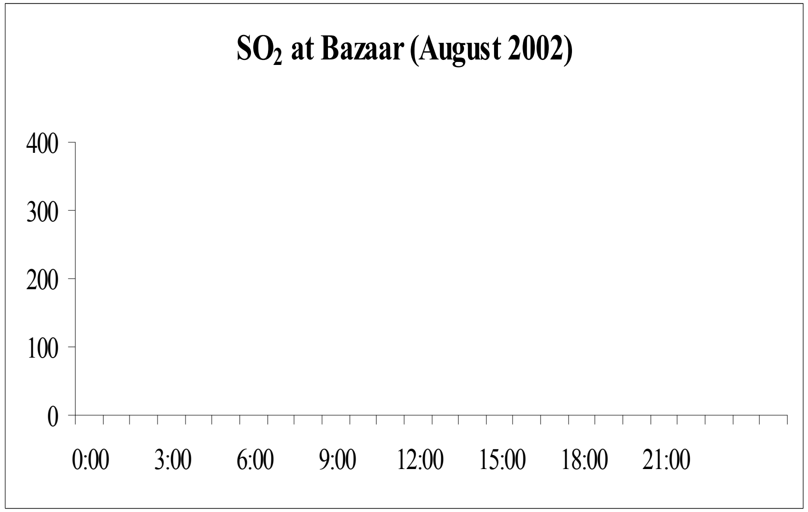

SO2 at Bazaar (March 2002)
400
300
200
100
0
µ g / m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

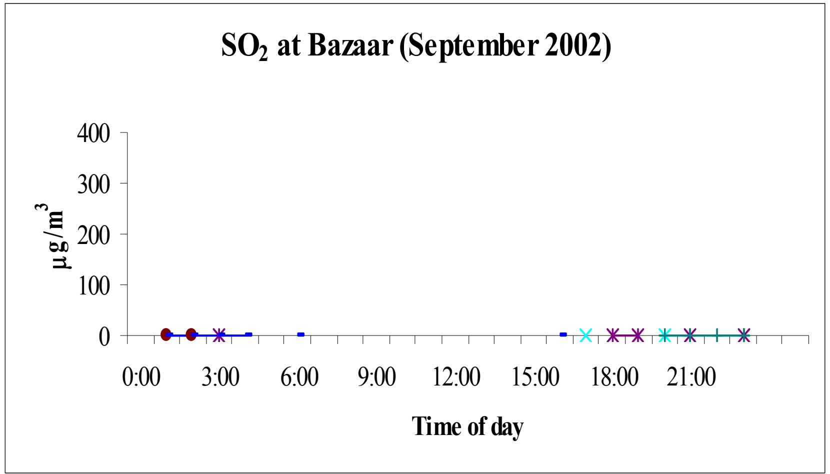

SO2 at Bazaar (April 2002)
400
300
200
100
0
µ g / m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

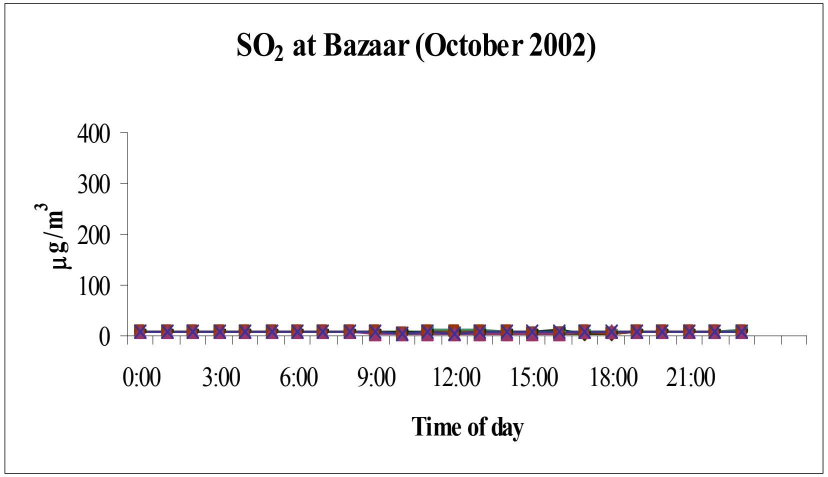

SO2 at Bazaar (May 2002)
400
300
200
100
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

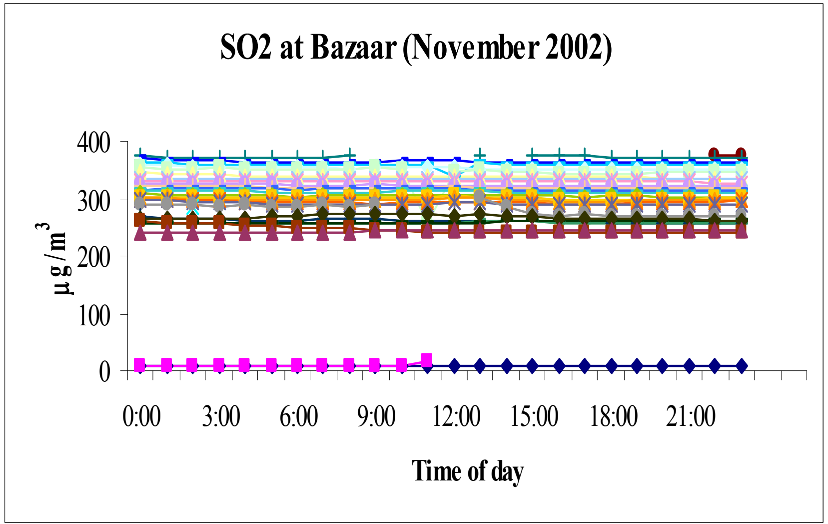

SO2 at Bazaar (June 2002)
400
300
200
100
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00

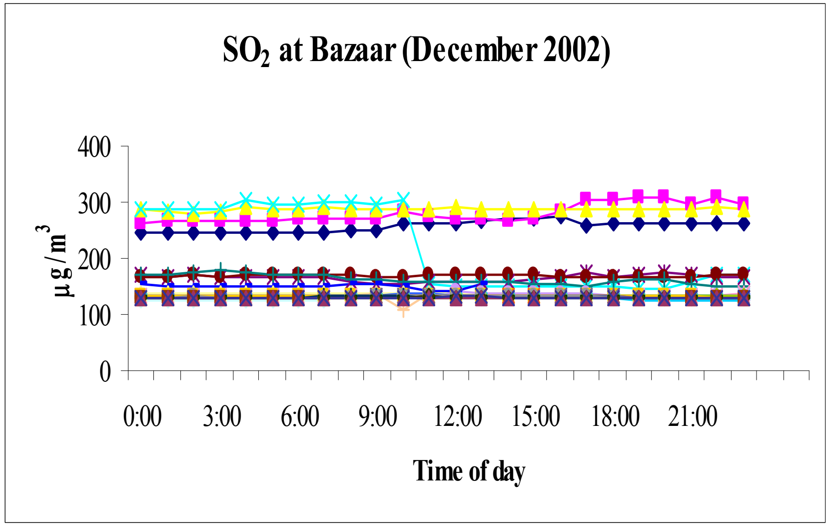

SO2 at Bazaar (July 2002)
400
300
200
100
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

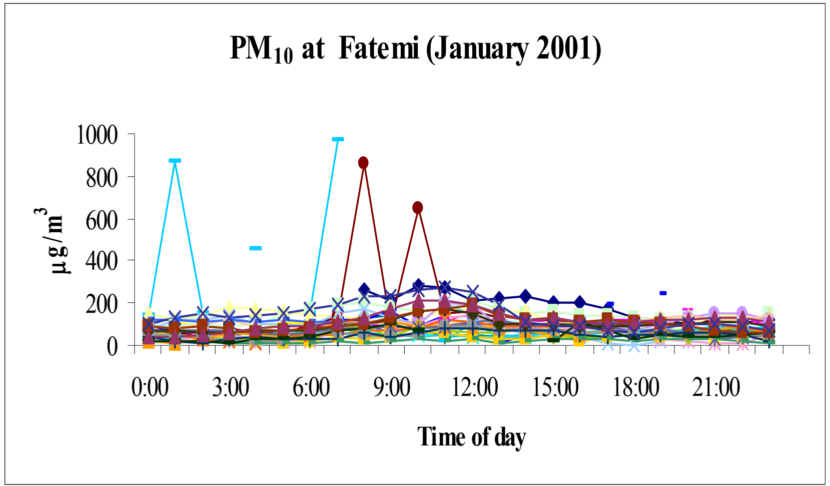

SO2 at Bazaar (August 2002)
400
300
200
100
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00

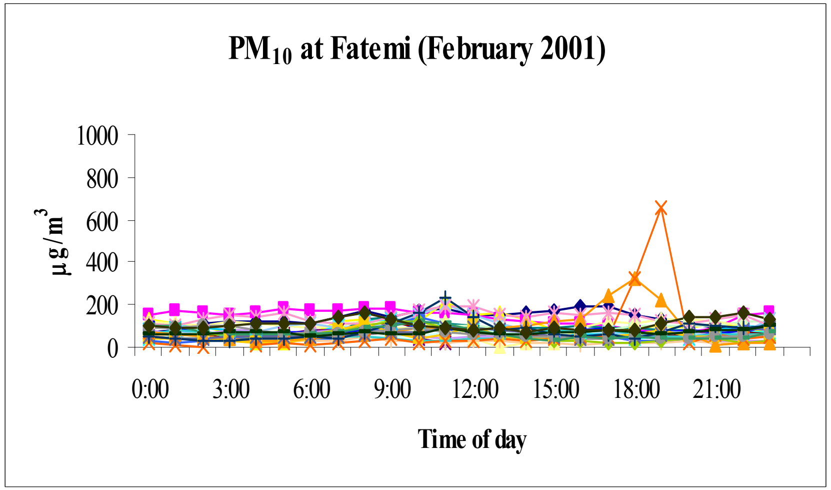

SO₂ at Bazaar (September 2002)
400
300
200
100
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

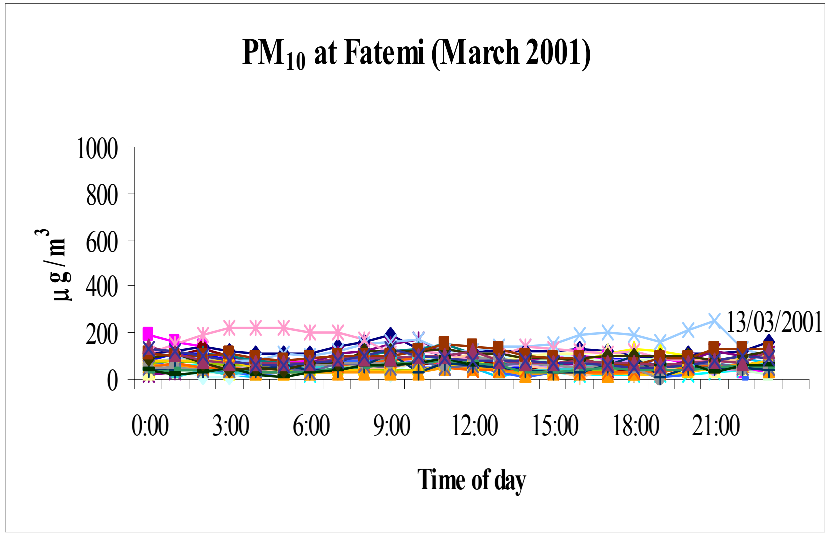

SO₂ at Bazaar (October 2002)
400
300
200
100
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

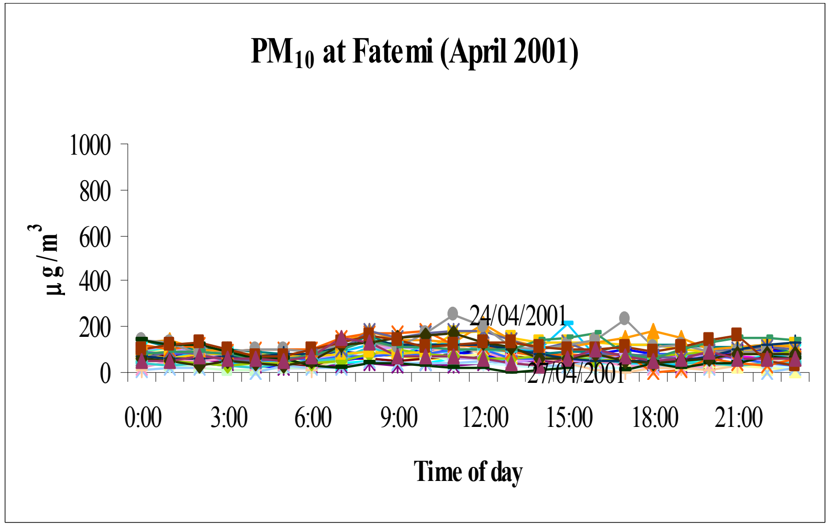

SO2 at Bazaar (November 2002)
400
300
200
100
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

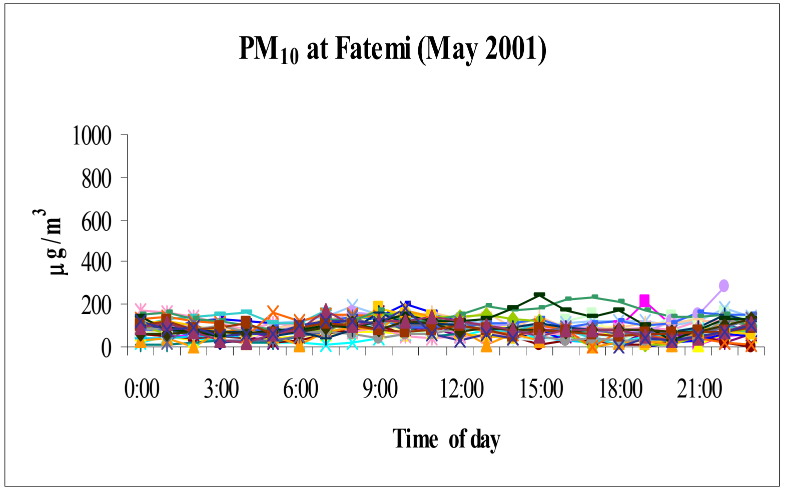

SO₂ at Bazaar (December 2002)
400
300
200
100
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

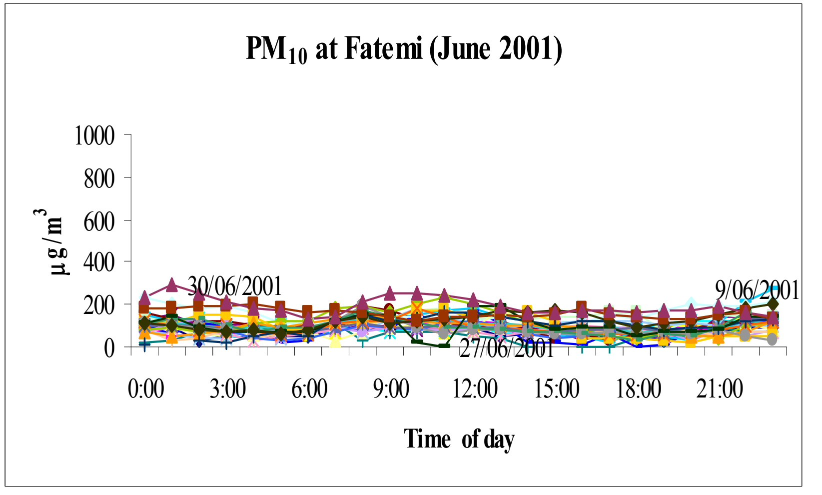

PM$_{10}$ at Fatemi (January 2001)
1000
800
600
400
200
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

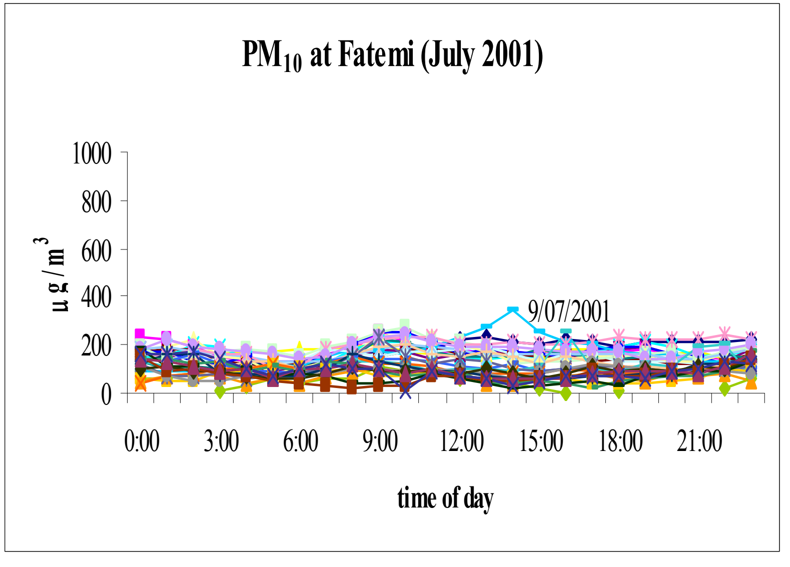

PM$_{10}$ at Fatemi (February 2001)
1000
800
600
400
200
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

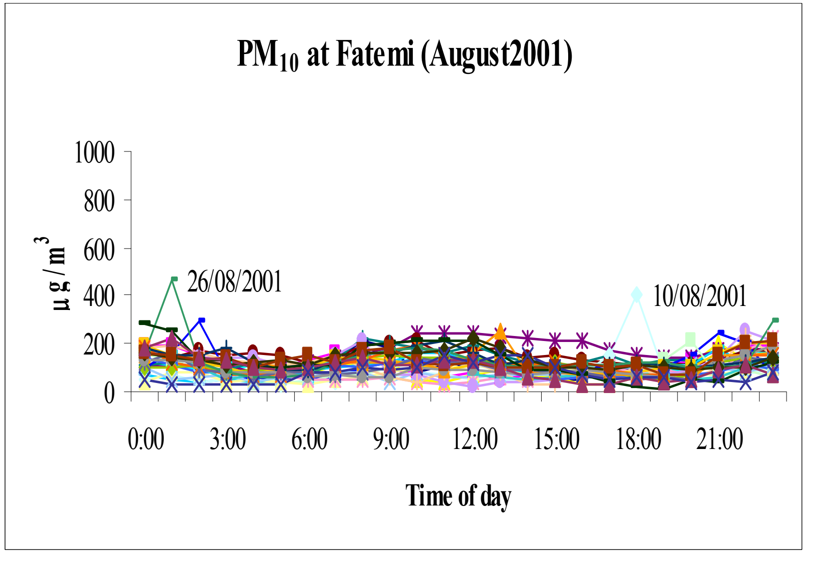

PM$_{10}$ at Fatemi (March 2001)
1000
800
600
400
200
0
μg/m^3
13/03/2001
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

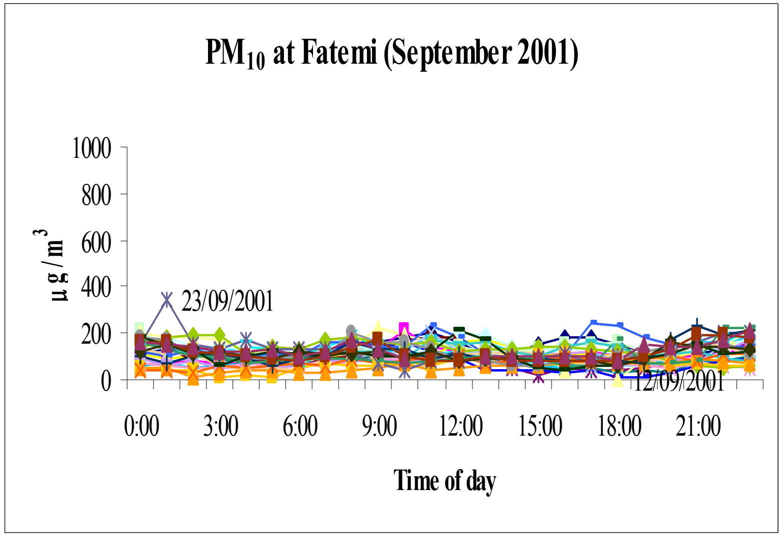

PM$_{10}$ at Fatemi (April 2001)
1000
800
600
400
200
0
μg/m^3
24/04/2001
27/04/2001
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


PM10 at Fatemi (May 2001)
1000
800
600
400
200
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

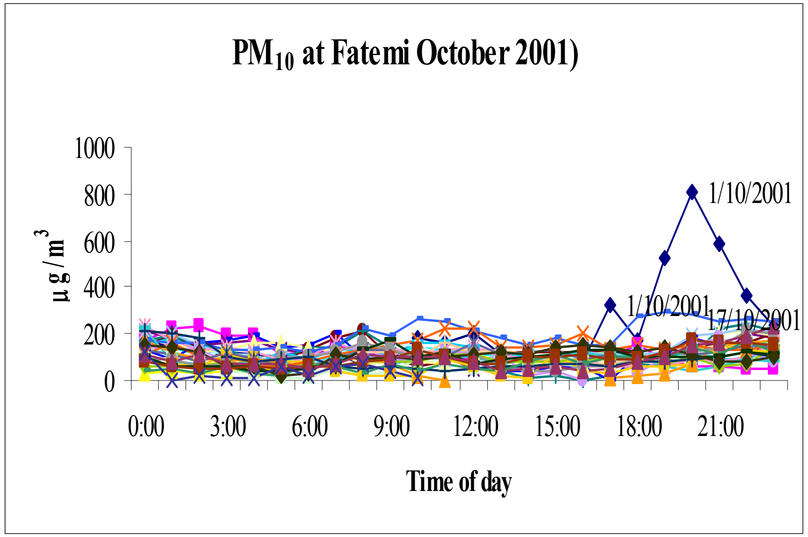

PM10 at Fatemi (June 2001)
1000
800
600
400
200
0
µg/m3
30/06/2001
9/06/2001
27/06/2001
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


PM10 at Fatemi (July 2001)
1000
800
600
400
200
0
µg/m3
9/07/2001
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
time of day

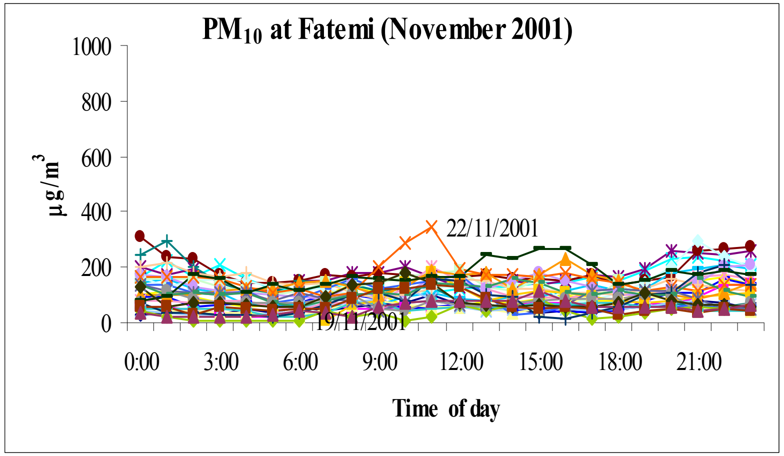

PM10 at Fatemi (August2001)
1000
800
600
400
200
0
µg/m3
26/08/2001
10/08/2001
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



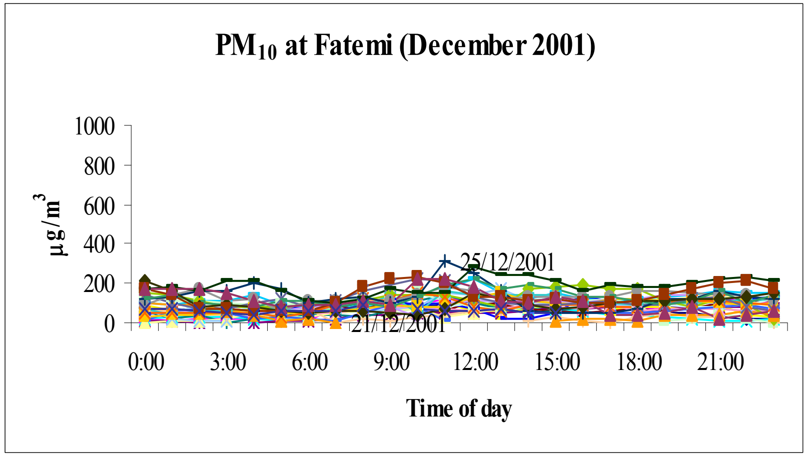
PM10 at Fatemi (September 2001)
1000
800
600
400
200
0
µg/m3
23/09/2001
12/09/2001
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



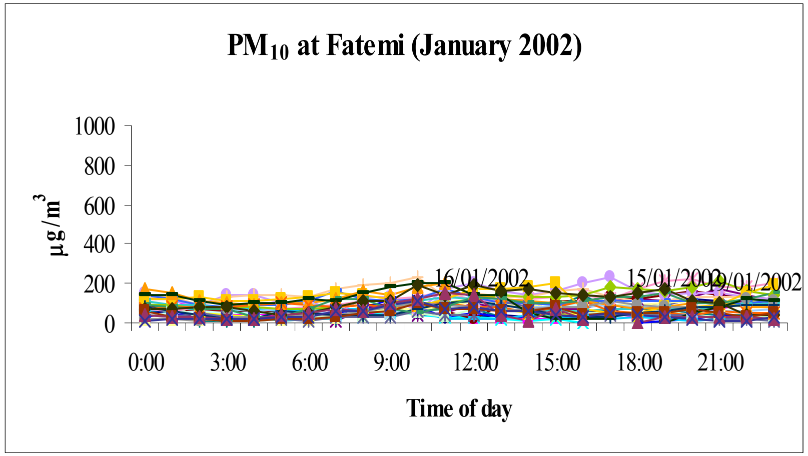
PM10 at Fatemi October 2001)
1000
800
600
400
200
0
µg/m3
1/10/2001
1/10/2001
17/10/2001
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

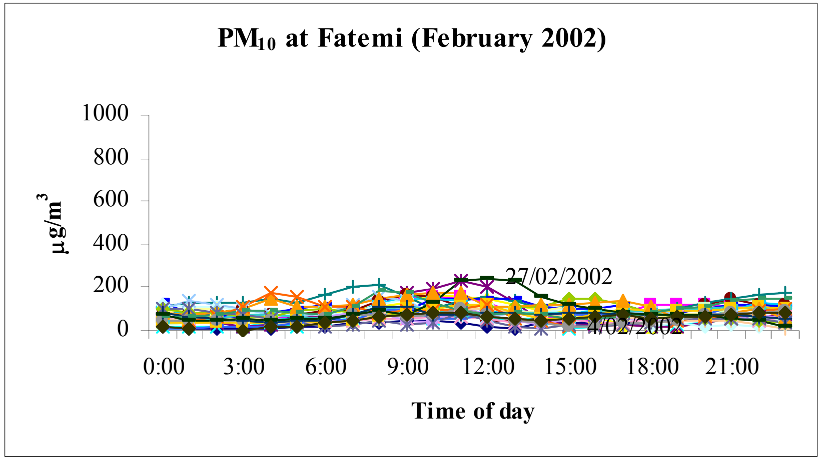


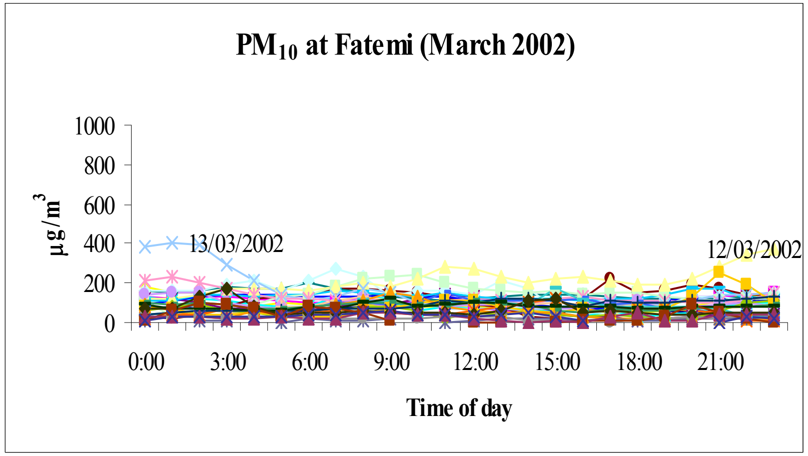
PM10 at Fatemi (November 2001)
1000
800
600
400
200
0
µg/m3
22/11/2001
19/11/2001
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

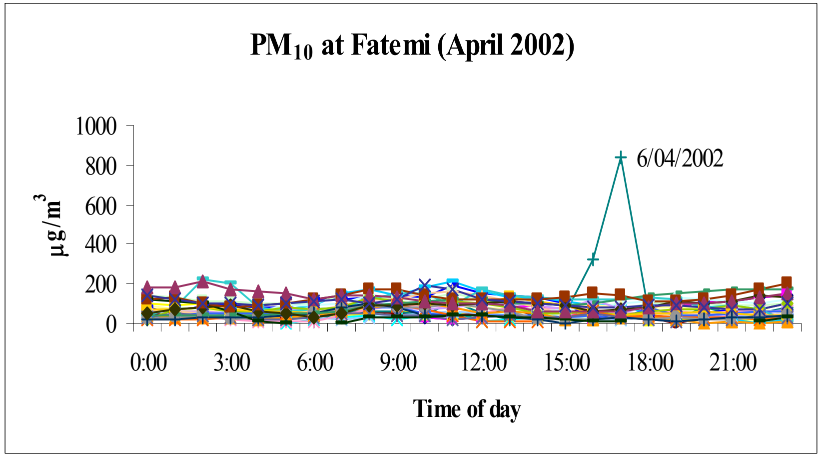


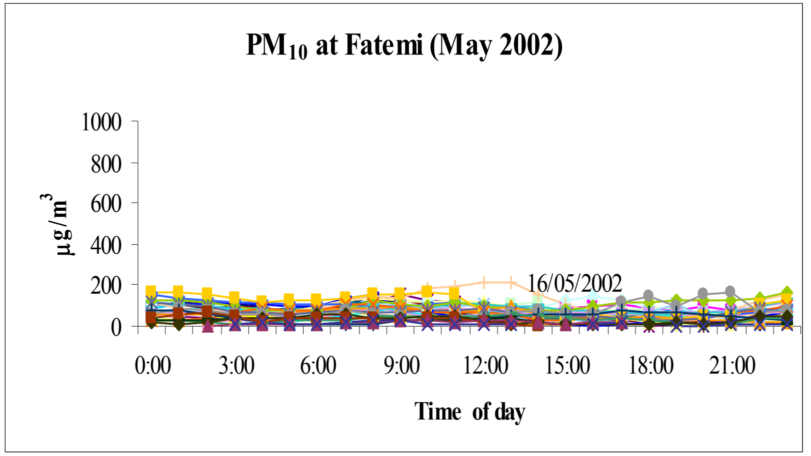
PM10 at Fatemi (December 2001)
1000
800
600
400
200
0
µg/m3
25/12/2001
21/12/2001
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

