Section A-Research paper
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Characterization of Water-soluble Ions in Ambient Particulates (PM_{10}) over a residential area of Korba City, Chhattisgarh state - India

A. L. Tiwari[1], A. Koshle[1*†], N. K. Jaiswal[2†], V. K. Jain[3], E. Yubero[4], A. Clemente[4]

[1]Department of Chemistry, Shri Rawatpura Sarkar University, Raipur-CG, India

[2]Department of Chemistry, ITM University, Naya Raipur-CG, India.

[3]Department of Chemistry, Govt. Engineering College, Raipur-CG, India

[4]Atmospheric Pollution Laboratory (LCA), Department of Applied Physics, Miguel Hernandez University, Avenida la Universidad S/N, 03203 Elche, Spain

*****Corresponding author: dr.anubhuti.k@gmail.com

[†]PhD Supervisor/Co-supervisor

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Abstract

Particulate Matter (PM_{10}) samples collected from a residential area of Korba city-Chhattisgarh during the non-sequential months of the year Nov. 2019 to Dec. 2021 were analyzed by Ion chromatography to quantify the water-soluble ions i.e., fluoride, chloride, sulfate, nitrate, oxalate, sodium, ammonium, potassium, calcium and magnesium concentrations. A high mass concentration trend of PM_{10} in the winter months of November, December, and January was observed during the sampling periods. High concentrations of fluoride, nitrate, and sulfate in particulates were observed due to huge coal combustion in the study area and its surroundings there. The values of PM_{10} throughout the study period indicated remarkable variation in local air quality. Relatively lower PM_{10} values were observed in March 2020, August 2020, and August 2021 with mass concentrations of 44, 35, and 44 µg/m^3 respectively may be due to non-monsoon precipitation and all India national lockdown due to COVID-19 spread. The PM values seem to show a general downward trend toward the PM_{10} end of the year 2021. Generally, higher PM_{10} concentrations can have adverse health effects, particularly on individuals with respiratory conditions, cardiovascular diseases, or compromised immune systems. The possible emission sources, meteorological parameters, and their correlation are discussed.

Keywords: PM_{10}, Sulphate, Korba, Particulates, water-soluble ions, ion chromatography

1. Introduction

Understanding the environmental and health implications of particulate matter (PM) requires an assessment of air quality[1–3]. PM_{10}, which refers to particles having an aerodynamic diameter of 10 micrometers µm (or less, has received a lot of attention because of its potential to harm human health. The presence of water-soluble ions in PM_{10} in particulates has been established as a substantial contributor to its health effects[4–6]. PM_{10} made up of a mixture of solid and liquid particles suspended in the air, is produced by natural and manmade causes. These particles can come from a variety of sources, including automobile emissions, industrial processes, building sites, and natural dust. When inhaled, PM_{10} can enter deep into the respiratory system, causing health problems. Sulphates (SO_4^{2-}), nitrates (NO_3^-), ammonium (NH_4^+), chlorides (Cl^-), and other water-soluble ions incorporated in PM_{10} play an important role in the overall composition and properties of PM_{10}.

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Extensive research has linked exposure to PM_{10} and its water-soluble ions with a range of health issues. The small aerodynamic diameter of PM_{10} enables it to evade the body's innate defense mechanisms and penetrate deep into the alveolar regions of the lungs. This ability to reach the lower respiratory tract is associated with various respiratory manifestations, including respiratory symptoms, asthma exacerbation, chronic bronchitis, reduced pulmonary function, and potential cardiovascular complications[7–12]. The specific chemical composition of the water-soluble ions within PM_{10} can further contribute to these health effects. The objective of the current work is to investigate the water-soluble ions of PM_{10} in Korba City, and to shed light on their potential consequences for human health. Korba City, located in the state of Chattisgarh, India, is a region that has witnessed rapid industrialization and urbanization over the past few decades[13]. The city is home to several coal-based thermal power plants and other industrial installations, which can contribute to elevated levels of PM_{10} and its water-soluble ions in the surrounding residential areas[14–16]. However, despite the potential health risks associated with such exposure, there is a lack of comprehensive studies focusing on the water-soluble ions of PM_{10} in the residential areas of Korba City.

