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# Spatio-temporal analysis of sensor based air pollutants in Raipur city, India

***Vinit Lambey*, A. D. Prasad***

Civil Engineering Department, National Institute of Technology Raipur, Raipur, India

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**CORRESPONDING AUTHOR:**

vinitlambey39@gmail.com
Tel: (+91 771) 2255920
Fax: (+91 771) 2255920

**ABSTRACT**

**Introduction:** Particulate matter pollutants and gaseous pollutants are some of the most hazardous pollutants released into the atmosphere. In order to determine how these pollutants impact the living being at breathing height, the current study measures these pollutants using wireless sensors at a height of 1 m above the ground.

**Materials and methods:** In this study, horizontal monitoring of the air pollutants using wireless sensors at twenty-four locations covering four zones including industrial, residential, public-place and transportation of the Raipur city has been evaluated. Spatial variation has been obtained using Inverse Distance Weighting (IDW) method in Geographic Information System (GIS).

**Results:** The obtained results indicate that as compared to the monsoon and post-monsoon seasons, the concentrations of air pollutants are highest in the winter. It was observed that Particulate Matters ($PM_{2.5}$ and $PM_{10}$) are the main causes of declining air quality, but Nitrogen dioxide ($NO_2$) and Sulfur dioxide ($SO_2$) concentrations were below Central Pollution Control Board (CPCB) guidelines except for $NO_2$ in winter. The Carbon monoxide (CO) concentration has been above the standard limit in all three seasons. The main finding of this study is to evaluate how air contaminants vary in space and time near the ground surface which is not possible through the static monitoring instruments in the study area.

**Conclusion:** The primary benefit of the obtained results is their great resolution in a compact area, effectively addressing the air quality issue. The findings suggest that seasonality has a substantial impact on the amount of pollutants in the city. According to the temporal distributions of the air pollutants, monsoon had the best air quality, followed by post-monsoon while the winter season has the highest concentration of pollution.

## Introduction

Many countries around the globe are very concerned about air pollution. The health of people is significantly impacted by atmospheric pollutants; they have been linked to a number of respiratory and cardiovascular conditions as well as cancer when exposed for long periods of time [1]. Nitrogen dioxide ($NO_2$), Sulfur dioxide ($SO_2$), Carbon monoxide (CO), and Particulate Matters (PM), and Ozone ($O_3$) are the main pollutants accounted for the failing air quality [2]. The poor air quality in urban areas is mainly due to population growth, increase in

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construction activity, poor road infrastructure, poor fuel quality and a high traffic density [3-5]. Pollutants can be transported by air over great distances. A barrier that leads to the deposition of pollutants is created by irregular topography and large buildings. In order to accurately represent actual events and provide information on how infrastructure affects the accumulation of pollutants, frameworks of pollution movement and dissemination in metropolitan areas have been developed [6]. Pollutant transport has been linked to so-called "street canyons", where streets are bordered by relatively high rise buildings [7, 8]. The arrangement and proportionality of the geometry of the roads, the shapes of the buildings, the pollution source (elevation and position), and the course of wind speed, all influence the movement of pollutants [6]. Field investigations are a crucial source of data because complexity of the phenomena and number of parameters to be evaluated need to be considered [9-12].

Presently, networks of static monitoring stations managed by the government agencies to monitor the air pollution. These stations are quite trustworthy and are able to measure a variety of air contaminants with accuracy. As it does not account for all places and activities that contribute to an individual's exposure, fixed station monitoring tends to underestimate personal exposure and does not offer spatial changes of pollutant concentrations across the city [13, 14]. The air quality data from these stations do not accurately reflect the air quality in areas with high traffic and narrow streets. Therefore, the analysis of health risks cannot be done with the current stationary monitoring network. Due to high installation and operating cost, the number of monitoring stations in an urban area are limited. In order to increase the spatial and temporal resolution of air quality data for both scientific and public awareness, it is necessary to supplement the current network of air quality monitoring systems with adaptable and cost-effective alternative technologies [15]. The current study includes measurement of $PM_{10}$, $PM_{2.5}$, CO, $SO_2$, and $NO_2$ having higher spatial and temporal resolution using wireless sensor-based monitoring system at an elvation of 1 m above ground level to observe the impact of these pollutants on the living being at breathing height. The principal objective of the study is to evaluate how air contaminants vary in space and time near the ground surface which is not possible through the static monitoring instruments in the study area. In past, studies has been done on the location specific observation of air pollutant [16, 17] but there has no study on individual exposure to air pollutants near the ground level. Hence this study is required for estimating the risk of air pollutant on individual in a micro-environment in an urban area. In this work, a technique for assessing and interpreting the observations related to analysis of the spatial quality of the air has been described. The major advantage of monitoring system used in this study is that it is mobile and can be used ay any place without help of any skilled person. The major drawback of this system is the requirement of the calibration of the sensors on the regular basis (twice in a month).

## Materials and methods

### *Study area*

On the western bank of the Mahanadi river, Raipur is located. It extents from 21°11'22" N to 21°20'02” N and 81°32'20” E to 81°41'50” E, respectively. The elevation of the city ranges from 219 to 322 metres above mean sea level. It has a generally level topography with a few high areas that slope northwest. The tropical climate in Raipur features both wet and dry seasons. Around 27°C is the average yearly temperature. Temperatures may approach 45°C in May. Annual rainfall is around 1330 mm approximately. The four seasons in Raipur are summer (March–May), monsoon (June–September), post–monsoon (October–November), and winter (December–February) (https://www.mausam.imd.gov.in). Fig. 1 shows the study area.