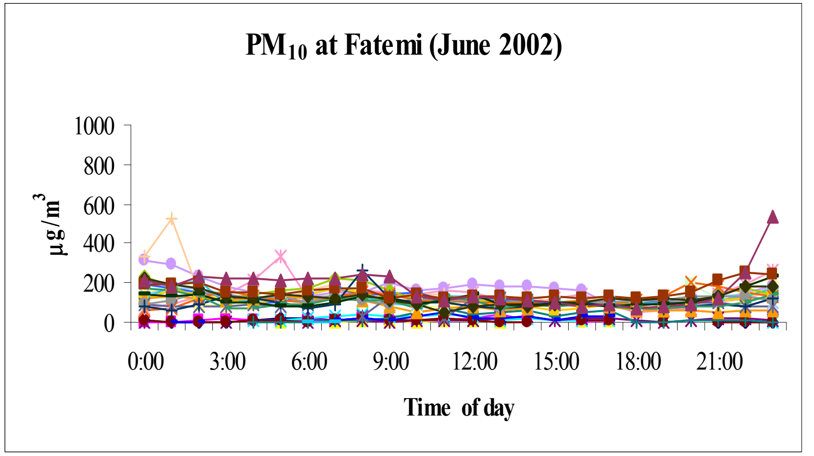

PM10 at Fatemi (January 2002)
1000
800
600
400
200
0
µg/m3
16/01/2002
15/01/2002
19/01/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

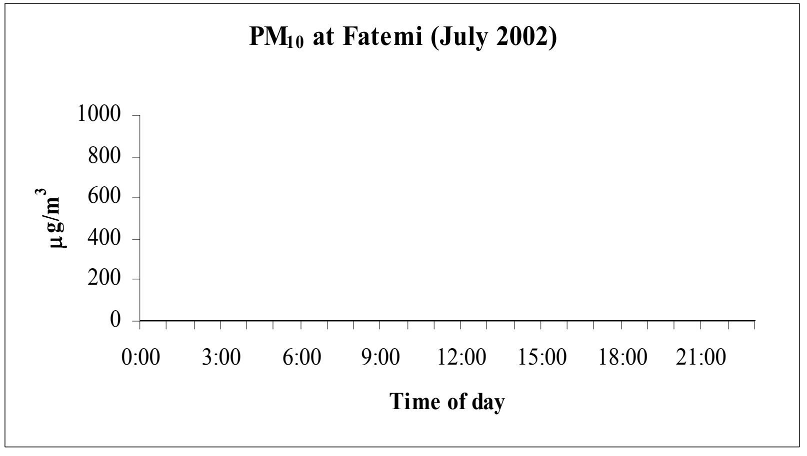

PM10 at Fatemi (February 2002)
1000
800
600
400
200
0
µg/m3
27/02/2002
4/02/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

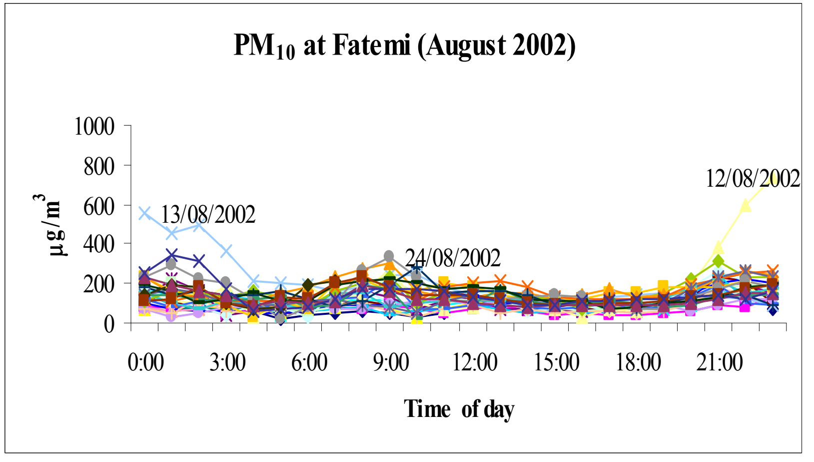

PM10 at Fatemi (March 2002)
1000
800
600
400
200
0
µg/m3
13/03/2002
12/03/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

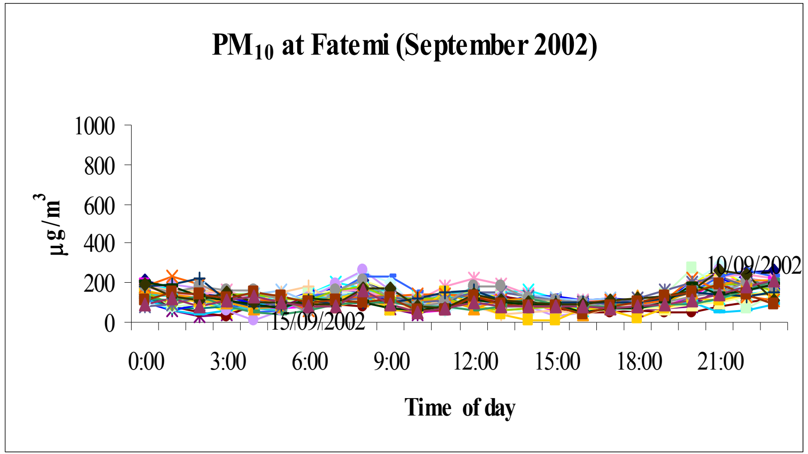

PM10 at Fatemi (April 2002)
1000
800
600
400
200
0
µg/m3
6/04/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


PM10 at Fatemi (May 2002)
1000
800
600
400
200
0
µg/m3
16/05/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

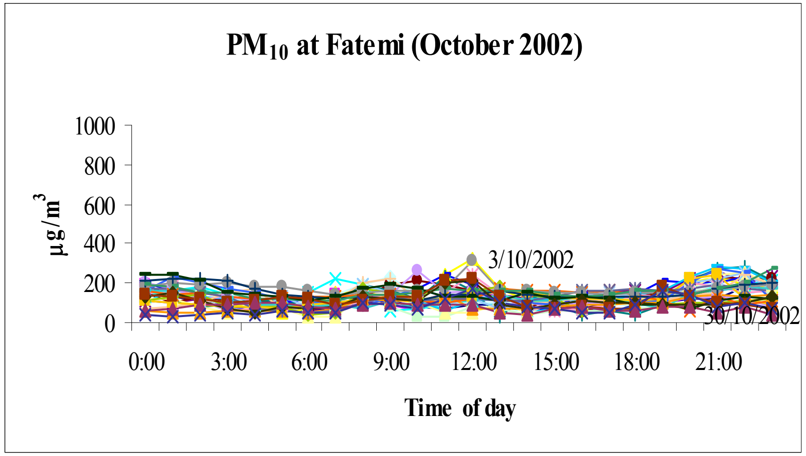

PM10 at Fatemi (June 2002)
1000
800
600
400
200
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


PM10 at Fatemi (July 2002)
1000
800
600
400
200
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

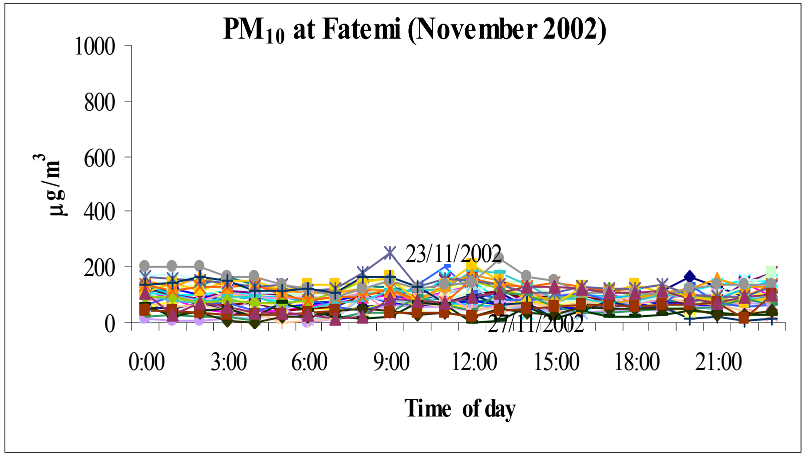

PM10 at Fatemi (August 2002)
1000
800
600
400
200
0
µg/m3
13/08/2002
24/08/2002
12/08/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



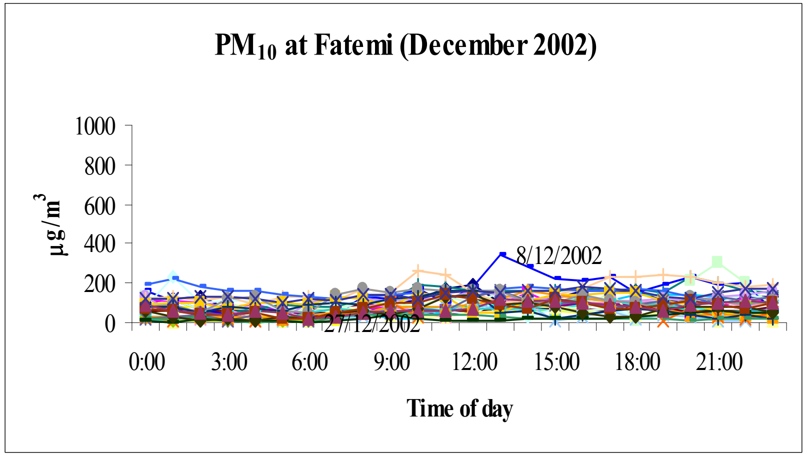
PM10 at Fatemi (September 2002)
1000
800
600
400
200
0
µg/m3
10/09/2002
15/09/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



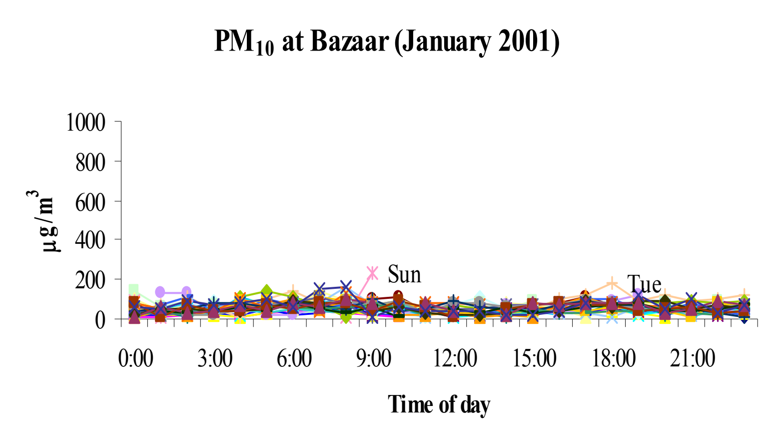
PM10 at Fatemi (October 2002)
1000
800
600
400
200
0
µg/m3
3/10/2002
30/10/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

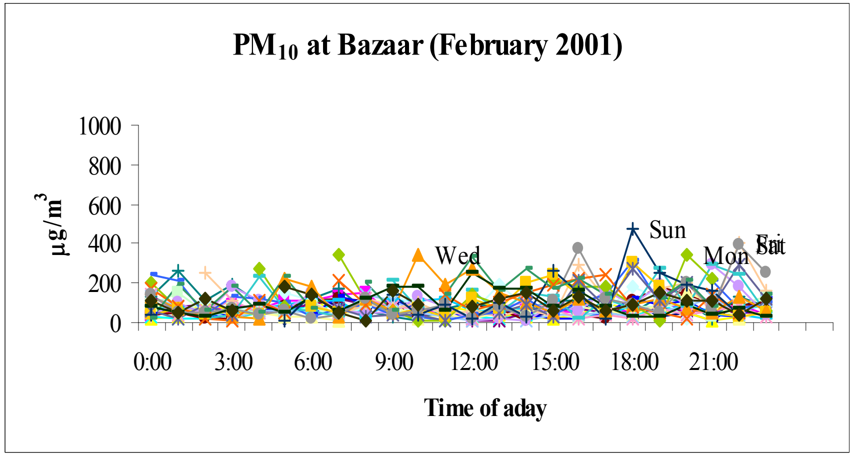


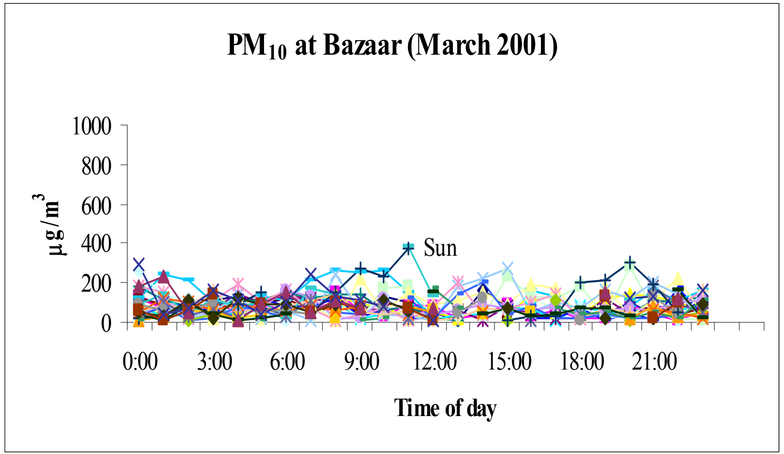
PM10 at Fatemi (November 2002)
1000
800
600
400
200
0
µg/m3
23/11/2002
27/11/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

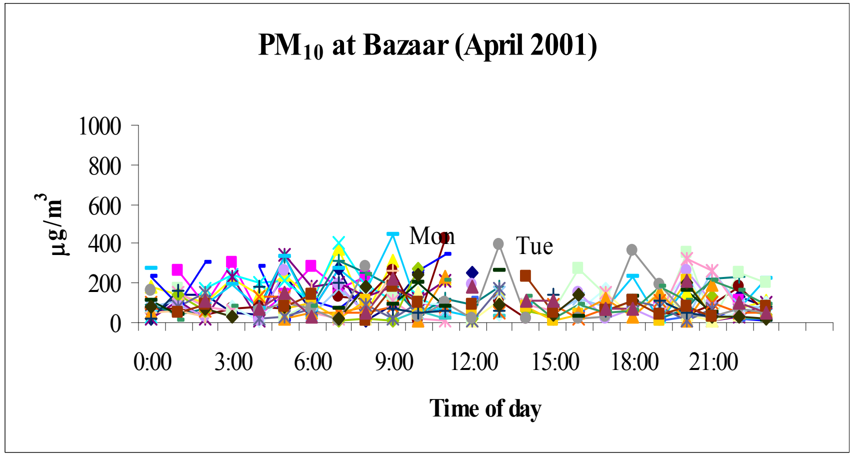


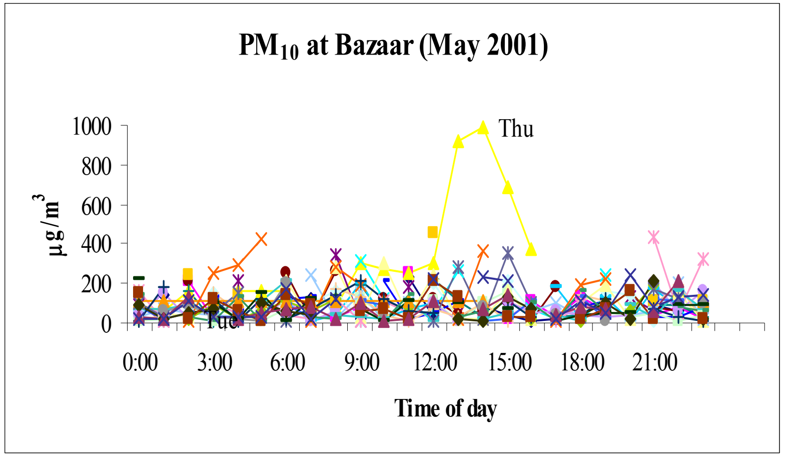
PM10 at Fatemi (December 2002)
1000
800
600
400
200
0
µg/m3
8/12/2002
27/12/2002
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

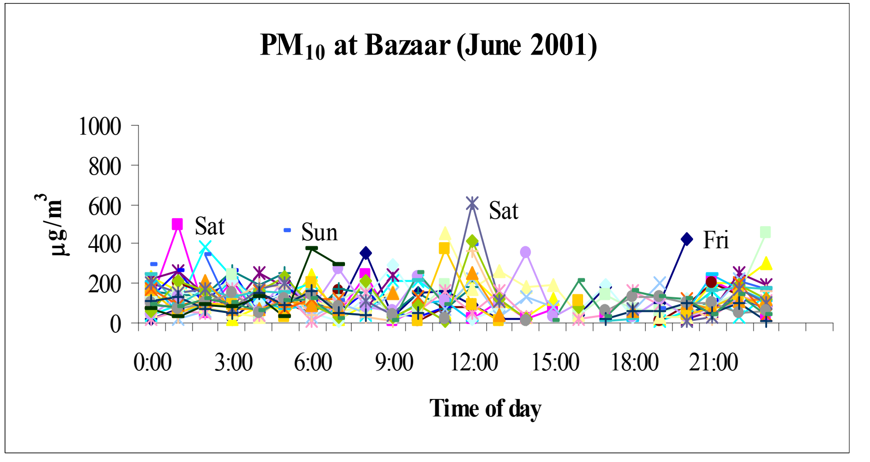

PM10 at Bazaar (January 2001)
1000
800
600
400
200
0
µg/m3
Sun
Tue
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

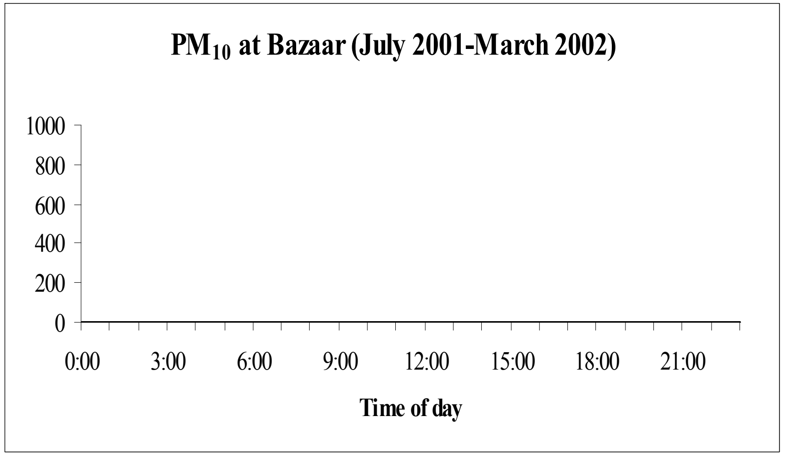

PM10 at Bazaar (February 2001)
1000
800
600
400
200
0
µg/m3
Sun
Wed
Mon
Sat
Fri
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of aday

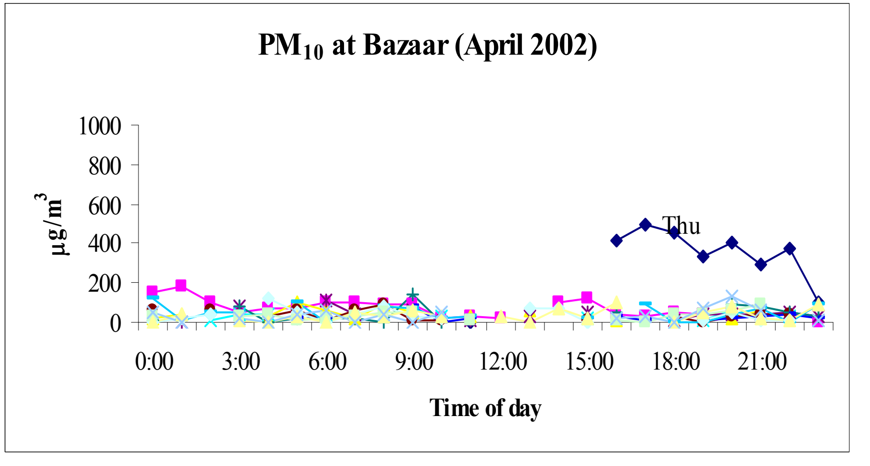

PM10 at Bazaar (March 2001)
1000
800
600
400
200
0
µg/m3
Sun
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

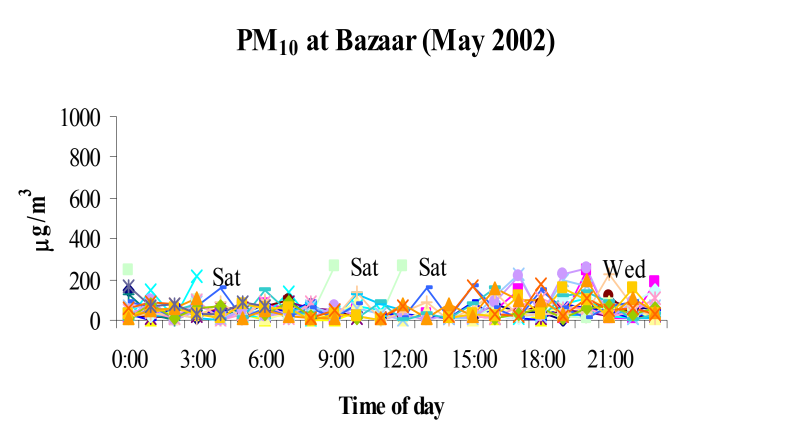

PM10 at Bazaar (April 2001)
1000
800
600
400
200
0
µg/m3
Mon
Tue
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

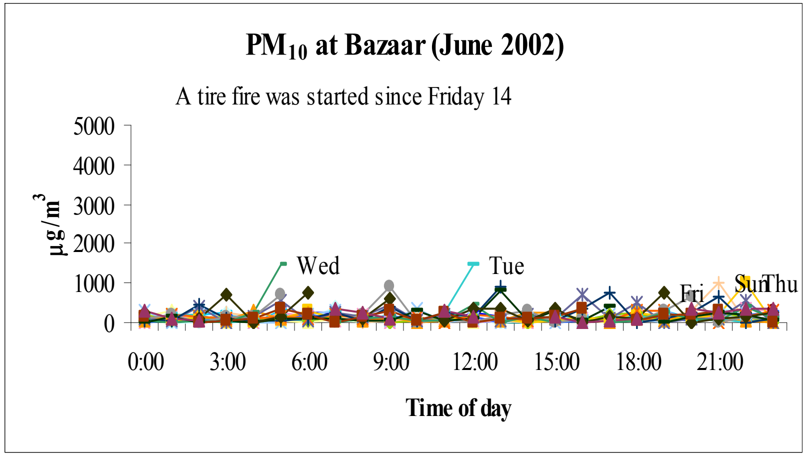

PM10 at Bazaar (May 2001)
Thu
Tue
μg/m3
Time of day

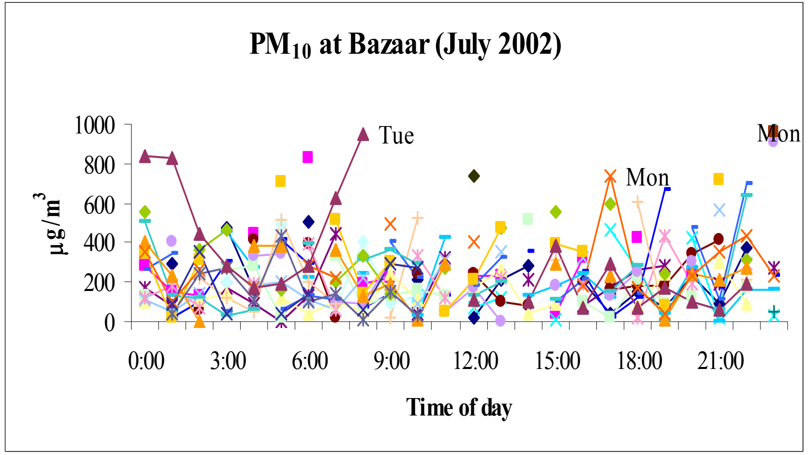

PM10 at Bazaar (June 2001)
Sat
Sun
Sat
Fri
μg/m3
Time of day

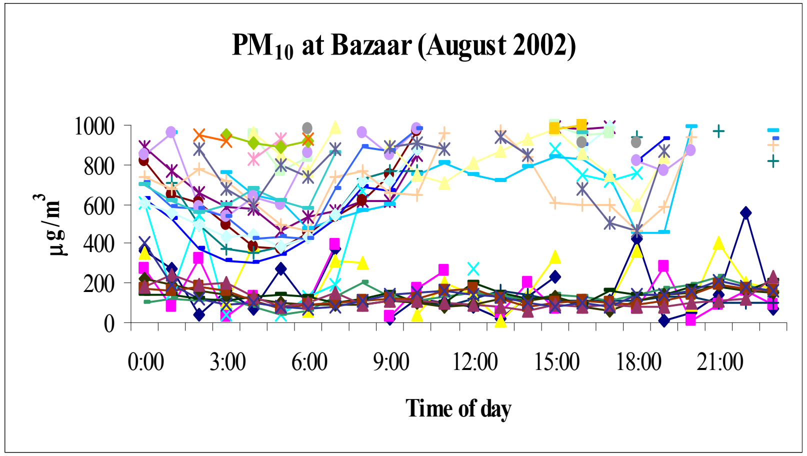

PM10 at Bazaar (July 2001-March 2002)
Time of day

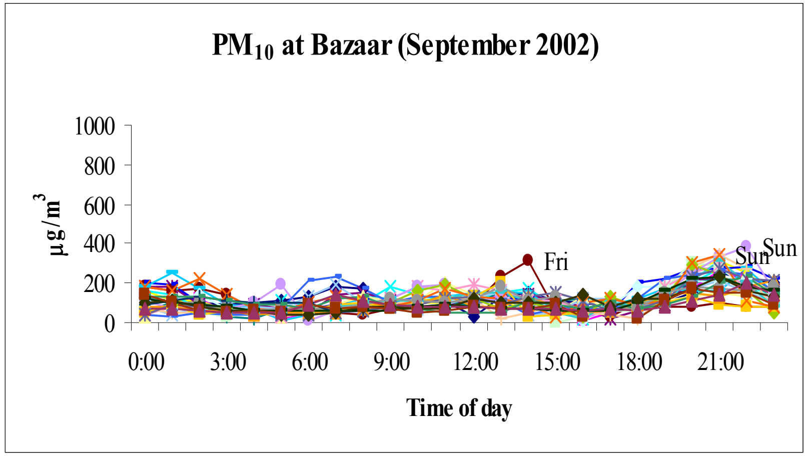

PM10 at Bazaar (April 2002)
Thu
μg/m3
Time of day

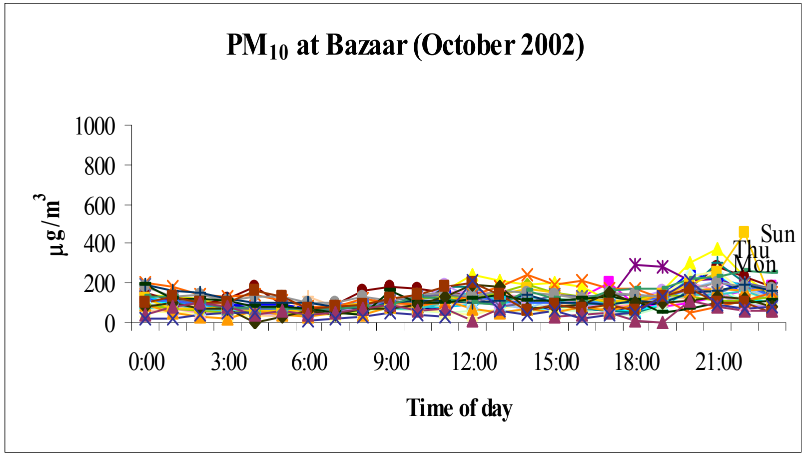

PM10 at Bazaar (May 2002)
1000
800
600
400
200
0
μg/m3
Sat
Sat
Sat
Wed
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

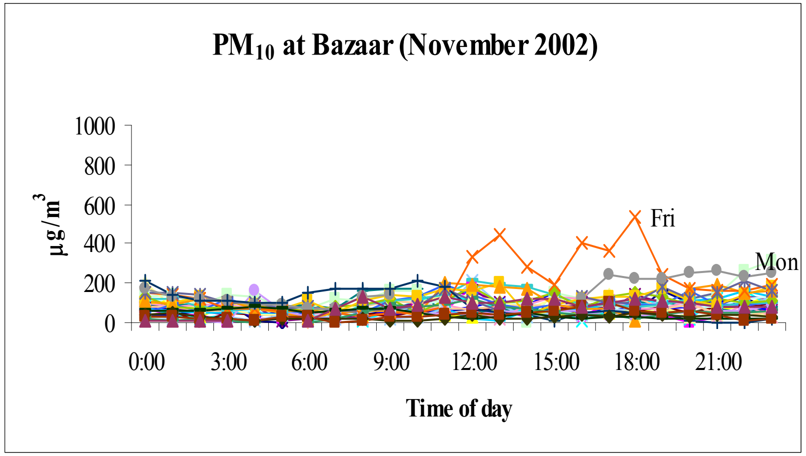

PM10 at Bazaar (June 2002)
A tire fire was started since Friday 14
5000
4000
3000
2000
1000
0
μg/m3
Wed
Tue
Fri
Sun
Thu
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

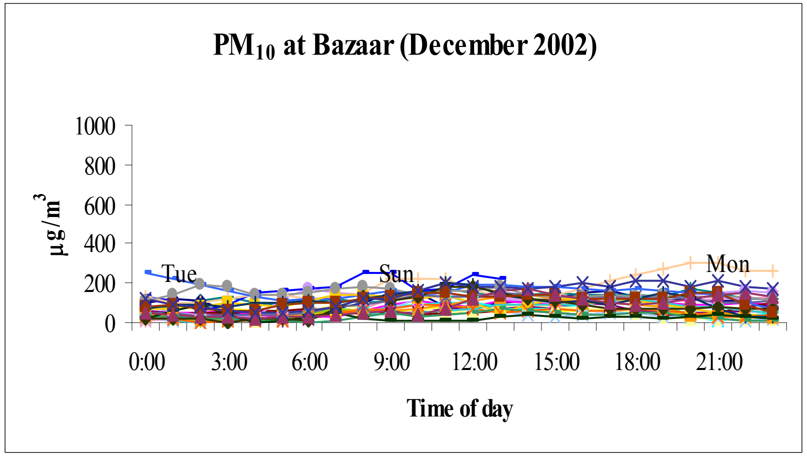

PM10 at Bazaar (July 2002)
1000
800
600
400
200
0
μg/m3
Tue
Mon
Mon
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

