SPATIAL-TEMPORAL VARIATIONS OF NITROGEN DIOXIDEIN AND AROUND LAHORE METROPOLITAN AREAS USING "GIS"TECHNIQUES

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ABSTRACT: In developing countries the process of urbanization has an impact on land use patterns of a city. The cities are performing according to their environmental, social, cultural, and economic conditions. The economic and commercial activities of the cities are increasing due to accelerated population growth. The cities of Pakistan are facing environmental issues which are creating damages in air, soil, ground water. Transport sector in a country has direct impact on the deterioration of air quality and high growth rate in transport sector causes energy consumption and leads to the greenhouse gases emissions especially NO_2in Lahore. The city of Lahore not yet started a regular air quality monitoring system. The data already available in the departments have highlightedthatit is not properly managed/shaped or mapped. A sustainable urban development in Lahore can only be achieved by managing land use, complete periodic study of air quality with weather variables and traffic management system of the hotspot areas.Thisstudyfocusseson spatial and temporal variations of NO_2at selected locations in LMA. On the bases of results, the LMA area are classified into risk zones of the air pollutant speciallyNO$_2$.

Key words: Environmental Pollution, Transport System, Use of GIS

INTRODUCTION

GSP (1996) explained the position of case study as Lahore district extends from 31° 15' and 31° 43' North latitude and 74° 10' and 74° 39' East longitude with 1772 SqKms. Lahoreis a capital of Punjab province and stands on the alluvial plain traversed by the river Ravi. According to the Integrated Master Plan for Lahore-2021 (2005), the Lahore continued to grow and by 1998 was transformed into a metropolis with a population of more than 5-million and in 2001 the metropolitan area of Lahore was estimated to have a population of more than 7-million.NESPAK (1997) described that the highest concentration of urban population was within and around the core areas of the city and it gradually decreased towards the outer areas of the Lahore. However about 80 percent population was living within the radius of 7-km. The overall average density of the city was 120 people per acre.Lahore has a catchment area comprising not only of the neighboring districts but also the other districts of the Punjab province(figure-1).Lahore regional catchment area is much wider than the limits of the metropolitan boundary. The urban area provides transport facilities to other urban centers of the country for quicker, easier and cheaper mobility. Lahore also provides local transport system from core to the hinterland and between coreto fringes. The city has expanded well beyond its capacity leading to an ultimate need for improving and managing the urban air quality.

Lahore Metropolitan Area enjoys mixed land use; residential, commercial and industrial which inherits many sources of air pollution (figure-2). In Lahore the transport sector is growing with high growth rate. Parekh, et. al. (1989) states that in the major cities of Pakistan like Karachi and Lahore, the emissions is due to mainly from vehicles and industries especially thermoelectric power plants that burn mostly the fossil fuel. The sources of continuous air pollutants are motor vehicles, industrial unit, workshop and others. Major problems of the city are high to moderate population density zones, traffic bottle necks which leads to increase the air pollutants especially nitrogen dioxide.

Lahore falls into a major climate type Sub-Tropical Continental Lowlands (high summer temperature and late summer monsoon rains) group. It is semi-arid type of climate weather as shown in figure-3.

Especially wind velocity and its direction during pre-monsoon season(April, May and June)that wind mostly calm and coming from north-east, north, and south east whereas during monsoon season (July and August) wind mostly calm and coming from south-east as shown in figure-4, and eastand general wind also effect the air quality of Lahore from trans-boundary air parcels when easterly windblown from India. The post-monsoon September, October and November) wind mostly calm and was blown from south-west, north-east. The wind velocity and its direction greatly affect the air quality of the Lahore.

