



Nitrogen Dioxide Monitoring In Urban Areas of Lahore, Pakistan

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Nitrogen dioxide (NO₂) 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 PM₁₀ 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 NO₂ level. Chemiluminescence technique was applied to identify NO₂ 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 NO₂ concentrations was developed by using geostatistical tool ArcGIS. The highest NO₂ values near the main roads were mainly due to intense traffic flow and vehicular emissions unlike residential and commercial locations. Moreover, the NO₂ 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: NO₂; 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 [1] and multiple emission sources [2]. 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 [3,4,5,6,7,8,9], (Kumar 2009). Most prominent air pollutants found in atmosphere are SO₂, NO₂, CO and PM₁₀ [3] which are recognized as major urban air pollutants in mega urban cities [10].

Out of several air pollutants, photochemical oxidants are amongst large group in which NO₂ has adverse impact on environment and human health [11], considered as the second most harmful pollutant after PM₁₀ [12]. 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 [8].

Tropospheric nitrogen oxides (NO_x : NO+NO₂) converted into NO₂ by the help of oxidation [12] which plays significant role in formation of secondary pollutants [13] thus cause environmental acidification [10]. NO₂ is originated from both primary sources and secondary transformation in the atmosphere [14]. The important attribute of NO₂ is that it's a precursor that alter the chemistry of atmosphere, which in turn impacts on local, regional and global scales in the environment [15]. The major sources of NO_x are industry and road transport [16]. NO_x emissions vary in composition in terms of large vehicles (Grundstrom et al. 2015). Mostly, diesel engines contain higher NO₂ fraction and different types of filters fitted for particles in fleet vehicles, which in turn emit high NO₂ [17]. From last few decades, its level is continuously rising in urban areas [10] due to vehicular emissions by incomplete combustion [18]. 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 NO₂ concentrations [19]. Furthermore, NO₂ causes numerous adverse effects on human health,

causing visibility issues [20], pulmonary edema and badly effect the central nervous system, tissues etc. [21,22].

NO₂ concentration remains different throughout the year. The highest values of NO₂ were observed in February, November and the month of December whereas lower concentration were observed in summer seasons particularly in May, June and July. [23,10]. High values in winter season are due to large number of people burn wood, cow dung and coal for heating and cooking [20]. However, according to Zhou et al. [24], NO₂ 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 NO₂ 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. NO₂ washout through precipitation and less cloud cover blockage to solar radiation.

Moreover, other studies indicates exposure of mixtures of NO₂ and SO₂ 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 [25,20]. However, there are large uncertainties in source strengths as well. Therefore, comprehensive studies are sought in Pakistan to contrive a strategy to alleviate emissions [12].

In this study, average concentrations of NO₂ were determined by using Chemiluminescence (ISO-7996) technique at Horiba Monitor; Model APNA-370. The aim of the study is to determine average NO₂ 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 NO₂ is very important in measuring potential effect of NO₂ on human health and urban environment. It's also play significant role in developing strategies for the effective control of NO₂ pollution.

2. MATERIALS AND METHODS

2.1 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 [26], (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 [27-31,26]. A map of the designated city Lahore is shown in Fig. 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.

2.2 Sampling Period

For NO₂ 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.

2.3 Instrument

Chemiluminescence (ISO-7996) technique (USEPA, 1986) was applied to identify NO₂ concentrations [32] 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.

2.4 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

Lahore	Sr#	Monitoring sites	Source of emission
		Ichra	Vehicular, Commercial and Residential
		Wapda roundabout	Vehicular and Commercial
		Gulberg	Commercial
		Ferozpur road (Khalid Colony)	Residential
		Barkat Market	Vehicular and Commercial
		Nasir Bagh/ GCU	Vehicular and Commercial
		Yateem Khana	Vehicular and Commercial
		Punjab Society	Residential
		Allahu Chowk, Johar town	Vehicular and Commercial
		Secretariat	Vehicular
		Samnabad	Vehicular
		Green Town	Vehicular and Commercial
		Sabzazar	Vehicular and Commercial
		Cavalry Ground	Commercial and Residential
		Muslim Town	Commercial and Vehicular

