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Investigation of the status, causes, and remedial measures of air pollution in an industrial town in Maharashtra, India

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ABSTRACT

Chandrapur City of Maharashtra state of India has undergone rapid industrialization, development, and infrastructure facilities along with prominent increase in population. Therefore, the present study was undertaken to study the air quality of the city. The mitigation measures of air pollution in the city were also discussed in the present study. Air quality monitoring was carried out at each monitoring station taken twice a week for 24 hours for particulate matter (PM_{10}), particulate matter ($PM_{2.5}$), sulphur dioxides (SO_2), nitrogen dioxides NO_2, and carbon monoxides (CO). The data revealed the high levels of particulate matter (PM_{10} and $PM_{2.5}$) to approximately 1.56-2.15 times and 1.47-2.21 times higher than National Ambient Air Quality Standards (NAAQS), respectively and were many times higher than WHO Global Air Quality Guidelines. The major sources of pollution were the emission from industries, mining activities and traffic. Observed concentrations of SO_2 (24.88 to 45 µg/m3), NO_2 (45.4 to 70.6 µg/m^3) and (0.63 to 0.88 mg/m^3) were below NAAQS. The obtained data was also processed for the calculation of air quality index (AQI). The AQI value at Chandrapur super thermal power station (CSTPS) was found higher (310) followed by MIDC with AQI of 302 (Very poor air quality) mainly due to higher particulate pollution, indicating respiratory illness to the people on prolonged exposure. AQI for remaining three stations namely, Jatpura gate, Bimba gate and Babupeth ranged from 264 to 284 (Poor air quality) mainly due to vehicular pollution indicating breathing discomfort to people on prolonged exposure. All the pollutants were observed higher than the concentrations recorded in earlier studies and showed increasing trend as compared to records of previous studies.

Introduction

The quality of the environment (air, water, and soil) and health status are interlinked. The polluted environment is responsible for the generation and spread of different diseases (Pope and Dockery 2006; Bhutiani *et al.,* 2021; Ahamad *et al.,* 2022). Air pollution is a matter of serious concern, especially for developing nations, due to their increasing population, reduced natural resources, and lack of efficient technologies (Ruhela *et al.,* 2022a). Globally, 7 million people die each year due to the inhalation of polluted air, while one in three children in the Asia-Pacific region die prematurely (WHO, 2020). In addition, various cities in India are among the most polluted cities in the world (https://www.bloombergquint.com/economy-finance/22-of-worlds-most-polluted-cities-are-in-india-report). In India, the air quality of most industrial clusters is reportedly polluted due to the combustion of fossil fuels, transport, construction activities, lack of forest area, and high population in and around. Therefore, monitoring the air quality of industrial towns is essential.

Chandrapur was extensively developed due to the establishment of the Chandrapur Super Thermal Power Station (CSTPS), which includes approximately 6000 industries, viz. paper, textiles, food and feeds, multiple organics, coal mining (popularly called city of black gold), limestone and

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minor minerals and an extensive road network for connectivity (Maharashtra Pollution Control Board, MPCB, 2019, Feb. 2018). Chandrapur is also famous for providing education facilities with schools and colleges, including Government Medical College and a Government Engineering College. However, Chandrapur city is at the top of the list of polluted cities in Maharashtra (The Energy and Resources Institute, TERI; retrieved from Apr 2021). The Tadoba Andhari Tiger Reserve is present along the eastern boundary of Chandrapur city. The city residents and wildlife in the nearby Tadoba Andhari Tiger Reserve are exposed to air pollution generated in Chandrapur. Therefore, the present investigation was undertaken to study the current status of air pollution in Chandrapur city based on primary and secondary data on sources of air pollution, causes of worst air pollution, lacunae in environmental management, transport management, road design, municipal sanitary services, vehicular emission management, etc., to enable us to suggest remedial measures to reduce air pollution in Chandrapur city in the near future to make it a clean city in all respects. Presently, the Chandrapur has achieved a Clean City award, which should be converted to a Clean City in all respects.

