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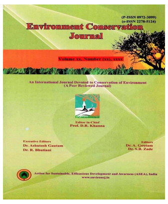

Assessment of air quality around the thermal power plant area, Chandrapur, Maharashtra, India

Vivek S. Manik
Department of Environmental Science, Gramgeeta Mahavidyalaya, Chimur, Chandrapur (MS) India

Swapnil K. Gudadhe✉
Department of Environmental Science, Dr. Khatri Mahavidyalaya, Tukum, Chandrapur (MS) India

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ABSTRACT

Air is the critical main constituent of life on the earth due to respiration phenomenon. Chandrapur city is well known for mining activity and industrial area. Thermal power plant, mining activities, factories and so many industries are established in Chandrapur district. Present study examines the ambient air quality around the thermal power plant for compliance parameters viz; Particulate Matter less than 10 microns and 2.5 microns size (i.e., PM_{10} and $PM_{2.5}$), as well as gaseous pollutants like Sulphur Dioxide (SO_2), Oxides of Nitrogen (NO_X), Ozone (O_3), Ammonia (NH_3), specific contaminant pollutants involving Hydrocarbons (HCs) and Carbon Monoxide (CO), and heavy metals such as Nickel (Ni), Lead (Pb), Arsenic (As), and Benzo [a] pyrene (BaP) at different areas around Thermal Power Plant, Chandrapur, Maharashtra (India). The National Ambient Air Quality Standard (NAAQS) 2009 was compared to the resultant situations. The results showed that although the levels of toxins and other pollutants near the thermal power plant were designed to be below permissible limits, they are nonetheless at alarmingly high levels from a health perspective.

Introduction

Due in large part to the presence of poisonous trace metals in the atmosphere as a result of rapid industrialization and widening of good moving companies, air pollution has recently become a severe environmental problem (Borbely *et al.,* 1999; Clarke *et al.,* 1996; Vadjic and Fugas, 1997; Ahamad *et al.,* 2022). The adverse health consequences of air pollution are caused by the way the atmosphere behaves (Almeids *et al.,* 1995; Sohrabpour *et al.,* 1999; Tsai *et al.,* 1997). Ambient air pollution is a major cause of respiratory health problems in industrial regions worldwide, and children are more vulnerable to it than adults are. Children are more susceptible to air pollution than adults are due to their greater susceptibility to air pollution (Gawande *et al.,* 2016). There are many different natural and manmade sources that contribute suspended particles to the atmosphere, but urban and industrialized regions are the main suppliers (Borbely *et al.,* 1999; Bhutiani *et al.,* 2021). Transportation, industry, burning biomass, and argarian activities are among the well-known anthropogenic processes causing airborne particulate pollution (Harrison *et al.,* 1997; Hien *et al.,* 2001; Arditsoglou and Samara, 2005; Valavanidis *et al.,* 2006; Ruhela *et al.,* 2022a&b). Particulate matter (PM) comprises a wide range of biological and inorganic composites of different sizes and with different elemental properties (Cheng and Lin, 2010). According to Dockery and Pope (1994), elevated PM exposure has been linked to higher rates of death and morbidity in civic populations. Fine aerosol particles, especially those with diameters smaller than 2.5 micrometres, have a significant negative impact on a person's health because they cause lung epithelial shell inflammation-like symptoms (Dockery & Pope, 1994). Studies have been conducted to determine the relationship between the elemental concentrations in urban areas and the size distribution of PM (Fang *et*