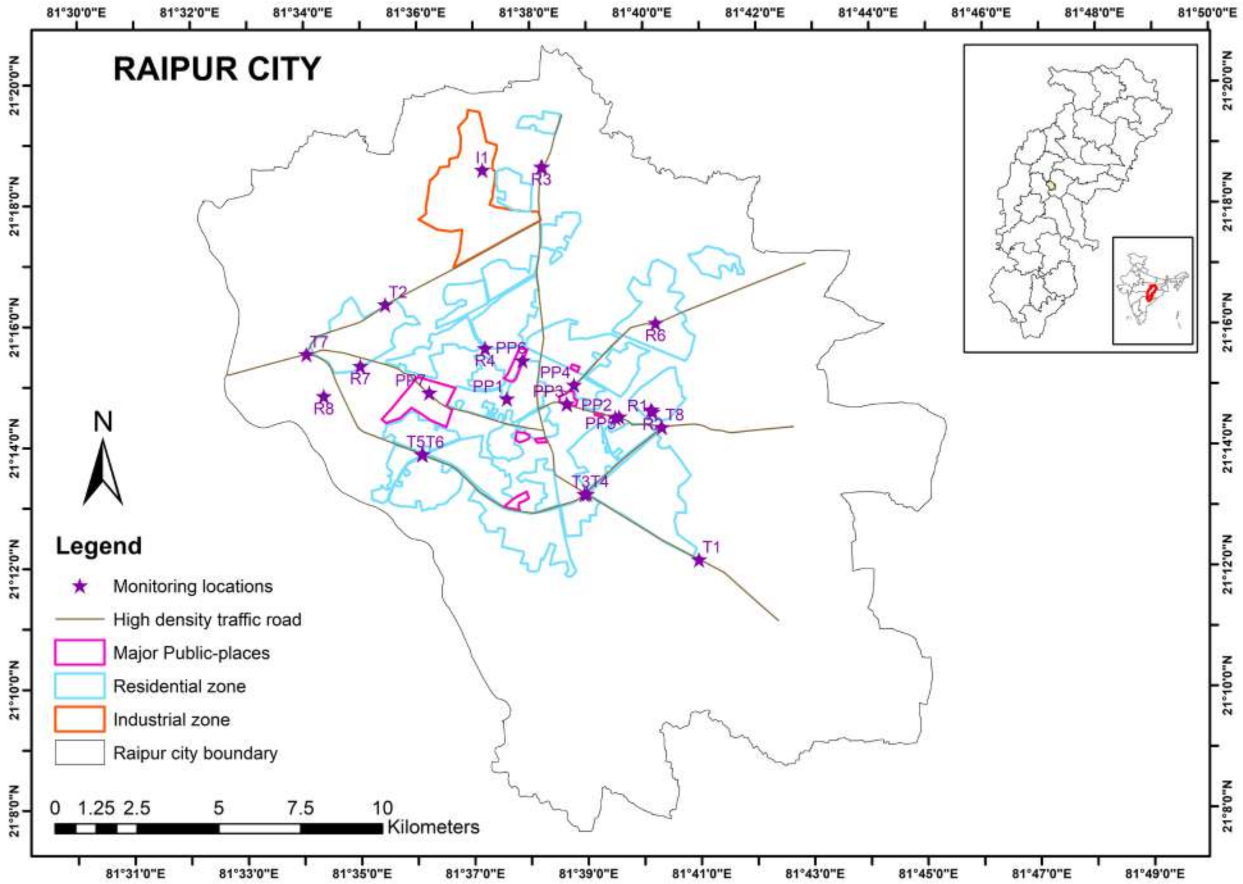


Fig. 1. Study area

### Methodology

The general methodology used in this work is depicted in Fig. 2. The monitoring system comprises of wireless sensors which mainly includes Alphasense B43F sensor for $NO_2$, SPEC sensor for $SO_2$, Plantower PMS7003 sensor for $PM_{2.5}$, $PM_{10}$ and MQ7 for CO. The collocation method has been used to assess the sensor's reliability [18-20]. The sensors have been placed at the same place where the fixed instrument has been placed and both has been operated for the same time interval. By altering the sensor's parameters, the data accuracy of the sensor has been increased after comparison with fixed instrument data. Using the Horiba APSA 370, a device that relies on the ultraviolet fluorescence approach, $SO_2$ has been measured for the purposes of the current study. The Horiba APNA 370 (based on the chemiluminescence approach) equipment was used to measure $NO_2$, and the Met One Instruments BAM 1020 (based on the beta attenuation method) device was used to monitor the concentration of particulate matter. All the above specified instruments are considered as standard tools to reference in this work.

The study area has been categorised into industrial zone, residential zone, transportation zone and public place zone. All 24 monitoring locations that are spread out throughout the city and fall under the aforementioned zones have had their pollution levels monitored at 1 m above ground level. This elevation has been chosen because according to the guidelines of United States Environmental Protection Agency (USEPA), the gas sensor should be kept 0.9-1.8 m above ground level for monitoring air pollutants. The main reason for selection of the monitoring location is its exposure to the air pollution which is caused due to various anthropogenic activities. Since the Raipur city is the capital city of Chhattisgarh state in India, there has been high growth of industries which surrounds the city which is one of the cause of air pollution.. Also a new capital city (known as Naya Raipur) is under development besides the existing city due to which there is large movement of vehicles causing air pollution. Table 1 lists the zone wise air pollution monitoring locations in study area, along with a description and nomenclature for each location. The monitoring has been done for a time period of six months (July 2021 to Janaury 2022) on daily basis.

Table 1. Zone wise monitoring locations

| | Monitoring Locations | | |
|---|---|---|---|
| Zone | Description (Nomenclature) | Latitude (N) | Longitude (E) |
| Residential | Avanti Vihar house roof (R1) | 21° 14' 33.828'' | 81° 40' 09.624'' |
| | Avanti Vihar road (R2) | 21° 14' 34.130'' | 81° 40' 09.454'' |
| | DM Tower at Bilaspur highway (R3) | 21° 18' 37.476'' | 81° 38' 13.524'' |
| | Gudiyari (R4) | 21° 15' 39.758'' | 81° 37' 12.201'' |
| | Kuhera (R5) | 21° 09' 18.288'' | 81° 48' 19.008'' |
| | Mowa (R6) | 21° 16' 01.941'' | 81° 40' 12.928'' |
| | Residence near AIIMS (R7) | 21° 15' 20.304'' | 81° 34' 59.736'' |
| | Sarona (R8) | 21° 14' 50.564'' | 81° 34' 20.953'' |
| Industrial | Urla (I1) | 21° 18' 34.488'' | 81° 37' 09.868'' |
| Public Place | Agrasen Chowk (PP1) | 21° 14' 46.920'' | 81° 37' 35.110'' |
| | Canal Linking Road near Telibandha Pond (PP2) | 21° 14' 28.410'' | 81° 39' 30.009'' |
| | Multilevel Parking near Collectorate Office (PP3) | 21° 14' 42.018'' | 81° 38' 38.418'' |
| | Pandri Bus Stand (PP4) | 21° 15' 00.932'' | 81° 38' 46.327'' |
| | Plaza in front of Telibandha Pond (PP5) | 21° 14' 29.079'' | 81° 39' 34.117'' |
| | Railway Station Chowk (PP6) | 21° 15' 25.344'' | 81° 37' 51.834'' |
| | National Institute of Technology Raipur (PP7) | 21° 14' 53.520'' | 81° 36' 12.880'' |
| Transportation | Deopuri (T1) | 21° 12' 07.066'' | 81° 40' 58.191'' |
| | Foot Over bridge at Ring Road no 2 (T2) | 21° 16' 21.334'' | 81° 35' 26.700'' |
| | Pachpedi Naka Bridge (T3) | 21° 13' 12.360'' | 81° 38' 56.929'' |
| | Pachpedi Naka Road (T4) | 21° 13' 12.676'' | 81° 38' 59.647'' |
| | Raipur Chowk bridge (T5) | 21° 13' 52.694'' | 81° 36' 05.626'' |
| | Raipura Chowk Road (T6) | 21° 13' 52.467'' | 81° 36' 04.827'' |
| | Tatibandh Chowk (T7) | 21° 15' 32.299'' | 81° 34' 02.661'' |
| | Telibandha Chowk (T8) | 21° 14' 18.492'' | 81° 40' 19.437'' |

