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Executive Summary

A number of studies in developed countries have identified the effects of particulate matter on health as the most important impact of air pollution. The size of the particles is important and recent studies have identified fine particle fractions called $PM_{2.5}$ (with a mean aerodynamic diameter of or smaller than 2.5 mm) as being especially harmful because they penetrate deeply and persist in the lungs and may reach the alveolar region.

There are fewer studies in developing countries than in developed countries, and more information is needed especially to assess the impact of the much higher concentrations of PM_{10} (with a mean aerodynamic diameter of or smaller than 10 mm) and $PM_{2.5}$ found in the large cities of developing countries.

Numerous studies suggest that PM_{10} and $PM_{2.5}$ contribute to excess mortality and hospitalizations for cardiac and respiratory tract disease. As $PM_{2.5}$ can penetrate into the alveoli of lungs these particles may cause serious damage to developing lungs of children. As most lung alveoli are formed postnatally, changes in the lung continue through adolescence and the developing lungs of children are more vulnerable to the adverse effects of air pollution than adult lungs. Children have increased exposure to particles than adults and are more susceptible because of higher ventilation rates, higher relative concentrations of particles into smaller lung volumes and higher levels of physical activity. In addition adverse impacts in childhood can continue throughout their adult lives.

To address the need for information on the effects of air pollutants on health in South Asia at the high concentrations commonly found in large cities in South Asia, this assessment of impact of PM_{10} and $PM_{2.5}$ on the health of school children of Dhaka, Bangladesh was conducted. This was a joint initiative by the United Nations Environment Programme RRCAP, Stockholm Environment Institute, Department of Environment and Department of Occupational & Environmental Health, National Institute of Preventive and Social Medicine (NIPSOM) of Bangladesh. This study was conducted under the Male Declaration sub-activity 4.1.2.

The aim of the study was to determine whether there is an association between daily mean PM_{10} and $PM_{2.5}$ concentrations and respiratory health and lung function in asthmatic and non-asthmatic children in Dhaka.

A baseline survey of 1618 school children was conducted to identify students with clinical evidence of asthma and a healthy control group. A total of 180 school children was identified after use of excluding factors such as a smoker in the home. This total consisted of 120 children with clinical evidence of asthma and 60 non-asthmatic control children. On a daily basis under the supervision of teachers and technicians, peak expiratory flow rate (PEFR), a measure of lung function, was measured every morning and afternoon and a diary of respiratory symptoms was maintained.

Daily measurements of PM_{10} and $PM_{2.5}$ concentrations were recorded from a monitoring site located within one kilometer of the schools in central Dhaka. Temperature, humidity and other data were also recorded. The data were tested for statistical associations using chi-square, t-tests, analysis of variance, correlation analyses, curvilinear regression and multiple regression and repeated measures analysis.

Ambient concentrations of PM_{10} and $PM_{2.5}$ at the monitoring station showed daily variability but some very high concentrations were recorded. The daily mean concentrations of PM_{10} varied from 38 to 385 $\mu g/m^3$ with a mean of 119 $\mu g/m^3$. It exceeded the Bangladesh daily PM_{10} standard of 150 $\mu g/m^3$ on 10 of the 42 days of health data collection. The daily mean concentrations of $PM_{2.5}$ varied from 18 to 233 $\mu g/m^3$ with a mean of 67 $\mu g/m^3$. It exceeded the Bangladesh daily $PM_{2.5}$ standard of 65 $\mu g/m^3$ on 13 of the 42 days of health data collection.

Although 16.5% of the 1618 children completing the questionnaire reported having asthma, 25.8% were diagnosed by the study physicians as having clinical symptoms of asthma. This figure is much higher than most international studies where the asthma rate is usually about 10% For example it is 7.7% in the USA.

The results of the study showed that there was a relationship between PEFR a measure of lung function, in both asthmatic and non-asthmatic children and PM_{10} and $PM_{2.5}$ concentrations. PEFR decreased by about 40% in both asthmatic and non-asthmatic children when PM_{10} increased from its lowest level of 38 $\mu g/m^3$ to its highest daily mean of 385 $\mu g/m^3$. Asthmatic children had about a 10% lower PEFR than non-asthmatic children but the difference was maintained across the range of PM_{10} concentrations.

PEFR decreased by about 30% in both asthmatic and non-asthmatic children when $PM_{2.5}$ increased from its lowest level of 18 $\mu g/m^3$ to its highest daily mean of 233 $\mu g/m^3$. The difference in PEFR between asthmatic and non-asthmatic children was also maintained across the range of $PM_{2.5}$ concentrations.

PEFR increased in both asthmatic and non-asthmatic children with increases in temperature and humidity. PEFR increased by about 25% when minimum temperatures increased from 15 to 27 ^{o}C, and by about 40% when average humidity increased from 60 to 90%.

Total annual expenditure for respiratory illnesses of asthmatic children (6918 Taka, about 100 USD) was twice the expenditure for respiratory illnesses of non-asthmatic children (3478 Taka). There are about 2.37 million children of school age in Dhaka, and this study suggest about 25.8% have clinical symptoms of asthma, about 0.61 million children. The additional annual expenditure on respiratory illnesses for about 0.61 million children with asthma is about USD 30 million.

Generally the results of this study are consistent with other studies. Many studies have demonstrated acute increases in asthma symptoms, medication use, pulmonary function decrements and hospital admissions for asthma soon after spikes of particulate matter in air. However, few have been conducted where particulate matter concentrations are at the highest levels found in many large Asian cities such as Dhaka, making this study especially important.

The decreased by about 40% in PEFR in both asthmatic and non-asthmatic children when PM_{10} increased from its lowest level of 38 $\mu g/m^3$ to its highest daily mean of 385 $\mu g/m^3$, and by 30% in both asthmatic and non-asthmatic children when $PM_{2.5}$ increased from its lowest level of 18 $\mu g/m^3$ to its highest daily mean of 233 $\mu g/m^3$ is a major and important finding.

Although data from Dhaka are not readily available, based on data from the USA, and assuming the same proportions apply to Dhaka, the 0.61 million children in Dhaka with asthma will have 12 million restricted activity days, 1.5 million school absence days, (2.48 days per child with asthma), and 51 school age children would die of asthma per year. Although quantitative data are not available from Dhaka, if ambient concentrations of PM_{10} and $PM_{2.5}$ could be reduced these impacts on respiratory health of children could be substantially reduced.

Chapter 1 Introduction

1.1 Background

Air is indispensable for the survival of most living organisms on the earth, including human beings. The ambient air quality has deteriorated both due to human activities, and natural sources. Among the air pollutants Particulate matter (PM) is a matter of concern. It consists of a mixture of particles that can be solid, liquid or both, are suspended in the air also called suspended particulate matters (SPM) and represent a complex mixture of organic and inorganic substances. The major PM components are sulfate, nitrates, ammonia, sodium chloride, carbon, mineral dust and water. These particles categorized according to their aerodynamic diameter.

- The coarse fraction is called PM_{10} (with an aerodynamic diameter smaller than 10µm), which may reach the upper part of the airways and the lungs.
- Smaller or fine particles are called $PM_{2.5}$ (with an aerodynamic diameter smaller than 2.5 µm); these are more dangerous because they penetrate more deeply into the lungs and may reach the alveolar region.

Fine particles (PM2.5) are emitted from combustion processes (especially diesel-powered engines, power generation, and wood burning) and from some industrial activities. Coarse particles (PM10) include windblown dust from dirt roads or soil and dust particles created by crushing and grinding operations. Toxicity of particles may vary with composition.1,2,3.

Particles may be classified as primary or secondary depending on their formation mechanism. Primary particles are directly emitted into the atmosphere through man-made (anthropogenic) and natural processes. Anthropogenic processes include combustion from car engines, solid-fuel combustion in households, industrial activities, erosion of the pavement by road traffic and abrasion of brakes and tyres, and work in caves and mines. In many developing countries the rapid growth of urban population, the development of industry, the intensification of traffic with limited access to clean fuel and lack of effective control programs have led to high level of air pollution.[1]The main sources of total anthropogenic emissions in Europe of primary PM_{10} are road traffic (10–25%), stationary combustion (40–55%) and industrial processes (15–30%).[4]

The European Environment Agency's Dobric report includes 3 major air pollution situation namely a. Winter type smog. b. Summer type smog. c. High annual concentration level of SO_2, SMP, benzo(a) pyrene and lead. According to the report 70% to 80% of surveyed cities exceeded the 1987 air quality guidelines of WHO during episode of winter type smog[5]. Several studies conducted in Europe; including the central European study on air pollution and respiratory health have indicated that the $PM_{2.5}$ constitutes, on average, about 70% of the PM_{10} mass and the seasonal variability of PM_{10} was entirely accounted for by the changes in $PM_{2.5}$ concentration.[6] The Dobric report further stated that short term maximum concentrations of CO, NO_2, and SPM may exceed air quality guideline by a factor of 2-4 depending on actual traffic and dispersion condition of the street and 9 to 18 million people are exposed to these higher concentration[5].

The particulate matter is one of the major air pollutant in developing countries, where levels frequently exceed current guidelines to protect health.[1,7,8,9,10,] Noticeable high levels of SO_2 were found in Chongquing (330 $\mu g/m^3$) and in Beijing 100 $\mu g/m^3$.[7-8] With respect to SPM, the most commonly reported indicator is the mass of total suspended particles (TSP). In most of the cities the TSP annual mean concentration exceeds 100 $\mu g/m^3$ with the level exceeding 300 $\mu g/m^3$ in several cities of China and India, and 200 $\mu g/m^3$ in the Kathmandu Valley in 1995.[1,11]

Recently, air pollution has received higher priority among environmental issues in Asia, as in other parts of the world. Exposure to air pollution has become important environmental threat to human health in many towns and cities[1]. Motor vehicles have been found to pollute the air through tailpipe exhaust emissions and fuel evaporation, contributing $PM_{2.5}$ and other air pollutants. Motor vehicles represent the principal source of air pollution in many communities, and concentrations of traffic pollutants are greater near major roads.[12]

The health impact of air pollution are manifold and can become manifest in any compartments of the human body like respiratory system, immune system, the skin and mucous tissues, the sensory system, the central and peripheral nervous system and the cardio-vascular system[13].

Recent studies[14] suggests that even at low levels of SPM (less than 100 µg/m^3) short term exposure is associated with daily mortality, daily hospital admission, exacerbation of respiratory system, bronchodilator use, cough and peak respiratory flow[15].

Most studies reviewed by WHO expert groups[14] and by Pope and Dockery[15] have suggested that SPM is a driving force for the observed health effects. Acute exposure to inhalable particulates can result in loss of lung function, onset of respiratory system, aggravation of existing respiratory conditions and increased susceptibility to infection. These problems may occur to a greater degree in asthmatic, small children and elderly with chronic respiratory and cardio-vascular disease.[2,3,15,16] Evidence is also emerging that long term exposure to low concentration of SPM in air is associated with mortality and other chronic effects, such as increased rates of bronchitis and reduced lung function.[14,15,17] Several cohort based morbidity studies conducted in the USA suggest that life expectancy may be 2-3 years shorter in communities with high SPM[18]. The result showed that long-term average exposures to low PM levels, starting at 10 µg/m^3 of fine particulate matter were associated with reduction in life expectancy[19]. A recent estimate for Delhi, India, suggests that an annual reduction of 100 µg/m^3 in TSP could be associated with a reduction of about 1400 premature deaths per year.[1, 20]

Increased $PM_{2.5}$ concentrations increase the risk of emergency hospital admissions for cardiovascular and respiratory causes; and PM10 affects respiratory morbidity, as indicated by hospital admissions for respiratory illness.[2,3,21-24]

There is consistent evident that air pollution increases the risk of chronic obstructive pulmonary disease and of acute respiratory infection among children[25,26]. Evidence also exists of association of low birth weight, increased infection and perinatal mortality, pulmonary tuberculosis, naso-pharyngeal and laryngeal cancer, cataract and lung cancer [25-27] A number of studies have been done in the developing world that give quantitative estimates of the relative risk of severe ARI for children living in exposure to particulates.[25-30] Several studies suggested that particle pollution contributes to excess mortality and hospitalizations for cardiac and respiratory tract disease. [31-34]

Particulate matters especially $PM_{2.5}$ can penetrate into the alveoli of lungs and may cause serious damage of developing cells of children.[23,24,35-37] Eighty percent of lung alveoli are formed postnatally, and changes in the lung continue through adolescence[1,38-39]. Therefore children are more vulnerable to the adverse effects of air pollution than are adults. Children have increased exposure to many air pollutants compared with adults because of higher minute ventilation and higher levels of physical activity. Children spend more time outdoors than do adults, consequently they have increased exposure to outdoor air pollution [4,39].

Air quality in Dhaka is a serious issue in view of the magnitude of its health and economic impacts. In the last few decades, the city has experienced huge population growth and rapid industrial, commercial, business, residential and infrastructure development.

As a result, the major components of the city environment both physical and social are greatly impacted leading to more or less continuous deterioration. Urbanization is an associated part of the process of economic development in Bangladesh, and its rate can be indicated by the large population growth in urban areas. With increased urbanization, the number of vehicles is also increasing rapidly, and contributing to more and more air pollution. Dust pollution due to road and building constructions and other development activities further aggravate the air pollution situation in cities. In order to accommodate the growing population, the construction of multistoried buildings is increasing rapidly. Most of the cars, jeeps, auto-rickshaws, motorcycles, etc., in the cities are old and many are reconditioned resulting in increased particulate emission. This has led to a deterioration of air quality, particularly in Dhaka[40]. The increasing number of transportation vehicles (Figure-01[41-42]) and their improper management and operation are responsible for degradation of the air quality. There is no doubt that air pollution is affecting human health in Bangladesh, especially in Dhaka City [41-42].

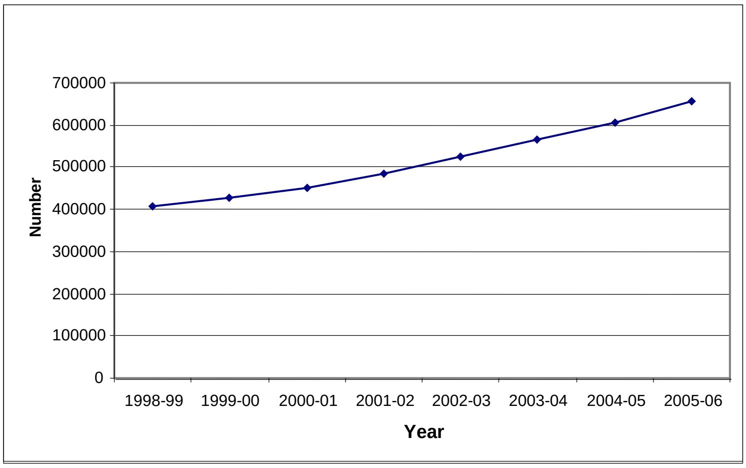

Figure 1: Number of registered motor vehicles in Bangladesh

The main air quality problem in Dhaka is the high level of particulate matter. Both PM_{10} and $PM_{2.5}$ levels are high (Figure-01)[43], being much above the proposed safety standards especially during the dry winter season.

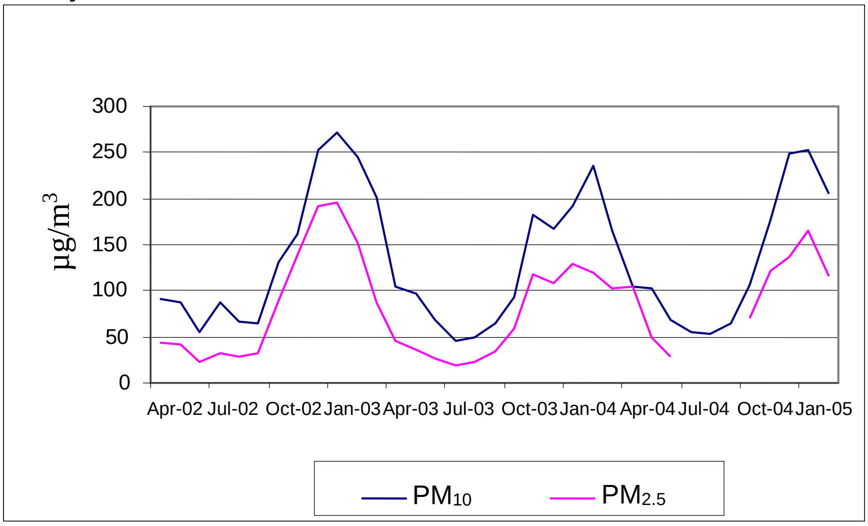

Figure 2: Average Concentrations of PM_{10} and $PM_{2.5}$ from April 2002 – February 2005

Both PM_{10} and $PM_{2.5}$ starts increasing in October, peaks in between December and February thereafter starts declining and is low in between April and October. The air quality standards are different for residential, industrial, commercial, and sensitive areas. According to various studies the worst affected areas in Dhaka city include: Hatkhola, Manik Mia Avenue, Tejgaon, Farmgate, Motijheel, Lalmatia, and Mohakhali. Surveys conducted between January 1990 and December 1999 showed that the concentration of suspended particles goes up to as high as 3000 μg/m^3 (Police Box Farmgate Station, 1999 December), although the allowable limit is 400 μg/m^3 [44].