Corresponding author E-mail: *swapnil.k.gudadhe@gmail.com*
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al., 2000, 2006). The concentrations of metals in total suspended particles (TSPs), PM_{10}, and $PM_{2.5}$ have been extensively examined in recent research on the health effects of heavy metals and related particulate matter. Since heavy metals can be absorbed into human lung tissues during inhalation, trace metals in air particulate matter pose a major health risk. Trace metal concentrations in suspended particulate matter increase in response to anthropogenic discharge substantially above background levels (Finlayson-Pitts & Pitts, 1999). Gaseous pollutants, including sulfur dioxide (SO_2), oxides of nitrogen (NOx), ammonia (NH_3), ozone (O_3) and carbon monoxide (CO), greatly contribute to this pollution. Sources of these gaseous pollutants include vehicular pollution; various industrialized processes from chemicals, fertilizers, textile mills, etc.; and partial combustion of carbon-containing composites, which contributes to the pollution of SO_2, NOx, CO and NH_3. NOx and volatile organic compounds (VOCs) undergo photochemical reactions to produce ozone, a secondary air pollutant. The impact of these industrialized contaminants in the surrounding atmosphere can be monitored to determine the present status of the atmosphere.

Chandrapur is notorious for its possession of the Chandrapur Super Thermal Power Station (CSTPS) because it can produce more than ten percent of its electricity and power overall in India. Chandrapur also includes ferroalloy factories, Ballarpur paper mills, cement factories, and mining actions as large-scale industries and has numerous small-scale industries because Chandrapur has become the 4th most polluted city in India. Housing developments in the Chandrapur district are close to companies and industrial regions that produce substantial amounts of hazardous emissions. People who reside close to industrial complexes or facilities may therefore be exposed to harmful contaminants. Studying the air quality in industrial regions is the primary focus of the present work.

Materials and Methods

Study area

Chandrapur was the Chanda region until 1964. Khandkya Ballal Sah, a 13th century Gond king, constructed Chandrapur. The city is surrounded by coal seams. Chandrapur is called the "black gold city" (Deogaonkar, 2007). The hinterland is 19.57°N, 79.18°E. Chandrapur is hot and arid. May is the hottest month, with a mean maximum temperature of 43°C, while December is the coldest month, with a minimum average temperature of 9°C. The maximum recorded temperature was 49°C on 2 June 2007. The lowest recorded temperature was 2.8°C in January 1899 and 2021. June to September is the monsoon season. The average yearly rainfall in the Chandrapur region is 1249.4 mm.

The 3,340 MW Chandrapur Super Thermal Power Station (CSTPS), owned by the Maharashtra State Power Generation Company Limited, is located 6 km from the city on 12,212 hectares (122.12 km^2). It generates almost 25% of the state's electricity and employs 3,460 people. A masonry dam on the Erai River 15 km from the station supplies the Chandrapur and the station with water. The station's foundation stone was laid by Central Energy Minister K. C. Pant on January 16, 1977. We measured the ambient air quality at 6 locations surrounding the thermal power facility. Durgapur, Arihant, Nirman, Lakhmapur, VichodaRayyatwari, and Padoli.

Experimental setup

The gaseous air pollutants were measured via wet chemical analysis. SO_2, NO_x and NH_3 were estimated as per the Improved West and Gaeke methods (IS 5182 Part 2 Method of Measurement of Air Pollution), Modified Jacob-Honchheiser (Na-Arsenite) (IS 5182 Part 6 Methods for Measurement of Air Pollution), and Indophenol Blue method (Method 401, Air Sampling and Analysis, 3rd Edition), respectively. Ozone was estimated by chemical methods (Method 411, Air Sampling and Analysis, 3 Edition) (Guidelines for the Measurement of Ambient Air Pollutants Volume I) (Board, 2013).

In the course of the summers of 2021 and 2022, samples of particulate matter (PM_{10} and $PM_{2.5}$) were collected using an eight-stage cascade impactor. The cascade impactor system was installed on a building's rooftop, approximately 12 meters above the ground. The particles were collected using glass fiber filters. Using a digital electronic balance, the filters were weighed both before and after sampling, and various particle dimension ranges were computed gravimetrically. After the samples had been digested with HNO_3, the concentrations of the trace metals Pb, Ni, and As were calculated. On an HC-CO analyzer, hydrocarbons and carbon monoxide were analyzed. HPLC/GC analysis was performed on BaP after solvent extraction. Analysis and reporting strictly adhered to the CPCB manual for NAAQM.