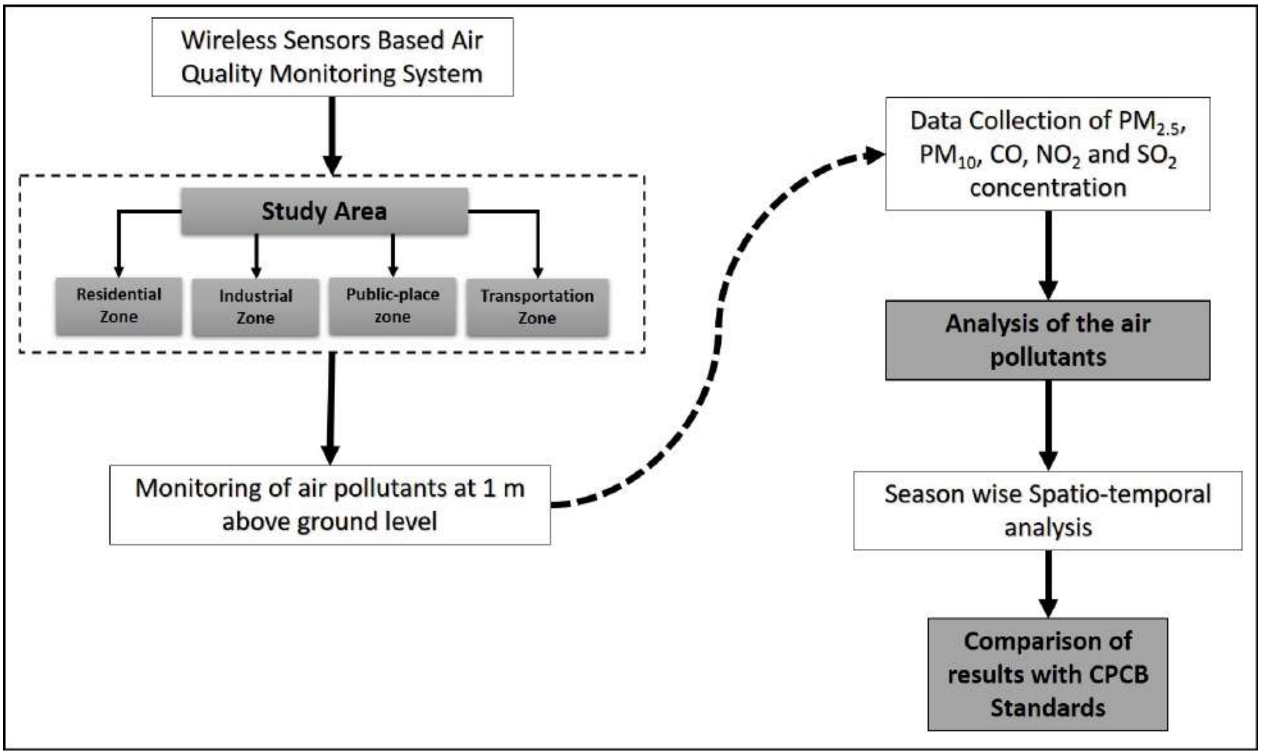


Fig. 2. Methodology

### *Data collection and analysis*

The monitoring system uses a Global System for Mobile (GSM) module to transmit real-time data to the ground station. The data is sent via the Message Queuing Telemetry Transport (MQTT) protocol. The concentration data obtained from the sensors has been sent to the user through SMS for real time data visualization. This SMS data can be converted to shapefile using POSTGRESQL programming for its spatial and temporal visualization in GIS software. The obtained concentration values have been processed in the GIS environment for season wise spatial and temporal analysis. Based on data interpolation, the spatial distribution of contaminants was identified using GIS (ArcGIS). The Inverse Distance Weighted (IDW) approach has been used for interpolation. It is also Shepard's method [21, 22]. IDW presumes that entities that are close to one another are more similar than those that are farther apart. IDW uses the measured values close to the prediction location to forecast a value for any unmeasured place. The measured values that are closest to where the forecast will occur have a greater impact than those that are farther away. According to IDW, measured points that are close to one another are more similar than those that are farther apart since each measured point has a local influence that decreases with distance. IDW uses the measured values close to the prediction location to forecast a value for any unmeasured place.

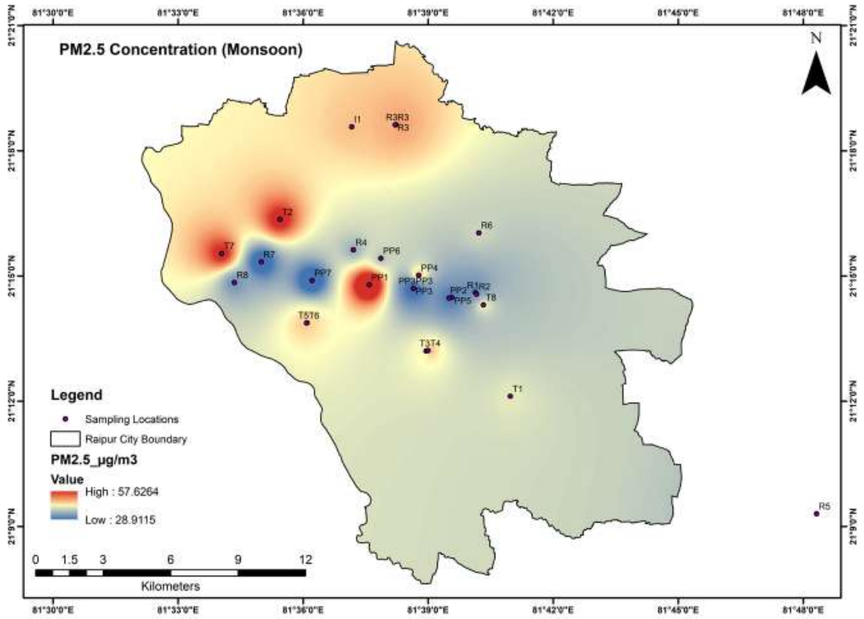
During measurement, it has been found that the observed data recorded from sensor is inappropriate (zero value or higher than the range of sensor). Removal of this data is essential so that there would be no misinterpretation of the air pollutants to the user. Hence, before processing and analysis of the data after field measurement, the inappropriate data is deleted.

### *Results and discussions*

Pollution accumulation and dispersion mechanisms are highly complex in nature. Local land use patterns and behaviour of local people might sometimes overshadow the influence of season on pollutant distribution. Other meteorological parameters, such as wind direction and speed, are also important in determining the quantity of pollution in a city. Strong winds drain away pollutants from the system, whilst low winds allow pollution to build up [23].

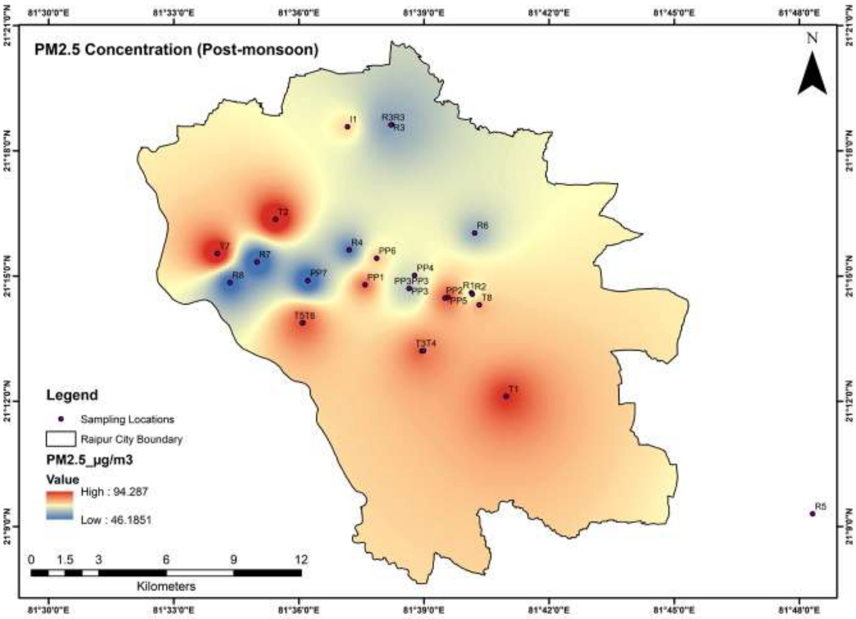
### *Spatio-temporal variation of $PM_{2.5}$ and $PM_{10}$ concentration*

In monsoon season, three locations were found to have high concentration of $PM_{2.5}$ and $PM_{10}$. One location (PP1) lies in the public-place zone while other two locations (T2 and T7) are under traffic zones. Higher level of particulate matter concentration is due to high traffic density. The concentration of $PM_{2.5}$ at PP1, T2 and T7 is observed to be 57.77 µg/m$^3$, 48.80 µg/m$^3$ and 48.38 µg/m$^3$ respectively. The $PM_{10}$ concentration for PP1 is observed as 66.95 µg/m$^3$. For T2 and T7, $PM_{10}$ concentration is observed to be 58.50 µg/m$^3$ and 58.89 µg/m$^3$ respectively. The observed values are less than prescribed CPCB standards. Fig. 3a and Fig. 4a represents the average concentration of $PM_{2.5}$ and $PM_{10}$ in study area during monsoon season. During post monsoon season, the concentration of $PM_{2.5}$ at T1, T2 and T7 is observed to be 99.34 µg/m$^3$, 86.34 µg/m$^3$ and 93.04 µg/m$^3$ respectively. The observed value is found to be higher than the CPCB limits (60 µg/m$^3$). The $PM_{10}$ concentration for T1, T2 and T7 is observed to be 113.42 µg/m$^3$, 97.98 µg/m$^3$ and 111.92 µg/m$^3$ respectively. Excluding T2, concentration at other locations were higher than the CPCB prescribed values (100 µg/m$^3$). Fig. 3b and Fig. 4b represents the average concentration of $PM_{2.5}$ and $PM_{10}$ in study area during post-monsoon season. Similarly, in winter season, PP6, T2, T5, T6 and T7 have high concentration of $PM_{2.5}$ and $PM_{10}$. At PP6, concentration of $PM_{2.5}$ and $PM_{10}$ is found to be 139.24 µg/m$^3$ and 154.56 µg/m$^3$. For locations T2, T5, T6 and T7, concentration of $PM_{2.5}$ is found to be 124.13 µg/m$^3$, 102.30µg/m$^3$, 139.40 µg/m$^3$ and 130.04 µg/m$^3$ respectively. These observed values is much higher than the standard prescribed values. The concentration of $PM_{10}$ for T2, T5, T6 and T7 is found to be 144.40 µg/m$^3$, 113.97 µg/m$^3$, 153.86 µg/m$^3$ and 155.03 µg/m$^3$ which were higher than CPCB values. Fig. 3c and Fig. 4c represents the average concentration of $PM_{2.5}$ and $PM_{10}$ in study area during winter season. Higher concentration during post-monsoon and winter season is due to stable atmosphere with low temperature where the particulate matters accumulates more near the



