NITROGEN DIOXIDE MONITORING IN URBAN AREAS OF LAHORE, PAKISTAN

Abstract

Nitrogen dioxide (NO_2) plays significant role in atmospheric chemistry mainly in secondary air pollutants formation which consequently result in environmental acidification. It has adverse impact on human health and considered as the second most harmful air pollutant after PM_{10} in major cities of Pakistan including Lahore. In this study, 15 major urban sites of Lahore with respect to vehicular flow were focused during rush hours from 1:30 pm to 9:30 pm for the monitoring of NO_2 level. Chemiluminescence technique was applied to identify NO_2 concentrations by using Horiba APNA-370 monitor. For sampling, four months of winter season November 2016 to February 2017 were selected and measured monthly average mean values; associated meteorological conditions like temperature, wind speed, rainfall and relative humidity were also monitored. A spatial distribution map of different locations for NO_2 concentrations was developed by using geostatistical tool ArcGIS. The highest NO_2 values near the main roads were mainly due to intense traffic flow and vehicular emissions unlike residential and commercial locations. Moreover, the NO_2 level exceeded the NEQS standards at most of the sampling points during study. Therefore, it is mandatory to take desired steps in order to develop effective mechanism to control air pollution before it becomes a serious hazard for human beings living in urban areas.

Keywords: NO_2, Air pollutants, Environment, Vehicular, Residential, Commercial, Urban areas, Traffic flow, Human health, Lahore, Pakistan

1: Introduction

Air is amongst the essential components of life that plays a significant role in survival of living beings, their breathing and other life-sustaining process but it's being polluted with onset of industrial revolution (Khan et al. 2008) and multiple emission sources (Ahmadi et al. 2015). Developing countries like under-developing countries are facing several environmental and health issues emerge due to increasing population, growing industrialization, motorization and inadequate management of solid waste (Mirza et al. 2013; Yasin 2012 ;Majid et al. 2012; Azmi et al. 2010; Shah et al. 2013; Chatterjee 2010; Sharholy, 2008; Kumar 2009). Most prominent air pollutants found in atmosphere are SO_2, NO_2, CO and PM_{10} (Mirza et al. 2013) which are recognized as major urban air pollutants in mega urban cities (Ahmad et al. 2011).

Out of several air pollutants, photochemical oxidants are amongst large group in which NO_2 has adverse impact on environment and human health (World Health Organization 2000), considered as the second most harmful pollutant after PM_{10} (Werner et al. 2013). Pak-EPA also declared it second most dangerous air pollutant in five big cities of Pakistan such as Lahore, Islamabad, Peshawar, Quetta and Karachi in 2006 (Colbeck et al. 2009).

Tropospheric nitrogen oxides (NO_x : $NO+NO_2$) converted into NO_2 by the help of oxidation (Werner et al. 2013) which plays significant role in formation of secondary pollutants (Shyam et al. 2008) thus cause environmental acidification (Ahmad et al. 2011). NO_2 is originated from both primary sources and secondary transformation in the atmosphere (Ravindra et al. 2008). The important attribute of NO_2 is that it's a precursor that alter th2e chemistry of atmosphere, which in turn impacts on local, regional and global scales in the environment (Stock et al. 2013). The major sources of NO_x are industry and road transport (Behera et al. 2015). NO_x emissions vary in composition in terms of large vehicles (Grundstrom

et al. 2015). Mostly, diesel engines contain higher NO_2 fraction and different types of filters fitted for particles in fleet vehicles, which in turn emit high NO_2 (Alvarez et al. 2008). From last few decades, its level is continuously rising in urban areas (Ahmad et al. 2011) due to vehicular emissions by incomplete combustion (Emberson et al. 2003). In the United Kingdom, motor vehicles are the major source of air pollution. Similarly, New South Wales, road transport is the single largest source of NO_x emissions that contributes more than 71% of total emissions. Other cities like Shanghai, New Delhi, Mumbai, Guangzhou, Chongqing, Calcutta, Beijing, and Bangkok are also violating WHO guidelines in terms ambient PM and NO_2 concentrations (Gulia et al. 2015). Furthermore, NO_2 causes numerous adverse effects on human health, causing visibility issues (ul-Haq et al. 2014), pulmonary edema and badly effect the central nervous system, tissues etc. (Lal and Patil 2001; Kampa and Castanas 2008).

