Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
**DOI 10.17605/OSF.IO/MCETF**

# INTERACTION OF CLIMATIC VARIABLES WITH ROADSIDE $NO_2$ IN A NORTH-WESTERN CITY OF THE HIMALAYAS

**MUHAMMAD BILAL***

Department of Environmental Sciences University of Peshawar, Peshawar 25120, Khyber Pakhtunkhwa, Pakistan. Corresponding Author

**ASIF KHAN KHATTAK**

Department of Environmental Sciences University of Peshawar, Peshawar 25120, Khyber Pakhtunkhwa, Pakistan.

**BUSHRA KHAN**

Department of Environmental Sciences University of Peshawar, Peshawar 25120, Khyber Pakhtunkhwa, Pakistan.

**JAVAID IQBAL***

Department of Environmental Sciences, University of Lakki Marwat, 28420, Khyber Pakhtunkhwa, Pakistan.coressponding Author

**ZARAK KHAN**

Department of Environmental Sciences University of Peshawar, Peshawar 25120, Khyber Pakhtunkhwa, Pakistan.

**HINA**

Department of Environmental Sciences University of Peshawar, Peshawar 25120, Khyber Pakhtunkhwa, Pakistan.

**SANAN ABID**

Department of Environmental Sciences University of Peshawar, Department of Occupational Health, Safety & Environment, Northwest General Hospital & Research Centre, Peshawar, 28420, Khyber Pakhtunkhwa, Pakistan.

**Abstract**

This study examines the interactions between climatic variables and roadside Nitrogen dioxide ($NO_2$) concentrations in a northwestern city located in the Himalayan region. The study collected ambient $NO_2$ concentrations using a standard procedure for $NO_2$ collection and divided the study region into three major areas: urban, suburban, and rural. Each area was further divided into five sampling locations, and each location was sampled five times on different days of the week during both the winter and summer seasons. The mean estimated values for $NO_2$ in urban, suburban, and rural areas during the winter season were 51, 38, and 40 µg/m$^3$, respectively, while in the summer season, the values were 44, 32, and 29 µg/m$^3$. Similarly, the mean predicted values of $NO_2$ for the study areas during the winter season were 52, 38, and 41 µg/m$^3$, and during the summer season, they were 45, 40, and 40 µg/m$^3$. The Tukey test was performed for all the concentration measurements at various locations, and there was almost a significant difference (0.05) among all the data sets. The correlations between temperature and $NO_2$ showed a positive value for both summer and winter seasons, while $NO_2$ showed negative correlations with wind speed and humidity (-0.8 to 0.6). Despite the variations in seasons and fleet flux in urban, suburban, and rural study sites, a significant level of agreement was found via correlations between $NO_2$ and the climatic variables. Overall, this study provides valuable insights into the interactions among climatic variables and roadside $NO_2$

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
**DOI 10.17605/OSF.IO/MCETF**

concentrations in a north-western Himalayan city and emphasizes the need for continued monitoring of air pollution levels in this region.

**Keywords:** Climatic variables Vehicular emissions $NO_2$ North-western Himalayas

## INTRODUCTION

Climatic variables are measurable properties of the atmosphere that characterize the climate of a specific region (Mehta and Yadav, 2022; Touhami et al., 2022; Gul et al., 2022). Pakistan is among the top ten most vulnerable countries to climate variations (Hussain et al., 2020; Qazalbash et al., 2021). According to a report by the Government of Pakistan (GoP, 2016), there has been a recorded increase of 0.57 $^{o}$C in temperature and variations in precipitation patterns. Pakistan is a significant agricultural country globally (Rehman et al., 2022), and its climate ranges from arid to semi-arid (Hayat et al., 2021). Unfortunately, due to excessive growth in industries, transportation, deforestation, and urbanization, the changes in climatic variables have surpassed acceptable limits (Khosla and Bhardwa, 2021; Williams et al., 2019). Consequently, these changes are impacting natural habitats, causing glacier melting, droughts, increased air pollution, and health issues (Honson et al., 2020; Li et al., 2020; Darmanto et al., 2019). The Task Force on Climate Change (TFFC) in Pakistan submitted a report on climate change in the country (Rahman et al., 2017). $NO_2$ is a highly reactive gas formed by the combustion of fossil fuels, particularly in vehicle emissions (Hickman et al., 2021; Goldberg 2019). $NO_2$ also reacts with other air pollutants, leading to the formation of secondary pollutants like ozone and particulate matter, which further worsen the impacts of vehicular emissions (Orellano et al., 2020; Zhao et al., 2020). High levels of $NO_2$ exposure can result in respiratory problems such as asthma, bronchitis, and pneumonia (Cheng et al., 2019; Yee et al., 2021; Cheng et al., 2019). It can also cause eye irritation, headaches, and fatigue. Furthermore, $NO_2$, in conjunction with other air pollutants, contributes to the formation of secondary pollutants such as ozone and particulate matter, which intensify the health consequences of vehicular emissions (Rovira et al., 2020; Naghan et al., 2022).