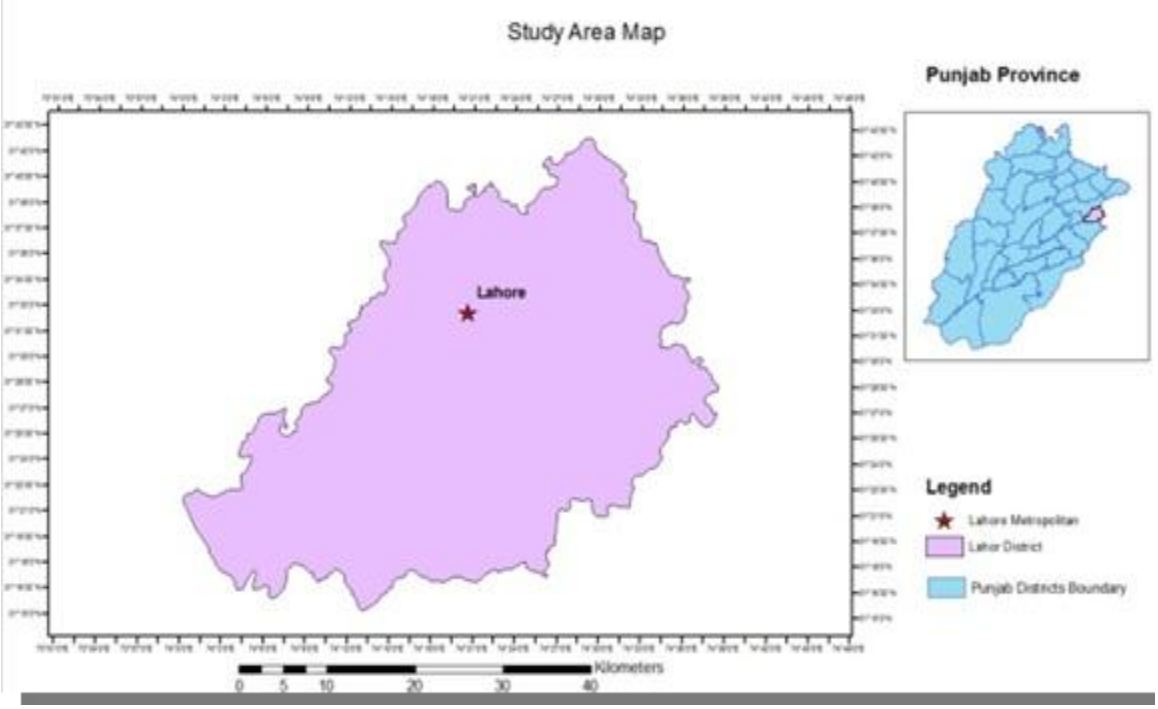


Figure-1: Location of case Study Area w.r.t. Punjab Province

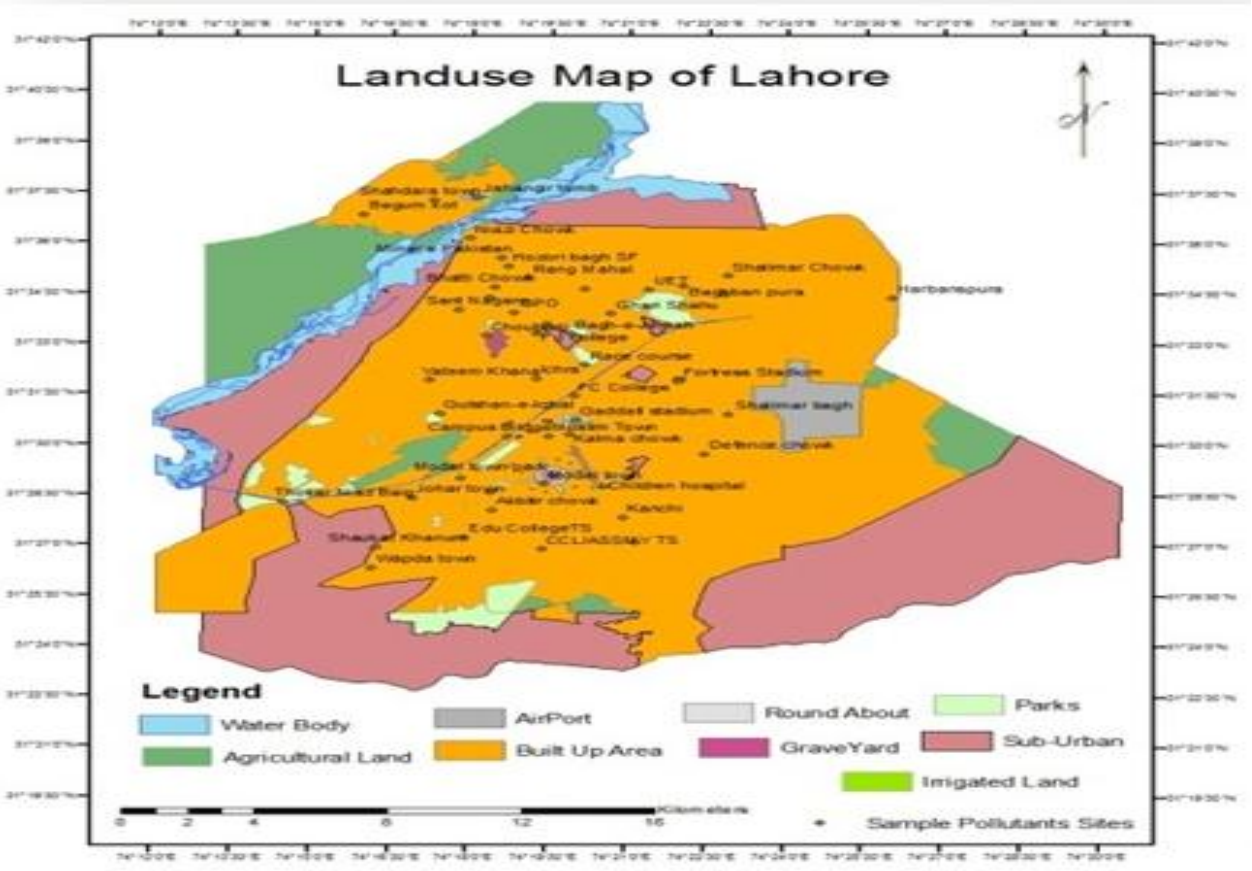


Figure-2: Land use map of Lahore Metropolitan Area

