Assessment of Spatio-Temporal Variations of Particulate Matter and Gaseous Pollutants in The Port City, Paradip, East Coast of India

Rashmi Ranjan Behera[1,2] Arakshita Majhi[1,2*] Deepty Ranjan Satapathy[1]

[1] CSIR-Institute of Minerals and Materials Technology (CSIR-IMMT), Environment and Sustainability Department, Bhubaneswar, Odisha, India, 751013

[2] Academy of Scientific and Innovative Research (AcSIR), CSIR-Institute of Minerals & Materials Technology (CSIR-IMMT), Bhubaneswar, Odisha, India, 751013

*Corresponding author: arakshita@immt.res.in

doi: https://doi.org/10.21467/proceedings.112.22

ABSTRACT

This study aims to assess the spatial and temporal variations of aerosol pollutants within the nine selected ambient air monitoring stations, including residential, commercial, and industrial sites in Paradip city based on two seasons, i.e., winter and summer, from January 2019 to June 2019. The particulate matter (PM) like PM_{10} and $PM_{2.5}$ and gaseous pollutants like sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and ammonia (NH_3) samples were collected at each monitoring stations. The 24-hour average concentrations of PM_{10} and $PM_{2.5}$ showed the highest levels in the winter season and lowest in the summer season. The value exceeded the permissible limit of India-national ambient air quality standards (IND-NAAQS) at all the monitoring stations. The 24-hour average concentrations of SO_2, NO_2, and NH_3 did not exceed the permissible limits at all the sites during the study period. The air quality was estimated in terms of the air quality index (AQI) by analysing the aerosol pollutants concentration like PM_{10}, $PM_{2.5}$, SO_2, NO_2, and NH_3. Linear regression analysis (LRA) to evaluate the percentage contribution of each aerosol pollutant to AQI. Particulate pollutants such as PM_{10} and $PM_{2.5}$ was the more significant contributor towards AQI during the two seasons. The AQI observed that industrial sites were under the "severe air pollution" category in the winter season. Hierarchical agglomerative cluster analysis (HACA) explains the pollutants dispersion and spatial variations in the Paradip city.

Keywords: Aerosol Pollutants; Spatio-Temporal Variation; Air Quality Index; HACA; Paradip Port City

1 Introduction

Air pollution is one of the significant environmental issue for both developed and developing countries, which influences various health effects in humans' body (Afroz et al.2003; Yang et al. 2004). The increasing health risk is related to particulate matter (PM) elevation, such as PM_{10} and $PM_{2.5}$. The increase of $PM_{2.5}$ concentration is closely related to respiratory and cardiovascular diseases (Araujo, 2011; Kim et al. 2015). Besides, particulate matter plays a significant role in climate change; some aerosol particles maybe scatter or absorb solar radiation, affecting the global atmosphere (Anenberg et al. 2012). Paradip port and its surroundings experience heavy air pollution in the past year due to rapid economic development with fast-growing shipping activity, cargo transportation, and accelerated urbanization. Paradip port is a major seaport situated at Odisha on the east coast of India. The marine ports and surrounding township are related to various environmental issues that significantly affect the air environment through cargo transport, road transport, ship traffic, rail traffic, industry, and usual residential emission. The major materials carried by Paradip port are minerals, coal, iron ore, fertilizer, petroleum products, etc. The anthropogenic emissions of aerosol pollutants in the urban area can change the atmospheric composition in the downwind regimes (Gupta et al. 2008). Therefore, developing nations are a massive challenge in controlling atmospheric pollution. A recent report revealed that about two million people

Proceedings DOI: 10.21467/proceedings.112; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-3-3

die every year due to atmospheric air pollution. Many people suffer from breathing ailments, heart disease, lung infections, and even cancer in developing countries (WHO, 2012). Vehicular emission is mostly responsible for an array of severe health problems in urban areas since it is a source of particulate matter, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and volatile organic compounds (VOC). SO_2 and NO_2 could be transformed to SO_4^{2-} and NO_3^- via gas to particle process under the condition of high relative humidity (RH), which has been proved to cause severe cloud (Niu et al. 2016). Gaseous pollutants like NO_2 could be probable precursors to photo-oxidants such as ozone in ambient air, causing haze pollutions (Zhou et al. 2014). Atmosphere variation is directly associated with air pollution, including particulate matter, sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone, and greenhouse gases (Begum et al. 2013). According to the world health organisation (WHO), India is the second highest country in the number of human death cases after China due to outdoor air pollution. Particulate matter represents a mixture of solid and liquid droplets suspended in the air, a complex mix of carbon, ammonia, nitrates, sulphates, minerals, trace elements, and water (Kavuri and paul, 2013). Particulate matter and gaseous pollutants are considered significant air pollutants in India due to fossil fuel burning (Ghio et al. 2012). The direct impact of aerosol pollutants on plants, animals, and soil can affect ecosystems' function, including self-control ability, thereby changing life quality (WHO 2005). The quick expansion in industrialization and automobile emissions has deteriorated air quality of Paradip city. So, it desires to monitor the ambient air quality of Paradip city regularly. This study represents the air quality assessment in terms of the air quality index (AQI) in between two seasons, i.e., winter-2019 and summer-2019, to know the status of air quality in Paradip city.