Peshawar, a major city in the north-western Himalayas, has experienced a significant increase in air pollutants due to the rising number of vehicles and inadequate emission control measures, posing a severe threat to the environment (Bilal et al., 2022), and public health (The impact of $NO_2$ on air quality and human health in Peshawar underscores the urgent need for effective emission control measures to reduce vehicular emissions. Possible solutions include promoting public transportation, adopting cleaner fuels, and implementing stricter emission standards and regulations (Singh et al., 2022; Ribeiro et al., 2022). Taking action to reduce vehicular emissions can improve air quality in the study area and safeguard the health and well-being of residents (Gonzalez-Martin et al., 2021).

Moreover, the effects of $NO_2$ emissions extend beyond Peshawar city, as air pollution can travel over long distances and impact neighboring regions (Rana et al., 2022; Jain et al., 2020; Ren et al., 2023). Additionally, the impacts of vehicular emissions extend beyond human health and encompass environmental consequences such as climate change and ecosystem damage (Zoran et al., 2020; Tyagi et al., 2022; Pasupuleti et al., 2022).

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
**DOI 10.17605/OSF.IO/MCETF**

Therefore, this study aims to investigate the correlation and interactions between various climatic variables and roadside $NO_2$ in the study region of Peshawar.

### Study area

District Peshawar (33.9437° N, 71.6199°E) is situated in a subtropical climate. The average temperature in summers rises to 40°C (May-Aug) whereas, in winters, it is 10 °C (Nov-Mar). Relative humidity averages about 46% (June-Aug) and 57% in (Nov-Mar). On the Western side of the Peshawar valley, there lies a Khyber Pass. In the North and Northeast, it is wrapped by mountains, which ultimately separate it from the Swat region. The Khyber mountain range is in the Northwest of Peshawar, District Peshawar is stretched towards Koh-e-sufaid (White Mountain) in the South. It is connected to the Northern region and other cities of Pakistan via motorway, Indus highway, and Karakorum highway. Sources of traveling are coaches, buses, wheelers, and for inside city moments, cars, rickshaws, motorcycles (two-stroke engines), etc., are used excessively. The industrial sector is developed which includes the industries of sanitary, food, beverages, wood, plastics, etc. Brick kilns and marble factories are situated in suburban and rural locations of the Peshawar district. It has a single tehsil, there are 92 union councils in which 56 are rural and 36 are urban (Bilal et al., 2022).

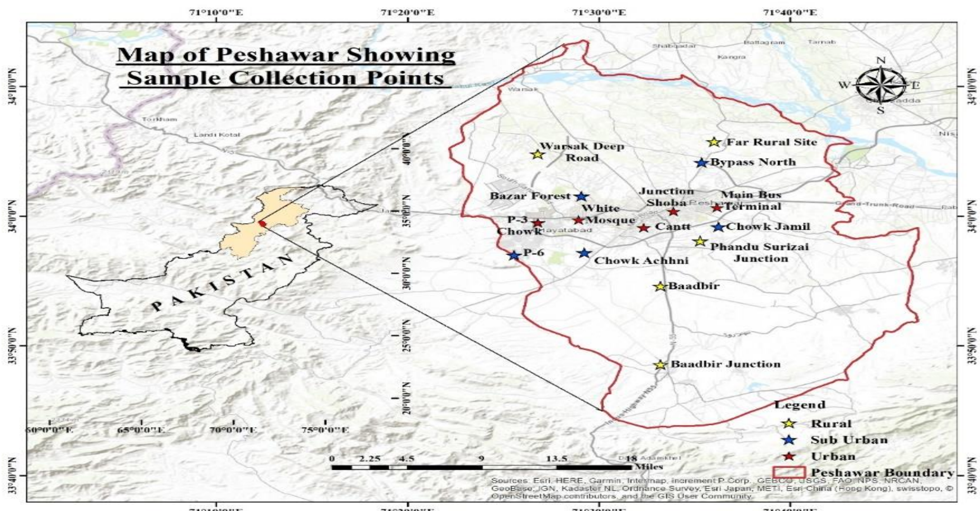



**Figure 1: Map of the study area (Bilal et al., 2022)**

## MATERIAL AND METHODS

### $NO_2$ Data collection

$NO_2$ concentrations were collected with the help of NOVA Model 600, Portable Multi-gas Ambient Air Analyzer–600 series. It is a portable electrochemical sensor, % RH by dielectric ceramic sensor-based device suitable for ambient outdoor air quality identification (Subhanullah et al., 2022). For the collection $NO_2$ data the portable device was fixed in the range of 2 meter height near the road

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
**DOI 10.17605/OSF.IO/MCETF**

side while going traffic to observe climatic $NO_2$ concentrations among the climatic variables. The samples were collected on the random days of week in both the summer and winter seasons.

### Statistical analysis

The Statistical analysis included correlations; Tuckey test analysis and Multilinear Regression Model were conducted via SPSS (V23), before finding out the final conclusion (Achen, 2021).