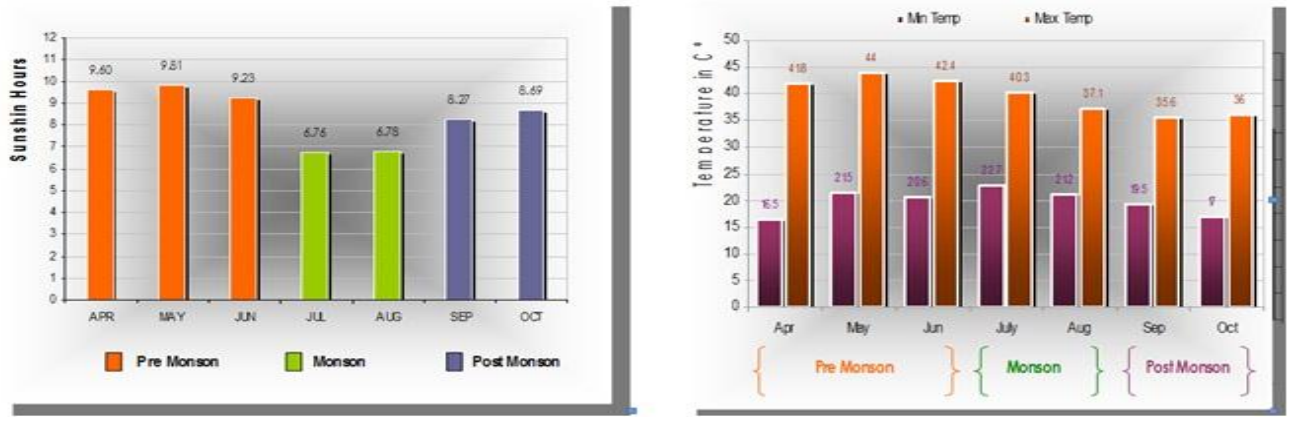


Figure-3: Periodic Meteorology of Lahore Metropolitan Area during the Field Surveys

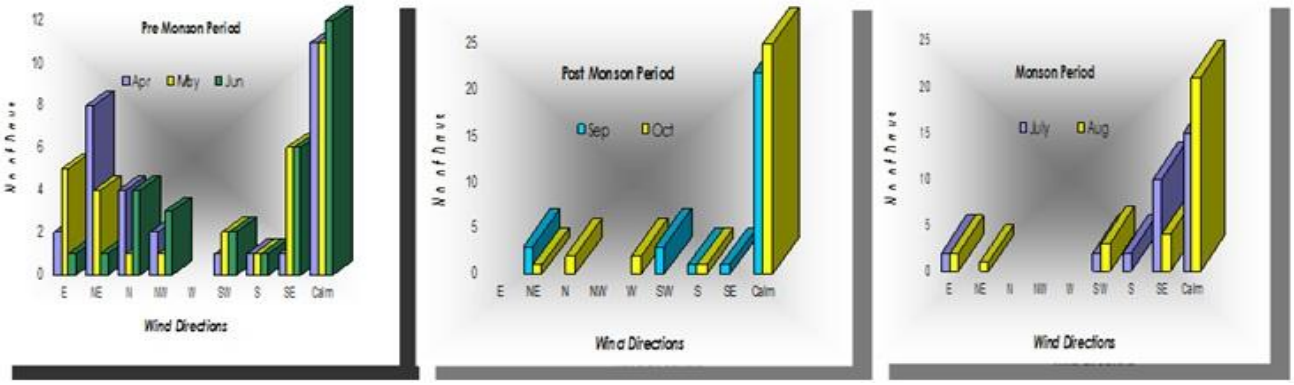
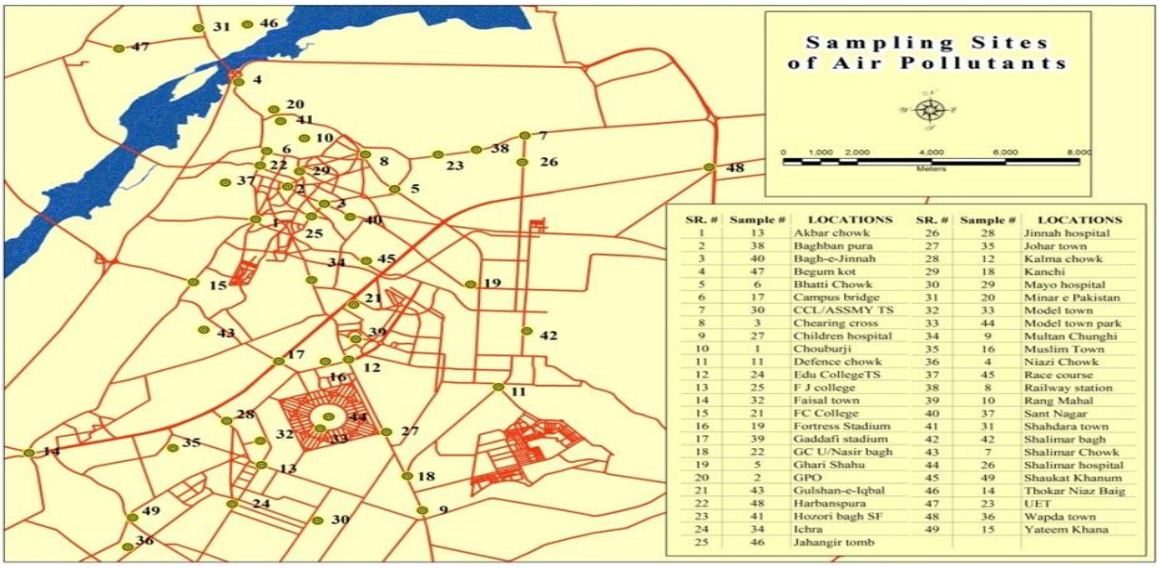


