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Seasonal and Temporal Variations of Criteria Air Pollutants and the Influence of Meteorological Parameters on the Concentration of Pollutants in Ambient Air in Lahore, Pakistan

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Abstract. Criteria air pollutants have their significance for causing health threats and damage to the environment. The study was conducted to assess the seasonal and temporal variations of criteria air pollutants and evaluating the correlations of criteria air pollutants with meteorological parameters in the city of Lahore, Pakistan for a period of one year from April 2010 to March 2011. The concentrations of criteria air pollutants were determined at fixed monitoring stations equipped with HORIBA analyzers. The annual average concentrations (µg/m^3) of $PM_{2.5}$, O_3, SO_2, CO and NO_x ($NO+NO_2$) for this study period were 118.94±57.46, 46.0±24.2, 39.9±8.9, 1940±1300 and 130.9±81.0 (61.8±46.2+57.3±22.19), respectively. $PM_{2.5}$, SO_2, CO and NO_x had maximum concentrations during winter whereas O_3 had maximum concentration during summer. Minimum concentrations of $PM_{2.5}$, SO_2 and NO_x were found during monsoon as compared to other seasons due to rainfall which scavenged these pollutants. The O_3 showed positive correlation with temperature and solar radiation but negative correlation with wind speed. All other criteria air pollutants showed negative correlation with wind speed, temperature and solar radiation. A significant ($P<0.01$) correlation was found between NO_x and CO ($r = 0.779$) which showed that NO_x and CO arise from common source that could be the vehicular emission. $PM_{2.5}$ was significantly correlated ($P<0.01$) with NO_x ($r = 0.524$) and CO ($r = 0.519$), respectively. High traffic intensity and traffic jams were responsible for increased air pollutants level especially the $PM_{2.5}$, NO_x and CO.

Keywords: $PM_{2.5}$, O_3, SO_2, CO, NO_x, seasonal variations, air pollution, meteorological parameters

Introduction

Among the current environmental problems faced by the society, air quality issues are most problematic to handle as more and more studies report the human health and environmental impact of air pollution (Desauziers, 2004). Lahore is the second largest city in Pakistan, it stands at number 40 in the ranking of world's most populated urban cities. The population of Lahore is growing at a rapid rate and has now reached 10 million (Hameed and Nazir, 2011). Lahore is situated in east of Pakistan (latitude 31.470 N and longitude 74.253 E) and has an altitude of 702ft from sea level (Fig. 1). It is commercial, industrial, cultural and educational hub of Pakistan. The selected site is ideal for the study as it represents the local and distant air pollution sources. Lahore city has arid and hot climate and it presents four seasons. The winter season starts from November and ends at February. The temperature is lowest during winter having an average of 12.14 ± 4.12 °C. Spring season comprises of two months March and April. The summer season is from May to July and temperature is highest during these months having an average of 34.8±11.8 °C.

Lahore receives bulk of rainfall during July to September and the fall season is in October. During the last 10 years the rainfall varied from 333-1232 mm and relative humidity in this area was 17% to 70%. The growing volume of population and traffic are major factors for rise in air pollution. The Lahore city has 1.4 million registered vehicles (Ali and Athar, 2008). Many earlier studies show that Lahore is one of the world's most polluted cities (Mehta *et al*., 2009; Hopke, 2009; Biswas *et al*., 2008; Wahid, 2006; Barletta *et al*., 2002; Parekh *et al*., 2001; Harrison *et al*., 1997; Hussain*et al*., 1990). In 1992 WHO conducted an air quality monitoring programme which revealed that total concentration of suspended particulate in Lahore was among the highest in the world (Smith *et al*., 1996; WHO and UNEP, 1992).

