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AIR QUALITY(PARTICULATE MATTER) AT HEAVY TRAFFIC SITES IN LAHORE, PAKISTAN

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ABSTRACT

The transport sector is a major contributor towards air pollution, particularly in the urban areas. Air quality at two major heavy traffic roads of Lahore, Pakistan was evaluated. Particulate matter (PM) was monitored for twenty four hours at each sampling sites. The total number of vehicles passing was also noted and correlated with the PM levels. The vehicular congestion as well as meteorological factors had a positive association with the PM levels. PM concentrations were significantly higher than the WHO recommended levels. It is necessary to control emissions from vehicular exhaust to reduce the level of pollutants in the ambient air in urban areas.

Keywords: Particulate matter, CO, vehicular traffic, heavy traffic roads, Lahore, Pakistan

INTRODUCTION

Air pollution has emerged as one of the biggest threats to human health in the rapidly developing world particularly in urban areas. This deterioration of air quality is primarily due to a significant rise in emission sources (automobile, industry, solid waste burning), population and urbanization along with inadequate air quality management and emission control strategies. Worldwide, approximately 3.7 million deaths were attributed to ambient air pollution in 2012 (WHO, 2014). Eighty eight percent of these were in low and middle income countries and this large burden of disease was associated with particulate matter. PM_{10} and $PM_{2.5}$ have been held responsible for cardiovascular and respiratory diseases and cancer (Correia *et al*. 2013; Loomis *et al*. 2013 Pope *et al*. 2009).

Recent studies on air quality in the Asian region has shown that levels of various air pollutants are typically in excess of WHO guidelines and ambient air quality standards in high income countries (HEI International Scientific Oversight Committee, 2010; Hopke*et al*. 2008). Motor vehicles are the fastest growing source of a range of ambient air pollutants (e.g. particulate matter, hydrocarbons, carbon monoxide, and oxides of nitrogen) in the region. In Pakistan, vehicular traffic along with the industrial sector is the leading contributor towards poor air quality.

The number of total vehicles in the country has seen a growth rate of 130.3% during 2001 – 02 to 2012-13 (Pakistan Economic Survey, 2013 - 2014).In the Punjab the total number of registered vehicles in 2010 was 7,483,860. The total length of metaled roads in Lahore is 1244.41 km^2 and according to government figures, the total number of registered vehicles in the metropolis was 0.5 million in 1998 with the number reaching 1.2 million in 2005. With the rate doubled over time, and keeping in view the highest growth rate of 16% among all cities of Punjab, the number of vehicles was estimated to be 2,400,000 in 2010 (Planning and Development Department, 2014; BOS, 2011).

As a consequence of this immense traffic burden on roads urban centres in the country are suffering from poor air quality along with increased incidence of respiratory allergies (Mirza *et al*., 2013; Jafary and Faridi, 2006). Overall, the state of ambient air quality in urban centres in Pakistan is alarming and levels of various air pollutants, especially, PM are many times higher than internal standards and WHO guidelines (Colbeck *et al*. 2010).The past few years have noticed a marked increase in number of automobiles on road along with small scale industries which are contributing significantly to the deterioration of ambient air quality (Mirza, 2013).

High concentrations of fine and ultrafine particles in an urban environment, especially around roads, can have significant health implications for daily commuters (including susceptible population - children and elderly) as well as to urban dwellers. Many studies including those of Chan *et al*. (2001), Ghauri *et al*. (2007), Colbeck *et al*. (2011) have been conducted in an effort to analyse mass concentrations of different fractions of PM at roadside in heavy traffic areas. Realizing the importance of knowledge on PM levels at heavy traffic sites, the current research was an attempt to assess the ambient levels of PM along two heavy traffic sites of Lahore to demonstrate the impact of traffic density on ambient air pollution.

MATERIALS AND METHODS

Study site: The provincial capital of Punjab, Lahore is known as the cultural heart of Pakistan. The historical city lies along the west bank of River Ravi (31o 32'N, 74o 20' E) and is spread over an area of 1,772 km^2. The second largest city of Pakistan is one of the densely populated cities of the world with an estimated population of around 12,500,000. It is the business hub of Punjab with majority of people engaged in industries, commerce and trade, attracting people from all over the country. Two heavy traffic sites were selected for the purpose of this research. Site 1 was the Campus Bridge, Punjab University while site 2 was ThokarNiazBaigChowk (Figure 1). Both sites are important busy roads located along the Lahore Canal and have a high inflow of traffic throughout the day.

Site 1: Campus Bridge, Punjab University runs over the Lahore Canal. The road receives traffic throughout the day from all directions i.e. from Wahdat Road, Barkat Market, Model Town, and along the Canal Road. Since there are a number of educational institutes and offices along the road, there is a marked increase in vehicular traffic during early morning and late afternoon.

