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# Application of GIS in Visualization and Assessment of Ambient Air Quality for $SO_2$ and $NO_x$ in Sheikhupura City, Pakistan

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## Abstract

Air Pollution is the most detrimental form of pollution in our environment. A significant increase has been seen in atmospheric pollutants sources in Asia while it is considered to be primarily an urban problem in Pakistan. Sheikhupura was selected as study area and data was collected randomly from 15 different points of Sheikhupura city. Data used in this research paper is of secondary type collected from EPD, Sheikhupura. One-way-ANOVA and Interpolation (IDW and Kriging) has been applied for the interpretation and analysis of $NO_x$ and $SO_2$ concentration at sampling sites. Results showed that concentration of $NO_x$ was very high at areas with high road traffic while that of $SO_x$ varied differently. The highest value of $NO_x$ found in the study area is 5 ppm while the lowest value is 0.06 ppm, on the other hand the highest value of $SO_x$ found in the study area is 1.9 ppm and the lowest value is 0.1 ppm. The most prone areas to $NO_x$ in Sheikhupura are Jhang Road, Jinnah Park, Rasul Pura and Landa Bazar. And the areas with high concentration of SOx in Sheikhupura are Ashraf General and Batti Hospital. Proper urban management can help to reduce air pollution.

**Keywords:** Air pollution; ANOVA; GIS; IDW; Kriging; $NO_x$; $SO_2$; Sheikhupura; Pakistan

## Introduction

From last some years, there is a substantial increase in development, urbanization, motorization associated with increased energy use in the Asian countries. A significant increase has been seen in atmospheric pollutants sources in Asia [1]. Industrial activities, increased population and substantial rise in vehicular use are potential cause of environmental degradation in South Asia [2]. As a result of these factors, air pollution has caused major threats to the environment, life quality, and health effects to the South Asian population. Poor air quality is deteriorating not only environment but also badly affecting health of individuals [3]. A recent report of the OECD says that by the year 2050, air pollution is expected to be the world's top environmental cause of death, prior to dirty water and poor sanitation [4]. Asian countries are suffering from elevated levels of atmospheric pollutants: Bangladesh [5], Malaysia [6], Indonesia [7], Pakistan [8], Thailand [7,9], India [7,10], Vietnam [7] and China [11]. According to [3], urban air quality badly affects health of individuals in metropolitan areas, and reports that there is an average annual increase of 14.1 % of vehicular emissions in Pakistan from year 1985-2005. Air pollution is considered to be primarily an urban problem in Pakistan [12].

Concentration of pollution has increased in major cities of Asia like in Lahore, Karachi, Kolkata, Mumbai, Chinghai, Beijing and many other cities. According to WHO report, air pollution is the sole reason for death of more than 2 million people all over the world. 90% of air pollution in urban areas is due to vehicular emissions [8]. Pakistan has the highest concentration of particulate matter and is placed by the WHO in a category called "unhealthy for the sensitive people". Pakistan's urban air pollution is among the most severe in the world and it engenders significant damage to human health and the economy [12]. Sheikhupura has developed an inspiring industrial base from the last some years(Javed et al. 2010). Depending on the Census of Manufacturing Industries, large scale industries are higher in Sheikhupura than in Lahore [13]. Total population of Sheikhupura city is approximately 3, 63,000 residents. Population is growing in a faster rate of 1.88% per year. This increased population is associated with the increased traffic resulted in a haphazard situation in Sheikhupura city. According to a survey, 55% of the public use motorbikes and 15% cars as their means of transportation [13].

Geo-information Sciences is being widely used in decision making regarding transport, land use pattern and environmental quality [14,15]. GIS is a key technology that can be easily used in health impact assessment [16]. Mapping and modeling of pollution and its analysis gives us a better idea of pollution patterns than ordinary techniques [17]. No doubt, geo-informatics has an important role in decision making but still it is important to calculate uncertainties linked with these models [18]. Study of air quality is a complex method because it is quite difficult to collect air samples. Geo-statistics is used for complete analysis and observation of air quality of the study area [19]. Techniques like GIS and RS can be used in order to sort out problems like atmospheric pollution [20]. The designed tool can be used largely by policy makers in residential, industrial and commercial zones [21].