In India, several studies have been conducted to investigate the composition and health impacts of PM_{10} in different regions[5,17–26]. Recent research carried out in metropolitan cities like Delhi [27,28]and Kolkata [29,30] has highlighted the significant contributions of water-soluble ions to PM_{10} and their association with adverse health effects. However, there is a need to bridge the existing research gap by examining the water-soluble ions of PM_{10} specifically in residential areas of Korba City, given its unique industrial and geographical characteristics. Therefore, this work aims to fill this research gap by conducting a comprehensive analysis of the water-soluble ions present in PM_{10} in the residential areas of Korba City, Chattisgarh. The findings from this study will contribute to our understanding of the composition, sources, and potential health impacts of PM_{10} in this specific urban setting. Moreover, the study will provide valuable insights for policymakers and public health officials in formulating effective mitigation strategies to reduce the exposure and associated health risks related to PM_{10} in residential areas.

2. Study area and sampling strategy

Korba (22 0 21’0” N, 82 0 40’ 48”E) is known as a power hub of the country due to its rich deposits of coal. The various units of thermal power plants consume more than 10000 MT of coal yearly to generate electricity of 40000 KW. Asia’s biggest Aluminium Plant is also considered a major emission source in the district. In the current work, a residential building Near Tehsil Office, Rampur Korba was selected to study the chemical composition of ambient particulates (Fig. 1).

Fig. 1. Residential area map and sampling site of Korba City Chattisgarh, India

Several sampling methods are employed for aerosol collection, depending on the specific objectives of the study. In the current study, the glass filters are utilized for the capturing of the ability of PM strategic selection of sampling sites is incorporated. Further, In PM_{10}, the analysis of water-soluble ions including inorganic anions Fluoride, Chloride, Nitrate, Sulfate, Oxalate and cations i.e, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+} was carried out.

3. Measuring of PM_{10} and Water-soluble ions

A High-volume sampler was deployed for the sampling of PM_{10} particles over ambient air. (Fig. 2). The sampler was operated at an average flow rate of 1.5 liters per minute. Quality assurance measures are implemented throughout the sampling process to ensure reliable and accurate results. The sampled filters were carefully retrieved from the sampler for laboratory analysis. The glass filter (size of 25.5 x 20.5 cm) was used for the sampling where the area of dust collection was 22.9 x17.9 cm. The mass concentration of PM_{10} samples was calculated by the gravimetric method. Filters were weighed before and after sampling by using an analytical balance (Shimadzu AUW220D) with a precision of up to 0.1 mg, making it suitable for high levels of accuracy. The duration of sampling is kept for 12 hrs. from 6:00 am to 6:00 pm.

Fig. 2. Respirable dust sampler for PM $_{10}$ analysis

Further, Dionex DX 500 Ion chromatography (IC) was used to analyze water-soluble ions in PM_{10} samples. It allows for the separation, identification, and quantification of different ions present in aerosol particles. The technique involves the use of a stationary phase, typically a resin or a column, which selectively interacts with the ions of interest. By adjusting the mobile phase composition and flow rate, different ions can be eluted at different times, allowing for their separation and subsequent analysis.

