environmental sciences proceedings

MDPI

Proceeding paper

Satellite-Based Analysis of Air Quality Altering Factors: A Multi-Sectoral Guide for Mitigating Environmental Smog †

Shazia Pervaiz [1],*, Kanwal Javid [2] and Filza Zafar Khan [3]

[1] Environmental Protection Agency, Punjab, Lahore, Pakistan
[2] Department of Geography, Government College University, Lahore, Pakistan; knwl.j92@gmail.com
[3] Pakistan Council of Scientific and Industrial Research, Lahore, Pakistan; pcsirtextilelab@gmail.com
* Correspondence: shaziapervaiz@gmail.com; Tel.: (+923233337197)

† Presented at the 5th International Electronic Conference on Remote Sensing, 7–21 November 2023; Available online: https://ecrs2023.sciforum.net/

Abstract: Aerosols are one of the major reasons to decline air quality world-wide. Vehicular/industrial emissions and crop waste burnings are the major contributors involved in deteriorating the air quality including metrological factors such as lack of rainfall and high relative humidity. Lahore Division of Punjab Pakistan has been affected by smog pollution during October and November since 2017. So, goal of the present study is to identify the key air pollution generating sources and their contribution in smog formation. In this study, aerosol optical depth (AOD) and thermal anomalies have been analyzed and examined with three metrological elements *i.e.* temperature, humidity and rainfall of October & November during 2018-2022 using satellite data. Transport, industrial and agricultural data derived from secondary sources has also been considered in this study. Results of the study exhibited that transport sector is playing leading role by having 43% share of pollutants emission into the ambient air. Whereas, results of the satellite imagery showed that AOD level increased in Lahore Division due to significant variation in metrological factors and thermal anomalies. Hence, results of the study suggest multi-sectoral short, medium and long term plans to tackle air pollution for environmental, social and economic sustainability.

Keywords: AOD; Lahore Division; Smog; Vehicular Emissions

Citation: To be added by editorial staff during production.

Academic Editor: First name Last-name

Published: date

1. Introduction

Atmospheric Aerosols [1] are dynamic mixtures of solid and liquid particles [2] suspended in the atmosphere [3] consist of aerodynamic diameter *i.e.* 0.001 to 100 µm [4]. Generally, aerosol particles are released into the ambient air from natural sources such as desert or soil dust [5,6], wildfires [7] and sea salt [2]. Whereas, the anthropogenic aerosols originate from vehicular and industrial emissions, biomass [8] and stubble burning. Notably, aerosols have a strong ability to absorb and scatter solar radiant energy and also have ability to alter climate, atmospheric stability and deteriorate the quality of air [2]. Moreover, the other common air pollutants, such as carbon monoxide (CO), nitrogen dioxide (NO_2), Sulfur dioxide (SO_2) and ground level ozone (O_3) are associated in formation of aerosols [2wang]. Further, photochemical and coal smog, sandstorm and dust aerosols [9] reduce the visibility and have adverse impact on economic, social and environmental wellbeing. Therefore, aerosol optical depth (AOD) is an important index for aerosol optical properties [10] and to measure aerosol load into the atmosphere. Also, AOD is a key factor used to determine the level of air pollution [1] and also helped in forecasting atmospheric pollutants [2wang].

Like other developing countries, Pakistan is also facing severe challenge of air pollution. Especially, 'Lahore' Punjab, Pakistan has drawn significant attention globally because of being affected by smog [11]. Several studies have been conducted by the different researchers on Lahore District so far. But to evaluate AOD trend of Lahore Division is still lacking and remains unaddressed where regional smog particularly called as seasonal smog prominently engulfs the cities during winter season. Therefore, by considering the grave concern there is a dire need to analyze AOD of Lahore Division (LD) at local scale for sustainable development. Therefore, the goal of the present study is to identify the key air pollution emitting sources and their contribution in smog formation with the objective to examine aerosol optical depth (AOD) and stubble burning with three metrological elements *i.e.* temperature, rainfall and humidity of October & November during 2018-2022 using satellite data.