### Tukey test

It is the statistical tool which determines the analysis of variance and shows the significance difference among the different data sets or groups (Janani et al., 2021)

### Multi Linear regression (MLR) model

Multi linear regression (MLR) model is a statistical tool that can be used in research projects for analysis. It can be used to identify the relationship among the dependent and independent variables and to calculate the predicted desired values. In multi linear regression, the independent variables are more than one (Temp, Humidity, and Wind speed) with the dependent variables (Concentration of $NO_2$). Generally, it can be,

$$Yj = \beta^o + \beta 1X1 + \beta 2X2 + \beta 3X3 \ldots\ldots \beta kXk + r \ldots\ldots\ldots\ldots\ldots\ldots \text{EQ 1.}$$

Whereas, for the set of Yj observations, Yj is a predicted variable and is calculated by coefficient, $\beta^o$ and independent variables set (X) and a residual error (r). This model identifies the mathematical relationship between the dependent variable and independent variables (Lee et al., 2019; Zhang and Yao, 2021).

**Table 1: The season-wise mean estimated values of $NO_2$**

| ***$NO_2$ N=150*** | ***Winter Urban n=25 µg/m³*** | ***Winter Sub urban n=25 µg/m³*** | ***Winter Rural n=25 µg/m³*** | ***Summer Urban n=25 µg/m³*** | ***Summer Sub urban n=25 µg/m³*** | ***Summer Rural n=25 µg/m³*** | ***PAK-NEQS 24hr (µg/m³) Rasheed et al., 2014*** | ***US-EPA 1hr ppb*** NAAQS USEPA, 2014*** |
|---|---|---|---|---|---|---|---|---|
| ***Mean values*** | 51 | 38 | 40 | 44 | 32 | 29 | 120 | 53 |

### Pearson Correlations (r)

The correlation analysis is the statistical analysis tool that identifies and predicts the relationship between two variables or among the various variables. Furthermore it marks the strength and relationship among variables (Jebli et al., 2021; Liu et al., 2021).

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
DOI 10.17605/OSF.IO/MCETF

## Results

The estimated mean concentrations of $NO_2$ measurements from urban, suburban and rural study areas in winter seasons were 51, 38 and 40 µg/m$^3$. The location-wise mean value measurements were for Phase 3 chowk, Jumat speen , Deans chowk (Cantt), Shuba bazar junction and haji camp (Bus terminal) were 51, 49, 53, 48 and 54 µg/m$^3$ similarly, for suburban locations the mean values for Achini chowk, Jameel chowk, Forest bazar, Northern bypass and Phase 6 (VII) were 37, 36, 40,39 and 38 µg/m$^3$. Followed by the measurements for rural study area locations i.e., for Deep warsak , Pandu –surizai junction, Badaber, Badaber –matani junction and far rural site were 39, 44,38,41 and 40 µg/m$^3$ (Table 1). The mean estimated values for summer season were 44, 32 and 29 µg/m$^3$. Location wise estimated concentration values in summer season for urban locations i.e., Phase 3 chowk, Jumat speen , Deans chowk (Cantt), Shuba bazar junction and Haji camp (Bus terminal) were 44, 45, 43, 49 and 42 µg/m$^3$, whereas for suburban locations for Achini chowk, Jamil chowk, Forest bazar, Far (Deep warsak ) and Phase 6 (VII) were 31, 33, 31, 34, 30 µg/m$^3$. Followed by the mean values for rural study area locations in summer season. Deep warsak, Pandu –surizai junction, Badaber, Badaber –matani junction and far rural site. i.e., 30, 32, 29, 27 and 28 µg/m$^3$ (Table 1) (Figure 2).

## REGRESSION ANALYSIS RESULTS

The regression analysis analysed the inter-dependency of the $NO_2$ with climatic variables. In the winter season it has been evident that the unknown factors in the rural study locations counts more impact in the relationship among $NO_2$ and climatic variables as compare to the urban and suburban study areas. Similarly, in the summer season the urban and rural study locations determined more weightage of the unknown factors as compared to the suburban study area. Furthermore, the temperature involvement was either minimum or negative as compare to the other climatic variables. The following equations are the predicted models for the study area locations in both the winter and summer seasons.

### Urban winter

$NO_2(Y^o)=44.927+(9.061)Wind+(1.110)Temp+(0.132)Hum$………………..EQ 2.

### Sub-urban winter

$NO_2(Y^o)=41.368+(1.265)Wind+(.186)Temp+(0.052)Hum$…………………………..EQ 3.

### Rural winter

$NO_2(Y^o) =47.196+ (4.732) Wind+ (.156) Temp+ (0.123) Hum$….............EQ 4.

### Urban summer

$NO_2(Y^o) =80.789+ (4.849) Wind+ (-1.185) Temp+ (0.088) Hum$…EQ 5.

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
**DOI 10.17605/OSF.IO/MCETF**

### Sub urban summer

$NO_{2}(Y^{o})$ =33.664+ (2.571) Wind+ (0.78) Temp+ (0.066) Hum…………………………….EQ 6.

### Rural summer

$NO_{2}(Y^{o})$ =66.783+ (0.078) Wind+ (0.950) Temp+ (0.17) Hum…………………………….EQ 7.

The regression model predicted the values by using the estimated values shown in EQ 2, 3, 4, 5, 6, and 7. Figure 3, evidenced the less variability in between the estimated and predicted values for all the study areas in both the seasons whereas, the variation in between the estimated and predicted values for urban suburban in summer and winter season were less as compare to the variations values for rural study area Figure 3 and Figure 5.