4. Data Analysis and Statistical Methods

From the large set of collection of data, the statistical tool mean, median, mode, and standard deviation have been used for the data analysis. The geometric mean is a measure of central tendency that is useful for understanding the average concentration or level of atmospheric aerosols in Korba. The median is another measure of central tendency that helps understand the typical or central value of aerosol concentrations in Korba. The standard deviation is a measure of dispersion or variability in the aerosol concentrations. It provides information about the spread of data points around the mean concentration. A higher standard deviation indicates a larger variation in aerosol concentrations, while a lower standard deviation suggests more consistency or uniformity. However, the current in the current presented study the arithmetic mean is utilized for the observation of seasonable variability (Table 1). The monthly mean mass concentration of PM_{10} and associated water-soluble ions for the non-sequential months of the year Nov. 2019 to Dec. 2021 shows the high mass concentration trend of PM_{10} in the winter months of November, December, and January during the sampling periods. High concentrations of fluoride, nitrate, and sulfate in particulates were observed due to huge coal combustion in the study area and its surroundings there. The meteorological parameters i.e., temperature, relative humidity, sunshine, wind speed, and wind direction were recorded during the sampling period to understand their effects on air pollutants emission dispersions. The meteorological factors: wind speed and wind direction remarkably influence the PM and carbon concentration in the air. The wind speed and temperature have a negative correlation with PM_{10} and major water-soluble ions [31]. An annual wind rose diagram to represent the wind speed and wind direction pattern in Korba city in Figure 3.

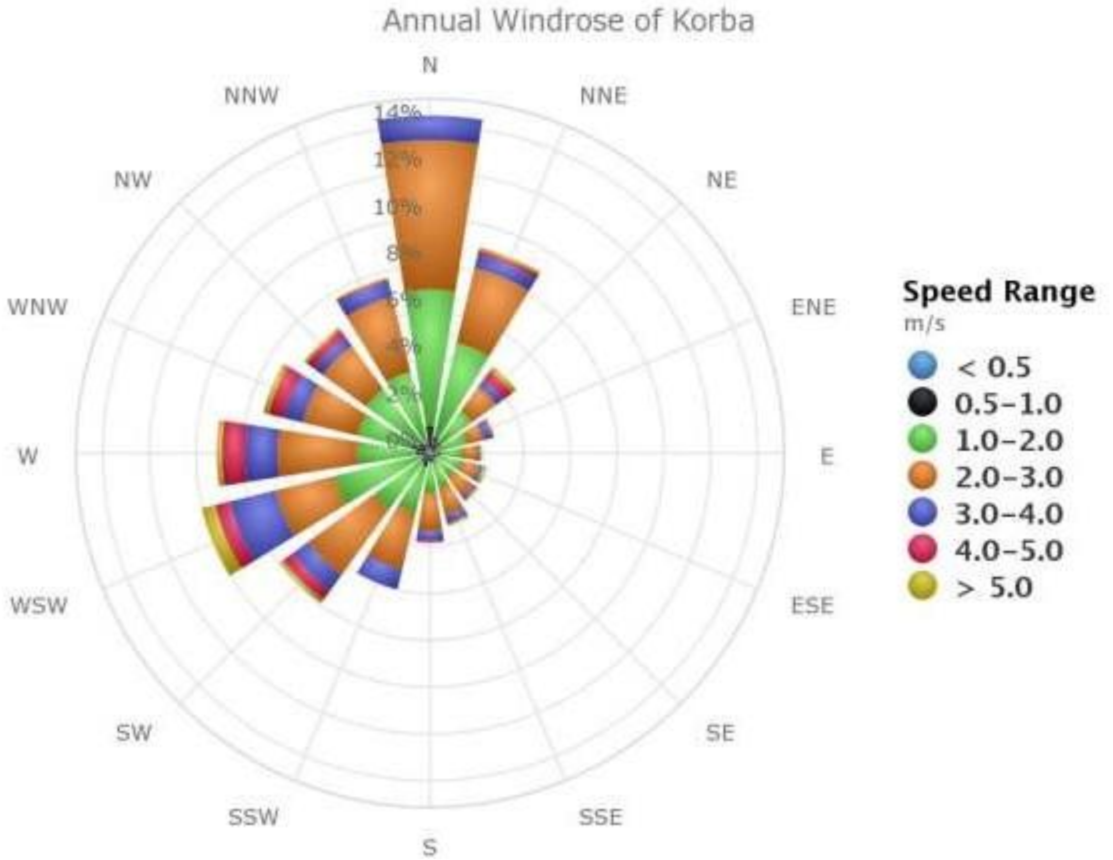

Figure 3: Annual Wind rose diagram for the city of Korba

Table 1: Mass concentration of PM_{10} and water-soluble ions (unit **µg/m³**)