NO_2 concentration remains different throughout the year. The highest values of NO_2 were observed in February, November and the month of December whereas lower concentration were observed in summer seasons particularly in May, June and July. (Gupta et al. 2003; Ahmad et al. 2011). High values in winter season are due to large number of people burn wood, cow dung and coal for heating and cooking (ul-Haq et al. 2014). However, according to Zhou et al. (2012), NO_2 highest monthly averaged values observed in June and the lowest values in March. This is because high rainfall, high temperature and humidity in summer season lead to soil erosion, which could be enhanced by the application of fertilizers in the rice growing fields. Another major source of high values of NO_2 is the usage of diesel and petrol generators for electricity during the electric power outage. Similarly, low values in winter mostly attributed to less soil emissions due to low temperature and precipitation. NO_2 washout through precipitation and less cloud cover blockage to solar radiation.

Moreover, other studies indicates exposure of mixtures of NO_2 and SO_2 to vegetation and plants may alter their growth and reduce their ability to withstand drought and frost stresses and could increase the growth rate of herbivorous insects and fungal pathogens (Shon et al. 2011; ul-Haq et al. 2014). However, there are large uncertainties in source strengths as well. Therefore, comprehensive studies are sought in Pakistan to contrive a strategy to alleviate emissions (Werner et al. 2013).

In this study, average concentrations of NO_2 were determined by using Chemiluminescence (ISO-7996) technique at Horiba Monitor; Model APNA-370. The aim of the study is to determine average NO_2 concentrations at different locations of the city, identification of monthly average mean values and investigation of meteorological variables on the measured concentrations. The monitoring of NO_2 is very important in measuring potential effect of NO_2 on human health and urban environment. It's also play significant role in developing strategies for the effective control of NO_2 pollution.

2: Materials and Method

3.1. Study Area

Lahore is known as the cultural heart of Pakistan, the capital of the Punjab with an estimated population of around 12,500,000 and the second largest city in the country. It is the business hub of Punjab with majority of people engaged in industries, commerce and trade, attracting people from all over the country. It has extremely hot weather during summer especially from March-July associated with monsoon rain and dust episodes, which starts from end of July to August. The highest ever-recorded rainfall was 221mm in August 2008 (Ashraf et al. 2013: Ali et al. 2015). Furthermore, city is surrounded with dense transport and industrial network which consequently effects badly not only urban environment of the city but human health also such as asthma, respiratory problems, kidney damage, hearing loss, sleeping disorders, depression etc (Stott 2000; Patz et al. 2000; Rao and Singh 2001; Wong et al. 2002; Kristin and Pan 2001; Ashraf et al. 2013). A map of the designated city Lahore is shown in **Figure. 1**. For Air monitoring campaign, 15 important urban sites of Lahore were selected which were further divided into vehicular, commercial and residential areas with respect to traffic flow. Air quality monitoring of these designated sites were conducted to assess the existing level of contamination as well as the possible effects of these air pollutants.

3.2. Sampling period

For NO_2 Sampling, four months of winter season (November, December, January and February) were selected and field visits were arranged accordingly, thus mean concentrations of selected air pollutants were identified. While sampling, coordinates of the specific sampling area were also noted. Rush hours were identified and hourly air monitoring by using fixed station for 8 hours from 1:30 pm to 9:30 pm carried out for 15 designated sites. However, sampling station of each city is shown in **Table 1**.

3.3. Instrument:

Chemiluminescence (ISO-7996) technique (USEPA, 1986) was applied to identify NO_2 concentrations (Hadad et al. 2005) by using Horiba Ltd; Model APNA-370 monitor having detection limit of about 0.5 ppb whereas range was about 0~1 ppm. APNA-370 is useful to get maximum accuracy and sensitivity.

3.4. Data Analysis:

The data obtained from the above experimental work were then presented graphically by using Microsoft Excel software. For monthly average mean values, Statistical Package for Social Science (SPSS v.16) and for the preparation of spatial maps, ArcGIS-*version* 16 were used. Moreover, comparisons of obtained results were also made with permissible NEQs limit for assessment and evaluation of pollution load.