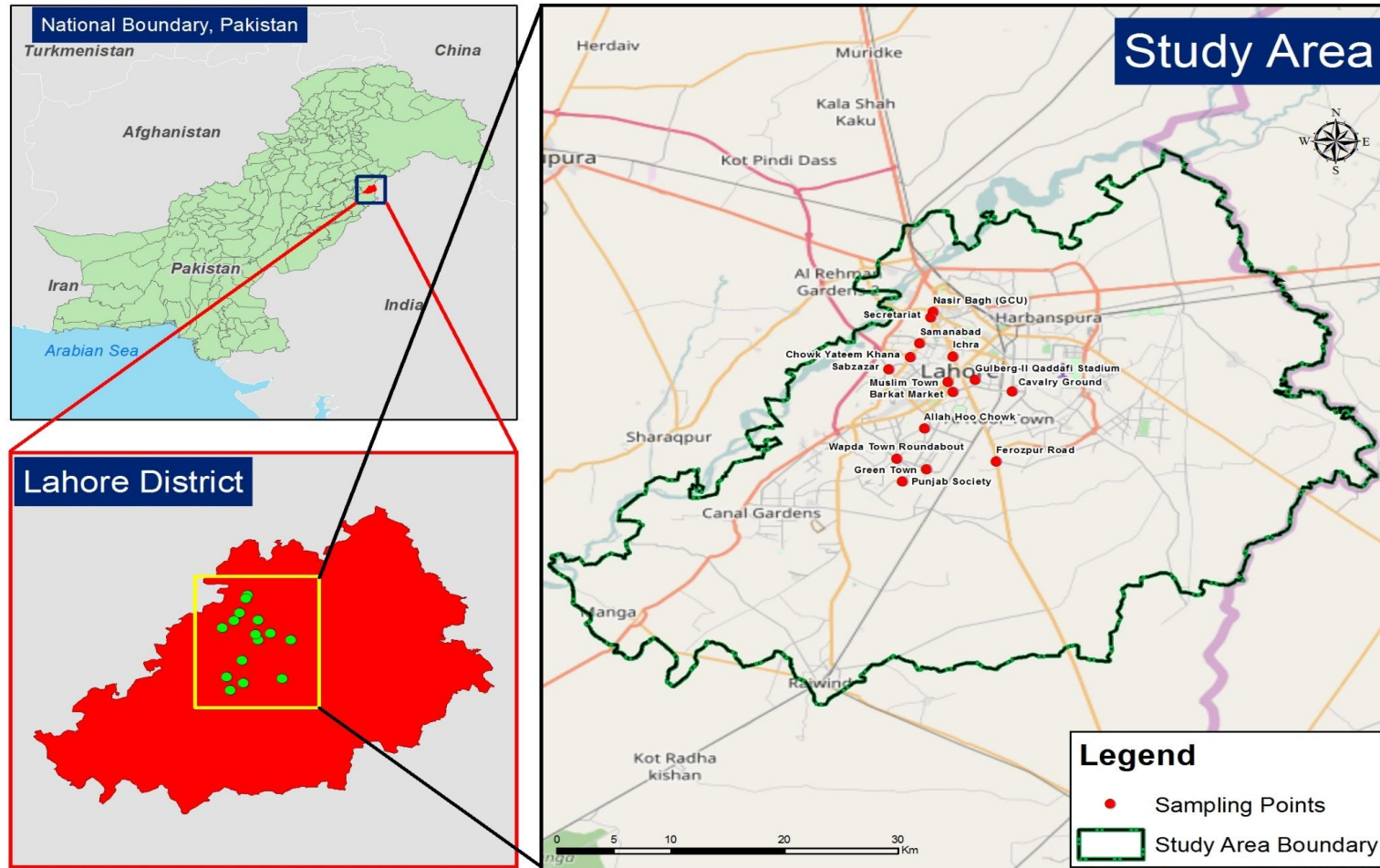


Fig. 1. Map showing Lahore city & sampling points

3. 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 [33]. During sampling, motorized road transport was found to be the leading source of NO₂ contamination in the atmosphere [13,10].

3.1 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.

3.2 Monthly Trends in the Level of NO₂

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 NO₂ has highest values in winter season [34] from November-February as compared to summer season observed in previous studies. The highest concentration of NO₂ 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 Fig. 2 and 3. It is clearly shown in the below

graphs that NO₂ 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.