2. Materials and Methods

2.1. Study Site

Lahore Division [12] is geographically located between 31°15′ N to 31°42′ N latitudes and 74°01′ E to 74°39′ E longitudes [13], occupies an area of land about 11413.5 km^2 (Figure 1) [14]. Administratively, Lahore Division comprises of four districts such Lahore (LHE), Sheikhupura (SKP), Kasur (KUS) and Nankana Sahib (NNS) [15]. Overall, a huge load of aerosols is obtained in Lahore Division from (i) vehicular and industrial emissions (ii) waste and stubble burning and (iii) fugitive dust that halt and reduce visibility under the relative high humidity.

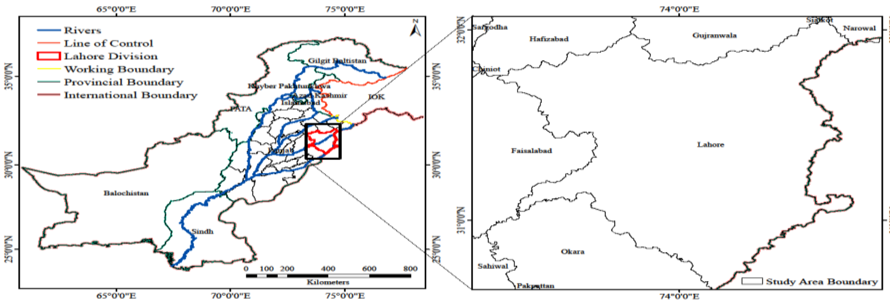

Figure 1. Map of the study area.

The LD is the commercial hub of industrial units [16] and well known for its industrial produce and contribute significantly in the country’s economy [17]. The LD consists of semi-arid to arid climate and divisible into considerable distinct seasons namely spring, summer, autumn and winter [18] including dynamic monsoon season [19]. The division is also the hot-spot of intense air pollution which is affected by regional and local transportation of aerosols.

2.2. Satellite Data

The research is satellite based [10] and consists of comparative analysis of AOD, stubble burning and metrological data. The data sources, sensors specifications and spatial resolutions are list in Table 1. However, the flowchart based on methodology is presented in Figure 2.

Table 1. Description of data.

Data Set Name	Sensor	Spatial Resolution	Data Acquisition Year	Months
Aerosol Optical Depth	Sentinel 5p	10m	2018, 2020 & 2022	October & November
Stubble Burning	VIIRS S-NPP	250m	2018, 2020 & 2022	October & November
Temperature	MERRA 2	1km	2018, 2020 & 2022	October & November
Rainfall	MERRA 2	1km	2018, 2020 & 2022	October & November
Relative Humidity	MERRA 2	1km	2018, 2020 & 2022	October & November

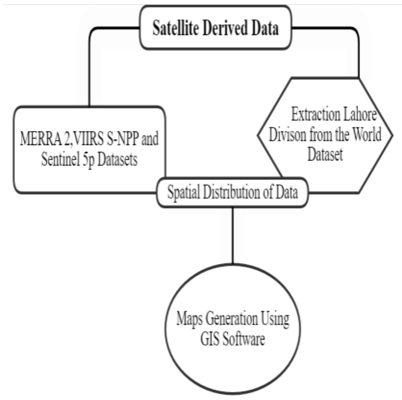

Figure 2. Flowchart of methodology.

2.3. Sources and Sectoral Contributors of Smog Causing Aerosols

Major AOD sources in the study area are combustion of fossil fuels vehicular, industrial emissions and stubble burning. Hence, sectoral data is based on transport, industries and agriculture sectors obtained from the study of United Nation Food and Agriculture Organization [20]. Whereas, registered vehicular data has been derived from the Government of the Punjab, Excise and Taxation Department Pakistan.