## Study Area

Sheikhupura in Punjab Province, Pakistan is selected as study area. Sheikhupura is a famous district of Punjab, situated at a distance of 36 km northwest from Lahore. It is well-known for its historical buildings, agricultural surroundings and the best quality rice. It is provincially known as "Qila Sheikhupura", because of the fort that was constructed by Mughal Emperor Jahangir [22]. Sheikhupura is located on following coordinates: Latitude=31° 42' 47" N and Longitude=73°

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58' 41" E. According to report of Punjab Development Statistics 2012, estimated population of Sheikhupura district is 2,980,000 covering an area of 3242 $Km^2$. It comes on 3rd ranking for population and 7th for the area as compared to 36 other districts of Punjab province [23] (Figure 1).

### Selection of sampling points

Data on air quality of Sheikhupura city from January to March for 2015 was collected from EPD Sheikhupura. 15 popular and most busy sites of Sheikhupura were observed for concentration of $NO_x$ and $SO_x$ emissions. Sampling was performed for random sites. Values of data were observed by placing instruments on 2-3 meters away from road sides (Figure 2).

## Methodology

### $SO_2$ monitoring data

Sulphur dioxide concentration was collected in glass impingers using sodium tetrachloro-mercurate as absorption solution using Air Sampling Pump (BD Pump, RMN26551 Model, and Manufactured by LaMotte, Maryland, USA). Three replicas for each sampling sites were collected for 24 hours observation and were transferred in to the laboratory in a cold box at 5°C. Samples were analyzed using Colorimetric method by estimating absorbance of $SO_2$ from absorbing reagent using Spectrophotometer at 540 nm.