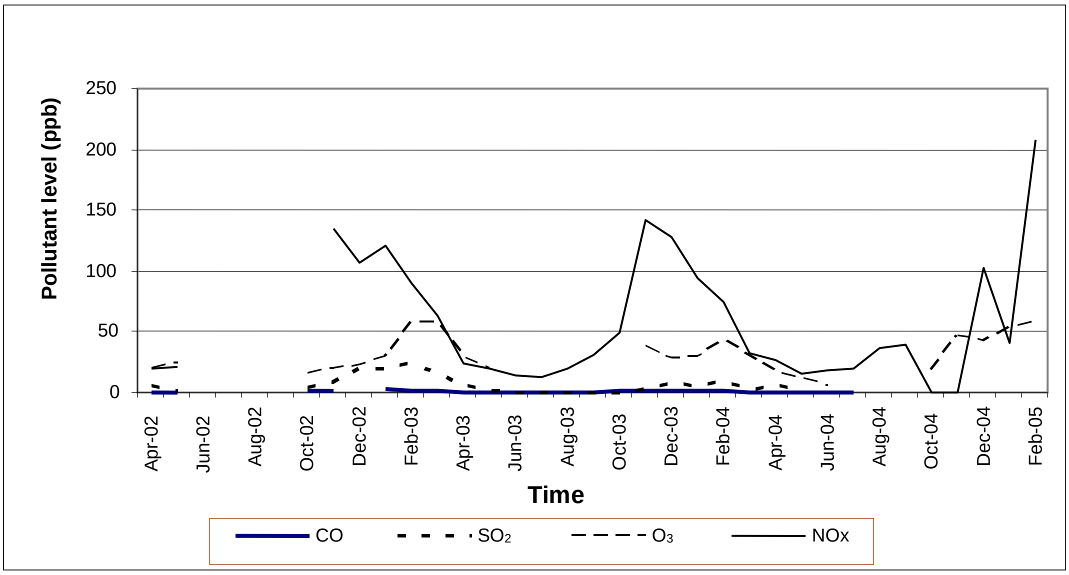

Figure 3: Average Concentrations during April 2002 – February 2005

The Air Quality Monitoring Project (AQMP) provides data from a continuous air monitoring station installed at Sangsad Bhaban area (a relatively cleaner area) with comparatively low vehicular traffic load. It shows the state of different air pollution parameters during the period 2002-2005 (Figure 3)[43-48] and the year 2003 (Figures 4 -5)[43-48]. Even in the Sangshad Bhaban area the PM_{10} and $PM_{2.5}$ concentrations were observed to be low during the period April to October.

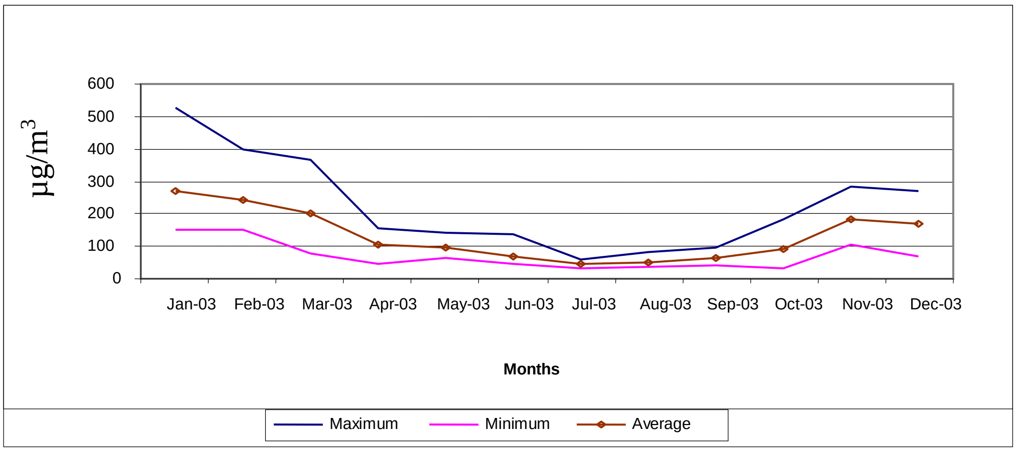

Figure 4: Monthly PM_{10} levels at Shangshad Bhavan area of Dhaka in 2003

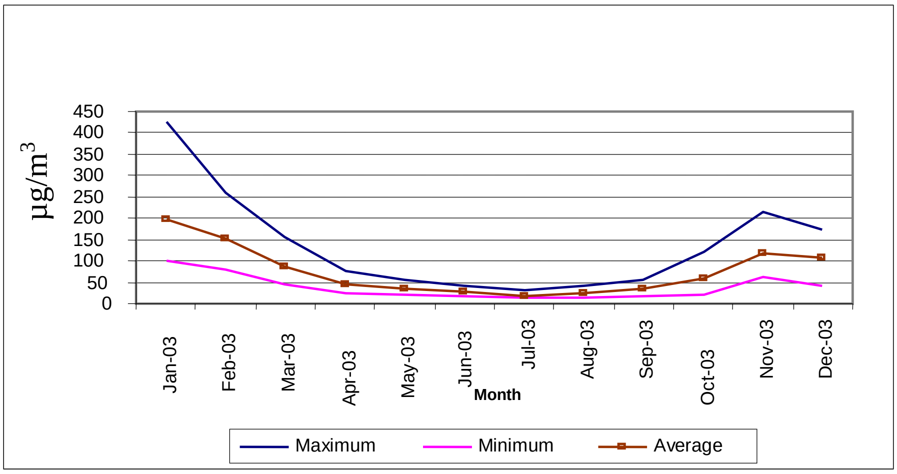

Figure 5: Monthly $PM_{2.5}$ levels at Shangshad Bhavan area of Dhaka in 2003

There is still a lack of formal studies showing the linkages between air pollution concentration and health impacts in most of the Asian Countries including Bangladesh. To address the need for information, an assessment on impact of air pollution among school children of Dhaka City was initiated jointly by the United Nations Environment Programme (UNEP), RRCAP, Stockholm Environment Institute (SEI) of Sweden, Department of Environment and Department of Occupational & Environmental Health, National Institute of Preventive and Social Medicine (NIPSOM) of Bangladesh. This study was conducted under the Male Declaration sub-activity 4.1.2., to determine health effects of air pollution through a cross sectional study by assessing whether the concentrations of particulates and socio-economic differences alters the relationship between particles and respiratory symptoms and lung function in children in Dhaka City. The findings of the study will address uncertainties and strengthen inferences of causality and develop a dose-response association.

1.2 Objective of the study

To determine whether there is an association between concentrations of $PM_{2.5}$ and PM_{10} with changes in respiratory symptoms and lung function (PEFR) in asthmatic children in Dhaka City.

Chapter 2 Assessment Methodology

The study consisted of a baseline survey followed by the assessment of health impact of air pollution among school children.

2.1 Phase I: Baseline Study

2.1.1 Sampling

The baseline survey was carried out in three schools situated in the central part of Dhaka city (well known areas of air pollution). The schools were Dhanmondi Boy's School (DBS), Tejgaon Girl's School (TGS) and Civil Aviation School (CAS). The schools are located within one kilometer of the central Air Quality Monitoring Station of the Department of Environment. It was assumed that the AQMP data of this station would represent the air quality state of the selected schools. All students (around 1800) of class V, VI, VII, VIII & IX of these schools (their age range was from 9-16 years) were targeted as participants for the baseline survey.

2.1.2 Data Collection

For the purpose of the survey based on 'The International Study of Asthma and Allergies in Childhood (ISAAC)' questionnaire[49] a modified structured English version ***questionnaire*** was prepared. The questionnaire was translated into Bengali. Pre-test was conducted in one of the participating schools.

The Questionnaire (Appendix 1) had 3 parts: *Part-I* had introductory information. *Part II*: had socio-demographic data, *Part-III* had Respiratory health related data. The questionnaire with a request letter was delivered to all the students through the respective class teachers and was asked to take it to their home and fill in with the assistance of their parents. The letter contained statements of request to cooperate the study, study rational, study objectives and instruction for proper filling up of the questionnaire.

A separate ***check list*** (Appendix 2) for recording the present state of respiratory health, relevant medical history and findings of clinical examination of respiratory system of the participating students was also prepared.

Thereafter, in the first week of February 2007 the structured pre-tested ***questionnaire*** was distributed to all students (around 1800) of class V, VI, VII, VIII & IX of the selected schools through their class teachers with instructions to return the filled in questionnaire to the respective class teachers on the following week. Out of the 1800 targeted students, 1618 students ultimately submitted the filled in questionnaire and were considered as participants of the study. The response rate was around 80%. Of the participating students, 720 were from DBS, 600 from TGS and 500 from CAS.

Subsequently each participating student underwent evaluation of the present state of respiratory health that included clinical examination of the respiratory system and history taking by six trained doctors. Six doctors with two of them in each school were deployed.

2.1.2 Data Analysis

Data obtained in the baseline survey were analysed to identify students with history or clinical evidence of asthma. The students who gave history of wheeze at any time in the last one year or a patient of diagnosed asthma with or without medication and if one is designated as an asthma patient identified by the medical examination conducted during the Base line survey were taken as asthmatic subjects. Ultimately 368 asthmatic subjects were identified.

2.2 Phase II: Health impact study

2.2.1 Sampling

From the 368 asthmatic subjects identified in the Base Line Survey, students whose father was a smoker or who did not provided smoking history were excluded. After exclusions all the 210 students who qualified to be a participant of the study were invited to undertake the self Peak Expiratory Flowmetry (PEFR) Test. Ultimately of the 197 asthmatic subjects, who consented to be participants of the Health Impact Study, 120 asthma students were selected randomly.

Enrolling healthy control children was difficult because most of the healthy subjects did not want to come to the school comparatively early in the morning and undertake six weeks of PEFR testing, which they considered unnecessary and troublesome. Ultimately a total of 180 students were selected for the study. The distributions of asthmatic subjects and control subjects by schools are shown in Table 1 below.

Table 1: School distribution Asthmatic and Control subjects

Schools	No of Asthmatics	No of Controls
Dhanmondi Boy’s School	60	30
Tejgaon Girl’s School	30	15
Civil Aviation School	30	15

2.2.2 Data Collection

Respiratory Data:

For recording Peak Expiratory Flow Rate a Peak Flow Meter named DATOSPIR PEAK – 10, made in Spain (www.sibelmed.com) was used.

For the entire period of data collection in the second phase, formatted colored Record Sheets for each student were used for recording the PEFR readings. The sheets contained a tabular form of PEFR readings started from 100 to 720 both for morning and afternoon in each row with date. One card contained column for two weeks, as such for each student three cards were filled for six weeks.

A pink colored sheet was used for the asthmatic subjects and a green colored sheet for the controls (Appendix 3). Individual cards contained a unique serial number, school name, class of the school, name and roll number of the student. In addition all the students were provided with a diary to make daily notes of any illness, particularly respiratory symptoms such as sore throat, runny nose, hoarseness, cough, phlegm, wheezing, fever, ear pain or discharge; hospital admission, physician consultation and additional medications if required in any occasion.

Class teachers of all sections of Class V, VI, VII, VIII & IX and designated technicians were trained up by the Principal and Co-Investigators of the study at the National Institute of Preventive and Social Medicine (NIPSOM) with emphasis on supervision of the daily diary writing, standard technique of Peak Expiratory Flow Rate (PEFR) measurement and recording of PEFR finding.

A roster for PEFR measurement of selected students in identified classes was prepared with the assistance of the Headmaster of each school who ensured the accomplishment of the schedule. One technician assigned for each school supervised the daily data collection and ensured quality assurance of PEFR measurement.

The use of Peak Flow Meter was demonstrated by the designated trained teachers and technician to study participants in small groups (individual classes). Each participant was also trained on individual basis as to how to use the peak flow meter and how to enter events like- taking of any airway medication and respiratory illnesses. Each participating student was provided with a peak flow meter.

PEFR was measured by the student themselves under the supervision of the assigned teachers and technician twice per day; once in the morning shortly before the classes began and again when the classes for the day ended. Morning measurements were recorded before taking of any airway medication. Each measurement was replicated three times in the standing position, and the highest reading was recorded. The reading was done by putting a dot mark in the PEFR record sheet. The reading was recorded by the teacher. The principal investigator and co-investigators frequently visited the schools for any guidance and quality collection of data.

The PEFR measurement was initiated on the last week of February 2007. Daily measurements were taken for a total of 6 weeks during the school time. But because of practical situations like school examinations, summer vacation and school closure for SSC examination, continuous data collection was not possible. Ultimately accommodating for these events, data collection was carried out during last week of February; 2nd, 3rd and 4th weeks of April; and 1st & 2nd week of June.

As the objective of the study was to determine if a correlation existed between increased concentrations of PM_{10} & $PM_{2.5}$ in the atmosphere and occurrence of respiratory symptoms, it was necessary to collect the data from school children during the peak dust (PM_{10} & $PM_{2.5}$) periods of dry season. Typically in Bangladesh the dry period starts in November. During the period of November to February the dust levels are usually higher than other months of the dry season.

To collect data for 35 days it took up to the third week of June 2007. During these 35 days of data collection the students had exposure to higher level of dusts only for 4-5 days of February and in other days the particulate level in the air remained unusually low. But to test the hypothesis this few days of higher exposure level data was not sufficient and would not be representative of typical particulate exposure in Dhaka. A few more days of data collection during the period of higher ambient particle concentrations were necessary. To get the same sample of students it was decided to collect data in November 2007 otherwise majority of the study samples might be missed because of their promotion and school change. Therefore, a further 7 days' data collection during the month of November 2007 was undertaken.

Particulate and Weather Data:

Corresponding data about particulates (PM_{10} and $PM_{2.5}$) of relevant period was collected from the Air Quality Management Project (AQMP) of the Department of Environment. Relevant metrological data (maximum, minimum and average daily temperature, relative humidity and wind speed) was obtained from the Department of Metrology.

2.2.3 Data analysis

A variety of statistical tests were used including chi-square tests to evaluate group data, student t-test and analysis of variance to test the difference between group means, correlation analyses, Curvilinear regression and Multiple regression analyses to establish which variables had a significant effect on PEFR. Repeated measures analyses were also undertaken to evaluate the changes in the morning and afternoon PEFR over time and also stratified by asthma status and gender. A significant result was defined by a p value of <0.05.

Chapter 3 Results of the Study

3.1. Phase I: Baseline Survey

The baseline survey targeted around 1800 students of class V, VI, VII, VIII and IX of Dhanmondi Boy's School (DBS), Tejgaon Girl's School (TGS) and Civil Aviation School (CAS). All students of these classes were provided with a structured questionnaire with instructions to fill it in consultation with their parents and return it to their respective class teacher. Out of the 1800 targeted students a total of 1618 students submitted the completed questionnaire, thus the response rate of the baseline survey was around 89%. Out of the total 1618 participants 60.5% were female. The participants of the baseline questionnaire survey were mostly Muslim (93.5%), Hindus, Buddhists, and Christians accounted for the remaining participants (Table 2). Students of class V & VI accounted for 25.8% and 21.4% of those who participated in the base line survey (Table 2).

Table 2: Selected Socio demographic status of School Children

Socio demographics		Number	Percent
School name	DBS	639	39.5
	CAS	422	26.1
	TGS	557	34.4
Gender	Male	639	39.5
	Female	979	60.5
Religion	Islam	1513	93.5
	Hinduism	100	6.2
	Buddhism	3	0.2
	Christianity	2	0.1
Class	V	418	25.8
	VI	347	21.4
	VII	267	16.5
	VIII	289	17.9
	IX	297	18.4

In the individual classes there was no difference ($p>0.05$) in the mean ages in either of the sexes (Table 3).

Table 3: Class wise Age and Gender distribution of School Children

Class	Gender	No	Mean age (±SD)	Difference
Class V	Male	206	10.25 (±0.86)	NS
	Female	212	10.40 (±0.89)	F=3.140 p=0.077
Class VI	Male	124	11.10 (±0.93)	NS
	Female	223	11.26 (±0.82)	F=2.663 p=0.104
Class VII	Male	102	12.20 (±0.82)	NS
	Female	165	12.28 (±0.78)	F=0.554 p=0.457
Class VIII	Male	98	13.11 (±0.90)	NS
	Female	191	13.05 (±0.71)	F=0.289 p=0.591
Class IX	Male	109	13.80 (±0.89)	NS
	Female	188	13.73 (±0.75)	F=0.425 p=0.515

Of the 1618 respondents 84.6% responded to the query if their child ever had wheezing or whistling in the chest in the past. Of the respondents 19.6% (268) confirmed such an event, and among them 59.0% (158) of the children had experienced such an event during the past year. Most (79.7%) had about less than 4 attacks and another 15.2% had about 4 to 12 attacks of wheezing in the past year. Amongst the children had experienced attacks of wheeze in the past year 19.6% had sleep disturbances in more than one night each week and another 40.5% it occurred in about one night a week. About 42% (67) who had wheezing in the past year reported it was severe enough to limit the child's speech to one or more words between breaths. Children with asthma accounted for 16.5% (235) of those who responded to the query if their child ever had asthma (1425). About 8% (114) of the children during or after exercise or playing had experienced a wheeze and about 26.4% (358) had dry cough at night not associated with common cold or fever in the past 12 months (Table 4).