2 Materials and methods

2.1 Study area

Paradip is a major seaport city in the Jagatsinghpur district of Odisha, India. Paradip has situated with geographical coordinates of 20.3166° north latitude and 86.6114° east longitude. This city covers 18 municipal wards, and the Paradip municipal corporation population is 68,585 as per the 2011 census. This city is a central industrial hub due to the largest seaport in eastern India. There are major industries such as Paradip phosphates limited (PPL), ESSAR steel plant, IFFCO fertiliser plant, Indian oil corporation limited (IOCL), Bharat petroleum corporation limited (BPCL), and Hindustan petroleum corporation limited (HPCL) are also situated in Paradip city. In this study, atmospheric aerosol samples were collected from nine different sampling stations based on industrial, commercial, and residential activities. The stations like AB (S1), MPH (S2), BPH (S3), AG (S4) & NBPH (S5) are present outside of the port, and MS (S6), GGPH (S7), G-2 (S8), and G-3 (S9) present inside the port. The details of all monitoring locations are shown in Table 1 and Fig. 1.

Table 1 Air quality monitoring stations

Sl. No.	Station Code	Station Name	Latitude	Longitude	Category
1	S1	Administrative Building (AB)	20° 16' 07" N	86° 39' 24" E	Commercial
2	S2	Madhuban Pump House (MPH)	20° 16' 06" N	86° 39' 00" E	Residential
3	S3	Brundaban Pump House (BPH)	20° 16' 28" N	86° 38' 55" E	Residential
4	S4	Atharabanki Gate (AG)	20° 17' 27" N	86° 39' 01" E	Commercial
5	S5	Naya Bazaar Pump House (NBPH)	20° 15' 41" N	86° 39' 40" E	Commercial
6	S6	Marine Site (MS)	20° 16' 13" N	86° 40' 05" E	Industrial
7	S7	Ghana Ghalia Pump House (GGPH)	20° 17' 06" N	86° 40' 25" E	Industrial
8	S8	Gate No-2 (G-2)	20° 17' 20" N	86° 39' 22" E	Industrial
9	S9	Gate No-3 (G-3)	20° 16' 54" N	86° 39' 24" E	Industrial

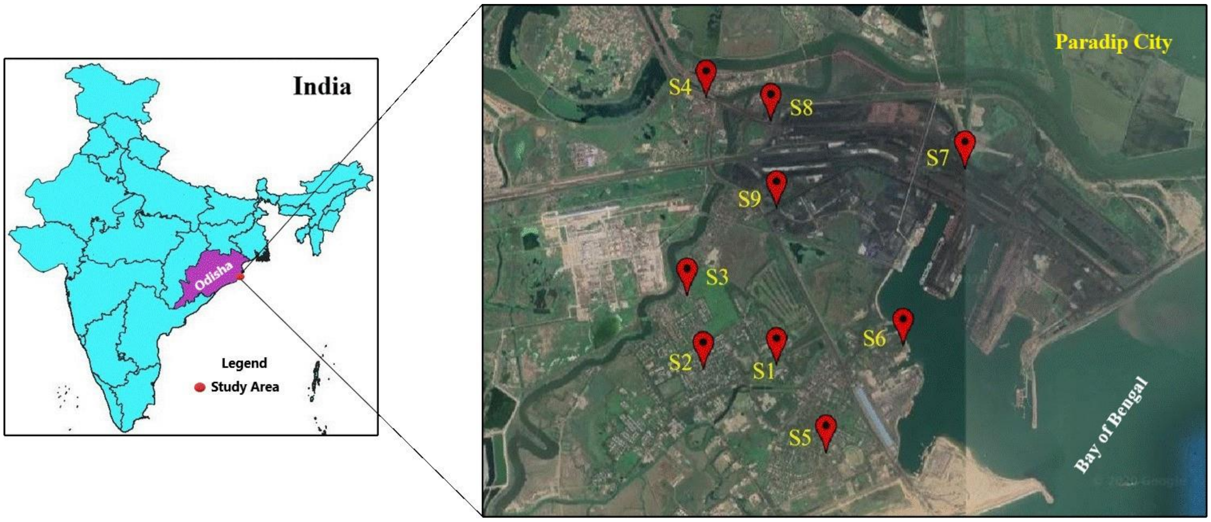

Fig. 1 Location of air quality monitoring stations in Paradip city.

2.2 Sampling and analysis

The ambient air sampling was carried out in two different seasons, i.e., winter (January-February 2019) summer (March-June 2019), to know the variation of air quality in Paradip city. The PM_{10} (particulate matter less than 10μm aerodynamic diameter) and $PM_{2.5}$ (particulate matter less than 2.5μm aerodynamic diameter) samples were collected on a rooftop (3m above the ground level) using a respirable dust sampler (Model: RDS-APM 460 NL, Envirotech) and fine particulate sampler (Model: APM 550 MFC, Envirotech). The sampler was run continuously for twenty-four-hour at an average flow rate of 1132 L/min and 16.7 L/min using glass fiber filter paper (Whatman) and Polytetrafluoroethylene (PTFE) membrane filter paper (Whatman), respectively. The filter papers used in this study were kept in controlled environmental conditions in a desiccator with the temperature at 20±5°C and relative humidity at 40±5% for 24 hr pre- and post-the collection of samples. These filter papers were weighed using an analytical microbalance (Model: Sartorius CPA225D, Germany) with a regarding precious of 10μg, and filter papers were kept in an airtight envelope to avoid contamination after sampling. The gaseous species like sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and ammonia (NH_3) were also collected from each location using thermo-electrically cooled gaseous sampling attachment (Model: APM 411 TE, Envirotech) at an average flow rate of 1L/min. The details of methods used for the sampling and analysis are shown in Table 2.