Statistical methods used:

Statistical analysis is one of the most important tools used in related studies. Most of the major discoveries in science and technology have come from studies that used statistical methods (Manik and Gudadhe, 2020) (Yennawar, 1970).

Standard deviation:

It is the positive square root of the arithmetic mean of the squares of the observation deviations. It is the most important statistic for the statistical forecasting of various research results and the most commonly used dispersion measure. (Manik and Gudadhe, 2020), (Mungikar, 2003).

Results and Discussion

The ambient air quality parameters around the CSTPS were compared with the reference range prescribed by the CPCB, 2009. A comparison of different parameters, such as particulate matter ($PM_{2.5}$ and PM_{10}), and gaseous pollutants, such as SO_2, NOx and NH_3, are presented in Table 1.

Particulate matter in ambient air

PM_{10} and $PM_{2.5}$ are present in the air and are composed of very small solid particles or liquid droplets. Size determines their classification, and measuring size is essential for determining air quality and health risks. Air pollution health hazards must be assessed by monitoring PM_{10} and $PM_{2.5}$ levels, which are crucial air quality indicators. High particulate matter levels can be a source of respiratory, cardiovascular, and other health issues over time.

Table 1 shows that the average PM_{10} concentrations at Durgapur, Arihant Nagar, Nirman Nagar, Lakhmapur, VichodaRayyatwari and Padoli were 59±12 $\mu g/m^3$, 54±7 $\mu g/m^3$, 69±7 $\mu g/m^3$, 67±15 $\mu g/m^3$, 63±9 $\mu g/m^3$, and 54±6 $\mu g/m^{3,}$ respectively. The highest PM_{10} concentration recorded was 85 $\mu g/m^3$ at Nirman Nagar, while the lowest PM_{10} concentration recorded was 30 $\mu g/m^3$ at Durgapur. At all the locations, the PM10 concentrations were confirmed to be below the NAAQS stipulated standards (24 hourly PM_{10}=100 $\mu g/m^3$).

$PM_{2.5}$: According to Table No. 1, the average $PM_{2.5}$ concentrations at the aforementioned locations were found to be 32±6 $\mu g/m^3$, 30±8 $\mu g/m^3$, 28±7 $\mu g/m^3$, 29±6 $\mu g/m^3$, 32±4 $\mu g/m^3$, and 28±5 µg/m3. The highest average $PM_{2.5}$ concentration recorded was 32 $\mu g/m^3$ at Durgapur and VichodaRayyatwari, while the lowest average $PM_{2.5}$ concentration recorded was 28 $\mu g/m^3$ at Padoli. At all the locations, the $PM_{2.5}$ concentrations were confirmed to be below the NAAQS stipulated standards (24 hourly $PM_{2.5}$ =60 $\mu g/m^3$).

Gaseous pollutants

Toxic gases discharged into the air by human activities, including manufacturing, transportation, and power generation, are known as gaseous pollutants. Both people and the environment are vulnerable to the harmful impacts of these gases.

SO_2: The average concentrations of SO_2 at Durgapur, Arihant Nagar, Nirman Nagar, Lakhmapur, VichodaRayyatwari and Padoli were 29±2 $\mu g/m^3$, 24±1 $\mu g/m^3$, 17±2 $\mu g/m^3$, 28±2 $\mu g/m^3$, 18±1 $\mu g/m^3$, and 23±2 $\mu g/m^{3,}$ respectively. The maximum concentration of SO_2 recorded was 30 $\mu g/m^3$ at Durgapur and Vichoda Rayyatwari, while the minimum concentration of SO_2 recorded was 17 $\mu g/m^3$ at Nirman Nagar. The $SO_{2\ concentrations}$ were less than the stipulated CPCB standards (24 hourly SO_2 = 80 $\mu g/m^3$).