3. Results and Discussion

3.1. Transport, Industrial And Agriculture Sectors

Various factors of road transport [21] are associated with air emissions [2] such as traffic density [22] traffic flow and congestion [23], vehicular speed [24], travel time [25], vehicle age and fuel [26]. In the context of Lahore Division, the contribution of vehicles in pollution is 43%, industry's role is 25%, agro-waste burning is 20% and power generation is 12%. [20]. Moreover, Figure 3 illustrates the view of automobiles' percentage in the study area (Figure 3) which is the most contributing factor in deteriorating ambient air.

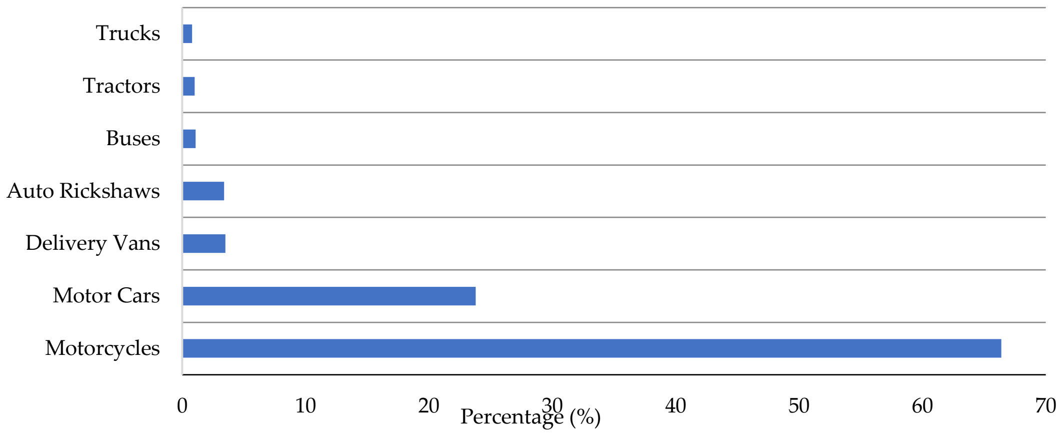

Figure 3. Vehicles percentage in the study area (Source: Government of the Punjab, Excise and Taxation Department Pakistan 2018.

3.2. AOD Trend over Lahore Division during October and November (2018 to 2022)

Lahore, Sheikhupura and Kasur are the industrial and urbanized cities of Lahore Division. Figure 4 has shown the significant variations of AOD in Lahore Division during October and November 2018-2022. Comparing results of AOD, it has been noticed that Lahore is the most affected districts of Lahore Division where vehicular emissions, industrial soot add black carbon (BC) are released into the ambient air. In addition, dust is also transported to Lahore from the southern side of Punjab as reported in the earlier study [27]. AOD is also transported to Lahore from India during stubble burning months through its shared boundary and provide ideal conditions for AOD in the presence of high relative humidity to elevate the level smog in Lahore.

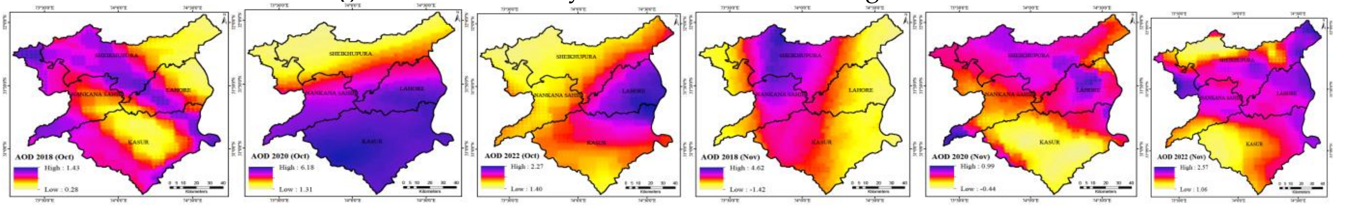

Figure 4. AOD trend over Lahore Division in October and November (2018 to 2022).