Table 2 Details of methods and standards used in analysis

Sl. No.	Pollutants	Methods of analysis	Standard value in μg/m³ for 24hr	
			NAAQS, India	NAAQS, US
1	Particulate matter as PM_{10}	Gravimetric method (CPCB, 2012)	100	150
2	Particulate matter as $PM_{2.5}$	Gravimetric method (CPCB, 2012)	60	35
3	Sulphur dioxide as SO_2	Improved West and Gaeke Method (CPCB, 2012)	80	-
4	Nitrogen dioxide as NO_2	Modified Jacob and Hochheiser Method (CPCB, 2012)	80	-
5	Ammonia as NH_3	Indophenol Method (CPCB, 2012)	400	-

The PM_{10} and $PM_{2.5}$ mass concentrations were determined gravimetrically by measuring the difference between pre-weight and post-weight filter paper. Gaseous pollutants like sulphur dioxide, nitrogen dioxide, and ammonia concentrations were measured using the modified West & Gaeke method, modified Jacob & Hochheiser method, and the Indophenol method using UV-Visible spectrophotometers (Model: Varian carry 50, US) as per IND-NAAQS (CPCB, 2012).

2.3 Air quality index (AQI)

The air quality index (AQI) is a measure of the aerosol pollutants concentration to know the status and trend of ambient air in different locations based on specific standards (Ziauddin and Siddiqui, 2006; Joshi and Semwal, 2011). The AQI is a vital tool for evaluating and representing air quality status homogeneously (Swamee and Tyagi, 1999). The cumulative impact of the concentration of different pollutants is often expressed through a single value in the form of AQI. The AQI was calculated using the following equation (1) given by Rao and Rao (1998).

$$AQI = 1/5\,(aPM_{10}/sPM_{10} + aPM_{2.5}/sPM_{2.5} + aSO_2/sSO_2 + aNO_2/sNO_2 + aNH_3/sNH_3) \times 100 \qquad (1)$$

Where, a: Actual Value, s: Standard Value. The actual values of aerosol pollutants were measured using the sampling data, and the standard values of aerosol pollutants are given in Table 2.

2.4 Statistical analysis

The statistical analysis was performed using the SPSS version 20.0 software package for the air quality data obtained from nine selected locations in Paradip city. All the graphs were made using the origin software version 2019b.

3 Results and discussion

3.1 Variation of aerosol pollutants

The statistics of the aerosol pollutants i.e., PM_{10}, $PM_{2.5}$, SO_2, NO_2, and NH_3 which includes minimum, maximum, mean, and standard deviation are given in Table 3. The temporal variations of pollutants in the winter and summer seasons are represented in Fig. 2. The results indicated that the particulate matter concentration (PM_{10} and $PM_{2.5}$) exceed the prescribed limits (Table 2) of the IND-NAAQS and US-NAAQS at all the stations during the winter and summer seasons.

Table 3 Statistics of pollutants in μg/m^3 during the winter and summer season in Paradip city (Min= Minimum, Max= Maximum, SD= Standard deviation)

Pollutants	Seasons	Statistics			
		Min	Max	Mean	SD
PM_{10}	Winter	124.86	633.84	297.10	189.94
	Summer	86.23	477.54	190.62	126.77
$PM_{2.5}$	Winter	72.23	294.97	159.97	82.07
	Summer	45.92	232.13	110.85	62.96
SO_2	Winter	1.46	9.41	3.89	2.33
	Summer	1.13	20.88	9.03	7.43
NO_2	Winter	1.71	15.37	5.63	4.49
	Summer	1.18	5.09	2.41	1.31
NH_3	Winter	7.27	21.68	15.61	4.96
	Summer	3.57	17.09	11.27	4.61