Table 4: Distribution of Respiratory Problems

Respiratory Problems	Response	No.	%	Total Response
Wheezing sound in respiration	yes	268	19.6	1369
	no	1101	80.4	(84.6%)
Sound in respiration in last 1	yes	158	59.0	268
year	no	110	41.0	(100%)
No. of attacks of wheezing in	1-3 times	126	79.7	158
past 1 year	4-12 times	24	15.2	(59%)
	>than 12 times	8	5.1	
Sleep disturbed for wheezing	never	63	39.9	158
	once in a week	64	40.5	
	> one in a week	31	19.6	
Severe wheezing	yes	67	42.4	158
	no	91	57.6	
Child suffered from asthma	yes	235	16.5	1425
	no	1190	83.5	(88.1)
Chest sounded wheezy during or after exercise (play)	yes	114	8.2	1396
	no	1282	91.8	(86.3)
Cold cough at night	yes	358	26.4	1357
	no	999	73.6	(83.9)

Amongst the total 1618 respondents 86.3% (1396) responded to the query if their child ever had a problem with sneezing, running or blocked nose despite not having clod or flu. Among those who responded 40.6% (567) mention of such experience. Among these 567 children 85.7% (486) had such an experience during the past 12 months. Among those who had at least an episode of the problem of sneezing, running or blocked nose despite not having clod or flu 71.2% (346) had additionally experienced itchy watery eyes. Among those children who had an episode of the problem of sneezing, running or blocked nose despite not having cold or flu in the past 12 months about 98% (477) responded to the query as to how much did the nose problem in the past 12 months interfere with the child's daily activities like studies and playing. Among them about 90% (430) did experience little or no problem. Out of the 1380 (85.3%) among the total 1618 respondents, 12.5% (172) children had ever experienced allergic fever (Table 5).

Table 5: Distribution of Respiratory Problems not due to general cold/fever

Respiratory Problems not due to general cold/fever	Response	No.	%	Total
Ever sneezing not due to general	yes	567	40.6	1396
cold/fever	no	829	59.4	(86.3)
In last 1 year sneezing not due	yes	486	85.7	567
to general cold/fever	no	81	14.3	(35.0)
Eye itching with nose problem	yes	346	71.2	486

	no	140	28.8	(30.0)
	never	161	33.8	
	little	269	56.4	
Study and play disturbed in last year	much disturbed	38	8.0	477
	most disturbed	9	1.9	(98.1)
Allergy related fever	yes	172	12.5	1380
	no	1208	87.5	(85.3)

Amongst the total 1618 respondents 81.5% (1319) responded to the query if their child in the past 6 months ever had an itchy rash that came and went. Of them about 20% (267) confirmed that their child had experienced such a problem. Amongst those who in the past 6 months had experienced an itchy rash that came and went 249 (93.2%) responded to the query about specific location of the itchy rash, of them 68.3% confirmed that the rash had appeared in locations that included the fold of the elbow, back of the knee, front of the ankle or around the neck, ears or eyes. Of those who had experienced an itchy rash that came and went during the past 6 months 90.3% (241) had experienced such rash in the past 1 year. Amongst those who mentioned that their child had experienced itchy rash 246 responded to the query if the rash had disturbed the child's night sleep in the past year, of them 41.2 % (107) confirmed that their child have had such an experience. 9.7% (136) mentioned that their child also suffered from eczema (Table 6).

Table 6: Distribution of Allergic Manifestations Other than Respiratory Problems

Other than Respiratory Problems	**Response**	**No**	**%**
Frequent rash in last 6 months (1319)	yes	267	20.2
	no	1052	79.8
Rash at least once in last one year (267)	yes	241	90.3
	no	26	9.7
Rash in elbow, knee, heel, throat, eye, ear (249)	yes	170	68.3
	No	79	31.7
Rash automatically cured in last one year (246)	yes	153	62.2
	no	93	37.8
Night sleep disturbed for rash in last one year (260)	never	153	58.8
	once in a week	66	25.4
	> once in a week	41	15.8
Child suffered from eczema (1395)	yes	136	9.7
	no	1259	90.3

The response rate for the query whether someone in the household of the child is a smoker was 89.2%. Among those who responded 39.8% (574) had a smoker in the household and among the smokers 49.7% (285) mentioned that the smoker smokes within the house (Table 7).

Table 7: Smoking status among the children's household

Smoking status		**N**	**%**	**Total**
Any smoker among the house hold	Yes	574	39.8	1443
	No	869	60.2	(89.2%)
Smoking in the house	Yes	285	49.7	574
	No	289	50.3	(39.8%)

Among the 1425 children for whom the response to the query if child ever had asthma was obtained 16.5% (235) reported having asthma. However, among these 1425 children 25.8% (368) were diagnosed by a study physician as having asthma. Previously diagnosed asthmatic children accounted for about 63.6% of the children diagnosed of having asthma (Table 8).

Table 8: Asthma status according to study physicians' diagnosis

Asthma diagnosed by study physician	Response regarding child ever suffered from Asthma		Total
	Yes	No	
Yes	234 (63.6%)	134 (36.4%)	368 (25.8)
No	1 (0.1%)	1056 (99.9%)	1057
Total	235 (16.5%)	1190 (83.5%)	1425

Among the 574 household with a smoker 158 (42.9%) respondents' children were reported to be suffering from asthma (Table 9).

Table 9: Asthma status in relation to a smoker in the house

Asthma status	Smoker in the house		Total
Children suffering from asthma	Yes	No	
Yes	158 (42.9%)	210 (57.1%)	368
No	416 (38.7%)	660 (61.3%)	1076
Total	574 (39.8%)	870 (60.2%)	1444

Among the 210 asthmatic children who did not have a smoker in the household, 54.3% (114) were male and 45.7% (96) were female (Table 10).

Table 10: Gender distribution of Asthmatic children without smoker in the house

Class	Gender		Total
	Male	Female	
V	40 (59.7%)	27 (40.3%)	67
VI	21 (58.3%)	15 (41.7%)	36
VII	13 (43.3%)	17 (56.7%)	30
VIII	21 (52.5%)	19 (47.5%)	40
IX	19 (51.4%)	18 (48.6%)	37
Total	114 (54.3%)	96 (45.7%)	210

3.2. Phase II: Health Impact Study Observations

This part of the report provides information about how the sample was selected and on the basic socio-demographic and other characteristics of the patients. It then goes on to test for homogeneity in socio-demographic and other variables between the groups.

Among the 1800 students of three schools of Dhaka City, 1618 students have responded to the baseline screening process. Students, who initially attended for assessment, 368 met the clinical criteria (presence of asthma). Of these, 210 students became eligible for the study as they were identified with asthma and there were no smoker at the household level. Finally, out of these 210 students, who agreed to participate in the study, a simple randomization was done to select 120 asthmatic students for the study. Another 60 students without asthmatic problem were included in the study after matching them with their age and sex and also they had provided their consent to participate in the study.

3.2.1 Socio-demographic analysis

A total of 180 students were included in the study, of which 90 were male and 90 were female. 90 male students were enrolled in the study from the Dhanmondi Boys High School (DBS), of which

60 students were with asthma and 30 were non-asthmatic students. Of the female students from Tejgaon Girl's High School (TGS) and Civil Aviation Girl's High School (CAS), 60 had asthma symptoms and 30 students had no asthma symptoms. The distribution of students by their sex and schools were presented in Tables 11 and 12.

Table 11: Number of students with asthma in relation to their gender

Gender of the student	Status of Asthma		Total number
	No Asthma	With Asthma	
Male	30	60	90
Female	30	60	90
Total	60	120	180

Table 12: Number of students with asthma in relation to their school

School	Status of Asthma		Total number
	No asthma	With Asthma	
DBS	30	60	90
TGS	15	30	45
CAS	15	30	45
Total	60	120	180

Other socio-demographic characteristics of the sample are presented in Table 13 and 14. Age ranged from 09 to 16 years and mostly between 10 to 14 years (about 90%). Students were included from Class five to class nine but more than half were from early two classes (Class five and six). Comparisons were made between the asthmatic and non-asthmatic groups, the results of these analyses are presented in Tables 13 and 14 and no significant differences were found among these two groups.

Table 13: Number of students with asthma in relation to their age

Age of the student in years	Status of Asthma		Total number	χ^2	p
	No asthma	With Asthma			
9	1	3	4	4.99	ns
10	12	16	28		
11	14	25	39		
12	7	20	27		
13	8	25	33		
14	12	22	34		
15	5	5	10		
16	1	4	5		
Total	60	120	180		

Table 14: Number of students with asthma in relation to their academic level

Academic Level	Status of Asthma		Total number	χ^2	p
	No asthma	With Asthma			
Class-V	17	28	45	2.04	ns
Class-VI	15	31	46		
Class-VII	11	20	31		
Class-VIII	6	21	27		
Class-IX	11	20	31		
Total	60	120	180		

The height of the students ranged from 126.0 cm to 182.0 cm with a mean of 149.77 cm and SD of 10.07 cm. Weight ranged from 24.0 kg to 90.0 kg with a mean of 45.51 kg and SD of 11.76 kg. At the beginning of the study, the Peak Expiratory Flow Rate in the Morning (PEFR-M) ranged from 150 L/min to 320 L/min, with a mean 237.72 L/min and SD was 34.80 L/min. The Peak Expiratory Flow Rate in the Afternoon (PEFR-A) was little lower with a range from 150 L/min to 310 L/min, mean 218.44 L/min and the SD was 38.98 L/min.

An exhaustive analysis was performed to explore the relationship of PEFR of morning and afternoon of the respondents to the socio-demographic characteristics, anthropometric measurements and other variables. No significant differences were observed for in the Morning (PEFR-M) and Afternoon Peak Expiratory Flow Rate (PEFR-A) with any of the respondent characteristics namely age, sex, academic level or admitted schools and also for the prevailing health problems. An expected significant relationship was observed with the PEFR-Morning reading (F= 7.09 and p=0.001) where the students with inhaler use had 37.62 L/min lower PEFR reading than students not using inhalers.

3.2.2 Testing for homogeneity based on the asthma status

The final set of comparisons was made for checking the homogeneity and was presented in Tables 15. No significant differences between the asthmatic and non-asthmatic groups with respect to the socio-demographic characteristics and anthropometric measurements were found. Significant differences were observed only for Peak Expiratory Flow Rate in the Morning (PEFR-M) and Peak Expiratory Flow Rate in the Afternoon (PEFR-A). The Morning PEFR mean of the asthmatic students group was lower than the non-asthmatic group (p=<0.001) and which also continued to be lower in the afternoon PEFR reading (p=<0.001). In the morning of the first day of data collection, PEFR was 57.17 L/min lower among the asthmatic students and this symptom was more intense in the afternoon with a 67.33 L/min lower PEFR reading than the non-asthmatic students. From these findings, it could be concluded that the data set was homogenous with respect to the socio-demographic and anthropometric variables. It could also be opined that the PEFR readings in the morning and in the afternoon were consistent with the study objectives and hypothesis.

Table 15: Number of students with asthma in relation to their anthropometry and PEFR

Variables of interest	Asthma status	Mean	Standard Deviation	t-test for Equality of Means				
				t- value	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Height of the student (cm)	No asthma	149.17	10.548	-0.564	0.573	-0.900	-4.049	2.249
	With Asthma	150.07	9.857					
Weight of the student (kg)	No asthma	45.53	12.213	0.022	0.982	0.042	-3.639	3.723
	With Asthma	45.49	11.586					
Morning PEFR (L/min)	No asthma	275.83	18.892	16.444	0.000	57.167	50.307	64.027
	With Asthma	218.67	23.369					
Afternoon PEFR (L/Min)	No asthma	263.33	19.193	18.874	0.000	67.333	60.293	74.373
	With Asthma	196.00	24.059					

3.2.3 Impact of Asthma and Gender on Peak Expiratory Flow Rate (PEFR)

3.2.3.1 Impact of Asthma on morning PEFR

Repeated measures analyses of variance were used to examine the changes of morning PEFR during the data collection period among the asthmatic and non-asthmatic students (Figure 1). The results showed that there was significant within subject variation in the morning PEFR over the study period of time (F= 307.93, p=<0.001). A significant interaction effect was also observed between the morning PEFR and asthma status (F= 2.20, p=<0.05) which tells us that morning PEFR significantly differs depending on asthma status. The variation of morning PEFR among the asthmatic and non-asthmatic groups of students was consistently different over the study period of time (F= 149.15, p=<0.001). Figure 6 shows that the morning PEFR reading of asthmatic students was generally significantly lower than the non-asthmatic students over the study period. There was a sharp rise of morning PEFR in both the groups from the 25th to 35th day of data collection which represented the data collection for the month of June. The 24th day of data collection was in April and the 36th day was in November.

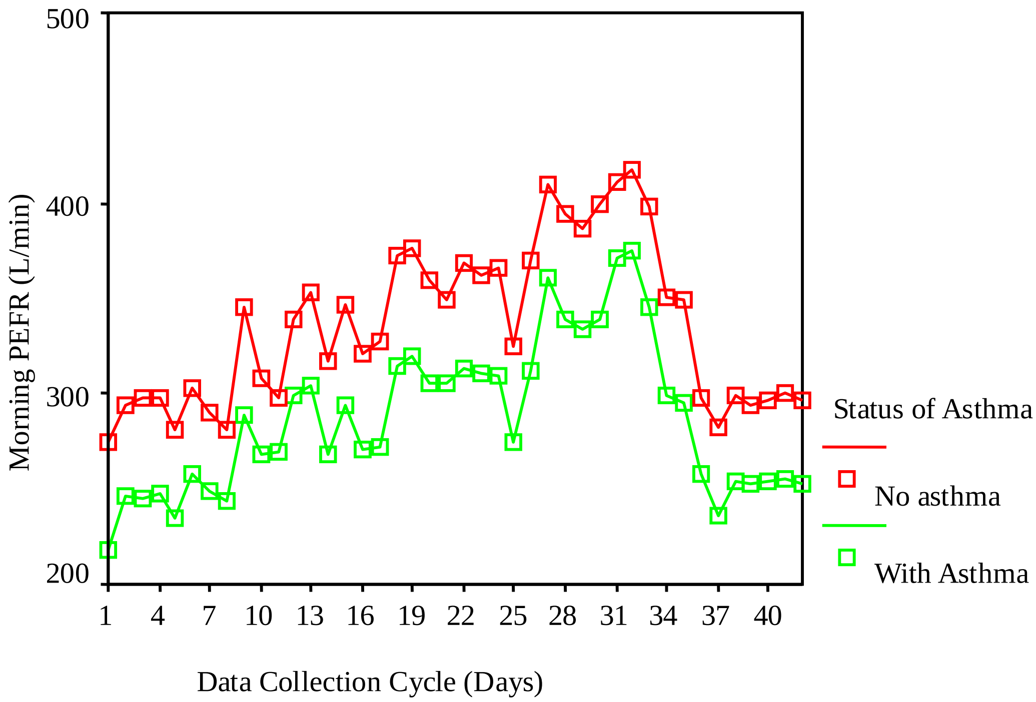

Figure 6: Change in morning PEFR in relation to asthma status

3.2.3.2 Impact of Asthma on afternoon PEFR

Repeated measures analyses of variance were used to examine the changes of afternoon PEFR during the data collection period among the asthmatic and non-asthmatic students (Figure 7). The results showed that there was significant within subject variation in the afternoon PEFR over the study period of time (F= 333.72, p=<0.001). A significant interaction effect was also observed between the afternoon PEFR and asthma status (F= 2.67, p=<0.01) which tells us that afternoon PEFR significantly differs depending on asthma status. The variation of afternoon PEFR among the asthmatic and non-asthmatic groups of students was consistently different over the study period of time (F= 176.64, p=<0.001). Figure 7 shows that the afternoon PEFR of asthmatic students was generally significantly lower than the non-asthmatic students over the study period of time. There was a sharp rise of afternoon PEFR in both the groups within 25th to 35th day of data collection which represented the data collection for the month of June.

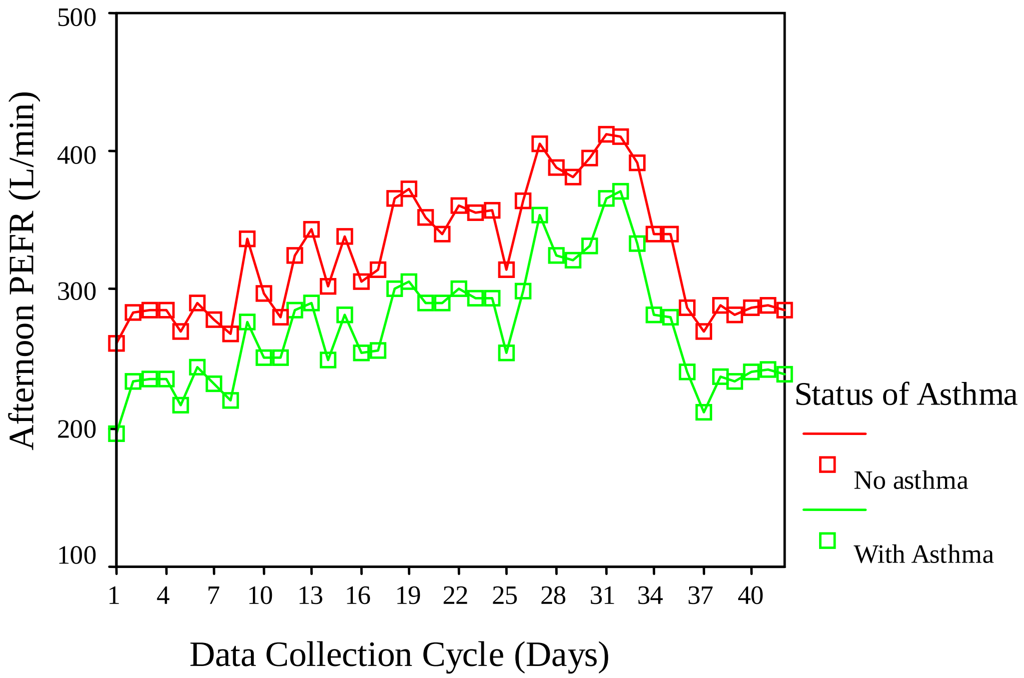

Figure 7: Change in afternoon PEFR in relation to asthma status

3.2.3.3 Impact of Gender on morning PEFR:

Repeated measures analyses of variance were used to examine the changes of morning PEFR during the data collection period among male and female students (Figure 8). The results showed that there was significant within subject variation in the morning PEFR over the study period of time (F= 338.71, p=<0.001). A significant interaction effect was also observed between the morning PEFR and gender (F= 2.31, p=<0.05) which tells us that gender of the student significantly influenced the morning PEFR. However, the variation of morning PEFR was not consistently different among the male and female students over the study period of time.

