Malé Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effect for South Asia

Assessment of Impacts of Particulate Air Pollution on the Respiratory Health of Schoolchildren: Studies in Kathmandu and Islamabad

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This report has been prepared mostly based on the inputs from the following institutes and the following reports:

PakEPA and PMRC 2013, Final Report: Impacts of Particulate Air Pollution on the Respiratory Health of Schoolchildren in Pakistan. Pakistan Environmental Protection Agency, and Pakistan Medical Research Council, Islamabad, Pakistan.

NHRC and ICIMOD 2013, Assessment of Impacts of Particulate Air Pollutants on Respiratory Health of School Children in Kathmandu Valley. Nepal Health Research Council and International Center for Integrated Mountain Development, Kathmandu, Nepal.

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Executive Summary

Air quality in large cities is a major health and environmental concern in most countries around the world. As many of the largest cities in developing countries of the Asia-Pacific region have grown, so have emissions of air pollutants. Numerous studies have shown that particulate matter has the greatest impact of all common air pollutants on health (e.g. WHO, 2006, Lim et al, 2012). The World Health Organization (WHO) states that the higher the concentration of particles in air the greater the risk to human health especially risk of respiratory and cardiovascular diseases (WHO, 2006). Recent studies have identified fine particles called $PM_{2.5}$ (particles in air with a mean diameter of 2.5 micrometres or smaller) as being especially harmful because they may reach and persist in the alveolar region of the lungs causing long-term damage.

The WHO Global Burden of Disease identifies especially high health risk threats (Lim et al, 2012). In the large cities of developing countries of Asia where air pollution levels are the highest in the world, outdoor air pollution, mostly due to particulates ranked the sixth highest risk to health in South Asia where it contributed to 712,000 deaths in 2010. The analysis found that reducing the burden of disease attributable to air pollution in Asia will require substantial decreases in the high levels of particulate emissions to air.

Far more studies have been conducted in developed countries than in developing countries. Consequently information is needed to assess the impacts of the high concentrations of fine particles found in the large cities of developing countries in the Asia-Pacific region. This assessment helps to address the need for information on the effects of particles on human health in South Asian cities. It provides locally-gathered evidence to support actions by governments to control particulate emissions. These studies were conducted on the health of children, as the developing lungs of children are more vulnerable to the adverse effects of air pollution than adult lungs. Children are more susceptible to air pollution than adults because of higher ventilation rates and higher levels of physical activity. In addition, adverse impacts in childhood can continue throughout their adult lives with health, social and economic consequences.

The activities of the Malé Declaration have concentrated on enhancing the capacity of key regional stakeholders, including government agencies and health professionals, in this case in health impact assessment methods and helping them to access relevant information. It also provides scientific evidence from South Asian cities to support informed policy decisions on air pollution.

This document reports on two similar studies conducted in different locations (PakEPA and PMRC, 2013; NHRC and ICIMOD, 2013). The objectives of the studies were to assess the impacts of particulate air pollution on the respiratory health of children at selected schools in the Kathmandu Valley, Nepal; and Islamabad, Pakistan and measure the association between the concentration of $PM_{2.5}$ and lung function in selected schoolchildren in these cities.

The studies had two components: Phase 1: a baseline survey and Phase 2: a health impact assessment. Both used quantitative methods and were conducted in 2011 and 2012. The baseline survey used a structured questionnaire, developed for international use by the International Study of Asthma and Allergies in Childhood (ISAAC, 2000). A baseline survey was conducted based on 801 children in Kathmandu and 328 children in Islamabad. The response rate was 68% in Kathmandu and 66% in Islamabad. The results showed a relatively high level of respiratory illnesses not associated with colds or flu in about a third of children in all studies. Children with pre-existing lung diseases,

allergy or other related factors were excluded while a representative sample of the remaining students were selected for Phase 2 of the studies.

A correlational study was conducted in Phase 2 to assess the impact on respiratory health of fine particles in air ($PM_{2.5}$), among 137 students in Kathmandu and 132 children in Islamabad. Children of age between 10-15 years in Kathmandu were assessed daily, and children 9-14 years old in Islamabad were assessed weekly for their lung function by measuring morning peak expiratory flow rate (PEFR). Meanwhile, measurements of $PM_{2.5}$ were recorded daily in Kathmandu and weekly in Islamabad using particulate measurement instruments. Weather data were also recorded. PEFR and $PM_{2.5}$ measurements were conducted simultaneously on a daily basis for a total of 31 days in a period of 42 days in Kathmandu and for a total of six weeks in Islamabad.

Results in Kathmandu, Nepal

The study in Kathmandu contrasted an urban roadside school with a semi-urban school in a residential area. The 24 hour mean concentration of $PM_{2.5}$ was 203 $\mu g/m^3$ (±75) in the urban school and 137 $\mu g/m^3$ (±45) in the semi-urban school and the difference is statistically significant ($p = 0.04$). Measured concentrations usually exceeded the Nepal daily $PM_{2.5}$ standard of 40 $\mu g/m^3$.

The PEFR level of the students at the urban school was found to vary with the changing levels of $PM_{2.5}$ concentration which ranged between 100 $\mu g/m^3$ and nearly 340 $\mu g/m^3$ (Figure 1). The PEFR levels of younger (10-12 years) children seem to be correlating with the changes in $PM_{2.5}$ concentrations in the initial days and later days of the assessment. Also, the PEFR levels of female children also seem to be associated with the variation in daily $PM_{2.5}$ concentrations on a few days. The daily PEFR levels of 20 students at the semi urban school fell with increases in $PM_{2.5}$ concentrations and rose with decreases in $PM_{2.5}$ concentrations for most days in later half of the monitoring period except for few days.

Although the children at the two schools were of very similar age, 13 years old and only 0.3 years difference in mean ages, and similar gender balance between the two schools, the children at the urban school were statistically significantly taller (by 5.6 cm) and heavier (by 9.56 kg) than children attending the semi-urban school. The weight difference was 25% of the mean body weight of the children at the semi-urban school. Unfortunately these differences also affected lung capacity and hence PEFR. The mean PEFR was statistically significantly higher for the urban school ($p < 0.05$, 95% CI 39.61 – 126.17) than the semi-urban school probably because the children were taller and heavier and hence had larger lungs.

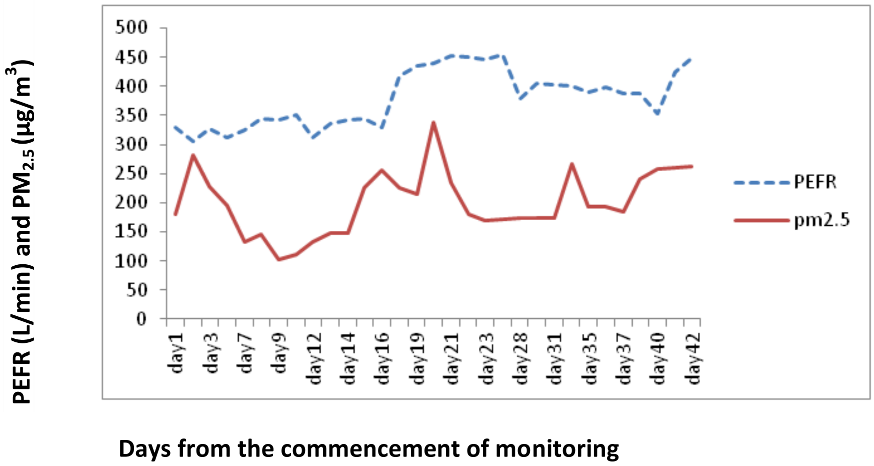

Figure 1: The relationship between peak expiratory flow rate (PEFR) (L/min) of 10 to 12 years old children and $PM_{2.5}$ (µg/m^3) concentration at the urban roadside school in Kathmandu.

Substantially more children were sampled from the urban roadside school (117 children) than the semi-urban school (20 children). The low numbers sampled at the semi-urban school prevented some statistical analyses and samples could not be pooled due to differences in the lung capacities of the two cohorts of children. It also appears that the data for the two variables, $PM_{2.5}$ and PEFR were not linear and this prevented regression analysis that may have linked them. The data showed some possible associations for some cohorts in some periods

It can be concluded that there may be an association between lung function with the concentration of $PM_{2.5}$ in the atmosphere. However, the relation could not be quantified statistically due to a small number of observations. The data showed some possible associations for some cohorts in some periods. The data may also suggest a lagged response, with PEFR possibly lagging $PM_{2.5}$ by 2 or 3 days in some periods.

The impact of $PM_{2.5}$ appeared to be more pronounced in the younger age groups and female children. Hence, any intervention needs to be focused to protect the most vulnerable groups from the pollutants. Overall the cross sectional component of this study conducted in the larger group as a baseline study before the impact assessment study hints that the burden of fine particles on the respiratory health could be huge and thus requires further investigation.

Results in Islamabad, Pakistan

The mean concentration of $PM_{2.5}$ in Islamabad was 81 µg/m^3 with a range of 25-142 µg/m^3. Measurements frequently exceeded the air quality standard in Pakistan of 40 µg/m^3. The peak expiratory flow rate (PEFR) ranged from 120 L/min to 420 L/min, with a mean of 287 L/min. There was no significant difference in PEFR among children of different schools.

Daily measurements were not taken in Islamabad. When possible associations between PEFR and $PM_{2.5}$ were investigated the study found that over the six weeks of monitoring of $PM_{2.5}$, its concentration started to increase in week 2 and kept on increasing till week 3 and then showed a decline. During this period a drop in PEFR was also observed which reverted to normal at week 4. However this association was not statistically significant.