Materials and Methods

Study area

Chandrapur city is situated in the eastern part of Vidarbha in Maharashtra State at 19.57°N and 79.18°E. It is situated at an altitude of 189 m amsl. The major sources of air pollution in Chandrapur city are the CSTPS, coal-fired industries, mines, and service sectors, such as vehicular pollution, streetvending, and scavenging.

Sampling and analysis

Air quality monitoring was carried out for one month in May 2021 as per the National Ambient Air Quality Standard (NAAQS) (CPCB, Nov 18, 2009a) and Central Pollution Control Board (CPCB) guidelines for the measurement of ambient air pollutants (Apr, 2021). A total of 5 air monitoring stations, based on different sources of air pollution (Table 1, Fig. 1), were selected in Chandrapur city viz. A-1 near CSTPS, A-2 in MIDC industrial Area, A-3 Jatpura gate (D/w to MIDC, 3 km on East) in dense residential area, A-4 Bimba gate (D/w to MIDC on SE at 3 km) in residential area near Erai River on one side and Ramala lake on other side, A-5 Babupeth on southern end of the city with less population and reduced human activity.

Table 1: Air monitoring stations

Station code	Place	Details
A-1	Near (CSTPS)	On the 2 km on the East of CSTPS (downwind direction)
A-2	MIDC Area	On the West side of the City & approx. 7 km SE of CSTPS
A-3	Jatpura gate	D/w to MIDC 3 km on East, located in the center of the City, approx. 5 km South of CSTPS
A-4	Bimba gate	In the City, East to Erai River & approx. 6.5 km South of CSTPS
A-5	Babupeth	In South City & approx. 8 km South of CSTPS

Five air pollutants, viz. PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO were monitored during the study. A calibrated high-volume respirable dust sampler (RDS) APM 460NL and APM 550 (for particulate matter) along with a gaseous sampler APM 433 (for SO_2 and NO_2) with a flow rate of 1.0 to 1.2 m3/min and equipped with glass fiber filter paper were used for sampling air pollutants. SO_2 in ambient air was measured by the modified West and Gaeke Method (IS 5182 Part 2 Method of Measurement of Air Pollution: Sulphur dioxide), and NO_2 in ambient air was measured by the Jacobs and Hochheister Method (IS 5182 Part 6 Methods of Measurement of Air Pollution: Oxides of nitrogen). Total suspended particulate matter (SPM) was measured by the addition of RSPM (PM10) and non-RSPM. PM10 was measured by a gravimetric technique (per IS 5182; Part IV) via the HVS-Filtration method on preweighed glass microfiber filter paper (20.3x25.4 cm, 8 × 10 inch). Carbon monoxide was monitored through a nondispersive infrared spectroscopic method. The sampling instruments were placed approximately 3 m to 10 m above ground level. The collected samples were subsequently brought to the laboratory for further analysis.

Data analysis

Air quality monitoring was carried out at each monitoring station twice a week for 24 hours and once a week for CO at uniform intervals. Thus, the monitoring was carried out weekly four times in May 2021, and the average values were computed for the minimum, maximum, average and 98th