Site 2: Thokar Niaz Baig Chowk is also located along the Lahore Canal and is an important busy road of Lahore as it receives traffic from not only within Lahore from Mohlanwal Road, Raiwind Road, Johar Town and Canal Road, but also from outside of Lahore i.e. the motorway M-II and Multan Road. The site is also the exit point from Lahore. Every morning there is a large number of buses and vans which carry their workers from Lahore to various locations. As a result peak traffic hours are observed during early morning i.e. between 6 to 8 am.

Figure 1: Location of sampling sites

Sampling of air quality: A Dust Trak DRX (Model 8533, TSI Inc.) was employed to measure the ambient levels of particulate matter at the two selected sites. The aerosol monitor was factory calibrated prior to monitoring. Data logging interval was set at 30 seconds and the instrument was placed at a height of 1 meter from ground level. Temperature and humidity were also simultaneously recorded using BW Gas Probe. The sampling duration was 24 hours during which time the number of vehicles passing on the road were also counted every five minutes.

RESULTS AND DISCUSSION

The levels of PM at both sites varied considerably throughout the day. Table 1 shows summary of level of PM in different size fraction.At site 1, higher mean levels were observed during rush hours i.e. between 8 to 9 am and then from 5 pm onwards. There was also a dust storm while sampling at site 1 contributing towards a higher mean concentration of PM10 (450 µg/m³) and PM_{Total} (516 µg/m³) (Figure 2). The total number of vehicles passing from this site for 24 hours was observed to be 124,044 vehicles including 61,762 motorcycles, 58,726 LTV and 3,556 HTV vehicles (Figure 4). The average temperature and humidity levels were 29.7°C and 27.8% respectively. At site 2, PM levels showed a higher mean concentration (613 µg/m^{-3}) at 6 am (Figure 3). During early hours, there are a large number of buses and vans leaving Lahore so the flow of traffic is high. The total number of vehicles counted in 24 hours passing from this site was 82,454 including 38,406 motorcycles, 39,634 LTV, and 4,416 HTV (Figure 4). The average temperature was 35°C, with a mean humidity level of 65.6%.

Table 1. Summary of PM concentration at two traffic sites in Lahore

	PM levels at Site1 (µg/m³)			PM levels at Site 2 (µg/m³)		
	24 hour mean (SD)	Hourly maximum	Hourly minimum	24 hour mean (SD)	Hourly maximum	Hourly minimum
PM_1	210 (97)	476	73	289 (49)	373	230
$PM_{2.5}$	222 (103)	501	77	302 (51)	389	238
PM_4	234 (106)	509	82	314 (53)	405	247
PM_{10}	286 (120)	551	103	365 (64)	501	275
PM_{total}	340 (135)	596	127	425 (80)	613	293