Conclusions from the studies

Generally the results of these studies showed a surprisingly high level of respiratory illnesses not associated with colds or flu in about a third of children. Many studies have demonstrated increases in respiratory illness, asthma symptoms, medication use, pulmonary function decrements and hospital admissions associated with increases in particulate matter concentrations in air. However, few have been conducted where particulate matter concentrations are at the highest levels found in many large Asian cities such as Islamabad and Kathmandu, making these studies especially important.

The results of the studies show very high levels of particulate pollution in these cities, which consistently exceed the World Health Organization (WHO) Air Quality Guidelines for $PM_{2.5}$ of 25 $\mu g/m^3$ expressed as a 24 hour mean (WHO, 2006). The WHO recommended that countries with areas not meeting the 24-hour guideline values undertake immediate action to achieve these levels in the shortest possible time.

Differences between the studies may be related to the different concentrations of $PM_{2.5}$. Other methodological factors may also have been important. The finding of these studies emphasise the high cost of air pollution to the health of the community and the need to implement cost-effective measures to reduce emissions of health-damaging air pollutants.

Future Steps

The following future steps may be considered:

- Carefully selected technical studies of the health impacts of $PM_{2.5}$ should be established to inform policy, with an emphasis on analysis of social and economic impacts of air pollution on health to enable more thorough national and regional assessments of impacts, policy options, costs and health benefits of key options.

- A regional study should be conducted to quantify and assess the health costs and associated social and economic costs of ambient concentrations of health damaging $PM_{2.5}$ particles in Malé Declaration countries and reporting to the Governments. The aim is to enable more thorough national assessments of impacts, policy options, costs and health benefits of key options to reduce the burden of disease caused by air pollution. This could be conducted by a team nominated by governments of Malé Declaration countries using national data and working to an agreed common methodology.

Contents

List of Tables

List of Figures

Acknowledgements

This report is based on the following two reports of studies conducted in Islamabad and Kathmandu and uses much of the text of these documents.

PakEPA and PMRC 2013, Final Report: Impacts of Particulate Air Pollution on the Respiratory Health of Schoolchildren in Pakistan. Pakistan Environmental Protection Agency, and Pakistan Medical Research Council, Islamabad, Pakistan.

NHRC and ICIMOD 2013, Assessment of Impacts of Particulate Air Pollutants on Respiratory Health of School Children in Kathmandu Valley. Nepal Health Research Council and International Center for Integrated Mountain Development, Kathmandu, Nepal.

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List of Abbreviations

AQMS	Air Quality Monitoring Station
BS	Black Smoke
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Disease
ICIMOD	International Center for Integrated Mountain Development
ISAAC	International Study of Asthma and Allergies in Childhood
m^3	Cubic metres
MD	Mean Difference
$\mu g/m^3$	Microgramme per cubic metre of air
min	minute
MOEST	Ministry of Environment Science and Technology, Kathmandu
NAAQS	National Ambient Air Quality Standard
NHRC	Nepal Health Research Council , Kathmandu
Pak EPA	Pakistan Environmental Protection Agency, Islamabad
PEFR	Peak Expiratory Flow Rate
PM	Particulate Matter
$PM_{2.5}$	particles with a mean aerodynamic diameter of 2.5 micrometres or smaller
PM_{10}	particles with a mean aerodynamic diameter of 10 micrometres or smaller
PMRC	Pakistan Medical Research Council, Islamabad
SD	Standard Deviation
SEI	Stockholm Environment Institute
SIDA	Swedish International Development Cooperation Agency
UNEP	United Nations Environment Programme
RRC-AP	Regional Resource Centre for the Asia Pacific, Bangkok
WHO	World Health Organization

Background

The air quality in large cities is a major health and environmental concern in most countries. As the largest cities in many developing countries in the Asia-Pacific region have grown, so have emissions of air pollutants and air quality is one of the key health and environmental issues in the region. Numerous studies have shown that particles in air have the greatest impact of air pollution on health (UNEP, 2007). The World Health Organization states that the higher the concentration of particles in air the greater the risk to human health especially as they increase the risks of respiratory and cardiovascular diseases (WHO, 2006). The size of particles is important as it determines the extent of penetration of particles into the respiratory system. Recent studies have identified fine particles called $PM_{2.5}$ (particles with a mean aerodynamic diameter of 2.5 micrometres or smaller) as being especially harmful because they may reach and persist in the alveolar region of the lungs (McGranahan and Murray, 2002).

The WHO Global Burden of Disease identifies and ranks relative health risk levels in UN member countries (Lim et al, 2012). The large cities of developing countries of Asia have the highest air pollution levels in the world. Outdoor air pollution, mostly associated with particulates ranked sixth in importance among all health risks in South Asia where it contributed to 712,000 deaths in 2010 (Figure 2). The analysis found that reducing the burden of disease due to air pollution in Asia will require substantial decreases in the high levels of particulate matter pollution. Improved data have resulted in risk estimates substantially higher than assessed in previous analyses (Lim et al, 2012).

Far more studies have been conducted in developed countries than in developing countries. The concentrations of air pollutants in major cities are higher and the sources and chemical composition of particles in cities in developed and developing countries may differ. Consequently information is needed to assess the impacts of the much higher concentrations of PM_{10} (particles with a mean aerodynamic diameter of 10 micrometres or smaller) 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 (McGranahan and Murray, 2002). As $PM_{2.5}$ can penetrate into the alveolar regions of the 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 more exposure to particles than adults and are more susceptible because of higher ventilation rates and higher levels of physical activity. In addition adverse impacts in childhood can continue throughout their adult lives with considerable social and economic consequences.

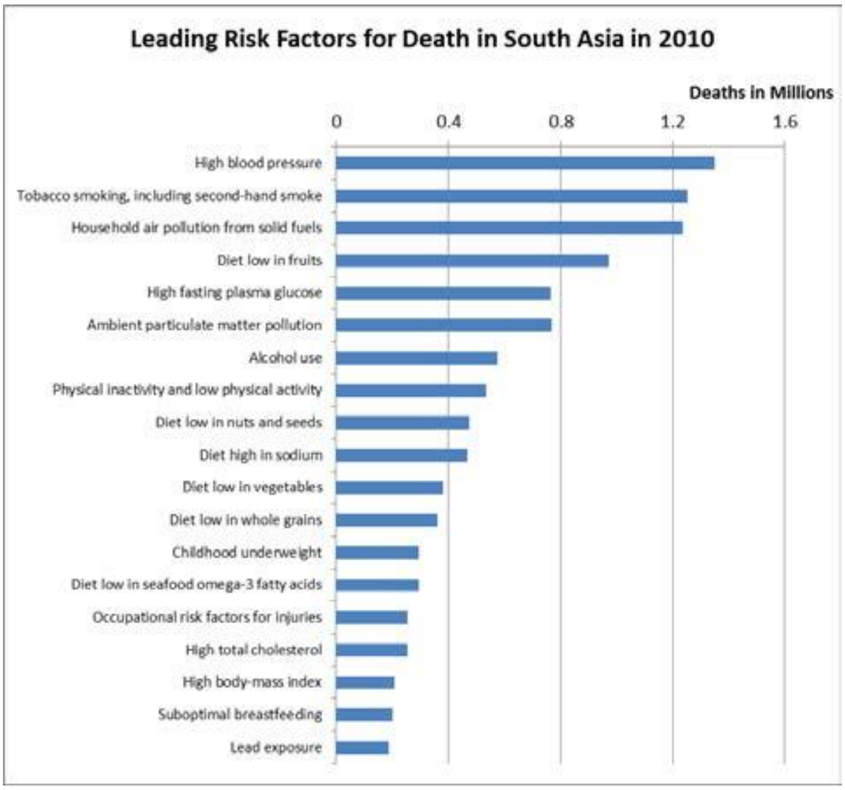

Figure 2: Number of Deaths Attributable to 20 Leading Risks in South Asia in 2010 (Lim et al, 2012)

This assessment helps 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, and it provides locally-gathered evidence to support actions by governments to control particulate emissions. Studies with similar designs to this have been successfully conducted in Bangkok, Dhaka and other Asian cities.

1.1 Objective of the study

The objective is to determine whether there is an association between daily mean $PM_{2.5}$ or PM_{10} concentrations and lung function in children in a chosen city, quantify the relationship and assess the scale and severity of impacts.

2. Assessment Methodology

2.1. Phase I: Baseline Study

2.1.1. Sampling

The baseline survey was conducted in enough schools with similar socioeconomic populations to obtain adequate questionnaire responses. Students of a suitable age (range from about 9-14 years) were participants for the baseline survey, an age for which it can be assumed and confirmed they are non-smokers yet old enough for them to reliably participate in the study. Ethics approval for the study was obtained.

2.1.2. Data Collection

A survey of the background of the children was completed to enable suitable children to be selected to participate in Phase 2 of the study. The questionnaire of the 'International Study of Asthma and Allergies in Childhood (ISAAC, 2000)' (Appendix 2) was used with modifications to suit local circumstances. The questionnaire was translated into the local languages. A pre-test of the questionnaire was conducted in some participating schools to check that was clearly understood by participants and modified if necessary before being used.

The ISAAC questionnaire has two parts:

Part I has introductory information. *Part II*: includes asthma and respiratory health data to be completed by students themselves or by their parents, and includes questions about respiratory health, asthma, allergy, smoking in the home, fuel use for cooking, etc.