NO_x: The average concentrations of NO_x were 39±1 $\mu g/m^3$, 33±5 $\mu g/m^3$, 32±1 $\mu g/m^3$, 44±2 $\mu g/m^3$, 39±1 $\mu g/m^3$, and 42±1 µg/m3. The maximum concentration of NOx recorded was 45 $\mu g/m^3$ at Lakhampur, while the minimum concentration of NOx recorded was 26 $\mu g/m^3$ at Arihant Nagar. The NO_x concentrations were less than the stipulated standards of the CPCB (NO_x = 80 $\mu g/m^3$).

NH_3: The average concentrations of NH_3 at Durgapur, Arihant Nagar, Nirman Nagar, Lakhmapur, VichodaRayyatwari and Padoli were found to be 53±10 $\mu g/m^3$, 51±6 $\mu g/m^3$, 53±6 $\mu g/m^3$, 52±6 $\mu g/m^3$, 54±5 $\mu g/m^3$, and 54±5 $\mu g/m^{3,}$ respectively. The maximum concentration of NH_3 recorded was 74 $\mu g/m^3$ at Lakhampur, while the minimum concentration of NH_3 recorded was 39 $\mu g/m^3$ at Durgapur. The NH_3 concentrations were less than the stipulated standards of CPCB (NH_3 = 100 µg/m^3).

CO:CO was found to be 0.93 mg/m^3, 0.57 mg/m^3, 0.45 mg/m^3, 1.20 mg/m^3, 0.5 mg/m^3, and 1.04 mg/m^3; all these concentrations are less than the stipulated standards (400 µg/m^3; CO for 1 hour:02 mg/m^3), which are the calculated values at all the monitored sites given in Table 2.

Table 1: Status of Ambient Air Quality

SN	Sampling Location	Avg. ± SD/(min.-max.)				
		PM_{10}	$PM_{2.5}$	SO_2	NO_x	NH_3
1	Durgapur	59±12 (30-72)	32±6 (23-41)	29±2 (25-30)	39±1 (37-40)	53±10 (39-74)
2	Arihant Nagar	54±7 (44-63)	30±8 (20-44)	24±1 (23-25)	33±5 (26-41)	51±6 (43-62)
3	Nirman Nagar	69±7 (63-85)	28±7 (21-39)	17±2 (15-19)	32±1 (30-34)	53±6 (43-63)
4	Lakhmapur	67±15 (39-84)	29±6 (23-36)	28±2 (25-30)	44±2 (40-45)	52±6 (41-59)
5	VichodaRayyatwari	63±9 (51-75)	32±4 (24-36)	18±1 (16-19)	39±1 (38-40)	54±5 (44-61)
6	Padoli	54±6 (45-65)	28±5 (23-36)	23±2 (20-25)	42±1 (40-43)	54±5 (42-60)
NAAQS (2009) 24 hr		**100 µg/m^3**	**60 µg/m^3**	**80 µg/m^3**	**80 µg/m^3**	**400 µg/m^3**

Table 2: Levels of particulate-associated toxic pollutants

SN	Sampling location	Pb	As	Ni	BaP	CO	N-CH_4	CH4	HCs
		Particulate associated pollutants				Volatile Organic Pollutants			
1	Durgapur	0.40	ND	4.32	0.16	0.93	0.93	0.82	1.75
2	Arihant Nagar	0.18	ND	6.7	0.07	0.57	0.25	1.05	1.3
3	Nirman Nagar	0.14	ND	8.5	0.06	0.45	0.39	0.65	1.04
4	Lakhmapur	0.06	ND	6.7	0.12	1.20	0.39	0.30	0.69
5	VichodaRayyatwari	0.08	ND	6.8	0.07	0.5	0.15	1.28	1.43
6	Padoli	0.09	ND	5.6	0.06	1.04	0.30	1.01	1.31
NAAQS (2009)		**1**	**6**	**20**	**1**	**04**	**03-10**		
		µg/m^3	**ng/m^3**	**ng/m^3**	**ng/m^3**	**mg/m^3**	**ppm**		

These results revealed that from a health perspective, the concentrations of gaseous pollutants were somewhat greater than but less than the permissible limit of the NAAQM standards.