Months	PM_{10}	Fluoride (F^-)	Chloride (Cl^-)	Nitrate (NO_3^-)	Sulphate (SO_4^{2-})	Oxalate ($C_2O_4^{2-}$)	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
Nov.2019	167	2.63	16.63	12.04	37.54	2.25	25.7	0.48	5.1	1.52	8.11
Dec.2019	147	1.77	14.81	7.94	30.55	1.58	22.2	1.03	2.33	1.19	6.08
Jan. 2020	84	1.81	13.05	3.4	12.35	0.81	15.77	0.1	1.2	0.83	4.1
Feb. 2020	148	0.7	14.69	8.19	27.86	1.95	23.03	0.12	1.87	1.16	5.84
Mar.2020	44	0.71	4.38	0.56	8.74	0.4	6.15	0.08	0.49	0.57	3.38
Aug.2020	35	0.81	5.19	0.99	8.57	0.47	7.19	0.14	0.32	0.62	3.73
Nov.2020	166	4.82	15.93	8.53	24.11	1.34	24.32	0.14	1.87	1.12	7.44
Jul-2021	54	0.9	9.49	3.25	6.08	0.83	10.09	0.1	0.6	0.48	2.84
Aug-2021	44	1.46	9.87	1.99	10.77	0.29	11.63	0.1	0.79	0.59	3.59
Sep-2021	49	0.9	10.96	2.09	11.81	0.34	14.2	0.12	1.15	0.43	1.26
Oct-2021	61	0.34	12.14	1.11	7.48	0.25	14.2	0.09	1.14	0.48	1.19
Nov.2021	95	0.62	12.76	2.81	11.07	0.59	12.87	0.12	1.62	0.65	2.04
Dec.2021	63	3.58	11.59	5.78	13.2	0.78	14.93	0.56	2.53	0.8	2.48

5. Results and Discussion

5.1 PM_{10} in a residential area of Korba

The values of PM_{10} throughout the study period indicated remarkable variation in local air quality (Fig. 4). The lowest value was observed at 35 µg/m^3 in August 2020. Some other months with relatively lower PM_{10} values were observed in March 2020, August 2020, and August 2021 with mass concentrations of 44, 35, and 44 µg/m^3 respectively may be due to non-monsoon precipitation and all India national lockdown due to COVID-19 spread. The PM values seem to show a general downward trend toward the PM_{10} end of the year 2021. Generally, higher PM_{10} concentrations can have adverse health effects, particularly on individuals with respiratory conditions, cardiovascular diseases, or compromised immune systems. Prolonged exposure to elevated PM_{10} levels may lead to respiratory symptoms, exacerbation of existing respiratory conditions, increased risk of cardiovascular events, and other health problems. It's possible to observe seasonal variations in PM_{10} levels. For instance, November 2019 and November 2020 both had relatively high PM10 values of 167 and 166 micrograms per cubic meter, respectively.