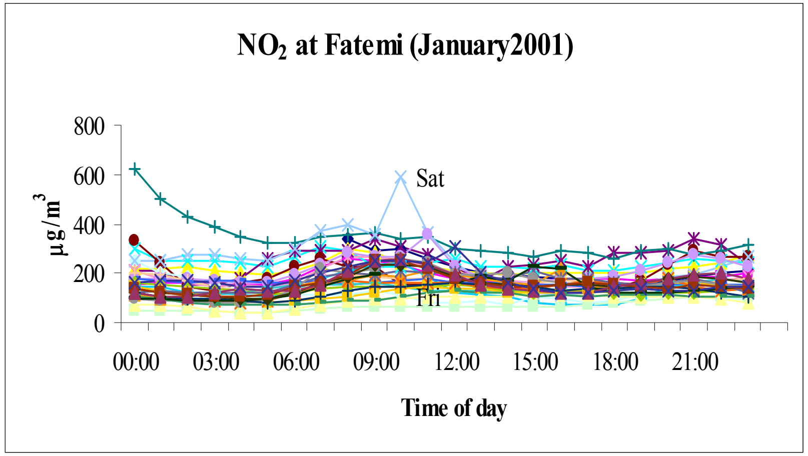

PM10 at Bazaar (August 2002)
1000
800
600
400
200
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


PM10 at Bazaar (September 2002)
μg/m3
1000
800
600
400
200
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Fri
Sun
Sun

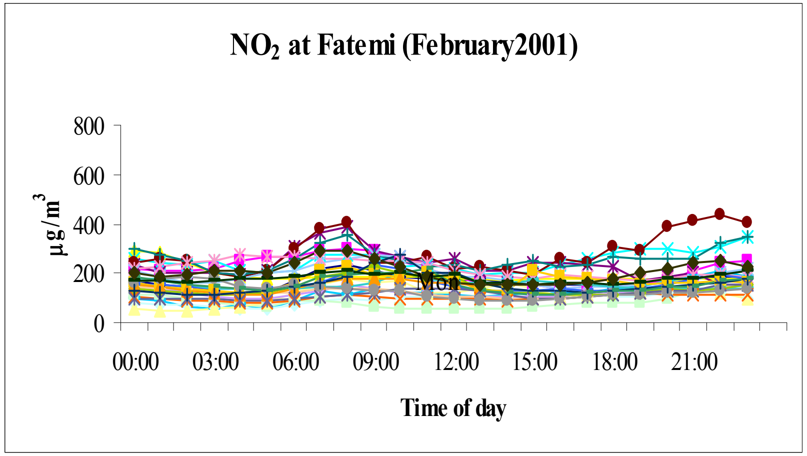

PM10 at Bazaar (October 2002)
μg/m3
1000
800
600
400
200
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Sun
Thu
Mon


PM10 at Bazaar (November 2002)
μg/m3
1000
800
600
400
200
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Fri
Mon

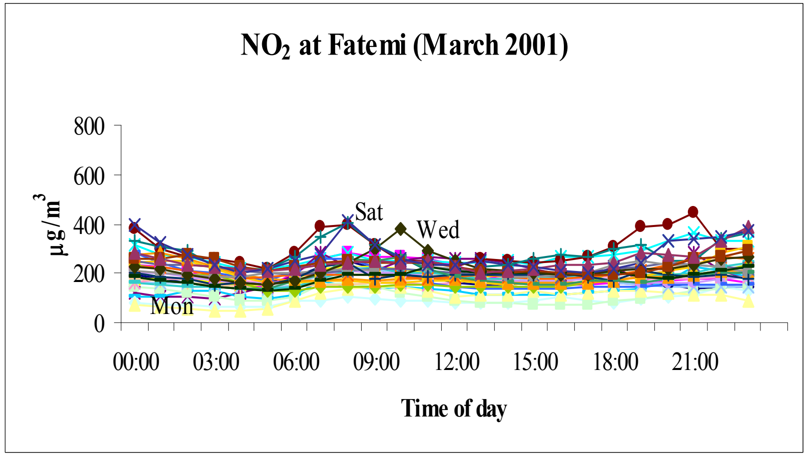

PM10 at Bazaar (December 2002)
μg/m3
1000
800
600
400
200
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Tue
Sun
Mon



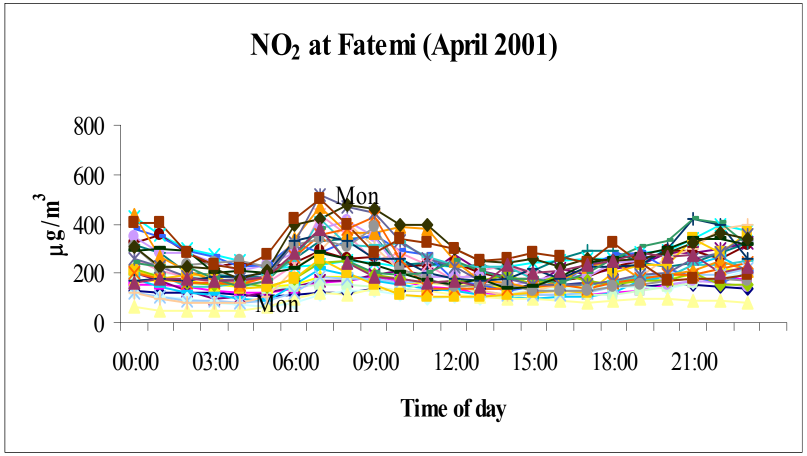
NO2 at Fatemi (January2001)
800
600
400
200
0
µg/m3
Sat
Fri
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



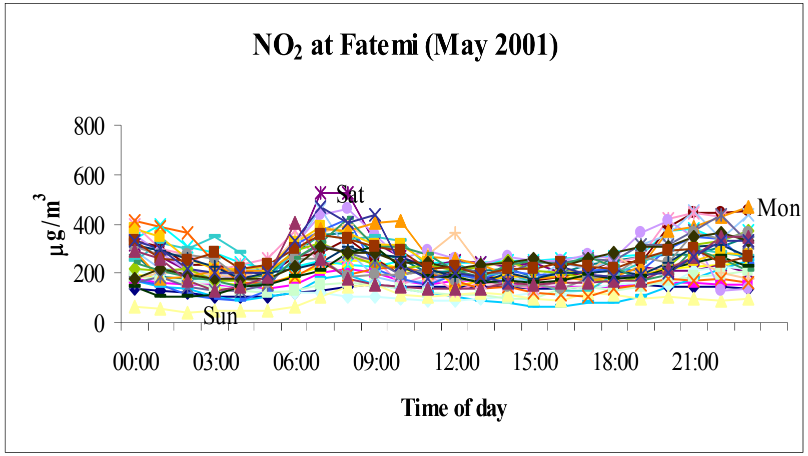
NO2 at Fatemi (February2001)
800
600
400
200
0
µg/m3
Mon
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



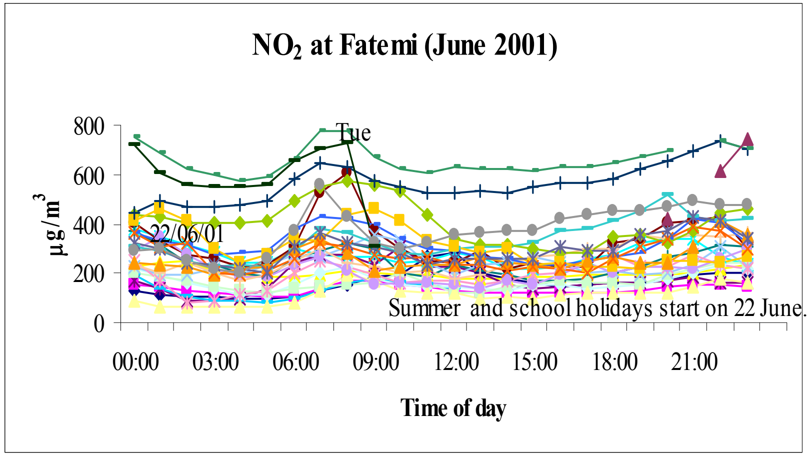
NO2 at Fatemi (March 2001)
800
600
400
200
0
µg/m3
Sat
Wed
Mon
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



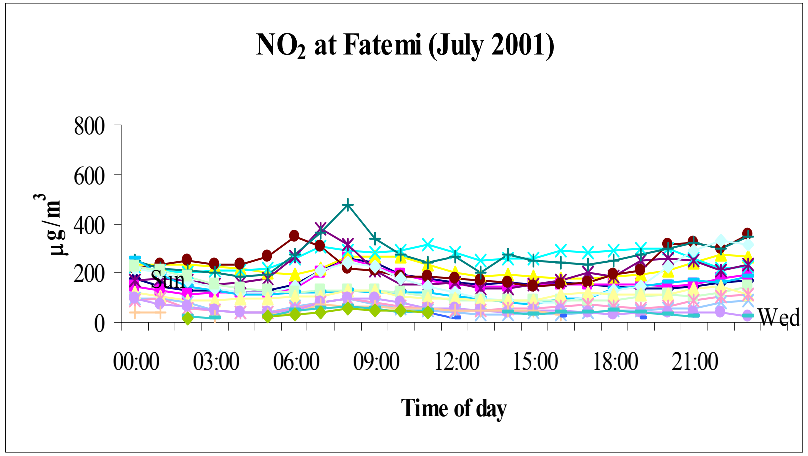
NO2 at Fatemi (April 2001)
800
600
400
200
0
µg/m3
Mon
Mon
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



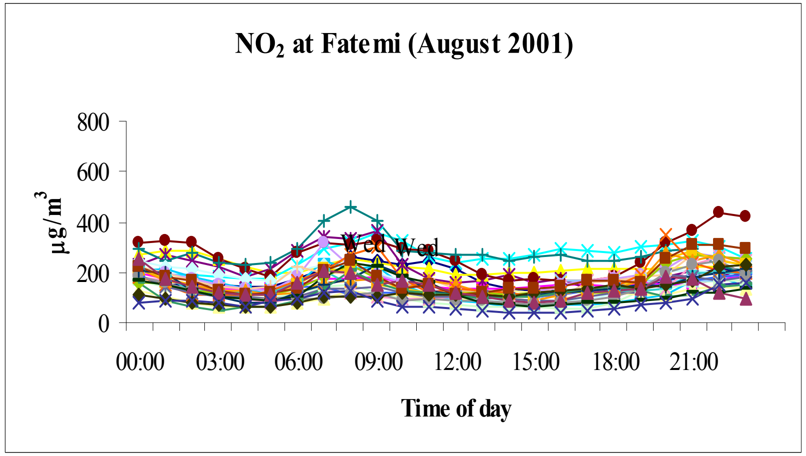
NO2 at Fatemi (May 2001)
800
600
400
200
0
µg/m3
Sat
Mon
Sun
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



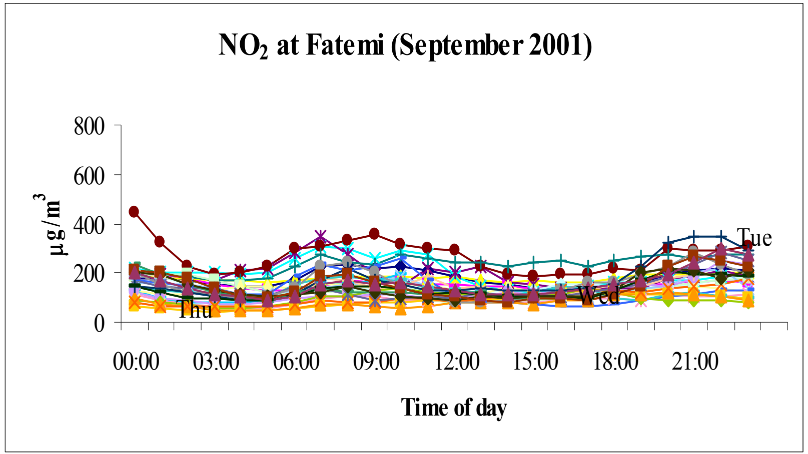
NO2 at Fatemi (June 2001)
800
600
400
200
0
µg/m3
Tue
22/06/01
Summer and school holidays start on 22 June.
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

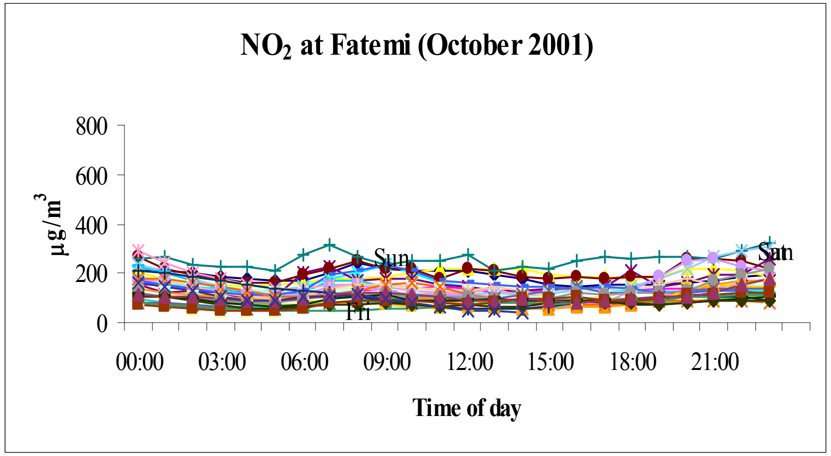


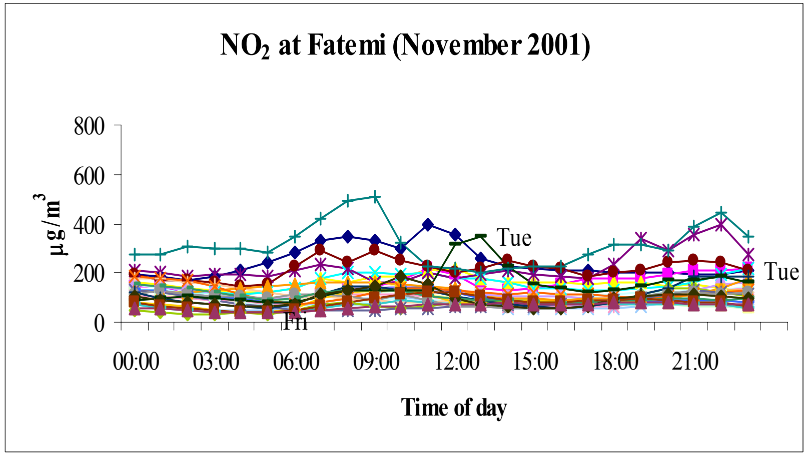
NO2 at Fatemi (July 2001)
800
600
400
200
0
µg/m3
Sun
Wed
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

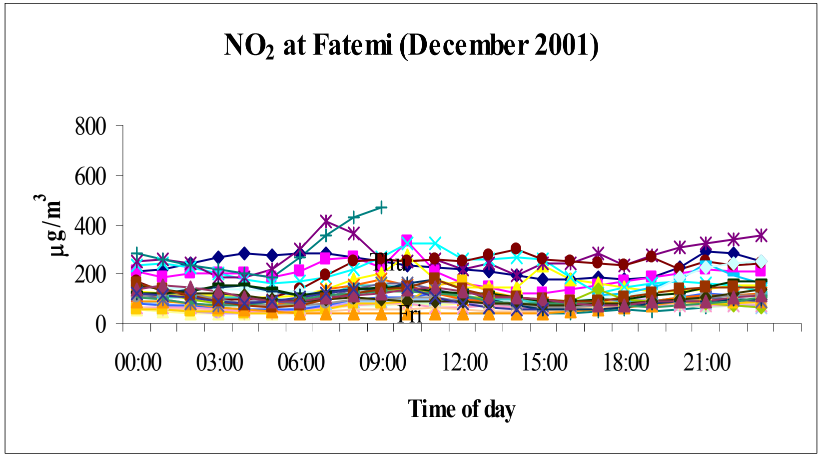


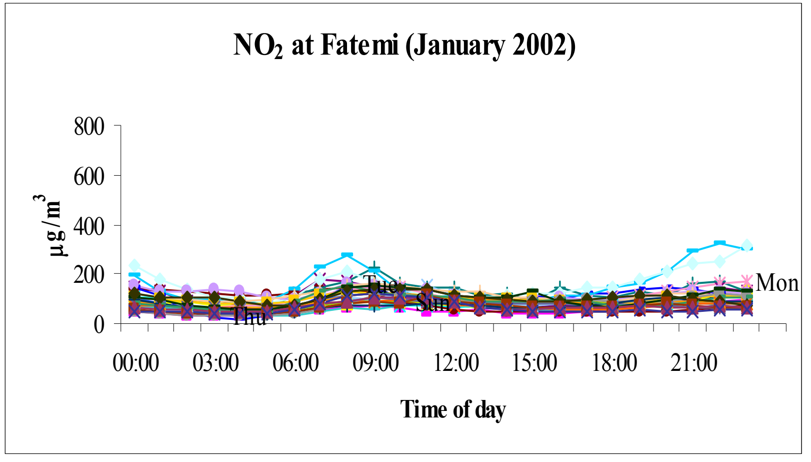
NO2 at Fatemi (August 2001)
800
600
400
200
0
µg/m3
Wed
Wed
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day


NO2 at Fatemi (September 2001)
800
600
400
200
0
µg/m3
Tue
Wed
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

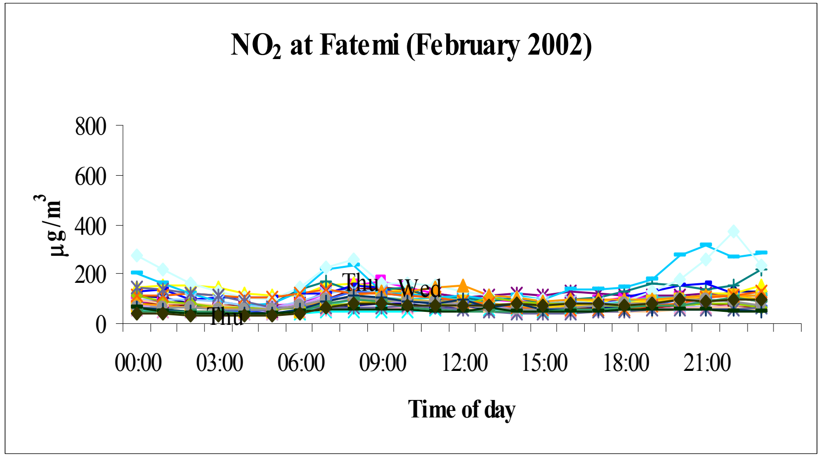

NO2 at Fatemi (October 2001)
800
600
400
200
0
µg/m3
Sun
Fri
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day


NO2 at Fatemi (November 2001)
800
600
400
200
0
µg/m3
Tue
Tue
Fri
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

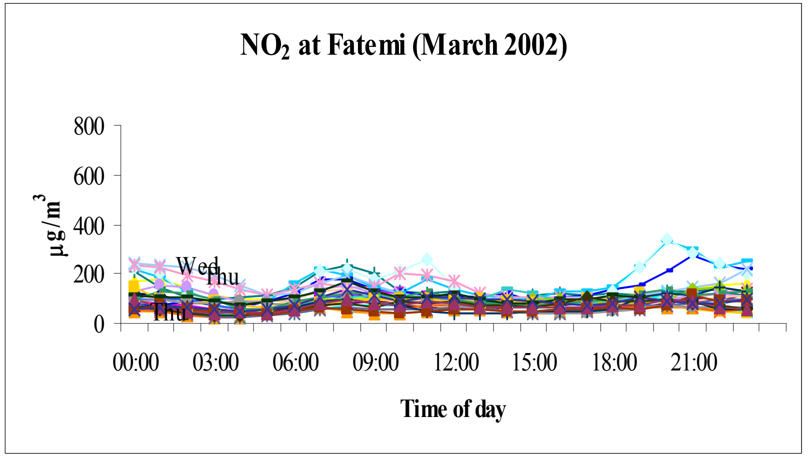

NO2 at Fatemi (December 2001)
800
600
400
200
0
µg/m3
Thu
Fri
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



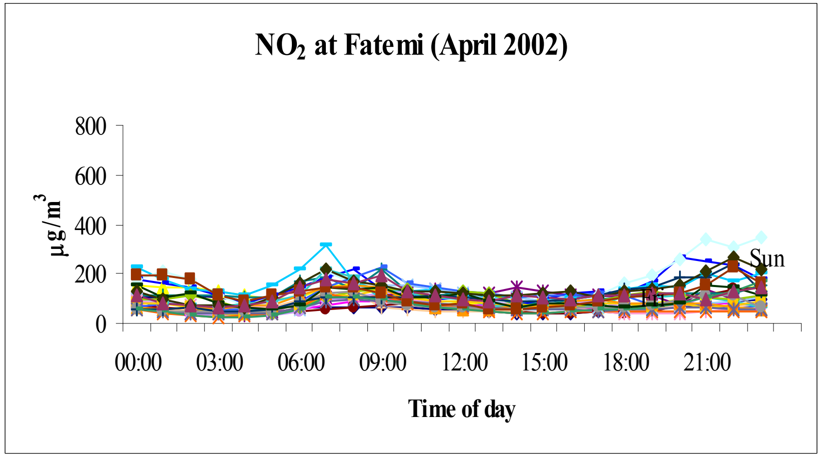
NO2 at Fatemi (January 2002)
800
600
400
200
0
µg/m3
Tue
Sun
Mon
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



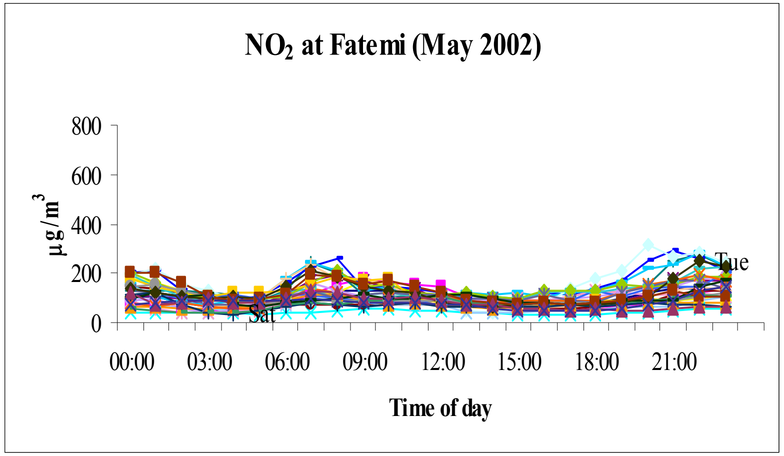
NO2 at Fatemi (February 2002)
800
600
400
200
0
µg/m3
Thu
Wed
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

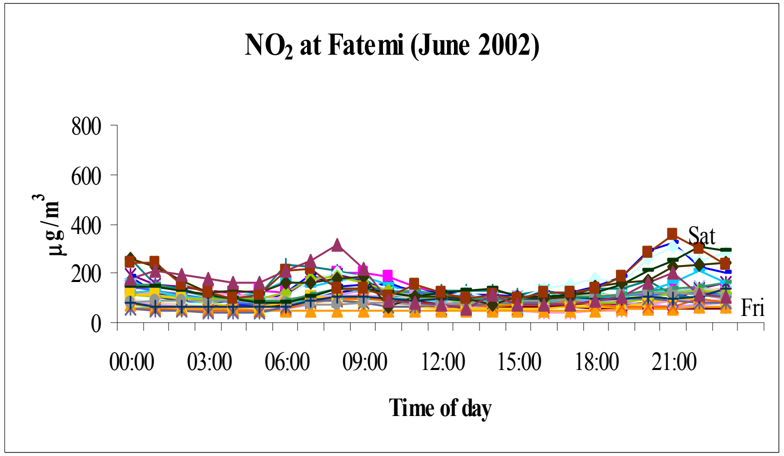


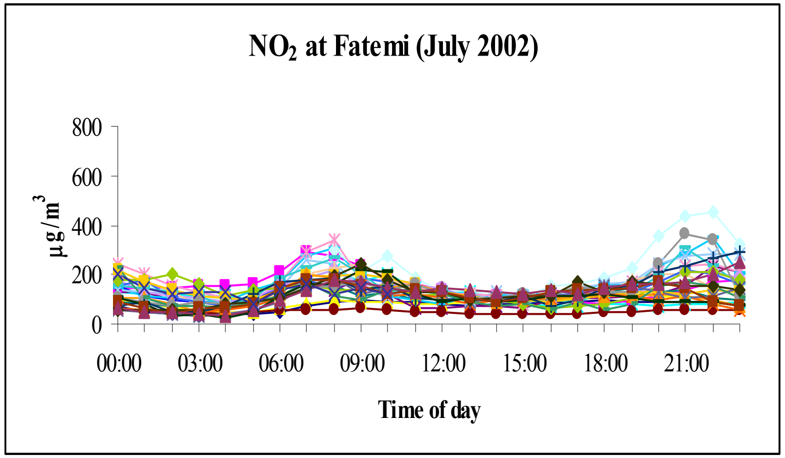
NO2 at Fatemi (March 2002)
800
600
400
200
0
µg/m3
Wed
Thu
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

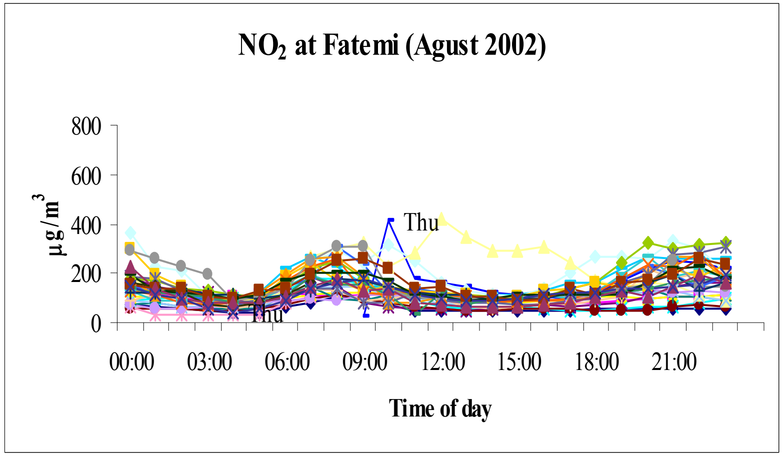


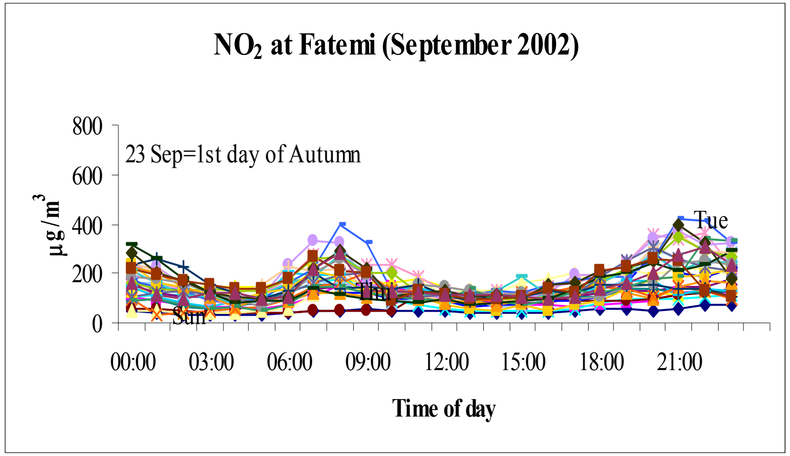
NO2 at Fatemi (April 2002)
800
600
400
200
0
µg/m3
Sun
Fri
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

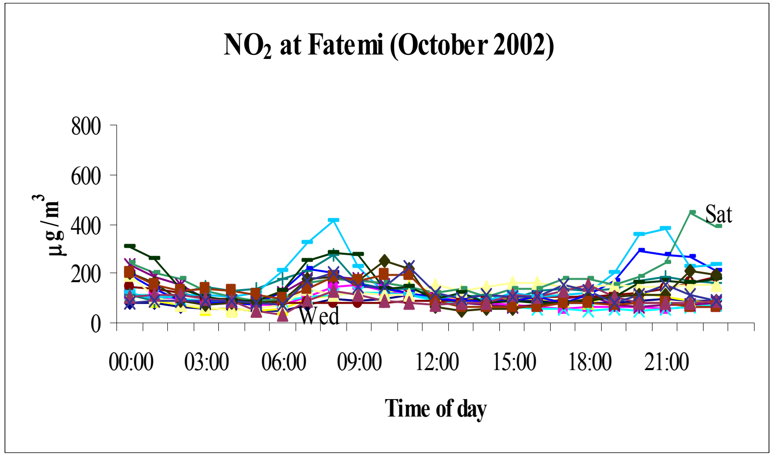

NO2 at Fatemi (May 2002)
800
600
400
200
0
µg/m3
Tue
Sat
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

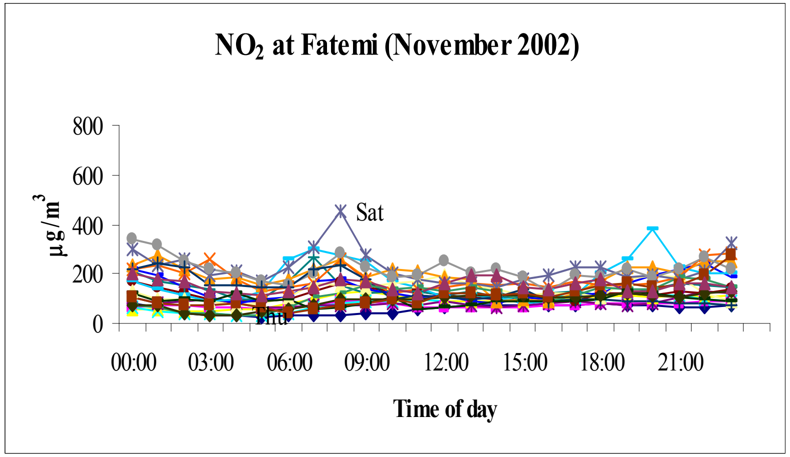

NO2 at Fatemi (June 2002)
800
600
400
200
0
µg/m3
Sat
Fri
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