Air pollution is caused mainly by fossil fuel (oil, coal and natural gas) use in industry, domestic sector, power generation and transport (Jaffary and Faridi, 2006). In addition; animal waste, agricultural waste and biomass

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burning also contribute in polluting air. The pollutant emission into ambient air has direct and indirect effects like eutrophication, stratospheric ozone depletion, acidification and production of ground level ozone. This may in turn worsen the air quality and leave its impact on the ecosystem, buildings, agriculture and human health (Schwella, 2008). Meteorological parameters have an important role in dispersion, dilution, formation and transport of pollutants in air (Ying *et al*., 2012). For understanding atmospheric air quality the accurate measurement and monitoring of meteorological parameter is a principal requirement (Seaman, 2003). The ambient weather conditions influence the chemical reaction of air pollutants (Elminir, 2005). The air quality of cities is correlated with the various meteorological factors like wind speed, air temperature and solar radiation (Gupta *et al*., 2004). This study was conducted to assess the seasonal and temporal variations of criteria air pollutants and evaluating the correlations of criteria air pollutants with meteorological parameters in the city of Lahore, Pakistan.

Fig. 1. Map of Lahore, Pakistan.

Materials and Methods

Description of study site. Complete monitoring data for the criteria air pollutants $PM_{2.5}$, O_3, SO_2, CO and NO_x ($NO+NO_2$) was obtained with the courtesy of Environment Protection Department (EPD) Lahore, Pakistan for a period of one year from April 2010 to March 2011. Figure 1 represents the map of Lahore. Environment Protection Agency Punjab is continuously monitoring the air quality of Lahore at two sites through fixed monitoring stations. One of them is located at Town Hall on lower Mall Area Lahore, Pakistan. This is a general air quality monitoring station situated on the roof top (25 f from ground level) of local EPA office. Its distance from the main busiest roads like Mall Road, Lower Mall, Bank Road and Anarkali Road is about 200 meter. Lower Mall Area is situated in the centre of the city. It is surrounded by busiest road of city and commercial activities. About 3 kilometers away from this site is an industrial centre named Badami Bagh industrial area. The dominant industrial activity in this area is steel scrap processing units and plastic industry. The other fixed monitoring station is located in Township in south of Lahore. It has residential area as well as small industrial area.

Instrument and statistical analysis. $PM_{2.5}$ was monitored with HORIBA instrument APDA-371. It works on the principle of betaray attenuation. The lower detection limit for 1 h is < 4.8 $\mu g/m^3$ and for 24 h is < 1.0 $\mu g/m^3$. CO monitoring was done with HORIBA instrument APMA-370. It uses solenoid valve cross flow modulation, non-dispersive infrared (NDIR) absorption technology (Detection limit 0.02 ppm). NO_x (NO_2+NO) were monitored with APNA-370. The principle of measurement is cross flow modulation type reduced pressure chemiluminescence (CLD) with lower detection limit of 0.5 ppb. O_3 was monitored with APOA-370. The instrument operates on cross flow modulation type, Ultra-violet-absorption method (NDUV) and the lower detection limit is 0.5 ppb. SO_2 was monitored with APSA-370. The instrument works on Ultra Violet Florescence Technology (lower detection limit 0.5 ppb).

Pearson correlation was used to correlate between criteria air pollutants and meteorological parameters using SPSS Statistics v20.

