Journal of Natural Environment Hazards
University of Sistan and Baluchestan
Print ISSN: 2676 - 4377 Online ISSN: 2676 - 4385
Homepage: https://jneh.usb.ac.ir

Journal of Natural Environmental Hazards, Vol.14, Issue 43, March 2025

Investigating the effects of criteria air pollutants and meteorological parameters on the change of black carbon concentration in Tehran and Tabriz

Parisa Kahrari[1], Shahriar Khaledi[2], Ghasem Keikhosravi[3*], Seyed Jalil Alavi[4]

1. PhD Student of Climatology, Department of Natural Geography, University of Shahid Beheshti, Tehran, Iran
2. Professor of Climatology, Department of Natural Geography, University of Shahid Beheshti, Tehran, Iran
3. *Corresponding Author*, Assistant Professor of Climatology, Department of Natural Geography, University of Shahid Beheshti, Tehran, Iran
4. Associate Professor of Forestry, Department of Forestry, University of Tarbiat Modarres, Mazandaran, Iran

Article Info

Article type:
Research Article

Article history:
Received: 09 February 2024
Revised: 15 July 2024
Accepted: 05 August 2024

Keywords:
Air pollution, Particulate matter, Machine learning, Nonparametric algorithms, R software, Spearman's correlation.

ABSTRACT

Black carbon (BC) is a primary component of fine particulate matter which has a significant effect on climate and human health, and anthropogenic activity along with weather conditions affects its long-term variability. This study aimed to investigate the statistical relationships between meteorological elements (temperature, rainfall, wind speed, relative humidity, air pressure, sunshine hours, solar radiation, and cloudiness), criteria air pollutants (CO, NO_2, SO_2, O_3, PM_{10}, and $PM_{2.5}$) and black carbon particles (BC), as well as assess and compare the efficacy of five different machine learning algorithms (multiple linear regression (MLR), generalized additive model (GAM), classification and regression trees (CART), random forest (RF) and gradient boosting machine (GBM)) in modeling pollutants and climatic factors responsible for variations in black carbon concentration levels in Tabriz and Tehran from 2004 to 2021 using R 4.3.2 software. The results of the present study showed a significant variation in the influence of meteorological parameters and criteria air pollutants on the level of black carbon pollutant concentration in Tabriz and Tehran depending on the different geographical locations, weather conditions, and regional structure. Black carbon particles have experienced a significant upward trend with a relatively equal speed during the statistical period studied in the cities of Tabriz and Tehran. Based on the results of Spearman's correlation analysis, black carbon particles have a positive correlation with $PM_{2.5}$, NO_2, CO, and SO_2 and a negative correlation with O_3. Black carbon was highly correlated with parameters of wind speed (negatively) and relative humidity (positively) in Tabriz and temperature (negatively) and air pressure (positively) in Tehran. Based on the performance evaluation of predictive models and concerning the parsimony principle, the GAM model in Tabriz and the MLR model in Tehran had better performance in predicting black carbon values than other models.

Cite this article: Kahrari, P., Khaledi, S., Keikhosravi, G., & Alavi, S. J. (2025). Investigating the effects of criteria air pollutants and meteorological parameters on the change of black carbon concentration in Tehran and Tabriz. Journal of Natural Environmental Hazards, 14(43), 11-14. DOI: 10.22111/jneh.2024.47935.2028

Publisher: University of Sistan and Baluchestan
DOI: 10.22111/jneh.2024.47935.2028

* Corresponding Author Email: gh_keikhosravi@sbu.ac.ir

INTRODUCTION

Black carbon is an important component of fine particulate matter air pollution which plays a key role in altering the energy balance of the atmosphere and contributes to global warming. However, the relation of these particle emissions with premature mortality has made it a major concern for local air quality. Therefore, understanding the associations between black carbon, meteorological parameters, and other air pollutants is crucial for enhancing environmental protection and promoting human health. A review of the domestic research literature indicates that so far, no comprehensive study has been conducted to investigate the effects of various meteorological parameters and criteria air pollutants on the concentration of black carbon. The present study aims to explore the relationships between meteorological parameters, criteria air pollutants, and black carbon on monthly and seasonal time scales, as well as to identify pollutants and meteorological factors affecting changes in black carbon pollutant concentration levels in the cities of Tabriz and Tehran during 2004-2021.