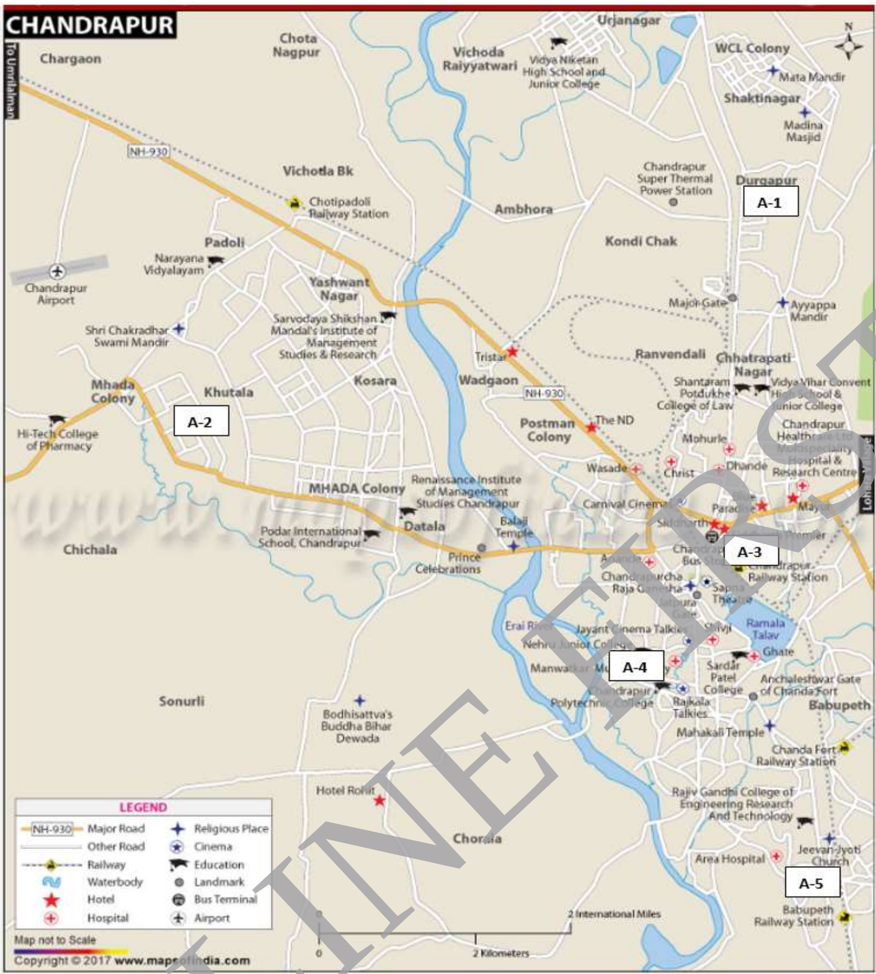

Figure 1: Map of Chandrapur city showing air monitoring stations

percentile values. The 98th percentile values were compared with the National Ambient Air Quality Standard (NAAQS) and Global Air Quality Guidelines (Global AQGs) established by the World Health Organization (WHO) (WHO, Sep 22, 2021).

Air quality index (AQI)

The national air quality index (CPCB, September 17, 2014) is a tool for the effective communication of air quality status in single numbers and is easy for people to understand (Ruhela *et al.,* 2022a&b). The national AQI was calculated based on values obtained for 5 air quality parameters. The AQI is a scale that varies from 0 to 500. An AQI of 50 represents good air quality with little potential to affect public health, while an AQI of 51-100 is satisfactory and may cause minor breathing discomfort to sensitive people. The higher the AQI is, the greater the level of air pollution and the greater the health concern. Based on the values of the air pollutants obtained, the national AQI was calculated for different air sampling stations in Chandrapur and was correlated with local sources of air pollution.

Results and Discussion

Atmospheric variables

The climate of the Chandrapur district is a hot tropical climate. The summer months include March to May and are very hot. May is the peak hot month in the summer season when the average maximum temperature varies from 28.2°C to 43°C and the average minimum temperature is 28.2°C. The annual average relative humidity (RH) is approximately 57.7%.