The questionnaire with a request letter was delivered to all the students through their respective class teachers and asked to take it home to complete with the assistance of their parents. The letter contained a request to cooperate in the study, study rationale, study objectives and instruction for completion of the questionnaire.

A separate ***checklist*** (Appendix 3) for recording the present state of respiratory health, relevant medical history and findings of clinical examination of respiratory system of the participating students was prepared.

The baseline survey was conducted at different locations in the Kathmandu valley with completed questionnaires received from 801 children in seven schools, and from 328 children at three schools in Islamabad. The response rate was 68% in Kathmandu and 66% in Islamabad.

2.1.2. Data Analysis

Data obtained in the baseline survey were analysed to identify students with a history of or clinical evidence of asthma. The students were taken as asthmatic subjects if one of the following is reported:

- a history of wheeze at any time in the last year;
- clinician-diagnosed asthma (with or without medication); or,
- an asthma patient identified by the medical examination conducted during the baseline survey.

As the aim was to assess children with healthy respiratory systems, asthmatic children were excluded from Phase 2.

2.2. Phase 2: Health impact study

2.2.1. Sampling

From the healthy subjects identified in the baseline survey, students who satisfied any of the four following exclusion criteria were excluded:

- Use of solid fuel in the home;
- Residing more than 3 km from the air monitoring station;
- Child having asthma or other chronic respiratory illness; or
- A person in the home who is a smoker in the home or who did not provided smoking history.

For the selected participants in Phase 2, a separate *checklist* (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 prepared.

Subsequently each participating student was evaluated by experienced medical practitioners to assess their present state of respiratory health including clinical examination of the respiratory system and history. After exclusions, all the students qualified to be a participant of the study were invited to undertake the Peak Expiratory Flow Rate (PEFR) Test with informed parental consent. Among the healthy subjects who consented to be participants of the study, participating students were selected randomly. Ultimately a total of at least 100 students was the aim for the study to completion.

In Islamabad, 328 students completed questionnaires, 150 fulfilled the inclusion criteria and were subject to medical examination and 132 students were enrolled in Phase 2. In the Kathmandu Valley, 330 students fulfilled the inclusion criteria in the urban school and 150 were randomly selected for Phase 2. At the semi-urban school only 20 students met the inclusion criteria after medical examination and all were selected for Phase 2.

2.2.2 Data Collection

Physical examination

The physical examination was conducted by a pediatrician and cases found to have respiratory or cardiac illness were excluded from the study. During the physical examination, height and weight of the students were measured using a standard measuring tape and weighing scale.

Respiratory Data:

For recording peak expiratory flow rate a Peak Flow Meter was used. Each participating student was provided with a peak flow meter. The use of a peak flow meter was demonstrated to study participants in small groups. Each participant was also trained on an individual basis as to how to use the peak flow meter and how to enter events including taking of any airway medication and respiratory illnesses. PEFR was measured by the student themselves under the supervision of the assigned teachers and technician once per day in Kathmandu and once per week in Islamabad. Each measurement was replicated three times in the standing position, and the highest reading was recorded (Appendix 4). The reading was done by putting a dot mark in the PEFR record sheet and recorded by the teacher. The investigators frequently visited the schools to provide guidance and ensure quality collection of data.

Class teachers of classes with study participants in each school were trained. A teacher ensured collection of data at a specified room each day in Kathmandu and once per week in Islamabad. However, due to practical factors, for example school examinations, national holidays and others, continuous data collection was not always possible. PEFR and $PM_{2.5}$ measurements were conducted simultaneously on a daily basis for 31 days in a period of 42 days in Kathmandu and for a total of six weeks in Islamabad.

For the entire period of data collection, formatted colored Record Sheets for each student were used for recording the PEFR readings (for example Appendix 4). Individual cards contained a unique identification 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.

Particulate and Weather Data:

Data for particulates (PM_{10} and $PM_{2.5}$) and other measured air pollutants (eg sulphur dioxide, ozone, nitric oxide, nitrogen dioxide, and/or carbon monoxide if available) were collected on days when the PEFR are measured. Measurements of the $PM_{2.5}$ concentration in Kathmandu used the DustTrak TSI model 8250 recording 24 hour averages. Measurements of these other air pollutants were not available in Kathmandu. Relevant meteorological data (maximum, minimum and average daily temperature, relative humidity and wind speed) for the same period was obtained from relevant meteorology agency.

Other data

Costs of medical supplies and medical support for children participating in the study were recorded in Kathmandu and data on annual expenditure on respiratory illnesses in children were found.

2.2.3 Data analysis:

All the data collected from the questionnaire survey was coded and then entered in Microsoft Excel which was then later transferred to SPSS version 16.0 for further analysis. Once transferred into SPSS the data was thoroughly checked for any discrepancies and any missing entry or faulty entries. The discrepancies found were corrected by cross-checking with the completed questionnaire. The data was decoded and analyzed for frequencies and distribution in different groups. The information thus generated was tabulated, grouping together the related variables.

2.2.3 Data Analysis

The general characteristics such as age, sex, height and weight of the students participating in the lung function assessment were analyzed and described in tabular forms. This information was grouped by school. Similarly the $PM_{2.5}$ concentrations and PEFR readings of the students were interpreted separately and the mean values were compared.

For the study in Kathmandu where there were sufficient numbers of students for statistical power the analysis was further categorized as per the sex and age group (higher – 13 to 15 years and lower – 10 to 12 years) of the students. For comparing the mean $PM_{2.5}$ concentrations, a Mann Whitney U test was used as the data was found not to follow the normal distribution. The mean PEFR readings of two schools as well as two different groups within the urban school were compared using independent samples t test.

The correlation of $PM_{2.5}$ and PEFR readings was done separately for the schools as well as two different groups within the urban school in Kathmandu by using graphical plots. As planned initially for measuring the association and quantifying the relation of $PM_{2.5}$ with PEFR in Kathmandu, the daily average data for PM and PEFR were tested for the linearity to perform multiple linear regressions by taking PEFR as dependent variable and weather data as independent variables along with $PM_{2.5}$. However, the data was not found to be linear and the log conversion, quadratic conversion, cubic conversion and exponential conversion also did not provide the required linear data. Hence, the regression analysis was omitted from the analysis.

Statistical analyses of the relationship between means of air quality parameters, meteorological factors especially daily temperature and humidity, PEFR, school attendance, comparisons between schools and other relevant factors were performed.

Economic assessments were performed in Kathmandu to assess:

- the costs of medical supplies and medical support in relation to daily changes in air quality; and,
- annual expenditure on respiratory illnesses in children.

3. Results

3.1 Phase I: Baseline Survey

3.1.1 Socio-demographic characteristics of school children

The socio-demographic characteristics of the participants in the Phase 1 questionnaire in Islamabad and Kathmandu are summarized by Table 1. The participants consisted of proportionately more males and of similar ages in the two cities. The results showed a relatively high level of respiratory illnesses not associated with colds or flu in about a third of children in both studies. Children with pre-existing lung diseases, allergy or other exclusion factors were excluded while a representative sample of the remaining students were selected for Phase 2 of the study.

Table 2: **Socio-demographic characteristics of school children from results of questionnaires in Phase 1**

	Islamabad	**Kathmandu**
Number of completed questionnaires	328	801
Male (%)	64	58
Female (%)	36	42
Age range (years)	9-14	10-15
Nasal allergy without cold or flu (%)	36	29
Asthma (%)	7	-
Wheeze (%)	14	-
Asthma, wheeze or whistling sound (%)	-	8
Eczema (%)	7	21

Phase 2 included a correlational study to assess the impact on respiratory health of $PM_{2.5}$ in two schools, an urban roadside school and a school in a semi-urban residential area among 137 students in Kathmandu and 132 children from three schools in Islamabad. Children of age between 10-15 years in Kathmandu and 9-14 years in Islamabad were assessed daily in Kathmandu and weekly in Islamabad for their lung function by measuring morning peak expiratory flow rate (PEFR). Meanwhile, measurements of $PM_{2.5}$ were recorded daily in Kathmandu and weekly in Islamabad using particulate measurement instruments. Weather data were also recorded. Lung function tests (PEFR) and $PM_{2.5}$ measurements were conducted simultaneously on a daily basis for 31 days in a period of 42 days in Kathmandu and for a total of six weeks in Islamabad. Diaries of respiratory symptoms were also kept by the participants. To identify the correlation of PM with lung function of children the average PEFR with average $PM_{2.5}$ concentrations for different groups was plotted daily in Kathmandu and weekly in Islamabad.

3.2 Phase 2: Health Impact Studies

Results in Kathmandu

The period of collection of PM and PEFR data was from 25 January 2012 to 06 March 2012 with a total span of 6 weeks. However, the actual number of days of observation of PEFR was 31 days. These data from both the schools are thus taken into consideration for showing the correlation with the changes in the PEFR of children of the same date.

The concentration of $PM_{2.5}$ at the urban roadside school varied between 102 to 337 µg/m^3 with a mean value of 200 µg/m^3 and a standard deviation of 54.39 (Table 2). The concentration of $PM_{2.5}$ at the semi urban school was lower. The mean concentration was 123 µg/m^3 with a standard deviation of 32.75 and values ranging between 76 to 231 µg/m^3.