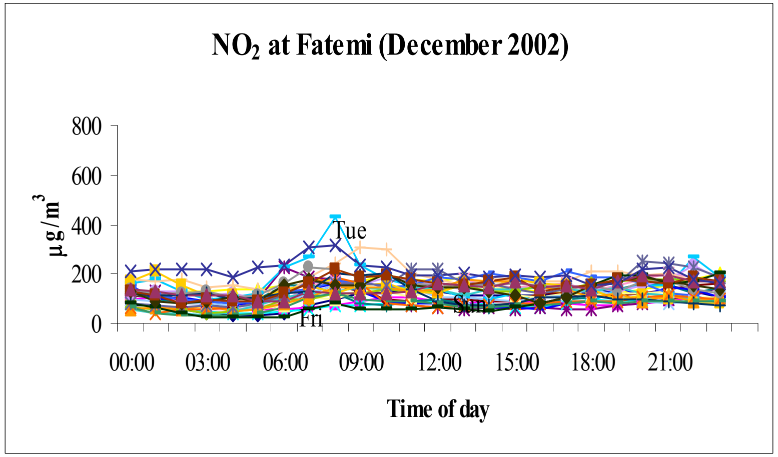

NO2 at Fatemi (July 2002)
800
600
400
200
0
µg/m3
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

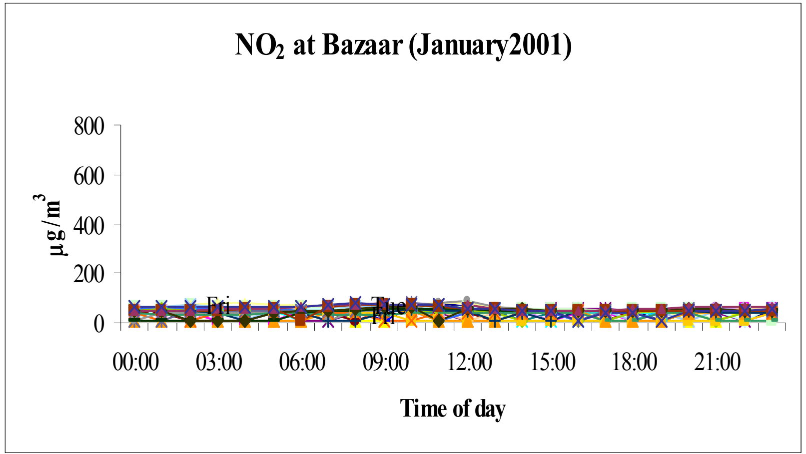

NO2 at Fatemi (Agust 2002)
800
600
400
200
0
µg/m3
Thu
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

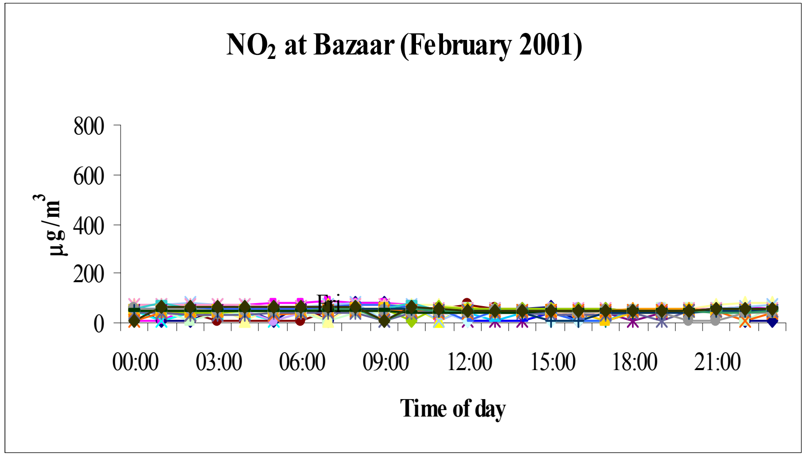

NO$_2$ at Fatemi (September 2002)
23 Sep=1st day of Autumn
Tue
Thu
Sun
800
600
400
200
0
μg/m^3
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

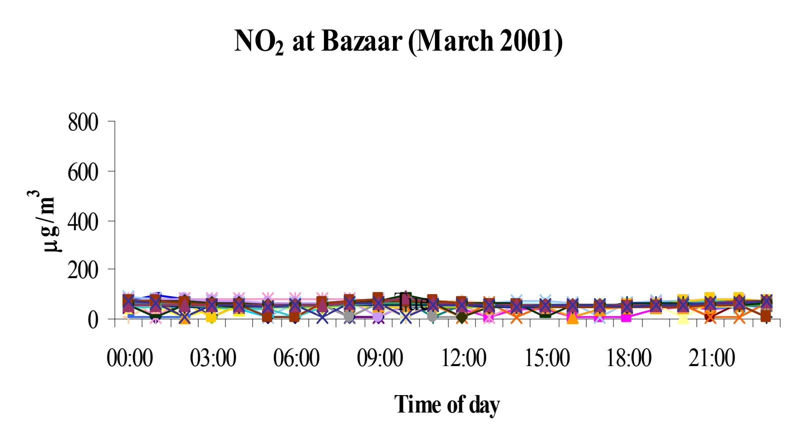

NO$_2$ at Fatemi (October 2002)
Sat
Wed
800
600
400
200
0
μg/m^3
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

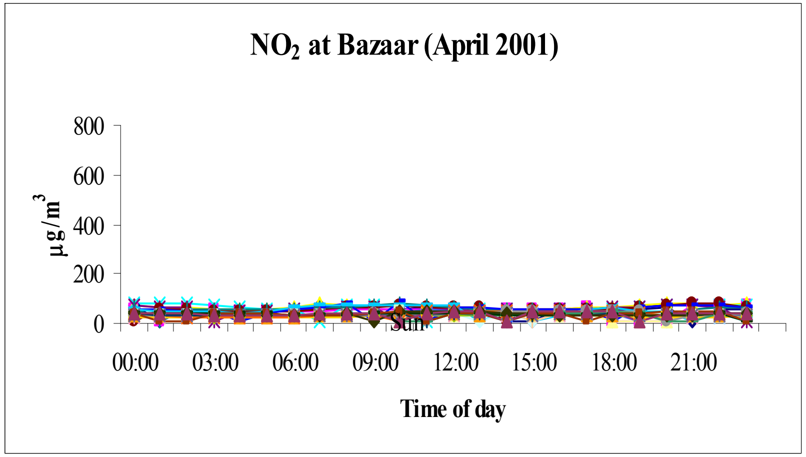

NO$_2$ at Fatemi (November 2002)
Sat
Thu
800
600
400
200
0
μg/m^3
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

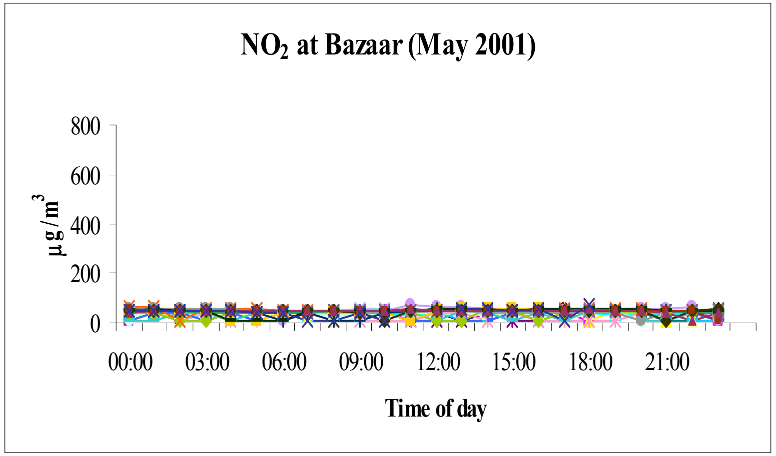

NO$_2$ at Fatemi (December 2002)
Tue
Sun
Fri
800
600
400
200
0
μg/m^3
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

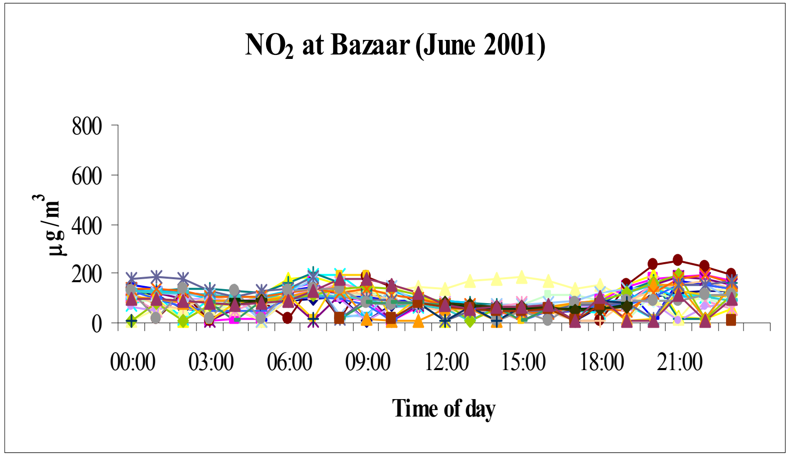

NO2 at Bazaar (January2001)
800
600
400
200
0
µg/m3
Fri
Tue
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

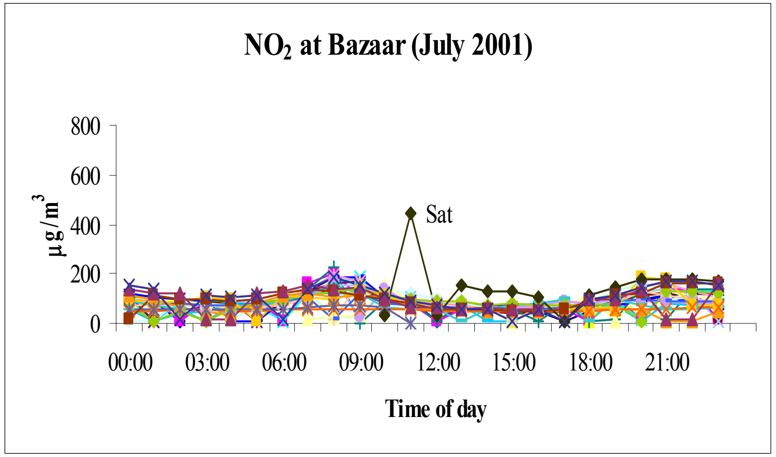

NO2 at Bazaar (February 2001)
800
600
400
200
0
µg/m3
Fri
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

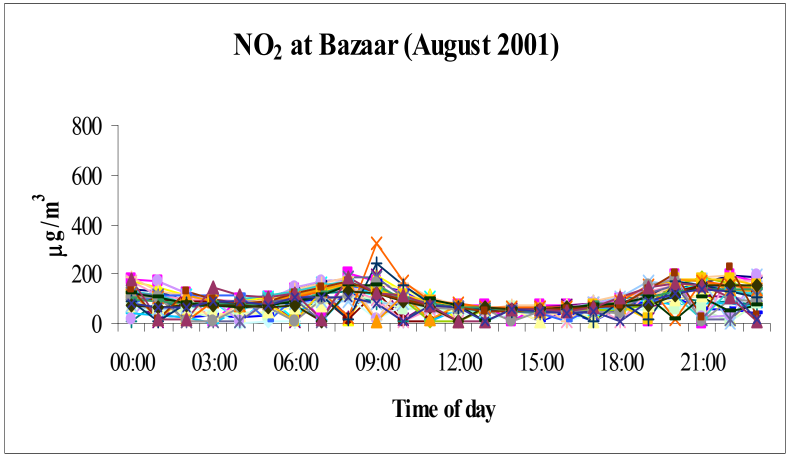

NO2 at Bazaar (March 2001)
800
600
400
200
0
µg/m3
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

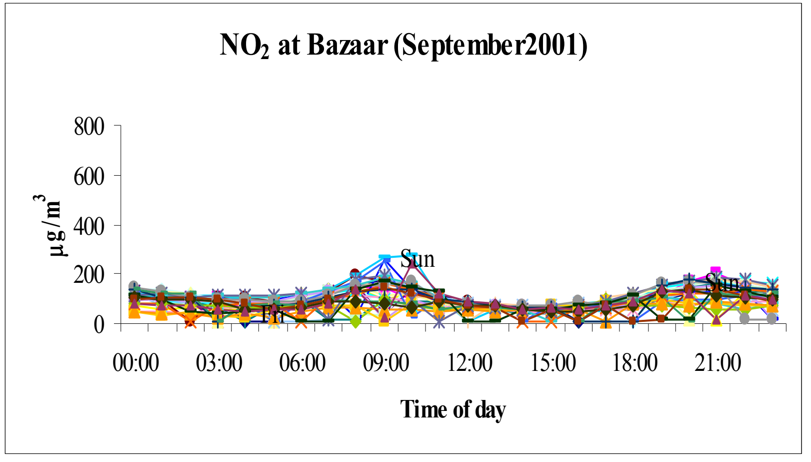

NO2 at Bazaar (April 2001)
800
600
400
200
0
µg/m3
Sun
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

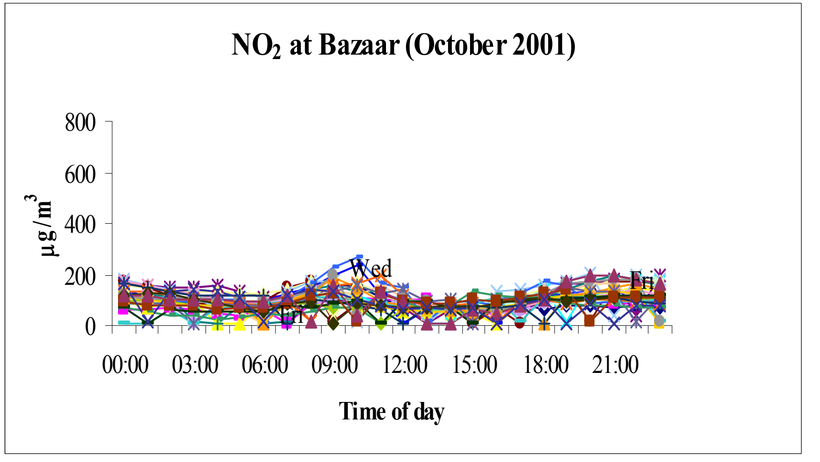

NO2 at Bazaar (May 2001)
800
600
400
200
0
µg/m3
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

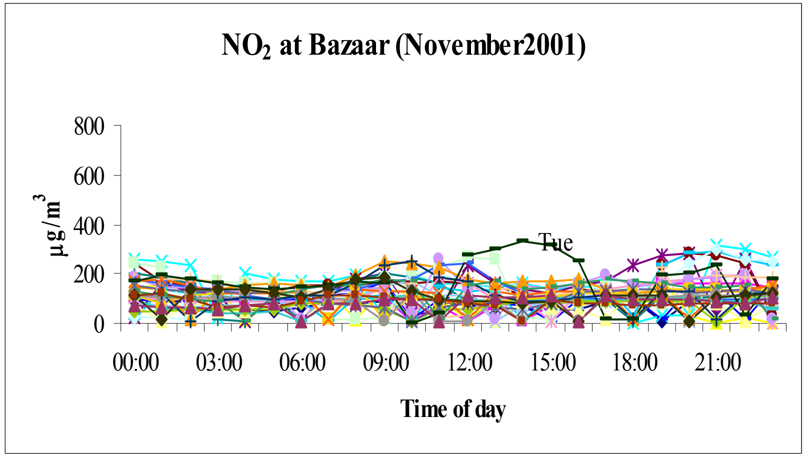

NO2 at Bazaar (June 2001)
800
600
400
200
0
µg/m3
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

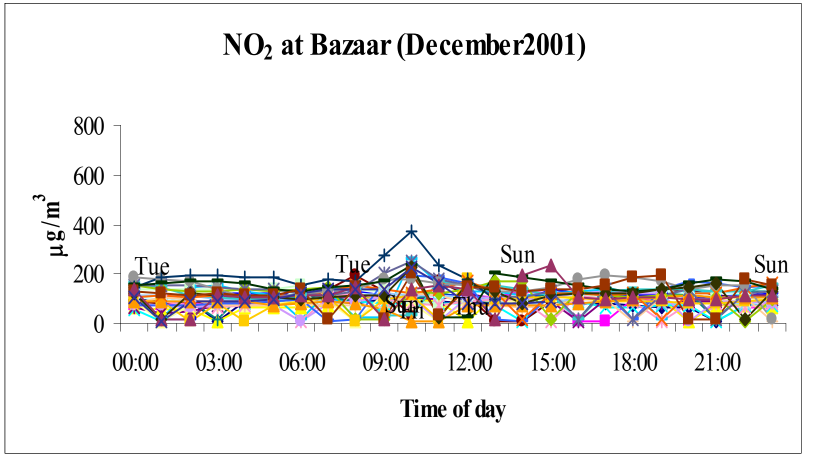

NO2 at Bazaar (July 2001)
800
600
400
200
0
µg/m3
Sat
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

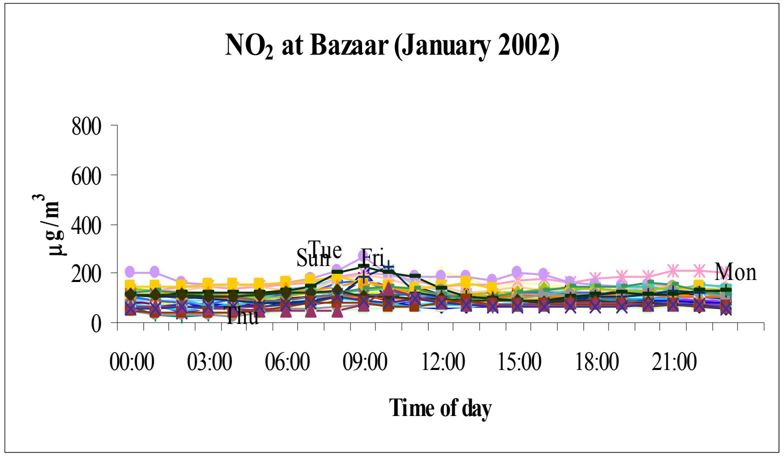

NO2 at Bazaar (August 2001)
800
600
400
200
0
µg/m3
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

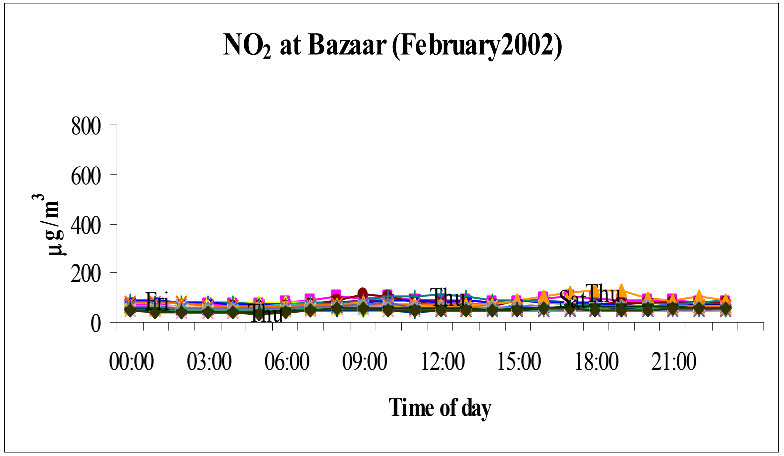

NO2 at Bazaar (September2001)
800
600
400
200
0
µg/m3
Sun
Sun
Fri
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

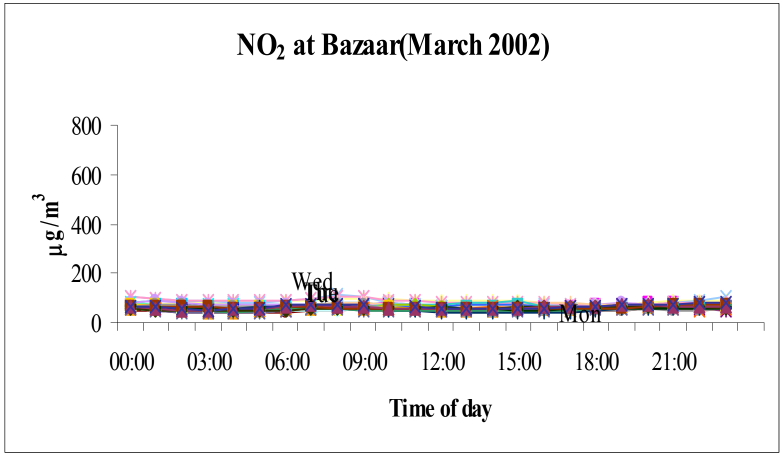

NO2 at Bazaar (October 2001)
800
600
400
200
0
µg/m3
Wed
Fri
Fri
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

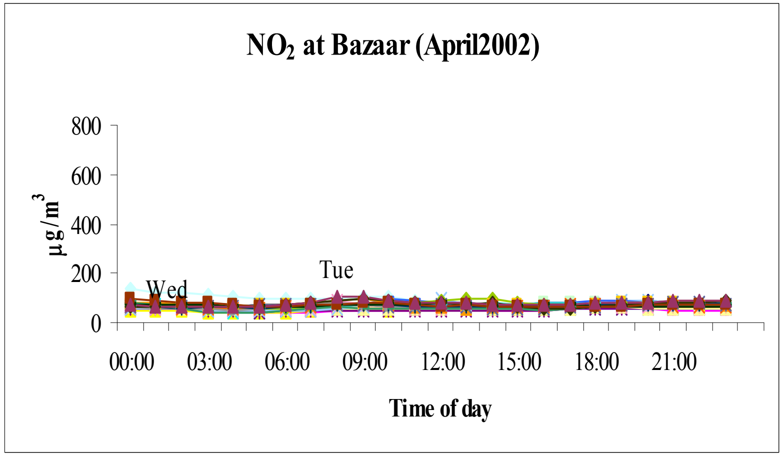

NO2 at Bazaar (November2001)
800
600
400
200
0
µg/m3
Tue
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

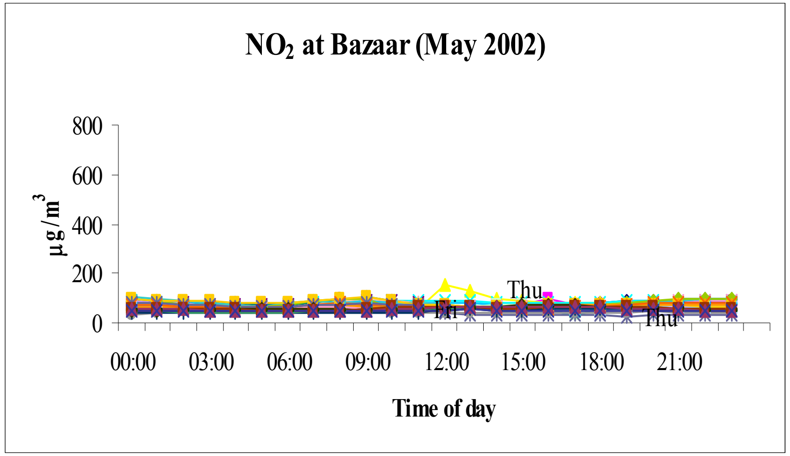

NO2 at Bazaar (December2001)
800
600
400
200
0
µg/m3
Tue
Tue
Sun
Sun
Sun
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day


NO2 at Bazaar (January 2002)
800
600
400
200
0
µg/m3
Tue
Sun
Fri
Mon
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

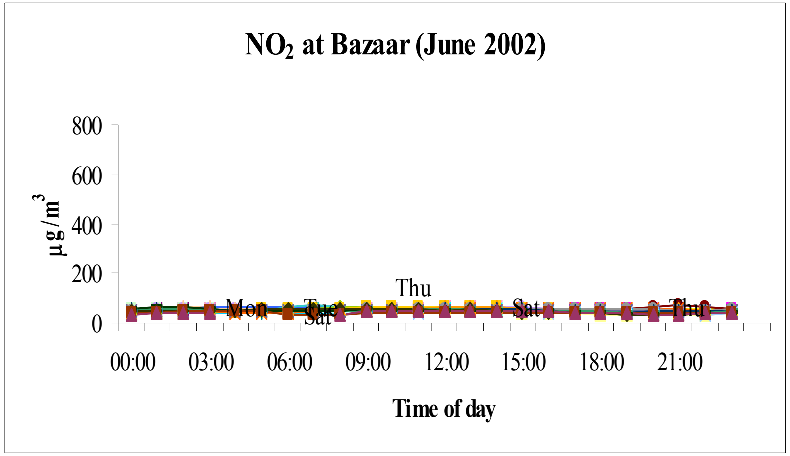

NO2 at Bazaar (February2002)
800
600
400
200
0
µg/m3
Fri
Thu
Thu
Sat
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day


NO2 at Bazaar(March 2002)
800
600
400
200
0
µg/m3
Wed
Tue
Mon
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

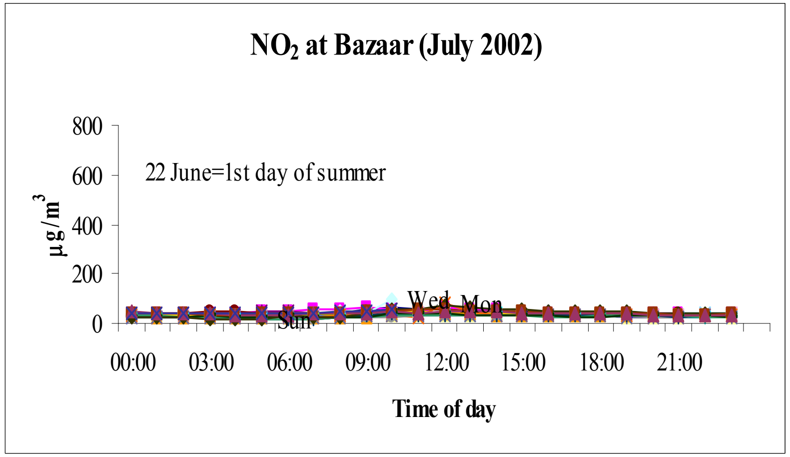

NO2 at Bazaar (April2002)
800
600
400
200
0
µg/m3
Wed
Tue
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



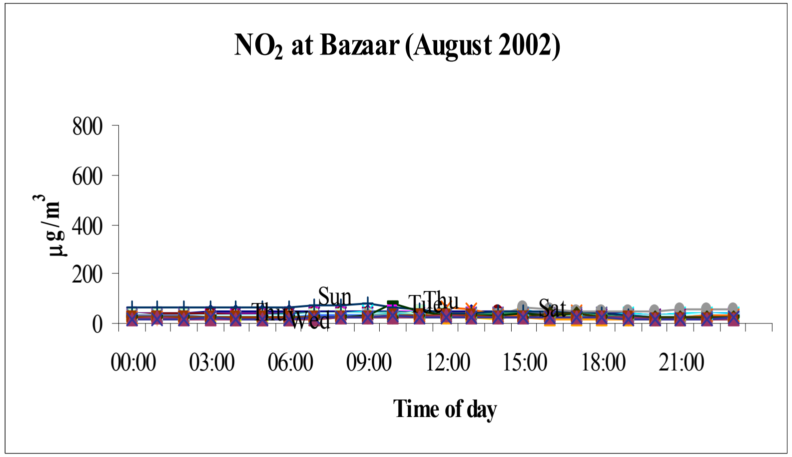
NO2 at Bazaar (May 2002)
800
600
400
200
0
μg/m3
Thu
Fri
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



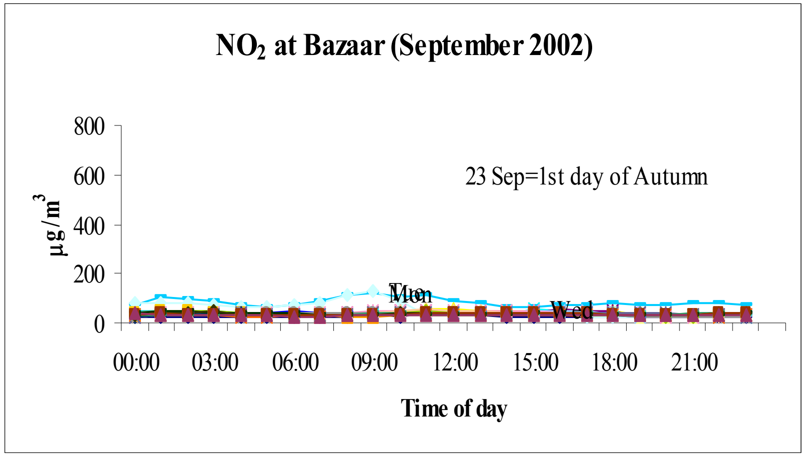
NO2 at Bazaar (June 2002)
800
600
400
200
0
μg/m3
Thu
Mon
Tue
Sat
Sat
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

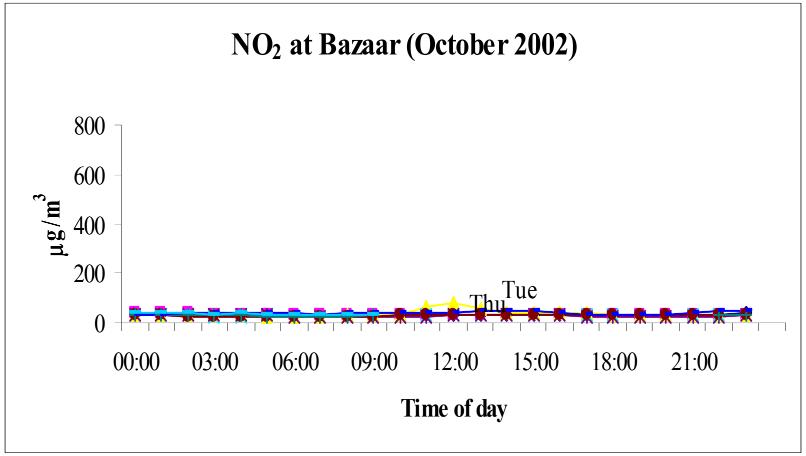


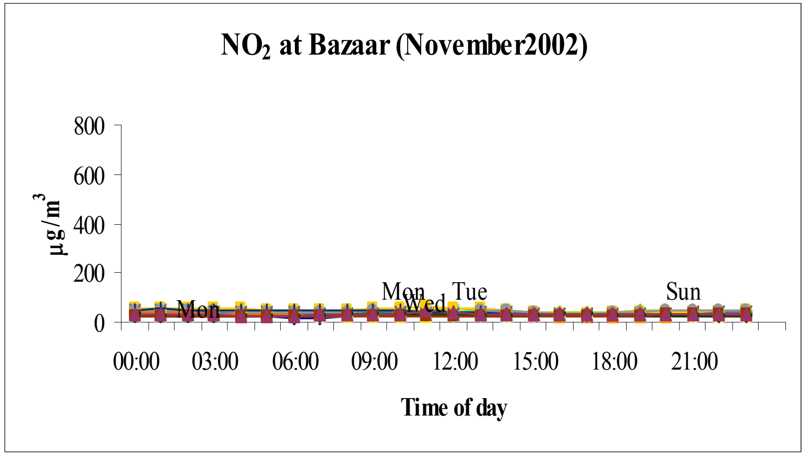
NO2 at Bazaar (July 2002)
800
600
400
200
0
μg/m3
22 June=1st day of summer
Wed
Mon
Sun
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