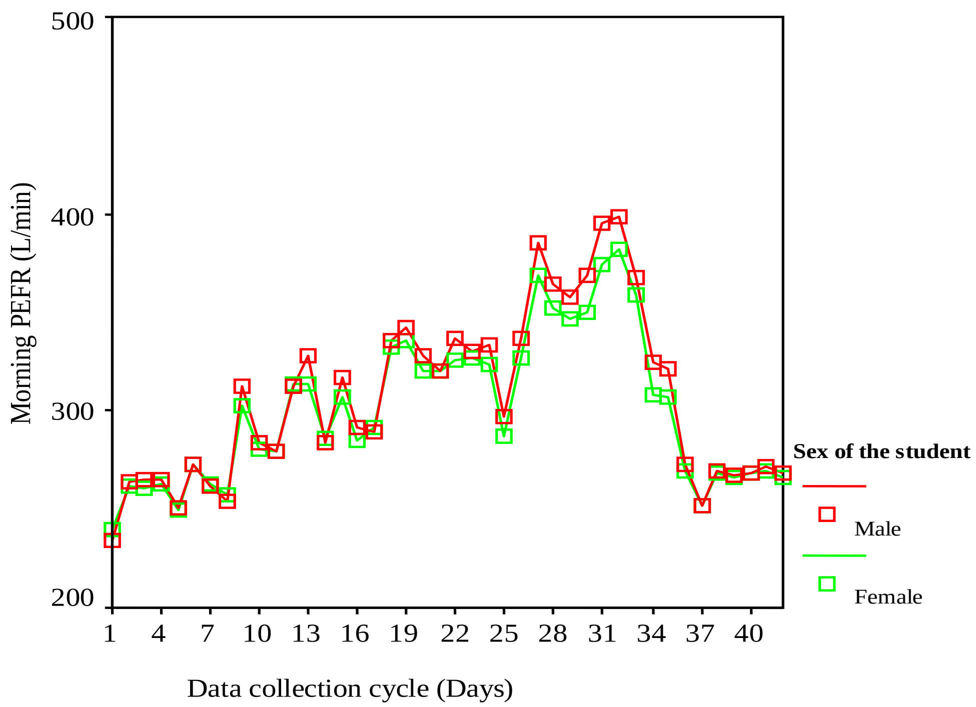

Figure 8 Change in morning PEFR according to their sex

3.2.3.4 Impact of Gender on afternoon PEFR:

Repeated measures analyses of variance were used to examine the changes of afternoon PEFR during the data collection period among male and female students (Figure 9). The results showed that there was significant within subject variation in the afternoon PEFR over the study period ($F= 366.05$, $p=<0.001$). A significant interaction effect was also observed between the afternoon PEFR and gender ($F= 2.08$, $p=<0.05$) which tells us that gender of the student significantly influenced the afternoon PEFR. However, the variation of afternoon PEFR was not consistently different among the male and female students over the study period of time.

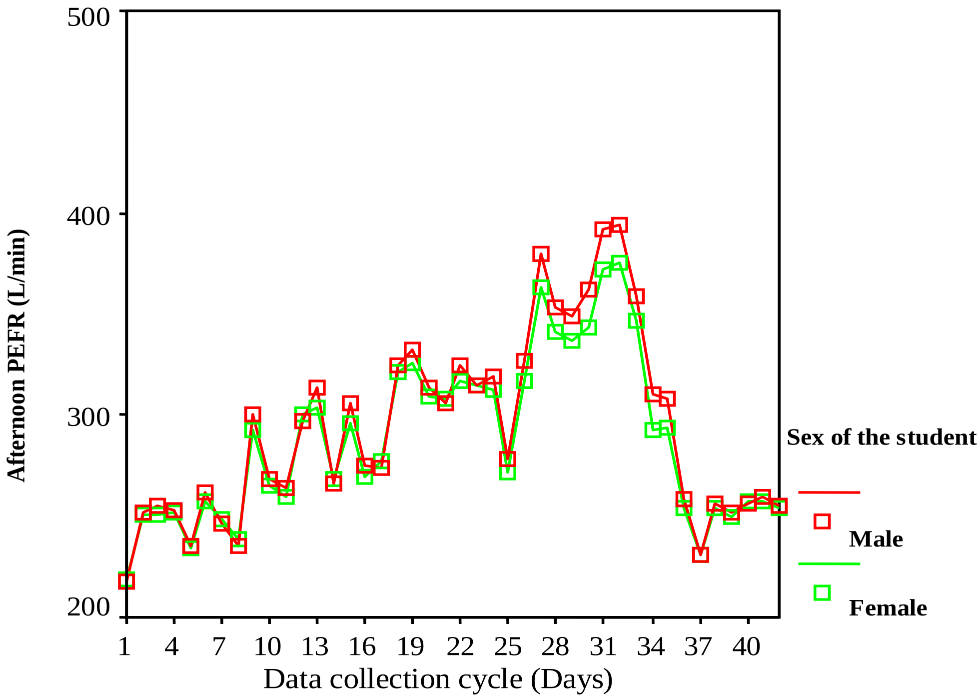

Figure 9: Change in afternoon PEFR according to their sex

3.2.4 The correlation between PEFR and Particulate matter, Daily temperature and Humidity

Curvilinear regression analyses were performed to examine the relationship of the PEFR of morning and afternoon and the difference of PEFR between the morning and afternoon measurements with the particulate matter concentration, daily average, minimum and maximum temperature and relative humidity measurements.

The analysis showed that morning PEFR had a curvilinear relationship with the concentration of the particulate matter 10 (PM_{10}) (linear term= -1.274; $p=<0.001$ and quadratic term = +0.0023; $p=<0.001$) and explained a significant amount of variance of morning PEFR (43.42%). The afternoon PEFR and the difference between the morning and afternoon reading of PEFR had showed the similar type of curvilinear relationship with the PM_{10} concentration (linear term= -1.362; $p=<0.001$, quadratic term = +0.0024; $p=<0.001$ and linear term= +0.087; $p=<0.001$, quadratic term = -0.001; $p=<0.001$ respectively) and explained 44.76% and 5.70% of variance of afternoon PEFR and the difference PEFR respectively.

All relationships were found to be similar for the $PM_{2.5}$ concentration with the three PEFR data with some smaller beta values but similar high level of significance (<0.001) as the PM_{10} concentration.

Significant linear and quadratic relationships were observed for the daily average temperature, daily maximum and the minimum temperature with the morning and afternoon PEFR reading but only the linear relationship existed for the difference between the morning and afternoon PEFR. The minimum temperature of the day could explain the highest amount of variance of morning PEFR among the temperature related variables (19.31%).

Average humidity of the day had significant linear relationship in linear term and significant quadratic relationship in quadratic term with all three PEFR data but there were highly significant curvilinear relationship existed between the minimum humidity of the day and the morning and afternoon PEFR (linear term= +2.344; p=<0.001 and quadratic term = -0.0055; p=<0.001 and linear term= +2.412; p=<0.001, quadratic term = -0.005; p=<0.001 respectively) and explained 26.13% and 25.93% of variance of morning and afternoon PEFR respectively. Maximum humidity status maintained only linear relationship with all three PEFR data.

3.2.4.1 EFR in relation to the Particulate Matter concentration

PM_{10} concentration

The regression analyses showed highly significant differences in morning PEFR in relation to asthma status of the respondents, where non-asthmatic students had a significantly higher mean morning PEFR than asthmatic students (F Change value =323.11; p=<0.001).

There was a highly significant effect of PM_{10} concentration on morning PEFR which alone accounted for 58.4% of the variance of the morning PEFR (with an F change value of 2624.20; p= <0.001). When asthma status was included in the model, there was a significant, but modest, increase in adjusted R^2 value to 60.10%. After holding asthma status constant, with the increase in PM_{10} concentration, there was a reduction in the morning PEFR (standardised coefficient beta =1.07). It was observed that the morning PEFR decreased by 37.60% in both asthmatic and non-asthmatic children from the lowest to the highest level of PM_{10} concentration (Figure 10).

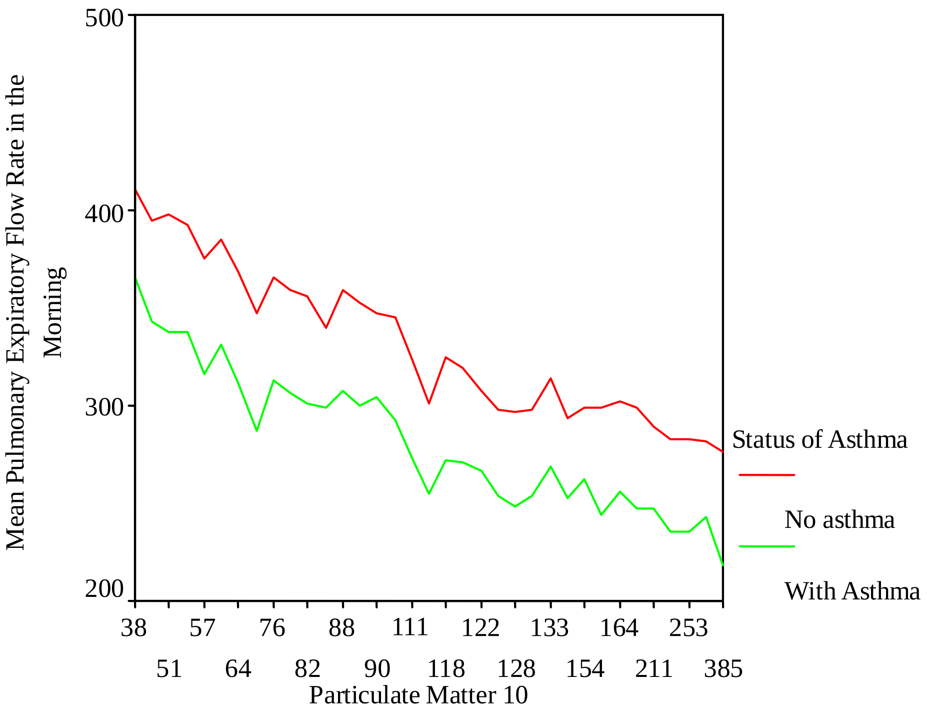

Figure 10: Relationship of morning PEFR with the PM_{10} concentration by asthma status

The analyses revealed highly significant differences in afternoon PEFR in relation to the asthma status of the respondent. The asthmatic students had a significantly lower mean afternoon PEFR than the non-asthmatic students (F Change value =380.48; p=<0.001).

There was highly significant effect of PM_{10} concentration on the afternoon PEFR that can account for the 60.9% variance of the afternoon PEFR (with an F change value of 2913.29; p= <0.001). When the asthma status was included in the model, the adjusted R^2 value increased to 62.7% which was statistically significant. It was observed that, holding the asthma status constant, the increase in PM_{10}

concentration was associated with a reduction in the afternoon PEFR (Standardised coefficient beta = 1.07). Analyses showed that the afternoon PEFR declined in both the study groups by 41.87% with the increase in PM10 concentration from its lowest to the highest level (Figure 11).

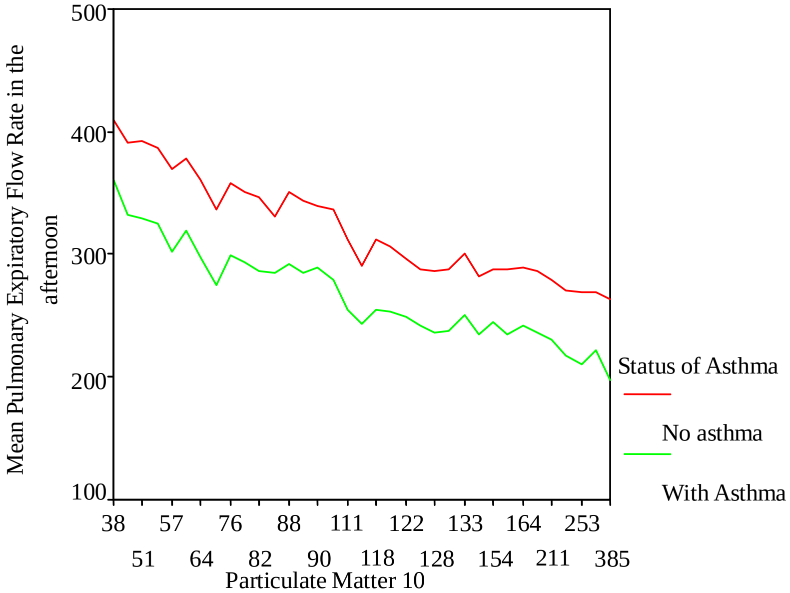

Figure 11: Relationship of afternoon PEFR with the PM_{10} concentration by asthma status

The analyses revealed highly significant effects of asthma status of the respondent on the difference between morning and afternoon PEFR, where non-asthmatic students had a significantly higher mean afternoon PEFR than the asthmatic students (F Change value =39.61; p=<0.001).

There was highly significant effect of PM_{10} concentration on the difference between morning and afternoon PEFR accounting for 9.30% variance of the difference PEFR (with an F change value of 191.35; p= <0.001). The asthma status could significantly increase the adjusted R^2 to 9.70%. The difference between morning and afternoon PEFR was low (4.22 L/min) with the lower level of PM_{10} concentration and the difference raised with the increase of PM_{10} concentration and reached to 18.72 L/min which is nearly 350% increase from the lowest level (Figure 12).

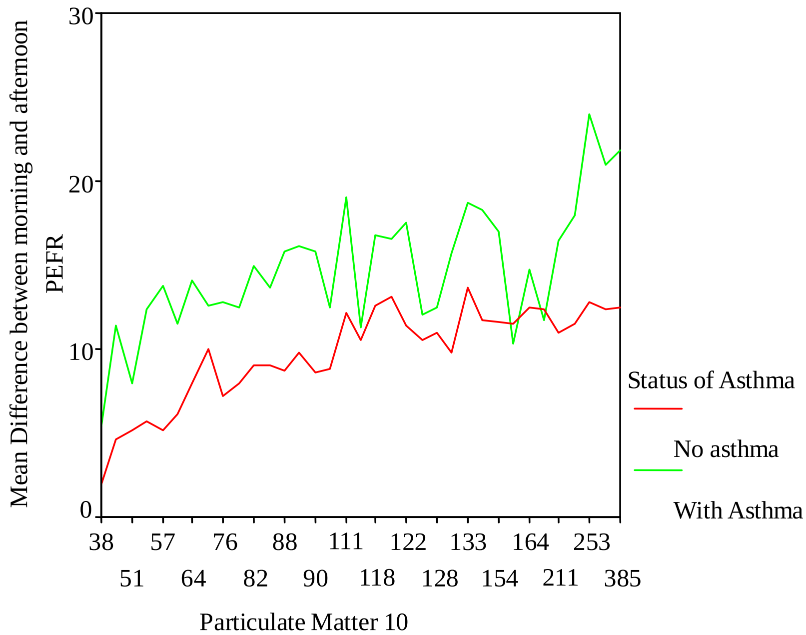

Figure 12: Relationship of difference between morning and afternoon PEFR with the PM_{10} concentration by asthma status

$PM_{2.5}$ concentration

The regression analyses revealed highly significant differences in morning PEFR in relation to the asthma status of the respondent, where non-asthmatic students had a significantly higher mean morning PEFR than the asthmatic students (F Change value =395.36; p=<0.001).

A highly significant effect of $PM_{2.5}$ concentration was observed on morning PEFR that alone accounted for 48.7% variance of the morning PEFR (with an F change value of 1776.57; p= <0.001). The asthma status could increase the adjusted R^2 value to 51.30% and the model was significant. Standardised coefficient beta data indicated that the increase in one standard deviation of $PM_{2.5}$ concentration while holding the asthma status constant would reduce the morning PEFR by 0.73 standard deviations. It was also observed that the morning PEFR decreased by 30% with the increase of $PM_{2.5}$ concentration from its lowest to highest level (Figure 13).

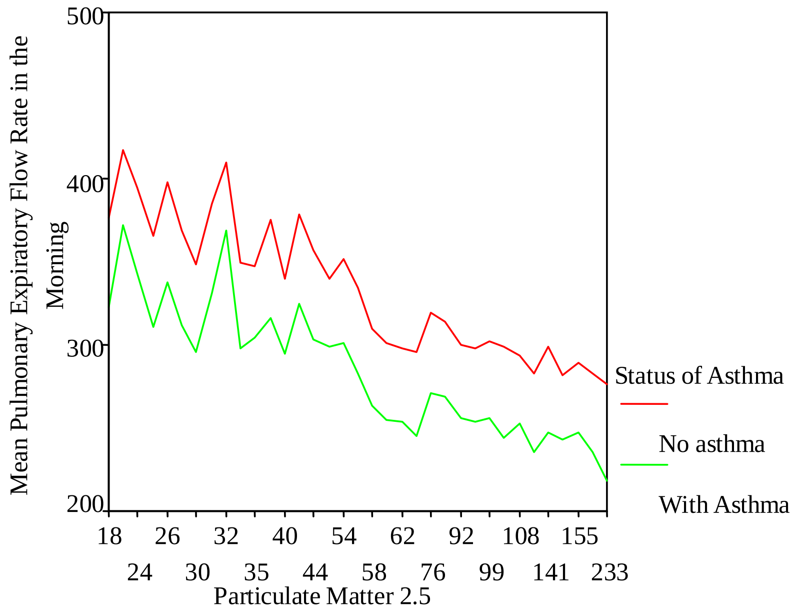

Figure 13: Relationship of morning PEFR with the $PM_{2.5}$ concentration by asthma status

Highly significant differences in afternoon PEFR were observed with the asthma status of the respondent, where non-asthmatic students had a significantly higher mean afternoon PEFR than the asthmatic students (F Change value =448.68; p=<0.001).