The leading source of NO₂ is burning of nitrogen-bearing fuels during combustion process [14] which is significant gaseous air pollutant and considered as second most dangerous after PM₁₀ pertaining to health [13,10]. 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 (Ghuri et al. 2007). Similarly, in Beijing, NO₂ concentration was observed higher during winter seasons near main traffic lines [35]. Similarly, road traffic is the leading source of NO_x as 50% of it enters in to the atmosphere through vehicular sources while 30% from power plants and 20% from industrial processes [10,16]. Pak-EPA also declared NO₂ presence in atmosphere is harmful for human health that not only reduces visibility but also contributes to form ozone (O₃) during situational analysis study in five major cities of Pakistan in 2006 [8]. NO₂ concentrations in other selected locations of Lahore showed values within the permissible limit of NEQs as shown in Fig. 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.

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

Monitoring sites	Months			
	November	December	January	February
	Concentrations			
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

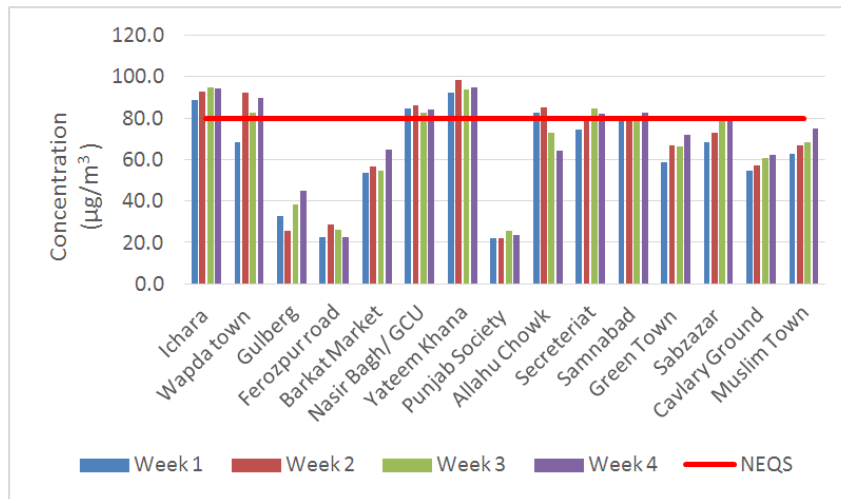


Fig. 2. Mean NO₂ concentration for the month of November

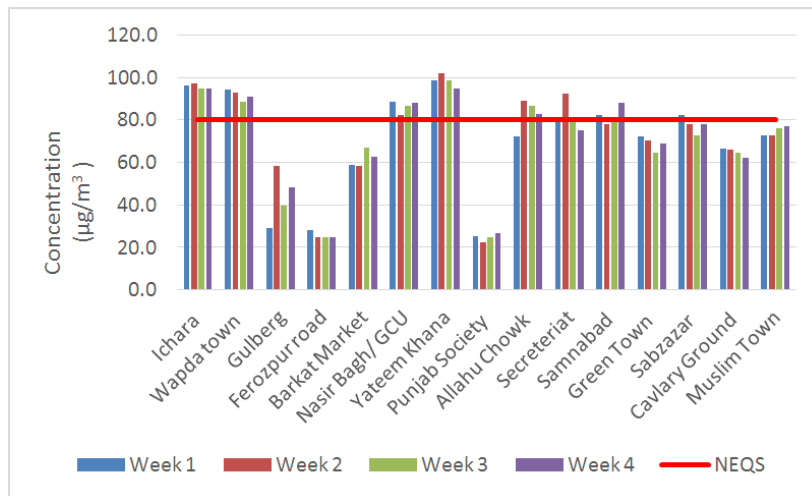


Fig. 3. Mean NO₂ concentration for the month of December

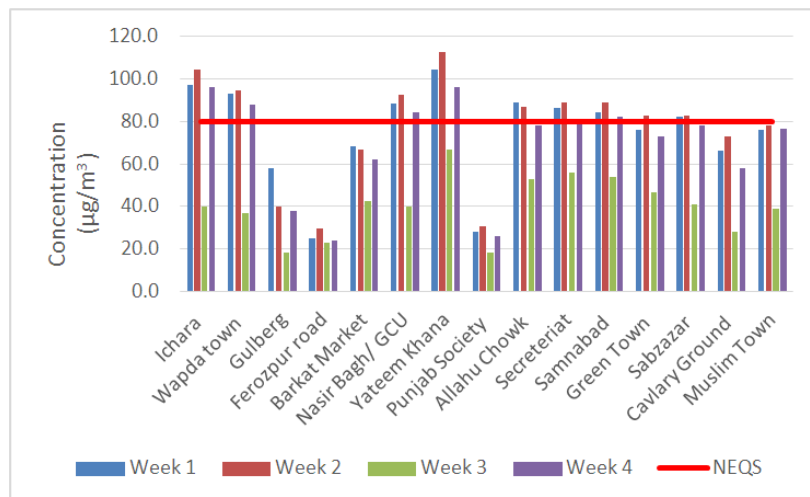