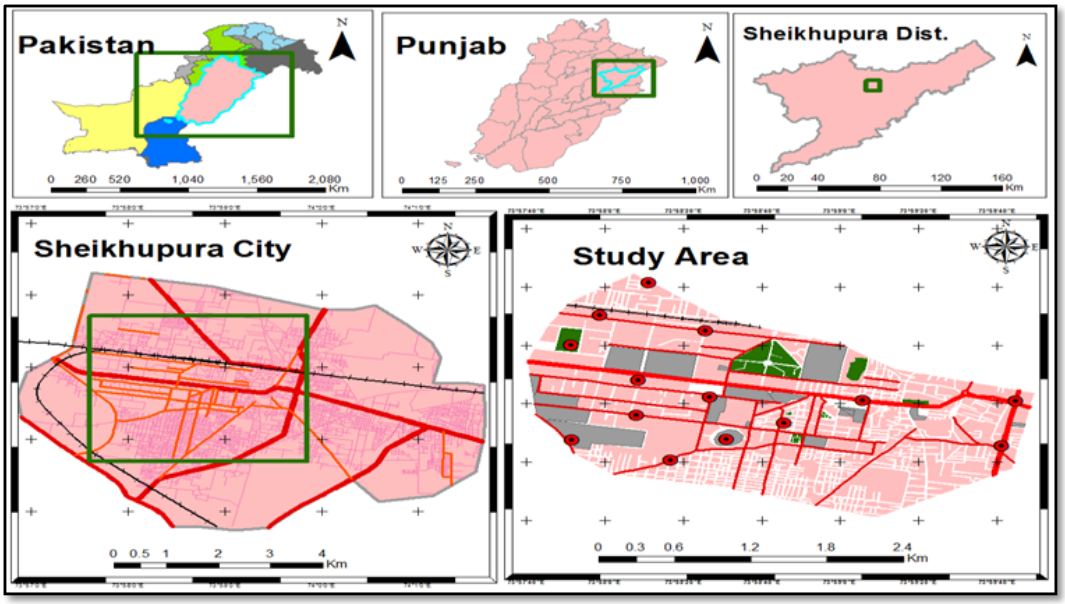



**Figure 1:** The location of study area in Pakistan.

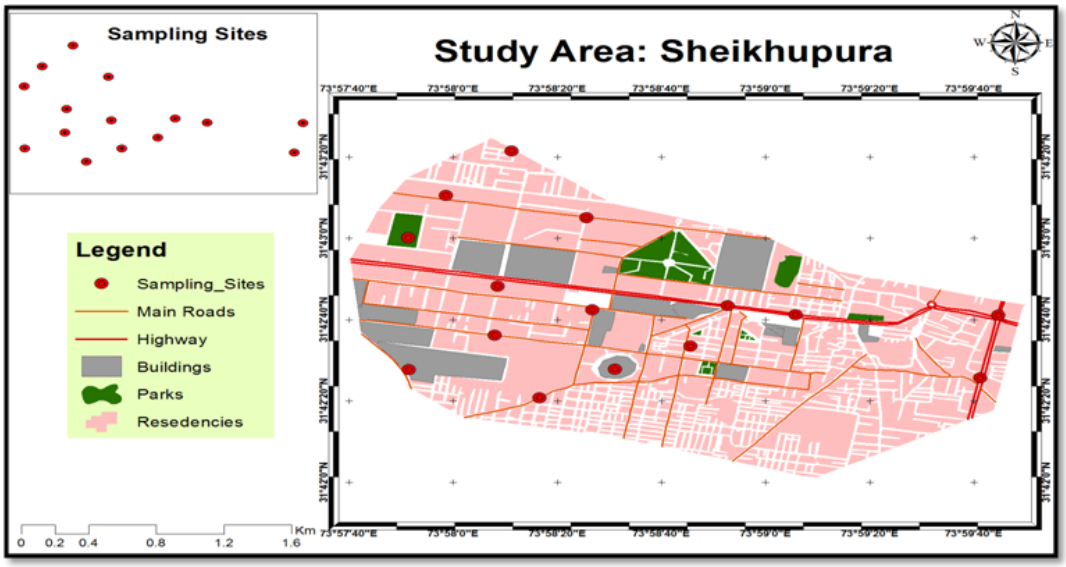



**Figure 2:** Study area and sampling sites.

### $NO_x$ monitoring data

Nitrogenous Oxides were collected in glass impingers by using sodium hydroxide and sodium arsenate as absorption solutions using Air Sampling Pump (BD Pump, RMN26551 Model, and Manufactured by LaMotte, Maryland, USA.). Transportation and sampling methods are same as $SO_2$.

### Data analysis and interpretation

ArcGIS 10, Google Earth and Statistix 10 were used for data analysis and interpretation. Microsoft Excel was used to arrange data according to geographic locations in Geographic Coordinate System (GCS) projection, WGS 1984 datum. ArcGIS interpret data which is geographically referenced to a projection system. Study area was Georef and digitized by using ArcGIS. Then excel sheet was converted into shape file (.shp) in order to perform analysis in GIS. Arranged data for 15 locations is given in table. It shows concentration of $NO_x$ and $SO_x$ with reference to longitudes and latitudes of sampling sites. Three replicates values are being taken for each of 15 sampling sites (Table 1).

Concentration of $SO_x$ and $NO_x$ is given in parts per million (ppm) while latitudes and longitudes are given in decimal degrees. One way ANOVA was applied between these parameters to determine whether there is a significant relation between means of three or more un-related groups or not.

### Statistical analysis

Data was organized in Excel for statistical analysis of two parameters. Each site contains three replica values for each parameter. Mean, Standard Deviation and coefficient of variance were found for each site by using replica values. Then graphs were designed with mean value and difference was finding from the standard deviation value using error bars. Difference of mean value and standard deviation showed that the mean value can deviate positively or negatively from the standard value. Statistix 10 software was used for application of one-way ANOVA on data set. The result of ANOVA shows a significant level.Values are mean of 3 different replicas bearing different letters that are significantly different from each other (at $p<0.05$) by using the Tukey HSD test. Mean of measured values are further compared with the NEQs.