(a)

Fig. 3. Seasonal variation of $PM_{2.5}$ concentration: a) Monsoon; b) Post-monsoon; c) Winter



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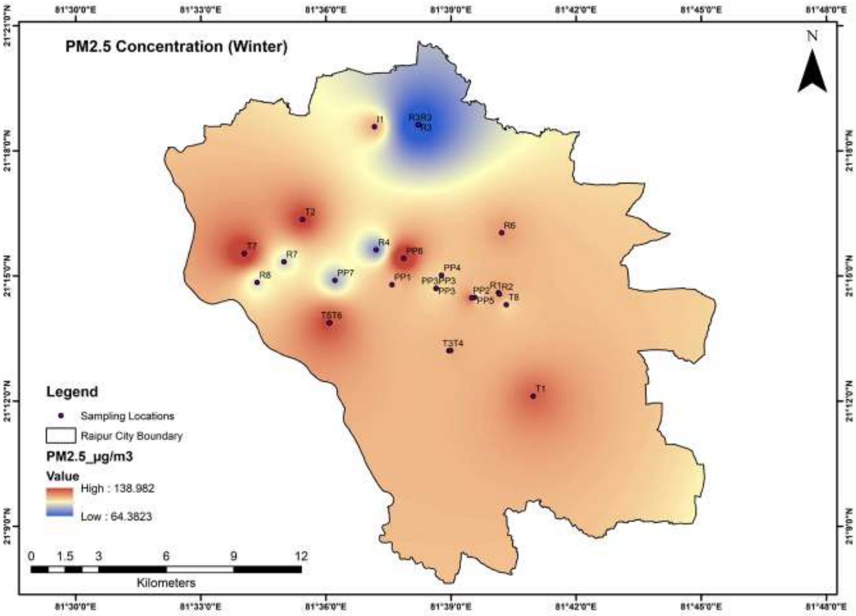
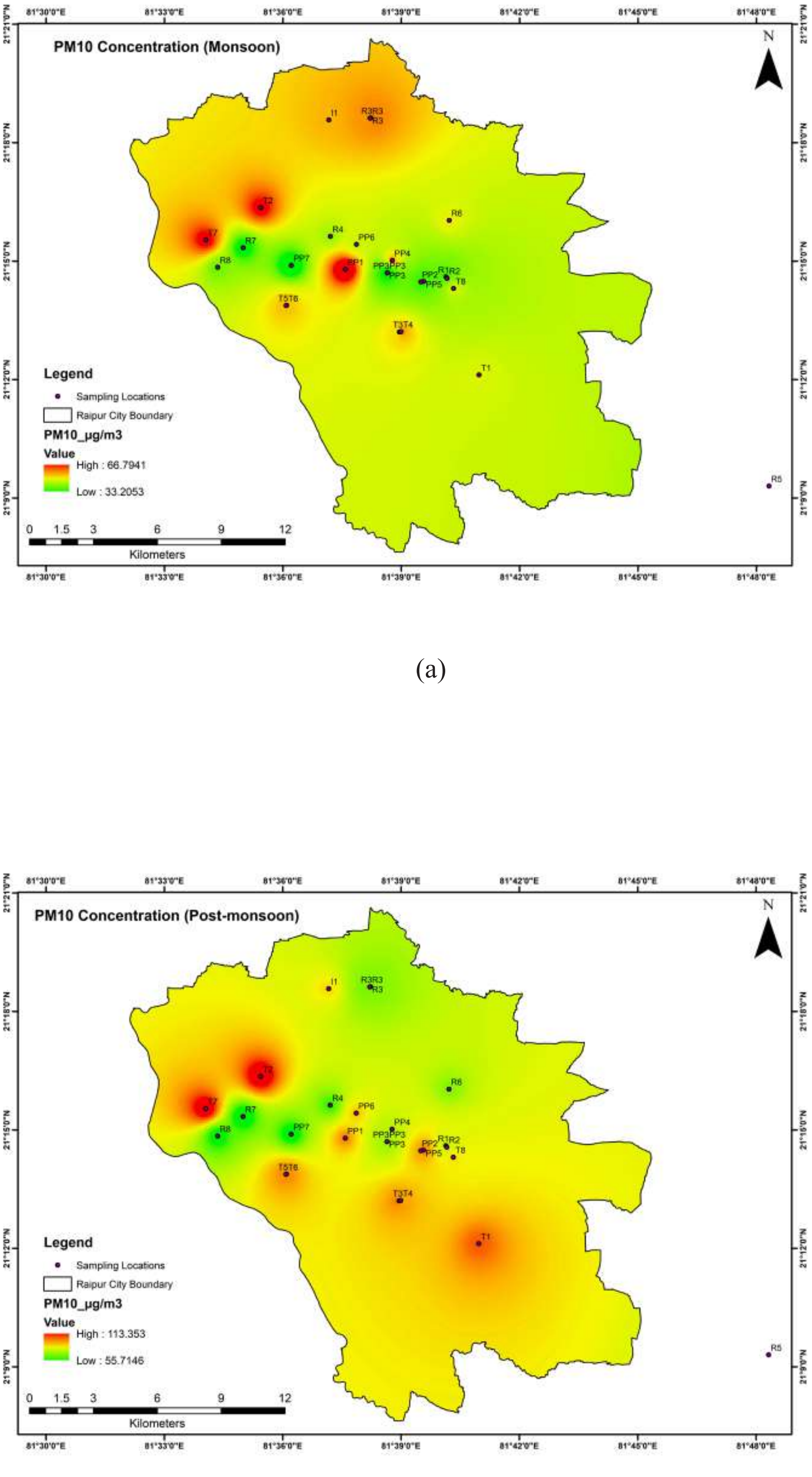


(c)

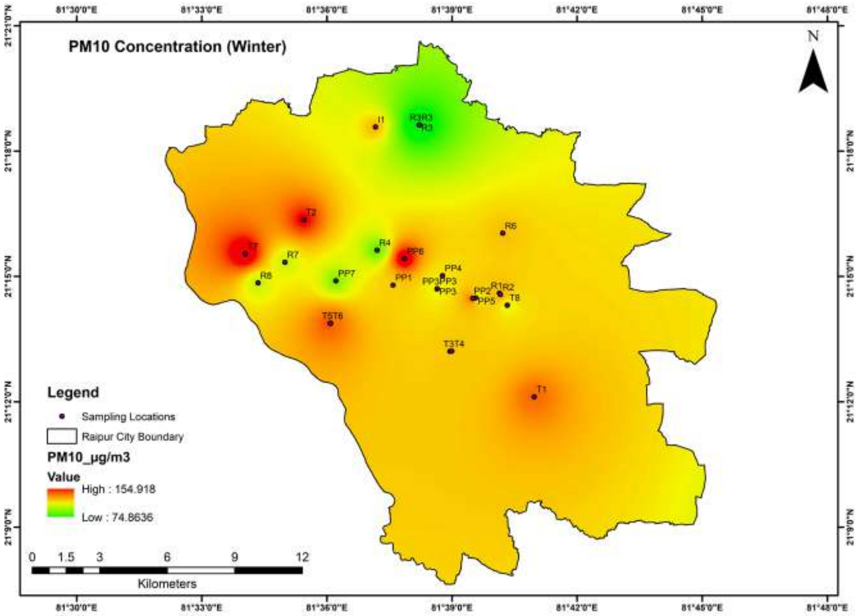
Fig. 3. Seasonal variation of $PM_{2.5}$ concentration: a) Monsoon; b) Post-monsoon; c) Winter



