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Original Research Paper

The Study of Particulate Matter Concentration in Schools of Lahore

Anila Rose Yousaf and Nikhat Khan
Department of Environmental Sciences, Kinnaird College for Women, 93-Jail Road, Lahore-54000, Pakistan

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ABSTRACT

Children spend a large part of their time in school. Air pollution due to high concentration of particulate matter in schools has a detrimental effect upon children and teachers health and achievement. This study was carried out to assess mass concentration of particulate matter (PM_{10}, $PM_{2.5}$) in schools of Lahore, Pakistan, by using portable Tactical Air Sampler (Minivol™ TAS) and questionnaire survey during working days of the schools, in 5 northern (downtown area), and 5 southern (suburban) schools of Lahore, from November 2010 to June 2011. Mean concentration of PM_{10} in sampling schools of northern and southern Lahore was 1433.04 µg/m^3 and 293.9µg/m^3 respectively, while that of $PM_{2.5}$ was 153.8 µg/m^3 and 54.79ìg/m^3 respectively. In both the areas, concentration of $PM_{2.5}$ was minimum at 6a.m. and maximum at noon. Concentration of PM_{10} and $PM_{2.5}$ was higher in winter than in summer, but was found to be lower on rainy days. In winter, northern and southern schools' mean PM_{10} was 1507.15 µg/m^3 and 314.5438 µg/m^3, and $PM_{2.5}$ was 169.1µg/m^3 and 59.5 µg/m^3. In summer, PM_{10} was 1365.4 µg/m^3 and 284.4 µg/m^3, and $PM_{2.5}$ was 137.8 µg/m^3 and 44.5 µg/m^3 respectively. PM_{10} and $PM_{2.5}$ concentration in northern schools was significantly higher than in southern schools. It exceeded WHO and NAAQS of Pakistan. Questionnaire revealed that adverse impacts of high PM concentration are more rigorous at northern schools than at southern schools of Lahore. Suitable site selection and public cooperation are vital for reduction of particulate matter in schools of Lahore.

INTRODUCTION

High concentration of particulate matter (PM) has harmful impact upon all age groups but the worst affected victims are the children who have developing organs and less immunity (Nkwocha & Egejuru 2008). School-aged children spend about 30% of their day in school, therefore, it is very important to minimize the concentration of particulate matter in schools (Fromme et al. 2007, Ashmore & Dimitroulopoulou 2009, Halek et al. 2005, WHO 2005, Schwartz 2001). Normally an adult breathes 13,000 litres of air per day, children breathe 50 percent more air per pound of body weight than adults, and hence, children inhale more particulate matter than adults (Ismail & Sofian 2012, US-EPA 1997, McConnell 1999). Particulate matter is a mixture of solid particles and liquid droplets found in the air. PM is described by its particle size as PM_{10} or $PM_{2.5}$ etc. (Diapouli 2007, Berry 2002, Wilson et al. 2010, Zota 2009, Langiano et al. 2008). Students and teachers in schools near main road are more exposed to particulate matter (Kim 2004, Brunekreef 1997).

Lahore is the second largest city in Pakistan; its population is about 8 million (Ahmad et al. 2012). Northern Lahore (downtown area) is thickly populated and is the historical commercial hub of Lahore. Whereas, southern Lahore, (suburban) is thinly populated having open cantonment area. The aim of this study was to compare the mass concentration of particulate matter (PM_{10}, $PM_{2.5}$) at schools in southern (suburban) and northern (downtown area) Lahore, and to assess whether schools in open area or in congested area have healthy environment for students.

MATERIALS AND METHODS

Study area/site selection and sampling program: The present study was conducted in schools of Lahore. The sampling sites were randomly selected. Five northern and five southern schools in Lahore were selected for study. Google Earth map was used for geographical position determination of sampling schools (Table 1).

On an average, there are 35 students in each classroom of suburban schools, and 53 students in each classroom of downtown schools. At the sampling sites, PM_{10} and $PM_{2.5}$ were measured from November 2010 to May 2011. The samples were collected once a week from each site.

All samples were collected from 6:00 a.m. to 4:00 p.m. according to the schedule approved by the school management i.e., at 6:00a.m., during assembly, break, games period, afternoon (half hour before the school was over to half hour after school was over) and at 4:00 pm.