3.3. Stubble Burning Trend over Lahore Division in October and November (2018 to 2022)

According to FAO 2018 study, the contribution of agriculture sector in smog formation is 20% and 3 out of 12 districts of Punjab in rice cultivation are associated with Lahore Division *i.e.* Lahore, Sheikhupura and Nankana Sahib [20] where rice crop is grown widely [28]. The grown species of rice generates the high amount of crop residues [29]. Stubble burning not only emits greenhouse gases but also emit particulate matter into ambient air which typically gets in peak during the first week of November. Also, the crop burning (Figure 5) emissions when combine with vehicular, industrial pollutants and high relative humidity generate smog. Stubble burning is the preferred technique by the farmers as they believe that burning rice stalks is helpful in improving soil fertility. However, it is evident that stubble burning incidents arose when manual harvesting shifted to mechanical harvesting. The results of spatial map exhibit the highest extent of stubble burning is recorded in Nankana Sahib which is known district for rice crop.

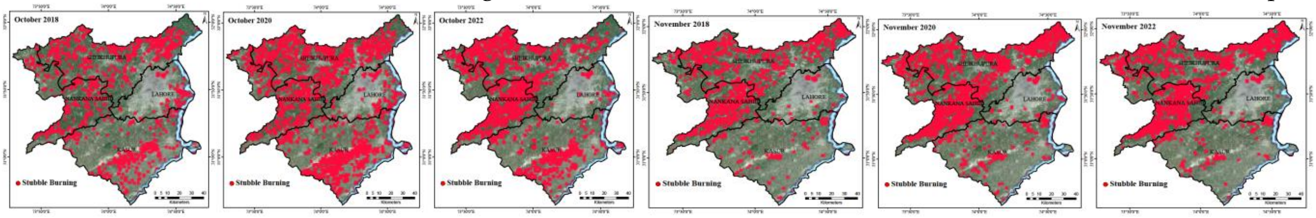

Figure 5. Stubble burning trend over Lahore Division in October and November (2018 to 2022).

3.4. Temperature Trend over Lahore Division in October and November (2018 to 2022)

Figure 6 of the study illustrates the variation of temperature of Lahore Division. By comparing results, it has been noted that low temperature prevailed in Lahore throughout 2018-2022. Low temperature of Lahore with the high relative humidity affect the air quality and ultimately becomes one of the major reasons of smog formation. The earlier study conducted on Lahore supported the similar findings of the study [27].

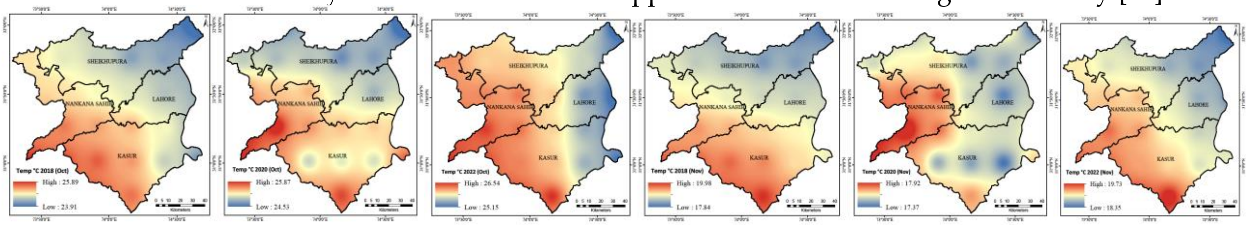

Figure 6. Temperature trend over Lahore Division in October and November (2018 to 2022).

3.5. Rainfall Trend over Lahore Division in October and November (2018 to 2022)

Metrological variable [30] such as rainfall [31] helps to reduce the concentration of air pollutants into atmosphere. Figure 7 depicts the low trend of rainfall in most of the Lahore Division during the study period. Therefore, lack of rains in October and November helped to increase the level of AOD in most of Lahore. By comparing results of 2020 of Kasur, it has been shown that low rainfall has a significant role in elevating the level of AOD in Kasur, a well-known twin city of Lahore and supported the findings of the previous studies.