(a)

(b)

Fig. 4. Seasonal variation of $PM_{10}$ concentration: a) Monsoon; b) Post-monsoon; c) Winter

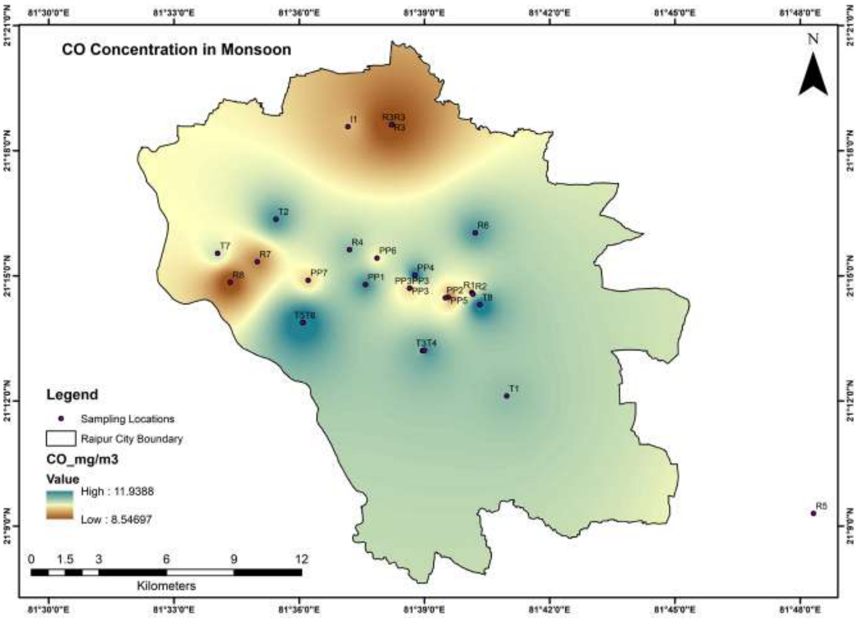


(c)

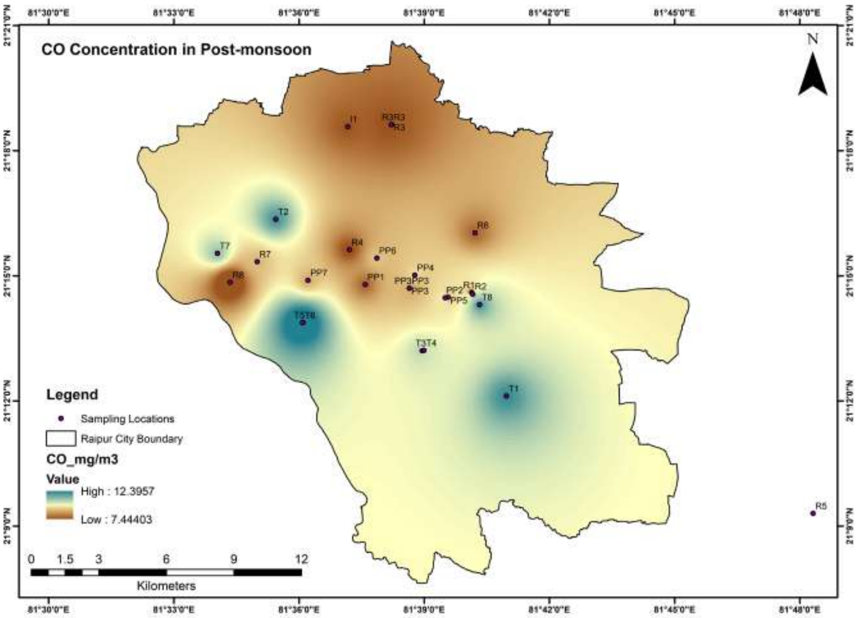
Fig. 4. Seasonal variation of $PM_{10}$ concentration: a) Monsoon; b) Post-monsoon; c) Winter

### *Spatio-Temporal variation of CO concentration*

It has been observed that CO concentration has been ranging from 8.21-12.11mg/m$^3$, 7.17-13.10 mg/m$^3$ and 9.51-16.62 mg/m$^3$ in monsoon, post-monsoon and winter season respectively with an average value of 10.23 mg/m$^3$, 9.66 mg/m$^3$ and 16.62 mg/m$^3$ respectively. In monsoon season, three locations were found to have high concentration of CO. All the three locations (PP2, PP3 and PP5) lies in the public-place zone. Higher level of CO concentration is due to high traffic density and also due to burning of coal at the food vending zones situated at public-places. The concentration of CO at PP2, PP3 and PP5 has been observed to be 13.86 µg/m$^3$, 17.01 µg/m$^3$ and 27.40 mg/m$^3$ respectively. The observed values are higher than prescribed CPCB standards (4 mg/m$^3$). Fig. 5a represents the average concentration of CO in study area during monsoon season. During post monsoon season, T2, T5 and T6 have the high concentration of CO. The concentration of CO at T2, T5 and T6 has been observed to be 11.21 mg/m$^3$, 11.17 mg/m$^3$ and 12.44 mg/m$^3$ respectively. The observed value is found to be higher than the CPCB limits. Fig. 5b represents the average concentration of CO in study area during post-monsoon season. Similarly, in winter season, PP6, T1, T5, T6 and T8 have high concentration of CO. At PP6, concentration of CO is found to be 13.29 mg/m$^3$. For locations T1, T5, T6 and T8, concentration of CO is found to be 13.63 mg/m$^3$, 13.04 mg/m$^3$, 14.68 mg/m$^3$ and 13.62 mg/m$^3$ respectively. Fig. 5c represents the average concentration of CO in study area during winter season.

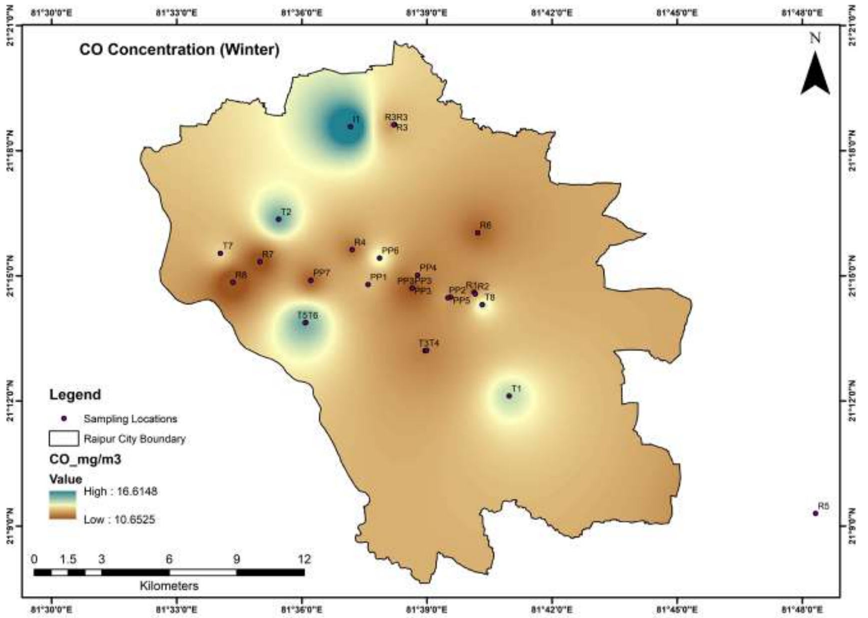


(a)