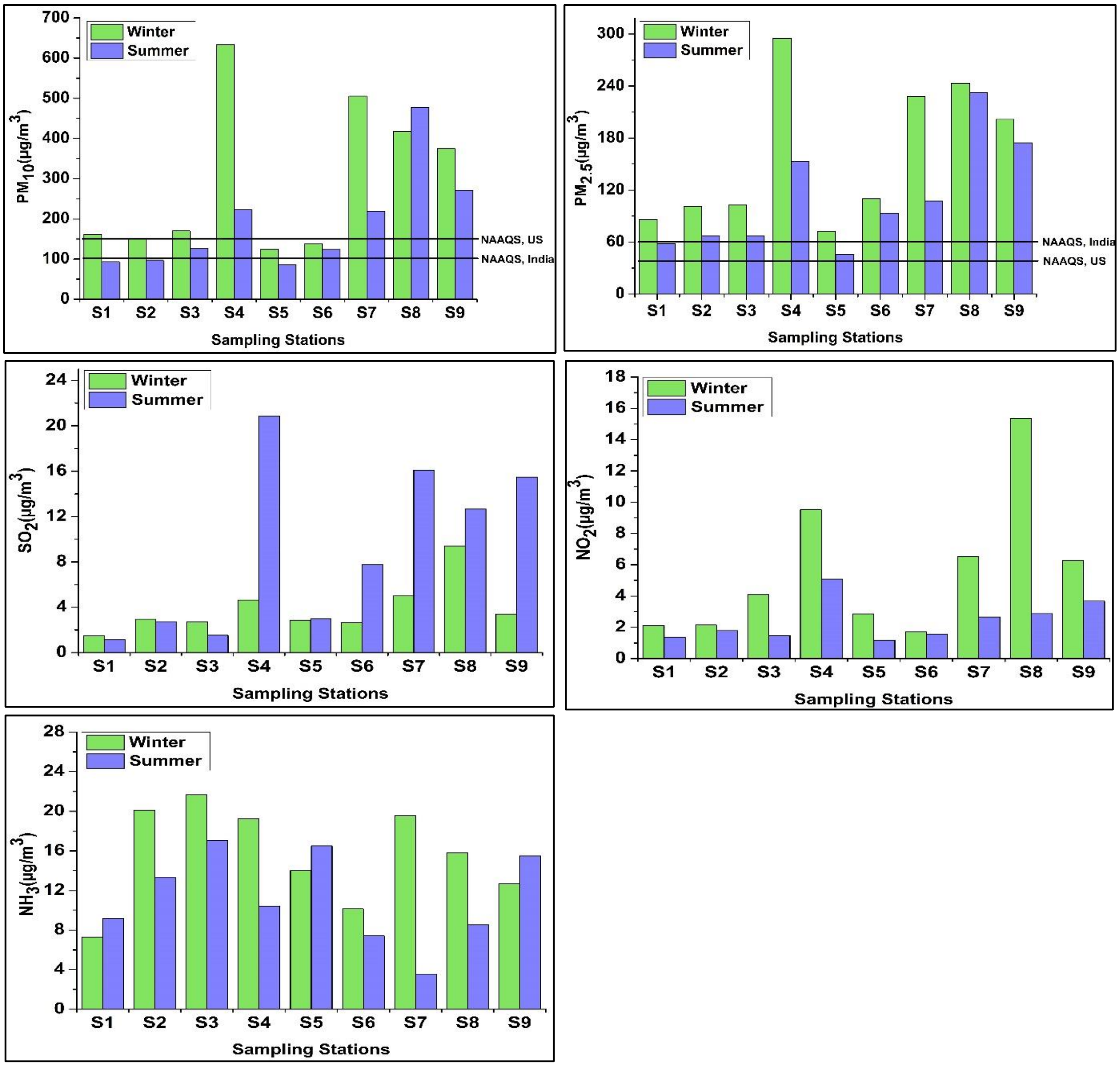

Fig. 2 Station wise variations of aerosol pollutants in winter and summer season at Paradip city.

The PM_{10} concentration was ranged between 86.23 μg/m^3 to 663.84 μg/m^3 during the study period. The highest PM_{10} concentration was measured in the Atharabanki gate (AG) station (633.84 μg/m^3) in the winter season due to large numbers of heavy vehicle movements, transportation of coal and iron ore into the port through AG occur. During the winter season, all the monitoring stations experienced light wind speed and low temperature, resulting longer retention time of particulates in the atmosphere causes a higher level of particulate matter concentrations (Dadhich et al. 2018). The lowest PM_{10} concentration was measured in Naya bazar pump house (NBPH) station (86.23 μg/m^3) in the summer season. Similarly, the highest $PM_{2.5}$ concentration was measured in the Atharabanki gate (AG) station (294.97 μg/m^3) in the winter season. The maximum $PM_{2.5}$ concentrations in the winter season are possibly contributed by biomass burning, coal combustion, less rainfall, lower temperature, lower boundary layer height, and less wind flow (Che et al. 2014). The lowest $PM_{2.5}$

concentration was measured in the Nayabazar pump house (NBPH) station (45.92 μg/m³) in the summer season.

Among residential, commercial, and industrial sites, the maximum SO_2 concentration was observed in the commercial station, i.e., AG (20.88 μg/m³) during the summer season. This may be due to emission from fossil fuel combustion and industrial boiler, which possibly contributed to the increase of SO_2 (Zhang et al. 2009). The maximum NO_2 concentration was observed in the industrial station, i.e., G-2 (15.37 μg/m³) during the winter season. This may be due to many vehicular movements, fossil fuel combustion, and low rainfall in the winter season. The major source of NO_2 in Paradip city due to more industrial activities and the number of automobiles. The highest NH_3 concentration was observed in the winter season at the residential station, i.e., BPH (21.68 μg/m³), and the lowest one in the summer season at the industrial station, i.e., GGPH (3.57 μg/m³). The average NH_3 concentration gradually increases in the order of Industrial site < Commercial site < Residential site, due to anthropogenic activities like agricultural activity, including fertilizer use, domestic sources, animal waste, vegetation, and livestock in the residential area. Overall, it has been observed that the 24-hour averaged concentrations of gaseous pollutants such as SO_2, NO_2, and NH_3 did not exceed the permissible limit set by NAAQS of India (Table 2) during the study period.