Results and Discussion

Monthly average concentrations of criteria air pollutants $PM_{2.5}$, O_3, SO_2, CO and NO_x ($NO+NO_2$) are presented in Fig. 2(a-e). and monthly ranges along with simultaneously measured meteorological data is represented in Table 1. The seasonal variation is presented in Fig. 3. Highest and lowest $PM_{2.5}$ levels were observed in winter and monsoon, respectively. The highest $PM_{2.5}$ concentration in winter months can be attributed to residential heating. The $PM_{2.5}$ concentration in winter was 2.2 times higher than the $PM_{2.5}$ concentration in summer and 3.7 times higher than the $PM_{2.5}$ concentration in monsoon season. The $PM_{2.5}$ level during the winter season was 7.7 times higher than the WHO prescribed limit of 25 µg/m^3 (WHO, 2006) and 4.8 times greater than the Pak-EPA limit of 40 µg/m^3 (Pak-EPA, 2009). During the summer season the $PM_{2.5}$ level was 3.4 times higher than the standard WHO limit (WHO, 2006) and 2.1 times greater than the Pak-EPA standards (Pak-EPA, 2009). The $PM_{2.5}$ level during the spring and fall also violated the standards. The $PM_{2.5}$ concentration was 4.2 times in excess the WHO standard (WHO, 2006) and 2.6 times in excess than Pak-EPA standard (Pak-EPA, 2009) during spring and 5.4 times in excess than WHO limit (WHO, 2006) and 3.4 times in excess than Pak-EPA limits (Pak-EPA, 2009) during fall. During monsoon the $PM_{2.5}$ level was 2 times greater than the WHO limit (WHO, 2006) and 1.3 times in excess the Pak-EPA standard (Pak-EPA, 2009). The $PM_{2.5}$ levels in air reduced during the monsoon season because the rain scavenges the particulate matter in air and wash it out (McCully *et al*., 1956). Yaseen (2000) reported similar results in Malaysia where rainfall drops washout the particulate in air and thus reduces its concentration in ambient air.

The first study on particulate matter in Lahore was carried out by Global Environment Monitoring System (GEMS) which reported that the annual mean suspended particulate matter (SPM) concentration in Lahore was 332 µg/m^3 in 1978 at commercial city centre and 749 µg/m^3 and 690 µg/m^3 during 1979 and 1980, respectively at the suburban residential site (WHO, 1984). Similarly Smith *et al*. (1996) studied annual mean total suspended particulate (TSP) level in Lahore and reported that 838, 590 and 607 µg/m^3 of particulate was present at rural, industrial and city site in Lahore, respectively. Pak-EPA/JICA (2001) reported the hourly average concentration of suspended particulate matter (SPM) at Lahore was 895 µg/m^3. Waheed *et al*. (2005) reported that the particulate matter in Lahore was in the range of 1, 128-1, 870 µg/m^3. Hussain *et al*. (2007) studied $PM_{2.5}$ level in Lahore during 2005-2006 and the $PM_{2.5}$ level was in range of 53-476 µg/m^3. Ghauri *et al*. (2007) reported that, total suspended particulate (TSP) in Lahore during 2003-2004 was 482 µg/m^3 and the level of PM_{10} in Lahore during 2003-2004 was 200 µg/m^3. Lodhi