Sample collection methodology: Samples were obtained by using a portable ambient air sampler MiniVol™ Tactical Air Sampler (TAS). Sampler was placed at 1-metre height at least 1 m away from obstacles. It was operated at a flow rate of 5 litres per minute, and the flow rates were checked before

and at the end of the study. Sampling time for PM_{10} was 24-hour, and sampling time for $PM_{2.5}$ was 1 hour. Samples were collected on 47 mm fibre-film filters; electronic balance with accuracy of 0.001 mg was used to weigh the filters. The filters were conditioned in electronic desiccators, with a temperature of 25°C and relative humidity of 50%, before and after sample collection. From weight of particulate matter, mass concentration of PM_{10} and $PM_{2.5}$ were calculated. *t*- test was used to statistically compare mean concentrations of PM_{10} and $PM_{2.5}$ among northern and southern schools of Lahore and with WHO standards as well as with NAAQS of Pakistan.

RESULTS AND DISCUSSION

After sampling, mean concentrations of $PM_{2.5}$ during various activities were calculated for each sampling school, these were compared with NAAQS, WHO value and together, this is given in Table 2 and Fig. 1.

Mean concentration of $PM_{2.5}$ varies due to different types of activities performed by the students during school hours. Mean concentrations of $PM_{2.5}$ follows a similar trend at all study sites, that is: 30 min before and after the last bell ring > at 4 p.m. > during break > during games period > during assembly > 6:00 a.m. The afternoon peak enhanced due to anthropogenic activities within the school and outside the school.

Figs. 2 and 3 illustrate the comparison of mean concentrations of $PM_{2.5}$ and PM_{10} among northern and southern schools of Lahore, as well as with NAAQS of Pakistan and WHO value. The mean concentrations of $PM_{2.5}$ and PM_{10} for northern and southern Lahore were 153.88.0 $\mu g/m^3$ and 54.79$\mu g/m^3$, and 1433.04 $\mu g/m^3$ and 293.9$\mu g/m^3$ respectively.

In northern schools, mean mass concentration of $PM_{2.5}$ is 6.15 times and PM_{10} is 5.76 times above NAAQS of Pakistan, while many times higher than WHO threshold value, but in southern Lahore it exceeds the NAAQS and WHO to lesser extent, thus, showing better air quality.

Figs. 4 to 7 show the distribution of the schools into different airshed on the basis of mass concentration of $PM_{2.5}$ and PM_{10} in them. It becomes clear from Figs. 4-7 that in northern schools airshed due to mass concentration of $PM_{2.5}$ and PM_{10} is highly polluted. Its main cause is presence of main bus stand (Lorry Adda) in this area (Green 2004, Lin 2002, Venn 2001) which produces a lot of smoke and other pollutants. Southern schools are considered to have healthy airshed according to NAAQS of Pakistan.

Schools situated near busy roads have higher concentration of $PM_{2.5}$ and PM_{10} but Govt. Junior and Central Model School No. 2, Rattigan Road, Lahore (downtown area), situated on less busy road, had higher mass concentration of particulate matter than Govt. Central Model School, Lower Mall Lahore (downtown area), situated on the bank of a most busy road, due to construction activities going on during school hours.

Figs. 8 and 9 illustrate the change in concentrations of $PM_{2.5}$ and PM_{10} due to rainfall. During sampling, there was rainfall on 30th December 2010 (6.8mm), 31st December 2010 (8.2mm), 8th February 2011 (7mm), 16th February 2011 (13.4mm), 27th February 2011 (4.2mm), 1st March 2011 (5mm), 3rd March 2011(2mm), 16th April 2011 (8mm), 17th April 2011 (4mm) and 6th May 2011(6mm). Concentration

Table 1: Details of sampling schools.