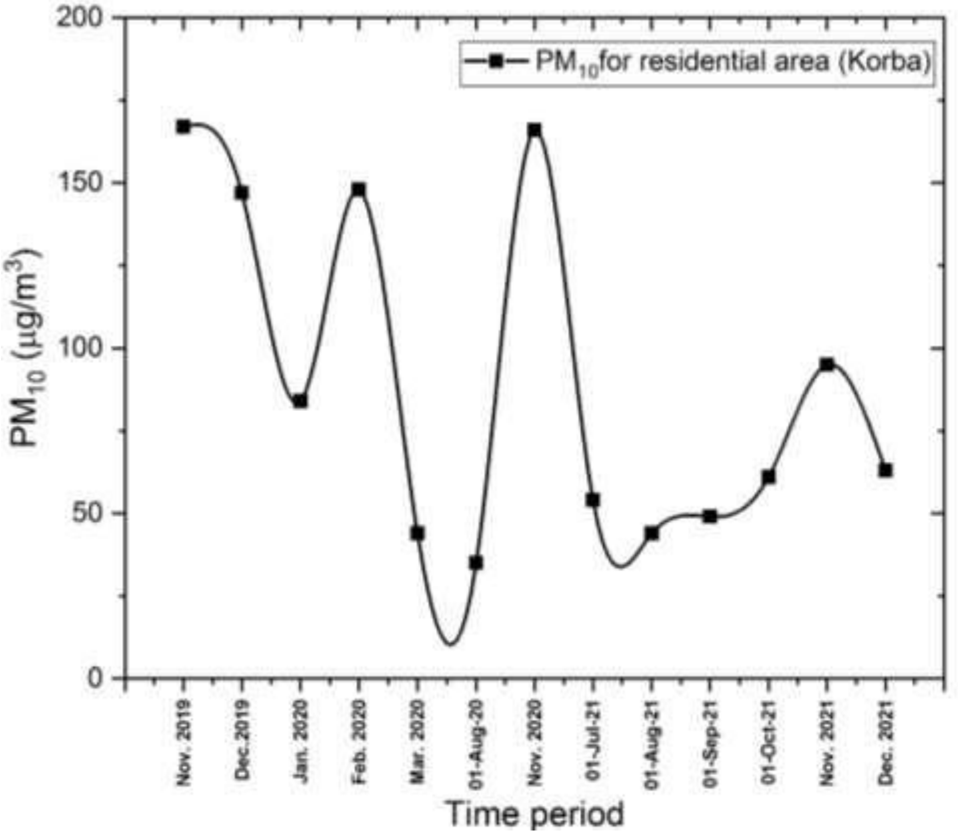

Fig. 4. PM_{10} analysis in a residential area of Korba

5.2 Water Soluble ions in aerosol in a residential area of Korba

Fig. 5. includes several ions commonly found in PM_{10} particles, such as fluoride ions, chloride ions, nitrate ions, sulphate ions, oxalate ions, sodium ions, ammonium ions, potassium ions, magnesium ions, and calcium ions. The analysis of ion concentrations in relation to the months reveals notable 10 variations. November 2019 recorded the highest concentrations of fluoride ion (4.83 µg/m^3), chloride ion (16.35 µg/m^3), nitrate ion (12.02 µg/m^3), sulfate ion (37.33 µg/m^3), oxalate ion (2.04 µg/m^3), sodium ion (24.94 µg/m^3), ammonium ion (0.40 µg/m^3), potassium ion (4.23 µg/m^3), magnesium ion

(1.51 µg/m³), and calcium ion (8.09 µg/m³). Conversely, October 2021 exhibited the lowest concentrations of fluoride ion (0.34 µg/m³), chloride ion (4.22 µg/m³), nitrate ion (0.55 µ g/m³), sulfate ion (4.92 µg/m³), oxalate ion (0.23 µg/m³), sodium ion (6.06 µg/m³), ammonium ion (0.078 µg/m³), potassium ion (0.31 µg/m³), magnesium ion (0.48 µg/m³), and calcium ion (1.12 µg/m³). These fluctuations indicate varying level of these ions throughout the months, which could be attributed to changes in emission sources, meteorological conditions, and pollution patterns. Further analysis and correlation with relevant environmental factors are necessary to understand the implications of these ion concentrations on air quality and human health.