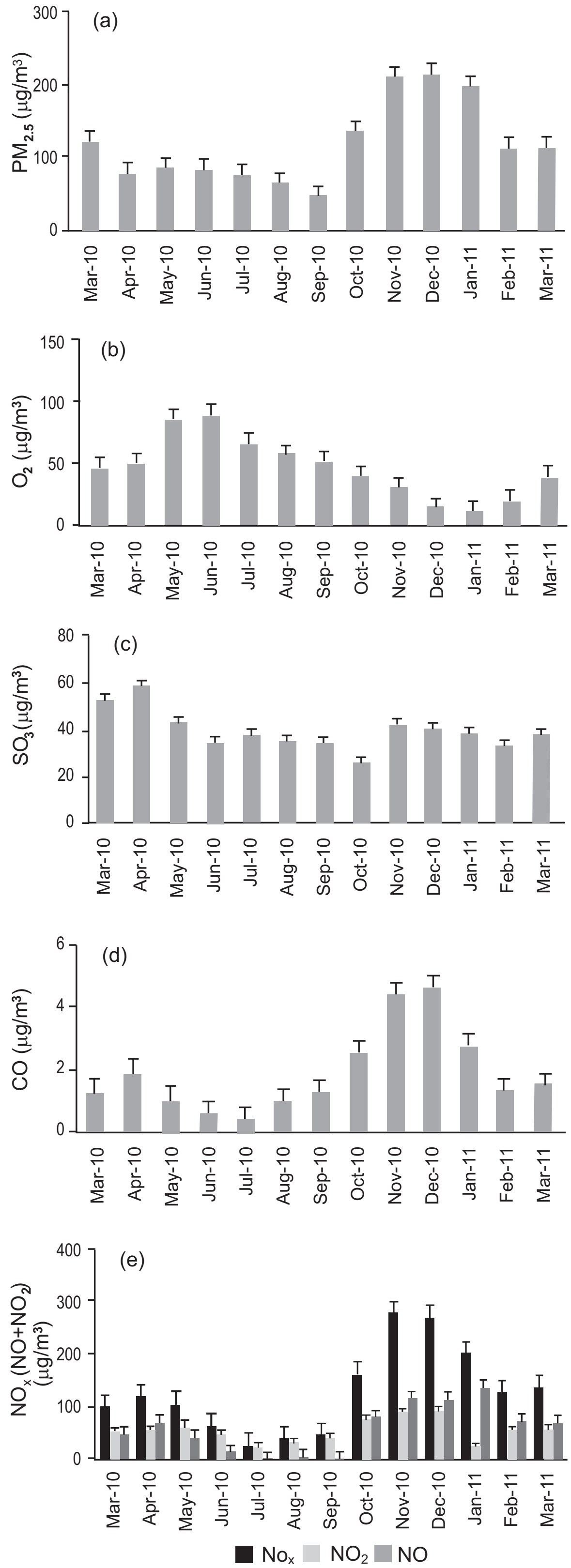

Fig. 2(a-e). Monthly average concentrations of criteria air pollutants in Lahore, Pakistan.

et al. (2009) reported that $PM_{2.5}$ annual arithmetic mean during 2007 was 103 μg/m³.

In the present study (2010-2011), the observed annual mean of $PM_{2.5}$ is 118.9 μg/m³. This level is 4.8 times in excess the WHO standard (WHO, 2006) and 3 times greater than the Pak-EPA limit (Pak-EPA, 2009). From this, it is obvious that Lahore is facing alarming particulate matter levels. This is due to excessive increase in vehicle use, outdated unfit vehicles, poorly maintained old vehicles, old buses model, fuel adulteration and lack of paved areas, road side vegetation and soil erosion. The number of vehicles in Lahore has reached up to 2.48 million (Haider, 2010). Motor vehicles emit a mixture of pollutants i.e. PM_{10}, CO, O_3 and NO_x (Kadiyali, 2008).To combat the excessive particulate matter concentration in air the government has encouraged the use of compressed natural gas (CNG) instead of diesel and petrol. Now, Pakistan ranks third in the world for using CNG and it is the largest CNG user in Asia (GOP, 2005). Although particulate matter levels are still elevated due to poor CNG technology use (Narain and Krupnick, 2007).

Seasonal O_3 variation showed inverse trend as compared to other gaseous pollutants monitored in study. The monthly concentrations are represented in Fig. 2b. The seasonal concentrations are presented in Fig. 3b. Ozone concentrations were lowest during winter season and greater during summer season. The highest O_3 concentration was found in June (88.6±56.8 μg/m³) and lowest O_3 concentration was observed in January (11.3±10.9 μg/m³). However, the O_3 concentration throughout the year was within the permissible limits of Pak-EPA (2009). The higher concentration of O_3 during summer as compared to winter is due to the high