(b)

Fig. 5. Seasonal variation of CO concentration: a) Monsoon; b) Post-monsoon; c) Winter

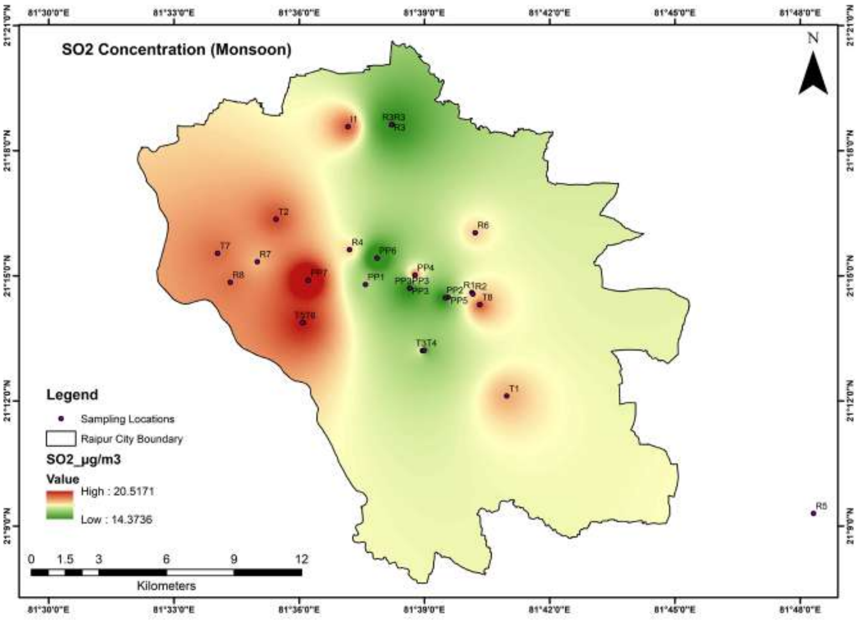


(c)

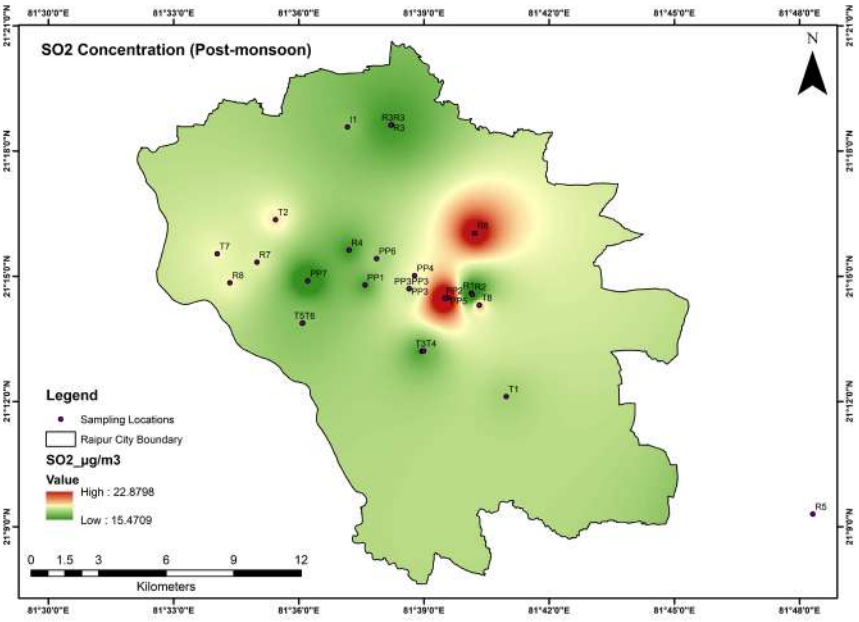
Fig. 5. Seasonal variation of CO concentration: a) Monsoon; b) Post-monsoon; c) Winter

### *Spatio-Temporal variation of $SO_2$ concentration*

Electricity production, industrial boilers, and other industrial operations are the primary sources of sulphur dioxide emissions. Old buses, diesel engines vehicles and off-road diesel equipment are other key sources for $SO_2$ emissions. In monsoon season, high concentration of $SO_2$ has been observed in industrial zone (I1), transportation zone (T2, T5, T6, T7, T8) and public-place zone (PP2, PP5). At I1, $SO_2$ concentration has been found to be 18.55 µg/m$^3$. This may be due to continuous industrial operations and heavy vehicular movement. For T2, T5, T6, T7 and T8, the $SO_2$ concentration has been observed to be 18.68 µg/m$^3$, 18.95 µg/m$^3$, 19.17 µg/m$^3$, 18.44 µg/m$^3$ and 18.68 µg/m$^3$ respectively. This may be due to continuous movement of vehicles especially diesel operated vehicles. At PP2 and PP5, the concentration of $SO_2$ emissions has been observed to be 17.24 µg/m$^3$ and 20.48 µg/m$^3$ respectively. The highest concentration has been observed in PP5 due to continuous movement of vehicles and also due to working off road equipments. The observed values are less than prescribed CPCB standards (80 µg/m$^3$). Fig. 6a represents the average concentration of $SO_2$ in study area during monsoon season. During post monsoon season, PP3 and R6 have the high concentration of $SO_2$. The concentration of $SO_2$ at PP3 has been observed to be 19.32 µg/m$^3$ and at R6 20.19 µg/m$^3$. The observed value is found to be lower than the CPCB limits. Fig. 6b represents the average concentration of $SO_2$ in study area during post-monsoon season. Similarly, in winter season, PP3 has the highest $SO_2$ concentration of 22.61µg/m$^3$. This observed value is lower than the standard prescribed values. The higher concentration is because of the movement of diesel engine based off-road equipment vehicles at the ongoing construction site located besides PP6. Also, the sampling location is a multilevel parking site which allows movement of numerous vehicles per day. Fig. 6c represents the average concentration of $SO_2$ in study area during winter season

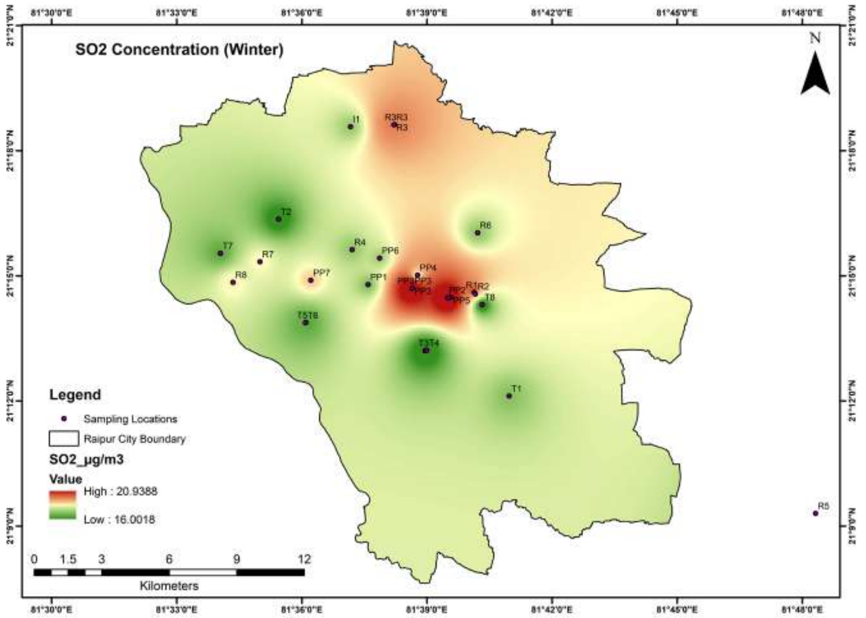


(a)



(b)

Fig. 6. Seasonal variation of $SO_2$ concentration: a) Monsoon; b) Post-monsoon; c) Winter