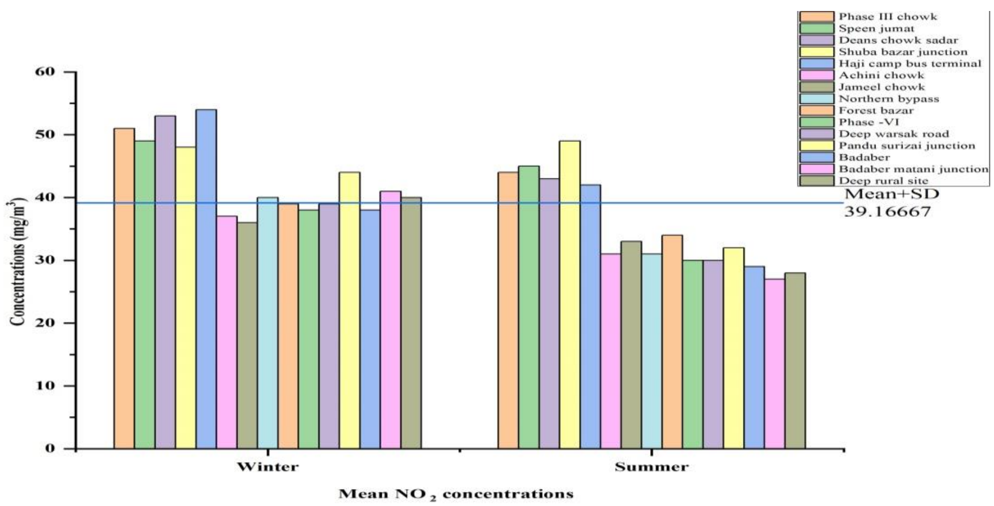



**Figure 2: The mean concentrations locations wise in both the summer and winter season**

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
**DOI 10.17605/OSF.IO/MCETF**

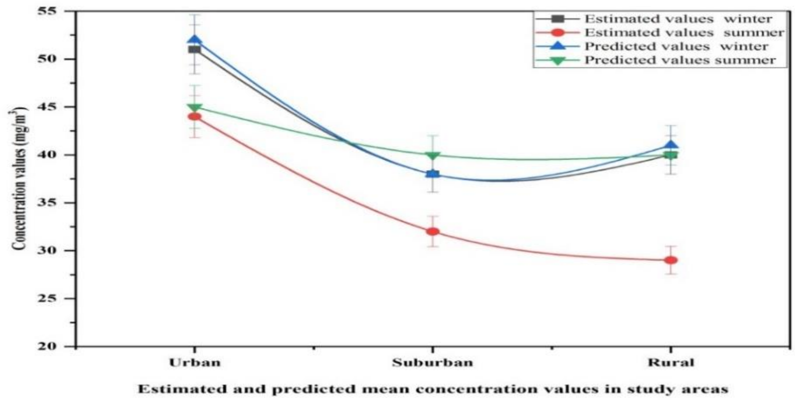



**Figure 3: Comparison between estimated and predicted mean values of $NO_2$**

## RESULTS PEARSON CORRELATION (r)

The correlation (r) analysis showed that the climatic variables are correlated with the $NO_2$ in both positively and negatively. Temperature determined the positive correlation $NO_2$ in both the seasons. However, the correlation in summer was less strong (0.35) as compared to the winter season (0.48). Similarly, the correlation value among the $NO_2$ concentration and Wind speed was found negative in both the winter and summer season, it was also noted that the correlations in winter season were less negative (-0.25) as compare to the summer season (-0.80). The correlation analysis further explained that the correlation values among humidity and $NO_2$ concentrations were bit more (-0.65) in summer season as compare to the winter season (-0.60) Figure 4.