Table 2: Mean $PM_{2.5}$ (in µg/m^3) measured at the two schools in Kathmandu

School	Number of Observations	Minimum	Maximum	Mean	Standard Deviation
Urban	31	102	337	200	54.39
Semi-urban	31	76.	231	123	32.75

To test the mean difference of $PM_{2.5}$ between these two schools the Mann-Whitney U test was used as the daily data was not found to follow the normal distribution (Table 3). It showed that the mean difference of $PM_{2.5}$ between the urban and semi-urban schools was statistically significant with a Mann-Whitney U test value of 104 and p value less than 0.05.

Table 3: A statistical comparison of the mean $PM_{2.5}$ at the two schools

School	Mean Rank	Mann-Whitney U	P Value
Urban	43.65	104	0.0000
Semi-urban	19.35		

Although the children at the two schools were of very similar age, 13 years old and only 0.3 years difference in mean ages, and similar gender balance between the two schools, the children at the urban school were statistically significantly taller (by 5.6 cm) and heavier (by 9.56 kg) than children attending the semi-urban school (Table 4). The weight difference was 25% of the mean body weight of the children at the semi-urban school.

Table 4: Comparison of age height and weight of participants in the two schools

Variables	School	Mean	SD	t - value	P-Value	Mean Diff	95% CI	
							Lower	Upper
Age of students (years)	Urban	13.15	1.15	-1.12	0.26	-0.30	-0.84	0.23
	Semi-urban	13.45	0.89					
Height of students (cm)	Urban	155.56	9.22	2.56	0.01	5.61	1.27	9.96
	Semi-urban	149.95	8.11					
Weight of students (kg)	Urban	50.31	11.02	3.73	0.00	9.56	4.49	14.63
	Semi-urban	40.75	7.50					

The differences in body height and weight also affected lung capacity and hence PEFR. The mean PEFR was statistically significantly higher for the urban school ($p < 0.05$, 95% CI 39.61 – 126.17) than the semi-urban school probably because the children were taller and heavier (Table 5) and hence had larger lung capacities.

Table 5: A statistical comparison of mean PEFR (L/min) of participants at the two schools

School	N	Minimum	MaxiMum	Mean	SD	t-value	P-value	Mean Diff	95% CI	
									Lower	Upper
Urban	31	357	452	409	28.90	7.88	0.000	50.23	37.47	62.99
Semi-urban	31	314	388	359	20.62					

Table 5 shows that the mean PEFR is higher for the urban school than the semi-urban school. The difference is statistically significant with a 95% CI (37.47– 62.99) and with a p value less than 0.05. The average PEFR of the children ranged from 357 to 452 L/min for the urban school whereas it ranged from 314 to 388 L/min for the semi-urban school.

3.2.3 Correlation of $PM_{2.5}$ and PEFR

The relations between $PM_{2.5}$ and PEFR were analyzed using graphical plots for the two schools separately. In addition the relation between $PM_{2.5}$ and PEFR at the urban school was shown separately for older and younger age groups as well as for male and female children. However, it was not possible to calculate the regression of these two variables as the data were not linear. Attempts to convert the data into linear form by log conversion, quadratic conversion, exponential conversion, and cubic conversion were not successful.

The $PM_{2.5}$ concentration measured at the urban roadside school varied daily between 100 µg/m^3 and nearly 340 µg/m^3 (Figure 3). However, with the changes in PM there appeared to be relatively little fluctuation in the average PEFR of the students.

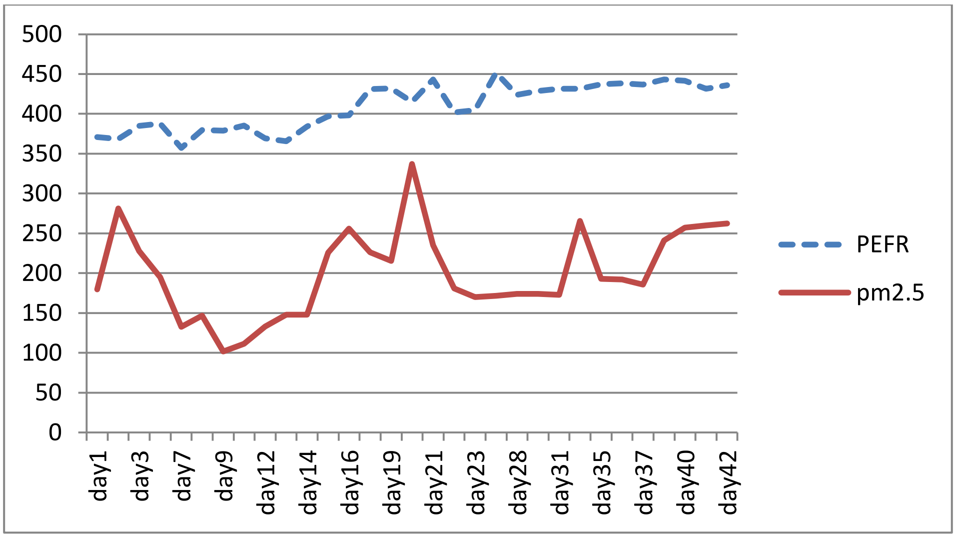

Figure 3: Correlation of PEFR and $PM_{2.5}$ at the urban roadside school. The vertical axis refers to both PEFR in L/min (dotted line) and $PM_{2.5}$ in µg/m^3 (solid line)

There are days when the daily PEFR falls with the rise in the $PM_{2.5}$ concentration, for example day 20 and there is rise in PEFR concentration with the fall in $PM_{2.5}$ concentration around day 28. On other days PEFR does not change with the daily change in $PM_{2.5}$. This suggests that there could be factors besides $PM_{2.5}$ affecting the lung function.

Figure 4 depicts the relation of PEFR with daily averages of $PM_{2.5}$. The PEFR of the older cohort (13 to 15 years) of children appears to vary slightly with the changes in $PM_{2.5}$ concentrations. In the period of day 19 to day 21 the increasing trend of $PM_{2.5}$ matched the decreasing trend in PEFR concentrations. In the days 28 and 29 the daily PEFR increased when the PM level was maintained in low levels. Otherwise, the PEFR of the older children seems to be not affected by daily changes in $PM_{2.5}$ concentrations**.**

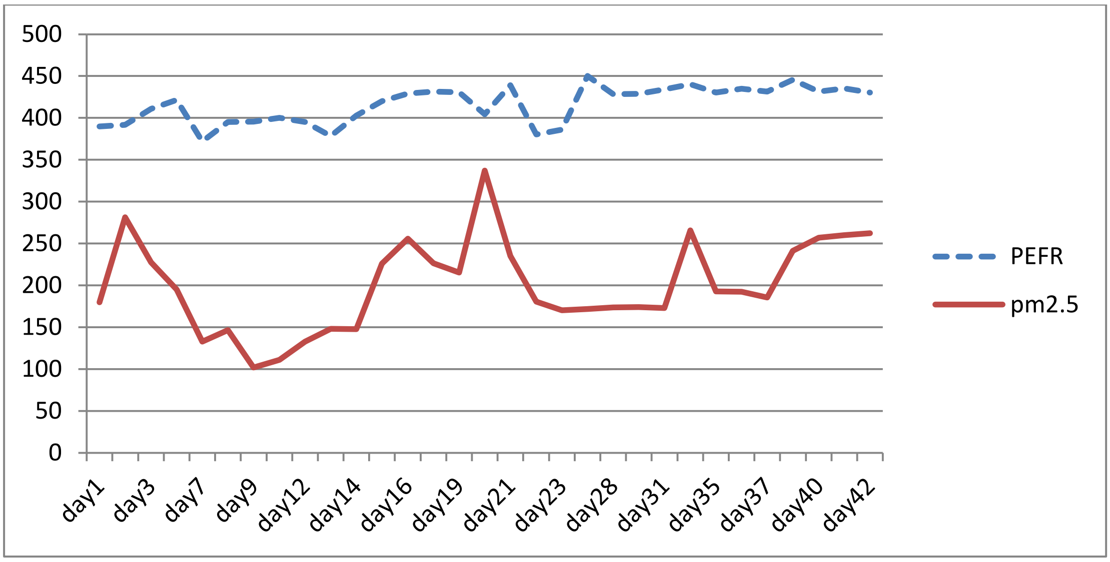

Figure 4: Correlation of PEFR of 13 to 15 years old children and $PM_{2.5}$ at the urban roadside school. The vertical axis refers to both PEFR in L/min (dotted line) and $PM_{2.5}$ in µg/m^3 (solid line)

The PEFR of children in the 10 to 12 year old cohort at the urban roadside school (Figure 5) showed that in the initial days and later days of the assessment there appeared to be a correlation. The PEFR levels appeared to decrease when the $PM_{2.5}$ level increased in the initial days and again around day 16. The daily PEFR level decreased around day 40 when the $PM_{2.5}$ concentration increased.