Table 1. Monitoring sites of Lahore and source of emission

	Sr#	MONITORING SITES	SOURCE OF EMISSION
Lahore	1.	Ichra	Vehicular, Commercial and Residential
	2.	Wapda roundabout	Vehicular and Commercial
	3.	Gulberg	Commercial
	4.	Ferozpur road (Khalid Colony)	Residential
	5.	Barkat Market	Vehicular and Commercial
	6.	Nasir Bagh/ GCU	Vehicular and Commercial
	7.	Yateem Khana	Vehicular and Commercial
	8.	Punjab Society	Residential
	9.	Allahu Chowk, Johar town	Vehicular and Commercial
	10.	Secretariat	Vehicular
	11.	Samnabad	Vehicular
	12.	Green Town	Vehicular and Commercial
	13.	Sabzazar	Vehicular and Commercial
	14.	Cavalry Ground	Commercial and Residential
	15.	Muslim Town	Commercial and Vehicular

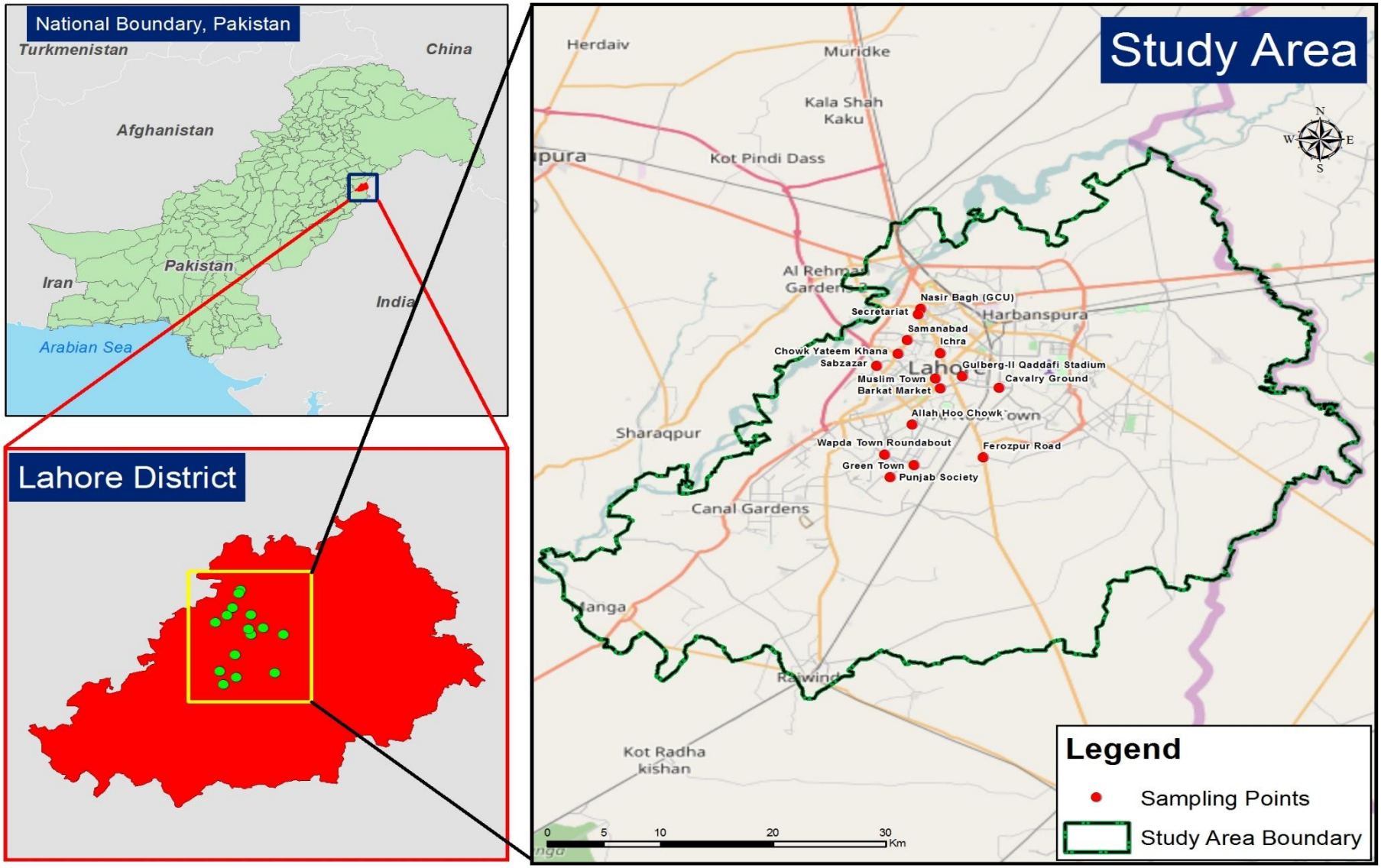


Figure 1. Map showing Lahore city & sampling points

4: Results and Discussion

Air quality monitoring provides information about the status of present air quality conditions. It helps in evaluating the existing policies and their effective implementation (Sivertsen 2008). During sampling, motorized road transport was found to be the leading source of NO_2 contamination in the atmosphere (Shyam et al. 2008; Ahmad et al. 2011).