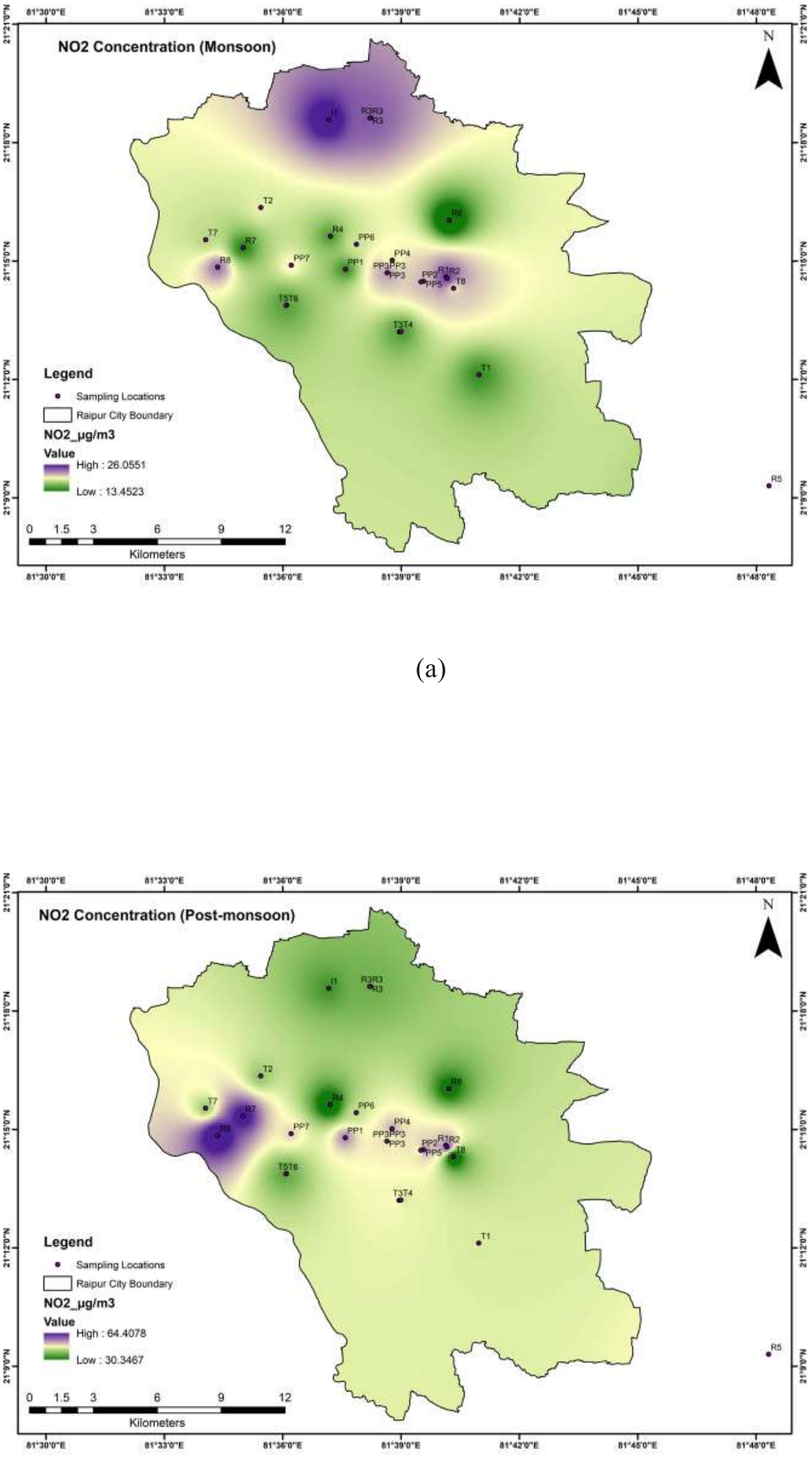


(c)

Fig. 6. Seasonal variation of $SO_2$ concentration: a) Monsoon; b) Post-monsoon; c) Winter

### *Spatio-Temporal variation of $NO_2$ concentration*

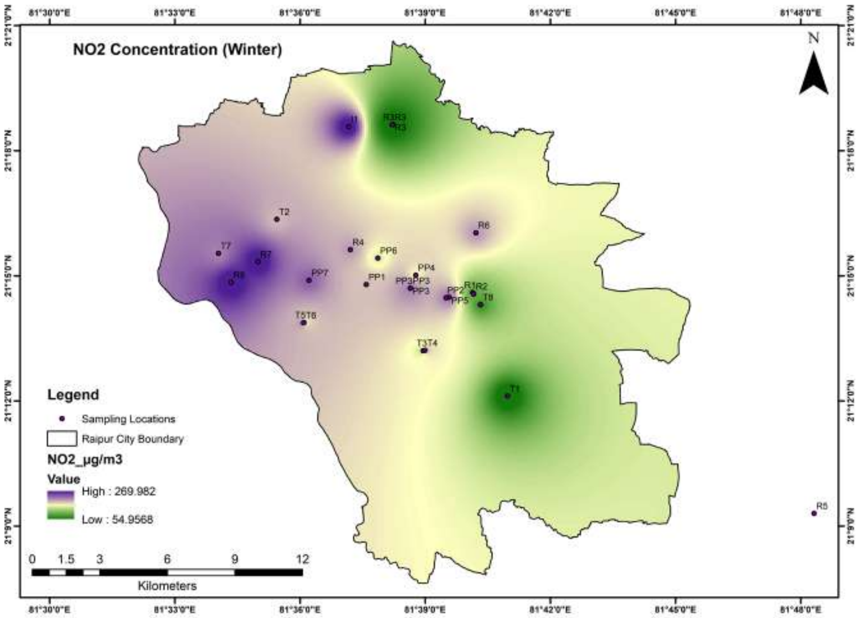
Nitrogen dioxide is emitted by automobiles, power plants, industrial pollutants, and off-road equipments used for construction purpose. To function, each of these sources needs fossil fuels. People who live or work close to congested highways may be subject to high pollution levels. In monsoon season, high concentration of $NO_2$ has been observed in residential zone (R1, R2, R3, R8) and public-place zone (PP2, PP3, PP5). For R1, R2, R3 and R8, the $NO_2$ concentration has been observed to be 23.54 μg/m$^3$, 23.78 μg/m$^3$, 23.22 μg/m$^3$ and 22.60 μg/m$^3$ respectively. This may be due to continuous movement of vehicles in these locations. At PP2, PP3 and PP5, the concentration of $NO_2$ emissions has been observed to be 21.44 μg/m$^3$, 21.93 μg/m$^3$and 21.90 μg/m$^3$ respectively. The highest concentration has been observed in PP3 as it is a parking site and it has continuous movement of vehicles. The observed values are lower than prescribed CPCB standards (80 μg/m$^3$). Fig. 7a represents the average concentration of $NO_2$ in study area during monsoon season. During post monsoon season, R7 and R8 have the high concentration of $SO_2$. The concentration of $SO_2$ at R7 has been observed to be 60.96 μg/m$^3$ and at R8 64.39 μg/m$^3$. Higher concentration has been observed in these two locations when compared to other location because of the movement of off-road equipments/ vehicles due to ongoing construction work. The observed value is found to be lower than the CPCB limits. Fig. 7b represents the average concentration of $NO_2$ in study area during post-monsoon season. Similarly, in winter season, I1, R7 and R8 has the highest $NO_2$ concentration of 269.98 μg/m$^3$, 267.03 μg/m$^3$ and 268.60 μg/m$^3$. This observed value is much higher than the standard prescribed values. The higher concentration is because of the movement of diesel engine vehicles at the industrial sites at I1. Fig. 7c represents the average concentration of $NO_2$ in study during winter season.