METHODS AND MATERIAL

The data used in the present study consists of the monthly averages of meteorological parameters (temperature, rainfall, wind speed, relative humidity, air pressure, sunshine hours, solar radiation, and cloud cover) collected from synoptic stations, the daily averages of concentrations of criteria air pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter) measured at air quality monitoring stations, and the hourly averages of black carbon concentration, which were obtained from MERRA-2 model-based reanalysis data using the Google Earth Engine. This research utilized R software version 4.3.2 to perform all statistical data analysis. The quality of the data was assessed by identifying and managing missing and outlier values. Monthly values of pollutant concentrations were then extracted to ensure they were temporally compatible with the meteorological data. The nonparametric Mann-Kendall trend test was applied to detect the presence of a monotonic trend in the monthly time series of meteorological elements and air pollutants. Sen's slope estimator test was also employed to estimate the true slope of an existing trend in the data series. The relationships between meteorological parameters, criteria air pollutants, and black carbon particles on monthly and seasonal time scales were analyzed by selecting an appropriate correlation analysis method based on the data distribution. To identify the pollutants and meteorological factors that significantly influence changes in black carbon pollutant concentrations in Tabriz and Tehran, several machine learning algorithms were applied. These include multiple linear regression, generalized additive model, classification and regression tree, random forest, and gradient boosting machine, all implemented in the tidy models package. Furthermore, the effectiveness of these predictive models was evaluated using the coefficient of determination and the root mean square error.

RESULTS AND DISCUSSION

The concentration of black carbon pollutants in Tabriz and Tehran showed the highest positive correlation with fine particulate matter and the highest negative correlation with ozone levels. The results of this study compellingly indicate that as temperature, wind speed, sunshine hours, and solar radiation rise, the concentration of black carbon tends to decrease. In contrast, our findings also reveal that higher levels of relative humidity, air pressure, and cloudiness correspond to an increase in black carbon concentration in Tabriz and Tehran. Black carbon pollution in Tabriz exhibits the strongest negative correlation with wind speed and the most notable positive correlation with relative humidity. In Tehran, the average concentration of black carbon pollutants is greatly influenced by temperature and air pressure, displaying the most substantial negative and positive correlations, respectively. According to the findings from machine learning algorithms, pollutants ozone, fine particulate matter, and nitrogen dioxide, along with meteorological parameters like wind speed, temperature, and solar radiation, are crucial factors in understanding the variations of black carbon concentration levels in Tabriz. In Tehran, temperature, air pressure, precipitation, fine particulate matter and ozone play a more effective role in expressing changes in the concentration level of black carbon pollutants. Based

on the performance evaluation of predictive models and the principle of parsimony, the generalized additive model in Tabriz and the multiple linear regression model in Tehran demonstrate superior performance in predicting black carbon values compared to other models.

CONCLUSION

Black carbon plays a crucial and complex role in shaping the climate impact of particulate matter in our atmosphere. Investigating how black carbon interacts with meteorological parameters and other air pollutants is essential for understanding its impact on the environment and public health. Reducing emissions of black carbon, which has a short lifetime in the atmosphere, could be an efficient strategy for mitigating global warming. Moreover, it would directly enhance human health by improving air quality. The findings of this study demonstrate that the MERRA-2 model reanalysis data serves as an effective tool for conducting qualitative analysis of black carbon data. However, given the low spatial resolution of this model data, it is necessary to design better air pollution monitoring systems to record black carbon pollution events and their environmental impacts in metropolitan areas. On the other hand, gaining insight into the intricate relationship between black carbon, weather, and air pollutants in urban areas with diverse climates and emission sources, particularly during various seasons, necessitates additional research. This knowledge is urgent for developing effective strategies to combat black carbon pollution and improve urban air quality.