Monthly Average Mean Values

The data was collected from 15 different locations of Lahore as mentioned in the previous section. Monthly average mean values of all the designated locations for winter season (November- February) were collected as shown in Table 2.

Table 2. Monitoring sites of Lahore and monthly average mean values

MONITORING SITES	Months November Concentrations	December	January	February
Ichra	92.69 ± 2.92	95.72 ± 1.09	89.37 ± 14.99	84.67 ± 9.46
Wapda roundabout	83.26 ± 10.66	91.72 ± 2.45	83.45 ± 14.40	80.67 ± 3.89
Gulberg (Qaddafi Stadium)	35.39 ± 8.16	43.85 ± 12.41	37.44 ± 11.04	31.88 ± 4.70
Ferozpur road (Khalid Colony)	24.89 ± 3.02	25.72 ± 1.72	24.48 ± 3.78	21.92 ± 6.18
Barkat Market	57.39 ± 5.09	61.60 ± 3.97	57.69 ± 7.24	51.88 ± 2.63
Nasir Bagh/ GCU	84.30 ± 1.54	86.38 ± 2.84	80.94 ± 12.04	76.80 ± 3.56
Yateem Khana	94.85 ± 2.52	98.57 ± 2.97	95.67 ± 9.27	94.26 ± 1.61
Punjab Society	23.25 ± 1.50	24.70 ± 1.83	23.93 ± 3.08	21.88 ± 1.23
Allahu Chowk, Johar town	76.19 ± 9.39	82.72 ± 7.37	78.02 ± 9.64	76.49 ± 3.19
Secretariat	80.50 ± 4.28	81.63 ± 7.42	79.14 ± 830	76.60 ± 5.10
Samnabad	80.57 ± 1.65	81.88 ± 4.51	79.30 ± 7.71	79.25 ± 3.37
Green Town	66.00 ± 5.65	69.06 ± 3.22	68.18 ± 7.85	67.68 ± 2.36
Sabzazar	75.00 ± 5.32	77.88 ± 3.95	73.43 ± 10.35	69.80 ± 5.76
Cavalry Ground	58.47 ± 3.46	64.88 ± 2.02	58.49 ± 10.06	54.30 ± 3.92
Muslim Town	68.18 ± 5.05	74.68 ± 2.18	68.27 ± 9.94	62.86 ± 2.78

Monthly trends in the Level of NO_2

As previously mentioned, 15 selected sites were divided in to three different sections such as vehicular, commercial and residential areas. It can be trenchantly seen that NO_2 has highest values in winter season (Ali et al. 2014) from November-February as compared to summer season observed in previous studies. The highest concentration of NO_2 was observed in November and December, which may be due to different meteorological factors and anthropogenic events. However, highest concentration during winter season is due to reduced solar radiation and lower temperature simultaneously as shown in **Figure 2 and 3.** It is clearly shown in the below graphs that NO_2 concentration in most of the selected locations during November and December was found to be higher than National Environmental Quality Standards (NEQS) that is 80/24hrs.