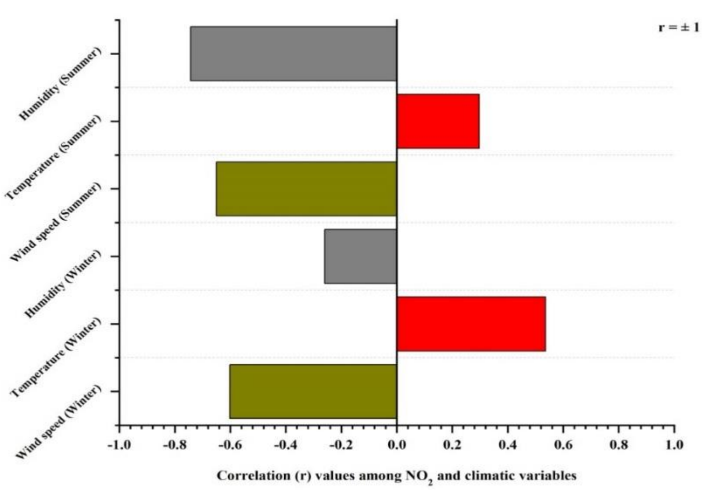



**Figure 4: Pearson correlations among climatic variables and $NO_2$**

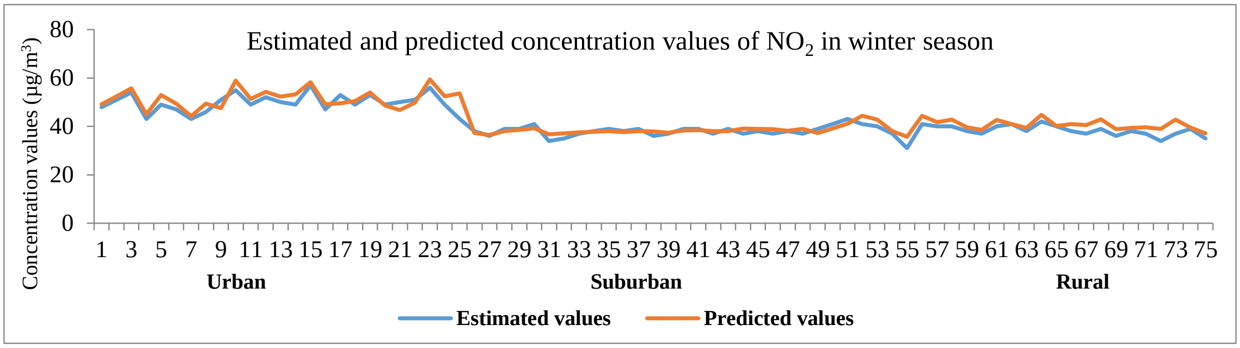
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
DOI 10.17605/OSF.IO/MCETF

## Tukey Test

Tukey test showed the data set of $NO_2$ for winter season concentrations in winter season were almost near to the significant level i.e., ranging from (0.44 to 0.56) while keeping the p value 0.05. Similarly for summer season the values ranged from 0.52 to 0.59. The result determined that all the data sets were almost significantly different from each other. (Appendix Table 1, Table 2).

## DISCUSSIONS

Climatic variations in climatic variables such as temperature precipitation and humidity occur due to the anthropogenic activities. Climatic variables interact with gaseous air pollutant such as $NO_2$. As an independent variables, climatic variables do have correlations interaction with the $NO_2$ in both the summer and winter seasons. The mean values of $NO_2$ in urban location in winter season was noted higher as compared to the suburban and rural locations, due to the traffic load density which resulted more emissions from the vehicles, whereas, $NO_2$ is the common pollutant emitted by vehicles. Similarly urban locations have high concentrations of industries and factories as well; alike is the scenario with the suburban and rural study areas. Urban locations have higher and denser building density causing the accumulation of air pollutants like $NO_2$ and force it to remain stagnant. As the study area is a valley especially the urban study area is more helpful to trap the air pollutants due to its flat topographic conditions. The urban locations experiences lower wind speed which ultimately results to the higher concentrations of $NO_2$ pollutants. In winter, lower temperatures and higher humidity levels can lead to an increase in $NO_2$ concentrations. This is because during the winter season, there is usually an increase in fossil fuel combustion for heating, which results in higher emissions of $NO_2$. Additionally, lower temperatures and higher humidity levels can cause a decrease in atmospheric mixing, trapping pollutants close to the ground and leading to higher concentrations. On the other hand, in summer, higher temperatures and higher wind speeds can lead to an increase in $NO_2$ concentrations. This is because higher temperatures can increase the rate of chemical reactions that produce $NO_2$, while higher wind speeds can transport pollutants from urban areas to suburban and rural areas. Additionally, summer weather conditions can lead to the formation of photochemical smog, which is characterized by high levels of $NO_2$, particularly during periods of high sunshine. It's worth noting that the relationship between temperature, humidity, wind speed and $NO_2$ concentrations can be complex and influenced by a range of other factors, such as the emission sources, topography, and atmospheric chemistry. Therefore, it is important to conduct a detailed analysis of the specific location and meteorological conditions to understand the relationship between these variables and $NO_2$ concentrations as well showed in Figure 5



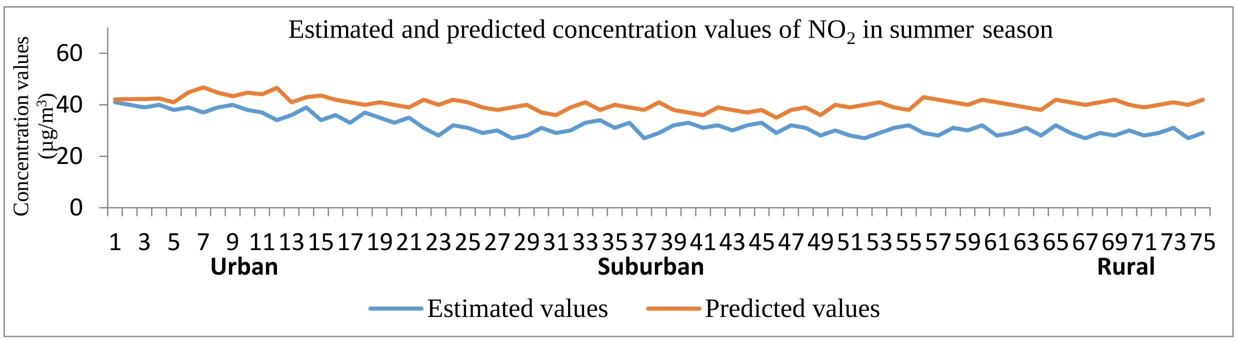




**Figure 5: Sample comparison among estimated and predicted values of $NO_2$ in both the summer and winter season**

## CONCLUSION

The research study found out the interactions among the climatic variables such as temperature, humidity, wind-speed and road side $NO_2$. The measured concentration values of $NO_2$ in winter season in urban study area were higher from suburban and rural study area locations. Whereas, the values for summer season were higher in urban study area. The suburban and rural study area values were almost in a similar range. The predicted mean values via regression model for winter season were higher in urban locations than the rural and suburban locations. The values were also higher from the estimated values. The predicted values in summer season for urban locations were higher than the suburban and rural locations however the predicted values were much higher than the estimated values. The Tukey test was performed for all the data sets of concentrations measurements at various locations. It almost showed near to the significance (0.05) difference among all the data sets of measurements. The $NO_2$ and temperature correlations showed positive correlations both for summer and winter seasons. Whereas, the wind speed, humidity showed negative correlations with the $NO_2$.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
DOI 10.17605/OSF.IO/MCETF