School name and location (suburban)	Latitude	Longitude	School Name and Location (downtown area)	Latitude	Longitude
FG Model High School (Girls), Sarwar Road, Lahore Cantt	31°32’39.35"N	74°22’37.20"E	Govt. Central Model School, Lower Mall Lahore	31°34’33.79"N	74°18’26.73"E
FG Middle School No. 3, Lahore Cantt	31°32’59.35"N	74°22’39.08"E	Govt. Asifa New Model Girls High School, Said Mitha Bazaar, Lahore	31°34’27.64"N	74°18’15.10"E
Govt. Muslim Boys High School, Sarwar Road, Lahore, Cantt.	31°32’39.36"N	74°22’37.28"E	Muhammadia Girls High School, Mohni Road, Lahore	31°34’57.18"N	74°18’10.00"E
Shamhadia School, Sadar Bazaar, Lahore Cantt	31°32’50.16"N	74°22’37.90"E	Govt. Islamia High School Mohni Road, Lahore	31°34’54.32"N	74°18’11.55"E
Govt. Islamia Girls High School, Dahaka Road, Lahore Cantt	31°32’47.14"N	74°22’42.25"E	Govt. Junior and Central Model School, Rettigon Road, Lahore	31°34’30.55"N	74°18’11.53"E

Table 2: Mean concentration of $PM_{2.5}$ and PM_{10} in the schools of Lahore. Averaging period for $PM_{2.5}$ = 1-hour. Averaging Period for PM_{10} = 24-hours

Name of sampling schools of Lahore	1 Hour Before the school starts µg/m³	During assembly µg/m³	During break µg/m³	During games period µg/m³	30 min before & after the last bell ring, µg/m³	At 4 p.m. µg/m³	Mean Concentration of $PM_{2.5}$	Mean Concentration of PM_{10}
FG Model High School (Girls) Lahore Cantt	23.1	29.9	40.9	35.3	49.8	41.8	36.8	240.5
FG Middle School No.3 Lahore Cantt	46.4	57.6	131.8	95.6	161.7	139.8	105.5	423.3
Govt. Muslim Boys High School, Lahore Cantt	27.6	34.4	45.6	38.9	54.5	46.0	41.2	251.9
Shamhadia School, Sadar Bazaar, Lahore Cantt	26.8	33.4	53.7	47.8	68.5	53.9	47.4	260.8
Govt. Islamia Girls High School, Lahore Cantt	32.6	36.7	42	39.4	57.4	50.6	43.1	292.8
Govt. Central Model School, Lower Mall, Lahore	82.5	120.0	183.8	137.3	271.1	220.3	169.0	1504.5
Govt. Asifa New Model Girls High School, Said Mitha Bazaar, Lahore	73.1	92.0	133.6	109.3	184.1	143.5	122.6	1278.1
Muhammadia Girls High School, Mohni Road, Lahore	74.8	100.0	155.6	125.5	255.3	174.4	147.6	1338.5
Govt. Islamia High School Mohni Road, Lahore	75.2	111.5	177.7	130.7	241.5	174.0	151.8	1444.7
Govt. Junior and Central Model School 2, Rettigon Road, Lahore	78.8	113.8	201.0	159.4	285.6	228.3	174.5	1599.4

Table 3: Comparison of number of cases suffering from medical problems in study areas.

Types of medical problems	% of cases at Northern Schools of Lahore	% of cases at Southern Schools of Lahore
Asthma	60	25
Heart	15	6
Skin allergy	50	20
Running nose	70	40
Bronchitis	30	8
Eye infections	25	11
Fever	38	16
Coughing	74	50

of particulate matter on rainy days, as well as on the next day after rain was less than the mass concentration of particulate matter on the days without rain. The low concentrations could be due to wash out effect due to rain.

Figs. 10 and 11 show that same trend was found in both the study areas (northern and southern Lahore) for mass concentration of particulate matter. It was highest in December and lowest in May. In winter, northern and southern schools mean PM_{10} was 1507.15 µg/m³ and 314.54 µg /m³, and $PM_{2.5}$ was 169.1µg/m³ and 59.5 µg/m³. In summer PM_{10} was 1365.4 µg/m³ and 284.4 µg /m³, and $PM_{2.5}$ was 137.8 µg/m³ and 44.5 µg/m³ respectively. There are many slums in and around northern Lahore who burn heaps of solid waste to keep them warm in winter season, resulting in significant increase in mass concentration of particulate matter in the winter season.

Data collected from the study area through questionnaire revealed that number of children and teachers suffering from various types of medical problems were higher in northern schools than in southern schools of Lahore (Fig. 12). This is consistent with the measured mass concentration of PM.