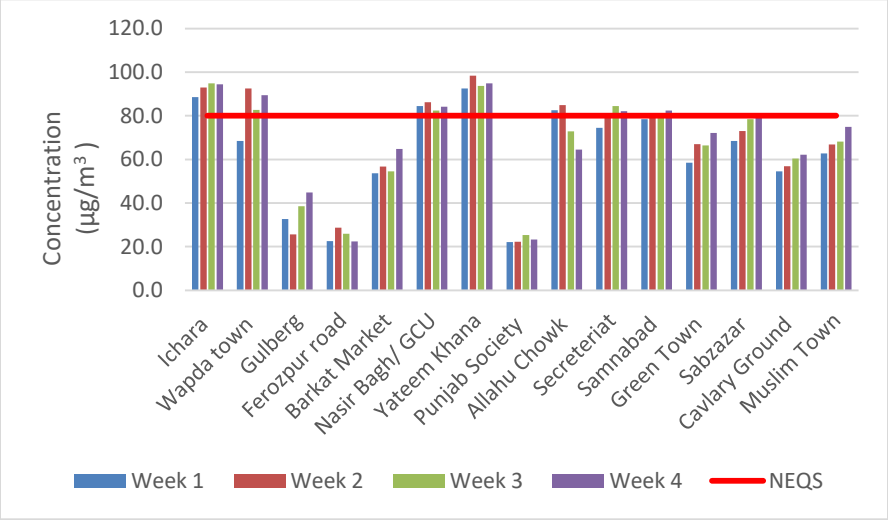


Figure 2. Mean NO_2 concentration for the month of November

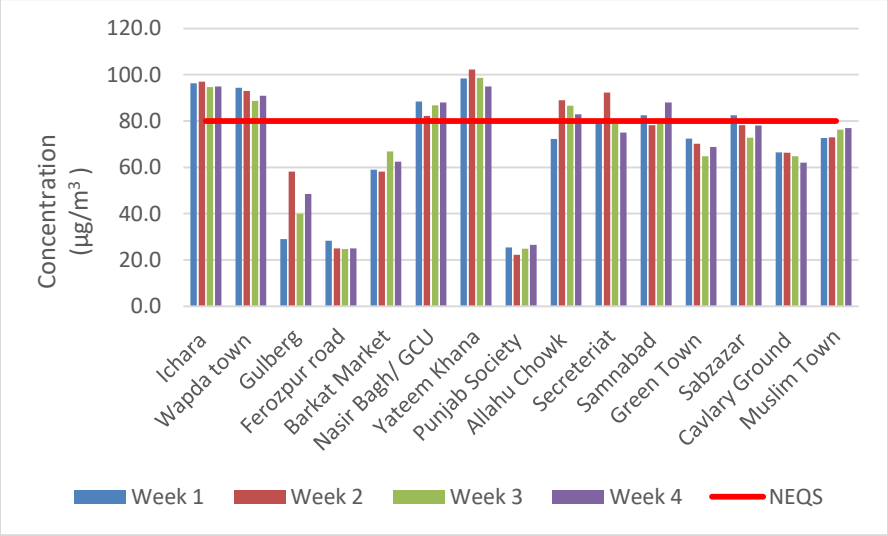


Figure 3. Mean NO_2 concentration for the month of December

The leading source of NO_2 is burning of nitrogen-bearing fuels during combustion process (Ravindra et al. 2008) which is significant gaseous air pollutant and considered as second most dangerous after PM_{10} pertaining to health (Shyam et al. 2008; Ahmad et al. 2011). During 2004, the major urban areas of Pakistan such as Karachi, Lahore, Peshawar, Rawalpindi and Quetta were selected by SUPARCO, and found the highest level of NO_x in winter season with respect to summer and monsoon (Ghauri et al. 2007). Similarly, in Beijing, NO_2 concentration was observed higher during winter seasons near main traffic lines (Chen et al. 2009). Similarly, road traffic is the leading source of NOx as 50% of it enters in to the atmosphere through vehicular sources while 30% from power plants and 20% from industrial processes (Ahmad et al. 2011; Behera et al. 2015). Pak-EPA also declared NO_2 presence in atmosphere is harmful for human health that not only reduces visibility but also contributes to form ozone (O_3) during situational analysis study in five major cities of Pakistan in 2006 (Colbeck et al. 2009). NO_2 concentrations in other selected locations of Lahore showed values within the permissible limit of NEQs as shown in **Figure 4 & 5**. This might be due to low traffic volume in these areas or vegetation cover around. There might be other factors as well such as temperature, wind and rainfall as discussed earlier.