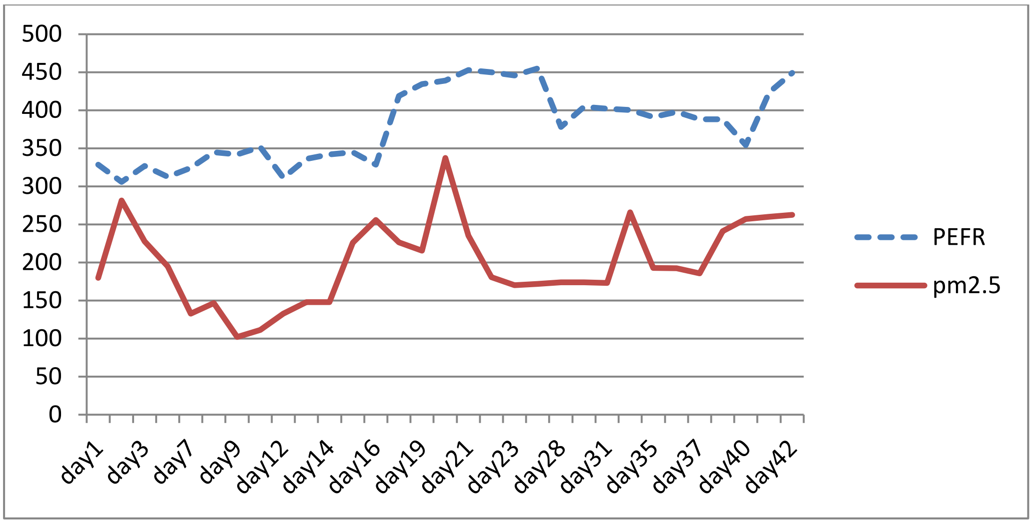

Figure 5: Correlation of PEFR of 10 to 12 year old children and $PM_{2.5}$ at the urban school. The vertical axis refers to both PEFR in L/min (dotted line) and $PM_{2.5}$ in µg/m^3 (solid line)

Figure 6 shows the correlation of daily $PM_{2.5}$ and PEFR of male children at the urban school. The PEFR levels seemed to slightly decrease when the $PM_{2.5}$ concentration rose around day 20. Otherwise there seemed to be little correlation between the daily variation in $PM_{2.5}$ and PEFR levels.

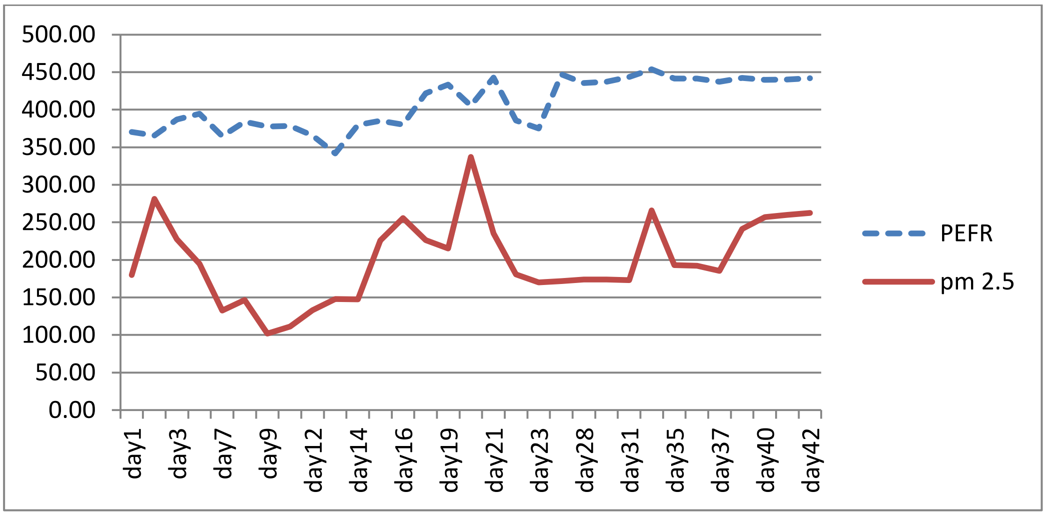

Figure 6: Correlation of PEFR of male children and $PM_{2.5}$ at the urban roadside school. The vertical axis refers to both PEFR in L/min (dotted line) and $PM_{2.5}$ in µg/m^3 (solid line)

The daily PEFR levels and $PM_{2.5}$ concentrations for female children show that there is little variation in the PEFR levels in line with the variation in daily $PM_{2.5}$ concentrations (Figure 7). The change in PEFR level is related with the change in $PM_{2.5}$ levels on most days. Around day 23 to 28 there is rise in the daily PEFR levels when the $PM_{2.5}$ level remained low. In comparison to the plots of male children, the plots of female children show a suggestion of an inverse relationship between $PM_{2.5}$

concentrations and PEFR levels. The PEFR increased on the days $PM_{2.5}$ remains at low levels. This association between PEFR and $PM_{2.5}$ could be associated with relatively lighter physical build of the female children.

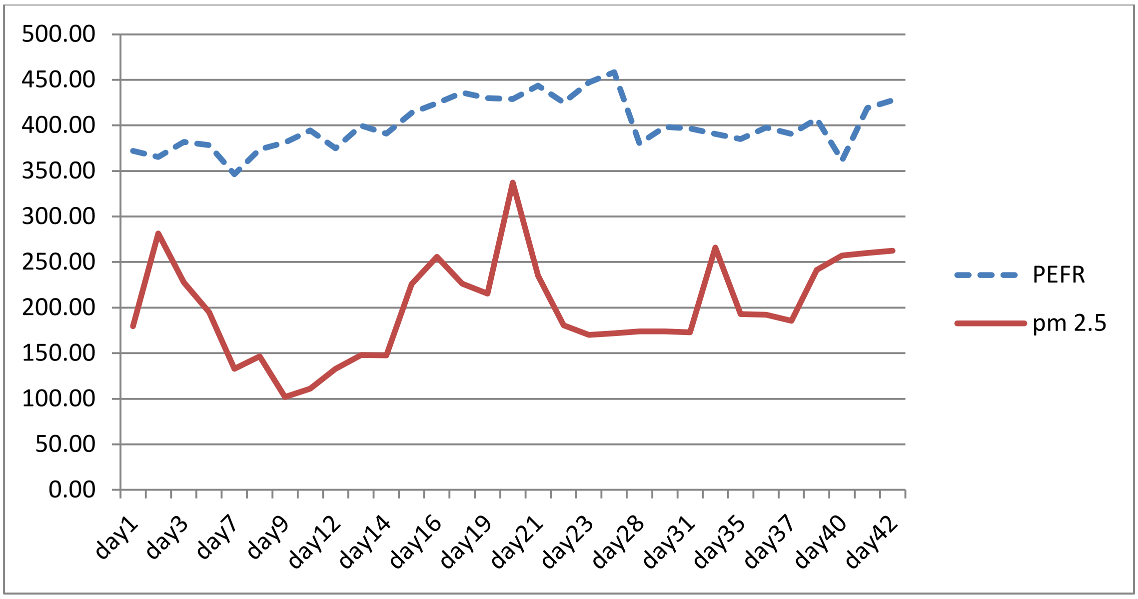

Figure 7: Correlation of PEFR of female children and $PM_{2.5}$ at the urban roadside school. The vertical axis refers to both PEFR in L/min (dotted line) and $PM_{2.5}$ in μg/m^3 (solid line)

The daily PEFR levels of 20 students attending the semi-urban school were plotted with the daily $PM_{2.5}$ concentrations (Figure 8). The $PM_{2.5}$ concentration is generally lower and less variable than in the urban school. The change in PEFR levels matches the change in $PM_{2.5}$ concentration in the later days. Around day 27 and day 32 the PEFR level decreases when the $PM_{2.5}$ concentration is increasing. In the earlier days the PEFR levels do not seem to vary with the small changes in $PM_{2.5}$ concentrations.

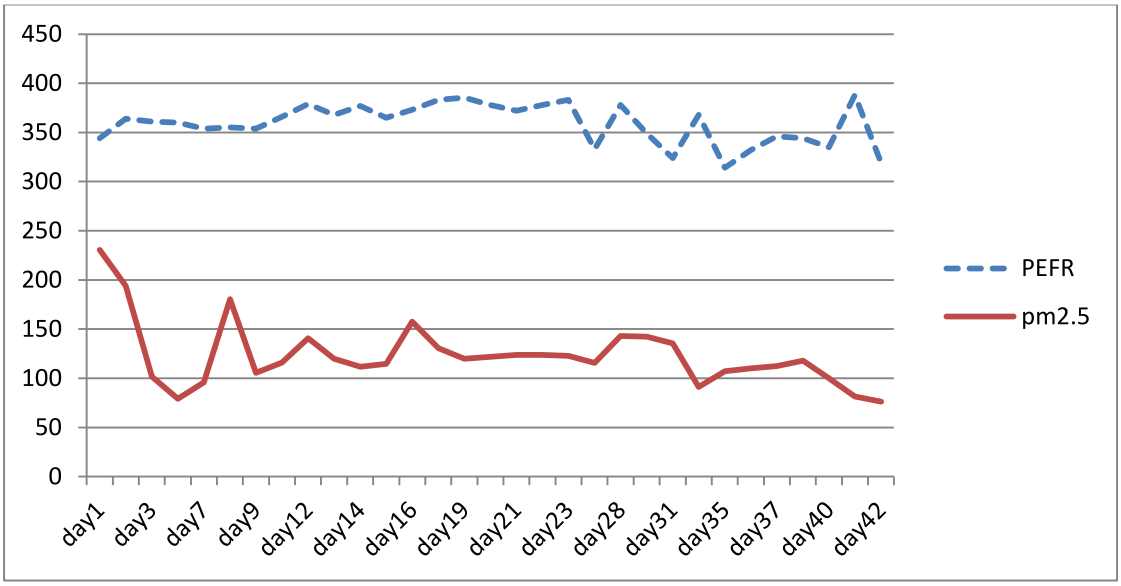

Figure 8: Correlation of $PM_{2.5}$ and PEFR of children attending the semi-urban school. The vertical axis refers to both PEFR in L/min (dotted line) and $PM_{2.5}$ in µg/m^3 (solid line)

The daily PEFR levels of 20 students at the semi-urban school fell with increases in $PM_{2.5}$ concentrations and rose with decreases in $PM_{2.5}$ concentrations for most days in the second half of the monitoring period except for few days. It can be concluded that there may be an association between lung function with the concentration of $PM_{2.5}$. However, the relation could not be quantified statistically due to a small number of observations.