### Spatial analysis

Spatial analysis of $NO_x$ and $SO_x$ data for study area was performed by using ArcGIS 10. Interpolation was performed for estimation of values of variables at those sites which are un-sampled. Both IDW and Kriging techniques are used for spatial representation of pollutants at and between sampling sites.

## Results and Discussions

The present research has inquired different pollutants and their sources, spatial patterns and analysis and exposure models in Sheikhupura. Geo-statistical analysis showed that increased concentration of atmospheric pollutants is closely related with the increased traffic but other sources are also of significant consideration for air pollutants like industries and especially brick kilns which are found abundantly in the surroundings of Sheikhupura city. Un-managed urban transport and urban development, especially an increasing number of industries in Sheikhupura surroundings have increased environmental threats. Geo-statistical results showed that vehicular emission, increased urban settlement and industrial development is a contributing factor in degradation of ambient air quality.

NEQ's value of $NO_x$ is 0.42 ppm (on average hourly value) while NEQs value for $SO_x$ is 0.14 ppm (based on average hourly value). The foremost reason for increased concentration of $NO_x$ in the air could be the increased traffic from the past few years. According to Transport Planning Unit Road traffic has increased in Sheikhupura up to 50% from the past few years, especially amongst the people having high and medium income. While the cause for increased concentration of $SO_x$ emissions could be use of coal and furnace oil in brick kilns, also the use of diesel oil and petrol for transport purposes. The most prone areas of $NO_x$ emissions in Sheikhupura are Jhang Road, Jinnah Park, Rasul Pura and Landa Bazar. Jinnah Park and Jhang road are highly populated roads in terms of traffic. While studies at Sarwar Shaheed Road show the lowest concentration of $NO_x$ emissions reason for this could be the decreased traffic density at this point. Results demonstrate that the areas with high concentration of $SO_x$ in Sheikhupura are Ashraf General Hospital and Batti Chowk. These two areas also have

| No | Site | Replicas | | | Date | Long. | Lat. | $NO_x$ | | | $SO_x$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | R1 | R2 | R3 | R1 | R2 | R3 |
| 1 | Rasul Pura | r1 | r2 | r3 | 12-1-2015 | 73.969779 | 31.722618 | 3.5 | 4.3 | 3.9 | 0.9 | 1.3 | 1.1 |
| 2 | Behari Colony | r1 | r2 | r3 | 20-2-2015 | 73.96629 | 31.719568 | 2.1 | 1.5 | 1.8 | 0.52 | 0.08 | 0.3 |
| 3 | Ayesha Park | r1 | r2 | r3 | 29-3-2015 | 73.964269 | 31.716707 | 3.9 | 3.1 | 3.5 | 0.7 | 1.1 | 0.9 |
| 4 | Damoana Road | r1 | r2 | r3 | 19-2-2015 | 73.964307 | 31.707678 | 0.8 | 3.8 | 2 | 0.32 | 0.06 | 0.1 |
| 5 | Jhang Road | r1 | r2 | r3 | 10-2-2015 | 73.971269 | 31.705764 | 1 | 5 | 3 | 1.2 | 0.6 | 0.9 |
| 6 | Sarwar Shaheed Road | r1 | r2 | r3 | 05-3-2015 | 73.968888 | 31.710018 | 3.2 | 0.06 | 1 | 0.04 | 0.07 | 0.01 |
| 7 | Colledge Road | r1 | r2 | r3 | 31-1-2015 | 73.969029 | 31.713372 | 1.9 | 1.5 | 1.7 | 0.09 | 0.4 | 0.2 |
| 8 | Malik Anwar Road | r1 | r2 | r3 | 28-2-2015 | 73.973772 | 31.718053 | 2.9 | 3.3 | 3.1 | 1.8 | 0.07 | 1.1 |
| 9 | Nadra Road | r1 | r2 | r3 | 03-2-2015 | 73.974096 | 31.711759 | 2.7 | 2.3 | 2.5 | 0.3 | 0.9 | 0.6 |
| 10 | Noor Stadium | r1 | r2 | r3 | 17-1-2015 | 73.975289 | 31.707716 | 3.5 | 3.3 | 3.1 | 1.2 | 0.6 | 0.9 |
| 11 | Jinnah Park | r1 | r2 | r3 | 14-2-2015 | 73.97933 | 31.709276 | 5 | 4.6 | 4.8 | 1.5 | 1.1 | 1.3 |
| 12 | Madina Chowk | r1 | r2 | r3 | 24-2-2015 | 73.981307 | 31.712055 | 3.1 | 2.7 | 2.9 | 0.09 | 0.4 | 0.2 |
| 13 | Landa Bazar | r1 | r2 | r3 | 10-3-2015 | 73.984946 | 31.711428 | 4.7 | 4.3 | 4.5 | 1.5 | 1.1 | 1.3 |
| 14 | Batti Chowk | r1 | r2 | r3 | 07-3-2015 | 73.995757 | 31.711385 | 2 | 6 | 4 | 1.9 | 1.5 | 1.7 |
| 15 | Ashraf General Hospital | r1 | r2 | r3 | 28-1-2015 | 73.994785 | 31.707113 | 2.9 | 2.5 | 2.7 | 1.5 | 1.7 | 1.9 |