3.2 Variation of AQI

The AQI for all the nine sampling stations in the winter and summer seasons is shown in Fig. 3. The AQI value of industrial areas was found higher than the residential and commercial areas. The highest AQI was measured at a commercial station, i.e., AG (AQI=229.60) in the winter season during the study period. Based on AQI, it has been observed that the industrial station, i.e., GGPH, G-2, & G-3, and one commercial station, i.e., AG was under the "severe air pollution" category (AQI > 100) in both the season. Other sites, i.e., AB, MPH, BPH, NBPH, and MS were under the "moderate air pollution" category (AQI=51-75) in the winter season. In the summer season, the stations like AB, MPH, BPH, and NBPH were under the "light air pollution" category (AQI=26-50). The concentrations of AQI in Paradip city decreased from winter > summer during the study period, suggesting the air quality was observed good in the summer season and worst in the winter season.

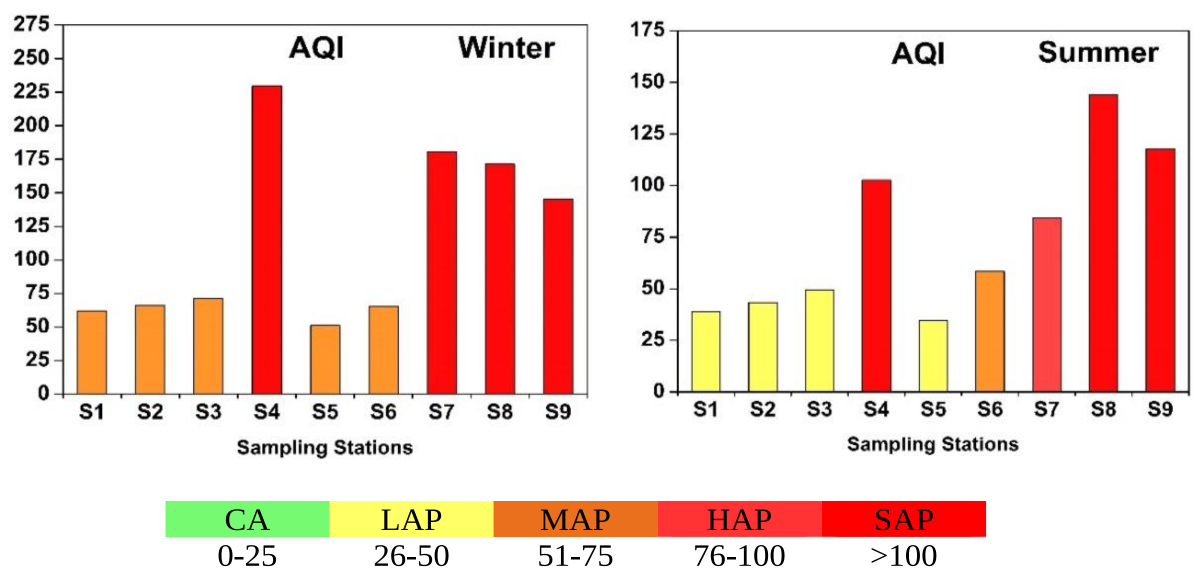

Fig. 3 Variation of AQI in Paradip city (CA= Clean air, LAP= Light air pollution, MAP= Moderate air pollution, HAP= Heavy air pollution, SAP= Severe air pollution).

3.3 Linear regression analysis (LRA)

Linear regression analysis of air quality index (AQI) with five pollutants was carried out to evaluate the relationship between the pollutant contribution towards the AQI and shown in Fig. 4. A significant strong positive relationship was observed between AQI with PM_{10} concentrations (R^2= 0.965) and AQI with $PM_{2.5}$ concentrations (R^2= 0.972) in the Paradip city, which indicated that the concentration of particulate matter (PM_{10} and $PM_{2.5}$) was more responsible towards the AQI in the Paradip city. A significant week positive relationship was observed between AQI with SO_2 concentrations (R^2= 0.089), AQI with NO_2 concentrations (R^2= 0.630), and AQI with NH_3 concentrations (R^2= 0.071) during the study period.