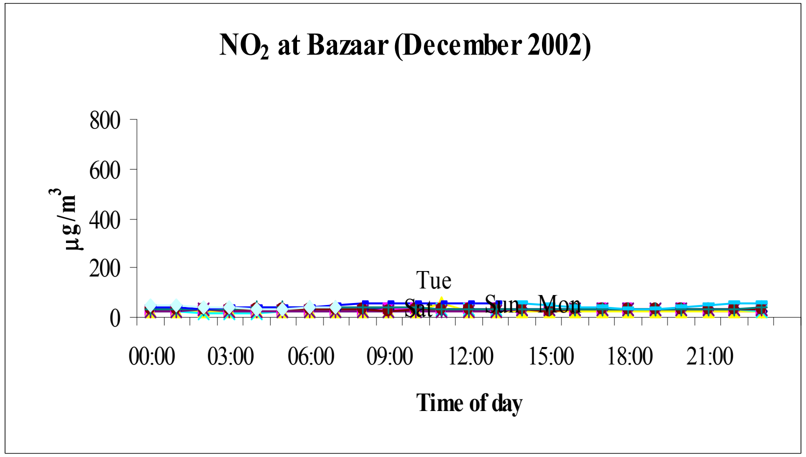


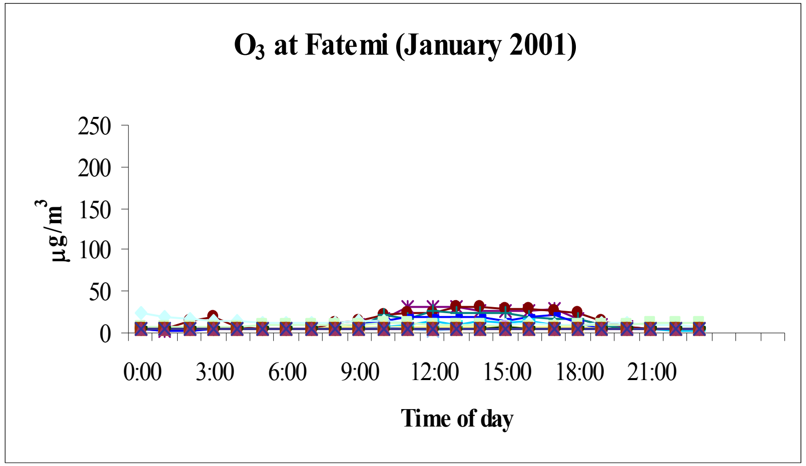
NO2 at Bazaar (August 2002)
800
600
400
200
0
μg/m3
Sun
Thu
Tue
Wed
Sat
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day


NO2 at Bazaar (September 2002)
800
600
400
200
0
μg/m3
23 Sep=1st day of Autumn
Tue
Mon
Wed
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

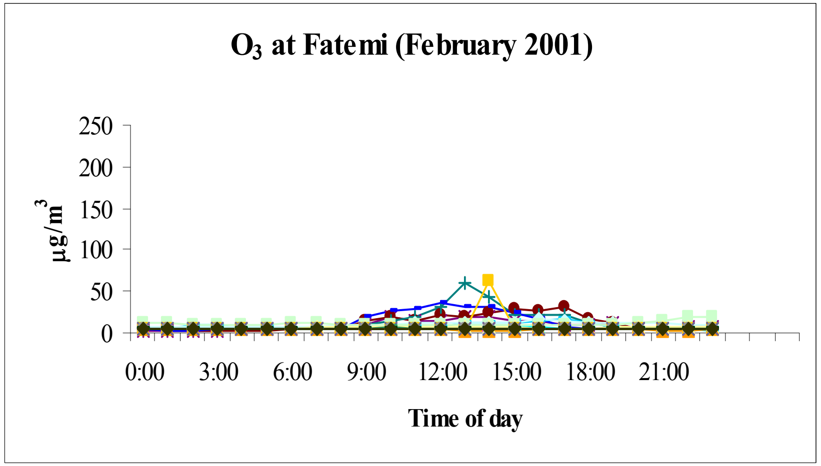

NO2 at Bazaar (October 2002)
800
600
400
200
0
μg/m3
Tue
Thu
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day


NO2 at Bazaar (November2002)
800
600
400
200
0
μg/m3
Mon
Mon
Wed
Tue
Sun
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day

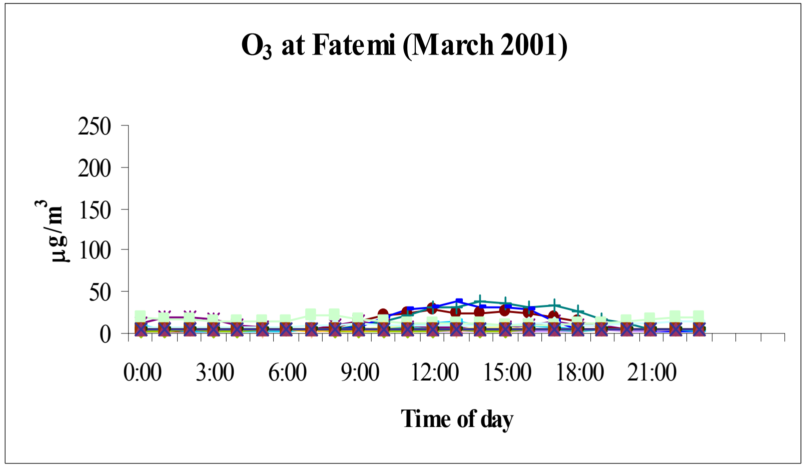

NO2 at Bazaar (December 2002)
800
600
400
200
0
μg/m3
Tue
Sat
Sun
Mon
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time of day



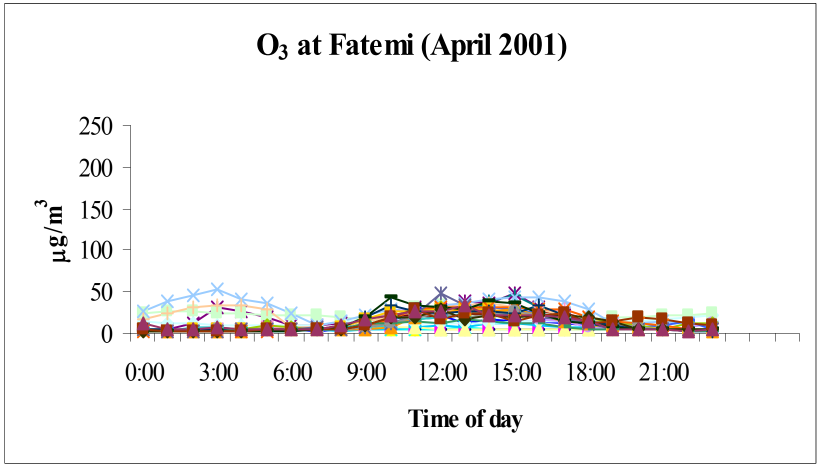
O3 at Fatemi (January 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



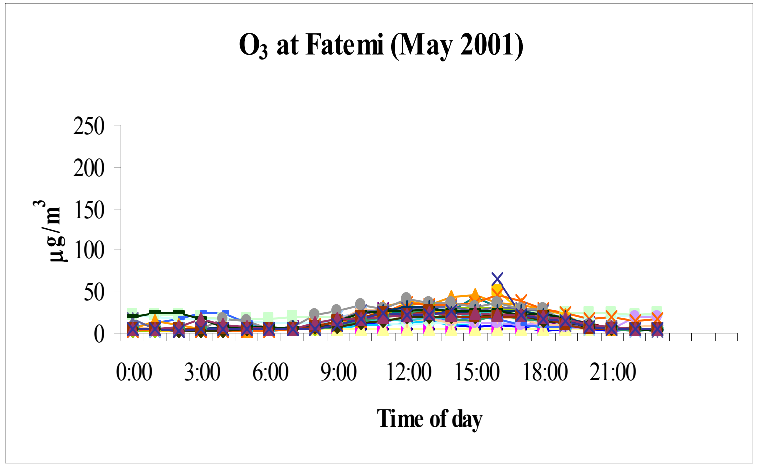
O3 at Fatemi (February 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

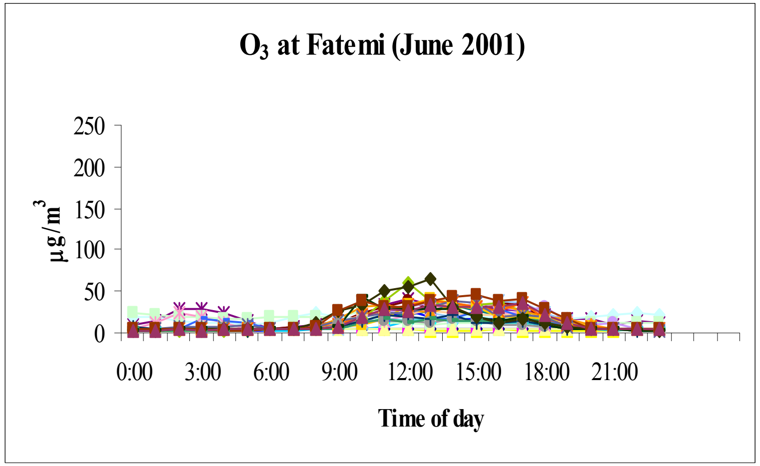


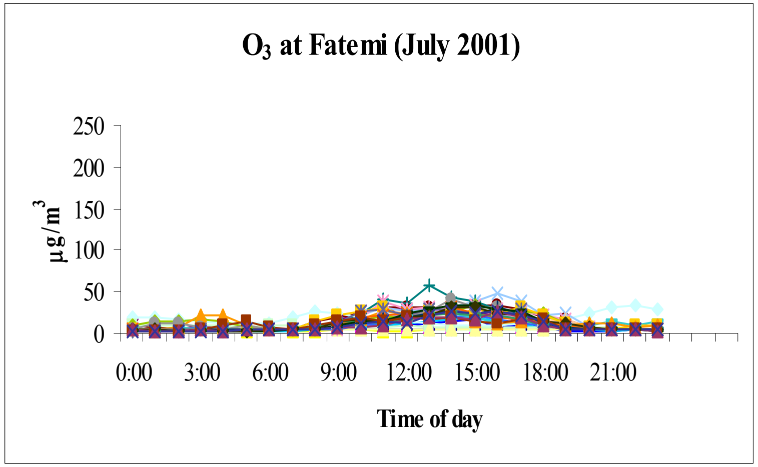
O3 at Fatemi (March 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

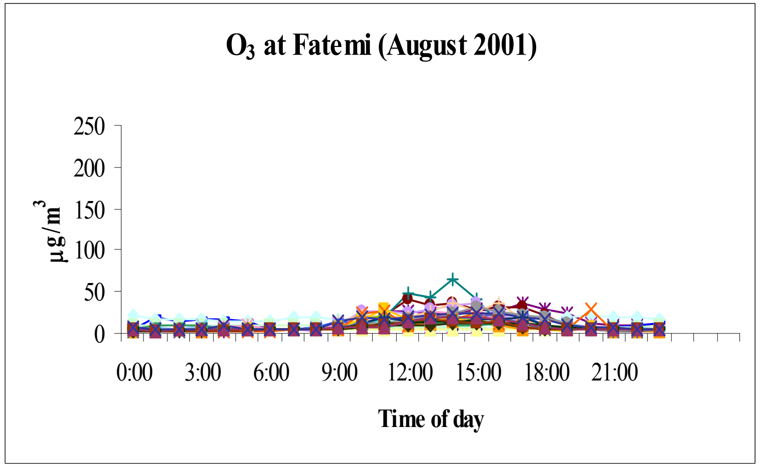


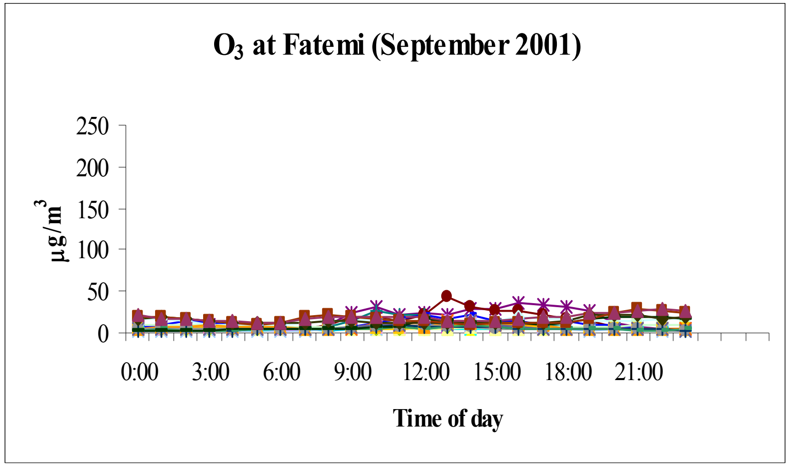
O3 at Fatemi (April 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

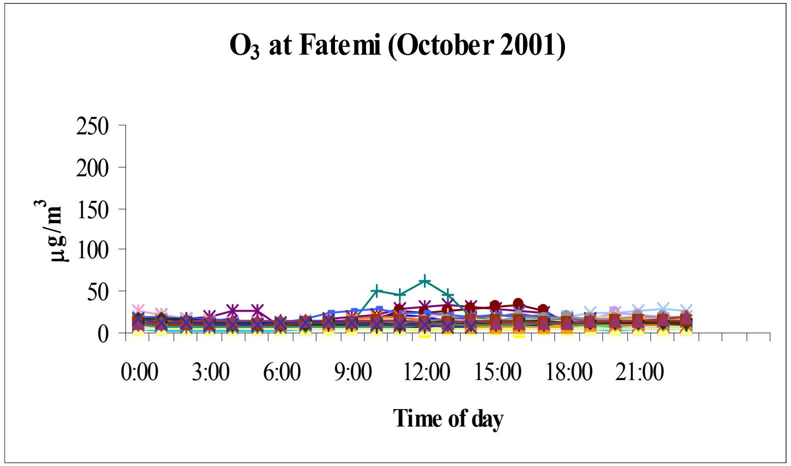

O3 at Fatemi (May 2001)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

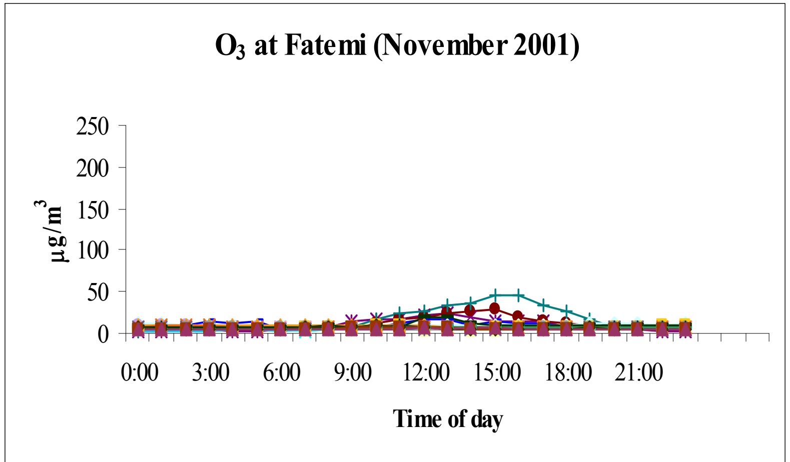

O3 at Fatemi (June 2001)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

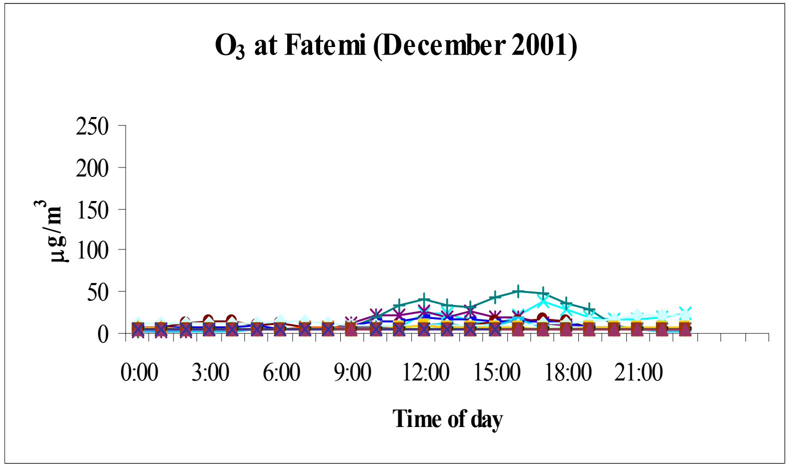

O3 at Fatemi (July 2001)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

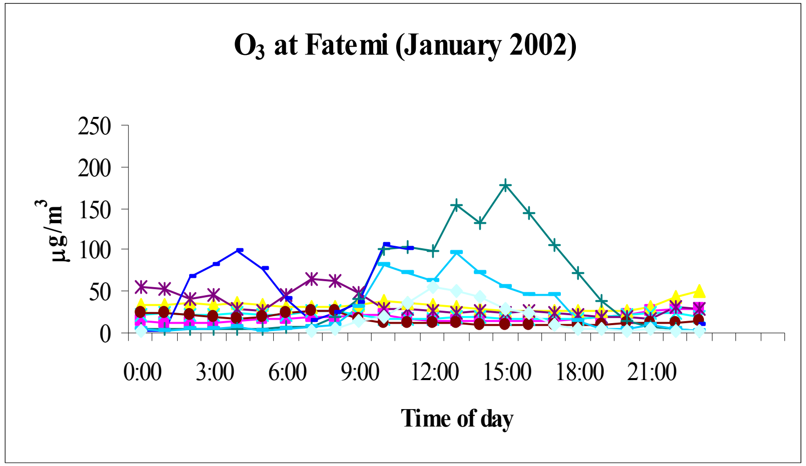

O3 at Fatemi (August 2001)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

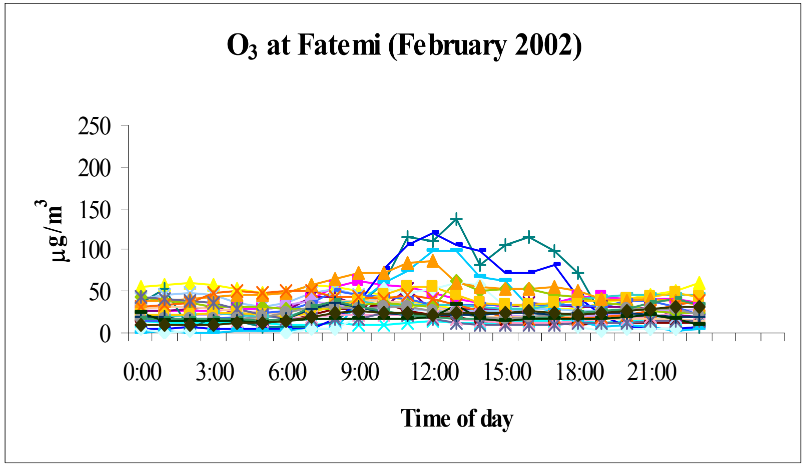

O3 at Fatemi (September 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

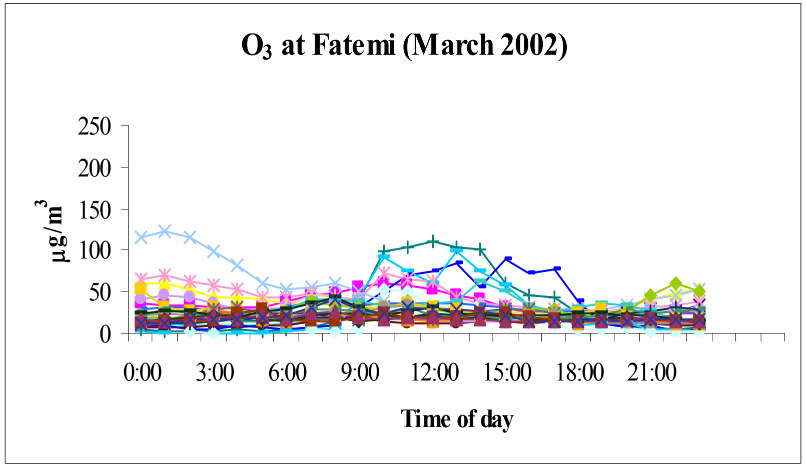

O3 at Fatemi (October 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

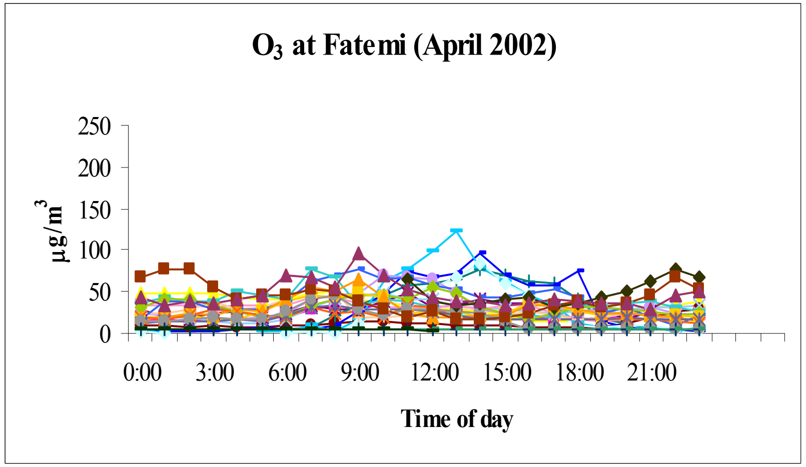

O3 at Fatemi (November 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

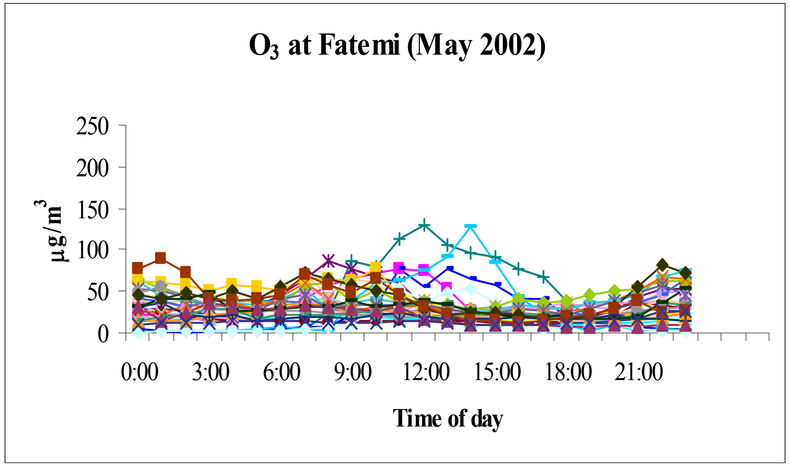

O3 at Fatemi (December 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

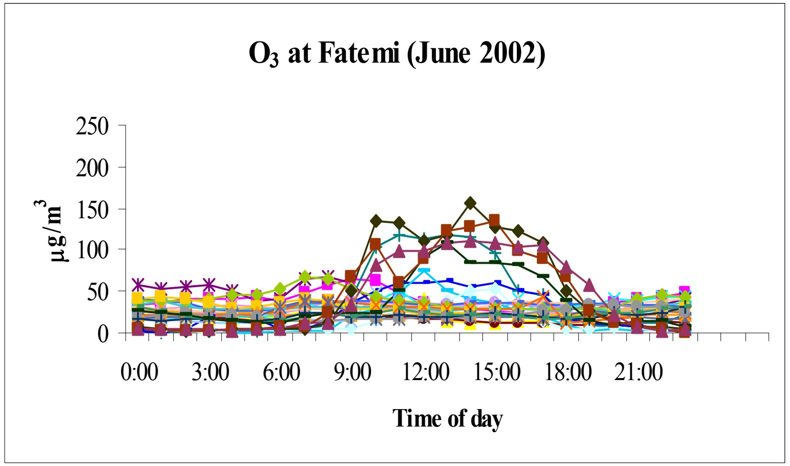

O$_3$ at Fatemi (January 2002)
250
200
150
100
50
0
µg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

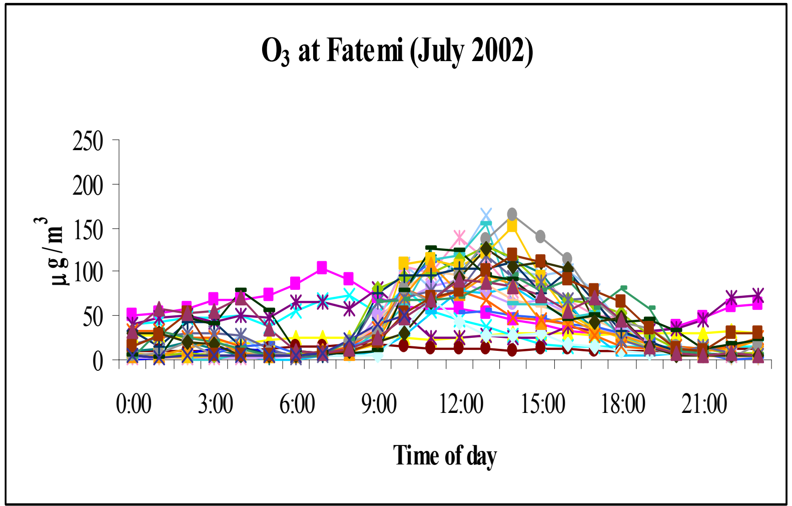

O$_3$ at Fatemi (February 2002)
250
200
150
100
50
0
µg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

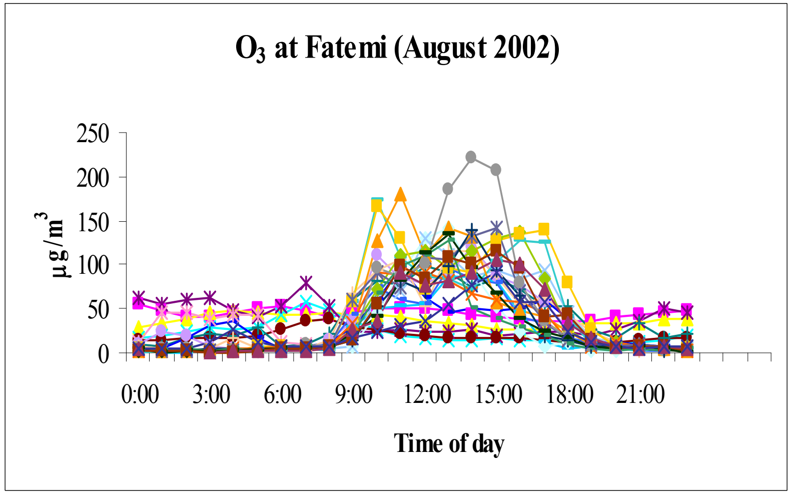

O$_3$ at Fatemi (March 2002)
250
200
150
100
50
0
µg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

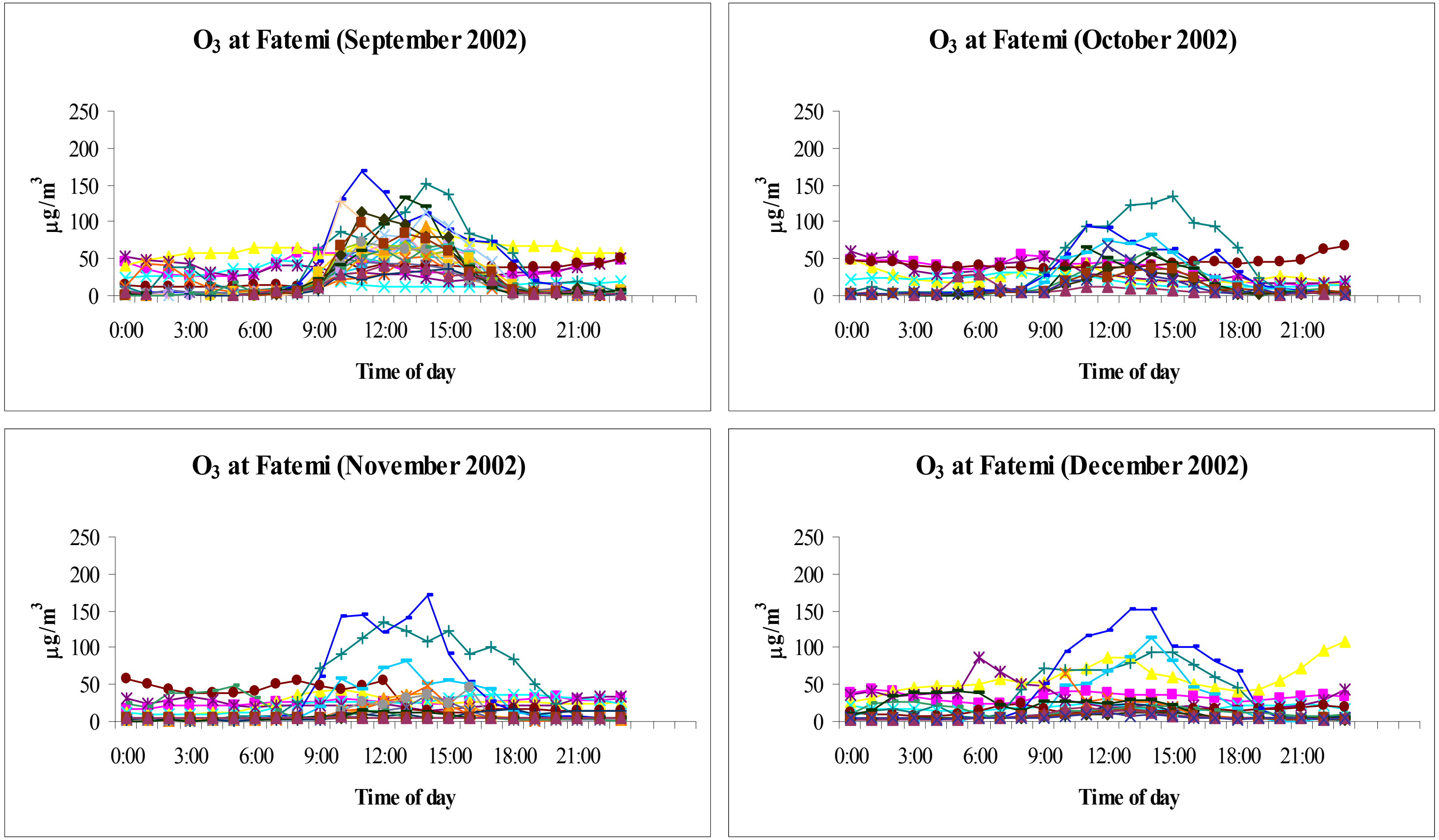

O$_3$ at Fatemi (April 2002)
250
200
150
100
50
0
µg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