Northern area of Lahore has high PM concentration so more individuals are suffering here from medical problems, which create financial burden on parents and affects students academically (Mazhar & Jamal 2009, Gabrio et al. 2007, English et al. 1999, Gauderman, 2007, Yasmeen et al. 2012). In both the study areas, most of the parents consider air pollu-

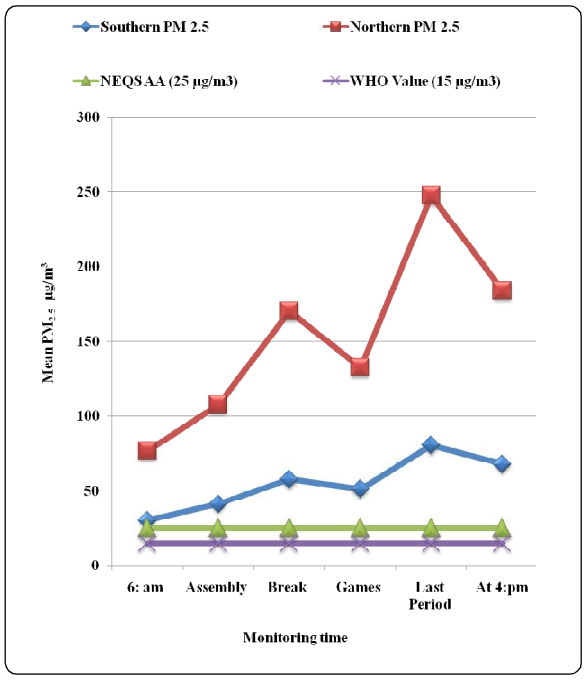

Fig. 1: Comparison of mean $PM_{2.5}$ among Northern and Southern Schools of Lahore.

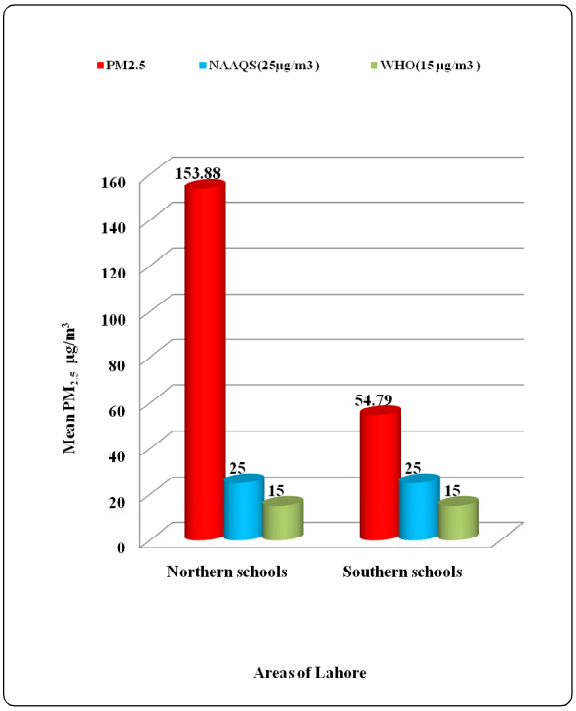

Fig. 2: Comparison of mean values of $PM_{2.5}$ in Northern and Southern Schools of Lahore.

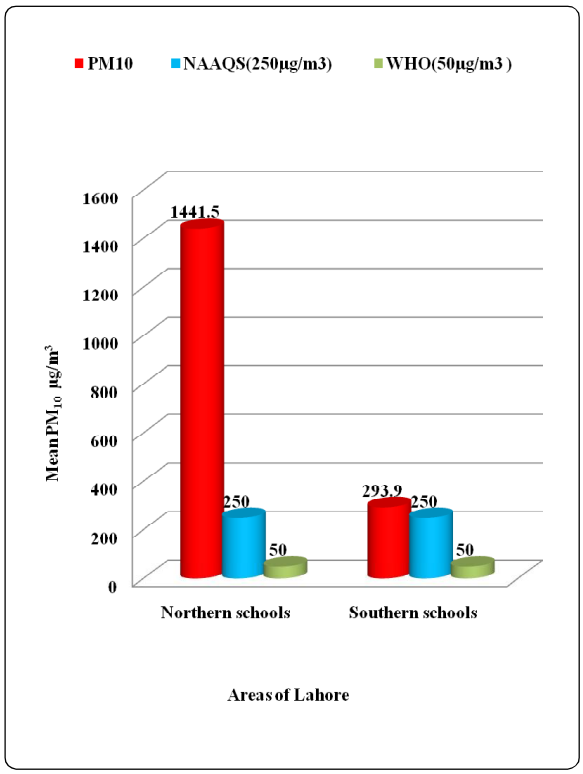

Fig. 3: Comparison of mean values of PM_{10} in Northern and Southern schools of Lahore.