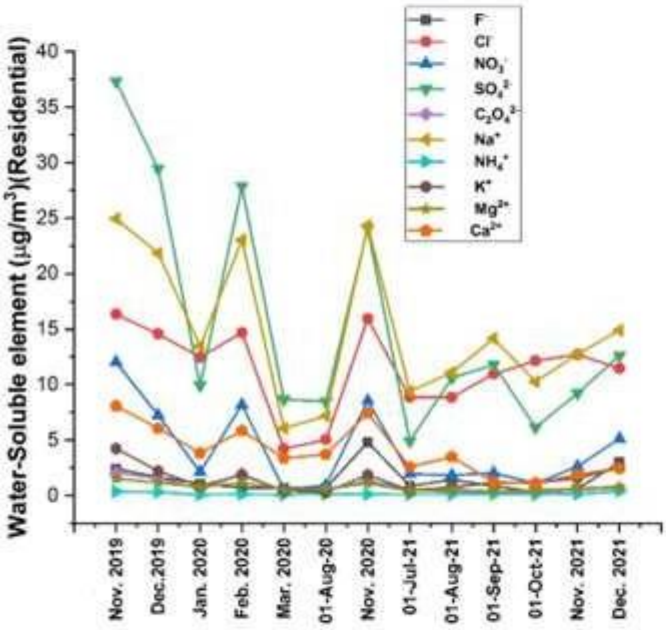

Fig. 5. Monthly variation in PM_{10} - associated water-soluble ions over the residential area of Korba.

6. Conclusion

Through the utilization of various data collection methods and instruments, a substantial dataset was obtained, allowing for a detailed analysis of particulate matter with a diameter of 10 micrometers. The collected data spanned over a specific period, enabling the assessment of temporal trends in air pollution.

- The analysis of PM_{10} revealed significant variations across different months, indicating the influence of various factors such as meteorological conditions, industrial activities, and seasonal variations in emissions. Certain months, such as November 2019, December 2019, and November 2021, exhibited higher PM_{10} concentrations, indicating potential pollution episodes or periods of increased emissions. On the other hand, months like August 2020 and September 2021 demonstrated comparatively lower PM_{10} levels.
- The water-soluble ions such as sulphate, sodium and calcium correspond to PM_{10} shows corresponding higher values compared to the other ions. Majority of the water-soluble ions are higher in winter season of the Korba city. In overall it is concluded that potentially favorable conditions or effective pollution control measures during those periods during the winter season of Korba city.

References

[1] S. Munir, T.M. Habeebullah, A.M.F. Mohammed, E.A. Morsy, M. Rehan, K. Ali, Analysing PM2.5 and its Association with PM10 and Meteorology in the Arid Climate of Makkah, Saudi Arabia, Aerosol Air Qual Res. 17 (2017) 453–464. https://doi.org/10.4209/AAQR.2016.03.0117.

[2] S. Kong, B. Han, Z. Bai, L. Chen, J. Shi, Z. Xu, Receptor modeling of PM2.5, PM10 and TSP in different seasons and long-range transport analysis at a coastal site of Tianjin, China, Science of The Total Environment. 408 (2010) 4681–4694. https://doi.org/10.1016/J.SCITOTENV.2010.06.005.

[3] A. Talbi, Y. Kerchich, R. Kerbachi, M. Boughedaoui, Assessment of annual air pollution levels with PM1, PM2.5, PM10 and associated heavy metals in Algiers, Algeria, Environmental Pollution. 232 (2018) 252–263. https://doi.org/10.1016/J.ENVPOL.2017.09.041.

[4] A. Dutta, W. Jinsart, Risks to health from ambient particulate matter (PM2.5) to the residents of Guwahati city, India: An analysis of prediction model, Https://Doi.Org/10.1080/10807039.2020.1807902. 27 (2020) 1094–1111. https://doi.org/10.1080/10807039.2020.1807902.

[5] P. Saxena, A. Kumar, S.K. Mahanta, B. Sreekanth, D.K. Patel, A. Kumari, A.H. Khan, G.C. Kisku, Chemical characterization of PM10 and PM2.5 combusted firecracker particles during Diwali of Lucknow City, India: air-quality deterioration and health implications, Environmental Science and Pollution Research. 29 (2022) 88269–88287. https://doi.org/10.1007/S11356-022-21906-3/TABLES/9.

[6] N. Hazarika, A. Srivastava, Estimation of risk factor of elements and PAHs in size-differentiated particles in the National Capital Region of India, Air Qual Atmos Health. 10 (2017) 469–482. https://doi.org/10.1007/S11869-016-0438-8/METRICS.

[7] P.G. Satsangi, S. Yadav, A.S. Pipal, N. Kumbhar, Characteristics of trace metals in fine (PM2.5) and inhalable (PM10) particles and its health risk assessment along with in-silico approach in indoor environment of India, Atmos Environ. 92 (2014) 384–393. https://doi.org/10.1016/J.ATMOSENV.2014.04.047.