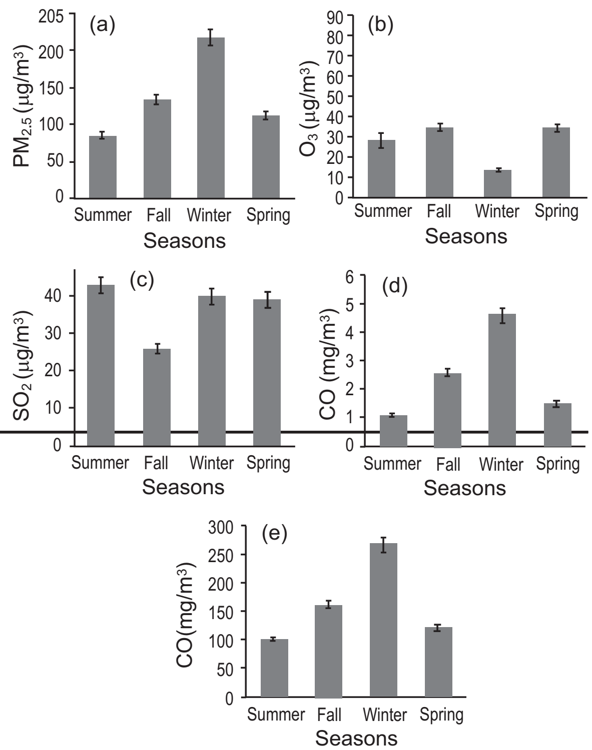

Fig. 3(a-e). Seasonal variations of criteria air pollutants in Lahore, Pakistan.

Table 1. Monthly ranges of criteria air pollutants and simultaneously measured meteorological data (March 2010 to March 2011) in Lahore, Pakistan

Months	$PM_{2.5}$	SO_2	CO	O_3 (μg/m³)	NO_x	NO_2	NO	Temperature (°C)	Wind speed (m/s)	Radiation (W/m²)
Apr-2010	0.27-336.00	7.50-247.60	270-16100	1.20-227.70	7.50-679.10	8.60-211.50	1.20-584.30	16.90-41.50	0.16-2.90	1.50-896.20
May-2010	17.67-443.00	4.77-316.20	250-13620	8.26-345.94	7.81-747.66	6.59-186.88	0.97-613.47	20.72-44.27	0.37-3.17	1.40-541.10
Jun-2010	19.50-391.80	3.20-262.80	150-10100	8.90-248.00	5.50-636.10	5.42-224.80	0.70-515.40	24.80-45.20	0.10-2.70	1.50-532.60
Jul-2010	10.10-399.50	1.03-43.90	70-4010	4.40-207.20	5.00-141.90	4.85-132.80	0.10-40.30	26.10-39.70	0.20-4.00	1.30-917.40
Aug-2010	15.00-174.00	1.70-56.10	20-6600	0.03-199.70	3.35-235.70	3.30-120.60	0.10-128.20	27.70-36.40	0.40-3.14	1.40-760.50
Sep-2010	5.00-113.30	1.80-44.50	40-9800	0.80-197.40	4.30-430.70	3.09-268.00	0.05-170.30	20.70-34.90	0.03-2.03	1.40-172.20
Oct-2010	18.00-430.01	0.24-140.77	250-18170	0.28-268.67	11.19-759.36	9.37-244.40	0.80-632.74	16.59-32.14	0.17-3.18	1.40-150.30
Nov-2010	21.1-825.00	9.40-193.80	330-19900	1.60-228.20	15.10-818.20	25.08-217.00	2.20-635.80	11.70-28.20	0.14-1.24	1.50-68.50
Dec-2010	30.33-560.00	10.95-305.34	490-20010	0.10-154.73	31.34-746.26	34.91-192.66	3.23-647.06	6.68-22.47	0.13-1.31	1.40-76.90
Jan-2011	1.79-413.00	6.01-230.50	300-21400	0.10-108.20	15.80-726.40	24.10-183.60	3.60-625.20	5.70-19.90	0.19-1.23	1.30-87.50
Feb-2011	21.00-377.30	7.07-134.90	150-10700	0.10-108.80	15.40-704.50	12.50-171.10	2.90-618.60	9.70-23.70	0.10-2.07	1.30-144.60
Mar-2011	24.00-347.00	6.68-183.66	160-10540	0.01-250.58	12.33-602.77	9.81-135.91	2.16-536.81	11.75-30.46	0.22-1.52	1.40-680.70

solar radiation during summer months. Selvaraj *et al*. (2010) reported similar results where high level of O_3 was present during summer months due to high solar radiations. Pak-EPA/ JICA (2011) also reported similar results where low concentration of O_3 during winter season was linked with low solar radiation.