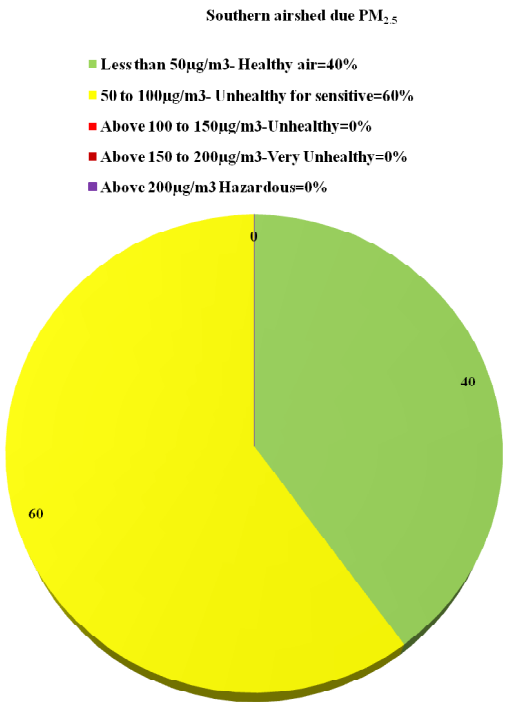

Fig. 4: Types of airshed due to concentration of $PM_{2.5}$ in Southern Schools of Lahore.

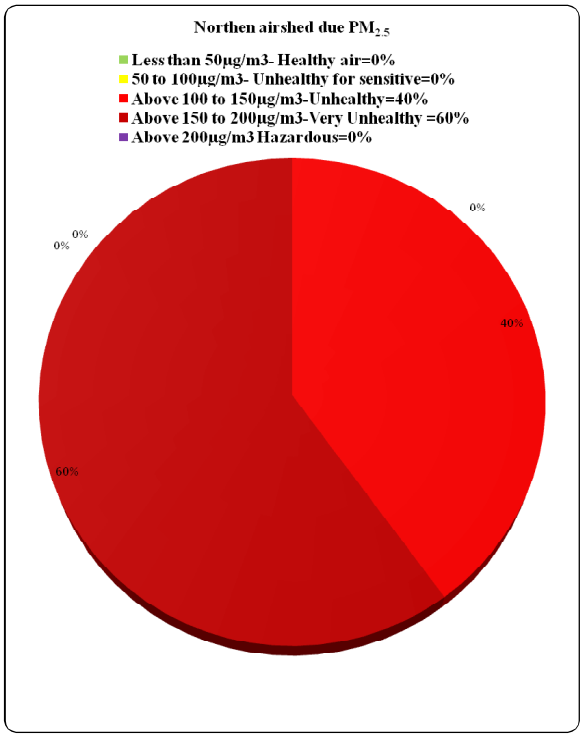

Fig. 5: Types of airshed due to concentration of $PM_{2.5}$ in Northern Schools of Lahore.

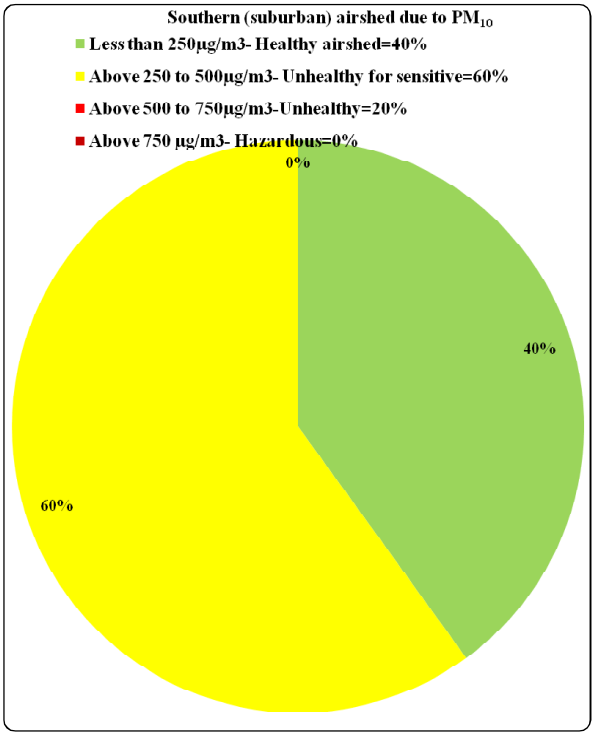

Fig. 6: Types of airshed due to concentration of PM_{10} in Southern Schools of Lahore.