**Table 1:** Concentration of observed pollutants at 15 different locations of Sheikhupura.

high traffic density but there are many small factories and brick kilns working in this area which also serves to the increased concentration of SOx in these areas. While Sarwar Shaheed Road has the lowest value for $SO_x$ emissions reason is again the same it is not commercial area and so contributes less towards $SO_x$ or $NO_x$ emission.

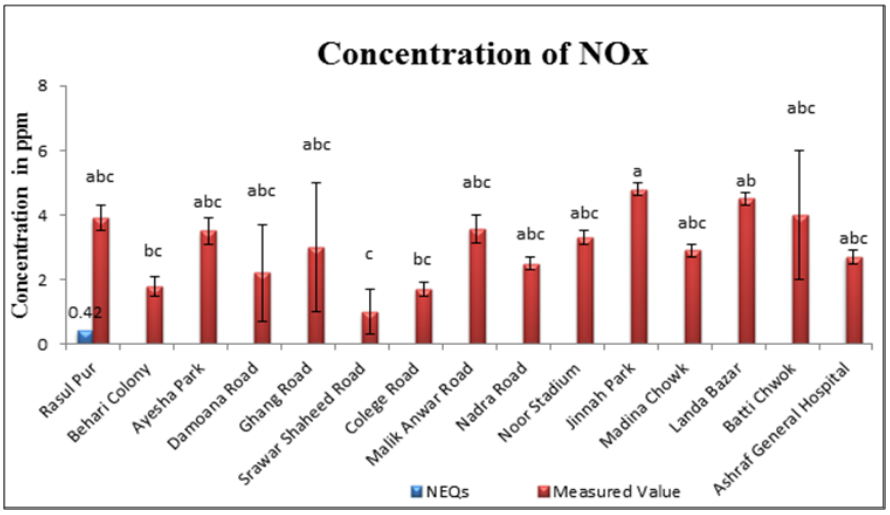
## $NO_x$ scenario

Concentration of $NO_x$ was high in study area in comparison to the NEQs (0.42 ppm based on average hourly value). Nitrogenous oxides have a visible relation with the road traffic emissions as shown in Graph 1. NO is released from the road traffic and industrial source. Trend shows that its concentration is high near roads and decreases near settlements or away from the road. It can be implicit that concentration of NOx decreases by increasing distance from roads and vice versa. Concentration of $NO_x$ at Jinnah Park is the highest while at Sarwar Shaheed Road is lowest and also values for both locations are significantly different from other groups. While sampling sites like Rasul Pura, Ayesha Park, Noor Stadium, Ghang Road, Malik Anwar Road showed almost same levels for $NO_x$ emissions (Graph 1) (Figures 3 and 4).