Toxic pollutants associated with particulate matter

Metals can be transported by airborne particles, some of which have deadly effects. The discharge methods used in the environment include wet and dry deposition, cloud processing, interchange of air between the border line and the open troposphere, and compound transformations, which can impact the concentrations and dimensional distributions of trace metals. Heavy metal analysis is necessary to assess the health risk, level of pollution, and emission sources associated with traffic, industrial, and residential activities. The concentrations of the selected heavy metals lead (Pb), nickel (Ni), and arsenic (As) detected in the PM_{10} samples varied between the research locations according to the current investigation (Kumari *et al.,* 2021). An increase in metal concentrations is a major hazard to people's health. Natural sources of lead (Pb), nickel (Ni), and arsenic (As) include the environment and manufactured goods. According to the projected results, each of the locations has an average concentration of these metals, i.e., Durgapur, Arihant Nagar, Nirman Nagar, Lakhmapur, VichodaRayyatwari and Padoli. Pb concentrations were 0.40 µg/m^3, 0.18 µg/m^3, 0.14 µg/m^3, 0.06 µg/m^3, 0.08 µg/m^3, and 0.09 µg/m3, and Ni concentrations were 4.32 ng/m^3, 6.7 ng/m^3, 8.5 ng/m^3, 6.7 ng/m^3, 6.8 ng/m^3, and 5.6 ng/m^3, respectively.However, the level of arsenic was less than the detection limit. These metal concentrations were all below the NAAQS' permitted levels. The observed results are tabulated in Table No. 2.

Concentration of hydrocarbons in ambient air

Atmospheric conditions are impacted by elevated levels of methane and nonmethane hydrocarbons (NMHCs). Nonmethane hydrocarbons (NMHCs) encompass all gaseous organic molecules excluding methane (Baker *et al.,* 2008; Wang *et al.,* 2015). Secondary pollutants such as peroxyacetyl nitrate (PAN), secondary organic aerosols (SOAs), and ozone are formed when NMHCs reach a certain concentration when exposed to sunlight; these pollutants have negative effects on both human and environmental health (Huang *et al.,* 2014; Liu *et al.,* 2017; Shen *et al.,* 2013;Ahmed *et al.,* 2015; Thoma *et al.,* 2022). Methane is a major contributor to many environmental issues, including those on a worldwide scale, such as global warming (Panopoulou *et al.,* 2018; Song *et al.,* 2012). To improve air quality and decrease ozone pollution, NMHC monitoring needs to be strengthened. Anthropogenic and natural sources both emit hydrocarbons into the atmosphere. Transport, fuel tank emissions, the disposal of solid waste, and other anthropogenic sources are among these sources. The average concentrations of total hydrocarbons are depicted in Table 2. At Durgapur, Arihant Nagar, Nirman Nagar, Lakhmapur, VichodaRayyatwari and Padoli, 1.75 ppm, 1.3 ppm, 1.04 ppm, 0.69 ppm, 1.43 ppm, and 1.31 ppm, respectively. Benzo α Pyrene (BaP) is the main polycyclic aromatic hydrocarbon (PAH) with two or more combined aromatic rings. Benzo[a]pyrene (BaP), which has the molecular formula $C_{20}H_{12}$, is classified as a polycyclic aromatic hydrocarbon (PAH). PAHs are hydrophobic in nature and are characterized by a complicated chemical structure composed of several aromatic nuclei (Seinfeld & Pandis, 1998). Benzo[a]pyrene (BaP) is a secondary chemical that is produced when organic materials are not fully burned and undergo incomplete combustion at temperatures ranging from 300 to 600°C. The primary sources of emissions include local heating systems, automobiles, thermal power stations that use fossil fuels, and industrial activities. Therefore, heavy metals are widely present in the environment, particularly near sources of emissions in affected locations, such as urban and industrial areas (Nielsen *et al.,* 1996). The observed BaP concentrations (Table 2) were 0.16 ng/m^3, 0.07 ng/m^3, 0.06 ng/m^3, 0.12 ng/m^3, 0.07 ng/m^3, and 0.06 ng/m3, respectively, which are less than the permissible limits of the NAAQ Standards of India (BaP: 1 ng/m^3).