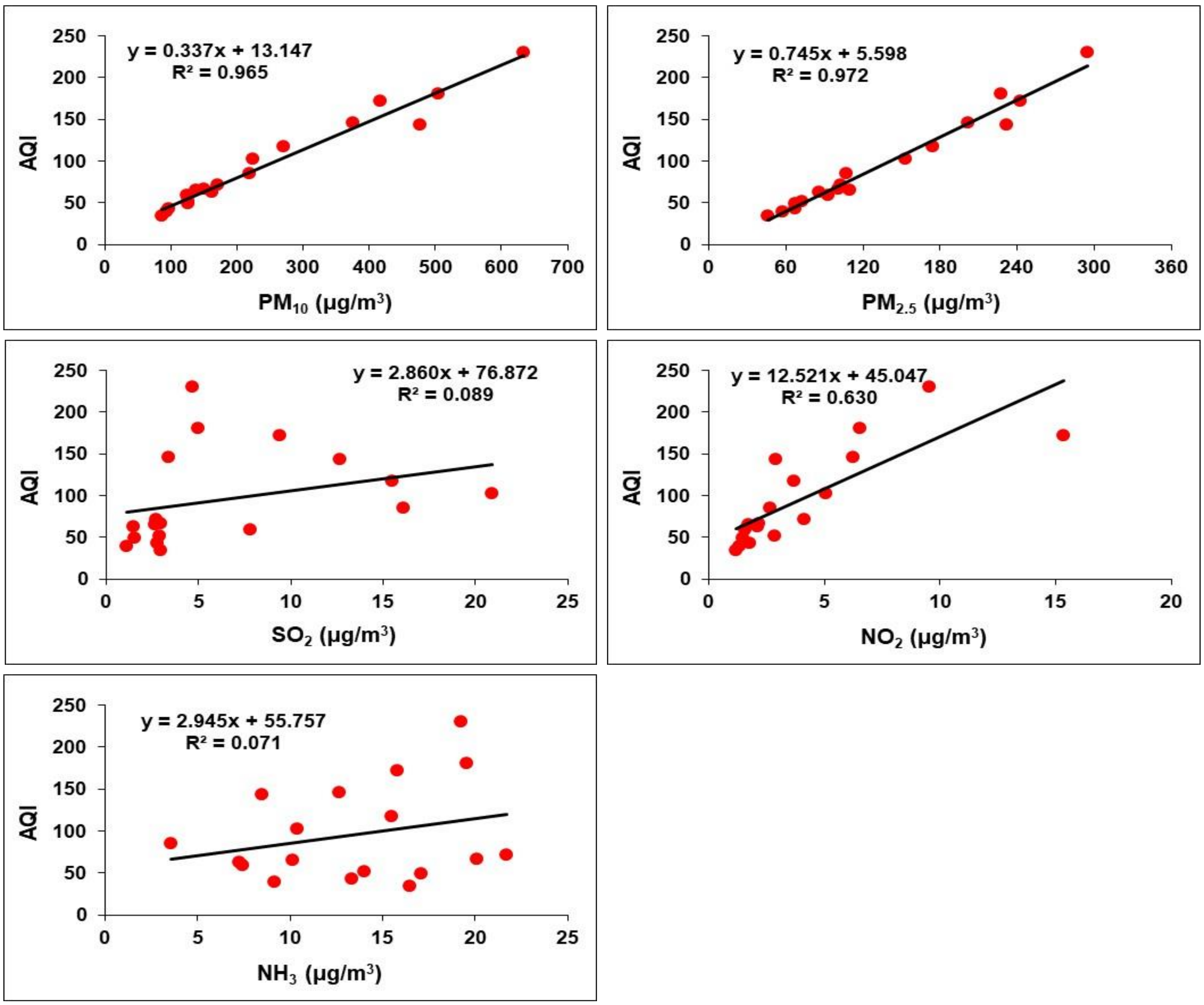

Fig. 4 Scatter plot diagram of the individual contribution of air pollutants to AQI.

The percentage contribution of air pollutants, i.e., PM_{10}, $PM_{2.5}$, SO_2, NO_2, and NH_3, towards AQI in both seasons are represented in Fig. 5. In two seasons, particulate pollutants such as PM_{10} and $PM_{2.5}$ was the greater contributor to AQI. About 95% of particulate pollutants contributed towards AQI in the winter season, which was the highest percentage during the study period. The results summarized that PM_{10} and $PM_{2.5}$ predominantly influenced air pollution in Paradip city.

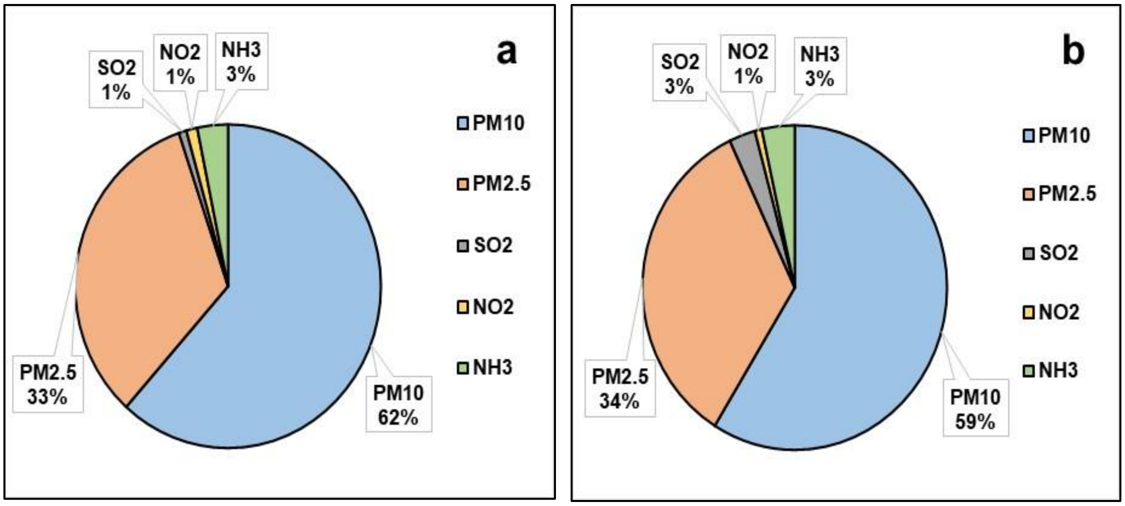

Fig. 5 Percentage contribution of pollutants towards AQI (a) winter (b) summer in paradip city.