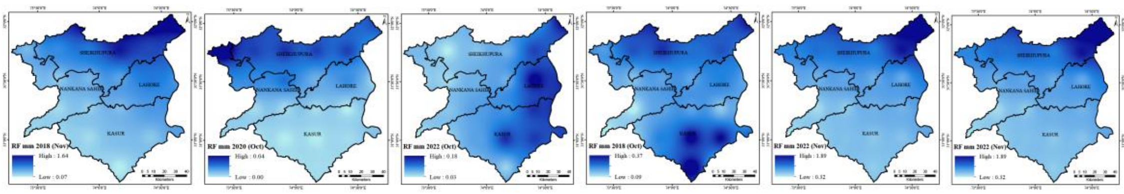

Figure 7. Rainfalltrend over Lahore Division in October and November (2018 to 2022).

3.6. Humidity Trend over Lahore Division in October and November (2018 to 2022)

Figure 8 shows the variations of relative humidity in the month of October and November for the year 2018, 2020, and 2022. In October 2018, the trend of relative humidity was evaluated high in Lahore and Sheikhupura and some parts of Kasur. While in 2020, the high level of relative humidity was examined in Lahore, Sheikhupura and central Kasur. However, in 2022, the highest level of relative humidity recorded in Lahore and Sheikhupura and in northern part of Kasur. Whereas, relative humidity level in Nankana Sahib found moderate to low level. From results, it is revealed that highest level of relative humidity is one of the significant causes to increase the magnitude of AOD and due to this metrological factor, Lahore is one of the districts of Lahore Division that is most affected by air pollution. The findings of the previous study on Lahore supported the results of the present study [27].

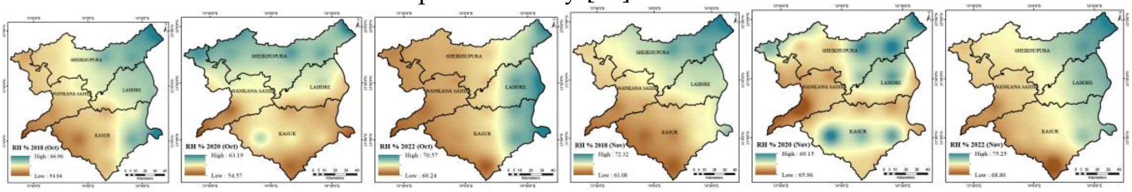

Figure 8. Relative Humidity trend over Lahore Division in October and November (2018 to 2022).

4. Conclusion and Recommendations

Results of the current study have exhibited the importance of remote sensing tool in examining the variation of AOD, stubble burning including metrological variables, such as temperature, rainfall and relative humidity in Lahore Division in October and November (2018 to 2022). Results of study have shown that high growth of vehicular population has adverse impact on the ambient air. Also, among metrological factors, relative high humidity has shown strong relationship with increase in the level of AOD in Lahore. Considering results of the study, a viable solution is required to improve the environment in the era of economic development. Hence, a sectoral guide to mitigate environmental smog is suggested below which require strong commitment and coordination among government bodies, industries, citizens and environmental organizations in ensuring the long-term sustainability for a healthier environment in Lahore Division.

Author Contributions: S. P. designed the research and wrote the manuscript. K. J. carried out the mapping. F. Z. K. proofread the manuscript. All authors have read and agreed to the publish version of the manuscript.

Funding: The present research did not receive any financial support.

Conflicts of Interest: The authors declare no conflict of interest.

Sectoral Guide to Mitigate Environmental Smog		
Transport Sector	Industrial Sector	Agriculture Sector
• Strict compliance at all entry points of Lahore Division for HTV and LTV • Mandatory Fitness certificates of vehicles for all public institutes • To enhance public transportation infrastructure • To introduce electric and hybrid vehicles	• Introduction of Self-Monitoring Reporting Tools for industry • To establish an emission control and monitoring industrial system to track compliance for environmental improvement • To adopt cleaner production technologies • To incentivize the use of low emission fuels • To introduce Green Industrial Zones • To mitigate carbon foot prints through plantation in industrial area • To install effective pollution control equipment	• Ban on stubble burning • To promote waste management practices • To explore and implement alternative crop residual disposal method such as waste to energy • To introduce uniform threshold limit for fire count using remote sensing data such as for SNPP-VIIRS 7 and MODIS 30% • To impart awareness and education to farmers