[8] X. Yang, L. Jiang, W. Zhao, Q. Xiong, W. Zhao, X. Yan, Comparison of Ground-Based PM2.5 and PM10 Concentrations in China, India, and the U.S., International Journal of Environmental Research and Public Health 2018, Vol. 15, Page 1382. 15 (2018) 1382. https://doi.org/10.3390/IJERPH15071382.

[9] B. Gugamsetty, H. Wei, C.N. Liu, A. Awasthi, C.J. Tsai, G.D. Roam, Y.C. Wu, C.F. Chen, Source Characterization and Apportionment of PM10, PM2.5 and PM0.1 by Using Positive Matrix Factorization, Aerosol Air Qual Res. 12 (2012) 476–491. https://doi.org/10.4209/AAQR.2012.04.0084.

[10] D. Raju, S.V.J. Kumar, M. Nimmakanti, Spatial variations in PM2.5/PM10 over time in Andhra Pradesh, India Life Period of Cyclonic Disturbances Over the North Indian Ocean During Recent Years View project, (n.d.). https://doi.org/10.13140/RG.2.2.16752.02562.

[11] H. Guo, S.H. Kota, S.K. Sahu, H. Zhang, Contributions of local and regional sources to PM2.5 and its health effects in north India, Atmos Environ. 214 (2019) 116867. https://doi.org/10.1016/J.ATMOSENV.2019.116867.

[12] J. Wang, X. Xie, C. Fang, Temporal and Spatial Distribution Characteristics of Atmospheric Particulate Matter (PM10 and PM2.5) in Changchun and Analysis of Its Influencing Factors, Atmosphere 2019, Vol. 10, Page 651. 10 (2019) 651. https://doi.org/10.3390/ATMOS10110651.

[13] B. Giri, K.S. Patel, N.K. Jaiswal, S. Sharma, B. Ambade, W. Wang, S.L.M. Simonich, B.R.T. Simoneit, Composition and sources of organic tracers in aerosol particles of industrial central India, Atmos Res. 120–121 (2013) 312–324. https://doi.org/10.1016/J.ATMOSRES.2012.09.016.

[14] P. Gargava, V. Rajagopalan, Source apportionment studies in six Indian cities—drawing broad inferences for urban PM10 reductions, Air Qual Atmos Health. 9 (2016) 471–481. https://doi.org/10.1007/S11869-015-0353-4/METRICS.

[15] R. Pal, S. Chowdhury, S. Dey, A.R. Sharma, 18-Year Ambient PM2.5 Exposure and Night Light Trends in Indian Cities: Vulnerability Assessment, Aerosol Air Qual Res. 18 (2018) 2332–2342. https://doi.org/10.4209/AAQR.2017.10.0425.

[16] R.K. Sumesh, K. Rajeevan, E.A. Resmi, C.K. Unnikrishnan, Particulate Matter Concentrations in the Southern Tip of India: Temporal Variation, Meteorological Influences, and Source Identification, Earth Systems and Environment. 1 (2017) 1–18. https://doi.org/10.1007/S41748-017-0015-9/METRICS.

[17] R. Das, B. Khezri, B. Srivastava, S. Datta, P.K. Sikdar, R.D. Webster, X. Wang, Trace element composition of PM2.5 and PM10 from Kolkata – a heavily polluted Indian metropolis, Atmos Pollut Res. 6 (2015) 742–750. https://doi.org/10.5094/APR.2015.083.

[18] R. Das, B. Khezri, B. Srivastava, S. Datta, P.K. Sikdar, R.D. Webster, X. Wang, Trace element composition of PM2.5 and PM10 from Kolkata – a heavily polluted Indian metropolis, Atmos Pollut Res. 6 (2015) 742–750. https://doi.org/10.5094/APR.2015.083.