Pak-EPA/JICA (2001) reported that hourly average concentration of O_3 was 17 µg/m^3. Ghauri *et al*. (2007) reported that level of O_3 in Lahore was 44 µg/m^3 (48 h mean) during 2003-2004. In the present study, the observed annual mean of O_3 was 46.04 µg/m^3. The O_3 concentration in Lahore was within the permissible limit of Pak-EPA of 130 µg/m^3 (Pak-EPA, 2009). However, as a result of rise in CNG vehicles use in Lahore the concentration is likely to rise due to emission of NO_2 from vehicles.

The concentration of SO_2 remained high throughout the year. The monthly concentrations are represented in Fig. 2c and seasonal variation is shown in Fig. 3c. Low concentration of SO_2 was observed during the monsoon season. This is due to the fact that SO_2 has been converted to H_2SO_4 due to the rainfall (Ravindra *et al*., 2003). Gupta *et al*. (2008) reported similar results in Kolkata, India where, the SO_2 concentration decreased in air due to monsoon precipitation.

GEMS study showed that SO_2 annual concentration in Lahore was 49 µg/m^3 in 1978 at city center and 40 µg/m^3 in 1979 at suburban residential area (WHO, 1984). Pak-EPA/JICA (2001) reported that hourly average concentration of SO_2 was 44.6 µg/m^3. Ghauri *et al*. (2007) found concentration of SO_2 in Lahore was 57.6 µg/m^3 (48 h mean) during 2003-2004.

In the present study, the observed SO_2 annual mean was 39.9 µg/m^3. The annual mean concentration of SO_2 (2010-2011) was below the permissible limit of 80 µg/m^3 of Pak-EPA (2009). The presence of SO_2 in air in Lahore is due to 1% (10,000 ppm) sulphur in diesel. The SO_2 level is low in air due to the use of CNG based public transport vehicles. According to Haider (2010) the number of total CNG vehicles in Lahore (628269) is about three folds higher in number as compared to diesel vehicles (207656). Moreover, a CNG bus emits 5.45 times less SO_2 than the diesel bus and CNG wagon emits 5 times less SO_2 than diesel wagon (Haider, 2010). Narain and Krupnick (2007) reported similar results in Delhi, India where, SO_2 levels decreased from 1997 to 2005 due to conversion of vehicles from diesel to CNG.

High CO concentrations were prevalent in winter months. The maximum CO monthly average was observed in December (4690±3910) and minimum CO concentration was recorded in July (540±490). Monthly variation in CO concentration is represented in Fig. 2d. The seasonal trends are shown in Fig. 3d, it reveals very high CO concentrations in winter months as compared to summer season. The concentration of CO in winter months in 2010-2011 approached the Pak-EPA standard of 5000 µg/m^3 (5 mg/m^3) (Pak-EPA 2009). These elevated CO level in colder days was due to residential heating.

Pak-EPA/JICA (2001) reported 2820 µg/m^3 hourly average concentration of CO. Ghauri *et al*., (2007) studied CO in Lahore and found its concentration as 4000 µg/m^3 (48 h mean) during 2003-2004. In present study, the observed annual mean of CO was 1940 µg/m^3. The level of CO is a result of burning of solid waste, increase in vehicular number and poorly maintained mass transit system. Lahore is a city with high pollution level per vehicle. The international and public pressure has forced the government so it took measures to control the pollution level through conver-sion of public transport to CNG, ban on two stroke vehicle production, subsidy on four stroke rickshaws and installation of CNG kits in diesel buses. Therefore, decrease in CO concentration seems to be due to shifting of vehicles on CNG. Kim and Chung (2008) reported similar results where CO level decreased in Korea due to switching to CNG fuel. In Delhi, India CO level declined from 1997-2005 due to shift in vehicle from diesel to CNG (Narain and Krupnick, 2007).