Figure-4: Periodic Wind Directions in Lahore Metropolitan Area

Pre-monsoon, monsoon and post monsoon in a yearportray the picture of air quality of an urban area like Lahore (figure-5).



SR. #	Sample #	LOCATIONS	SR. #	Sample #	LOCATIONS
1	13	Akbar chowk	26	28	Jinnah hospital
2	38	Baghban pura	27	35	Johar town
3	40	Bagh-e-Jinnah	28	12	Kalma chowk
4	47	Begum kot	29	18	Kanchi
5	6	Bhatti Chowk	30	29	Mayo hospital
6	17	Campus bridge	31	20	Minar e Pakistan
7	30	CCL/ASSMY TS	32	33	Model town
8	3	Chearing cross	33	44	Model town park
9	27	Children hospital	34	9	Multan Chunghi
10	1	Chouburji	35	16	Muslim Town
11	11	Defence chowk	36	4	Niazi Chowk
12	24	Edu CollegeTS	37	45	Race course
13	25	F J college	38	8	Railway station
14	32	Faisal town	39	10	Rang Mahal
15	21	FC College	40	37	Sant Nagar
16	19	Fortress Stadium	41	31	Shahdara town
17	39	Gaddafi stadium	42	42	Shalimar bagh
18	22	GC U/Nasir bagh	43	7	Shalimar Chowk
19	5	Ghari Shahu	44	26	Shalimar hospital
20	2	GPO	45	49	Shaukat Khanum
21	43	Gulshan-e-Iqbal	46	14	Thokar Niaz Baig
22	48	Harbanspura	47	23	UET
23	41	Hozori bagh SF	48	36	Wapda town
24	34	Ichra	49	15	Yateem Khana
25	46	Jahangir tomb			

Figure-5: Survey Sample Sites of Nitrogen Dioxide in the Lahore Metropolitan Area

MATERIALS AND METHODS

15 field surveys of Nitrogen Dioxide $NO_2$are conducted and 49 locations were conducted with reference to different land uses. The samples of sites were collected, analyzed and the results were managed. The study was based on the periodic collection of NO_2 surveys, so the metrological data collected regarding

temperature (maximum and minimum), relative humidity, rainfall, sunshine hours, wind (velocity and direction) and GPS surveys were also conducted for ground trothing. The location of survey sample sites in and around the metropolitan areas of Lahore is very significant for the monitoring of air pollutants. Therefore, the sampling stations are representing true picture of all the characteristics of a site. The survey work has been divided into three phases, e.g., pre-monsoon, monsoon, and post-monsoon in the year. This was to portray the picture of air quality of an urban area like Lahore as shown in figure-5. Fifteen (15) field surveys of Nitrogen Dioxide (NO_2) of 49 locations were conducted with reference to the different land use. The samples of the sites were collected, analysed and the results were managed. The study was based on the periodic collection ofNO_2surveys, so the meteorological data collected regarding temperature (maximum and minimum), relative humidity, rainfall, sunshine hours, wind (velocity and direction) and GPS surveys were also conducted for ground trothing.