Figure 4. Mean NO_2 concentration for the month of January

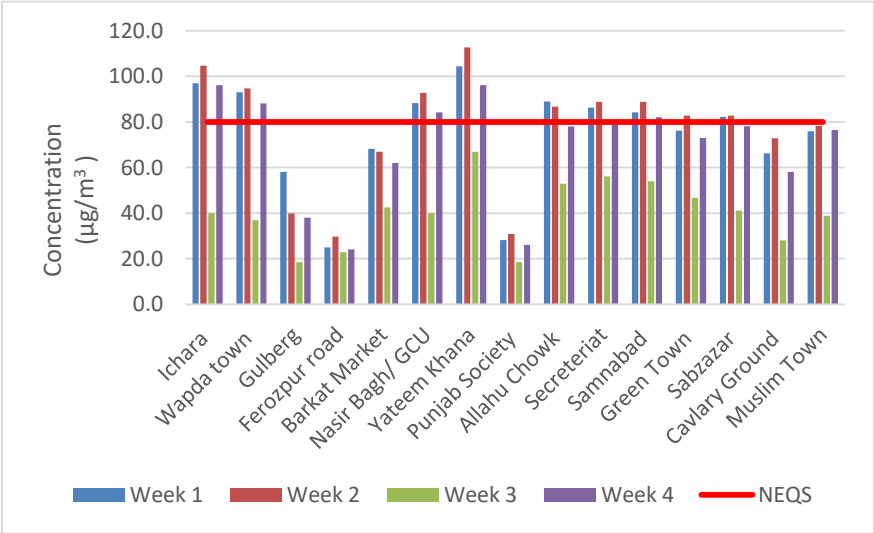
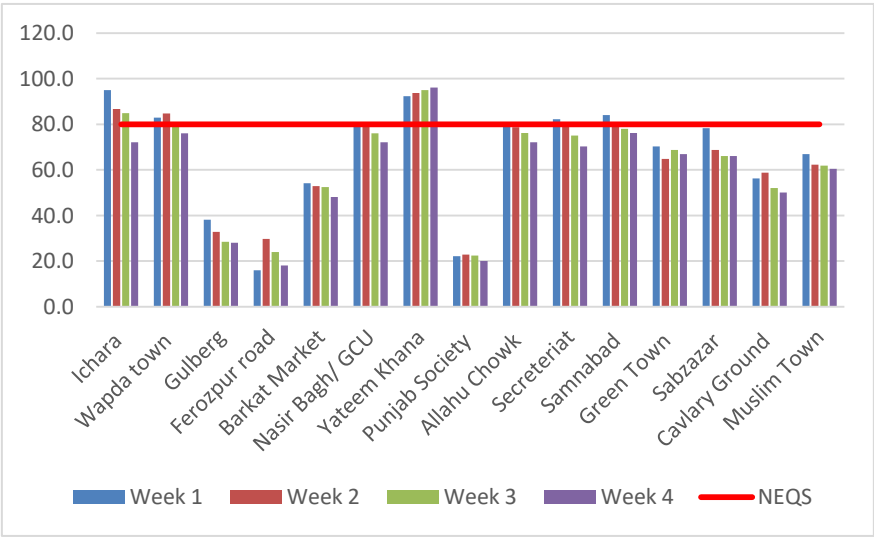


Figure 5. Mean NO_2 concentration for the month of February



Relationship with Climatologic Variables

Meteorological parameters such as temperature, wind speed, relative humidity and rainfall play significant role in concentration of air pollutants as fluctuation in these parameter influence contaminants concentrations **(**Shan et al. 2009; Ahmad *et al*. 2011; Zhou *et al*. 2012**).** The monthly mean values of NO_2 were nexus with these climatologic variables. The relationship between these climatic variables and NO_2 is trenchantly shown in **Figures 6 and 7**, which illustrate that NO_2 level, might be directly proportional and positively related to humidity, which is measured in percentage whereas negatively related to temperature which is measure in degree Celsius. Seasonal variations are also very important to determine the concentration of NO_2 in specific area as lower temperature and higher humidity results in higher NO_2 concentration (Markovic et al. 2008; ul-Haq et al. 2014). Climate of Lahore during winter seasons remain dry; thus, NO_2 values were higher in months of November, December, January and February as described earlier by various researchers (Chan *et al*. 2001; Martin et al. 2009;Ali *et al*. 2014; Behera *et al* 2015). The highest monthly average values in winter are observed due to reduced solar radiation and lower temperature; hence, NO_2 are not undergone photolysis and tends to accumulate (Ali et al. 2014; Ahmad *et al*. 2011). Other factors such as burning of cow dung, wood and coal for heating and

cooking are the major contributor of NO_2. On the contrary, lowest NO_2 values in winter mostly attributed to low temperature and higher precipitation and presence of less cloud cover for the blockage of solar radiations (Shan et al. 2009; Ali et al. 2014; Behera et al 2015).