Correlations among the climatic variables and $NO_2$ showed worth interactions among them, however, regression model also predicted the other unknown factors that bears impacts on these correlations and interactions.

## References


1. Mehta, D. J., & Yadav, S. M. (2022). Long-term trend analysis of climate variables for arid and semi-arid regions of an Indian State Rajasthan. *International Journal of Hydrology Science and Technology*, *13*(2), 191-214.
2. Touhami, I., Moutahir, H., Assoul, D., Bergaoui, K., Aouinti, H., Bellot, J., & Andreu, J. M. (2022). Multi-year monitoring land surface phenology in relation to climatic variables using MODIS-NDVI time-series in Mediterranean forest, Northeast Tunisia. *Acta Oecologica*, *114*, 103804.
3. Gul, A., Xiumin, W., Chandio, A. A., Rehman, A., Siyal, S. A., & Asare, I. (2022). Tracking the effect of climatic and non-climatic elements on rice production in Pakistan using the ARDL approach. *Environmental Science and Pollution Research*, 1-15.
4. Hussain, M., Butt, A. R., Uzma, F., Ahmed, R., Irshad, S., Rehman, A., & Yousaf, B. (2020). A comprehensive review of climate change impacts, adaptation, and mitigation on environmental and natural calamities in Pakistan. *Environmental monitoring and assessment*, *192*, 1-20.
5. Qazlbash, S. K., Zubair, M., Manzoor, S. A., ul Haq, A., & Baloch, M. S. (2021). Socioeconomic determinants of climate change adaptations in the flood-prone rural community of Indus Basin, Pakistan. *Environmental Development*, *37*, 100603.
6. Rehman, A., Farooq, M., Ullah, A., Nadeem, F., Im, S. Y., Park, S. K., & Lee, D. J. (2020). Agronomic biofortification of zinc in Pakistan: Status, benefits, and constraints. *Frontiers in sustainable food systems*, *4*, 591722.
7. Hayat, S., Szabó, Z., & Tóth, Á. (2021). MAR site suitability mapping for arid–semiarid regions by remote data and combined approach: A case study from Balochistan, Pakistan. *Acque Sotterranee-Italian Journal of Groundwater*, *10*(3), 17-28.
8. Hickman, J. E., Andela, N., Tsigaridis, K., Galy-Lacaux, C., Ossohou, M., & Bauer, S. E. (2021). Reductions in NO2 burden over north equatorial Africa from decline in biomass burning in spite of growing fossil fuel use, 2005 to 2017. *Proceedings of the National Academy of Sciences*, *118*(7), e2002579118.
9. Goldberg, D. L., Lu, Z., Oda, T., Lamsal, L. N., Liu, F., Griffin, D., ... & Streets, D. G. (2019). Exploiting OMI NO2 satellite observations to infer fossil-fuel CO2 emissions from US megacities. *Science of The Total Environment*, *695*, 133805.
10. Orellano, P., Reynoso, J., Quaranta, N., Bardach, A., & Ciapponi, A. (2020). Short-term exposure to particulate matter (PM10 and PM2. 5), nitrogen dioxide (NO2), and ozone (O3) and all-cause and cause-specific mortality: Systematic review and meta-analysis. *Environment international*, *142*, 105876.
11. Zhao, Y., Zhang, K., Xu, X., Shen, H., Zhu, X., Zhang, Y., ... & Shen, G. (2020). Substantial changes in nitrogen dioxide and ozone after excluding meteorological impacts during the COVID-19 outbreak in mainland China. *Environmental Science & Technology Letters*, *7*(6), 402-408.
12. Cheng, C. Y., Cheng, S. Y., Chen, C. C., Pan, H. Y., Wu, K. H., & Cheng, F. J. (2019). Ambient air pollution is associated with pediatric pneumonia: A time-stratified case–crossover study in an urban area. *Environmental Health*, *18*(1), 1-9.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
**DOI 10.17605/OSF.IO/MCETF**