## $SO_2$ scenario

The concentration of Sulphur Oxides in different locations of Sheikhupura city varies from Ashraf General Hospital to Rasul pura and it exceeds from the limits of National Environmental Quality standards. Ashraf General Hospital and Batti Chowk shows the highest concentration of $SO_x$ emissions and Sarwar Shaheed Road and Damoana Road showed the lowest concentration (Graph 2).

Concentration of $SO_2$ was not as higher in the study area in comparison to the NEQs (0.14 ppm based on average hourly value). $SO_2$ is generated as a result of influx of vehicular emission and industrial pollution. Geo-statistical analysis has proved that $SO_2$ produced in




**Graph 1:** Concentration of oxides of nitrogen in 15 locations of Sheikhupura city.

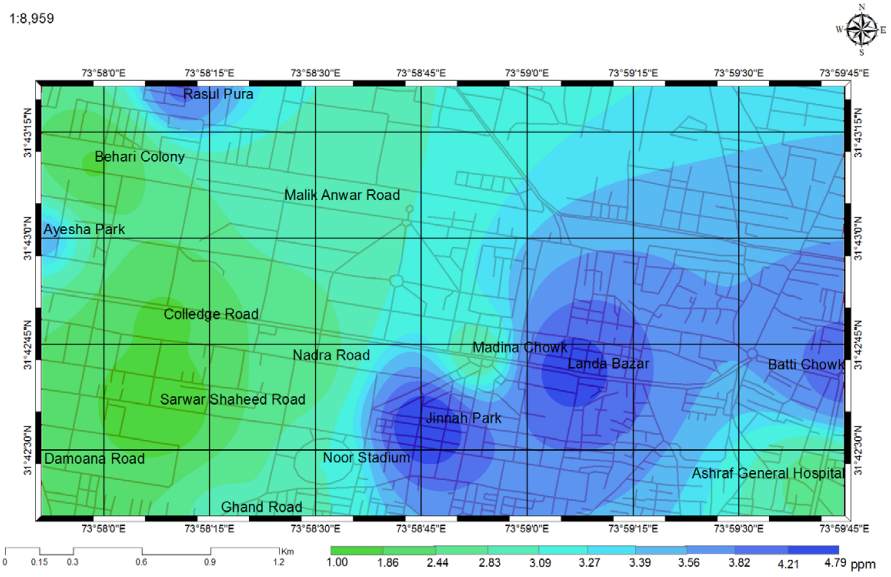



**Figure 3:** IDW map for concentration of $No_x$ in Sheikhupura city.

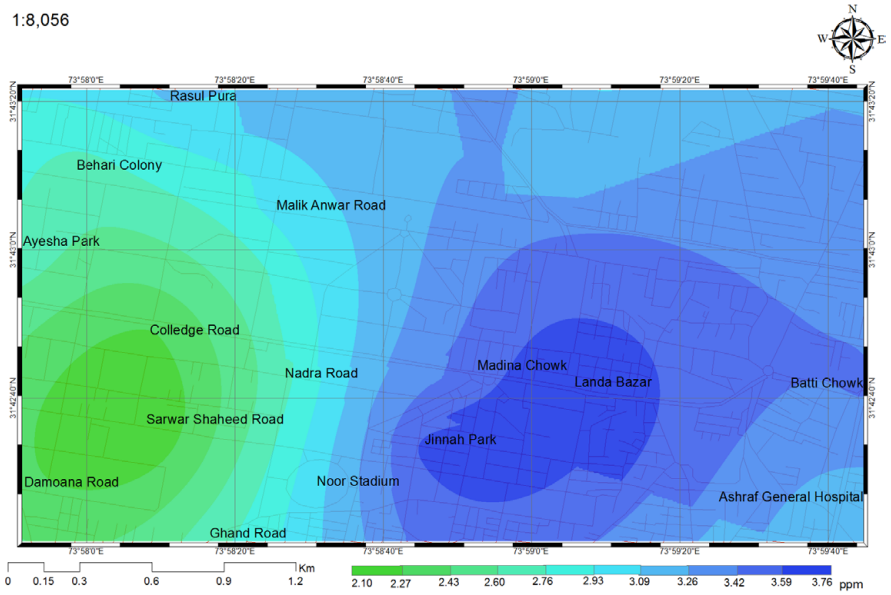
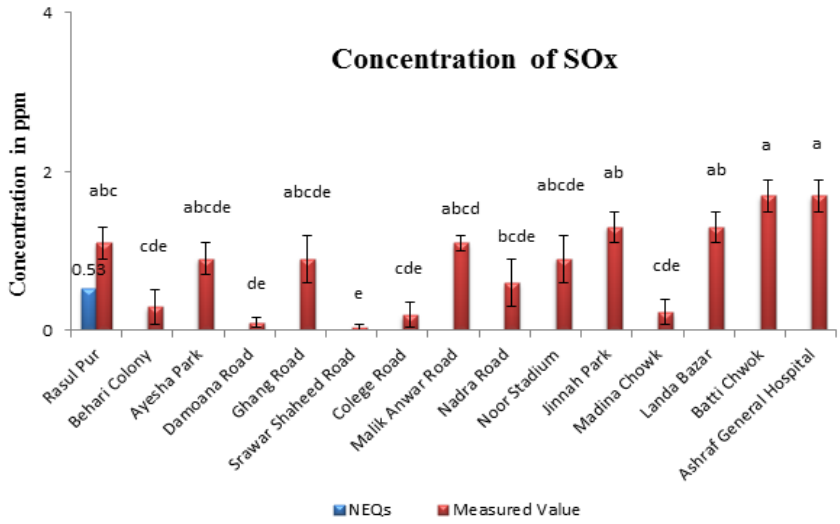



**Figure 4:** Krigingmap for concentration of $No_x$ in Sheikhupura city.




**Graph 2:** Concentration of oxides of sulphur in 15 locations of Sheikhupuracity.

Sheikhupura city is also due to vehicular emission along with sources. It follows the same trends like $NO_x$. With increase in distance from extreme density roads concentration of $SO_2$ decreases. Results showed that traffic could be a contributing factor towards $SO_2$ emissions but is not the only one. Main factor in increase of $SO_x$ concentration, other than road traffic could be the burning of coal in brick kilns. Use of coal and furnace oil in brick kilns increases the levels of $SO_x$ in air. Concentration of $SO_x$ at Batti Chowk and Jinnah Park is the highest while at Sarwar Shaheed Road is lowest and also values for both locations are significantly different from other groups (Figures 5 and 6).

## Conclusion

GIS based assessments of an environmental factor have always been an interesting study. GIS along with statistical techniques is best method to find trend in pollution level. GIS is a new and modern tool for assessment and management of environmental problems and is also useful in decision making. Jinnah Park and Rasul Pura is more concentrated with respect to air pollution because of dense settlement. The highest value of $NO_x$ found in the study area is 5 ppm while the lowest value is 0.06 ppm, on the other hand the highest value of $SO_x$ found in the study area is 1.9 ppm and the lowest value is 0.1 ppm. The most prone areas to $NO_x$ in Sheikhupura are Ghang Road, Jinnah Park, Rasul Pura and Landa Bazar. And the areas with high concentration of $SO_x$ in Sheikhupura are Ashraf General and Batti Hospital. Proper urban management can help to reduce air pollution. Concentration of $NO_x$ is more than SOx because of multiple factors towards its contribution in air like traffic (major source) and industries. Unmanaged urban development and unplanned road infrastructure is major cause of