In this study for the determination of Nitrogen Dioxide (NO2) the diffusion tube is used for the ground surveys. For the preparation of the diffusion tube the gas was passively sampled by molecular diffusion along a tube to an absorbing medium. Triethanolamine (TEA) impregnated onto stainless steel mesh. For a tube of known length and internal diameter with an efficient absorber at one end, the NO_2 sampling rate may be calculated using Flick's Law of the unidirectional flow of gas through a mixture of gases under constant. According to Atkins, et. al. (1978), the temperature dependence of diffusing co-efficient was 0.2 % per ^oC and the collection of gases in diffusing tubes was independent of pressure. The sampling rate of the tubes used here was calculated to be 62.3 ml of air per hour with a diffusing tube constant of 10437.8 (ug NO_2 $ppbh^{-1}$).The diffusion tubes (7.lcm x l.lcm internal diameter) as shown in figure-6. Tubes were acid washed (5% HCI) and thoroughly rinsed several times with distilled water. These were further rinsed with distilled water, dried and stored before use. During the collection of the samples at different sites of the surveys, semi-transparent colored end caps were removed and to prevent the entry of rain water and dust particles the tubes mounted vertically with absorbent uppermost and open end pointing downwards as shown in figure-6. Time at the start and end of the exposure was recorded accurately and sampling carried out on biweekly basis. This has been acquired through 1.5 ml each of distilled water and sulphjanilamide / phosphoric acid reagent were added to each sample tube from the opposite end to the mesh collectors and the open-end cap closed after addition of this reagent. Tubes were gently shaken after 10 minutes and then left undisturbed for more than 20 minutes. The nitrite ion released from the mesh collectors in the solution diazotized the sulphanilamide. The salt formed became coupled with NEDA and a purple-red azo-dye was produced whose optical absorption was measured on U.V. range spectrophotometer at 520 nm with reagent blank in the reference cell. Standards were made by dilution from at 100 ppm solution of 'ananlar' sodium nitrite and a range of 0.05 to 1.0 ppm was sufficient to cover all samples.

Figure-6: Sampling Site and Diffusion Tube

In the study, GIS technology is used to analysis and gives support to identify the risk zones of the city. For the monitoring of the extent of problem in an urban area, GIS is a meaningful tool for the spatial and temporal analysis as well as in the processes of visualization and overlay analysis. Periodic mapping of NO_2within a GIS environment was developed. The air quality surveys covered the pre-monsoon, monsoon and post-monsoonNO_2 contamination of the Lahore metropolitan area. This study has developed a network of survey activities to ensure the regular visits and schedule of the survey sites, clearly defined monitoring objectives, collection of the sample from the survey locations, level of accuracy in analysis, procedures of handling or record

keeping of refined data, operation and maintenance of the equipment, review of the data, preparation of the final documents, publishing the surveyed data on maps, interpolation of air pollutant (NO_2) data using ArcGIS 9.3 with IDW technique and finally identified the risk zones of the Lahore metropolitan areas.

Data and its Sources

Periodic(Pre-monsoon, Monsoon, Post-monsoon) contamination of NO_2. Nitrogen Dioxide is reported moderate in pre-monsoon due to high light intensity, maximum sunshine hours and vehicles pollutions whereas during monsoon become moderate to lowest and increases during post-monsoon season. The maximum reading of NO_2 was monitored during Post-monsoon (November). The highest values (81.78ppb to 100.16ppb) are monitored at and around main road crossings especially at hotspots of Lahore metropolitan areas. These highest readings were prevailed in almost three months (September, October and November) of post-monsoon season. Periodic differences among NO_2mean value readings are examined with respect to spatial locationsas shown in figures-7, 8 and 9. It has been found that main road crossings and residential locations are the most polluted areas of Lahore metropolitan. Raven, et. al. (2010) pointed out that the Nitrogen Oxides gases are produced by the chemical interactions between atmospheric nitrogen and oxygen when a source of energy, such as combustion of fuels, produces high temperatures.

Pre-monsoon NO_2 contamination at different geographical conditions: The mean values of pre-monsoon NO_2 contamination in the air are calculated at different geographical conditions, e.g., main road crossings, educational institutions, hospitals, industrial, residential, parks, and suburban areas. In pre-monsoon season (15th April to 30th June) the moderate concentrations of NO_2 is observed during the year in the metropolitan areas of Lahore due to high light intensity, maximum sunshine hours and vehicle's emission. During this season the highest concentration is observed at main road crossings near Rang Mehal 77.48 ppb and 76.34 ppb near Niazi Chowk. The extremely high cluster of $NO_2$is observed around these sample sites as shown in figure-7 and reported in table-1. The lowest concentrations of NO_2 is noted near suburban areas of Lahore, e.g., 42.04 ppb in and around Shauket Khanum and 42.60ppb near Harbanspura and highlighted in extremely low to low contamination zones.