References

1. Sun, Y.; Zeng, J.; Namaiti, A. Research on the Spatial Heterogeneity and Influencing Factors of Air Pollution: A Case Study in Shijiazhuang, China. *Atmos*. 2022, *13*(5), 670.
2. Wang, P.; Tang, Q.; Zhu, Y.; He, Y.; Yu, Q.; Liang, T.; Ran, Y. Coupling Coordination Degree of AOD and Air Pollutants in Shandong Province from 2015 to 2020. *Atmos*. 2023, *14*(4), 654.
3. Ali, M. A.; Bilal, M.; Wang, Y.; Qiu, Z.; Nichol, J. E.; de Leeuw, G.; Islam, M. N. Evaluation and comparison of CMIP6 models and MERRA-2 reanalysis AOD against Satellite observations from 2000 to 2014 over China. *Geosci Front*. 2022, *13*(2), 101325.
4. Bao, Y.; Zhu, L.; Guan, Q.; Guan, Y.; Lu, Q.; Petropoulos, G. P.; Hou, Y. Assessing the impact of Chinese FY-3/MERSI AOD data assimilation on air quality forecasts: Sand dust events in northeast China. *Atmos. Envi*. 2019, *205*, 78-89.
5. Yousefi, R.; Wang, F.; Ge, Q.; Shaheen, A.; Kaskaoutis, D. G. (2023). Analysis of the winter AOD trends over Iran from 2000 to 2020 and associated meteorological effects. *Remote Sens*. 2023, *15*(4), 905.
6. Khan, R.; Kumar, K. R.; Zhao, T.; Ullah, W.; de Leeuw, G. Interdecadal changes in aerosol optical depth over Pakistan based on the MERRA-2 reanalysis data during 1980–2018. *Remote Sens.* 2021, *13*(4), 822.
7. Yu, X.; Lary, D. J.; Simmons, C. S. PM2. 5 modeling and historical reconstruction over the continental USA utilizing GOES-16 AOD. *Remote Sens.* 2021, *13*(23), 4788.
8. Jiang, T.; Chen, B.; Chan, K. K. Y.; Xu, B. Himawari-8/AHI and MODIS aerosol optical depths in China: evaluation and comparison. *Remote Sens*. 2019, *11*(9), 1011.
9. Xun, L.; Lu, H.; Qian, C.; Zhang, Y.; Lyu, S.; Li, X. Analysis of aerosol optical depth from sun photometer at Shouxian, China. *Atmos. 2021, 12*(9), 1226.
10. Raptis, I. P.; Kazadzis, S.; Amiridis, V.; Gkikas, A.; Gerasopoulos, E.; Mihalopoulos, N. A decade of aerosol optical properties measurements over Athens, Greece. *Atmos. 2020, 11*(2), 154.
11. Pervaiz, S.; Shirazi, S.A.; Ahamad, M.I. Greenhouse gas emissions and aerosol distribution in brick kiln zones of Punjab, Pakistan: an appraisal using spatial information technology. *NASIJ, 2023, 4*(1), 62-79.
12. Saeed, A.; Saeed, H.; Saleem, Z.; Fang, Y.; Babar, Z. U. D. Evaluation of prices, availability and affordability of essential medicines in Lahore Division, Pakistan: A cross-sectional survey using WHO/HAI methodology. *PloS one*. 2019, *14*(4), e0216122.
13. Aslam, R. A.; Shrestha, S.; Usman, M. N.; Khan, S. N.; Ali, S.; Sharif, M. S.; Arshad, A. Integrated SWAT-MODFLOW Modeling-Based Groundwater Adaptation Policy Guidelines for Lahore, Pakistan under Projected Climate Change, and Human Development Scenarios. *Atmos. 2022, 13*(12).
14. Hassan, I. Rapid commercial conversion of agriculture land in Lahore Division, Pakistan. Adv. Life Sci. 2018, *5*(4), 192-203.
15. Khan, H. U.; Rashid, I.; Israr, J.; Zhang, G. Geotechnical characterization and statistical evaluation of alluvial soils of Lahore. Arab. J. Geosci. 2022, *15*(9), 845.
16. Abbas, S.; Ali, G.; Qamer, F. M.; Irteza, S. M. Associations of air pollution concentrations and energy production dynamics in Pakistan during lockdown. Environ. Sci. Pollut. Res. 2022, *29*(23), 35036-35047.
17. Rana, I. A.; Bhatti, S.S. Lahore, Pakistan–Urbanization challenges and opportunities. Elsevier sci. *2018, 72*, 348-355.
18. Fowler, H. J.; Archer, D.R. Conflicting signals of climatic change in the upper Indus Basin. J. Clim. 2006, 19(17), 4276-4293.