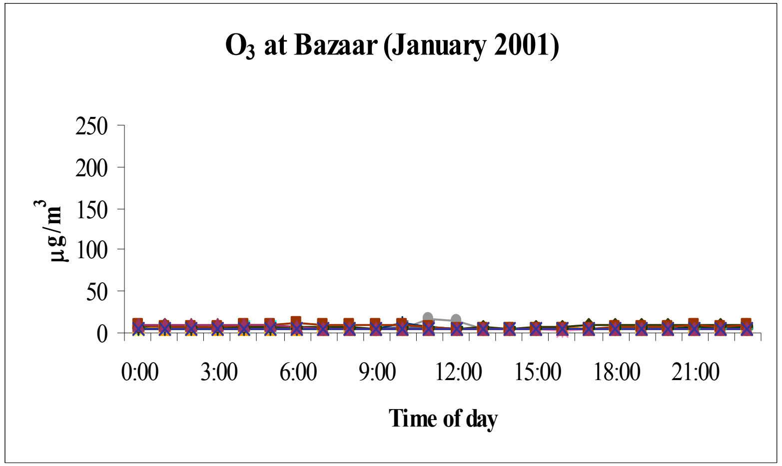

O3 at Fatemi (May 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

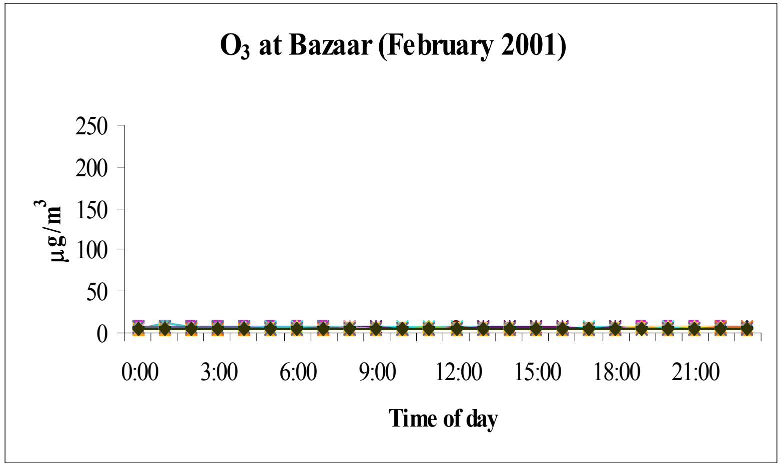

O3 at Fatemi (June 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

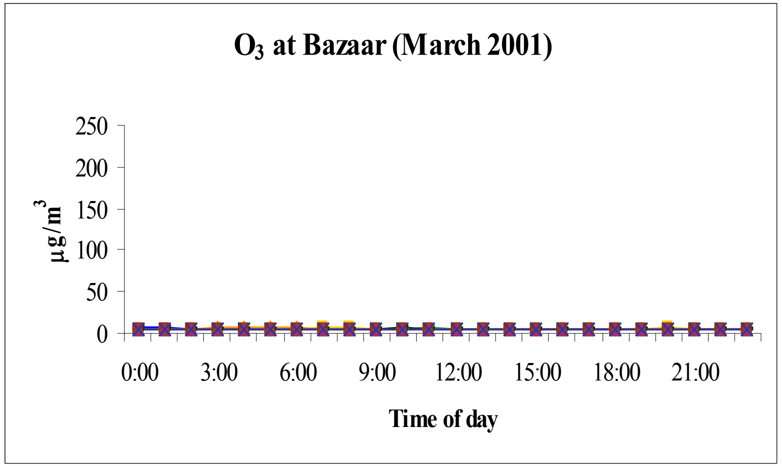

O3 at Fatemi (July 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

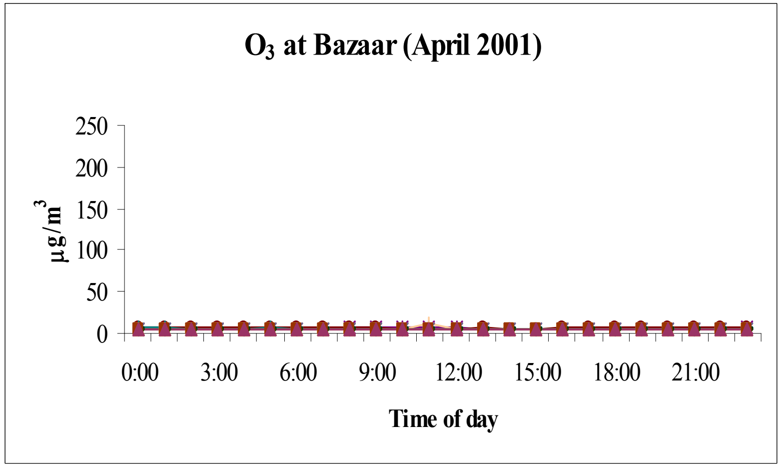

O3 at Fatemi (August 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

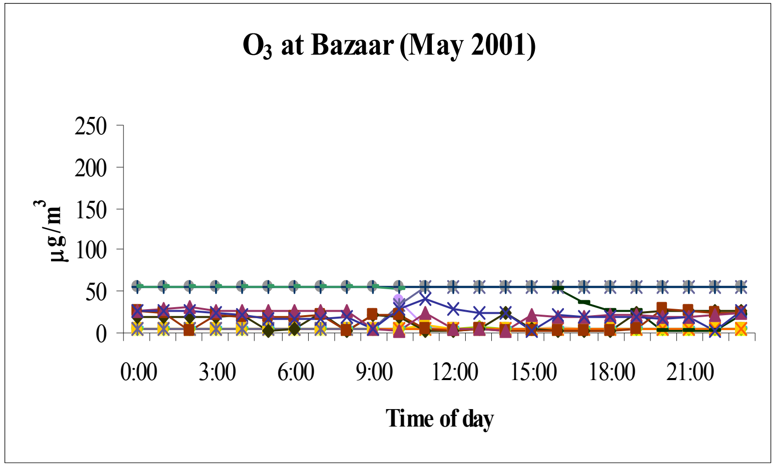

O3 at Fatemi (September 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
O3 at Fatemi (October 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
O3 at Fatemi (November 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
O3 at Fatemi (December 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


O3 at Bazaar (January 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

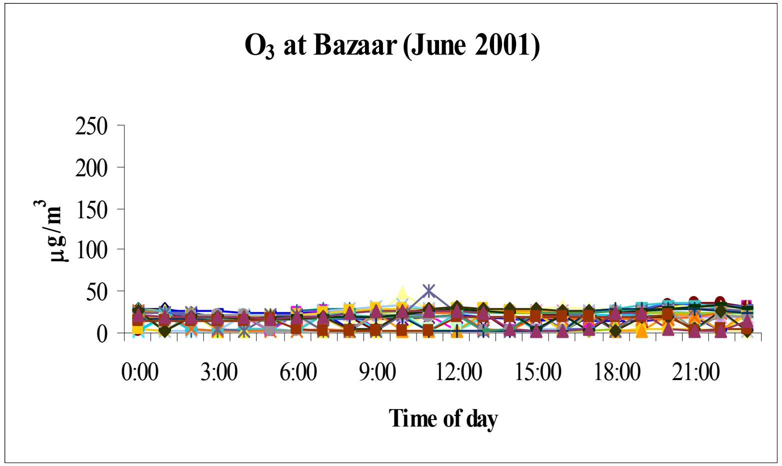

O3 at Bazaar (February 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


O3 at Bazaar (March 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

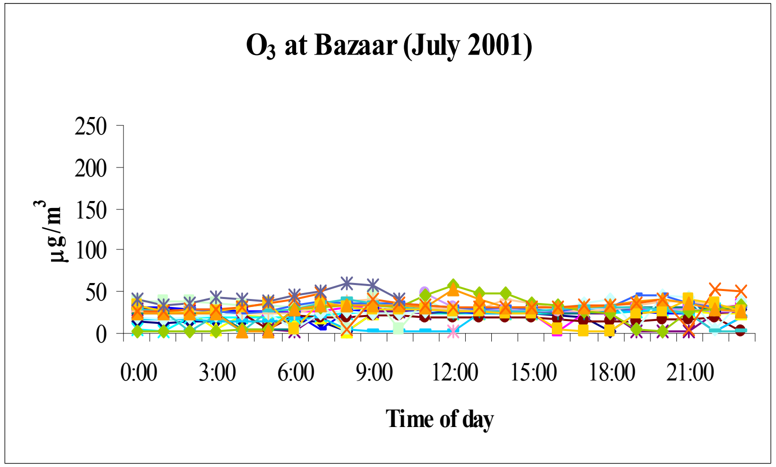

O3 at Bazaar (April 2001)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



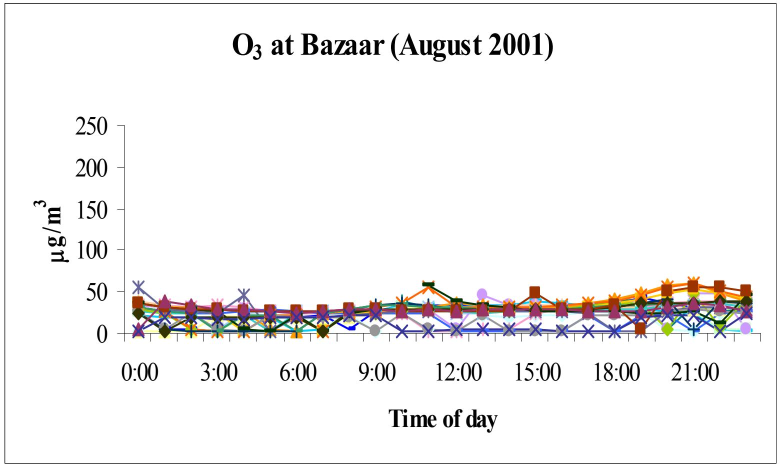
O_3 at Bazaar (May 2001)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



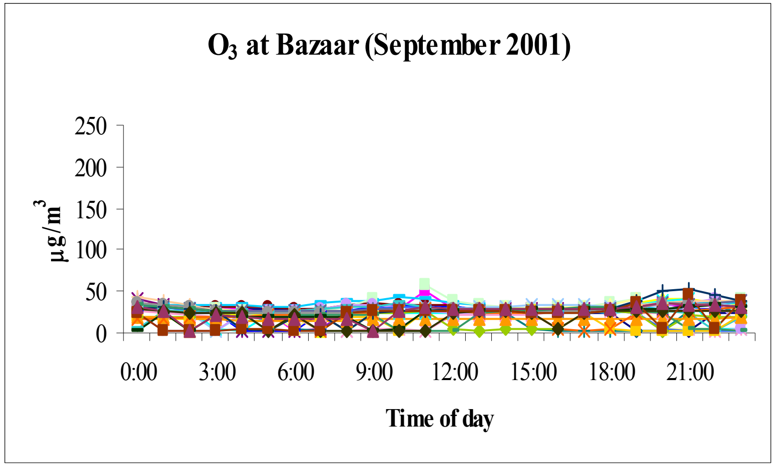
O_3 at Bazaar (June 2001)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

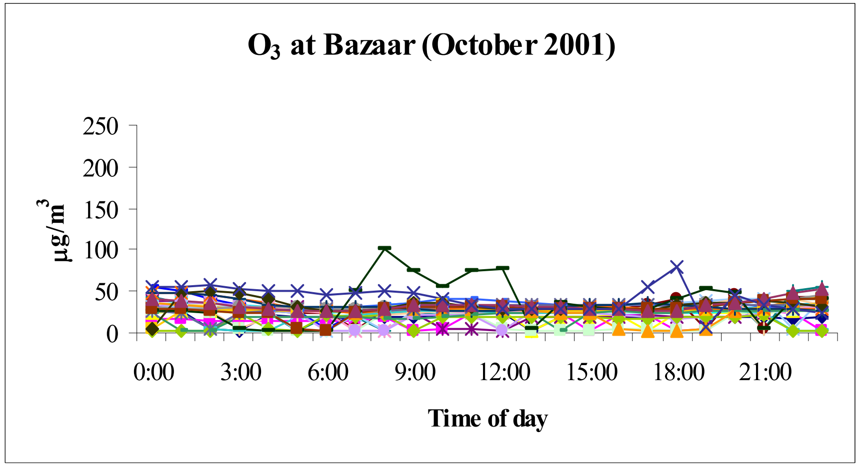


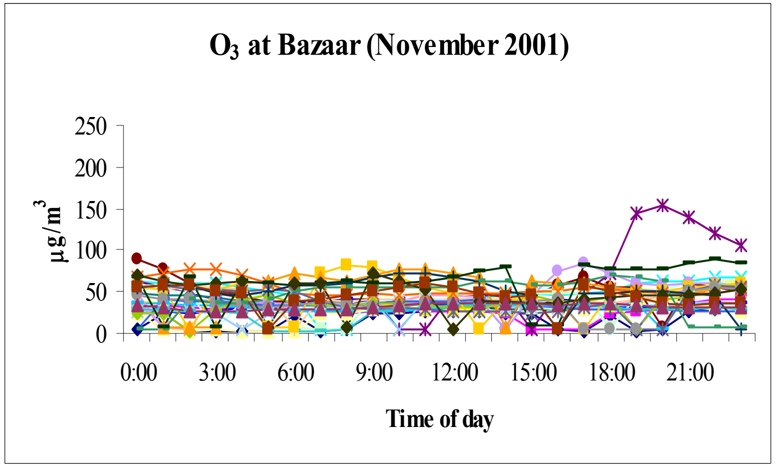
O_3 at Bazaar (July 2001)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

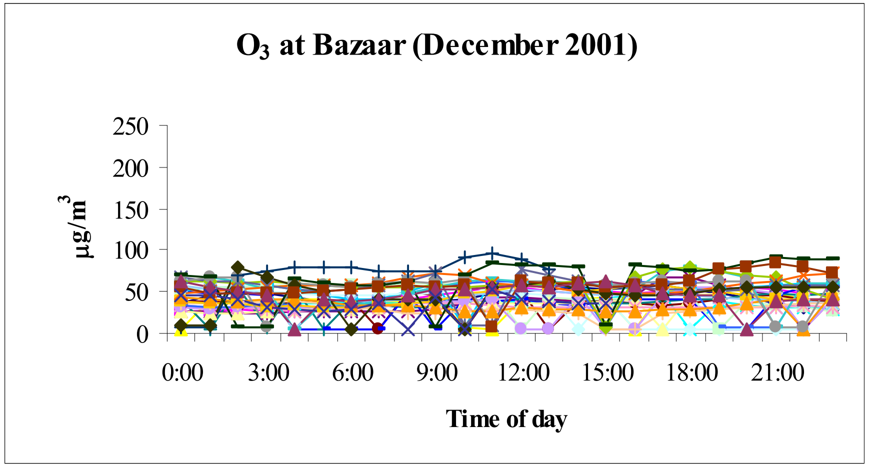


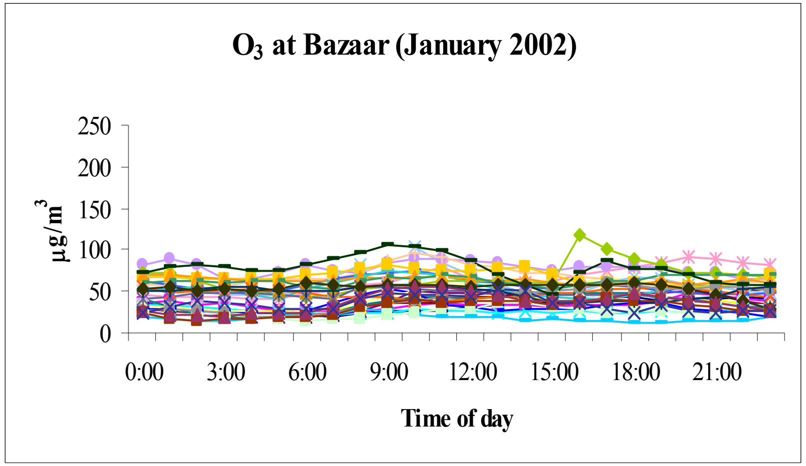
O_3 at Bazaar (August 2001)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

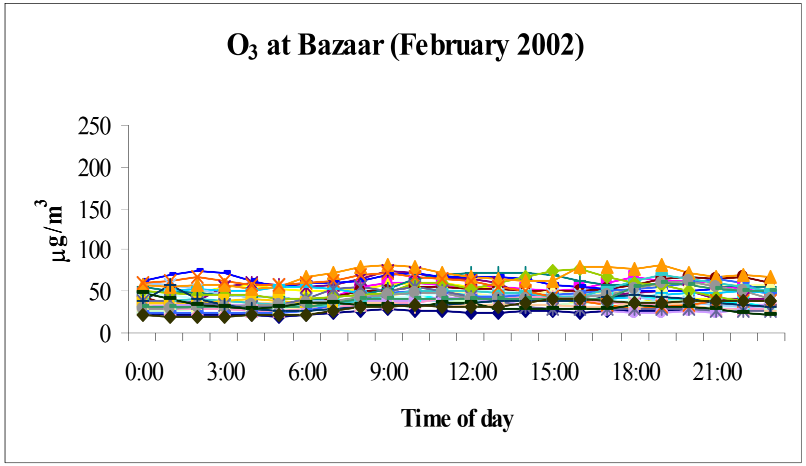

O$_3$ at Bazaar (September 2001)
250
200
150
100
50
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

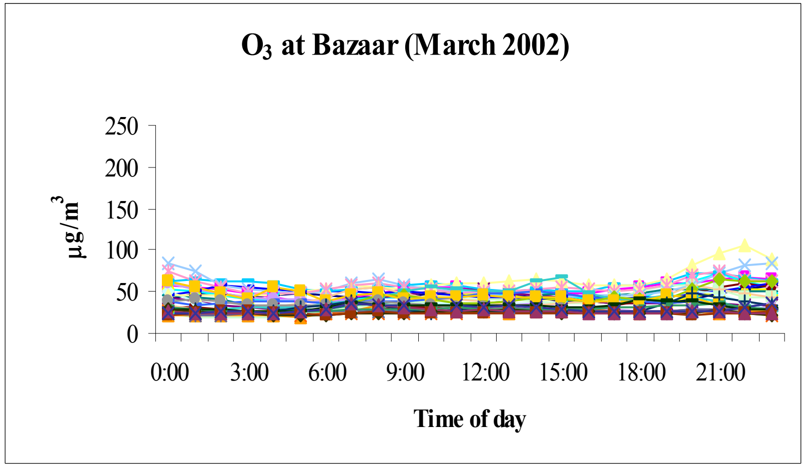

O$_3$ at Bazaar (October 2001)
250
200
150
100
50
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

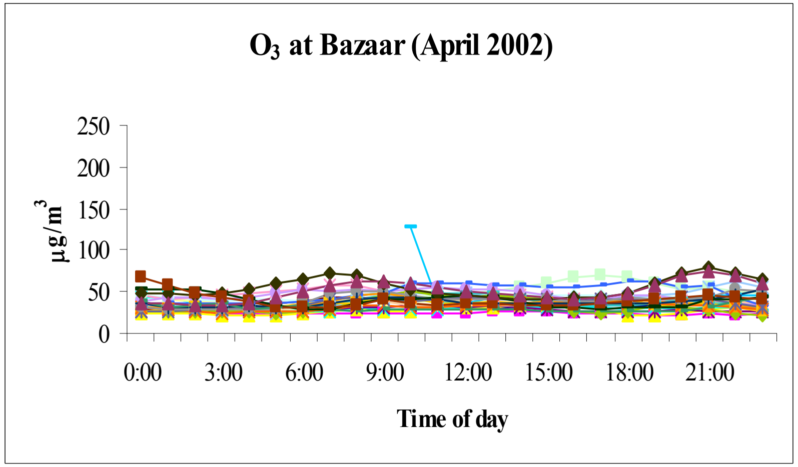

O$_3$ at Bazaar (November 2001)
250
200
150
100
50
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

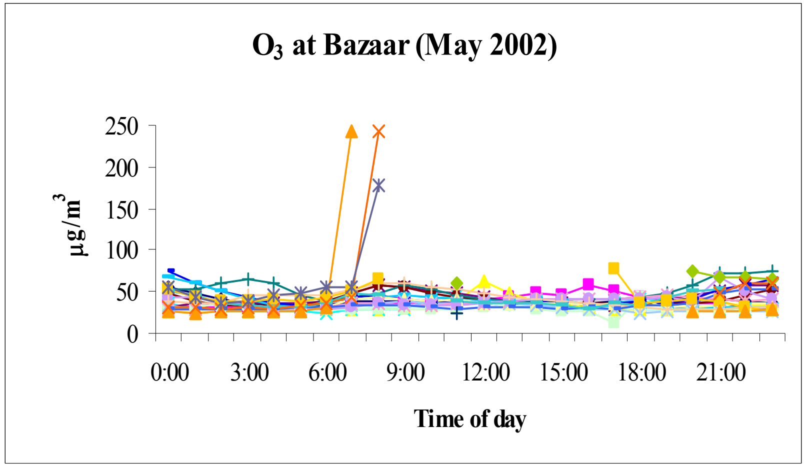

O$_3$ at Bazaar (December 2001)
250
200
150
100
50
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


O3 at Bazaar (January 2002)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

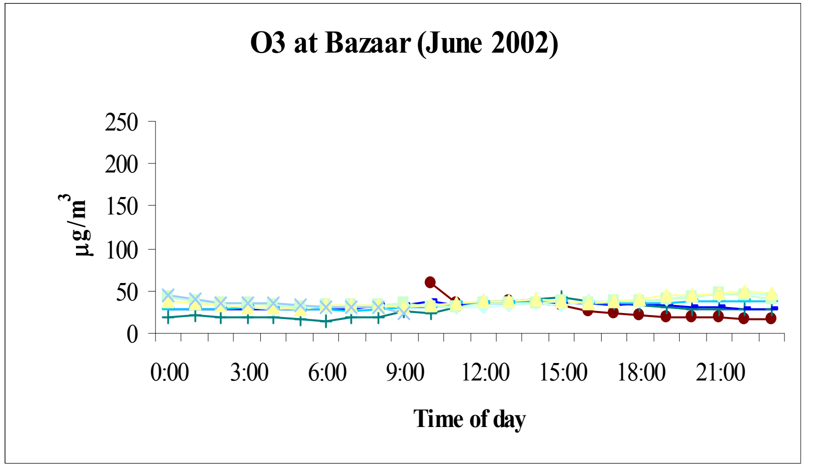

O3 at Bazaar (February 2002)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


O3 at Bazaar (March 2002)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

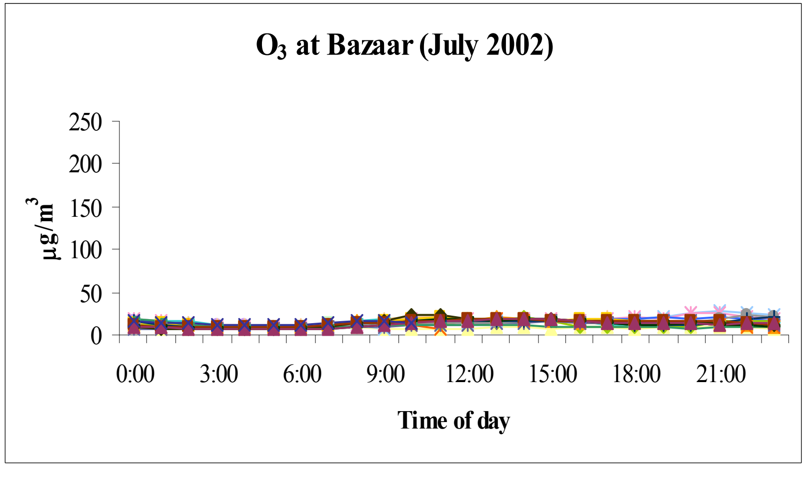

O3 at Bazaar (April 2002)
250
200
150
100
50
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



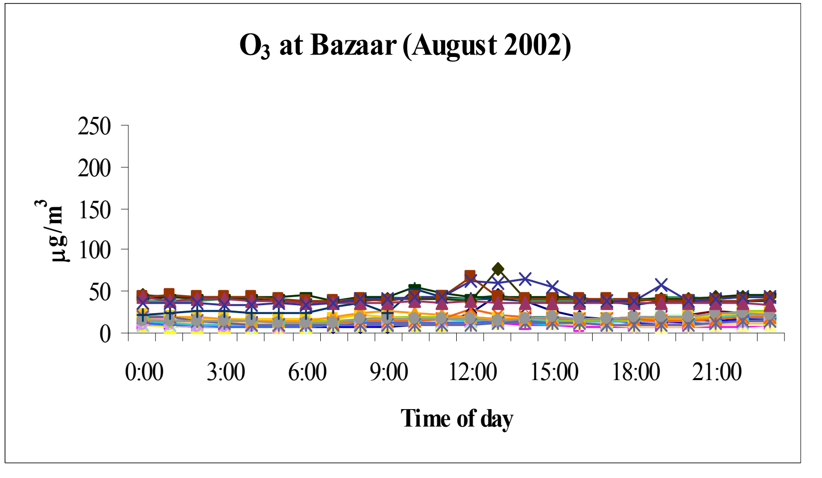
O_3 at Bazaar (May 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



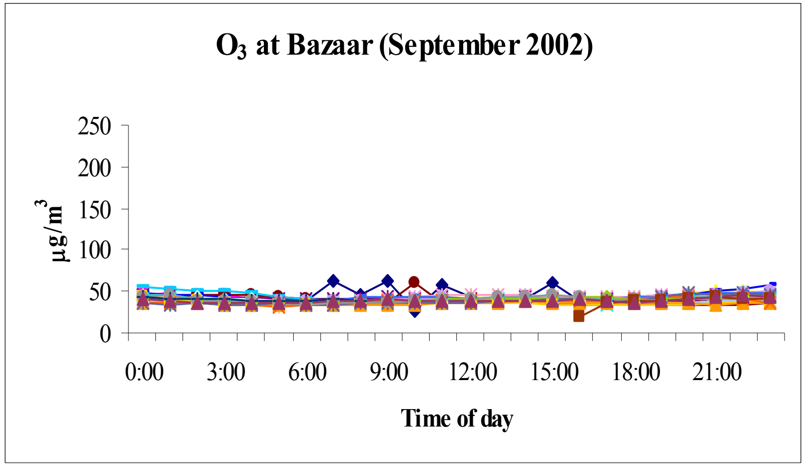
O3 at Bazaar (June 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

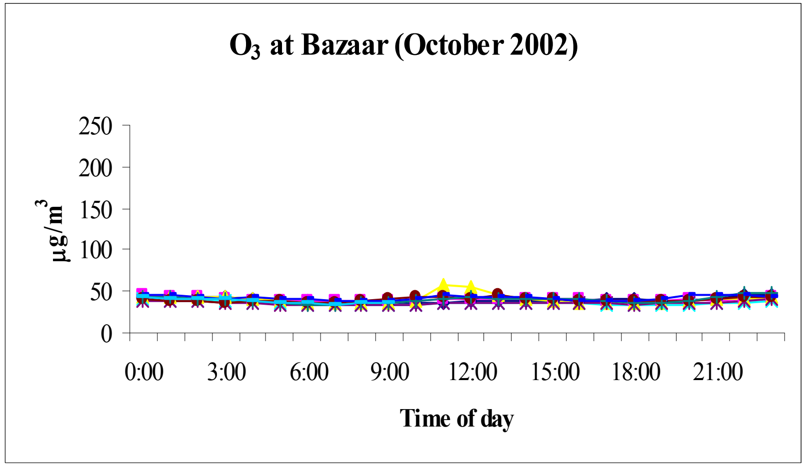


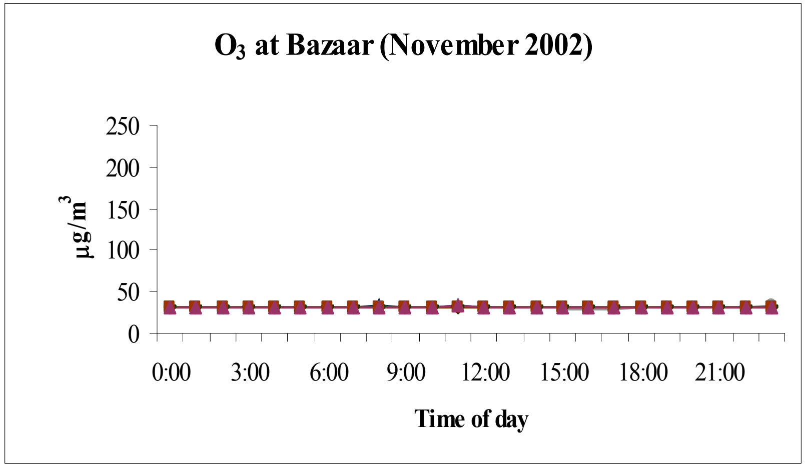
O_3 at Bazaar (July 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

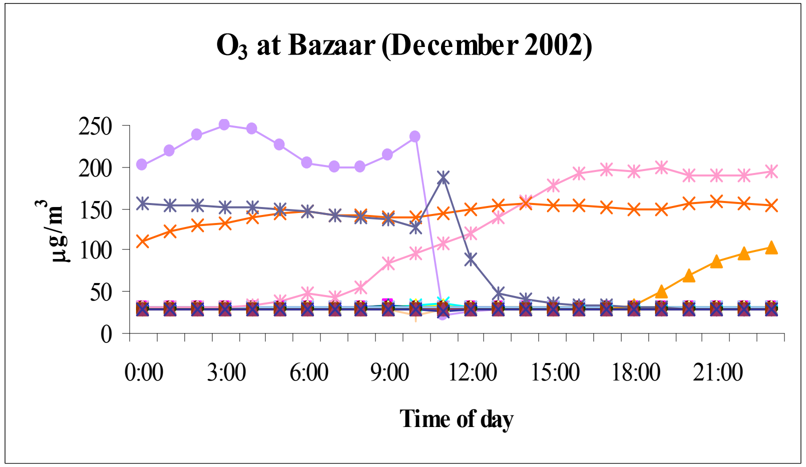


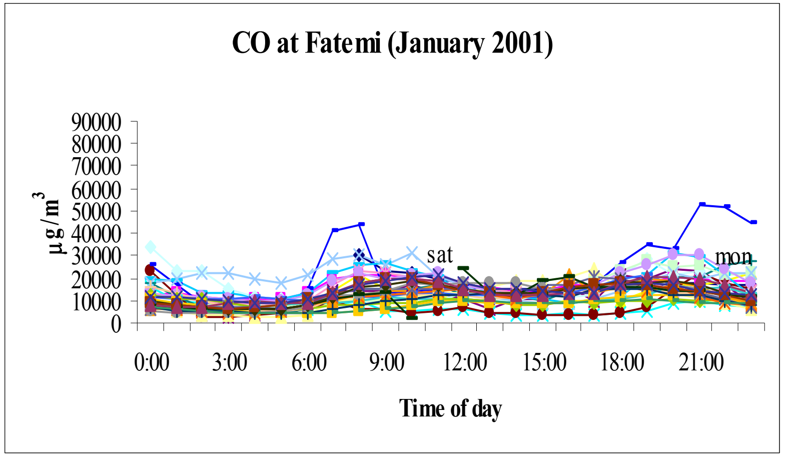
O_3 at Bazaar (August 2002)
250
200
150
100
50
0
µg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