(a)

(b)

Fig. 7. Seasonal variation of $NO_2$ concentration: a) Monsoon; b) Post-monsoon; c) Winter



(c)

Fig. 7. Seasonal variation of $NO_2$ concentration: a) Monsoon; b) Post-monsoon; c) Winter

With higher spatial and temporal resolution of the air pollutants, the effect of air pollutants on living being has been observed at the breathing height which was not possible through static monitoring instruments. According to the results obtained from the observed data, it has been found that with the changing season, the effect of the air pollutant has also been varying. The high effect of air pollutants on human has been found in winter season than monsoon and post-monsoon season. Due to industrialization and development of new capital city besides the existing city, there has been higher emission of pollutants from vehicles and the industries.

## Conclusion

Raipur city has experienced severe air pollution issues after being made the capital city of the Chhattisgarh state. As a result, the air pollutants such as $PM_{10}$, $PM_{2.5}$, CO, $SO_2$ and $NO_2$ have been examined in this study using wireless sensors in order to assess the seasonal and spatio-temporal pattern of the air pollutants in the study area. The ability to thoroughly understand the distribution of pollutants' concentration in a chosen area is provided by the spatial analysis of pollutants. The primary benefit of the obtained results is their great resolution in a compact area, effectively addressing the air quality issue. Particulate pollution concentration was found to be higher than gaseous pollution. The findings suggest that seasonality has a substantial impact on the amount of pollutants in the city. According to the temporal distributions of the air pollutants, monsoon had the best air quality, followed by post-monsoon while the winter season has the highest concentration of pollution. The concentration of $PM_{2.5}$ concentration has been observed to be in the range of 28.91-57.62 µg/m$^3$ during monsoon season, 46.18-94.28 µg/m$^3$ during post-monsoon and 64.38-138.98 µg/m$^3$ during winter season. The $PM_{10}$ concentration range during monsoon, post-monsoon and winter season has been observed to be 33.20-66.79 µg/m$^3$, 55.71-113.35 µg/m$^3$ and 74.86-154.91 µg/m$^3$ respectively. The concentration of the CO has been found to be in the range of 8.54-11.43 mg/m$^3$ in monsoon season, 7.44-12.39 mg/m$^3$ in post-monsoon season and 10.65-16.61 mg/m$^3$ in winter season. Similarly, the concentration of $SO_2$ concentration has been observed to be in the range of 14.37-20.51 µg/m$^3$ during monsoon season, 15.47-22.87 µg/m$^3$ during post-monsoon and 16.00-20.93 µg/m$^3$ during winter season. The $NO_2$ concentration range during monsoon, post-monsoon and winter season has been observed to be 13.45-26.05 µg/m$^3$, 30.34-64.40 µg/m$^3$ and 54.95-269.98 µg/m$^3$ respectively.

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## Competing interests

Authors declare no conflict of interest.

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## Ethical considerations

The authors declare that ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed

## References

1. Mage D, Ozolins G, Peterson P, Webster A, Orthofer R, Vandeweerd V, et al. Urban air pollution in megacities of the world. Atmospheric Environment. 1996 Mar 1;30(5):681-6.

2. Gulia S, Nagendra SS, Khare M, Khanna I. Urban air quality management-A review. Atmospheric Pollution Research. 2015 Mar 1;6(2):286-304.

3. Gurjar BR, Butler TM, Lawrence MG, Lelieveld J. Evaluation of emissions and air quality in megacities. Atmospheric Environment. 2008 Mar 1;42(7):1593-606.

4. Patankar AM, Trivedi PL. Monetary burden of health impacts of air pollution in Mumbai, India: implications for public health policy. Public health. 2011 Mar 1;125(3):157-64.

5. Srimuruganandam B, Nagendra SS. Characteristics of particulate matter and heterogeneous traffic in the urban area of India. Atmospheric Environment. 2011 Jun 1;45(18):3091-102.

6. Lateb M, Meroney RN, Yataghene M, Fellouah H, Saleh F, Boufadel MC. On the use of numerical modelling for near-field pollutant dispersion in urban environments− A review. Environmental Pollution. 2016 Jan 1; 208:271-83.

7. Murena F, Mele B. Effect of short–time variations of wind velocity on mass transfer rate between street canyons and the atmospheric boundary layer. Atmospheric Pollution Research. 2014 Jul 1;5(3):484-90.

8. Kikumoto H, Ooka R. A numerical study of air pollutant dispersion with bimolecular chemical reactions in an urban street canyon using large-eddy simulation. Atmospheric environment. 2012 Jul 1; 54:456-64.

9. Zhang Y, Kwok KC, Liu XP, Niu JL. Characteristics of air pollutant dispersion around a high-rise building. Environmental Pollution. 2015 Sep 1; 204:280-8.

10. Zwack LM, Paciorek CJ, Spengler JD, Levy JI. Characterizing local traffic contributions to particulate air pollution in street canyons using mobile monitoring techniques. Atmospheric Environment. 2011 May 1;45(15):2507-14.

11. Galatioto F, Bell MC. Exploring the processes governing roadside pollutant concentrations in urban street canyon. Environmental Science and Pollution Research. 2013 Jul;20(7):4750-65.

12. Rakowska A, Wong KC, Townsend T, Chan KL, Westerdahl D, Ng S, et al. Impact of traffic volume and composition on the air quality and pedestrian exposure in urban street canyon. Atmospheric Environment. 2014 Dec 1; 98:260-70.

13. Meng QY, Turpin BJ, Korn L, Weisel CP, Morandi M, Colome S, et al. Influence of ambient (outdoor) sources on residential indoor and personal PM2. 5 concentrations: analyses of RIOPA data. Journal of Exposure Science & Environmental Epidemiology. 2005 Jan;15(1):17-28.

14. Van Roosbroeck S, Li R, Hoek G, Lebret E, Brunekreef B, Spiegelman D. Traffic-related outdoor air pollution and respiratory symptoms in children: the impact of adjustment for exposure measurement error. Epidemiology. 2008 May 1:409-16.

15. Mead MI, Popoola OA, Stewart GB, Landshoff P, Calleja M, Hayes M, Baldovi JJ, McLeod MW, Hodgson TF, Dicks J, Lewis A. The use of electrochemical sensors for monitoring urban air quality in low-cost, high-density networks. Atmospheric Environment. 2013 May 1; 70:186-203.

16. Kingham S, Longley I, Salmond J, Pattinson W, Shrestha K. Variations in exposure to traffic pollution while travelling by different modes in a low density, less congested city. Environmental Pollution. 2013 Oct 1;181:211-8.

17. Nieuwenhuijsen MJ, Donaire-Gonzalez D, Foraster M, Martinez D, Cisneros A. Using personal sensors to assess the exposome and acute health effects. International Journal of Environmental Research and Public Health. 2014 Aug;11(8):7805-19.

18. Gonzalez A, Boies A, Swason J, Kittelson D. Field calibration of low-cost air pollution sensors. Atmospheric Measurement Techniques Discussions. 2019 Aug 19:1-7.

19. Van Zoest V, Osei FB, Stein A, Hoek G. Calibration of low-cost $NO_2$ sensors in an urban air quality network. Atmospheric environment. 2019 Aug 1; 210:66-75.

20. Giordano MR, Malings C, Pandis SN, Presto AA, McNeill VF, Westervelt DM, et al. From low-cost sensors to high-quality data: A summary of challenges and best practices for effectively calibrating low-cost particulate matter mass sensors. Journal of Aerosol Science. 2021 Nov 1; 158:105833.

21. Robichaud A, Ménard R. Multi-year objective analyses of warm season ground-level ozone and $PM_{2.5}$ over North America using real-time observations and Canadian operational air quality models. Atmospheric Chemistry and Physics. 2014 Feb 17;14(4):1769-800.

22. Shepard D. A two-dimensional interpolation function for irregularly-spaced data. InProceedings of the 1968 23rd ACM national conference 1968 Jan 1 (pp. 517-524).

23. Gupta AK, Karar K, Ayoob S, John K. Spatio-temporal characteristics of gaseous and particulate pollutants in an urban region of Kolkata, India. Atmospheric Research. 2008 Feb 1;87(2):103-15.