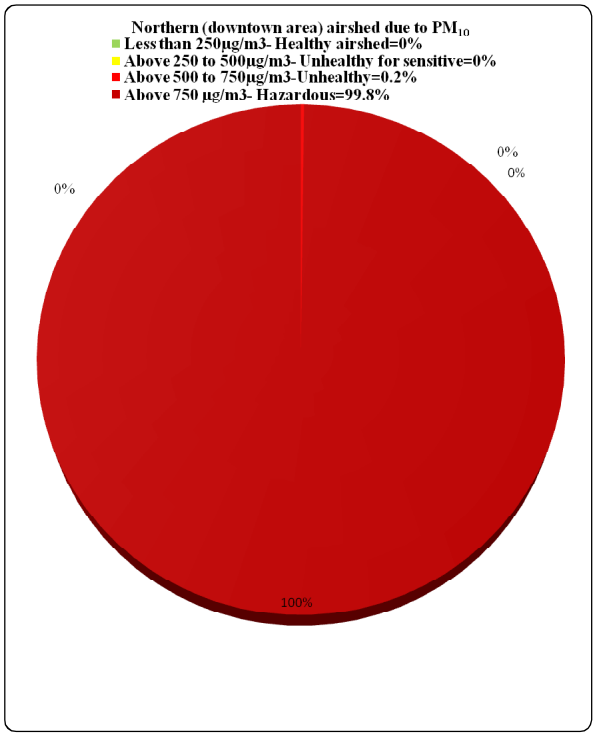

Fig. 7: Types of airshed due to mass concentration of PM_{10} in Northern Lahore.

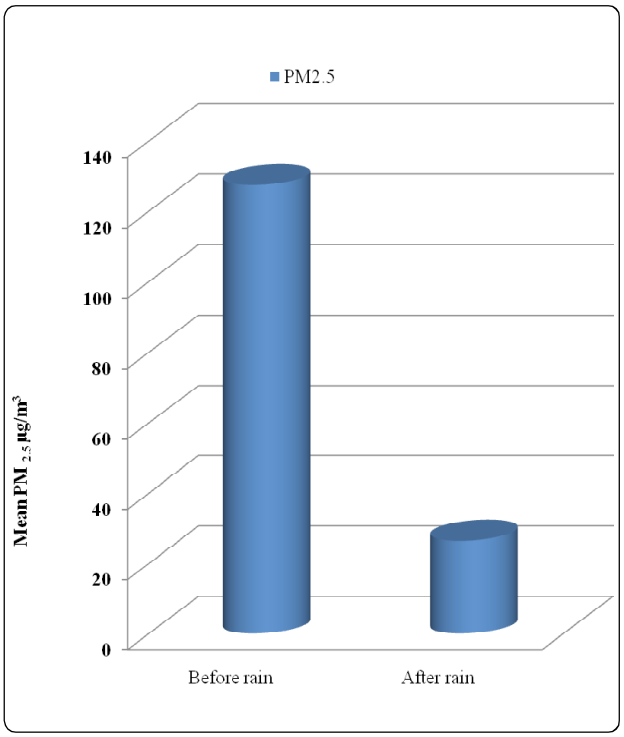

Fig.8: Change in Concentrations of $PM_{2.5}$ after rain.