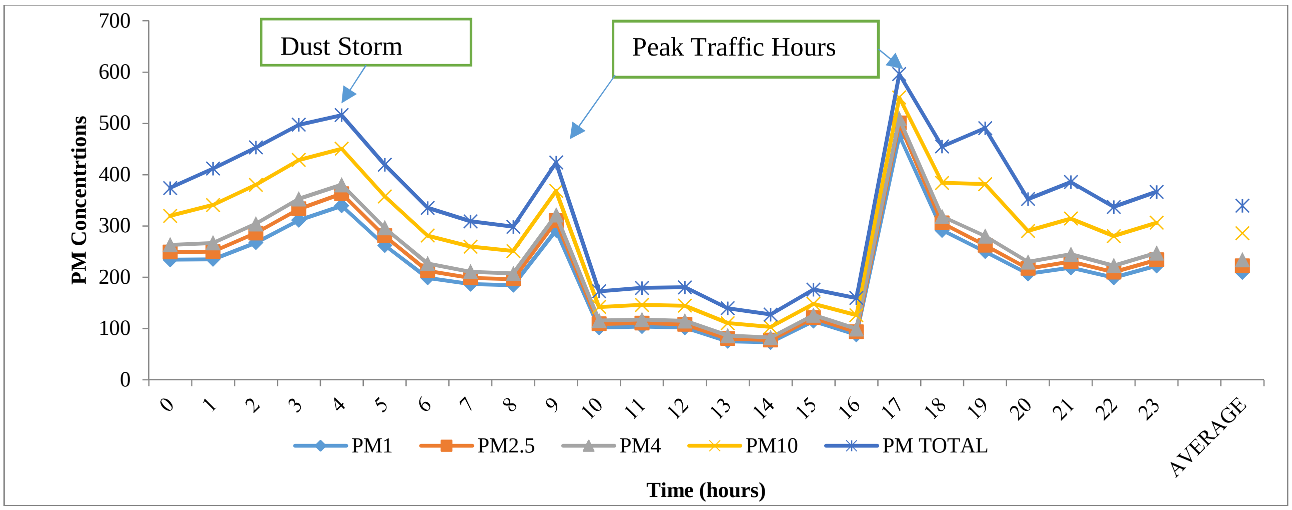

Figure 2: Hourly mean levels of PM at site 1

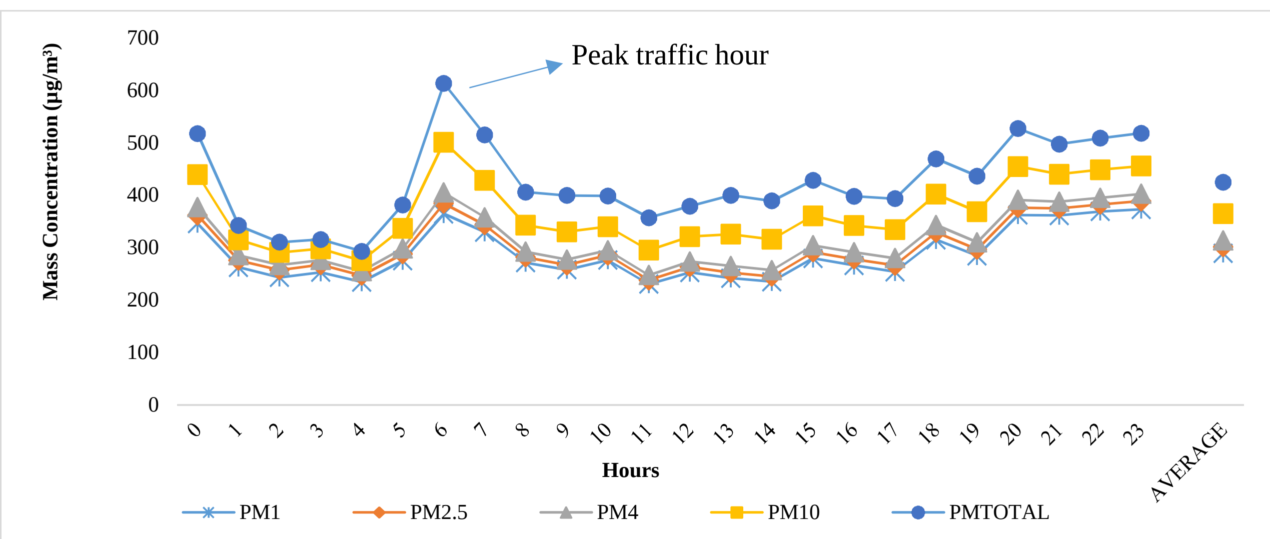

Figure 3: Hourly mean levels of PM at site 2

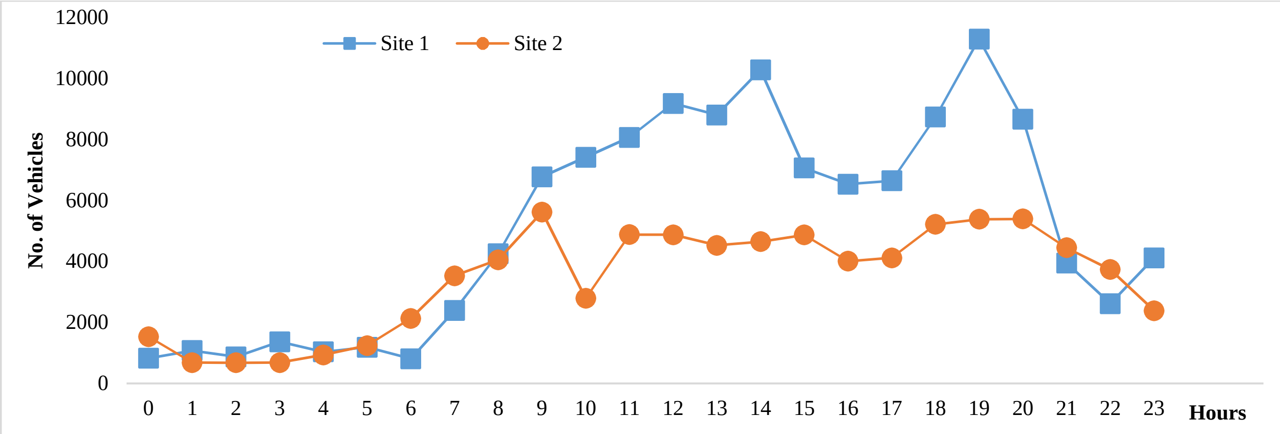

Figure 4: Hourly trend of motor vehicles passing throughout the 24 hours at site 1 and 2

A strong impact of meteorological factors as well as traffic congestions upon pollutant levels on roadsides have been recorded by many studies including those of Voutsa *et al*. (2002), Charron and Harrison (2003), and Ghauri *et al*. (2007). In order to analyse the impact of these factors upon PM levels in our study, a multiple linear regression model was applied. The independent variables were number of vehicles, temperature and relative humidity, while the PM fractions were the dependent variables. At site 1, temperature showed a negative association with PM fractions while all the remaining factors exhibited a positive significance with the PM levels. At site 2 however, all the independent variables were found to regress to the dependent variable to varying levels and this relation was positive.