There was a highly significant effect of $PM_{2.5}$ concentration on afternoon PEFR that alone accounted for 50.50% variance of the afternoon PEFR (with an F change value of 1910.51; p= <0.001). The asthma status can significantly contribute to the model and increase the adjusted R^2 value to 53.30%. The increase in $PM_{2.5}$ concentration while holding the asthma status constant would reduce the afternoon PEFR (Standardised coefficient beta =0.718). A 33.85% reduction of afternoon PEFR was observed from the lowest to the highest level of $PM_{2.5}$ concentration (Figure 14).

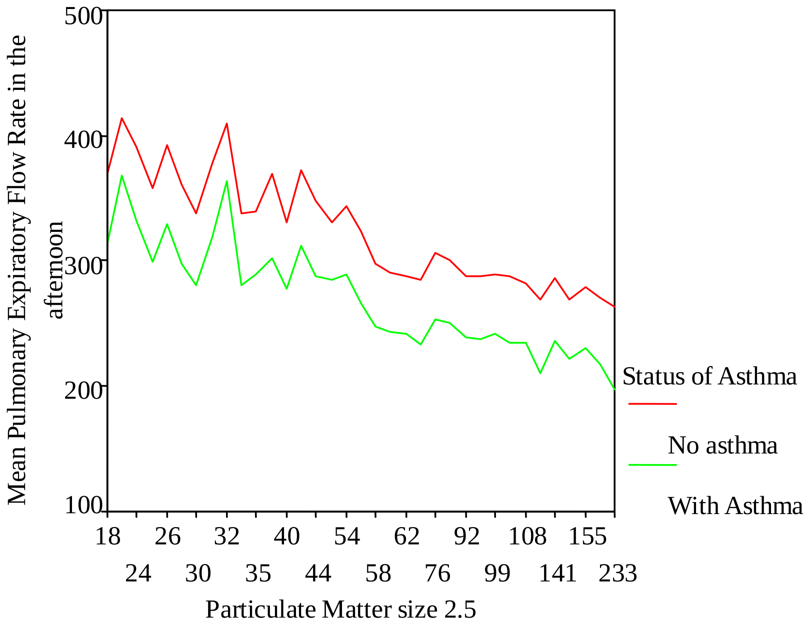

Figure 14: Relationship of afternoon PEFR with the $PM_{2.5}$ concentration by asthma status

The analyses showed highly significant effects of asthma status of the respondent on the difference between morning and afternoon PEFR, where non-asthmatic students had a significantly higher PEFR difference than the asthmatic students (F Change value =52.23; p=<0.001).

There was highly significant effect of $PM_{2.5}$ concentration on the difference between morning and afternoon PEFR that accounted for 7.20% variance of the PEFR difference (with an F change value of 145.78; p= <0.001). The asthma status could significant but modestly increase the adjusted R^2 value to 7.80%. It was found that the difference between morning and afternoon PEFR increased with the increase of $PM_{2.5}$ concentration from 8.56 L/min to 18.72 L/min which is nearly a 120% increase from the lowest level (Figure 15).

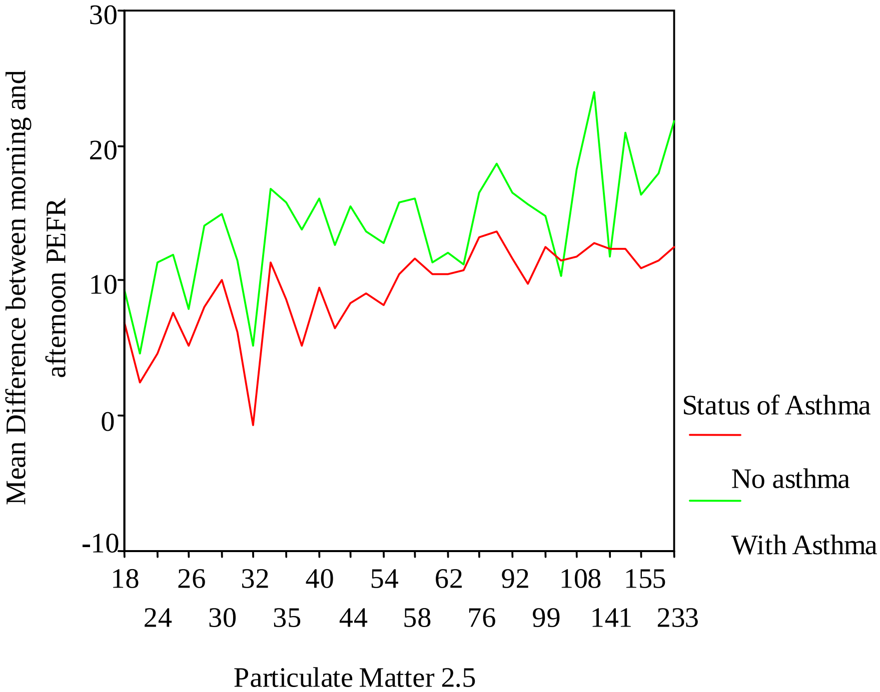

Figure 15: Relationship of difference between morning and afternoon PEFR with the $PM_{2.5}$ concentration by asthma status

3.2.4.2 The Relationship between PEFR and Daily Temperature:

Daily average temperature

Daily average temperature tends to be associated with morning PEFR and alone accounted for 29.1% variance of the morning PEFR (with an F change value of 1027.19; p= <0.001). When the asthma status was included in the model, there was a significant increase of adjusted R^2 value to 29.20% (with and F Change value of 9.48; p=0.002 for asthma status). Holding the asthma status constant, the increase in daily average temperature would increase the morning PEFR (Standardised coefficient beta =0.50) and an overall 13.26% of morning PEFR was observed from the lowest level of daily average temperature to it's highest level. The graph shows that the raise of morning PEFR was highest between the daily average temperature of 26 ^{0}C to 29 ^{0}C (Figure 16).

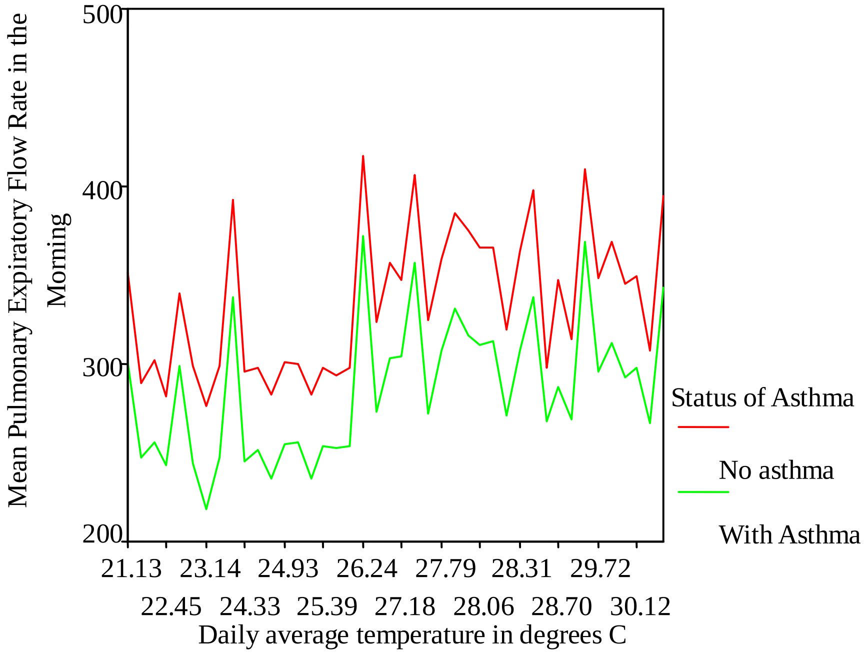

Figure 16: Relationship of morning PEFR with the daily average temperature by asthma status

There was a highly significant effect of daily average temperature on afternoon PEFR that alone accounted for 29.9% variance of the afternoon PEFR (with an F change value of 1069.09; p= <0.001). When the asthma status was included in the model, there was a significant increase in adjusted R^2 value to 30.00% (with and F Change value of 8.80; p=0.003 for asthma status).

Afternoon PEFR increased with the increase of daily average temperature in both the groups and an overall rise of 14.44% from its lowest to the highest level was observed (Standardised coefficient beta =0.46). Similar to the morning PEFR, there was higher rise of afternoon PEFR between the daily average temperature of 26 ^{0}C to 29 ^{0}C (Figure 17).

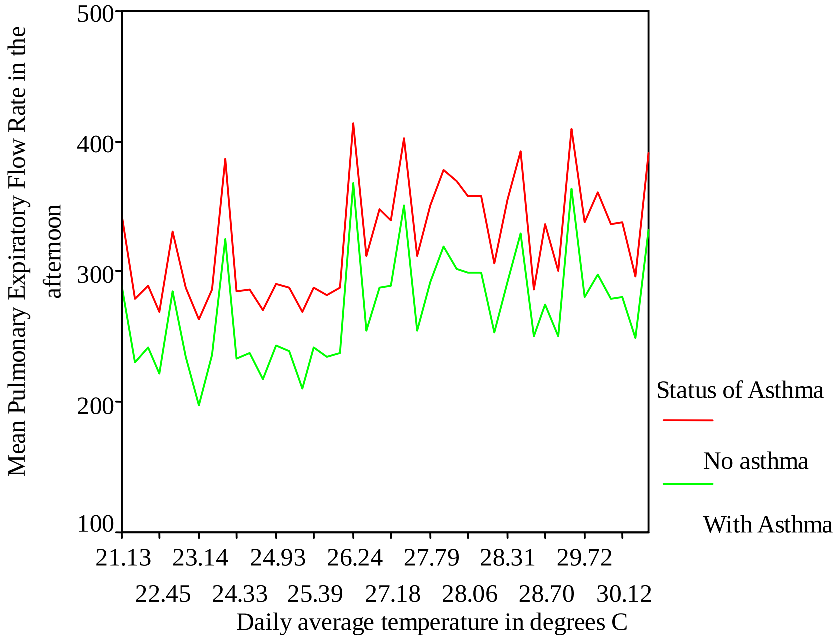

Figure 17: Relationship of afternoon PEFR with the daily average temperature by asthma status

Daily average temperature had significant effect on the difference between morning and afternoon PEFR but it accounted for only 4.30% variance of the morning PEFR (with an F change value of 112.25; p= <0.001). There was no significant effect of asthma status on the difference PEFR. The difference between morning and afternoon PEFR was 11.22 L/min on the coldest day of the data collection and it was reduced to 9.11 L/min on the warmest day (18.81% reduction). The reduction was marked within the daily average temperature of 26 ^{0}C to 29 ^{0}C (Figure 18).

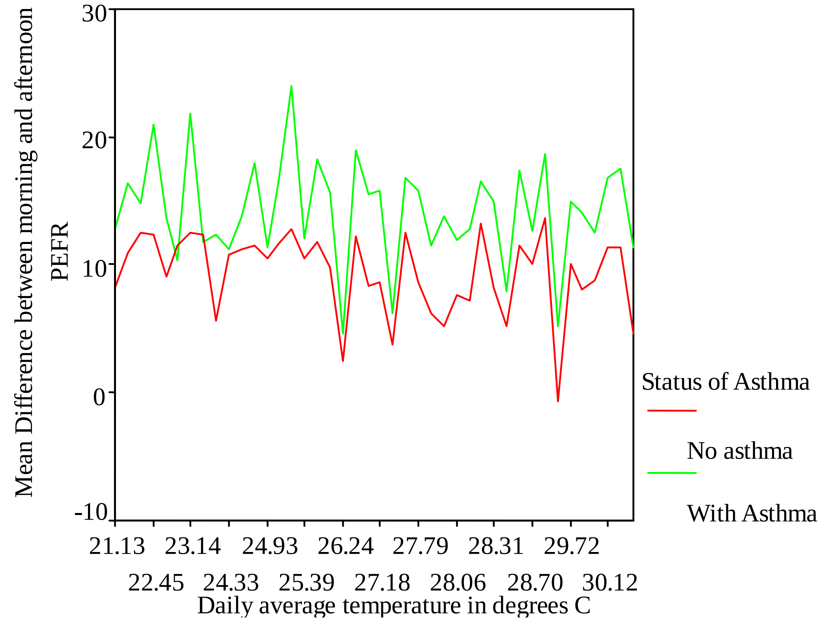

Figure 18: Relationship of difference between morning and afternoon PEFR with the daily average temperature by asthma status

<u>Daily minimum temperature</u>

There was highly significant effect of daily minimum temperature on morning PEFR that alone accounted for 36.30% variance of the morning PEFR (with an F change value of 1064.97; p= <0.001). The asthma status of the student had no significant explanatory capacity on morning PEFR, when included in the model with the daily minimum temperature.

The analyses indicated that an increase of daily minimum temperature, while holding the asthma status constant, was associated with an increase in the morning PEFR (Standardised coefficient beta =0.70). The colder days were associated with a lower morning PEFR than the warmer days in both the groups. There was an overall 23.53% increase of morning PEFR from the lowest to the highest level of daily minimum temperature (Figure 19).

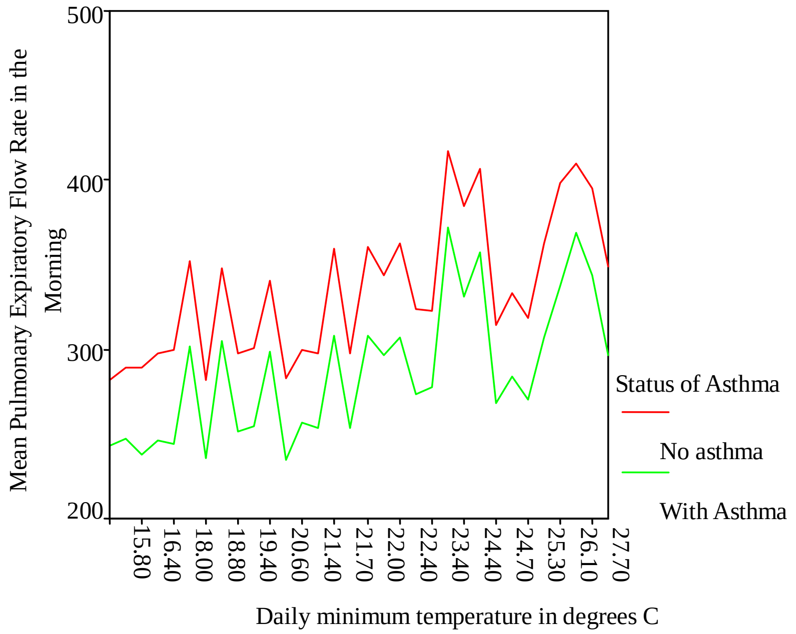

Figure 19: Relationship of morning PEFR with the daily minimum temperature by asthma status

There was highly significant effect of daily minimum temperature on afternoon PEFR that alone accounted for 37.30% of the variance in the morning PEFR (with an F change value of 1112.12; p= <0.001). The asthma status of the student had no significant explanatory capacity on afternoon PEFR, when included in the model with the daily minimum temperature.

Similar findings were observed for the afternoon PEFR where there was an overall 26.98% increase of afternoon PEFR from the coldest to the warmest days of data collection period (Figure 20).

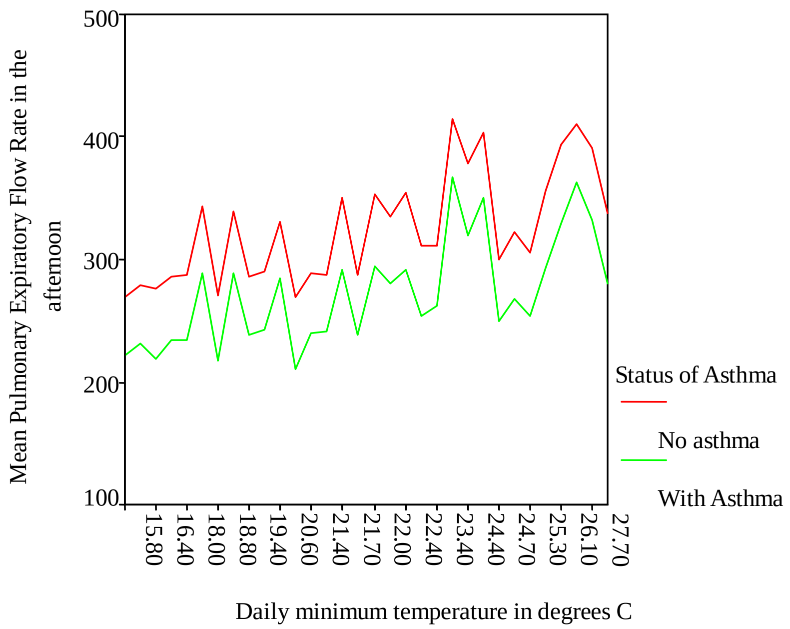

Figure 20: Relationship of afternoon PEFR with the daily minimum temperature by asthma status

There was highly significant effect of daily minimum temperature on the difference between morning and afternoon PEFR but it accounted for only 5.00% of the variance of the morning PEFR (with an F change value of 98.72; p= <0.001). There was no significant effect of asthma status on the difference PEFR.

Figure 21 shows that the difference between morning PEFR and the afternoon PEFR followed the similar trend among the asthmatic and non-asthmatic groups and was higher during the cooler days. This difference was reduced by 21.67% from the coolest to the warmest day of data collection period (Figure 21).