Figure 6. ***Relationship between NO_2 concentration, temperature, and relative humidity***

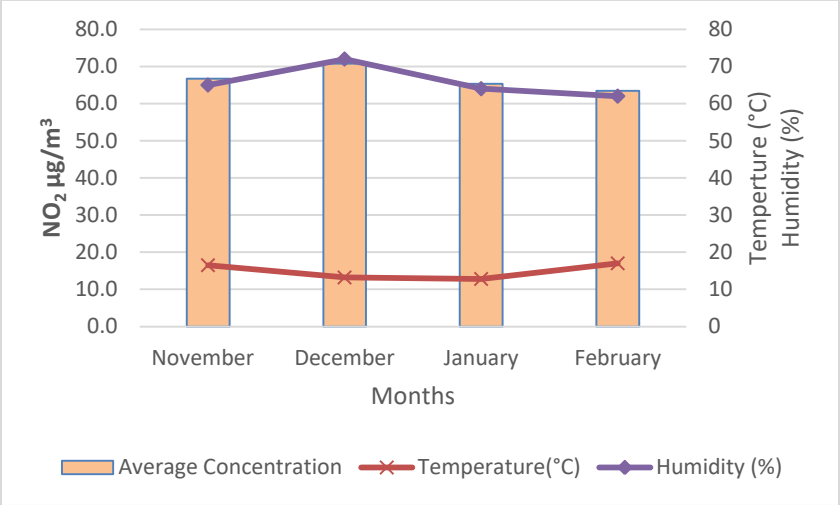
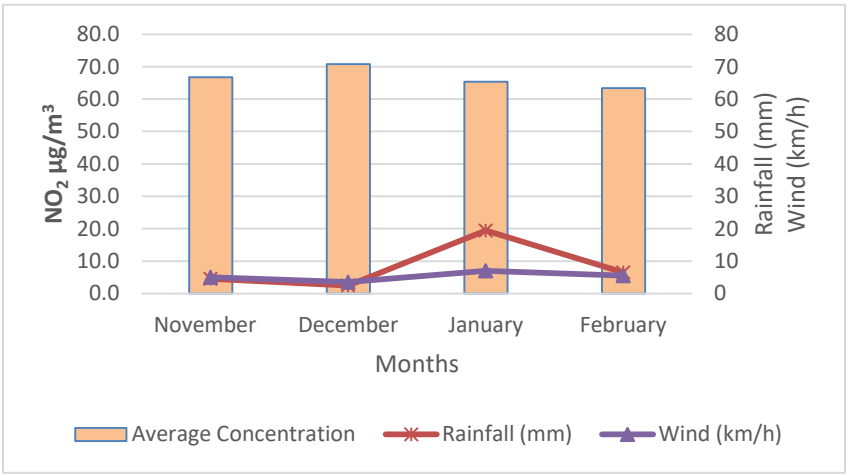


Figure 3 represents relationship between wind speed, which is measured in kilometers per hour (km/h), and rainfall that is measured in millimeters. This figure unequivocally shows the fact that higher rainfall associated with wind attributed to lower NO_2 concentration; thus, remarkable decrease in NO_2 concentration could be observed during rainy monsoon season. Wind speed also has prominent role in lowering NO_2 concentration as higher wind speed and rainfall lowers the concentration of NO_2 through transportation and dispersion (Ahmad et al. 2011). In summers, from May to June the values are expected to be lower than winter season as rainfall increased but according to Zhou et al. (2012), there are some factors contribute towards higher NO_2 values such as more water application to agriculture fields that in turn alter microbial activity contribute towards soil erosion and emissions. Furthermore, monsoon reduces the solar radiation due to cloud cover hence reduces the removal of NO_2 by the process of photolysis; this also increases the level of NO_2 in the atmosphere (Ul-Haq et al. 2014).

Figure 7. ***Relationship between NO_2 concentrations, wind speed and rainfall***



Spatial Distribution Map

A spatial distribution map was developed for mapping the NO_2 concentrations of different locations as shown as Figure 8 by using ArcGIS 16 geostatistical tool that could manage a wide range of data (Behera et al. 2011). Graph clearly represents the locations of higher and lower concentrations of NO_2 in which dark shades represent higher concentrated levels whereas lighter shades represent lower concentrated locations. Mostly vehicular and commercial areas had higher NO_2 concentration level whereas residential areas had lower concentration. Therefore, the drastic increase in vehicles growth is the cause of highest concentration of NO_2 in Lahore as compared to previous studies; it is alarming that still vehicles are continuously increasing day-by-day (Ahmad *et al*. 2011).