Conclusion

With the increasing number of industries and industrial zones, number of vehicles, use of fuel with poor environmental performance and weak environmental legislation, environmental pollution becomes increasingly hazardous. The magnitude of numerous industrial zones situated in urban environments surpasses that of their rural counterparts; consequently, industrial pollution poses a more severe challenge in urban settings. In the present study, the samples were collected and investigated for PM_{10}, $PM_{2.5}$, SO_2, NOx, NH_3, CO, and Pb. Ni, As, BaP, benzene, and total hydrocarbons, including methane and nonmethane hydrocarbons. From the aforementioned findings, it can be determined that while all parameters of ambient air quality monitoring were calculated to fall below the NAAQ standards' permissible limits, there has been an increase in concentration levels that may pose a risk to the health of people living in those particular geographic regions due to ongoing rapid industrialization, urbanization, and vehicular pollution. It is important to control rising levels of air pollution while maintaining a healthy perspective. It is recommended that a substantial belt of green plantation be constructed in the surrounding area. It is advisable to grow trees that are efficient at capturing dust along roadways and to consistently sprinkle water in areas where particulate matter is generated. To reduce emissions and offset the negative impacts that they have on air quality and public health, it is necessary to monitor and manage air pollutants. These efforts should include regulatory measures, technological advancements, and public awareness campaigns on the subject matter.

Conflict of interest

The authors declare that they have no conflicts of interest.

References

Ahmed, E., Kim, K. H., Jeon, E. C., & Brown, R. J. (2015). Long term trends of methane, non methane hydrocarbons, and carbon monoxide in urban atmosphere. *Science of the Total Environment*, 518–519, 595–604.

Ahamad, F. Bhutiani, R. & Ruhela, M. (2022). Environmental Quality Monitoring Using Environmental Quality Indices (EQI), Geographic Information System (GIS), and Remote Sensing: A Review. *GIScience for the Sustainable Management of Water Resources*, 331. (Chapter number-18, 331-348, Almeida, A.A., & Lima, J.L. (1995). Determination of Cd, Cr, Cr, Ni, and Pb in industrial atmospheric particulate matter by ETA-AAS using solid samples directly from trapping filters. *Atomic Spectroscopy*, 16, 261-265.

Arditsoglou, A., & Samara, C. (2005). Levels of total suspended particulate matter and major trace elements in Kosovo: a source identification and apportionment study. *Chemosphere*, 59(5), 669–678.

Baker, A. K., Beyersdorf, A. J., Doezema, L. A., Katzenstein, A., Meinardi, S., Simpson, I. J., Blake, D. R., & Sherwood Rowland, F. (2008). Measurements of nonmethane hydrocarbons in 28 United States cities. *Atmospheric Environment*, 42(1), 170–182.

Bhutiani, R., Kulkarni, D. B., Khanna, D. R., Tyagi, V., & Ahamad, F. (2021). Spatial and seasonal variations in particulate matter and gaseous pollutants around integrated industrial estate (IIE), SIDCUL, Haridwar: a case study. *Environment, Development and Sustainability*, 23(10), 15619-15638.