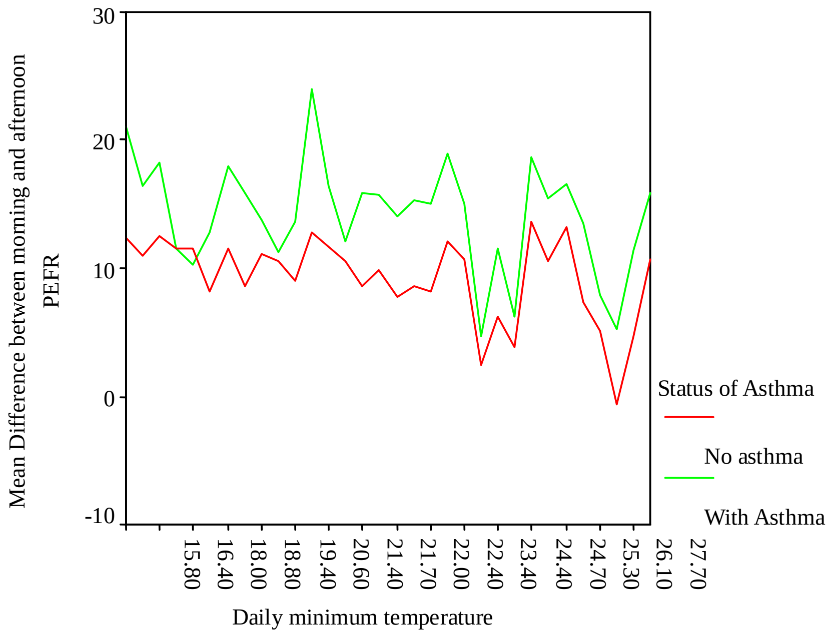

Figure 21: Relationship of difference between morning and afternoon PEFR with the daily minimum temperature by asthma status

<u>Daily maximum temperature</u>

There was a highly significant effect of daily maximum temperature on morning PEFR that alone accounted for 21.70% of the variance of the morning PEFR (with an F change value of 693.42; p= <0.001). When the asthma status was included in the model, there was a significant raise of adjusted R^2 value to 21.80% (with and F Change value of 7.20; p=0.007 for asthma status).

Standardised coefficient beta indicated that the increase in one standard deviation of daily maximum temperature while holding the asthma status constant was associated with a decrease in the morning PEFR by 2.55 standard deviations. Analyses also showed that the morning PEFR declined by 7.0 L/min from the lowest to the highest range of daily maximum temperature. Figure 22 indicates that the decline was mainly influenced by the 27-30 ^{0}C range of the daily maximum temperature.

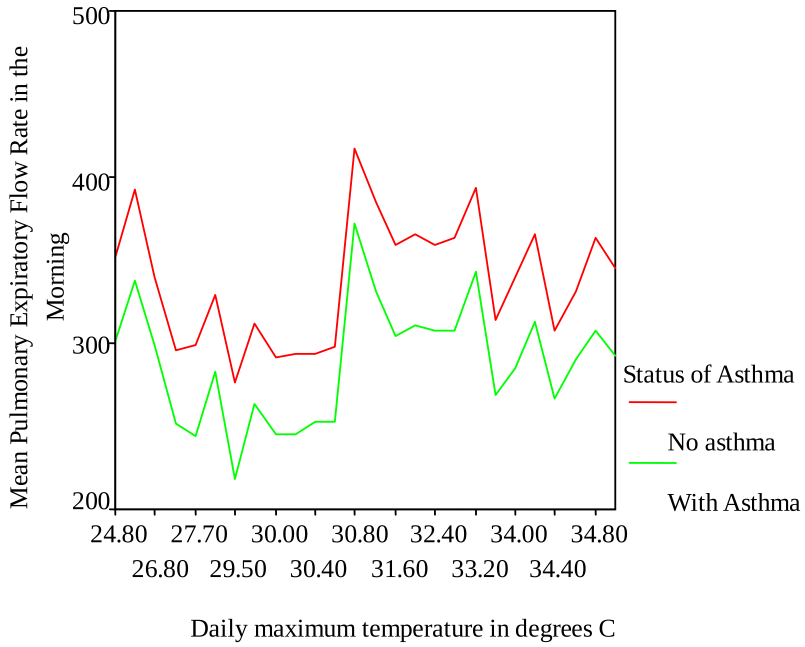

Figure 22: Relationship of morning PEFR with the daily maximum temperature by asthma status

There was highly significant effect of daily maximum temperature on afternoon PEFR that alone accounted for 22.5% of the variance of the afternoon PEFR (with an F change value of 729.16; p= <0.001). When the asthma status was included in the model, there was a significant increase in adjusted R^2 value to 22.60% (with and F Change value of 5.97; p=0.015 for asthma status).
Holding the asthma status constant, standardised coefficient beta indicated that the increase in one standard deviation of daily maximum temperature would decrease the afternoon PEFR by 2.43 standard deviations. There was only a 2.30% reduction of afternoon PEFR from the lowest to the highest range of daily maximum temperature (Figure 23).

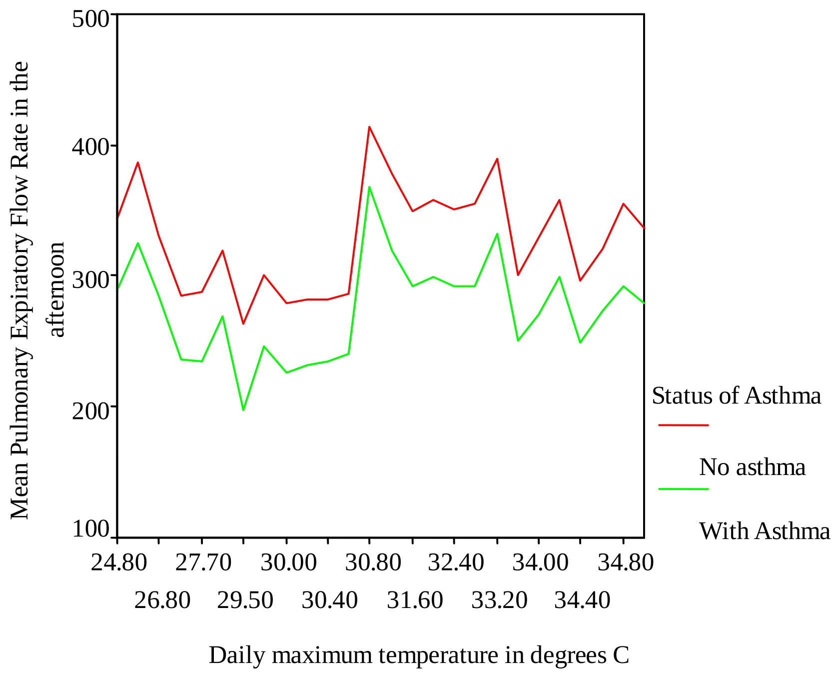

Figure 23: Relationship of afternoon PEFR with the daily maximum temperature by asthma status

There was a highly significant effect of daily maximum temperature on the difference between morning and afternoon PEFR but it accounted for only 3.90% of the variance of the difference PEFR (with an F change value of 102.24; p= <0.001). There was no significant effect of asthma status on the difference PEFR.

The difference between morning and afternoon PEFR was slightly raised (0.03%) with the increase of daily maximum temperature in both the groups of children (Figure 24).

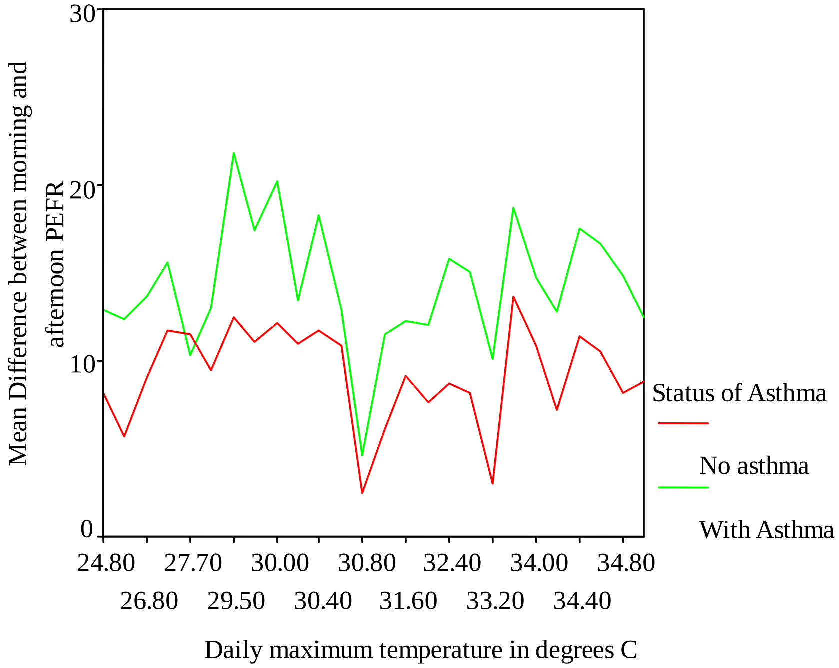

Figure 24: Relationship of difference between morning and afternoon PEFR with the daily maximum temperature by asthma status

3.2.4.3 Association between PEFR and Humidity

Daily Average Humidity

There was a highly significant effect of daily average humidity on morning PEFR that alone accounted for 19.10% of the variance of the morning PEFR (with an F change value of 1772.47; p= <0.001). When the asthma status was included in the model, there was a significant raise of adjusted R^2 value to 36.00% (with and F Change value of 1984.13; p=<0.001 for asthma status).

Keeping the asthma status constant, the increase of daily average humidity was associated with an increase in the morning PEFR (Standardised coefficient beta 0.44). Figure 25 shows that with an increase of daily average humidity from about 60% to 90%, there was around 40% increase of morning PEFR in both the groups of children.

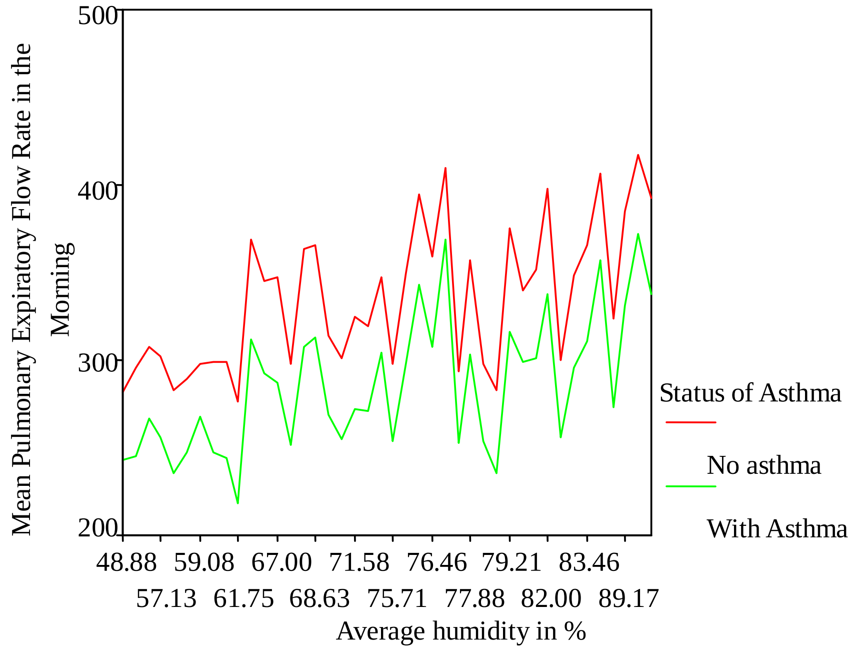

Figure 25: Relationship of morning PEFR with the daily average humidity by asthma status

Highly significant effects of daily average humidity were observed on afternoon PEFR that alone accounted for 19.10% of the variance of the afternoon PEFR (with an F change value of 1768.14; p= <0.001). The asthma status could significant increase the adjusted R^2 value to 37.30% (with and F Change value of 2184.79; p=<0.001 for asthma status).
Holding the asthma status constant, with an increase of daily average humidity, the afternoon PEFR also raised (Standardised coefficient beta =0.44). Figure 26 indicates that in both groups of children, there was about 47% increase of afternoon PEFR with the rise of daily average humidity from 60% to 90%.

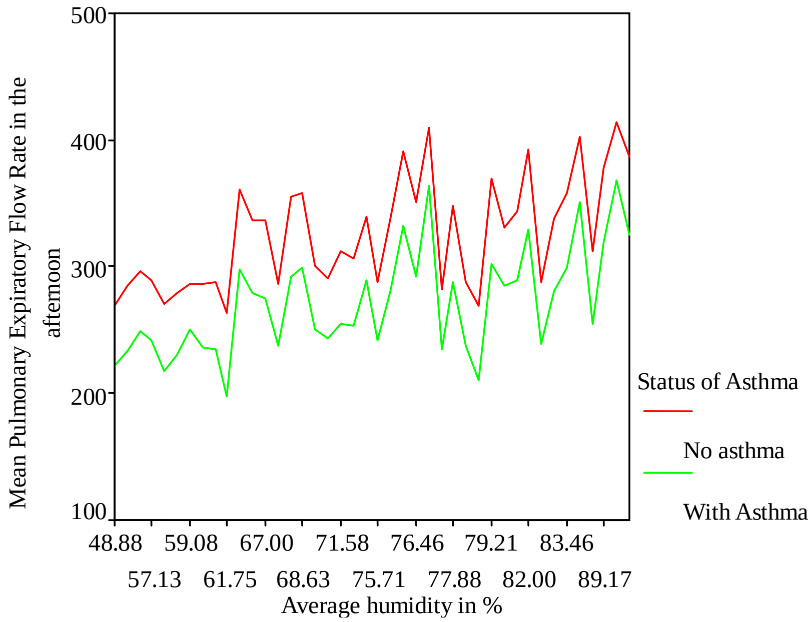

Figure 26: Relationship of afternoon PEFR with the daily average humidity by asthma status

There was a significant effect of daily average humidity on the difference between morning and afternoon PEFR but it accounted for only 1.50% of the variance (with an F change value of 102.91; p= <0.001). When the asthma status was included in the model, there was a significant increase in

adjusted R^2 value to 5.30% (with and F Change value of 307.61; p=<0.001 for asthma status).
In both the groups, the difference between the morning and afternoon PEFR was high with low level of humidity but 43.34% of this difference was minimized from the lowest to the highest range of daily average humidity of the data collection period (Figure 27).

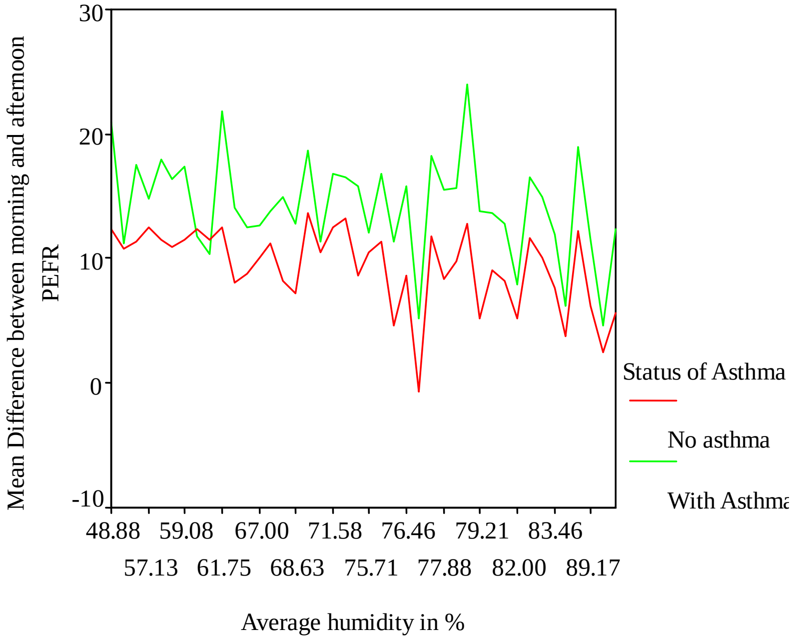

Figure 27: Relationship of difference between morning and afternoon PEFR with the daily average humidity by asthma status

Daily minimum humidity

There was a highly significant effect of daily minimum humidity on morning PEFR that alone accounted for 26.00% variance of the morning PEFR (with an F change value of 2634.02; p= <0.001). The asthma status could significantly contribute to the model and could raise the adjusted R^2 value to 42.90% (with and F Change value of 2225.56; p=<0.001 for asthma status).
Figure 28 shows that an increase in daily reading of minimum humidity from 17% to 78% was associated with an increase in morning PEFR of around 40% (Standardised coefficient beta =0.51).

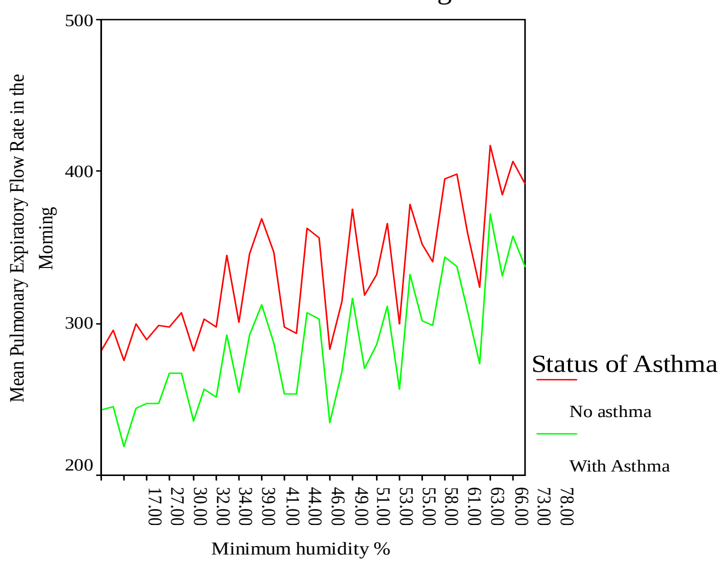

Figure 28: Relationship of morning PEFR with the daily minimum humidity by asthma status

There was a highly significant effect of daily minimum humidity on afternoon PEFR and was

alone accounted for 25.80% variance of the afternoon PEFR (with an F change value of 2611.35; p= <0.001). When the asthma status was included in the model, there was a significant increase in adjusted R^2 value to 44.10% (with and F Change value of 2451.10; p=<0.001 for asthma status).
An increase in minimum relative humidity from 17% to 78% was associated with an increase in afternoon PEFR of more than 47% in both the groups of children (Standardised coefficient beta =0.51) (Figure 29).