[19] N.L. Devi, A. Kumar, I.C. Yadav, PM10 and PM2.5 in Indo-Gangetic Plain (IGP) of India: Chemical characterization, source analysis, and transport pathways, Urban Clim. 33 (2020) 100663. https://doi.org/10.1016/J.UCLIM.2020.100663.

[20] N.L. Devi, A. Kumar, I.C. Yadav, PM10 and PM2.5 in Indo-Gangetic Plain (IGP) of India: Chemical characterization, source analysis, and transport pathways, Urban Clim. 33 (2020) 100663. https://doi.org/10.1016/J.UCLIM.2020.100663.

[21] A.R. Aswini, P. Hegde, P.R. Nair, Carbonaceous and inorganic aerosols over a sub-urban site in peninsular India: Temporal variability and source characteristics, Atmos Res. 199 (2018) 40–53. https://doi.org/10.1016/J.ATMOSRES.2017.09.005.

[22] M. Saxena, A. Sharma, A. Sen, P. Saxena, Saraswati, T.K. Mandal, S.K. Sharma, C. Sharma, Water soluble inorganic species of PM10 and PM2.5 at an urban site of Delhi, India: Seasonal variability and sources, Atmos Res. 184 (2017) 112–125. https://doi.org/10.1016/J.ATMOSRES.2016.10.005.

[23] B.K. Saikia, M. Sarmah, P. Khare, B.P. Baruah, Investigation on inorganic constituents in Indian coal and emission characteristics of the particulates (PM 2.5 and PM 10), ENERGY EXPLORATION & EXPLOITATION ·. 31 (2013) 287–315.

[24] P. Saini, M. Sharma, Cause and Age-specific premature mortality attributable to PM2.5 Exposure: An analysis for Million-Plus Indian cities, Science of The Total Environment. 710 (2020) 135230. https://doi.org/10.1016/J.SCITOTENV.2019.135230.

[25] P. Saini, M. Sharma, Cause and Age-specific premature mortality attributable to PM2.5 Exposure: An analysis for Million-Plus Indian cities, Science of The Total Environment. 710 (2020) 135230. https://doi.org/10.1016/J.SCITOTENV.2019.135230.

[26] R. Goyal, M. Khare, Indoor air quality modeling for PM10, PM2.5, and PM1.0 in naturally ventilated classrooms of an urban Indian school building, Environ Monit Assess. 176 (2011) 501–516. https://doi.org/10.1007/S10661-010-1600-7/METRICS.

[27] A. Shukla, A. Mishra, B. Nirmalbhai, T. Tandel, Is Exposure to PM2.5 and PM10, a Factor of Surge of 2nd Wave of COVID-19-A Case Study of Delhi, India?, (2021). https://doi.org/10.21203/rs.3.rs-808021/v1.

[28] S. Chowdhury, S. Dey, L. Di Girolamo, K.R. Smith, A. Pillarisetti, A. Lyapustin, Tracking ambient PM2.5 build-up in Delhi national capital region during the dry season over 15 years using a high-resolution (1 km) satellite aerosol dataset, Atmos Environ. 204 (2019) 142–150. https://doi.org/10.1016/J.ATMOSENV.2019.02.029.

[29] H.T. Diong, R. Das, B. Khezri, B. Srivastava, X. Wang, P.K. Sikdar, R.D. Webster, Anthropogenic platinum group element (Pt, Pd, Rh) concentrations in PM10 and PM2.5 from Kolkata, India, Springerplus. 5 (2016) 1–9. https://doi.org/10.1186/S40064-016-2854-5/TABLES/4.

[30] S. Nag, A.K. Gupta, U.K. Mukhopadhyay, Size Distribution of Atmospheric Aerosols in Kolkata, India and the Assessment of Pulmonary Deposition of Particle Mass, Http://Dx.Doi.Org/10.1177/1420326X05057949. 14 (2005) 381–389. https://doi.org/10.1177/1420326X05057949.

[31] Indian Climate, Indian meteorological data archive, Retrieved on 20 October 2022, https://www.indianclimate.com/wind-data.php?baithak=587103191.