13. Yee, J., Cho, Y. A., Yoo, H. J., Yun, H., & Gwak, H. S. (2021). Short-term exposure to air pollution and hospital admission for pneumonia: a systematic review and meta-analysis. *Environmental Health*, *20*(1), 1-10.
14. Cheng, F. J., Lee, K. H., Lee, C. W., & Hsu, P. C. (2019). Association between particulate matter air pollution and hospital emergency room visits for pneumonia with septicemia: A retrospective analysis. *Aerosol and Air Quality Research*, *19*(2), 345-354.
15. Rovira, J., Domingo, J. L., & Schuhmacher, M. (2020). Air quality, health impacts and burden of disease due to air pollution (PM10, PM2. 5, NO2 and O3): Application of AirQ+ model to the Camp de Tarragona County (Catalonia, Spain). *Science of the total environment*, *703*, 135538.
16. Naghan, D. J., Neisi, A., Goudarzi, G., Dastoorpoor, M., Fadaei, A., & Angali, K. A. (2022). Estimation of the effects PM2. 5, NO2, O3 pollutants on the health of Shahrekord residents based on AirQ+ software during (2012-2018). *Toxicology Reports*.
17. Bilal, M., Khattak, A. K., Iqbal, J., Khalid, S., & Naz, A. (2022). Observations and Analysis of The Interaction Of Sulfur Dioxide (So2) Emissions From Vehicles And Roadside Wind Speed At The Foothill City Of Northwestern Himalayas, Pakistan. *湖南大学学报 (自然科学版)*, *49*(11).
18. Singh, T. S., Rajak, U., Verma, T. N., Nashine, P., Mehboob, H., Manokar, A. M., & Afzal, A. (2022). Exhaust emission characteristics study of light and heavy-duty diesel vehicles in India. *Case Studies in Thermal Engineering*, *29*, 101709.
19. Ribeiro, C. B., Rodella, F. H. C., & Hoinaski, L. (2022). Regulating light-duty vehicle emissions: an overview of US, EU, China and Brazil programs and its effect on air quality. *Clean Technologies and Environmental Policy*, 1-12.
20. Rana, A., Rawat, A. S., Afifi, A., Singh, R., Rashid, M., Gehlot, A., ... & Alshamrani, S. S. (2022). A Long-Range Internet of Things-Based Advanced Vehicle Pollution Monitoring System with Node Authentication and Blockchain. *Applied Sciences*, *12*(15), 7547.
21. Jain, S., Paliwal, A., Gupta, V., & Tomar, M. (2020). Long Range Surface Plasmons assisted highly sensitive and room temperature operated NO2 gas sensor. *Sensors and Actuators B: Chemical*, *311*, 127897.
22. Ren, Y., Wang, G., Wei, J., Tao, J., Zhang, Z., & Li, H. (2023). Effects of long-range transport of air pollutants on nitrogenous organic matters in mountain background region of Southeast China: Sources and influencing factors identified by observation and modal calculation. *Atmospheric Chemistry and Physics Discussions*, 1-34.
23. Tyagi, S., Chaudhary, M., Ambedkar, A. K., Sharma, K., Gautam, Y. K., & Singh, B. P. (2022). Metal oxide nanomaterial-based sensors for monitoring environmental NO 2 and its impact on the plant ecosystem: a review. *Sensors & Diagnostics*, *1*(1), 106-129.
24. Pasupuleti, K. S., Reddeppa, M., Chougule, S. S., Bak, N. H., Nam, D. J., Jung, N., ... & Kim, M. D. (2022). High performance langasite based SAW NO2 gas sensor using 2D g-C3N4@ TiO2 hybrid nanocomposite. *Journal of Hazardous Materials*, *427*, 128174.
25. Rahman, M. A., Yunsheng, L., & Sultana, N. (2017). Analysis and prediction of rainfall trends over Bangladesh using Mann–Kendall, Spearman's rho tests and ARIMA model. *Meteorology and Atmospheric Physics*, *129*(4), 409-424.
26. GoP. 2016. Technology need assessment for climate change adaptation. Pakistan meteorological department. Ministry of climate change Islamabad, Pakistan.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
**DOI 10.17605/OSF.IO/MCETF**

27. Lee, S. I., Lee, J., & Hwang, B. (2019). Microstructure-based prediction of yield ratio and uniform elongation in high-strength bainitic steels using multiple linear regression analysis. *Materials Science and Engineering: A*, *758*, 56-59.

28. Jebli, I., Belouadha, F. Z., Kabbaj, M. I., & Tilioua, A. (2021). Prediction of solar energy guided by pearson correlation using machine learning. *Energy*, *224*, 120109.

29. Zhang, H., & Yao, D. (2020). The Bayes recognition model for mine water inrush source based on multiple logistic regression analysis. *Mine Water and the Environment*, *39*(4), 888-901.

30. Liu, Y., Mu, Y., Chen, K., Li, Y., & Guo, J. (2020). Daily activity feature selection in smart homes based on pearson correlation coefficient. *Neural Processing Letters*, *51*, 1771-1787.

31. Achen, C. H. (2021). *The statistical analysis of quasi-experiments*. University of California Press.

32. Janani, K., Palanivelu, A., & Sandhya, R. (2020). Diagnostic accuracy of dental pulse oximeter with customized sensor holder, thermal test and electric pulp test for the evaluation of pulp vitality: an in vivo study. *Brazilian dental science*, *23*(1), 8-p.

33. Khosla, R., & Bhardwaj, A. (2019). Urbanization in the time of climate change: Examining the response of Indian cities. *Wiley Interdisciplinary Reviews: Climate Change*, *10*(1), e560.

34. Williams, D. S., Máñez Costa, M., Sutherland, C., Celliers, L., & Scheffran, J. (2019). Vulnerability of informal settlements in the context of rapid urbanization and climate change. *Environment and urbanization*, *31*(1), 157-176.