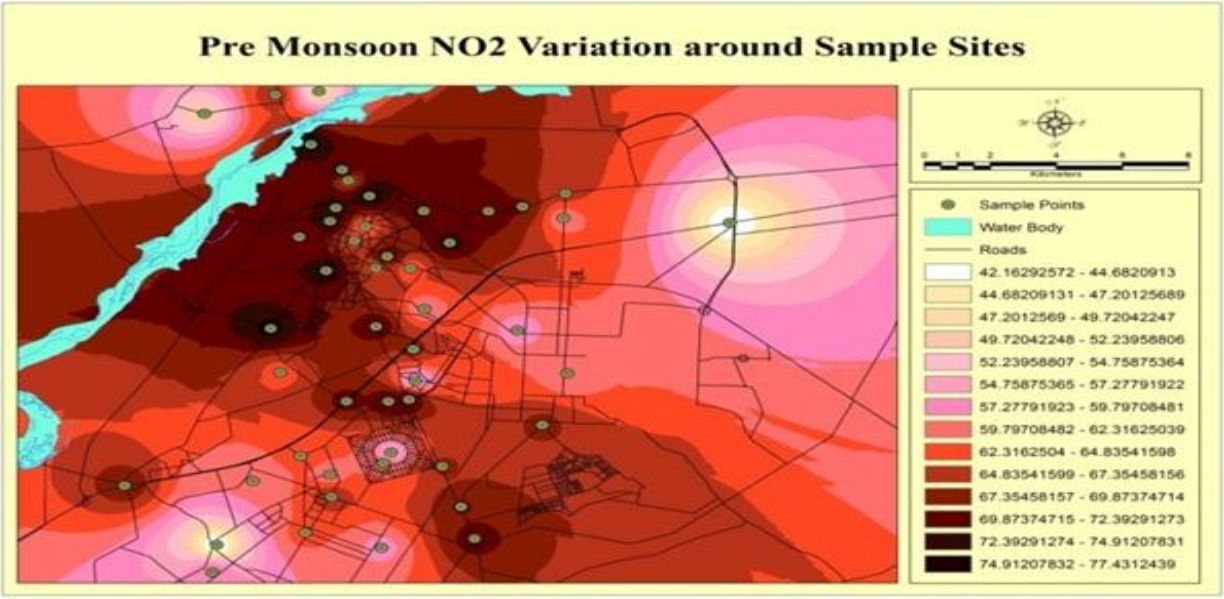


Figure-7: Pre Monsoon Contamination of NO_2 in Lahore Metropolitan Areas

Monsoon NO_2 contamination at different geographical conditions: The monsoon NO_2contamination at different geographical conditions, e.g., main road crossings, educational institutions, hospitals, industrial, residential, parks, and suburban areas of Lahore are surveyed. During the monsoon season (01st July to 31 August) the moderate to lowest contamination of the mean values of the NO_2 in urban air of Lahore are found. During this season the highest concentration of NO_2 is found at main road crossings, e.g., 83.70 ppb near Rang Mahel and 81.99ppb in and around Yateem Khana. The extremely high cluster of NO_2 around these sample sites are shown in figure-8 and reported in table-1. The lowest concentrations were found at suburban areas e.g. 48.73ppb near Harbanspura and

50.59 ppb near Shauket Khanum and highlighted in extremely low to low contamination zones.