Borbély Kiss, I., Koltay, E., Szabó, G., Bozó, L., & Tar, K. (1999). Composition and sources of urban and rural atmospheric aerosol in eastern Hungary. *Journal of Aerosol Science*, 30(3), 369–391.

Cheng, Y. H., & Lin, Y. L. (2010). Measurement of Particle Mass Concentrations and Size Distributions in an Underground Station. *Aerosol and Air Quality Research*, 10(1), 22–29.

Clarke, A., Chen, J. M., Pipitsangchand, S., & Azadi-Bougar, G. (1996). Vehicular particulate emissions and roadside air pollution. *Science of the Total Environment*, 189–190, 417–422.

Deogaonkar, S. G. (2007). *The Gonds of Vidarbha*. Concept Publishing Comany.

Dockery, D. W., & Pope, C. A. (1994). Acute Respiratory Effects of Particulate Air Pollution. *Annual Review of Public Health*, 15(1), 107–132.

Fang, G. C., Chang, C. N., Wu, Y. S., Wang, V., Fu, P. P. C., Yang, D. G., Chen, S. C., & Chu, C. C. (2000). The study of fine and coarse particles, and metallic elements for the daytime and night-time in a suburban area of central Taiwan, Taichung. *Chemosphere*, 41(5), 639– 644.

Fang, G. C., Wu, Y. S., Chang, S. Y., Huang, S. H., & Rau, J. Y. (2006). Size distributions of ambient air particles and enrichment factor analyses of metallic elements at Taichung Harbor near the Taiwan Strait. *Atmospheric Research*, 81(4), 320–333.

Finlayson-Pitts, B. J., & Pitts, J. N. (1999). Chemistry of the Upper and Lower Atmosphere. Elsevier.

Gawande, U., Khanvilkar, A., Kadam, S., & Salvitthal, G. (2016). Effects of ambient air pollution on respiratory health of adults: findings from a cross-sectional study in Chandrapur, Maharashtra, India. *International Journal of Research in Medical Sciences*, 1546–1557.

Harrison, R. M., Smith, D., Piou, C., & Castro, L. (1997). Comparative receptor modeling study of airborne particulate pollutants in Birmingham (United Kingdom), Coimbra (Portugal) and Lahore (Pakistan). *Atmospheric Environment*, 31(20), 3309–3321.

Hien, P., Binh, N., Truong, Y., Ngo, N., & Sieu, L. (2001). Comparative receptor modeling study of TSP, PM2 and PM_2– PM_{10} in Ho Chi Minh City. *Atmospheric Environment*, 35(15), 2669–2678.

Huang, R. J., Zhang, Y., Bozzetti, C., Ho, K. F., Cao, J. J., Han, Y., Daellenbach, K. R., Slowik, J. G., Platt, S. M., Canonaco, F., Zotter, P., Wolf, R., Pieber, S. M., Bruns, E. A., Crippa, M., Ciarelli, G., Piazzalunga, A., Schwikowski, M., Abbaszade, G., Prévôt, A. S. H. (2014). High secondary aerosol contribution to particulate pollution during haze events in China. *Nature*, 514(7521), 218–222.

Kumari, S., Jain, M. K., & Elumalai, S. P. (2021). Assessment of Pollution and Health Risks of Heay Metals in Particulate Matter and Road Dust Along the Road Network of Dhanbad, India. *Journal of Health and Pollution*, 11(29).

Liu, C., Ma, Z., Mu, Y., Liu, J., Zhang, C., Zhang, Y., Liu, P., & Zhang, H. (2017). The levels, variation characteristics, and sources of atmospheric nonmethane hydrocarbon compounds during wintertime in Beijing, China. *Atmospheric Chemistry and Physics*, 17(17),10633–10649.

Manik, V. S. and Gudadhe, S. K. (2020). Ambient Air Quality Monitoring Study around the Industrial Areas of Aurangabad, Maharashtra, India. *International Research Journal of Science & Engineering*. Special Issue A7: 642-646.