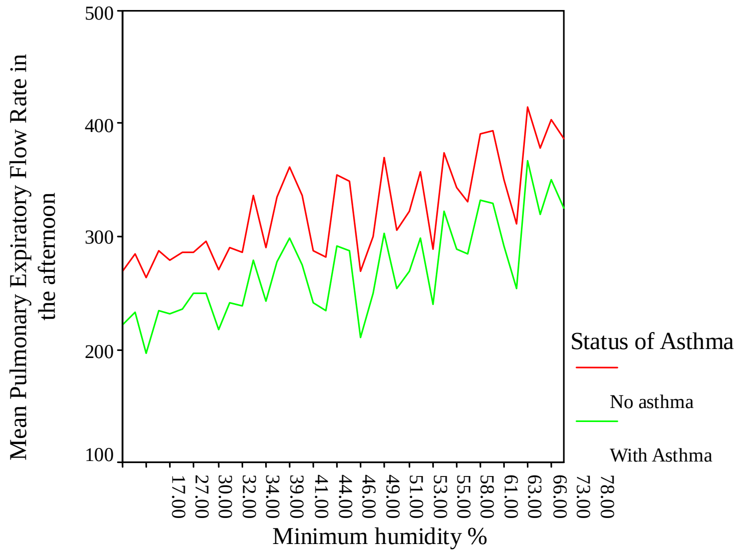

Figure 29: Relationship of afternoon PEFR with the daily minimum humidity by asthma status

There was a significant effect of daily minimum humidity on the difference between morning and afternoon PEFR but it accounted for only 1.90% of the variance of the difference PEFR (with an F change value of 142.01; p= <0.001). When the asthma status was included in the model, there was a significant increase in adjusted R^2 value to 5.70% (with and F Change value of 308.97; p=<0.001 for asthma status).

An increase in daily minimum humidity from 17% to 78% was associated with an overall decrease of 7.77 L/min (43.34%) in the difference between morning and afternoon PEFR in both the groups (Figure 30).

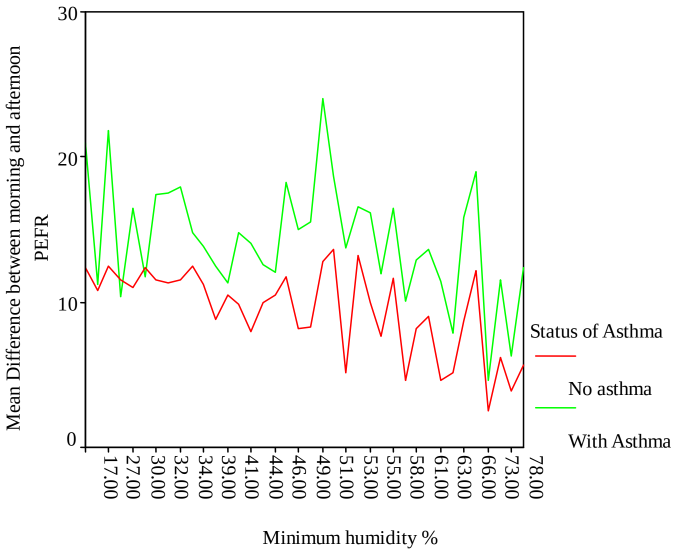

Figure 30: Relationship of difference between morning and afternoon PEFR with the daily minimum humidity by asthma status

Daily maximum humidity

A significant effect of daily maximum humidity was observed on morning PEFR that accounted for 2.80% of the variance (with an F change value of 212.83; p= <0.001). When the asthma status was included in the model, there was a significant substantial raise of adjusted R^2 value to 19.70% (with and F Change value of 1579.95; p=<0.001 for asthma status).

With a 17% increase in daily maximum humidity, there was more than 25% increase of morning PEFR among the students of both the groups (Figure 31).

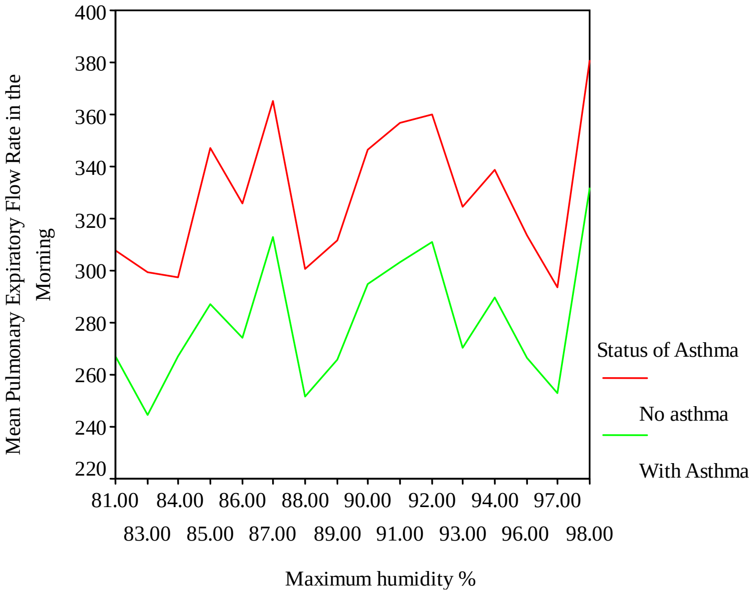

Figure 31: Relationship of morning PEFR with the daily maximum humidity by asthma status

There was a significant effect of daily maximum humidity on afternoon PEFR that alone accounted for 2.80% variance of the afternoon PEFR (with an F change value of 214.47; p= <0.001). The asthma status could significantly increase the adjusted R^2 value to 21.00% (with and F Change value of 1733.72; p=<0.001 for asthma status).

Holding the asthma status constant, the increase of daily maximum humidity was associated with an increase in the afternoon PEFR (standardised coefficient beta =0.17). With a 17% relative rise of daily maximum humidity, there was nearly 30% increase of afternoon PEFR in both the groups (Figure 32).

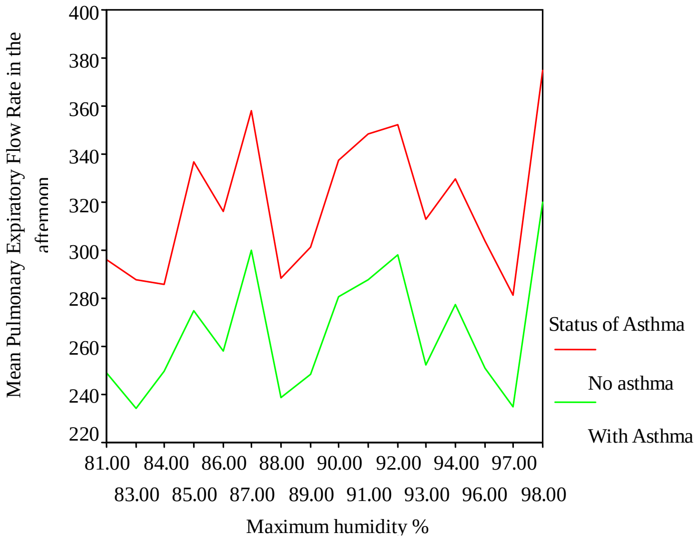

Figure 32: Relationship of afternoon PEFR with the daily maximum humidity by asthma status

Significant effects of daily maximum humidity were observed on the difference between morning and afternoon PEFR but they accounted for only 0.30% variance of the difference PEFR (with an F change value of 18.98; p= <0.001). When the asthma status was included in the model, there was a significant increase in adjusted R^2 value to 4.10% (with and F Change value of 303.68; p=<0.001 for asthma status).

With the lowest range of maximum humidity, the difference between the morning and afternoon PEFR was 15.33 L/min among the students of both the groups but this difference was reduced to 9.5 L/min (38.04% reduction) at the highest level of humidity (Figure 33).

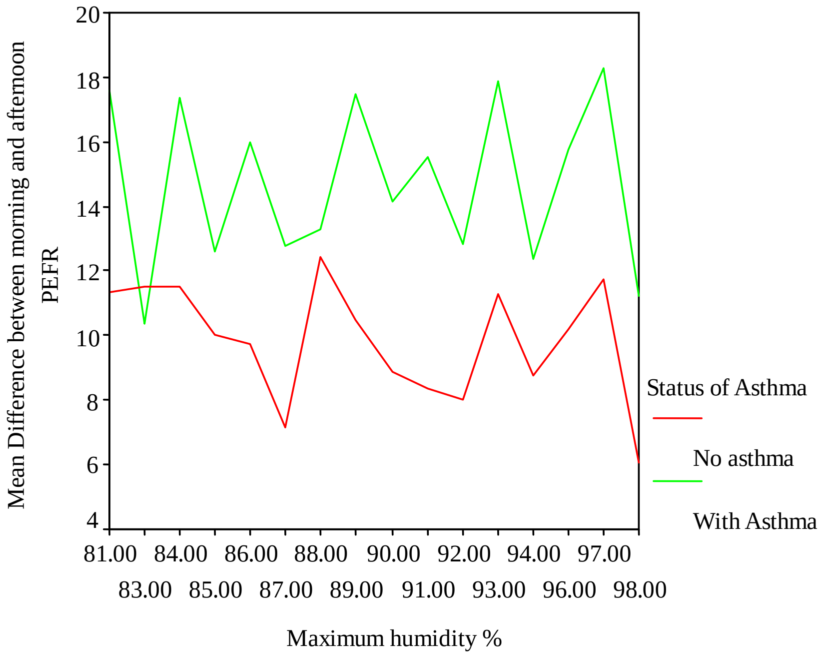

Figure 33: Relationship of difference between morning and afternoon PEFR with the daily maximum humidity by asthma status

3.2.5 Seasonal Variation of PEFR and PM10 PM2.5

The concentration of PM_{10} varies from dry season to wet season with a higher mean of 104.04 µg/m^3 in dry season than wet season (t=71.29, p=<.001). The concentration of $PM_{2.5}$ was also high during dry season with a mean value of 115.5 g/m^3 whereas it was only 40.9 µg/m^3 during the wet season (t=771.98, p=<.001).

When the relationship of morning PEFR was explored with the seasonal variation it was observed that the morning PEFR was significantly higher in the wet season than the dry season (mean difference= 62.90 L/m) (t=61.91, p=<.001). A similar relationship was observed for afternoon PEFR with a mean difference of 65.57L/m (t=60.39, p=<.001).

The difference between morning and afternoon PEFR also significantly varies between dry and wet season where the value was 2.67L/m higher in the dry season than the wet season (t=9.38, p=<.001). The difference between the morning and afternoon PEFR of the non-asthmatic patients decreased during the wet season. The decrease of PEFR difference (morning to afternoon PEFR) from wet season to dry season significantly varies among the non asthmatic and asthmatic patients.

The difference between morning and afternoon PEFR decreases from dry to wet season in both asthmatic and non asthmatic group, however, the extent of this decrease is more pronounced among the non-asthmatic group and is also highly statistically significant (F=40.18 and P=<001).

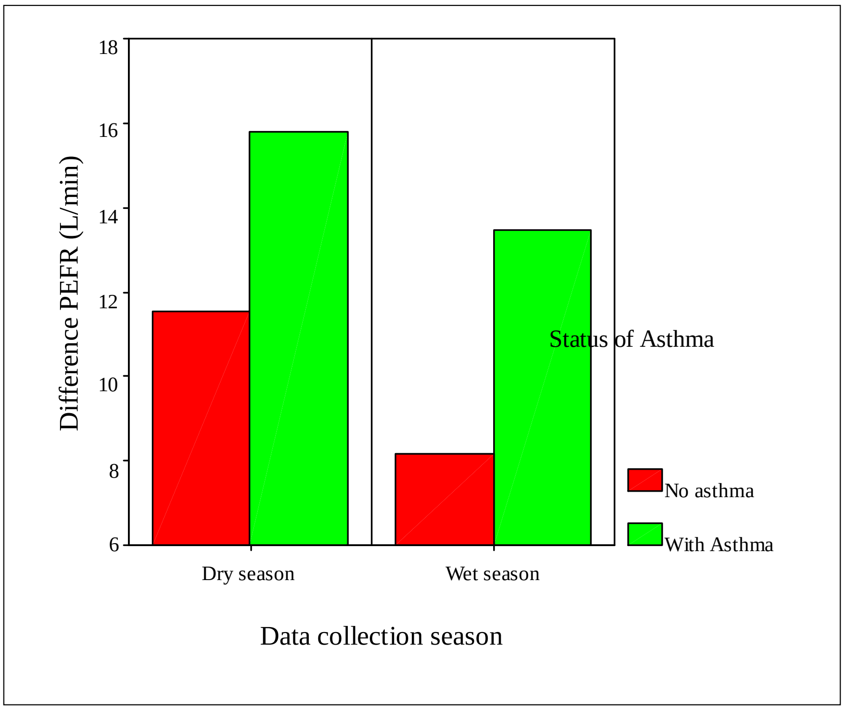

Fig 34: Seasonal variation of difference between morning and afternoon PEFR among the asthmatic and non-asthmatic students

3.3 Frequency of Respiratory problems and Expenditure for respiratory problems

Among the 180 participants who participated in the main study 88.3% (159) responded to the queries regarding frequency of respiratory problems suffered by the child during the past year, number of days of absence from school and cost involved for the problem. Response rate for non asthmatic children was 91.7% while that for asthmatic children was 86.7% (Table 16).

Table 16: Response to queries on episodes of respiratory problems of the child in last year

Respiratory problem	**Response to queries on episodes of respiratory problems of the child within last year**		**Total**
	No	Yes	
Non-asthmatic	5 (8.3%)	55 (91.7%)	60
Asthmatic	16 (13.3%)	104 (86.7%)	120
Total	21 (11.7%)	159 (88.3%)	180

The number of episodes of respiratory problem amongst the asthmatic children was 2.51 (±2.18) and significantly higher (t=-4.953, df157; $p<0.001$) than among the non asthmatic children with 1.18 (±1.20) episodes. Similarly school absenteeism was significantly higher ($p<0.001$) among asthmatic children (11.53±9.63 days) than among the non asthmatic children (3.35±3.85 days).

No statistically significant difference between the groups was detected in terms of expenditure as doctor's fee ($p=0.183$) and expenditure for transportation ($p=0.464$). But the expenditure for medicines was significantly higher ($p<0.001$) for asthmatic children Tk3276.36 (±2539.29) than for non asthmatic children Tk1086.54 (±1694.47) (Table 17).

Table 17: Respiratory Problems, Duration and Expenditure

Respiratory Problems with Duration and Expenditure	Status of Asthma	Mean (±SD)	Min	Max	Significance
No of episodes of respiratory problems in last year	No asthma (55)	1.18 (±1.20)	0	5	t=-4.953, df157; p<0.001
	With Asthma (104)	2.51 (±2.18)	0	10	
Days of absence in school for these problems	No asthma (55)	3.35 (±3.85)	0	10	t=-7.597, df157; p<0.001
	With Asthma (104)	11.53 (±9.63)	0	36	
Total taka spend for doctor's fee for these problem	No asthma (55)	585.45 (±1029.41)	0.00	5000.00	t=-1.338, df157; p= 0.183
	With Asthma (104)	830.29 (±1131.08)	0.00	5000.00	
Total taka spend for medicine for these problem	No asthma (55)	1086.54 (±1694.47)	0.00	10000.00	t=-6.480, df157; p<0.001
	With Asthma (104)	3276.36 (±2539.29)	0.00	9763.00	
Total taka spend for transportation for these problem	No asthma (55)	208.54 (±434.69)	0.00	2000.00	t=-0.734, df157; p= 0.464
	With Asthma (104)	260.97 (±424.65)	0.00	2000.00	

Table 18: Lab Expenditure for Asthma Status

Investigation Cost	Status of Asthma	Mean (±SD)	Min	Max	Significance
Total taka spend for lab investigation for respiratory problems	No asthma (8)	1266.25 (±916.42)	450.00	2500.00	t=-0.309, df34; p<0.759
	With Asthma (28)	1364.29 (±755.70)	450.00	2500.00	

The cost involved for laboratory investigation was significantly higher (p<0.001) among asthmatic children (1364.29 ±755.70) than among non asthmatic children (1266.25 ±916.42) (Table 18)

Table 19: Extra Expenditure for the Respiratory Problems in regards to Asthma Status

Status of Asthma	Spending any other money for extra expenditure in regards to Asthma		Total
	No	Yes	
No asthma	46 (83.6%)	9 (16.4%)	55 (100.0%)
With Asthma	89 (85.6%)	15 (14.4%)	104 (100.0%)
Total	135 (84.9%)	24 (15.1%)	159 (100.0%)

Only 15.1% of the 159 participants had spent money for purposes other than doctor's fee, medicine cost and transportation. Higher proportions of non asthmatics (16.4%) than asthmatics (14.4%) had such expenditures (Table 18).