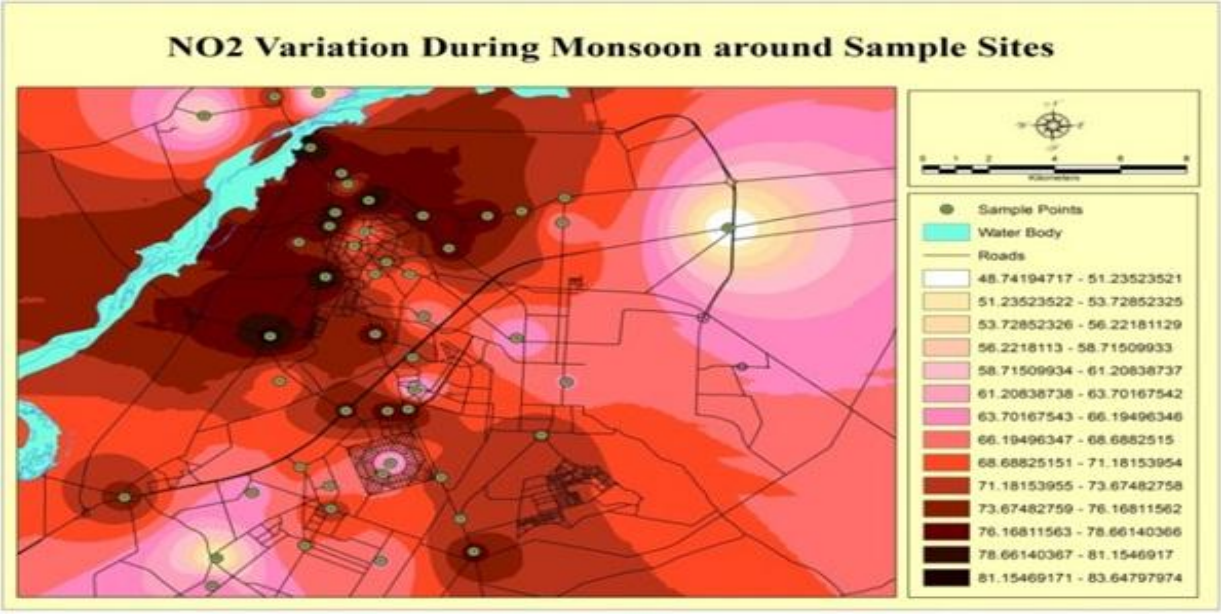


Figure-8: Monsoon Contamination of NO_2 in LMA

Post-monsoon NO_2 contamination at different geographical conditions

The post-monsoon NO_2 contamination in the air at different geographical conditions, e.g. main road crossings, educational institutions, hospitals, industrial, residential, parks, suburban areas is surveyed. In post-monsoon season (01st September to 31st October) the lowest to moderate concentration of NO_2 during the year observed in the metropolitan areas of Lahore. The highest is monitored at main road crossings which are 91.75 ppb near Rang Mehal and 89.64 ppb in and around Yateem Khana Chowk. The extremely high cluster of NO_2 around these sample sites are shown in figure-9 and reported in table-1. The lowest concentrations were found at suburban areas, e.g., 57.93 ppb in and around Shuaket Khanum and 60.19 ppb in and around Jahangir Tomb and highlighted in extremely low to low contamination zones.

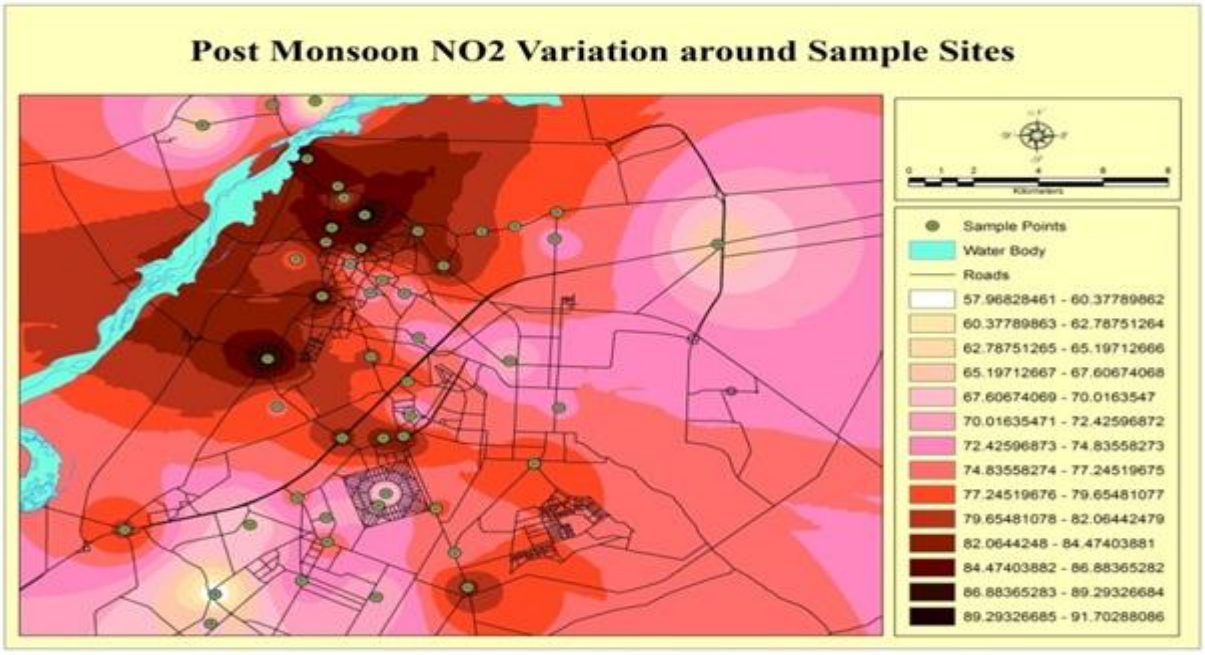


Figure-9: Post monsoon Contamination of NO_2 in the Lahore Metropolitan Areas

Table-1. Periodic Monitoring of NO_2 (mean values) at Different Geographical Locations in Lahore Metropolitan Areas