NO_x is mainly comprised of nitrogen dioxide and nitric oxide. Fig. 2e, illustrates the seasonal variation of NO_x ($NO+NO_2$). The maximum and minimum NO_x monthly average concentration was observed in December (279.8±233.9 µg/m^3) and in July (28.3±23.9 µg/m^3), respectively. The seasonal concentrations are represented in Fig. 3e. The highest NO_x concentration was during winter season and lowest NO_x level was during summer and monsoon season. The cold season has 3.7 times greater concentration of NO_x as compared to hot season. The anthropogenic sources of NO_x include power plants, residential combustion units industry and motor vehicles. In our study, NO_x showed elevated concentration during cold season mainly due to residential heating. During the cold season, the NO_x concentration was 5.7 times higher than the WHO limits of 40 µg/m^3 (WHO, 2006) and 2.9 times greater than the Pak-EPA standards of 80 µg/m^3 (Pak-EPA 2009). The lower NO_x concentration in monsoon is due to washout of NO_x by rainfall (Ravindra *et al*., 2003). Gupta *et al*. (2008) reported similar results in Kolkata, India where the NO_x level decreased in air due to monsoon.

Pak-EPA/JICA (2001) reported the hourly average concentration of NO 88.4 µg/m^3 and NO_x 156.6 µg/m^3. Ghauri *et al*. (2007) studied NO_x in Lahore and found its concentration to be 55 µg/m^3 (48 h mean) during 2003-2004. In the present study, the observed annual mean of NO_x, NO_2 and NO was 130.9, 57.3 and 61.8 µg/m^3, respectively. This NO_x level is 3.3 times greater than the WHO standard (WHO, 2006) and 1.6 times greater than the Pak-EPA limit (Pak-EPA, 2009). A study was carried out in Brazil which revealed that conversion of vehicle from gasoline to CNG reduced CO by 53% but increased NO_x by 171% (LuzDondero and Goldemberg, 2005). Narain and Krupnick (2007) reported similar results in Delhi, India where, NO_x levels increased from 1990-2005 due to use of CNG vehicles.

Correlation of criteria air pollutants with meteorological parameters. Concentration of all the criteria air pollutants was correlated with wind speed, temperature and solar radiation (Table 2).

Wind is the air in motion and wind speed is rate of air motion. No seasonal fluctuations were observed with varying wind speed and low wind speed values were dominant ranging from 0.03 to 3.18 m/s. The average wind speed was 1.14 m/s. Significant inverse correlation was observed between wind speed and criteria air pollutants ($P<0.01$). The inverse relationship between variables can be explained on the basis of fact that when wind speed is low, it will not influence the distribution of air pollutants in an area but when the wind speed will be high it will disperse the pollutants and thus reducing the concentration of air pollutants in an area. Tasdemir *et al.* (2005) reported similar results.

$PM_{2.5}$, NO_x, CO and SO_2 were negatively correlated ($P<0.01$) with air temperature and solar radiation. The SO_2 showed lowest correlation value with air temperature and solar radiation. This can be linked with the burning of coal containing sulphur, used for the heating purpose but the 'r' values were not high enough. The lower burning efficiency of coal also contributed to elevated CO and $PM_{2.5}$ emissions. $PM_{2.5}$ was significantly correlated with NO_x ($r = 0.524$, $P<0.01$) and CO ($r = 0.519$, $P<0.01$). Positive correlation depicts a similar source for these gases. High traffic intensity and traffic jams were responsible for increased air pollutants level especially the $PM_{2.5}$, NO_x and CO.