Fig. 4. Mean NO₂ concentration for the month of January

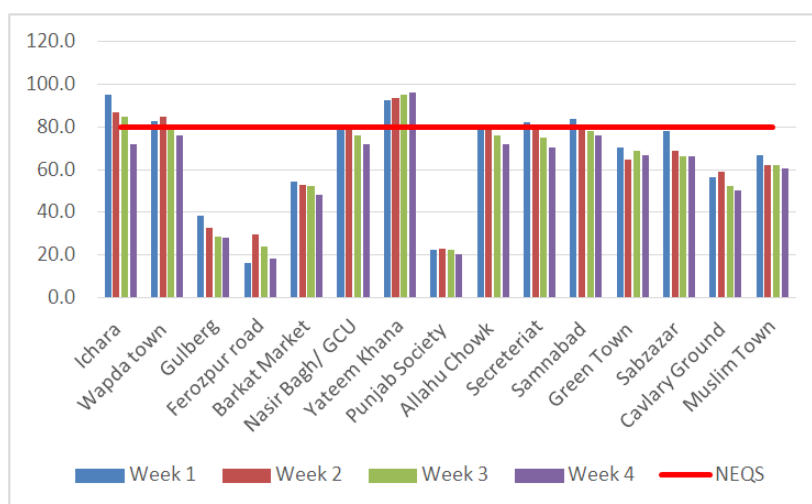


Fig. 5. Mean NO₂ concentration for the month of February

3.3 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 [36,10,27]. The monthly mean values of NO₂ were nexus with these climatologic variables. The relationship between these climatic variables and NO₂ is trenchantly shown in Figs. 6 and 7, which illustrate that NO₂ 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 NO₂ in specific area as lower temperature and higher humidity results in higher NO₂ concentration [37,20]. Climate of Lahore during winter seasons remain dry; thus, NO₂ values were higher in months of November, December, January and February as described earlier by various researchers (Chan et al. 2001; [38,34,16]. The highest monthly average values in winter are observed due to reduced solar radiation and lower temperature; hence, NO₂ are not undergone photolysis and tends to accumulate [34,10]. Other factors such as burning of cow dung, wood and coal for heating and cooking are the major contributor of NO₂. On the contrary, lowest NO₂ values in winter mostly attributed to low temperature and higher precipitation and presence of less cloud cover for the blockage of solar radiations [36,34,16].

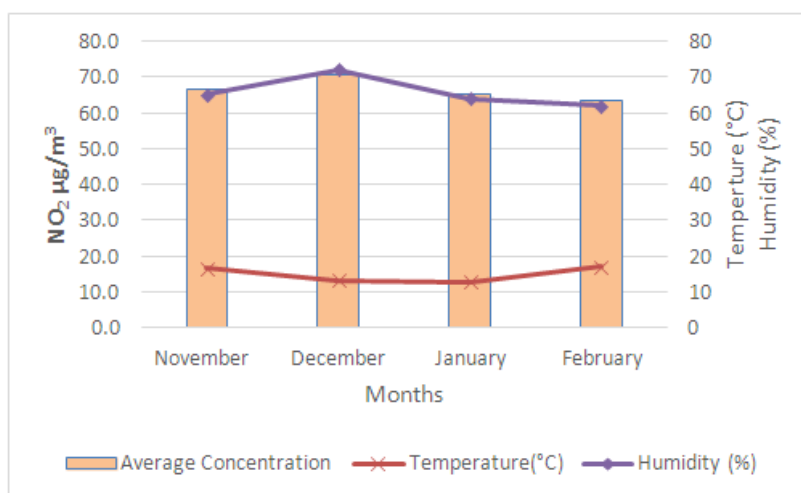


Fig. 6. Relationship between NO₂ concentration, temperature, and relative humidity