REFERENCES

References (in Persian)

Raispour, K., & Khosravi, Y. (2021). Long-term monitoring of the concentration of carbon black pollutants in Iran using NASA/MERRA-2 base model data. Environmental Sciences, 19(3), pp 99-122. https://doi.org/10.52547/envs.2021.33941. [In Persian]

Sarvar, H., Esmaeilpour, M., Kirizadeh, M. & Amrai, M. (2020). Spatial analysis of factors affecting air pollution in Tabriz city. Journal of Natural Environmental Hazards, 9(24), pp 151-172. https://doi.org/10.22111/JNEH.2020.31469.1558. [In Persian]

References (in English)

Bounakhla, Y., Benchrif, A., Costabile, F., Tahri, M., El Gourch, B., El Hassan, E.K., Zahry, F. & Bounakhla, M. (2023). Overview of PM10, PM2.5 and BC and Their Dependent Relationships with Meteorological Variables in an Urban Area in Northwestern Morocco. Atmosphere, 14(1), p 162. https://doi.org/10.3390/atmos14010162

Chen, C., McCabe, D. C., Fleischman, L. E., & Cohan, D. S. (2022). Black carbon emissions and associated health impacts of gas flaring in the United States. Atmosphere, 13(3), p 385. https://doi.org/10.3390/atmos13030385

Kuhn, M. & Wickham, H. (2020). Tidymodels: A Collection of Packages for Modeling and Machine Learning using Tidyverse Principles. https:/www.tidymodels.org

Kutzner, R. D., von Schneidemesser, E., Kuik, F., Quedenau, J., Weatherhead, E. C., & Schmale, J. (2018). Long-term monitoring of black carbon across Germany. Atmospheric Environment, 185, pp 41-52. https://doi.org/10.1016/j.atmosenv.2018.04.039

Liakakou, E., Stavroulas, I., Kaskaoutis, D.G., Grivas, G., Paraskevopoulou, D., Dumka, U.C., Tsagkaraki, M., Bougiatioti, A., Oikonomou, K., Sciare, J. & Mihalopoulos, N. (2020). Long-term variability, source apportionment and spectral properties of black carbon at an urban background site in Athens, Greece. Atmospheric Environment, 222, p 117137. https://doi.org/10.1016/j.atmosenv.2019.117137

Liu, X., Wei, Y., Liu, X., Zu, L., Wang, B., Wang, S., Zhang, R. & Zhu, R. (2022). Effects of Winter Heating on Urban Black Carbon: Characteristics, Sources and Its Correlation with Meteorological Factors. Atmosphere, 13(7), p 1071. https://doi.org/10.3390/atmos13071071

Şahin, Ü.A., Onat, B., Akın, Ö., Ayvaz, C., Uzun, B., Mangır, N., Doğan, M. & Harrison, R.M. (2020). Temporal variations of atmospheric black carbon and its relation to other pollutants and meteorological factors at an urban traffic site in Istanbul. Atmospheric Pollution Research, 11(7), pp 1051-1062. https://doi.org/10.1016/j.apr.2020.03.009

Sand, M., Samset, B. H., Tsigaridis, K., Bauer, S. E., & Myhre, G. (2020). Black carbon and precipitation: An energetics perspective. Journal of Geophysical Research: Atmospheres, 125(13), e2019JD032239. https://doi.org/10.1029/2019JD032239

Sankar, T. K., Ambade, B., Mahato, D. K., Kumar, A., & Jangde, R. (2023). Anthropogenic fine aerosol and black carbon distribution over the urban environment. Journal of Umm Al-Qura University for Applied Sciences, pp 1-10. https://doi.org/10.1007/s43994-023-00055-4

Yeganeh, B., Khuzestani, R. B., Taheri, A., & Schauer, J. J. (2021). Temporal trends in the spatial-scale contributions to black carbon in a Middle Eastern megacity. Science of the Total Environment, 792, p 148364. https://doi.org/10.1016/j.scitotenv.2021.148364

Zhang, Y., Li, Y., Guo, J., Wang, Y., Chen, D., & Chen, H. (2019). The climatology and trend of black carbon in China from 12-year ground observations. Climate Dynamics, 53, pp 5881-5892. https://doi.org/10.1007/s00382-019-04903-0.