WHO guidelines values for PM2.5 is 10µg/m^3 (annual mean) and 25 µg/m^3(24-hour mean)while for PM10 (20 µg/m^3 annual mean) and 50µg/m^3(24-hour mean). At site 1, 24-hours average concentration of PM2.5 was recorded as 222 µg/m^3 which is 9-times higher than WHO guidelines values while 24-hour average concentration of PM10 was recorded as 286 µg/m^3 i.e. 6-times higher than WHO guidelines values. Similarly at site 2, the respective 24-hour average concentration of PM2.5 and PM10 were 302 µg/m^3 and 365 µg/m^3 which are 12 times and 7 times higher than the WHO recommended levels.

As observed in Figure 2 and 3, the mass concentrations of all fractions of PM showed significant variations in 24-hours. This clearly shows the impact of traffic density, temperature, relative humidity and wind speed and direction. During the course of this study, the peak values of PM concentrations were observed during the morning hours (office going hours) and evening time (off-time). These hours are generally rush hours as people commute to and back from offices and/or educational institutes. It is of importance that the traffic density was much or less the same during the rush hours as that throughout the day. During the rush hours the traffic tends to slow down due to a temporary increased load on roads. Decreased speed tends to increase the emissions from the vehicles as a car covering a distance of 1 km moving at a speed of 10 km/hour may emit ten times the weight of carbon monoxide. With an increase in speed, a marked decrease in emission of PM10 and volatile organic compounds (VOCs) occurs (Tiwari and Colls, 2010). This can be a possible reason of increased PM levels during the rush hours.

In a study conducted by Chan and co-workers (2001), roadside sampling to measure the total suspended particulate matter, PM10, PM2.5 in different areas in Hong Kong was carried out. Different samples were collected to measure the mass concentrations of TSP, PM10 and PM2.5. The observed values of PM10 and PM2.5 ranged from 67.67 to 142.68 µg/m^3 and 50.01 to 125.12µg/m^3, respectively. Meanwhile, the observed average values of PM of the current study are approximately 3.5 times higher than the above mentioned work. Voutsa *et al.* (2002) observed high concentrations of PM10 with an 80% increase of the proposed daily limit. The concentrations were similar to the limits observed in a moderately polluted urban environment. Variation with time and place and different meteorological conditions were observed which effect the concentrations of particulate matter (Voutsa *et al*., 2002). Likewise Charron and Harrison (2003) studied the particulate matter concentration at roadsides and different size fractions were recorded. Their study concluded that the particle number near a road depends, not only on vehicle emissions intensity, but also on favourable meteorological parameters.

In Pakistan, with an increase in number of on-road vehicles, a growing need has arisen to monitor and control the emissions of pollutants into the air. Ghauri*et al*., (2007) noted the highest levels of CO (14 ppm) in Quetta. On the contrary, PM_{10}, TSP, SO_2, NO_x, and O_3 were observed in higher amounts in Lahore with the respective mean levels of total suspended particles (TSP) and coarse particles (PM_{10}) to be 996 µg/m^3 and 368 µg/m^3. Highest pollutant levels were observed at major roads and a direct correlation with traffic density was observed. Studies conducted by Pak-EPA regarding the ambient air quality at major roads in larger cities of the Punjab observed that higher levels of particulate matter had a significant association with the vehicular traffic on roads.

Conclusion: Exposure tohigh levels of PM are directly related with increased morbidity and mortality. In this study the levels of PM fractions were observed to be directly related with motor traffic and were many times higher than the recommended levels set by WHO. There is an urgent need to adopt air quality management strategies. Improvement in air quality in urban centres can be achieved by maintaining traffic flow, providing public transport facilities, improving automotive technologies and promoting the use of cleaner fuels. As an alternative, bio-fuels may be employed so as to reduce the harmful emissions from petroleum based fuels. Compressed natural gas (CNG) is a green fuel with lower emissions which is now rapidly becoming a priority for many transporters. Ethanol is also environmental friendly as it is sulphur free. Bio-diesel also emits lower quantities of carbon monoxide, PM and hydrocarbons (Tiwary and Colls, 2010).Most importantly the Government should ensure the compliance with National Environmental Quality Standards for motor vehicle exhaust, noise and ambient air quality.

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