3.4 Hierarchical agglomerative cluster analysis (HACA)

The dendrogram plots indicated the relationship among the monitoring stations in the Paradip city are subjected to hierarchical cluster analysis (rescaled distance cluster combine) using Ward's method (linkage between groups) with Euclidean distance (Fig. 6). The parameters like PM_{10}, $PM_{2.5}$, SO_2, NO_2, and NH_3 were used as variables and showed a sequence in their association and the degree of pollution into the stations. In the winter season, the stations, i.e., S1 and S9, S4 and S7, S3 and S5, formed three clusters, while other stations did not show any proper clustering (Fig. 5a). Similarly, in the summer season, the stations like S7 and S8; S3 and S5; S1 and S2; S4 and S9 formed four clusters, although the other one station, i.e., S6, do not show clustering (Fig. 5b). From the results of HCA, it was quite clear that a mixed cluster was found during the study period, which indicated relatively high pollution due to industrial activities, port activities, loading and unloading operations, and movements of heavy vehicles in these regions. On the other hand, the stations such as S1, S2, S3, and S5 showed comparatively less pollution attributed to residential activities and light automobile movements in such stations.

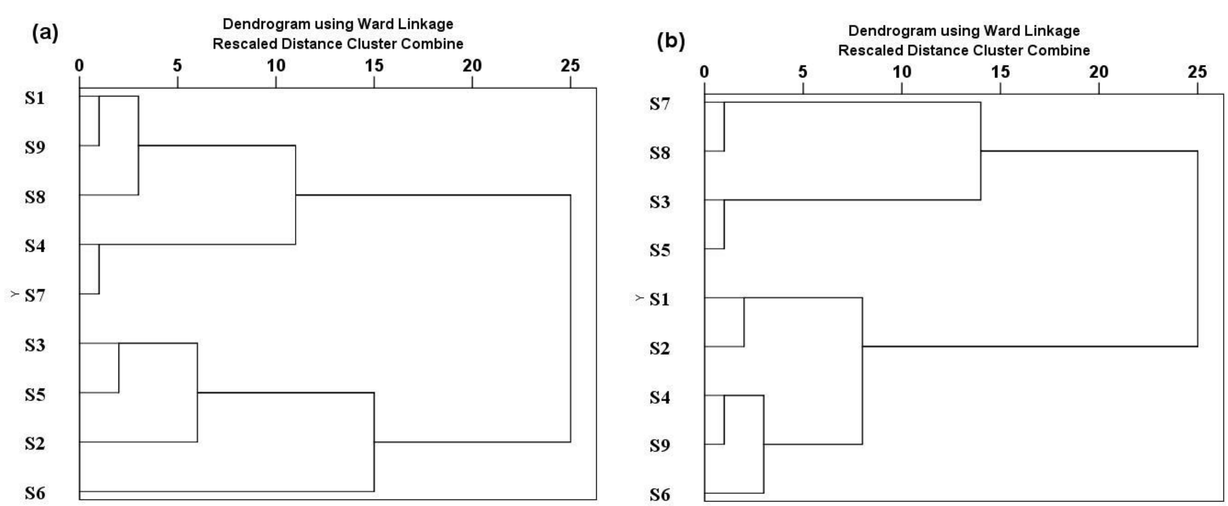

Fig. 6 Dendrogram resulting in the cluster analysis of different air monitoring sites during (a) winter and (b) summer.

4 Conclusion

The ambient air quality study of Paradip city in terms of the air quality index (AQI) was assessed by monitoring the quantum of particulate matter and gaseous air pollutants in the nine stations during the winter and summer seasons. The concentrations of PM_{10} and $PM_{2.5}$ exceeded the IND-NAAQS and US-NAAQS for all of the stations during the study period. The particulate matter (PM_{10} and $PM_{2.5}$) showed the highest levels in the winter and lowest levels in the summer season. However, the gaseous pollutants (SO_2, NO_2, and NH_3) were well within the permissible limit at all stations. From the air quality index (AQI) values, it was found that the industrial areas were found high AQI than the residential and commercial areas. The AQI showed a strong positive correlation with particulate pollutants (PM_{10} and $PM_{2.5}$), and a week positive correlation with gaseous pollutants (SO_2, NO_2, and NH_3). About 95% of particulate pollutants contributed towards AQI in the winter season, which was the highest percentage during the study period. HACA showed that the pollution behaviour of stations changed in different sampling periods. To control the particulate matter concentrations within a tolerable level, it is suggested that huge green plantation must be taken up in the whole city, trees having high dust trapping efficiency are to be planted along the roadside and water is to be sprinkled continuously at the source of generation of particulate matter immediately.

5 Acknowledgments

The authors wish to acknowledge the Chairman, Paradip Port Trust (PPT), Ministry of Shipping, Government of India, for providing financial assistance. The authors also wish to acknowledge Professor Suddhasatwa Basu, Director, CSIR- Institute of Mineral and Materials Technology (IMMT), Bhubaneswar, Government of India, for his kind support to accomplish the present work.

How to Cite this Article:

Behera, R. R., Majhi, A., & Satapathy, D. R. (2021). Assessment of Spatio-Temporal Variations of Particulate Matter and Gaseous Pollutants in The Port City, Paradip, East Coast of India. *AIJR Proceedings*, 179-188.