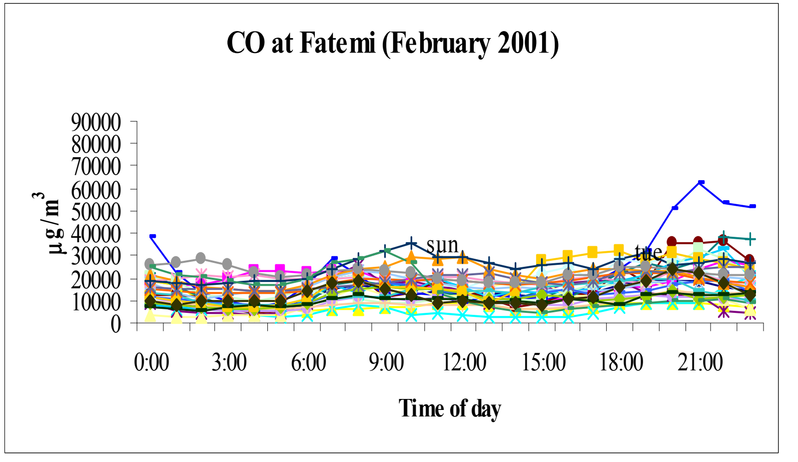

O$_3$ at Bazaar (September 2002)
250
200
150
100
50
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

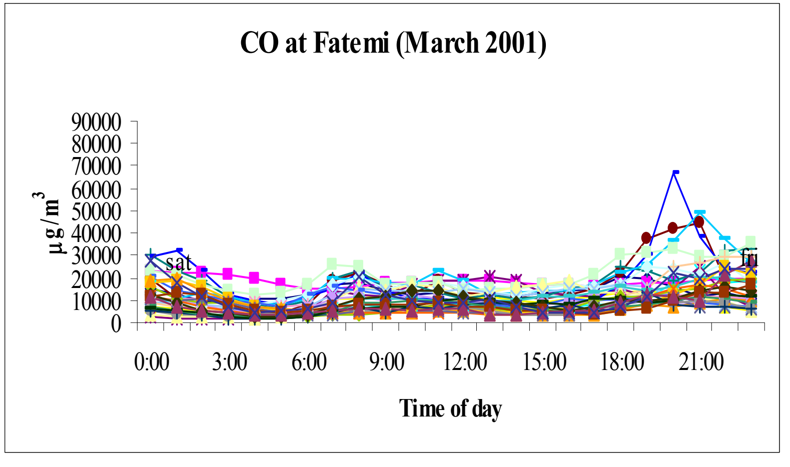

O$_3$ at Bazaar (October 2002)
250
200
150
100
50
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

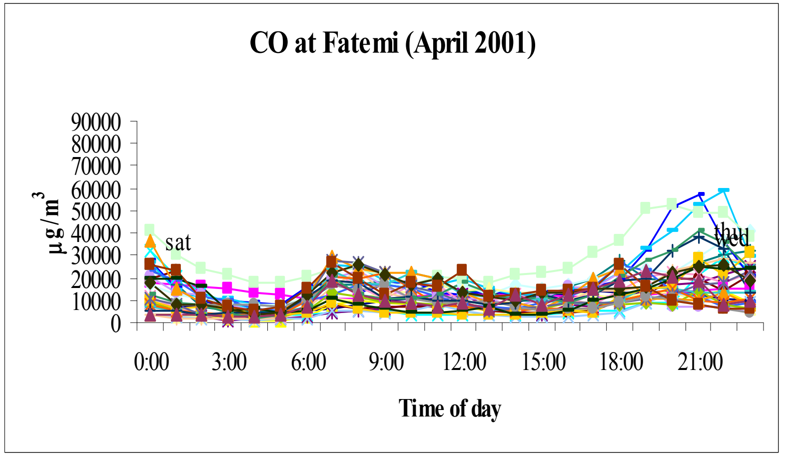

O$_3$ at Bazaar (November 2002)
250
200
150
100
50
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

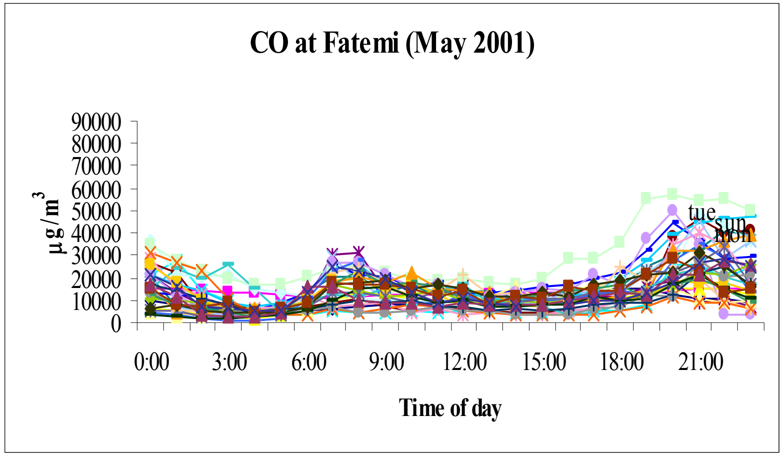

O$_3$ at Bazaar (December 2002)
250
200
150
100
50
0
μg/m^3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

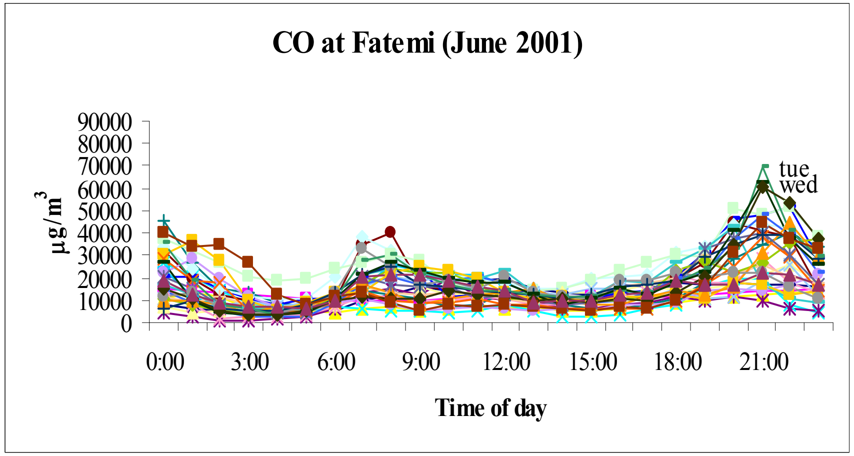

CO at Fatemi (January 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
sat
mon
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

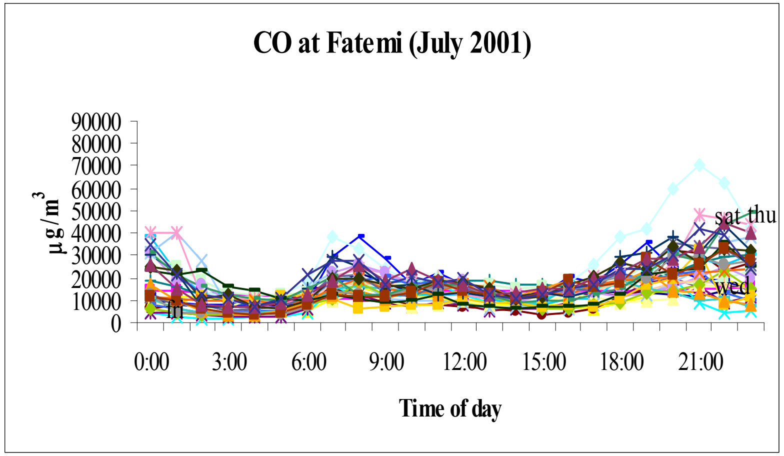

CO at Fatemi (February 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
sun
tue
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

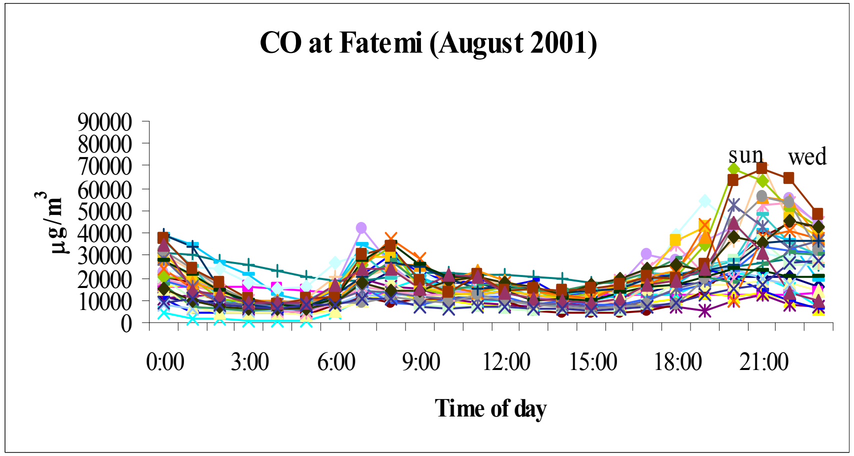

CO at Fatemi (March 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
sat
fri
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

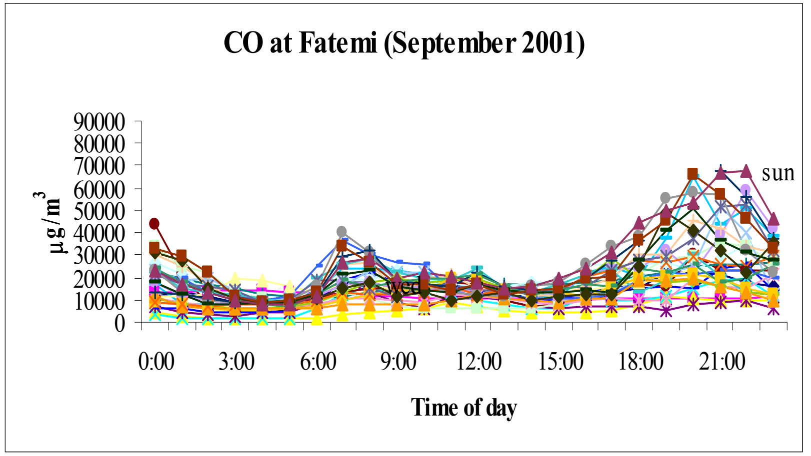

CO at Fatemi (April 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
sat
thu
wed
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


CO at Fatemi (May 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
tue
sun
mon

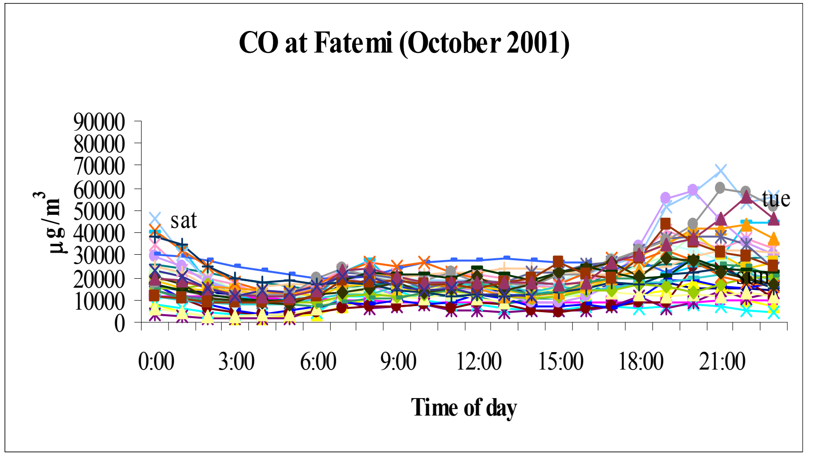

CO at Fatemi (June 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
tue
wed


CO at Fatemi (July 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
sat
thu
wed

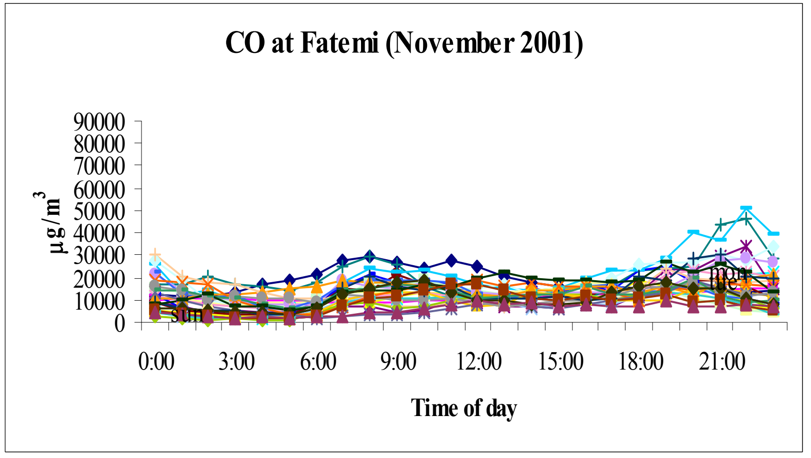

CO at Fatemi (August 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
sun
wed



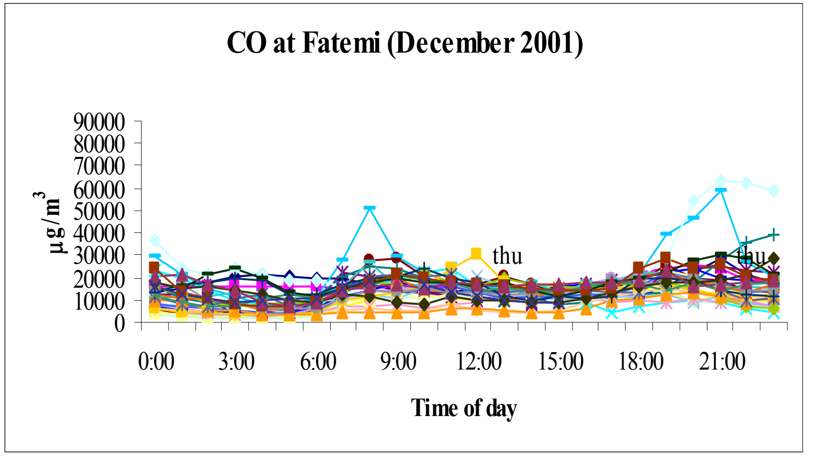
CO at Fatemi (September 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
sun
wed
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



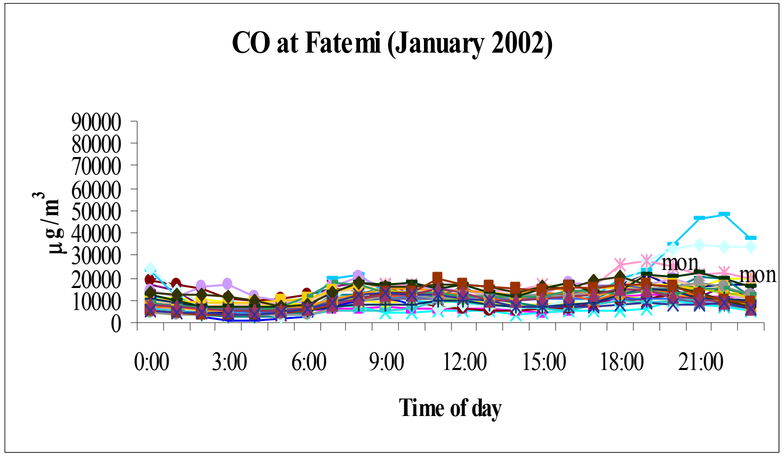
CO at Fatemi (October 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
sat
tue
sun
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



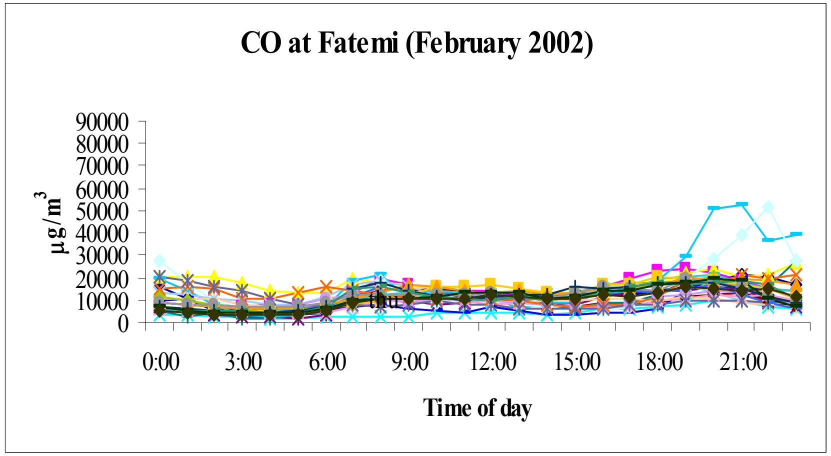
CO at Fatemi (November 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
sun
mon
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



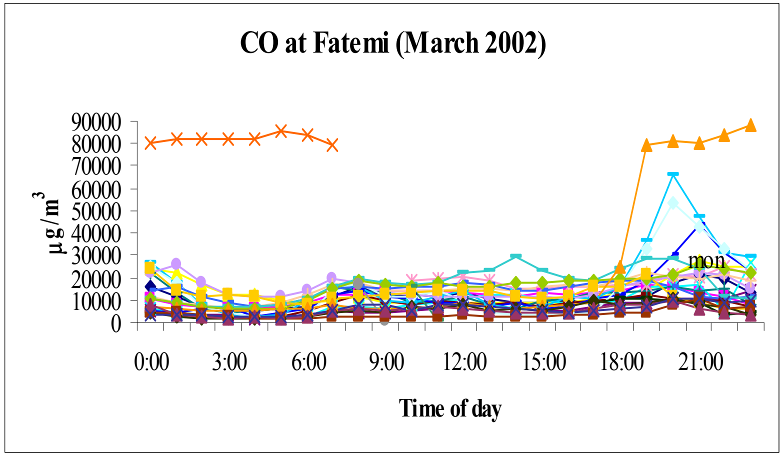
CO at Fatemi (December 2001)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
thu
thu
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



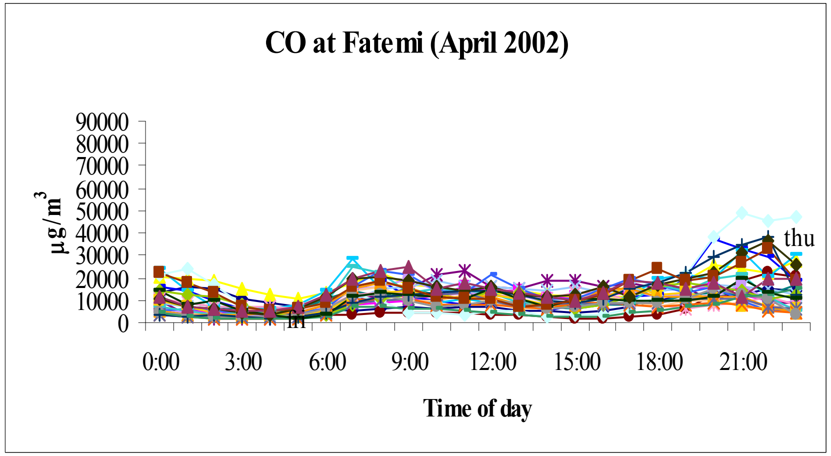
CO at Fatemi (January 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
µg/m3
mon
mon
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day



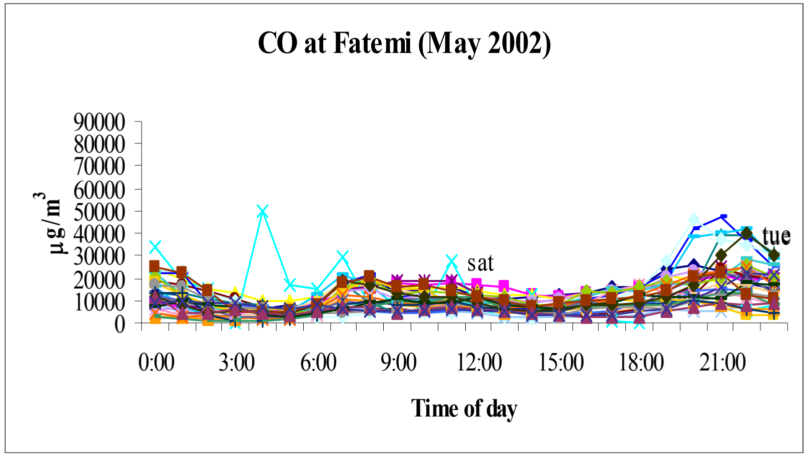
CO at Fatemi (February 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
µg/m3
thu
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

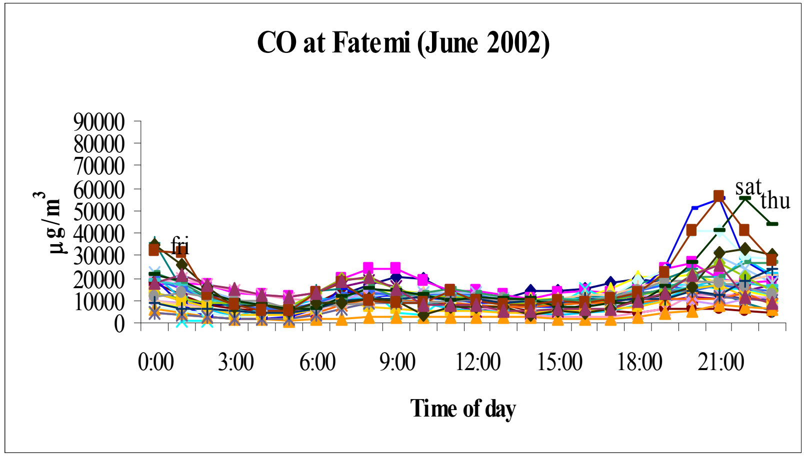


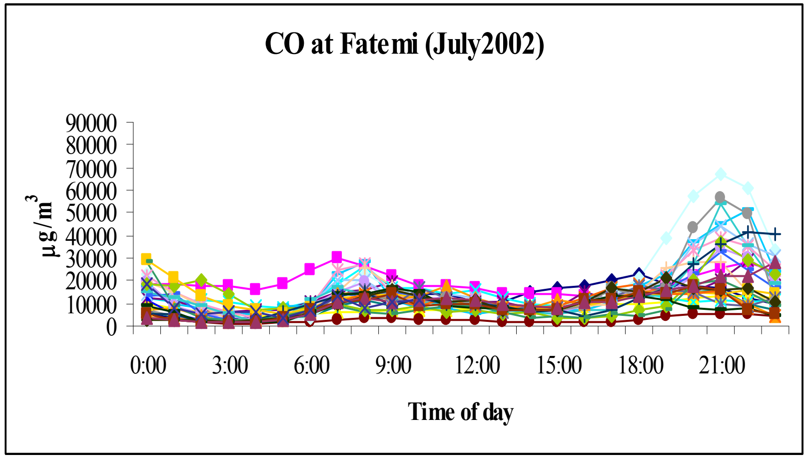
CO at Fatemi (March 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
µg/m3
mon
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

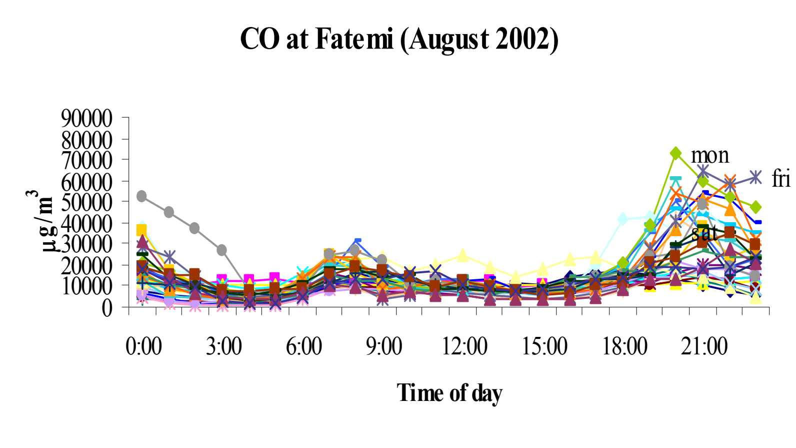


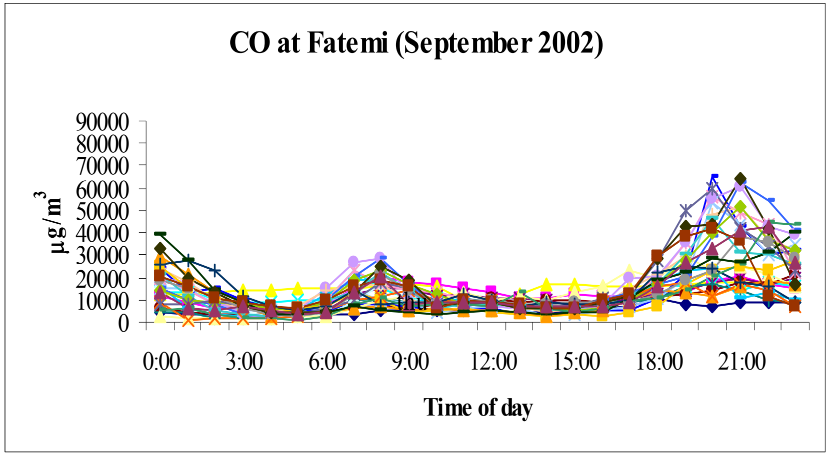
CO at Fatemi (April 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
µg/m3
thu
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

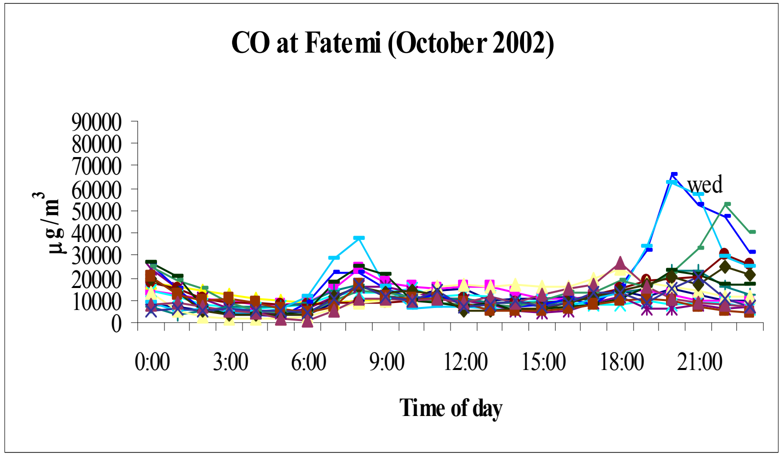

CO at Fatemi (May 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
sat
tue

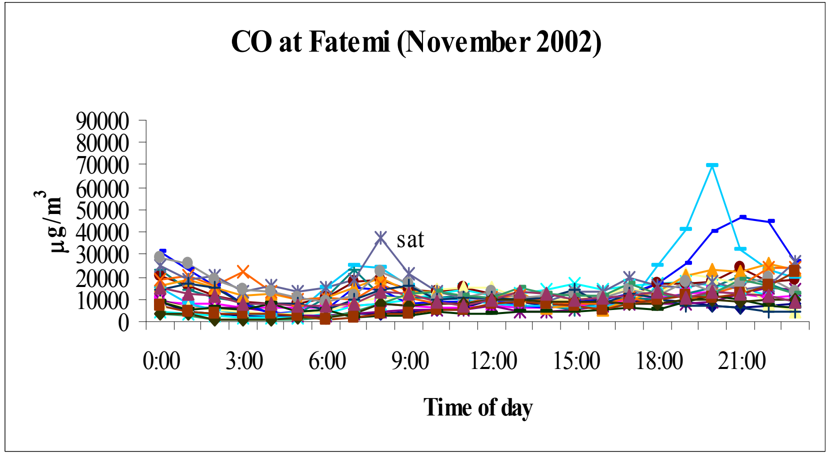

CO at Fatemi (June 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
fri
sat
thu

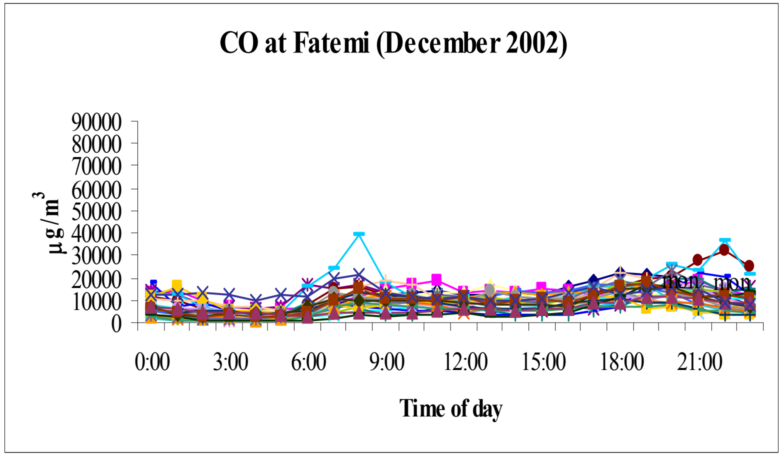

CO at Fatemi (July2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

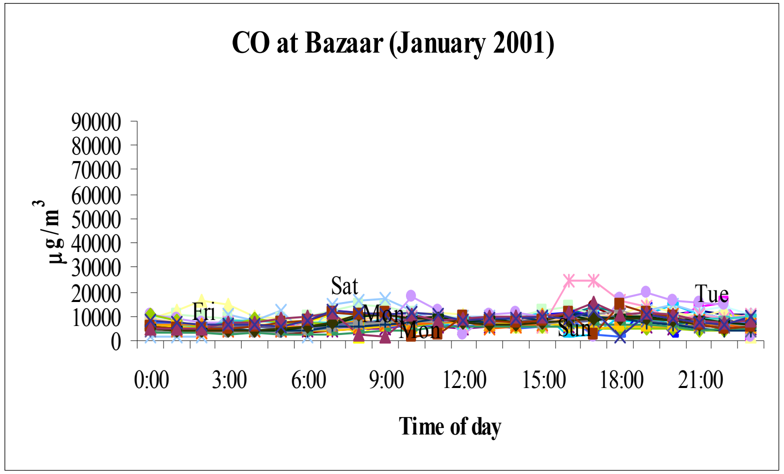

CO at Fatemi (August 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
mon
fri
sat