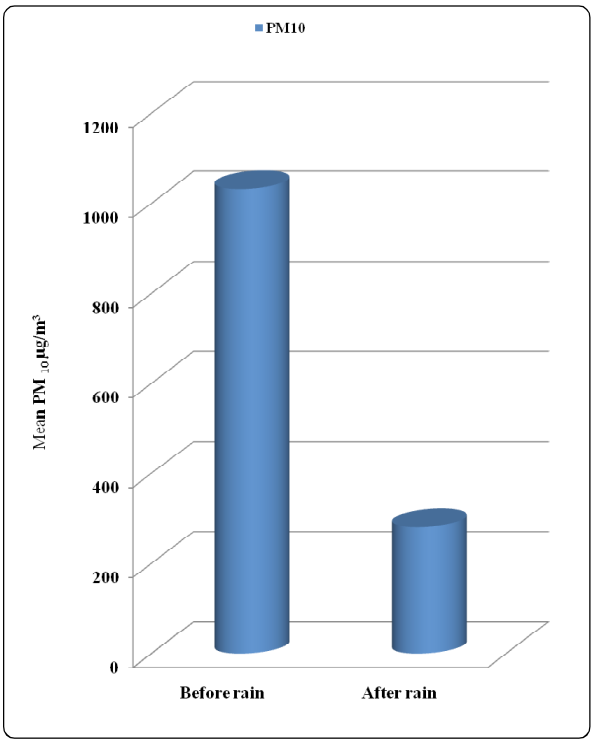

Fig. 9: Change in concentrations of PM_{10} after rain.

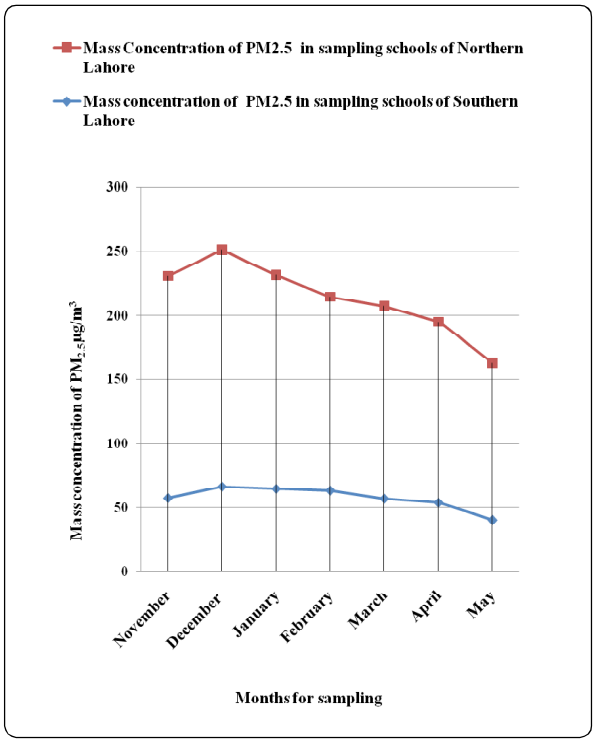

Fig. 10: Change in mean concentration of $PM_{2.5}$ with change in weather.

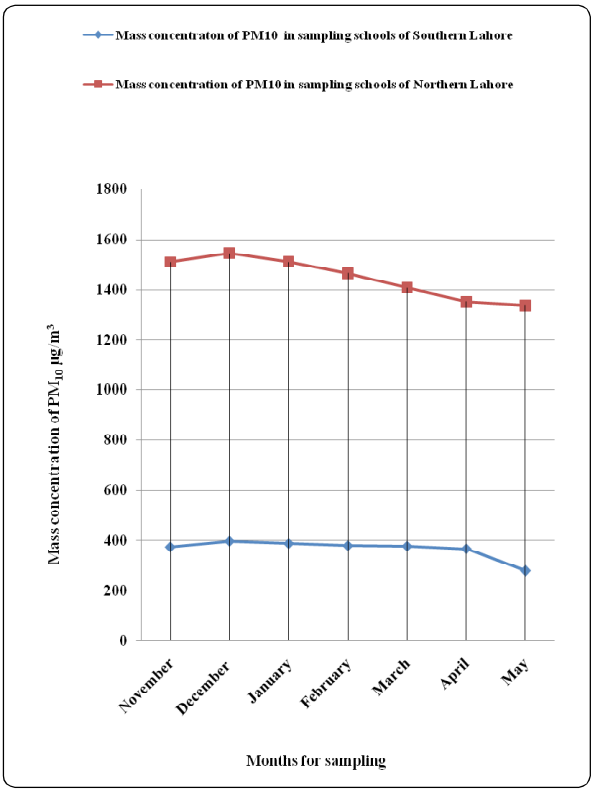

Fig.11: Change in mean concentration of PM_{10} with change in weather.