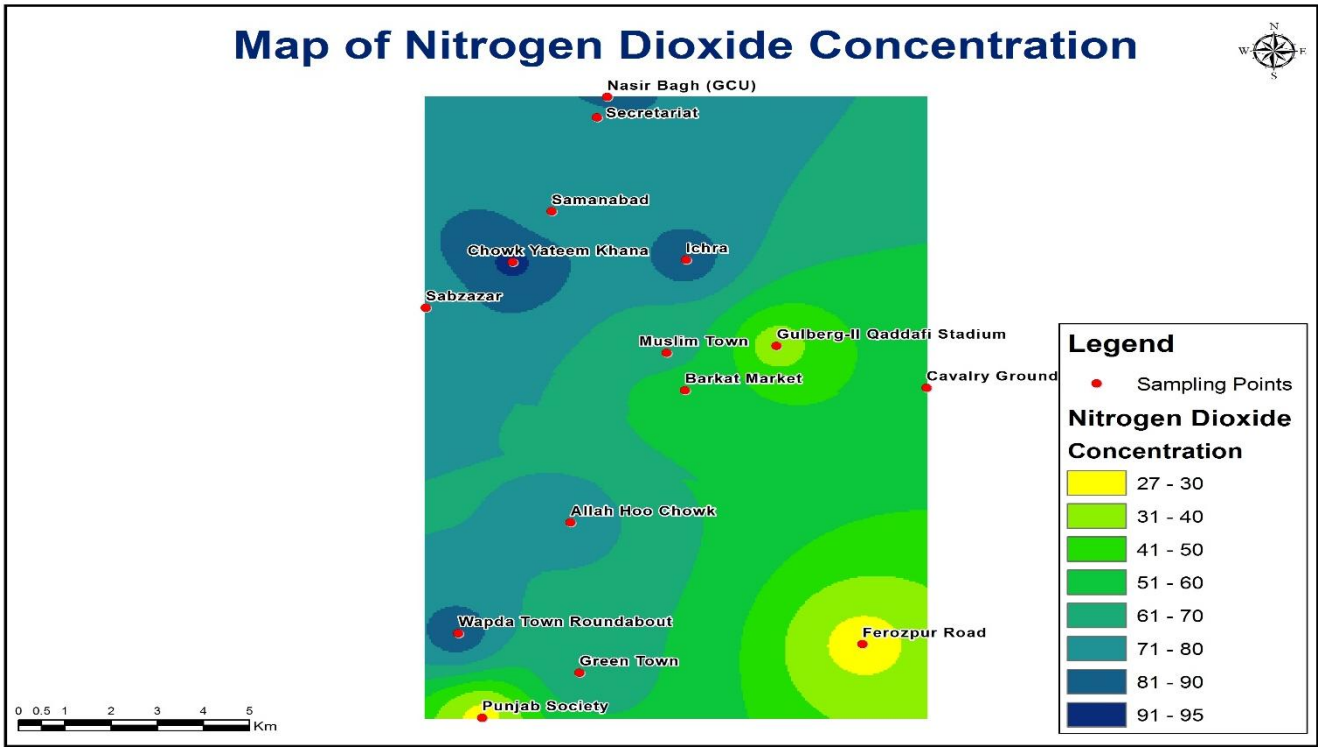


Figure 8. Spatial distribution map of NO_2 concentration in Lahore city

Conclusion

Air pollution is a serious matter of concern in major urban areas of Punjab cities which require vigilant approach otherwise it would have dire repercussions. The study revealed that vehichular emissions are the prominent source of urban air pollution hence concentration of pollutants are increasing at regular interval which is a defiant violation of NEQS. The average concentrations of NO_2 from November to Jabuary were found to be exceeded the permissible limit at dense traffic zones. The highest values were measured at Yateem Khana which is 94.76 $\mu g/m^{3.}$ Furthermore, a negative correlation was found between NO_2 concentrations and rainfall, temperature and wind speed whereas a positive correlation between NO_2 concentration and relative humidity.Therefore, to address the problem, effective traffic planning, improving automobile technologies, and most importantly concerned authorities must ensure the compliance with NEQS to ameliorate the air quality.

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