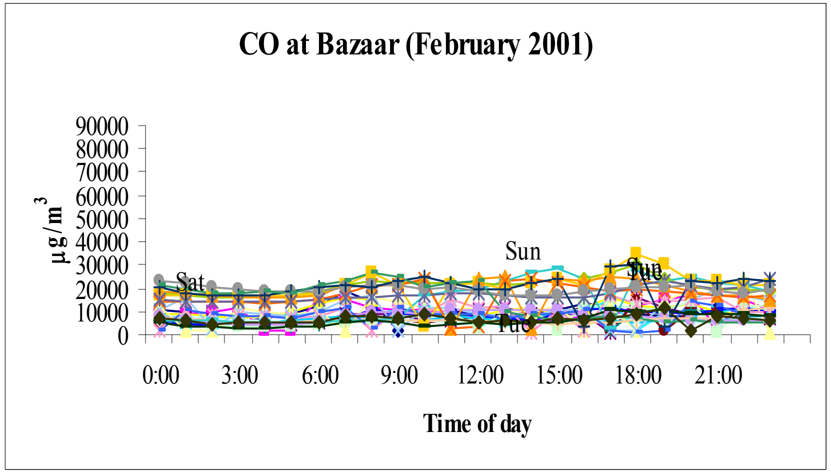

CO at Fatemi (September 2002)
µg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
thu
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

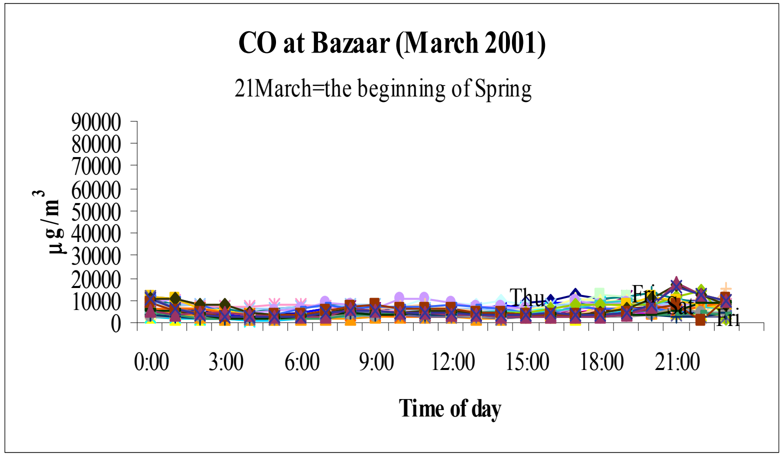

CO at Fatemi (October 2002)
µg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
wed
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

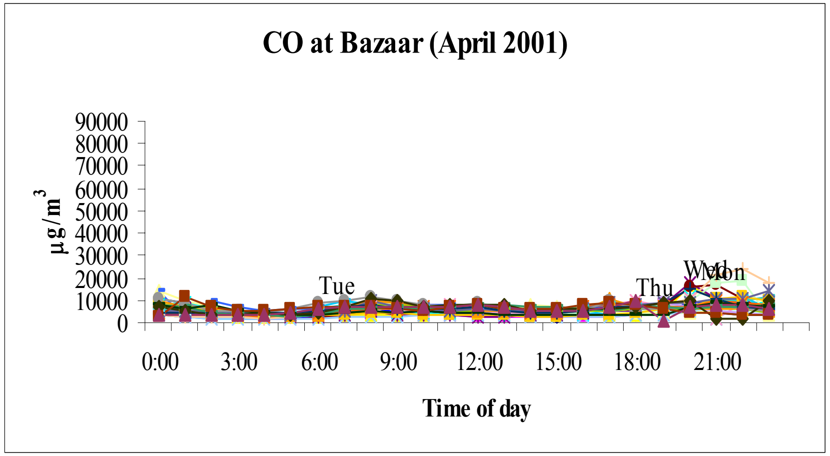

CO at Fatemi (November 2002)
µg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
sat
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

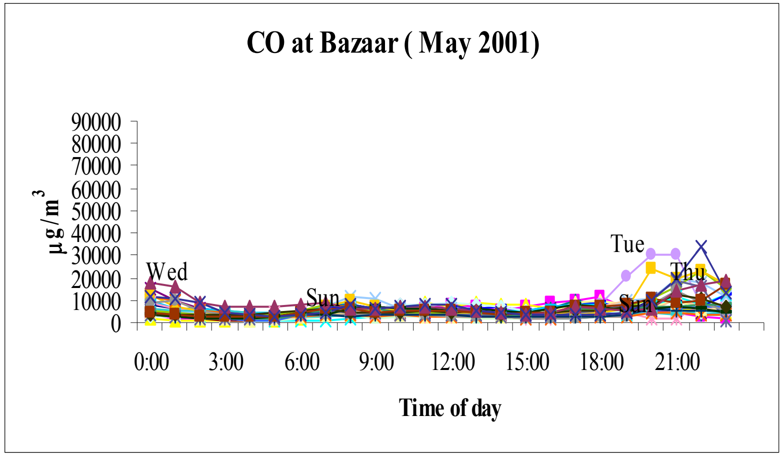

CO at Fatemi (December 2002)
µg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
mon
mon
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

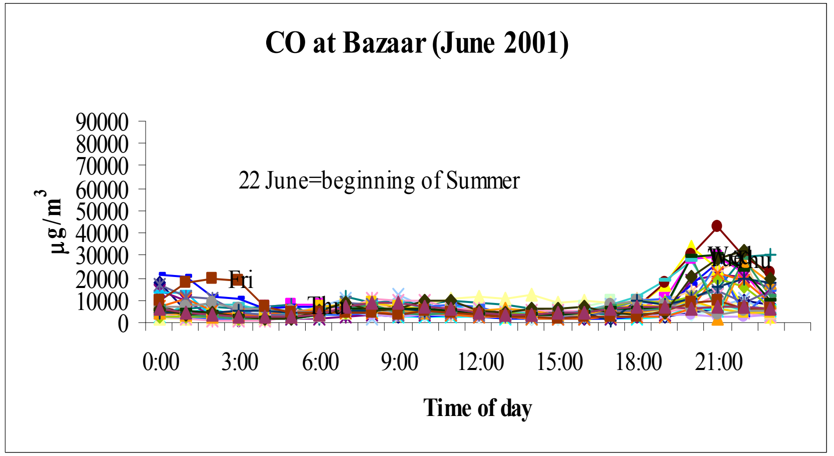

CO at Bazaar (January 2001)
μg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Fri
Sat
Mon
Mon
Sun
Tue

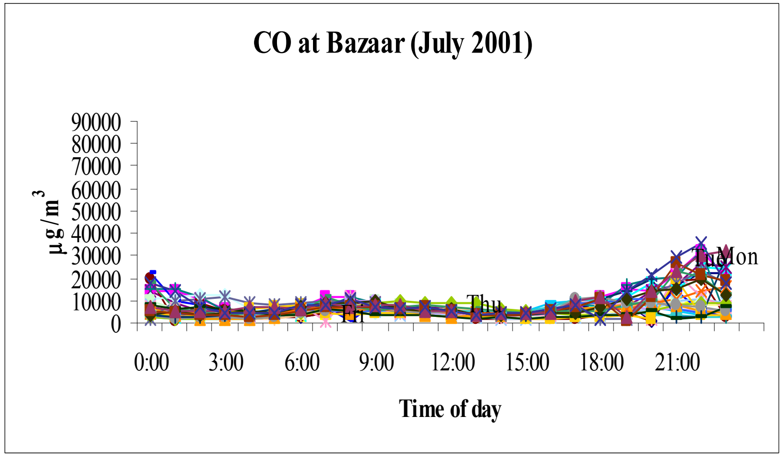

CO at Bazaar (February 2001)
μg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Sat
Sun
Tue

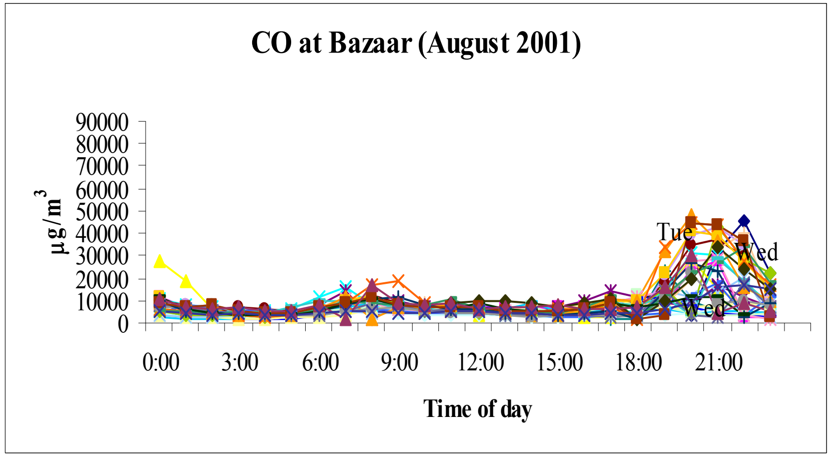

CO at Bazaar (March 2001)
21March=the beginning of Spring
μg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Thu
Fri
Sat
Fri

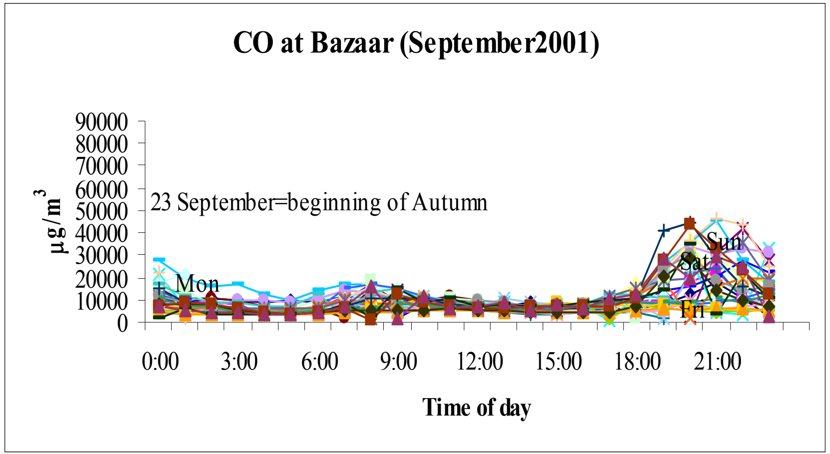

CO at Bazaar (April 2001)
μg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Tue
Thu
Mon

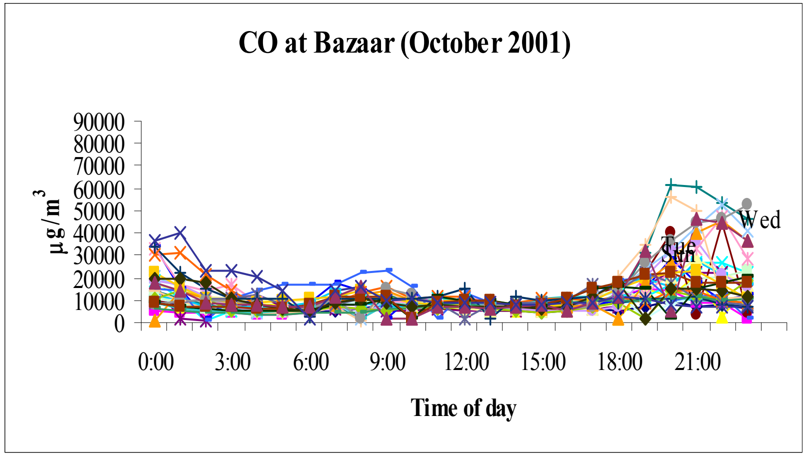

CO at Bazaar (May 2001)
μg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Wed
Sun
Tue
Thu
Sun
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

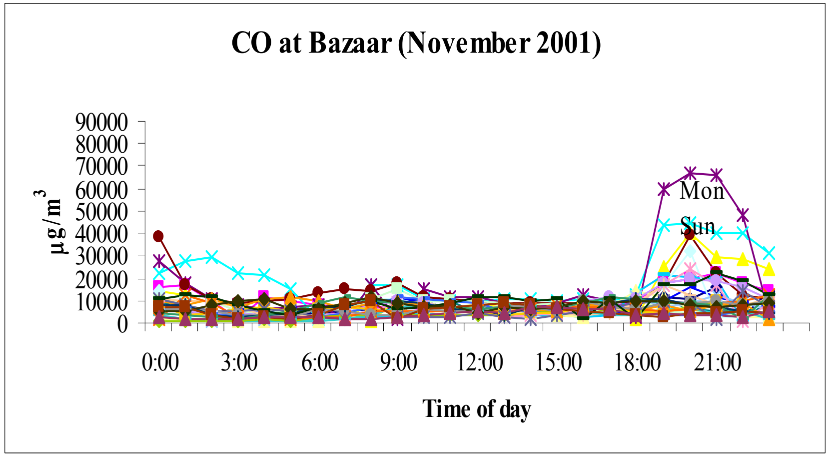

CO at Bazaar (June 2001)
22 June=beginning of Summer
μg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Fri
Thu
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

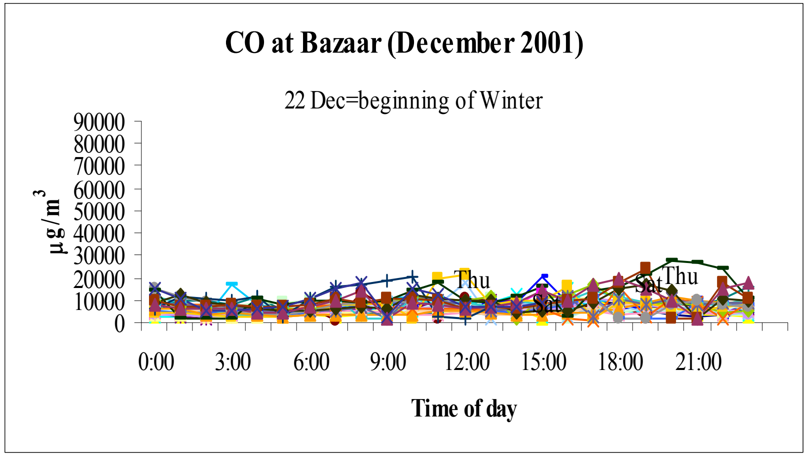

CO at Bazaar (July 2001)
μg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Fri
Thu
Mon
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

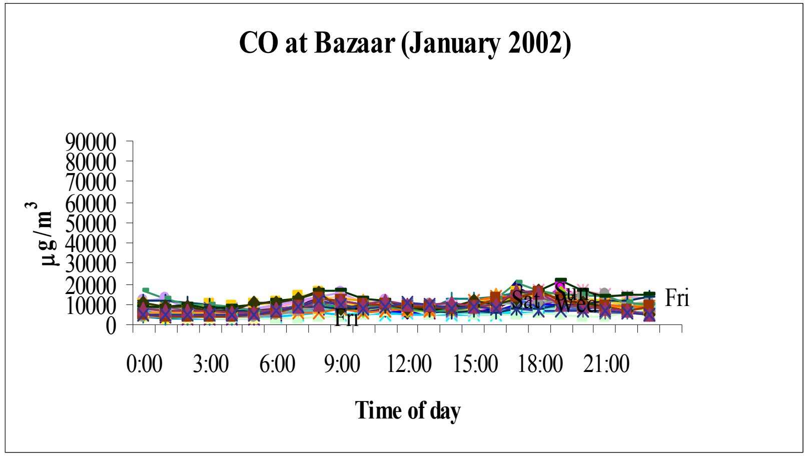

CO at Bazaar (August 2001)
μg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Tue
Wed
Wed
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day

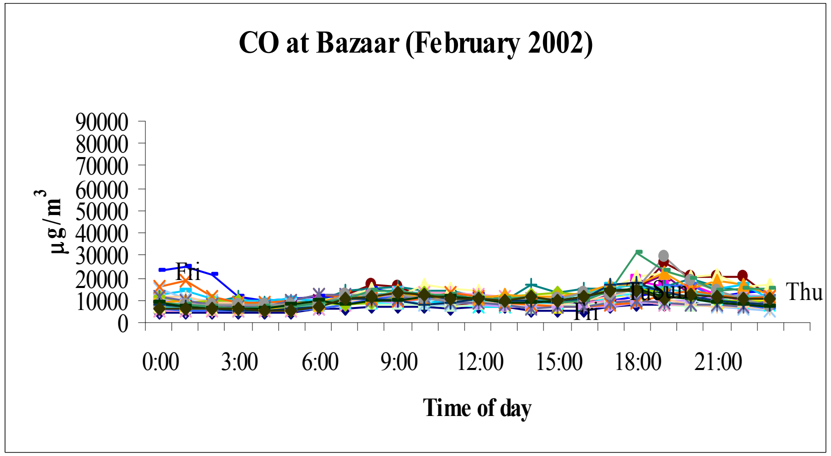

CO at Bazaar (September2001)
23 September=beginning of Autumn
Mon
Sun
Sat
Fri
µg/m3
Time of day

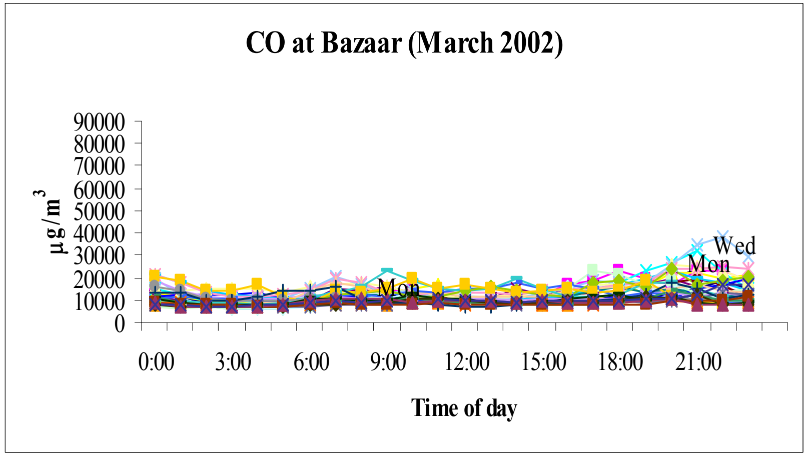

CO at Bazaar (October 2001)
Wed
µg/m3
Time of day

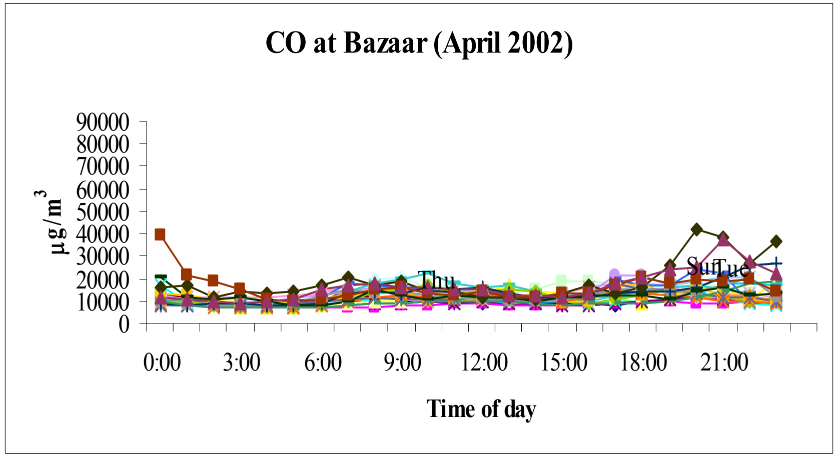

CO at Bazaar (November 2001)
Mon
Sun
µg/m3
Time of day

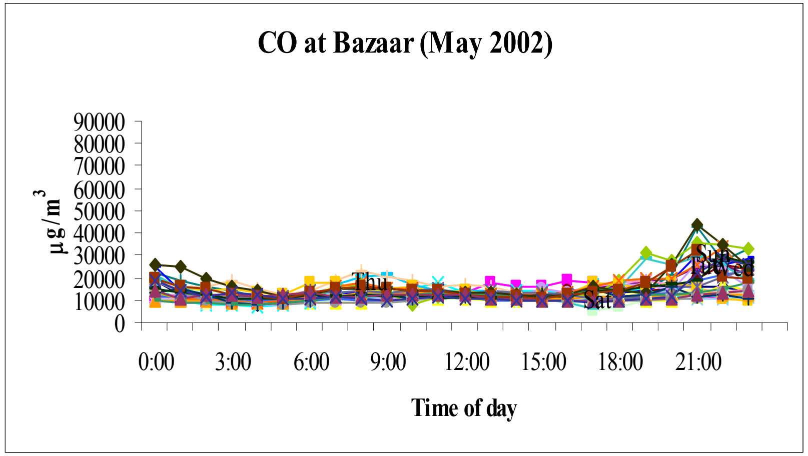

CO at Bazaar (December 2001)
22 Dec=beginning of Winter
Thu
Sat
Thu
µg/m3
Time of day


CO at Bazaar (January 2002)
µg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Fri
Sat
Wed
Fri

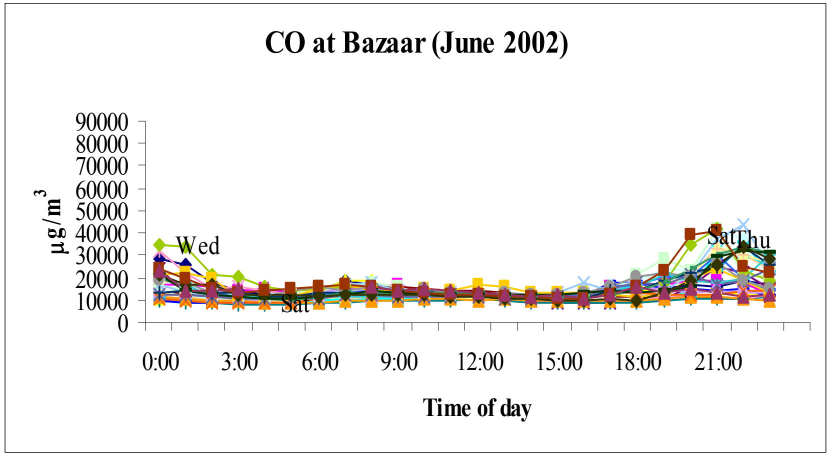

CO at Bazaar (February 2002)
µg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Fri
Thu


CO at Bazaar (March 2002)
µg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Wed
Mon
Mon

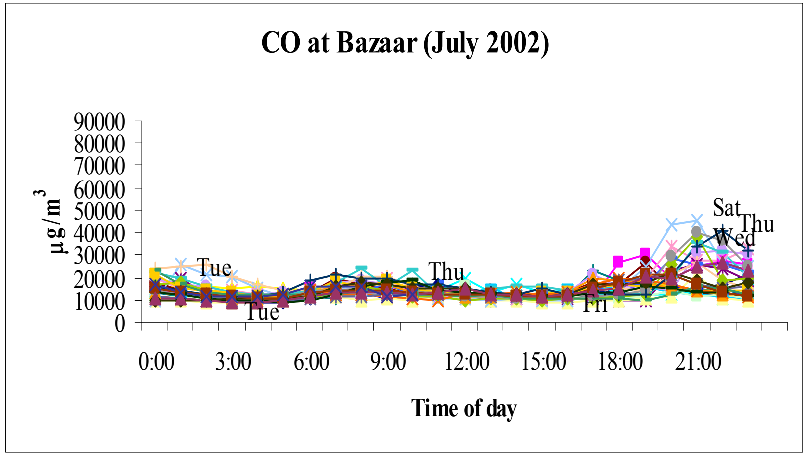

CO at Bazaar (April 2002)
µg/m3
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Thu



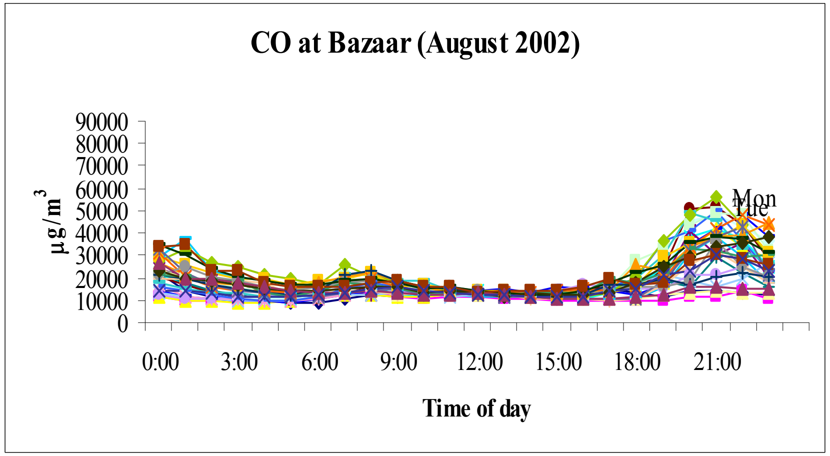
CO at Bazaar (May 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Thu
Sat
Sun
Tue
Wed



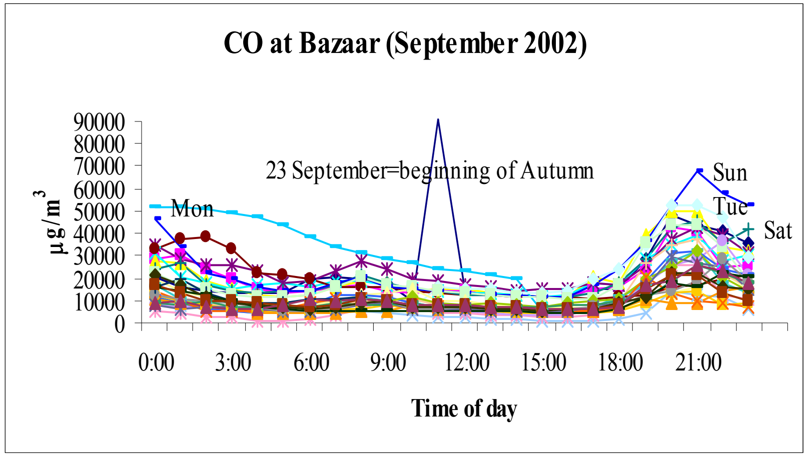
CO at Bazaar (June 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Wed
Sat
Sat
Thu

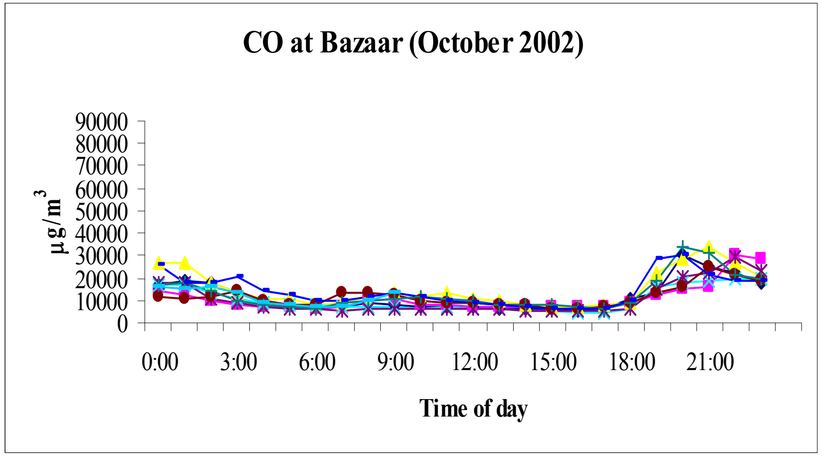


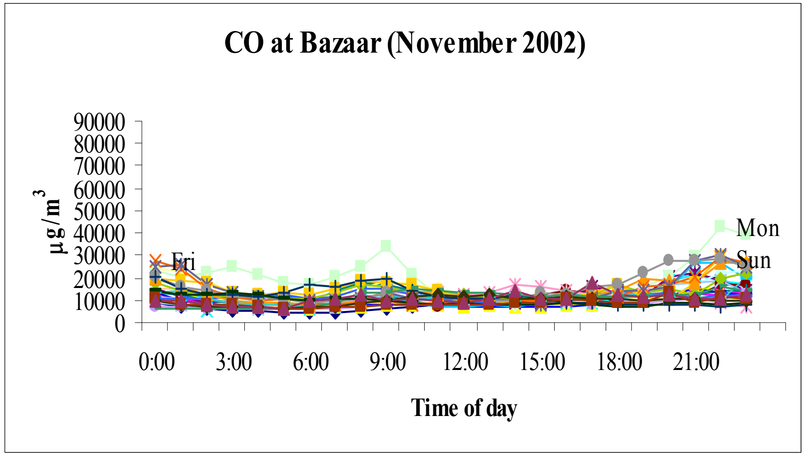
CO at Bazaar (July 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Tue
Tue
Thu
Fri
Sat
Thu
Wed

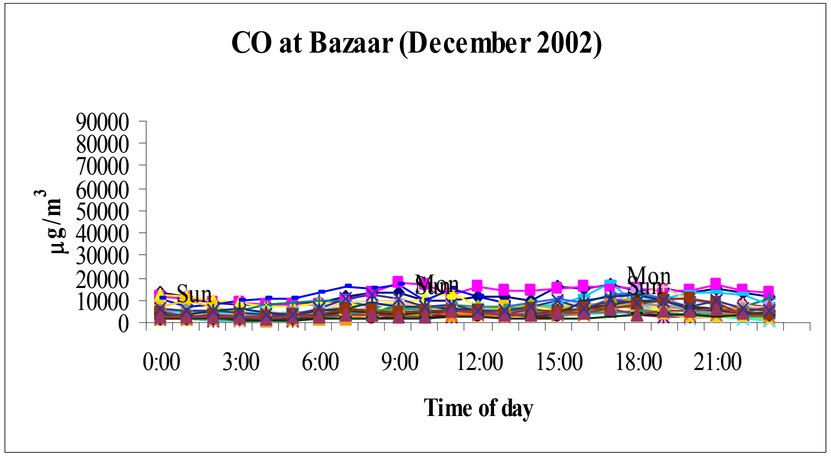


CO at Bazaar (August 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day
Mon
Tue


CO at Bazaar (September 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
23 September=beginning of Autumn
Mon
Sun
Tue
Sat
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


CO at Bazaar (October 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


CO at Bazaar (November 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
Fri
Mon
Sun
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day


CO at Bazaar (December 2002)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
μg/m3
Sun
Mon
Mon
Sun
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
Time of day