19. Chand, S.; Ahmad, M. Appraisal of spatial and temporal behavior in monsoon precipitation series of Punjab-Pakistan using hierarchical Bayesian Models. Environ. Earth Sci. 2020, *79*(12), 304.
20. FAO (2018). Remote sensing for spatio-temporal mapping of smog in Punjab and identification of the underlying causes using GIS techniques (R-Smog). Retrieved on 20.09.2023. http://www.gcisc.org.pk>R-SMOG-Report.
21. Muthu, M.; Gopal, J.; Kim, D. H.; Sivanesan, I. Reviewing the impact of vehicular pollution on road-side plants—future perspectives. *Sustain*. 2021, *13*(9), 5114.
22. Pandian, S.; Gokhale, S.; Ghoshal, A. K. Evaluating effects of traffic and vehicle characteristics on vehicular emissions near traffic intersections. Transp Res D Transp Environ. 2009, *14*(3), 180-196.
23. Gately, C. K.; Hutyra, L. R.; Peterson, S.; Wing, I.S. Urban emissions hotspots: Quantifying vehicle congestion and air pollution using mobile phone GPS data. *Environ pollut.2017*, *229*, 496-504.
24. Khandar, C.; Kosankar, S. A review of vehicular pollution in urban India and its effects on human health. J. Adv. Lab. Res. Biol. 2014, *5*(3), 54-61.
25. Shrivastava, R. K.; Neeta, S.; Geeta, G. Air pollution due to road transportation in India: A review on assessment and reduction strategies. J. Environ. Res. Dev. 2013, *8*(1), 69.
26. Sharmilaa, G.; Ilango, T. A review on influence of age of vehicle and vehicle traffic on air pollution dispersion. *Materials Today*: Proc. 2022, *60*, 1629-1632.
27. Tariq, S.; Mehmood, S.; Nisa, A.; Ul-Haq, Z.; Mehmood, U. Remote sensing of aerosol properties during intense smog events over Lahore (Pakistan). Kuwait J. Sci. 2021, *48*(4), 1-16.
28. Younas, M.; Rehman, M. A.; Hussain, A.; Ali, L.; Waqar, M. Q. Economic comparison of direct seeded and transplanted rice: Evidences from adaptive research area of Punjab Pakistan. Asian J. Agri. Biol. 2015, *4*(1), 1-7.
29. Jain, N.; Bhatia, A.; Pathak, H. (2014). Emission of air pollutants from crop residue burning in India. Aerosol. Air. Qual. Res. 2014. *14*(1), 422-430.
30. Kayes, I.; Shahriar, S. A.; Hasan, K.; Akhter, M.; Kabir, M. M.; Salam, M.A. The relationships between meteorological parameters and air pollutants in an urban environment. Glob. J. Environ. Sci. 2019, *5*(3), 265-278.
31. Pervaiz, S.; Khan, F.; Javid, K.; Altaf, A.; Aslam, F.; Tahir, M.; Hayat, S. Development of air quality and brick kilns during the onset Of Covid-19: An analysis. *Biol. Clin. Sci. Res. J.* 2022, (1), 1-11.