Sr. No.	Locations	Pre Monsoon Mean	Monsoon Mean	Post Monsoon Mean
Main Road Crossing				
1	ChouburjiChowk	75.80	81.75	86.15
2	GPO Chowk	63.55	68.77	72.24
3	Chearing cross	73.23	75.01	75.96
4	NiaziChowk	76.34	81.87	87.62
5	GhariShahu	73.79	78.77	84.05
6	BhattiChowk	74.30	80.14	88.38
7	Shalimar Chowk	65.54	71.70	78.01
8	Railway station	71.57	78.14	84.00
9	Multan Chunghi	71.31	77.16	82.85
10	Rang Mahal	77.48	83.70	91.75
11	Defencechowk	68.17	73.90	79.82
12	Kalmachowk	74.09	79.87	86.09
13	Akbar chowk	67.91	73.88	77.70
14	Thokar	69.12	74.83	80.17
15	YateemKahna	75.86	81.99	89.64
16	Muslim town	73.16	78.45	84.10
17	Campus bridge	71.23	77.09	83.09
18	Kanchi	70.21	71.12	75.83
19	Fortress stadium	58.26	64.12	70.12
20	Yadgar	73.89	80.09	87.34
Educational Institutions				
21	FC College	68.39	73.80	79.00
22	GC U/Nasirbagh	75.44	80.79	86.13
23	UET GC Education	72.31	77.80	82.34
24	College Town ship	63.40	68.86	74.02
25	F J college	63.48	68.81	73.28
Hospitals				
26	Shalimar hospital	59.91	65.78	72.79
27	Children hospital	68.04	73.80	77.79
28	Jinnah hospital	63.09	69.847	75.90
29	Mayo hospital	60.04	65.81	87.59
Industrial CCL/ASSMY				
30	Township	58.64	65.95	70.17
Residential				
31	Shahdara town	67.09	72.8	75.69
32	Faisal town	60.50	65.76	69.20
33	Model town	62.36	67.99	70.62
34	Ichra	72.37	77.87	80.32
35	Johar town	60.24	65.14	67.05
36	Waoda town	60.35	65.92	68.25
37	Sant Nagar	70.38	76.01	78.23
38	Bagh ban pura	70.40	74.90	77.04
Parks				
39	Ghazhafi stadium	52.47	58.15	68.44
40	Bagh-e-Jinnah	62.15	67.77	73.39
41	Shahi fort/Hozoribagh	64.21	69.83	79.35
42	Shalimar bagh	60.01	65.93	74.55
43	Gulshan-e-Iqbal	63.33	68.78	76.78
44	Model town park	54.47	60.91	67.85
45	Race course	59.27	65.74	72.55
Sub urban				
46	Jahangir tomb	47.74	53.66	60.19
47	Begum kot	49.45	57.31	65.30
48	Harbanspura	42.60	48.73	65.30
49	ShauketKhanum	42.04	50.59	57.89

RESULTS AND DISCUSSION

1. In present study a temporal (pre-monsoon, monsoon, and post-monsoon) air quality monitoring system has been selected for the surveys of air pollutant (Nitrogen Dioxide). The projected seasonal emissions data is highlighted using ArcGIS platform with IDW techniques. To calculate the true analysis of Lahore metropolitan air pollutant the meteorological data fields (sunshine hours, wind velocity, wind direction, humidity, maximum and minimum temperature) of same days were also monitored.
2. The ambient air has been contaminated due to the emissions of the certain gases especially nitrogen dioxide, so for analysis of the data Lahore metropolitan area was divided into residential, main road crossings, industrial locations, educational institutions, parks, and suburban places. The 49 sampling sites of NO_2were selected on the basis of different land uses.
3. The present study has resulted that the digital mapping of air pollutant e.g., NO_2 exposing the pollution impact analysis on the areas and population. So this show the spatial variation of air quality risk zones in Lahore as shown in figures-7, 8 and 9.
4. This study has contributed in calculating the risk zones (from extremely high to extremely low) which provided the base line information regarding the future risk zones of the Lahore metropolitan areas.
5. The study has revealed that air pollutant e.g. nitrogen dioxide is most prominent contamination in the air. All the geographical conditions which are main road crossing, residential, industrial, educational institutions, parks, suburban have medium to extremely high level of contamination of NO_2.
6. Nitrogen Dioxide is reported moderate in pre-monsoon (15th April to 30th June) due to high light intensity, maximum sunshine hours and vehicles pollutions whereas during monsoon (01st July to 31 August) become moderate to lowest and increases during post-monsoon (01st September to 31st October) season. This study has highlighted that highest NO_2 values were found with high traffic volume or closer to hotspot areas. Differences among mean value readings within seasons are examined in spatial locations and found that main road crossings are the most polluted areas of Lahore.
7. It is evident in this study to establish air quality monitoring networks for the selected cities of Pakistan. It is essential to establish the baseline data for air quality and to determine the exposure levels of the air pollutants especially NO_2 in the city of Lahore. It is also profoundly significant to determine the background of pollution levels for future industrial zoning and for the spatial planning.
8. The regular air quality monitoring system along with the traffic counts of the hot spot areas or bottle necks give the true picture of air quality situation of the city. This leads to the proper guideline to the town planner, environmentalists, government agencies and for all the stakeholders to work for future air quality of the city.
9. In this study, the potential risks for the land use of Lahore metropolitan areas e.g. residential, main road crossings, industrial locations, education institutions, parks, suburban places are identified as shown in figures-7, 8 and 9. The air quality surveys represent and identify each potential location (about an area of 3-5 kilometers radius) within a GIS layer. Each geographical location also represents a population cluster ranging from minimum of about 5000 persons to maximum 15000.

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