Table 2. Correlations of criteria air pollutants with meteorological parameters

Parameters		$PM_{2.5}$	NO_x	O_3	CO	SO_2	Wind speed	Temperature	Radiation
$PM_{2.5}$	Pearson coefficient (r)	1	-	-	-	-	-	-	-
	Significance (P)	-	-	-	-	-	-	-	-
NO_x	Pearson coefficient (r)	.524**	1	-	-	-	-	-	-
	Significance (P)	.000	-	-	-	-	-	-	-
O_3	Pearson coefficient (r)	-.330**	-.450**	1	-	-	-	-	-
	Significance (P)	.000	.000	-	-	-	-	-	-
CO	Pearson coefficient (r)	.519**	.779**	-.422**	1	-	-	-	-
	Significance (P)	.000	.000	.000	-	-	-	-	-
SO_2	Pearson coefficient (r)	.316**	.331**	-.176**	.261**	1	-	-	-
	Significance (P)	.000	.000	.000	.000	-	-	-	-
Wind speed	Pearson coefficient (r)	-.253**	-.332**	-.284**	-.327**	-.117**	1	-	-
	Significance (P)	.000	.000	.000	.000	.000	-	-	-
Temperature	Pearson coefficient (r)	-.324**	-.264**	.469**	-.253**	-.039*	.179**	1	-
	Significance (P)	.000	.000	.000	.000	.044	.000	-	-
Radiation	Pearson coefficient (r)	-.161**	-.244**	.369**	-.232**	-.030	.314**	.304**	1
	Significance (P)	.000	.000	.000	.000	.121	.000	.000	-

In the present study, a high correlation was found between NO_x and CO (r = 0.779, P<0.01). A positive correlation between CO and NO_x indicates that they arise from same source. Kimmel *et al*. (2002); Bogo *et al*. (1999) and Cardens *et al*. (1998) suggested that NO_x and CO arise from common source(s) that could be the vehicular emission. NO_x and CO are emitted from incomplete combustion of organic fuel in motor vehicles (Goyal and Sidhartha, 2003).

The O_3 showed positive relation with solar radiation and air temperature (P<0.01). This is due to the fact that the reaction between nitrogen oxides, volatile organic compounds and carbon monoxide take place in the presence of sunlight to produce ozone. So, the availability of high amount of solar radiation contributes to the production of ozone at ground level and increased its concentration in ambient air (Selvaraj *et al*. 2010). The negative correlation of NO_x with O_3 (r = -0.450, P<0.01) also support this argument. Shan *et al.* (2008) and Tu *et al*. (2007) reported the positive correlation of ozone concentration with air temperature. Pulikesi *et al*. (2006) linked the ozone concentration with intense solar radiation.

Conclusion

Criteria air pollutants are known to cause serious health issues and damage to environment. Keeping this fact in mind, the present study was conducted in Lahore, Pakistan for the assessment as well as correlation of criteria air pollutants with meteorological parameters. Results showed that O_3 concentration increased in summer season while the concentration of $PM_{2.5}$, SO_2, CO and NO_x raised during winters. $PM_{2.5}$ concentration was highest in winter due to heating but its elevated levels were also found during summer due to poorly maintained out dated vehicles, lack of paved areas and vegetation. O_3 remained highest in summer season due to high solar radiations which enhance the production of ground level ozone. SO_2 and CO level remained within the permissible limit due to shifting in vehicle from petrol and diesel to CNG. Level of NO_x remained high and its elevated level was contributed by CNG vehicles. $PM_{2.5}$, SO_2 and NO_x remained lowest during monsoon due to washout from rains. O_3 remained lowest in winter due to less solar radiation. CO remained lowest during summer due to decreased residential burning. The concentration of air pollutants was negatively correlated with wind speed showing that the increase in wind speed causes dispersion of pollutants. O_3 showed positive correlation with temperature and solar radiation but negative correlation with wind speed. All other criteria air pollutants showed negative correlation with wind speed, temperature and solar radiation.

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