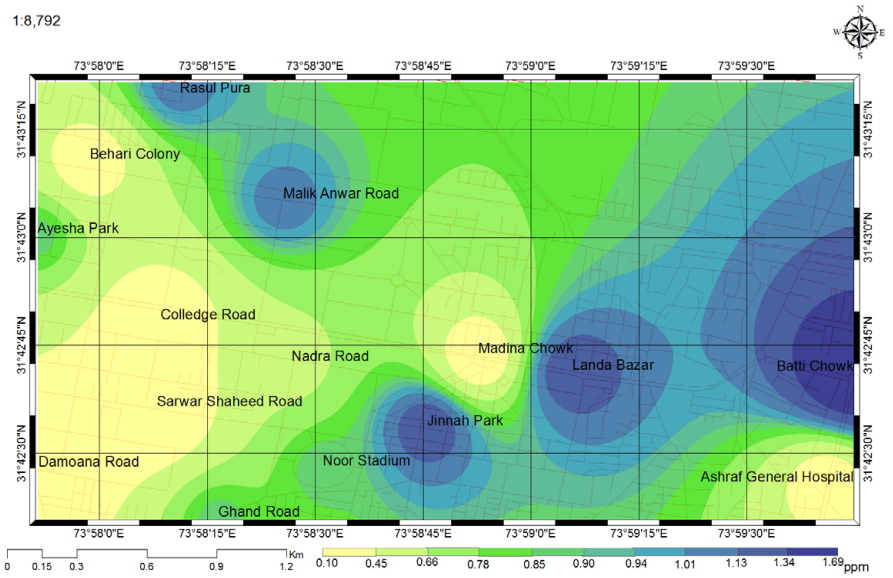



**Figure 5:** IDW map for concentration of $SO_x$ in Sheikhupura city.

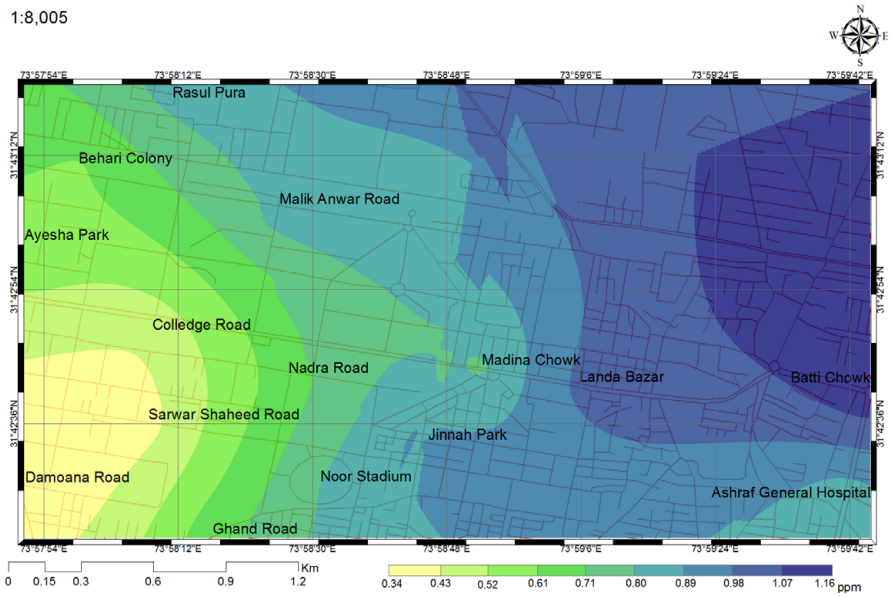



**Figure 6:** Kriging map for concentration of $SO_x$ in Sheikhupura city.

pollution in Sheikhupura. Data was collected within 3 months and there are greater chances that meteorological conditions and data collection and preservation techniques can affects the data collected.

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