Substantially more children were sampled from the urban roadside school (117 children) than the semi-urban school (20 children). The low numbers sampled at the semi-urban school prevented some statistical analyses and samples could not be pooled due to differences in the lung capacities of the two cohorts of children. It seems that the data for the two variables, $PM_{2.5}$ and PEFR were not linear, preventing regression analysis. The data showed some possible associations for some cohorts in some periods. The data may also suggest a lagged response, with PEFR possibly lagging $PM_{2.5}$ by 2 or 3 days in some periods.

Results in Islamabad

During the study period, the weekly mean concentration of $PM_{2.5}$ in Islamabad was 81 (±30.2) µg/m^3 and it ranged between 25 to 142 µg/m^3. The daily air quality standard for $PM_{2.5}$ in Pakistan is 40 µg/m^3 and it is shown in Figure 9 along with the annual average concentration of $PM_{2.5}$ for five years in Islamabad. The weekly mean concentration of O_3 during the study period was 40 (±28.8) µg/m^3. The weekly mean concentration of SO_2 was 20 (±13.3) µg/m^3, NO_2 was 56 (±18.2) µg/m^3 and NO was 85 (±77.9) µg/m^3. The mean temperature of the atmosphere during the study period was 18.3^{o}C (±5.2). It ranged between 11-33^{o}C. The mean relative humidity during the period was 58.8% (± 8.0), ranging between 35-82 %.

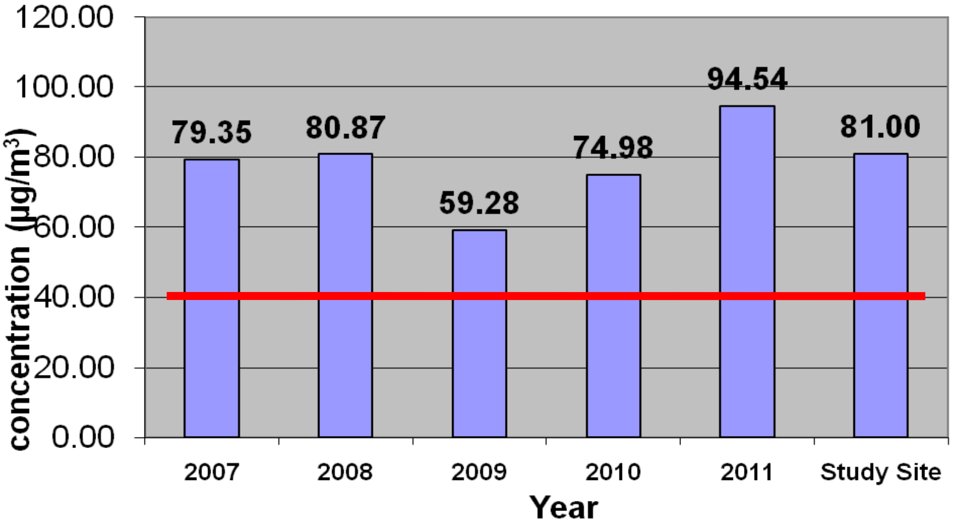

Figure 9: Annual average concentration of PM2.5 for 2007-2011 at the study site in Islamabad. The 24 hour air quality standard is shown by the red bar

The PEFR ranged from 140 L/min to 517 L/min, with a mean of 286 L/min. There was a significant difference in PEFR among both genders ($p<0.001$) being higher in males. There was no significant difference in PEFR among children of different schools. The data of PEFR was analyzed with the demographic characteristics and environmental factors. The rise in PEFR was directly associated with increase in age, weight and height ($p<0.001$).

When possible associations between PEFR and $PM_{2.5}$ were investigated the study found that over the six weeks of monitoring of $PM_{2.5}$, its concentration started to increase in week 2 and kept on increasing until week 3 and then showed a decline (Figure 10). During this period a drop in PEFR was also observed which reverted to normal at week 4. However this association was not statistically significant.

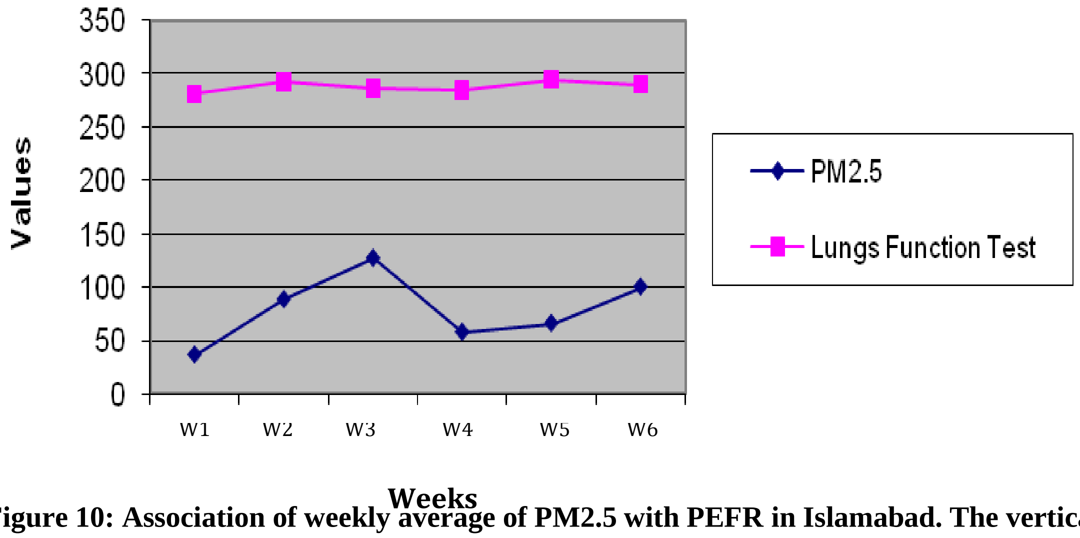

Figure 10: Association of weekly average of PM2.5 with PEFR in Islamabad. The vertical axis refers to both PEFR in L/minute and $PM_{2.5}$ in µg/m^3

3.1.3 Economic cost analysis

The economic burden as well as other impacts of respiratory problems was estimated by analyzing the number of school days missed, work days missed as well as the cost incurred by the respondents in the treatment of their children for respiratory issues (Table 6).

Table 6: Respiratory issues and loss to the children and parents

	Frequency	**Percent**
Any kind of respiratory problems faced in last year		
No	**564**	**70.4**
Yes	**237**	**29.6**
Total	**801**	**100.0**
Number of school days missed by child		
Not missed school	**35**	**14.8**
Missed 1 to 2 days	**102**	**43.0**
Missed 2 to 4 days	**63**	**26.6**
Missed more than 4 days	**37**	**15.6**
Absence from work by Guardian		
Yes	**99**	**41.8**
No	**138**	**58.2**
Total	**237**	**100.0**

Out of the total children 237 children, nearly 30%, were found to be suffered with one or the other kind of respiratory problems and had to visit the doctor/health facility (Table 6). Due to these respiratory health problems 43 % of the children missed school for 1 to 2 days and 27% of children for 2 to 4 days and nearly 16% missed for more than 4 days. Similarly, 42 % of the child guardians were absent from work due to these respiratory health problems in children and the number of days missed from work were mostly 1 to 2 days.

Out of the 237 children who had to visit the health facility/doctors for their respiratory problems it was found that they spent a minimum of NRs 100 to a maximum of NRs 20000 with mean expenditure of 1966 and median of 1000 (Table 7). Similarly, the median expenditure for travelling was NRs 200 with mean value of NRs 408 and minimum of NRs 50 to a maximum of NRs 3000. Accordingly, total expenditure ranged from NRs 150 to NRs 23000 with median of NRs 1400 and mean of NRs 2375.

Table 7: Expenditure in Nepali Rupees (NRs) for the respiratory illnesses of children

Expenditure (NRs)	Number of children	Mean NRs	Standard Deviation	Minimum NRs	Maximum NRs
Expenditure on medicines and doctor	**237**	**1966**	**2670**	**100**	**20000**
Money spent on travel during the medical visit	**237**	**408.9**	**525.2**	**50**	**3000**
Total money spent for respiratory problems	**237**	**2375.4**	**3063.8**	**150**	**23000**

4. Discussion

The activities of the Malé Declaration have concentrated on enhancing the capacity of key regional stakeholders, including government agencies and health professionals in this case in health impact assessment methods and helping them to access relevant information. The activities provide scientific evidence from South Asian cities to support informed policy decisions on air pollution. This assessment helps to address the need for information on the effects of particles on human health in South Asian cities. It provides locally-gathered evidence to support actions by governments to control particulate emissions. Three health studies were conducted on the health of school children during Phases III and IV of the Malé Declaration in different locations in major South Asian cities. The objectives of the studies were to assess the impacts of particulate air pollution on the respiratory health of school children of selected schools in Dhaka, Bangladesh in Phase III; and the Kathmandu Valley, Nepal; and Islamabad, Pakistan in Phases IV. The studies investigated the relationship between changes in lung function, in this case peak expiratory flow rate (PEFR) in children in response to daily variations in concentrations of $PM_{2.5}$ particulates in air.