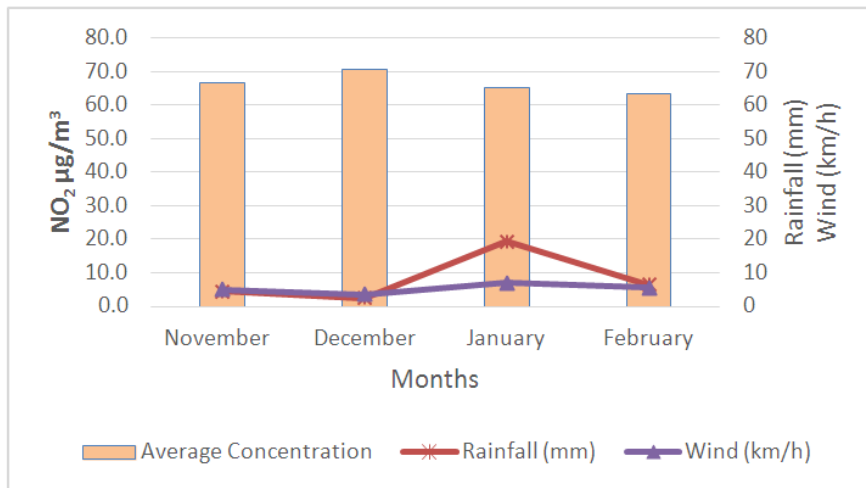


Fig. 7. Relationship between NO₂ concentrations, wind speed and rainfall

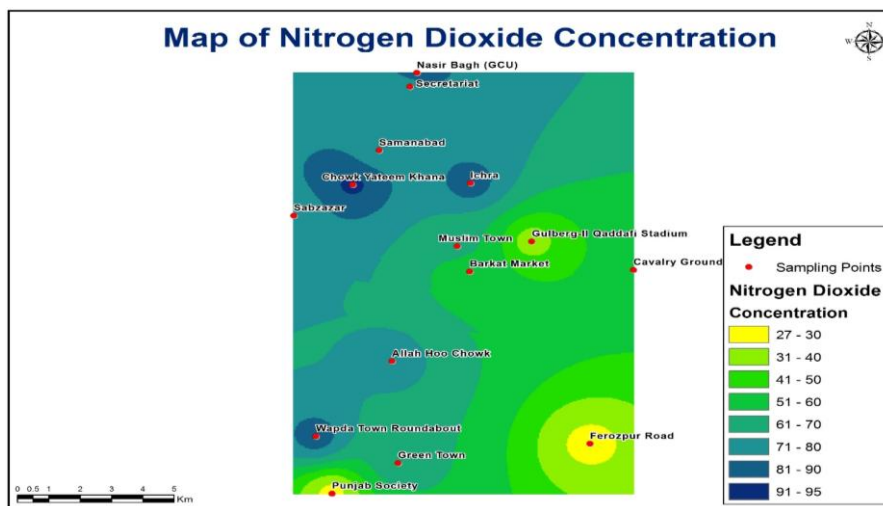


Fig. 8. Spatial distribution map of NO₂ concentration in Lahore city

3.4 Spatial Distribution Map

A spatial distribution map was developed for mapping the NO₂ concentrations of different locations as shown as Fig. 8 by using ArcGIS 16 geostatistical tool that could manage a wide range of data [16]. Graph clearly represents the locations of higher and lower concentrations of NO₂ in which dark shades represent higher concentrated levels whereas lighter shades represent lower concentrated locations. Mostly vehicular and commercial areas had higher NO₂ concentration level whereas residential areas had lower concentration [39,40]. Therefore, the drastic increase in vehicles growth is the cause of highest concentration of NO₂ in Lahore as compared to previous studies; it is alarming that still vehicles are continuously increasing day-by-day [10].

4. 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 vehicular 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 NO₂ from November to January were found to be exceeded the permissible limit at dense traffic zones. The highest values were measured at Yateem Khana which is 94.76 µg/m³. Furthermore, a negative correlation was found between NO₂ concentrations and rainfall, temperature and wind speed whereas a positive correlation between NO₂ 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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COMPETING INTERESTS

Author has declared that he or she has no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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