References

Afroz, R., Hassan, M.N. and Ibrahim, N.A. (2003). *Review of air pollution and health impacts in Malaysia*. Environmental research, 92(2), 71-77.

Anenberg, S.C., Schwartz, J., Shindell, D., Amann, M., Faluvegi, G., Klimont, Z., Janssens-Maenhout, G., Pozzoli, L., Van Dingenen, R., Vignati, E. and Emberson, L. (2012). *Global air quality and health co-benefits of mitigating near-term climate change through methane and black carbon emission controls*. Environmental health perspectives, 120(6), 831-839.

Araujo, J.A. (2011). *Particulate air pollution, systemic oxidative stress, inflammation, and atherosclerosis*. Air Quality, Atmosphere & Health, 4(1), 79-93.

Begum, B.A., Hopke, P.K. and Markwitz, A. (2013). *Air pollution by fine particulate matter in Bangladesh*. Atmospheric Pollution Research, 4(1), 75-86.

Central Pollution Control Board (CPCB) (2009). *National Ambient Air Quality Standards (NAAQS)*. Gazette Notification, New Delhi, India. https://scclmines.com/env/DOCS/NAAQS-2009.pdf.

Central Pollution Control Board (CPCB) (2012). *Guidelines for the measurement of Ambient Air Pollutants. Volume-I*. Gazette Notification, New Delhi, India. http://indiaenvironmentportal.org.in/files/NAAQSManualVolumeI-1.pdf.

Che, H., Xia, X., Zhu, J., Li, Z., Dubovik, O., Holben, B., Goloub, P., Chen, H., Estelles, V., Cuevas-Agulló, E. and Blarel, L. (2014). *Column aerosol optical properties and aerosol radiative forcing during a serious haze-fog month over North China Plain in 2013 based on ground-based sun photometer measurements.* Atmospheric Chemistry and Physics, 14(4), 2125-2138.

Dadhich, A.P., Goyal, R. and Dadhich, P.N. (2018). *Assessment of spatio-temporal variations in air quality of Jaipur city, Rajasthan, India.* The Egyptian Journal of Remote Sensing and Space Science, 21(2), 173-181.

Ghio, A.J., Carraway, M.S. and Madden, M.C. (2012). *Composition of air pollution particles and oxidative stress in cells, tissues, and living systems*. Journal of Toxicology and Environmental Health, Part B, 15(1), 1-21.

Gupta, A.K., Karar, K., Ayoob, S. and John, K. (2008). *Spatio-temporal characteristics of gaseous and particulate pollutants in an urban region of Kolkata, India*. Atmospheric research, 87(2), 103-115.

Joshi, P.C. and Mahadev, S. (2011). *Distribution of air pollutants in ambient air of district Haridwar (Uttarakhand), India: A case study after establishment of State Industrial Development Corporation*. International Journal of Environmental Sciences, 2(1), 237-258.

Kavuri, N.C. and Paul, K.K. (2013). *Chemical characterization of ambient PM10 Aerosol in a steel city, Rourkela, India*. Research Journal of Recent Sciences, 2(1), 32-38.

Kim, K.H., Kabir, E. and Kabir, S. (2015). *A review on the human health impact of airborne particulate matter.* Environment international, 74, 136-143.

Niu, H., Hu, W., Zhang, D., Wu, Z., Guo, S., Pian, W., Cheng, W. and Hu, M. (2016). *Variations of fine particle physiochemical properties during a heavy haze episode in the winter of Beijing*. Science of the Total Environment, 571, 103-109.

Rao, M.N., Rao, H.N.V.: Air Pollution. Tata McGraw Hill Publishing Company Limited, New Delhi (1998).

Swamee, P.K. and Tyagi, A. (1999). *Formation of an air pollution index*. Journal of the Air & Waste Management Association, 49(1), 88-91.

United states Environmental protection Agency (US EPA) (1990). https://www.epa.gov/criteria-air-pollutants/naaqs-table.

World Health Organization (WHO) (2005). *Air quality guidelines global update*. https://www.who.int/airpollution/publications/aqg2005/en/.

World Health Organization (WHO) (2012). *Air quality and health*. Fact sheet Number 313, Updated September 2011. http://www.who.int/mediacentre/factsheets/fs313/en/ Accessed on Mar 2012.

Yang, C.Y., Chang, C.C., Chuang, H.Y., Tsai, S.S., Wu, T.N. and Ho, C.K. (2004). *Relationship between air pollution and daily mortality in a subtropical city: Taipei, Taiwan*. Environment international, 30(4), 519-523.

Zhou, R., Wang, S., Shi, C., Wang, W., Zhao, H., Liu, R., Chen, L. and Zhou, B. (2014). *Study on the traffic air pollution inside and outside a road tunnel in Shanghai, China*. PloS one, 9(11), e112195.

Ziauddin, A. and Siddiqui, N.A. (2006). *Air quality index (AQI)-A tool to determine ambient air quality*. Pollution research, 25(4), 885-887.

Zhang, Q., Streets, D.G., Carmichael, G.R., He, K.B., Huo, H., Kannari, A., Klimont, Z., Park, I.S., Reddy, S., Fu, J.S. and Chen, D. (2009). *Asian emissions in 2006 for the NASA INTEX-B mission.* Atmospheric Chemistry and Physics, 9(14), 5131-5153.