These studies were conducted on the health of children as the developing lungs of children are more vulnerable to the adverse effects of air pollution than adult lungs. Children are more susceptible to air pollution than adults because of higher ventilation rates and higher levels of physical activity. In addition, adverse impacts in childhood can continue throughout their adult lives with health, social and economic consequences.

The results of air quality monitoring during the period of the studies in Islamabad and Kathmandu show that ambient concentrations of $PM_{2.5}$ exceed the relevant national air quality standards by substantial margins (Table 8). The mean concentration of $PM_{2.5}$ during the study period in Islamabad was about twice the Pakistan air quality standard. The mean concentration of $PM_{2.5}$ during the study period at the urban school in Kathmandu was more than five times the Nepal air quality standard. At the semi-urban school it was more than three times the standard. At neither school in Kathmandu during the study period was the Nepal air quality standard attained for a day and the $PM_{2.5}$ concentration was rarely less than twice the relevant air quality standard.

Table 8: Concentrations of $PM_{2.5}$ during these studies in Islamabad and Kathmandu

Parameter (in µg/m^3)	Islamabad	Kathmandu Urban school	Kathmandu Semi-urban school
Mean concentration	81	203	137
Maximum concentration	142	337	231
Minimum concentration	25	102	76
Air quality national standard	40	40	40

The $PM_{2.5}$ concentration in this study in Kathmandu at the urban roadside school varied in 24 hour mean concentrations between 102 μg/m^3 and 337 μg/m^3 which exceed the national standard of $PM_{2.5}$ concentration of 40 μg/m^3 every day of the 31 days measured. The mean concentration of $PM_{2.5}$ in Islamabad was 81 μg/m^3 with a range of 25-142 μg/m^3. Measurements frequently exceeded the 24 hour air quality standard in Pakistan of 40 μg/m^3. In the Phase III study conducted in Dhaka, Bangladesh, the 24 hour mean PM_{10} concentration level on the days of data collection ranged from 38 to 385 μg/m^3 with a mean value of 119 (±70) μg/m^3 (Department of the Environment, 2008). The 24 hour mean $PM_{2.5}$ concentration ranged from 18 to 233 μg/m^3 with a mean value of 68 (±48) μg/m^3.

The mean PEFR was higher at the urban roadside school than the semi-urban school in Kathmandu and the difference of 50 L/min is statistically significant with 95% CI (37– 63) and a p value less than 0.05. The average PEFR of the children ranged from 357 to 452 L/min for the urban roadside school whereas it ranged from 314 to 388 L/min for the semi urban school. This difference in the average PEFR between two schools may be due to varying anthropometric measurements. The average height and weight of the students of the semi urban school is significantly lower than the urban school with a mean difference of 5.6 cm in height and 9.56 kg in weight.

Average PEFR levels of all the students of the urban roadside school in Kathmandu were plotted along with the daily average $PM_{2.5}$ concentrations. The $PM_{2.5}$ concentration varied between 100 μg/m^3 and nearly 340 μg/m^3. However, with the changes in $PM_{2.5}$ there is a much smaller fluctuation in the average PEFR of the students. There are few days when the daily PEFR falls with the rise in the $PM_{2.5}$ concentration and there is a rise in PEFR with a fall in $PM_{2.5}$ concentration in a few other days. This suggests that there is an inverse relationship between the daily $PM_{2.5}$ concentrations and PEFR of school children. However on some days PEFR does not appear to change with the daily change in $PM_{2.5}$.

The PEFR of the older age group (13 to 15 years) of children in Kathmandu appeared to vary slightly with the changes in $PM_{2.5}$ concentrations. In the period of day 19 to day 21 the increasing trend of $PM_{2.5}$ is matching with decreasing trend in PEFR concentrations. In the days 28 and 29 the daily PEFR is seen to be increasing when the $PM_{2.5}$ level is maintained in low levels. Otherwise, the older children's PEFR seems to be not affected by daily changes in $PM_{2.5}$ concentrations. This could be because of other factors such as nutritional status of the children including anthropometry that the lung function has not been affected by changes in the $PM_{2.5}$ levels.

The PEFR of children studied in Islamabad showed there was no significant difference in PEFR among children of different schools. When possible associations between PEFR and $PM_{2.5}$ were investigated the study found that over the six weeks of monitoring of $PM_{2.5}$, its concentration started to increase in week 2 and kept on increasing till week 3 and then showed a decline. During this period a drop in PEFR was also observed which reverted to normal at week 4. However this association was not statistically significant. If daily measurements of PEFR and $PM_{2.5}$ had been available the likelihood of a statistically significant association being found would have been considerable higher.

A study to measure the short term effects of air pollution on respiratory morbidity among asthmatic children from the Czech Republic showed that that elevated levels of air pollution were associated with decreased peak expiratory flow rates, increased respiratory symptoms, increased prevalence of school absence and fever, and increased medication use (Zemp et al, 1999).

A study conducted to assess the association between daily changes in respiratory health and PM_{10} in Utah among fifth and sixth grade students showed relatively small but statistically significant

($p<0.01$) negative associations between PEFR and PM_{10} among both symptomatic and asymptomatic children. This association was however, stronger among the symptomatic children. The study concluded that both symptomatic and asymptomatic children may suffer acute health effects of respirable particulate pollution, with symptomatic children suffering the most (Pope et al, 1999). These results are similar to a study conducted on Bangkok children to assess the impact of PM_{10} pollution on child health (Preutthipan et al, 2004).

Children with symptoms of asthma are more susceptible to the effect of PM_{10}, black smoke (BS), SO_2 and NO_2 than children without symptoms (Zee et al, 1999). The study found decrements in evening PEFR had a positive association with concentration of PM_{10}. Another study reported a negative association between PEFR and PM_{10} for both asthmatic and non-asthmatic samples of children but symptomatic children suffers the most (Pope and Dockery, 1992). Similar associations between PEFR and PM_{10} have been reported in many studies (Pope et al, 1999, Romieu et al, 1996 ; Braun-Fahrlander et al, 1992; Schwartz et al, 1994; Timonen and Pekkanen, 1997; Ward and Ayres, 2004).

A study in Holland reported that an increase of 83% in the number of subjects with a reduced PEF response was associated with an increase in the mean PM_{10} concentration of 100 $\mu g/m^3$ (Zee et al, 1999). Morning PEFR decreased among asthmatic children in urban areas of Finland for a 10 $\mu g/m^3$ increase in daily mean PM_{10} concentration (Timonen and Pekkanen, 1997). A study in Germany reported a reduction of suspended particulates by 10-20 $\mu g/m^3$ was associated with a 20% reduction of total bronchial disease prevalence (Heinrich et al, 2000). It can be concluded from these studies that an increase in particulate matter concentration reduces the PEFR, hence increases the respiratory health risks.

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 (Ward and Ayres, 2004). When a comparison was made between 12-15 year old children lived in high and low air pollution exposure areas of Indonesia, it was observed that children has a lower PEFR in the area with the higher air pollutant level than those who lived in lower air pollution area (Sawtri et al, 2003).

The results of these studies in Kathmandu and Islamabad show a surprisingly high level of respiratory illnesses not associated with colds or flu in about a third of children. In both cities, nearly 30% of children were reported to have respiratory symptoms such as sneezing, running nose or nasal blockage even when they did not have common cold or flu. Of the students with respiratory symptoms, about 70% of them had such symptoms in the last 12 months and about a quarter of them had symptoms that hampered their studies and activities.

The study in Islamabad showed that 54% children were suffering from some chronic respiratory diseases or allergic disorders including asthma, wheeze, nasal allergy, urticaria and eczema. A study from Karachi reported a prevalence of asthma of 15.8% in school-age children (Hasnain et al, 2007).

Nasal allergy is associated with asthma. In the Islamabad study 38% of children suffered from nasal allergy i.e. presence of sneezing, running nose or nasal blockage without common cold or flu. In Kathmandu 29% of children suffered from nasal allergy. In the Islamabad study 19% children also reported itchy watery eyes. Hay (allergic) fever and eczema were each seen in 17% of children in Islamabad and in 13% and 21% respectively in Kathmandu.

The finding of these studies emphasise the high cost of air pollution to the health of the community and the need to implement cost-effective measures to reduce emissions of health-damaging air pollutants. The studies in Kathmandu and Islamabad showed that nearly 30% of all child participants were found to be suffered with respiratory health issues and had to visit a doctor or other health facility. Due to these respiratory health issues in Kathmandu 43% of the children missed school for one or two days, 42 % of the childrens' guardians missed their work due to these illnesses in children and the number of days missed were mostly one or two days. The median expenditure in Kathmandu for the health facility or doctor was NRs 1000 and for travelling to medical facilities was NRs 200. The total median expenditure was NRs 1400.

A study in Bangladesh reported that the total annual per capita expenditure for respiratory problems experienced by study participants was 5803 Taka and it was significantly higher ($p<0.001$) for asthmatic children (6919 Taka) than for non-asthmatic children (3479 Taka) (Department of the Environment, 2008). An estimate of asthma patients in Bangladesh showed that seven million people are suffering from asthma including four million children of the country (Hassan et al, 2002). Based on that estimate, around 27.67 billion taka (about US$ 395 million) is needed for the treatment of four million children. This expenditure could be substantially reduced with greater control of air pollution emissions.