35. Johnson, L. R., Trammell, T. L., Bishop, T. J., Barth, J., Drzyzga, S., & Jantz, C. (2020). Squeezed from all sides: Urbanization, invasive species, and climate change threaten riparian forest buffers. *Sustainability*, *12*(4), 1448.

36. Li, D., Wu, S., Liang, Z., & Li, S. (2020). The impacts of urbanization and climate change on urban vegetation dynamics in China. *Urban Forestry & Urban Greening*, *54*, 126764.

37. Darmanto, N. S., Varquez, A. C. G., Kawano, N., & Kanda, M. (2019). Future urban climate projection in a tropical megacity based on global climate change and local urbanization scenarios. *Urban Climate*, *29*, 100482.

38. Zoran, M. A., Savastru, R. S., Savastru, D. M., & Tautan, M. N. (2020). Assessing the relationship between ground levels of ozone (O3) and nitrogen dioxide (NO2) with coronavirus (COVID-19) in Milan, Italy. *Science of The Total Environment*, *740*, 140005.

39. Subhanullah, M., Ullah, S., Javed, M. F., Ullah, R., Akbar, T. A., Ullah, W., .. & Sajjad, R. U. (2022). Assessment and Impacts of Air Pollution from Brick Kilns on Public Health in Northern Pakistan. *Atmosphere*, *13*(8), 1231.

40. Gonzalez-Martin, J., Kraakman, N. J. R., Perez, C., Lebrero, R., & Munoz, R. (2021). A state–of–the-art review on indoor air pollution and strategies for indoor air pollution control. *Chemosphere*, *262*, 128376.

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
DOI 10.17605/OSF.IO/MCETF

## AppendixTable 1: Tukey test winter season

| $NO_2$ | | | | |
|---|---|---|---|---|
| Tukey HSD | | | | |
| Location | N | Subset | | |
| | | 1 | 2 | 3 |
| Jameel chowk | 5 | 36.0 | | |
| Achini chowk | 5 | 37.4 | 37.4 | |
| Phase 6 | 5 | 38.2 | 38.2 | |
| Badaber | 5 | 38.2 | 38.2 | |
| Forest bazar | 5 | 38.6 | 38.6 | |
| Deep warsak road | 5 | 39.2 | 39.2 | |
| Northern bypass | 5 | 40.0 | 40.0 | 40.0 |
| Deep rural site | 5 | 40.4 | 40.4 | 40.4 |
| Badaber matani junction | 5 | 41.4 | 41.4 | 41.4 |
| Pandu surizai junction | 5 | 44.4 | 44.4 | 44.4 |
| Shuba bazar junction | 5 | 48.4 | 48.4 | 48.4 |
| Speen jumat | 5 | 49.8 | 49.8 | 49.8 |
| Phase 3 chowk | 5 | | 51.2 | 51.2 |
| Deans chowk sadar | 5 | | | 53.8 |
| Haji camp bus terminal | 5 | | | 54.4 |
| Sig. | | .046 | .053 | .056 |
| Means for groups in homogeneous subsets are displayed.<br>Based on observed means.<br>The error term is Mean Square (Error) = 42.120. | | | | |
| a. Uses Harmonic Mean Sample Size = 5.000. | | | | |
| b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed. | | | | |
| c. Alpha = .05. | | | | |

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 06 | 2023
DOI 10.17605/OSF.IO/MCETF

## Table 2; Tukey Test summer season

| NO$_2$ | | | | | | |
|---|---|---|---|---|---|---|
| **Tukey HSD** | | | | | | |
| **Location** | **N** | **Subset** | | | | |
| | | **1** | **2** | **3** | **4** | **5** |
| Badaber matani junction | 5 | 27.4 | | | | |
| Deep rural site | 5 | 27.8 | | | | |
| Badaber | 5 | 29.2 | | | | |
| Phase 6 | 5 | 30.4 | | | | |
| Deep warsak road | 5 | 30.4 | | | | |
| Achini chowk | 5 | 31.4 | 31.4 | | | |
| Northern bypass | 5 | 31.4 | 31.4 | | | |
| Pandu surizai junction | 5 | 32.2 | 32.2 | | | |
| Jameel chowk | 5 | 33.4 | 33.4 | 33.4 | | |
| Forest bazar | 5 | 34.0 | 34.0 | 34.0 | 34.0 | |
| Haji camp bus terminal | 5 | | 42.6 | 42.6 | 42.6 | 42.6 |
| Deans chowk sadar | 5 | | 43.2 | 43.2 | 43.2 | 43.2 |
| Phase 3 chowk | 5 | | | 44.2 | 44.2 | 44.2 |
| Speen jumat | 5 | | | | 45.4 | 45.4 |
| Shuba bazar junction | 5 | | | | | 48.6 |
| Sig. | | | .052 | .059 | .057 | .054 |
| Means for groups in homogeneous subsets are displayed.<br>Based on observed means.<br>The error term is Mean Square (Error) = 28.013. | | | | | | |
| a. Uses Harmonic Mean Sample Size = 5.000. | | | | | | |
| b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed. | | | | | | |
| c. Alpha = .05. | | | | | | |