Table 20: Total Expenditure for respiratory problem by Asthma Status

Respiratory Problems	Mean (±SD)-Taka	Min	Max	Significance
No asthma (35)	3478.86 (±4171.34)	200.00	19000.00	F=-21.456, p<0.001
With Asthma (73)	6918.68 (±3315.18)	1411.00	17200.00	
Total (108)	5803.43(±3942.15)	200.00	19000.00	

Total expenditure for respiratory problems experienced by study participants during the past year was found to be significantly higher ($p<0.001$) for asthmatic children (Tk 6918.68 ±3315.18) than for non asthmatic children (Tk 3478.86 ±4171.34) (Table 20).

Chapter 4 Discussion

In lieu with the increasing trend of urbanization and increase in number of motorized vehicles on the roads of Dhaka, Bangladesh the air quality has been deteriorating over the years. To explore the health effects of air pollution this study was carried out to seek to understand the relationship between changes in lung function (PEFR) in children with varying concentrations of particulates in air (PM_{10} and $PM_{2.5}$). A cohort of 1618 students of classes V to IX participated in a baseline survey by returning a completed questionnaire provided to the students to assess their respiratory health and possible relevant exposures such as type of fuel used for cooking, smoker in the household, etc. The questionnaire survey was followed by a clinical examination. From the cohort 368 asthmatic subjects were identified. Among these asthmatics 210 students were identified who did not have a smoker in the household. From among them, of the 197 asthmatic subjects, who consented to undertake self Peak Expiratory Flowmetry test twice each day for six weeks, 120 asthma students were selected randomly as participant of the Health Impact Study. From the available non-asthma students who agreed to participate, 60 healthy subjects were selected as controls.

Age of the study participants ranged from 9 to 16 years. The groups were found to be comparable ($p>0.05$) in terms of gender (table 11), age (table 13) academic level (table 13). No significant differences between the asthmatic and non-asthmatic groups with respect to anthropometric measurements was found (table 14). Thus it could be concluded that the data set of Asthmatic and Non-asthmatic was homogenous with respect to the socio- demographic and anthropometric variables.

The 42 days of data collection spanned over the last week of February; 2nd, 3rd & 4th weeks of April; 1st & 2nd week of June and 7 days' of November 2007. The 24 hour mean PM_{10} concentrations levels on the days of data collection ranged from 38 to 385 $\mu g/m^3$ with a mean value of 119.12 (±70.26) $\mu g/m^3$. Within the 42 days of data collection period, the PM_{10} concentration exceeded the Bangladesh standard daily average [50] value of 150 $\mu g/m^3$ on 10 days of data collection. These results are similar to a study conducted on Bangkok children to assess the impact of PM_{10} pollution on them[51], where it was observed that the mean PM_{10} concentration was 111 $\mu g/m^3$ and violation of the 24-hr standard (120 $\mu g/m^3$) occurred on 14 days out of the total 31 days.

The 24 hour mean $PM_{2.5}$ concentrations levels on the days of data collection ranged from 18 to 233 $\mu g/m^3$ with a mean value of 67.57 (±47.82) $\mu g/m^3$, and if we consider the ambient particulate standard for Bangladesh[50], the concentration exceeded the Bangladesh standard-daily average value of 65 $\mu g/m^3$ on 13 days of the data collection period. Thus the PM_{10} and $PM_{2.5}$ concentrations in Dhaka, as observed in this study exceeded relevant health standards and can be expected to produce significant adverse risks for respiratory health.

At the beginning of the study, the Peak Expiratory Flow Rate in the Morning (PEFR-M) ranged from 150 L/min to 320 L/min (mean and SD was 237.72±34.80 L/min). Higher level of morning PEFR (329 L/min) was observed in a study conducted in Nederland[52] with the children aged 7-11 years of age. In this study, the afternoon Peak Expiratory Flow Rate (PEFR-A) was little lower in the range of 150 L/min to 310 L/min (218.44 ± 38.98 L/min). The PEFR-M was lower among the asthmatic students compared to the non-asthmatic students and this symptom was more intense in the afternoon but in a study on 6-14 years children of Sokolov, Czech Republic, PEFR was high in the afternoon compared to the morning reading[53]. The difference between the studies could be because of much lower levels of PM concentration and the daily average temperature in Czech Republic compared to Bangladesh.

Within subject variation in the morning PEFR over the study period of time was found to be significant ($F= 307.93$; $p=<0.001$). And the morning PEFR ($F= 2.20$; $p=<0.05$) differed significantly depending on asthma status. The variation of morning PEFR among the asthmatic and non-asthmatic groups of students was consistently different over the study period of time ($F= 149.15$; $p=<0.001$).

A significant within subject variation in the afternoon PEFR over the study period of time (F= 333.72; p=<0.001) was detected. The afternoon PEFR differed significantly (F= 2.67; p=<0.01) depending on asthma status. The variation of afternoon PEFR among the asthmatic and non-asthmatic groups of students was consistently different over the study period of time (F= 176.64; p=<0.001).

A study in Nederland[52] showed that the children with symptoms of asthma are more susceptible to the effect of particulate air pollution like PM_{10}, black smoke (BS), SO_2 and NO_2 than children without symptoms. The study result revealed decrements in evening PEFR had a positive association with concentration of PM_{10}. Another study[54] in USA shows that a negative association between PEFR and PM_{10} for both asthmatic and non asthmatic samples of children but symptomatic children suffers the most. Similar association has been reported with PM_{10} in many studies [16, 54-58]. But in one study though it showed that effects of air pollution are larger among asthmatic than among other children but these adverse effects of air pollution were observed on morning PEFR but not on evening PEFR[58]. In terms of difference between morning and afternoon PEFR, a highly significant effect of asthma status was found and non-asthmatic students were found to have a significantly higher mean afternoon PEFR than the asthmatic students (F Change value =39.61; p=<0.001). A study[53] in Czech Republic showed a weaker association for PEFR in the morning than PEFR in the afternoon among the asthmatic children due to winter air pollution. A highly significant effect of PM_{10} concentration on the difference between morning and afternoon PEFR was detected and it accounted for 9.30% variance of the difference PEFR (with an F change value of 191.35; p= <0.001). When $PM_{2.5}$ concentration was taken into consideration a highly significant effect of asthma status of the respondent on the difference between morning and afternoon PEFR, where non-asthmatic students had a significantly higher mean afternoon PEFR than the asthmatic students (F Change value =52.23; p=<0.001). Moreover a highly significant effect of $PM_{2.5}$ concentration on the difference between morning and afternoon PEFR was detected and was it accounted for 7.20% variance of the difference PEFR (with an F change value of 145.78; p= <0.001). There was 35%-40% decrease of PEFR value with the increase of PM_{10} concentration and the difference between the morning and afternoon PEFR was raised by 350% with the rise of PM_{10} concentration from it's lowest to the highest level. Similar trend with little lower level (30%-35%) of decrease of PEFR reading was observed for the increase of $PM_{2.5}$ concentration. There was 120% increase of the difference between the morning and afternoon PEFR with the rise of $PM_{2.5}$ concentration. In Nederland, it was revealed from a study[52] that an increase of 83% in the number of subjects with a PEF response of that magnitude was associated with an increase in the mean PM_{10} concentration of 100 $\mu g/m^3$. A study in Finland[58] showed that morning PEFR decreased by 0.27% among the asthmatic children in the urban areas for a 10 $\mu g/m^3$ increase in daily mean PM_{10} concentration. In another study in Germany[59], a reduction of suspended particulates by 10-20 $\mu g/m^3$ was associated with a 20% reduction of total bronchial disease prevalence. So, it could be concluded from these study findings that an increase in particulate matter concentration reduces the PEFR, hence increases the respiratory health risks, which was also reflected in the present study results.

It appears from the findings of the current study concentrations of PM_{10} and $PM_{2.5}$ in air adversely affects the PEFR more in asthmatics than in non asthmatics and the deterioration of PEFR in the evening compared to that in the morning could be explained by possible increase in particulate matter (both PM_{10} and $PM_{2.5}$) concentrations in air due to introduction of new particulates as well of re-suspension of the precipitated particulates with increase of human activity and vehicular movements. A number of studies indicate an adverse effect of particulate air pollution that is greater for $PM_{2.5}$ than PM_{10} especially for PEFR [60], though the present study did not explore any such differentiation between PM_{10} and $PM_{2.5}$. A study on Bangkok children (with or without asthma) showed that there was adverse effect of elevated PM_{10} concentration[51]. When a comparison was made between 12-15 year old children lived in high and low air pollution exposure areas of Indonesia[61], it was observed that children has a lower PEFR in higher air pollutant level area than those who lived in lower air pollution area.

In the current study there was about a 13%-18% increase of PEFR with the rise of daily average temperature and a 21%-27% increase with increase across the range of daily minimum temperatures. The effect was even more intense in case of humidity where there was more than 40% increase of PEFR with the rise of humidity from its lowest to the highest level in this study. Moreover a decline of differences between PEFR-M and PEFR-A with increasing of temperature and humidity as observed in the study is consistent with the fact that with increasing humidity it is possible that particulates adsorb moisture resulting in increased particulate mass thereby increasing the tendency of the particulates to precipitate rather than remain suspended in air.

It was observed that the total per capita expenditure for respiratory problems experienced by study participants during the past 12 months was 5803.43 Taka and it was significantly higher ($p<0.001$) for asthmatic children (Taka 6918.68) than for non asthmatic children (3478.86). An estimate of asthma patients in Bangladesh showed that seven million people are suffering from asthma including four million children of the country[62]. Based on that estimate, around 27.67 billion taka (US$ 394.86 million) is needed for the treatment of four million children. This expenditure could be substantially reduced with greater control of air pollution of the country. This estimate resembles with the findings of another study conducted by Azad AK, Jahan S and Sultana J of Khulna University, Bangladesh[63], where they have shown that around 20 billion taka is needed as the cost of chronic bronchitis. As a conservative estimate, there are about 2.37 million children living in Dhaka [62]. As the study was conducted in Dhaka city, so, another effort was made to estimate the treatment cost of asthmatic children of Dhaka city and it was calculated that around 1.22 billion taka was needed for the treatment of asthmatic children within one year which could be greatly minimized if the air pollution level could be reduced to a satisfactory level. It was observed that up to 10% of respiratory infections and disease in Bangladesh has been attributed to urban air pollution for which ambient air PM_{10} concentration has been implicated[64]. This study has revealed that PM_{10} and $PM_{2.5}$ concentrations of ambient air has a significant adverse bearing not only on the health of the children whether asthmatic or non asthmatic but also has an economic bearing on the families of affected children. It has been estimated that the reduction of PM_{10} concentration by 20% - 80% could allow for avoidance of 1,200 – 3,500 deaths, 80 – 235 million cases of sickness and a saving of US$ 169 – 492 million equivalent to 0.34 – 1.0 % of GNI[64]**.** Thus measures to reduce particulate matter emissions by stringent ambient air quality control measures could not only contribute in reducing individual sufferings but also contribute towards attaining Millennium Development Goals in health as well as poverty alleviation sectors.

A limitation of this study that is shared by all other such studies is that the ambient pollution concentrations may not adequately reflect exposures of individual subjects. Since most of a child's time during a school year is spent indoors, and since indoor pollutant concentrations, and particulates, can be markedly different from those outdoors, the outdoor concentrations measured in this study may not have been valid estimates of each subject's exposure. Another weakness of this study is that PEFR is primarily a measure of large airways function. Thus, to the degree to which the anticipated effect is due to small airways abnormalities, PEFR may not be a sensitive measure of pulmonary function decrement due to air pollution. Despite these limitations the findings of the current study is indicative that air pollution especially the particulates (both PM_{10} and $PM_{2.5}$) are adversely affecting the respiratory health of the children in Dhaka, Bangladesh, and those having adverse lung conditions like asthma are being more affected than healthy children.

Chapter 5 Conclusions and Recommendations

5.1 Conclusions

In most of the days of the year, the pollutants load, both PM_{10} and $PM_{2.5}$, in the air and the humidity level of Dhaka, Bangladesh is quite high. These factors are detrimentally affecting the respiratory health of the children of Dhaka city and in turn have great adverse economical implication both at the family and the national level.

5.2 Recommendations

a. Recognise air pollution as an important cause of morbidity and mortality and also the economic cost to nation.
b. Identify the major causes and sources of air pollution especially the particulate matter.
c. Stringent enforcement of air pollution control measures.
d. Create planned green belt in Dhaka city, especially around the schools.
e. Strengthen the school health program with especial emphasis on respiratory health problems.
f. Conduct further study to identify the specific sub fraction(s) of PM which are mostly contributing towards adverse effects on respiratory health.

Appendix

APPENDIX 1

Title: Assessment of impact of air pollution among the school children in selected schools of Dhaka city. (Baseline study questionnaire)

Department of Environment, Industrial Health Division of DGHS, and Occupational and Environmental Health Department of NIPSOM is jointly conducting a research on impact of air pollution among the school children in selected schools of Dhaka City. For the research few of the information on the relevant issues is necessary and which we would like to collect from you. Your cooperation in this regard will definitely enable us to conduct the research smoothly. All the information will be used for research purpose only and will be regarded as confidential. Thanks for extending your hands.

Serial No. Date:

1. **Name of school:**
2. **Time of interview: Commencement- Ending:**
3. **Name of child:**
4. **Parent/Guardian's name:**
5. **Parent's educational level:**
6. **Age of the child (in complete years):**
7. **Date of birth:**
8. **Gender: Male / Female 9. Religion: Islam / Hindu / Buddism/ Christainity**

10. Asthma/ Respiratory problem related information.

10.1. Did your child ever experience asthma like/ whistling sound in the chest?
1. Yes 2. No If No go to question no 10.6

10.2. In past 12 months did your child ever experience asthma like/ whistling sound in the chest?
1. Yes 2. No If No go to question no 10.6

10.3. Frequency of asthma like/ whistling sound in the chest in last one year?
1. None 2. 1 to 3 times 3. 4 to 12 times 4. >12 times.

10.4. In past 12 months, did asthma like symptom / respiratory symptom cause sleep disturbance?
1. Never 2. Once a week. 3. More than once a week.

10.5. In last one year did asthma like/ whistling sound aggravate to that extent that hampered the child's speech wile breathing?
1. Yes 2. No.

10.6. Did your child ever experience asthma/wheeze?
1. Yes 2. No.

10.7. Did your child ever experience asthma/wheeze during exercise or playing in last one year?
1. Yes 2. No.

10.8. Did your child suffer from cold/ or non febrile dry cough at night in last one year?
1. Yes 2. No.

11. The following questions are about problems which occur when your child did not have a cold or flu:

11.1. Did your child ever suffer from sneezing, running nose or nasal blockade when he /she did not have a cold or flu?
1. Yes 2. No. If you answered "No" go to question 11.6.

11.2. In past 12 months, did your child suffer from sneezing, running nose or nasal blockade when he /she did not have a cold or flu?

1. Yes 2. No. If you answered “No” go to question 11.6.

11.3. In last one year did the child have eye itching/ watering along with nasal ailments

1. Yes 2. No. If you answered “No” go to question 11.6.

11.4. In which month did you experience the problem

January February March April May June July August
September October November December

11.5. Did the nasal problem of your child cause difficulty /hamper of his/her study and play in last one year?

1. Yes 2. No.

11.6. Did your child ever suffer from hay fever (allergic fever)?

1. Yes 2. No.

12. Did your child ever suffer from urticaria which lasted three to six months?

1. Yes 2. No. If No go to question 13.0.

12.1. Was the rash also present in other parts of the body like- front of the elbow,back of the knee, back of the ankle, around the neck or beneath the ear or eye?

1. Yes 2. No.

12.2. Did these rashes disappear spontaneously?

1. Yes 2. No.

12.3. Did this rash cause sleep disturbances in last one year?

1. Never 2. Less than once a week 3. More than once a week

13. Did your child ever suffer from eczema.

1. Yes 2. No.

14. Do any member of your household smoke?

1. Yes 2. No.

14.1 If any member of your household is a smoker, does he smoke indoor?

1. Yes 2. No.

APPENDIX 2

MEDICAL EXAMINATION CHECKLIST

ID No____________ Date___________

Name of school____

Name____

Age (in complete years) _____________ Gender: Male /Female

History of respiratory problem: ____

____

History of taking prophylactic drug (Ketotofen etc.):__________________________

General Health: ____

Height (in cm):

Weight (in kg):

Anemia: None Mild Moderate Severe.

Temperature: ____________ Normal Raised.

Pulse: /min.

Heart (List any abnormality detected):______________________________________

Lung (List any abnormality detected):______________________________________

Eye problem : None Redness of eye Other___________________

Skin rash: Absent Present Otherr__________________

Any other Problem____

Comment____

Signature of the Physician

APPENDIX 3

ID NO:

Title: Assessment of impact of air pollution among the school children in selected schools of Dhaka city.

Name of school   Name of student

Name of class   Gender   Male   /   Female

Age (in years)

Format for recording PEFR (2 weeks)

Date: / / 07 to / / 07	Date: / / 07 to / / 07

Day of week

PEFR	SAT		SUN		MON		TUES		WED		THUR	
	M	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**
720												
700												
680												
660												
640												
620												
600												
580												
560												
540												
520												
500												
480												
460												
440												
420												
400												
380												

Day of week

PEFR	SAT		SUN		MON		TUE		WED		THUR	
	M	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**
720												
700												
680												
660												
640												
620												
600												
580												
560												
540												
520												
500												
480												
460												
440												
420												
400												
380												

36
0
34
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32
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30
0
28
0
26
0
24
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22
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20
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18
0
16
0
14
0
12
0
10
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36
0
34
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32
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30
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28
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26
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24
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22
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20
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18
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16
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14
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12
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10
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