Mungikar A.M. (2003). *Biostatistical Analysis*. Saraswati Printing Press, Aurangabad. 1-88.

Nielsen, T., Jørgensen, H. E., Larsen, J. C., & Poulsen, M. (1996). City air pollution of polycyclic aromatic hydrocarbons and other mutagens: occurrence, sources and health effects. *Science of the Total Environment*, 189–190, 41–49.

Panopoulou, A., Liakakou, E., Gros, V., Sauvage, S., Locoge, N., Bonsang, B., Psiloglou, B. E., Gerasopoulos, E., & Mihalopoulos, N. (2018, November 9). Nonmethane hydrocarbon variability in Athens during wintertime: the role of traffic and heating. *Atmospheric Chemistry and Physics*, 18(21), 16139–16154.

Ruhela, M., Sharma, K., Bhutiani, R., Chandniha, S. K., Kumar, V., Tyagi, K., & Tyagi, I. (2022a). GIS-based impact assessment and spatial distribution of air and water pollutants in mining area. *Environmental Science and Pollution Research*, 1-15.

Ruhela, M., Maheshwari, V., Ahamad, F., & Kamboj, V. (2022b). Air quality assessment of Jaipur city Rajasthan after the COVID-19 lockdown. *Spatial Information Research*, 30(5), 597-605.

Seinfeld, J. H., & Pandis, S. N. (1998). *Atmospheric Chemistry and Physics*. Wiley-Interscience.

Shen, X., Zhao, Y., Chen, Z., & Huang, D. (2013). Heterogeneous reactions of volatile organic compounds in the atmosphere. *Atmospheric Environment*, 68, 297–314.

Sohrabpour, M., Mirzaee, H., Rostami, S., & Athari, M. (1999). Elemental concentration of the suspended particulate matter in the air of Tehran. *Environment International*, 25(1), 75–81.

Song, P., Geng, F. H., Sang, X. F., Chan, C. Y., Chan, L. Y., & Yu, Q. (2012). Characteristics and sources of nonmethane hydrocarbons and halocarbons in wintertime urban atmosphere of Shanghai, China. *Environmental Monitoring and Assessment*, 184(10), 5957–5970.

Thoma, M., Bachmeier, F., Gottwald, F. L., Simon, M., & Vogel, A. L. (2022). Mass spectrometrybased Aerosolomics: a new approach to resolve sources, composition, and partitioning of secondary organic aerosol. *Atmospheric Measurement Techniques*, 15(23), 7137– 7154.

Tsai, C. J., Shih, T. S., & Sheu, R. N. (1997). Characteristics of Lead Aerosols in Different Work Environments. *American Industrial Hygiene Association Journal*, 58(9), 650–656.

Vadic, V., Fungas, M., 1997. Assessment of air quality in Croatia. *Environmental Research Forum (Air quality management)* 7–8, 593–598.

Valavanidis, A., Fiotakis, K., Vlahogianni, T., Bakeas, E. B., Triantafillaki, S., Paraskevopoulou, V., & Dassenakis, M. (2006). Characterization of atmospheric particulates, particle-bound transition metals and polycyclic aromatic hydrocarbons of urban air in the center of Athens (Greece). *Chemosphere*, 65(5), 760–768.

Wang, M., Shao, M., Chen, W., Lu, S., Liu, Y., Yuan, B., Zhang, Q., Zhang, Q., Chang, C. C., Wang, B., Zeng, L., Hu, M., Yang, Y., & Li, Y. (2015, February 11). Trends of nonmethane hydrocarbons (NMHC) emissions in Beijing during 2002–2013. *Atmospheric Chemistry and Physics*, 15(3), 1489–1502.

Yennawar, P. (1970). Short Term Air Quality Surveys in Four Major Cities of India. *Environmental Health*, 12, 355–383.