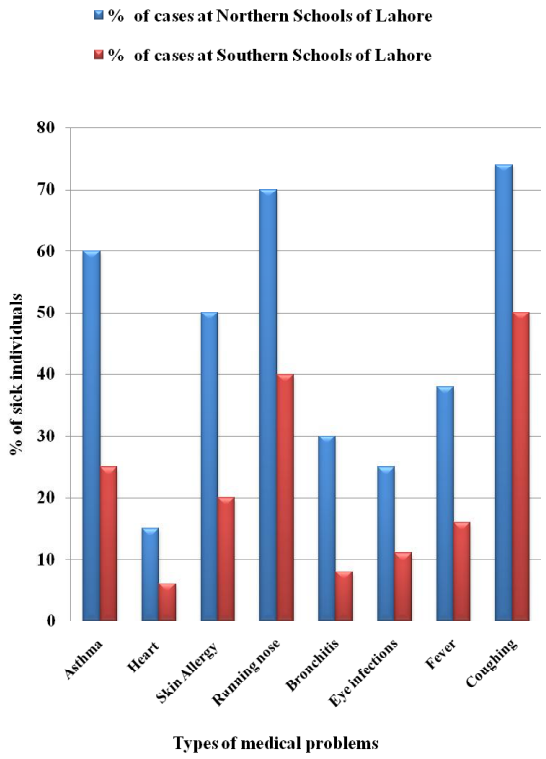

Fig. 12: Comparison of number of medical cases in the study areas.

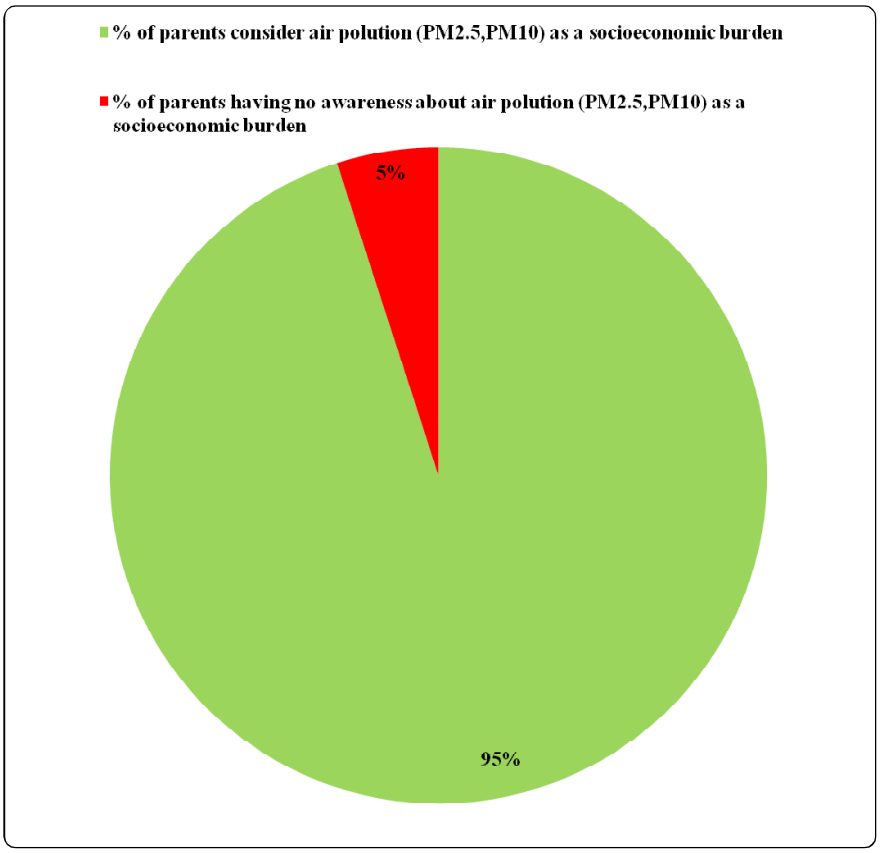

Fig.13: % of parents consider air pollution ($PM_{2.5,}$ PM_{10}) as an economic burden.

tion as economical burden for themselves but some semi-literate parents do have any awareness as illustrated in Fig. 13.

CONCLUSION

High concentrations of $PM_{2.5}$ and PM_{10} in schools of northern Lahore revealed that the schools have poor air quality, which is injurious for the children. Southern schools of Lahore have better air quality, which is good for children's health and academic performance.

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