This study has revealed that $PM_{2.5}$ concentrations in ambient air have a significant adverse economic impact on the families of affected children. It has been estimated that the reduction of PM_{10} concentration by 20% - 80% in Dhaka could allow for avoidance of 1,200 to 3,500 deaths, 80 to 235 million cases of sickness and a saving of US$ 169 to 492 million equivalent to 0.34 – 1.0 % of Gross National Income (World Bank, 2006). Clearly measures to reduce particulate matter emissions by prudent air quality control measures could not only contribute in reducing individual suffering but also contribute towards attaining Millennium Development Goals in health as well as poverty alleviation.

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. This study has limitations of being done for six weeks only in two selected areas of the study city which may not represent the national situation. It is recommended that long term studies need to be done on national level to establish a reliable baseline.

5. Conclusions

The objective of this study was to determine whether there is an association between daily mean $PM_{2.5}$ concentrations and lung function in children in a chosen city, quantify the relationship and assess the scale and severity of impacts.

Generally the results of these two studies are consistent with other studies and show a surprisingly high level of respiratory illnesses not associated with colds or flu. Many studies have demonstrated increases in respiratory illness, asthma symptoms, medication use, pulmonary function decrements and hospital admissions associated with increases in particulate matter concentrations in air (McGranahan and Murray, 2002). However, few studies have been conducted where particulate matter concentrations are at the highest levels found in many large Asian cities such as Islamabad and Kathmandu, making these studies especially important. The concentrations of $PM_{2.5}$ in the atmosphere measured in this study are far in excess of the WHO air quality guidelines intended to protect human health from the adverse impacts of air pollution.

The finding of these studies emphasise the high cost of air pollution to the health of the community and the need to implement cost-effective measures to reduce emissions of health-damaging air pollutants. In both cities, nearly 30% of children were reported to have respiratory symptoms such as sneezing, running nose or nasal blockage even when they did not have common cold or flu. Of the students with respiratory symptoms, more than 69% of them had such symptoms in last 12 months and 23% of them had symptoms that hampered their studies and activities.

The study in Kathmandu showed that nearly 30% of all child participants were found to be suffered with respiratory health issues and had to visit a doctor or other health facility. Due to these respiratory health issues 43% of the children missed school for 1 to 2 days and 42% of the childrens' guardians missed their work due to these illnesses in children and the number of days missed were mostly 1 to 2 days. The median expenditure on charges by the health facility or doctor was NRs 1000 and costs for travelling to medical facilities were NRs 200. The total median expenditure was NRs 1400.

Even though a strong correlation has not been seen in this study, the high level of $PM_{2.5}$ could have a significant impact on the health status of people especially children, according to international studies. The impact of $PM_{2.5}$ in this study was measured in terms of variation in PEFR levels and it shows an inverse relationship between $PM_{2.5}$ concentrations and PEFR levels in some of the days in Kathmandu. The younger children and female children have been found to be affected more than the older children and male children respectively as seen by the differences in the plots of these groups. This indicates that age and gender could be factor that play an important role in the manifestation of impacts of pollutants in the atmosphere.

This study suggests that the impact of $PM_{2.5}$ in air is more pronounced in the younger age groups and female children. Hence, the intervention needs to be focused to protect the most vulnerable groups from the increasing pollutants. The cross sectional component of this study conducted in the larger group as a baseline study before the impact assessment study hints that the burden of fine particles on the respiratory health could be very substantial and thus requires further investigation.

6. Future Steps

The following future steps could be considered by the Malé Declaration countries:

- Carefully selected technical studies of the health impacts of $PM_{2.5}$ should be established to inform policy, with an emphasis on analysis of social and economic impacts of air pollution on health to enable more thorough national and regional assessments of impacts, policy options, costs and health benefits of key options.

- A regional study should be conducted to quantify and assess the health costs and associated social and economic costs of ambient concentrations of health-damaging $PM_{2.5}$ particles in Malé Declaration countries and reporting to the Governments. The aim is to enable more thorough national assessments of impacts, policy options, costs and health benefits of key options to reduce the burden of disease caused by air pollution. This could be conducted by a team nominated by governments of Malé Declaration countries using national data and working to a common methodology.

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Appendix 1: Illustrations of different activities of the study

Physical examination of the child by Consultant Pediatrician

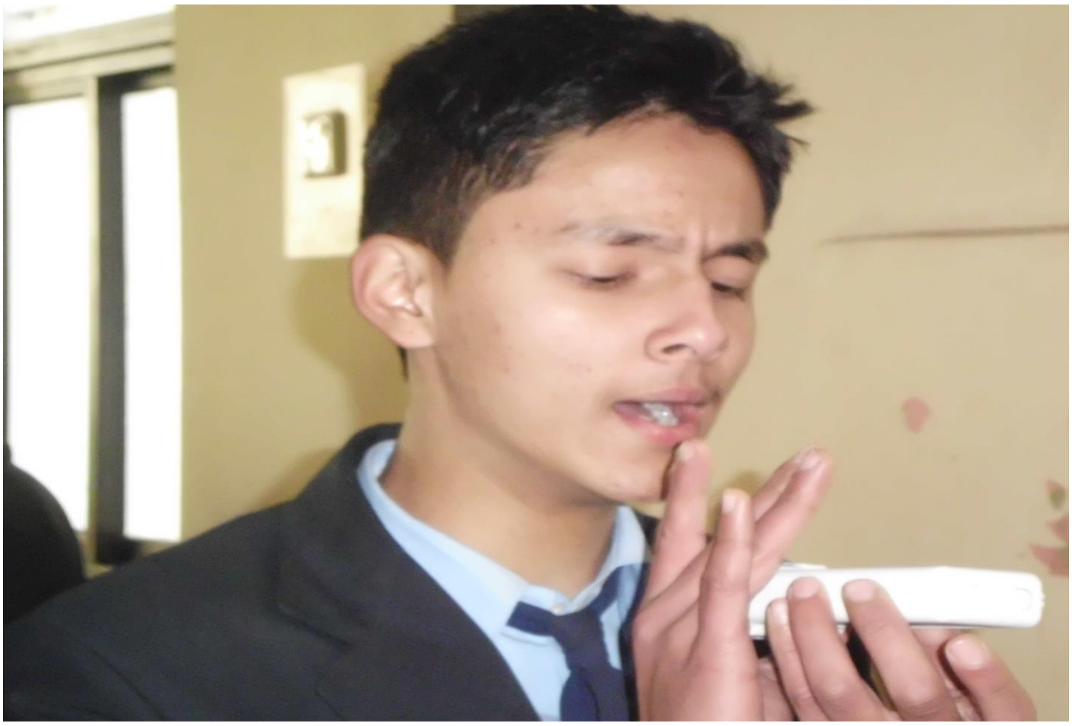
Collection of preliminary Information of the child before physical examination

Physical examination in progress

Team of Doctors, Investigators and Research Assistants

One of the Teachers involved in data collection

Research assistant guiding the children in the measurement of PEFR



A child taking a PEFR reading

Principal (Father) of St. Xavier's School (Urban Roadside School) receiving a certificate from the study leaders

Students of Santaneshwor Vidya Mandir School (Semi-Urban School) with the study leaders

Presentation of a Certificate of Participation to the Students

Presentation of a Certificate of Participation to the Teachers

Appendix 2: Phase 1 study questionnaire

Title: Assessment of impact of air pollution among the school children

The Departments of ??? are jointly conducting a study of impact of air pollution on school children in selected schools to design measures to protect health. Some information is necessary on the health of your child. Your cooperation in providing this information will help us to protect school children in our city. All the information will be used for research purpose only and will be regarded as confidential. Thank you for your assistance.

ID 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:
10. Asthma/ Respiratory problem related information.

10.1. Did your child ever experience asthma-like or 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 or whistling sound in the chest?

1. Yes   2. No   If No go to question no 10.6

10.3. Frequency of asthma-like or 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 symptoms or respiratory symptom cause sleep disturbance?

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

10.5. In last one year did an asthma-like or whistling sound hamper the child's speech while breathing?

1. Yes 2. No.

10.6. Did your child ever experience asthma or wheeze?

1. Yes 2. No.

10.7. Did your child ever experience asthma or wheeze during exercise or playing in last one year?

1. Yes 2. No.

10.8. Did your child suffer from cold or dry cough at night in the last one year?

1. Yes 2. No.

11.0 The following questions are about problems that occur when your child did not have a cold or flu:

11.1.1. 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.

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

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

11.1.3. In the last one year did the child have eye itching or watering along with nasal ailments?

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

11.1.4. In which month did you experience the problem

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

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

1. Yes 2. No.

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

1. Yes 2. No.

12.0 Did your child ever suffer from urticaria that lasted three to six months?

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

12.1. Was the rash 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

13.0 Did your child ever suffer from eczema.

1. Yes 2. No.

14.0 Do any members of your household smoke?

1. Yes 2. No.

14.1 If any member of your household is a smoker, does he/she smoke indoors?

1. Yes 2. No.

Appendix 3: 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:_____________________________________

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** **Other________________**

Any other Problem____

Comment____

Signature of the Physician

Appendix 4: PEFR Recording Sheet

Date:							Date:					
	Sun	Mon	Tues	Wed	Thur	Fri		Sun	Mon	Tues	Wed	Thurs	Fri
PEFR												
720							720						
700							700						
680							680						
660							660						
640							640						
620							620						
600							600						
580							580						
560							560						
540							540						
520							520						
500							500						
480							480						
460							460						
440							440						
420							420						
400							400						
380							380						
360							360						
340							340						
320							320						
300							300						
280							280						
260							260						
240							240						
220							220						
200							200						
180							180						
160							160						
140							140						
120							120						

Place a tick in the correct box