Table 2: Observations of air pollutants during the air pollution survey

Station no.	Air pollutants & different sampling locations	Max	Min	Average	98th percentile	NAAQS	WHO AQG
Particulate matter PM10 (μg/m³)							
A-1	**Near CSTPS**	215	85	170.9	215	100	50
A-2	**MIDC**	187	112	171.8	186.9	100	50
A-3	**Jatpura gate**	190	128	156	187.9	100	50
A-4	**Bimba gate**	158	68	109.5	155.8	100	50
A -5	**Babupeth**	144	85	96	137.14	100	50
Particulate matter PM2.5 (μg/m³)							
A-1	**Near CSTPS**	133	53	114.1	132.4	60	25
A-2	**MIDC**	123	68	108.8	122.8	60	25
A-3	**Jatpura gate**	112	78	83.1	109.2	60	25
A-4	**Bimba gate**	118	37	67.3	112.4	60	25
A -5	**Babupeth**	93	51	58.4	88.2	60	25
Sulphur dioxide (SO_2), (μg/m³)							
A-1	**Near CSTPS**	45	18	37.6	45.0	80	20
A-2	**MIDC**	43	16	27.3	42.3	80	20
A-3	**Jatpura gate**	39	18	24.8	37.46	80	20
A-4	**Bimba gate**	26	4	14.5	24.88	80	20
A -5	**Babupeth**	29	17	19	27.6	80	20
Nitrogen dioxide (NO_2), (μg/m³)							
A-1	**Near CSTPS**	74	35	42.25	69.9	80	NS
A-2	**MIDC**	68	33	39.3	64.78	80	NS
A-3	**Jatpura gate**	72	29	46.8	70.6	80	NS
A-4	**Bimba gate**	56	19	38.5	54.46	80	NS
A -5	**Babupeth**	46	28	37	45.4	80	NS
Carbon monoxide (CO), (mg/m³)							
A-1	**Near CSTPS**	0.89	0.48	0.65	0.88	4	NS
A-2	**MIDC**	0.74	0.23	0.39	0.69	4	NS
A-3	**Jatpura gate**	0.81	0.24	0.61	0.80	4	NS
A-4	**Bimba gate**	0.69	0.36	0.51	0.69	4	NS
A -5	**Babupeth**	0.68	0.33	0.545	0.63	4	NS

which varies from 15.1% to 99%. The average annual rainfall is 1249.4 mm, and the average rainfall days in a year are 59.2 (Indian Climate: Climate of Chandrapur, no date; Wikipedia, May 2, 2023).

Air quality parameters

The air pollutant (maximum, minimum, average and 98th percentile) monitoring data collected in Chandrapur city are given in Table 2. The 98th percentile values were compared with the NAAQS and Global AQG values.

Particulate matter (PM_{10} and $PM_{2.5}$)

The PM_{10} concentrations at all the stations ranged from 155.8 to 215 μg/m³ (Table 2), which were much greater than the NAAQS of 100 μg/m³ and the Global AQG of 50 μg/m3. The lowest concentration, 194.6 μg/m³ (1.56 times higher than NAAQS), was observed at the Bimba gate. The highest concentration, 215 μg/m³ (2.15 times greater than NAAQS), was recorded near CSTPS, followed by Babupeth, Jatpura and MIDC, which had more or less equal PM10 concentrations but 1.87 to 1.95 times greater than NAAQS. Similar observations were made for 0.67 to 0.81 mg/m³ CO in the Chandrapur city area (MPCB, February 2018). The $PM_{2.5}$ (98th percentile) concentrations at all the monitoring stations varied from 88.2 to 132.4 μg/m³ (Table 2), which are much greater than the NAAQS of 60 μg/m³ and the WHO guideline of 25 μg/m³. The lowest concentration, 88.2 μg/m³ (1.47 times higher than NAAQS), was observed in Babupeth, and the highest concentration, 132.4 μg/m³ (2.21 times higher than NAAQS), was observed near CSTPS. The next highest concentration was 122.8 μg/m³ (2.1 times higher than NAAQS) in the MIDC area, 112.4 μg/m³ (1.87 times higher than NAAQS) in the Bimba gate and 109.2 μg/m³ (1.82 times higher than NAAQS) in the Jatpura gate. $PM_{2.5}$ is responsible for haze and a reduction in visibility, lake and stream acidity, nutrient depletion in soil, damage to forests and crops, corrosion and acid rain effects (United States Environmental Protection Agency, US EPA, 2022). CSTPS appears to be the main source of total particulate pollution. Observations have shown that particulate matter (PM_{10} and $PM_{2.5}$) pollution has reached an alarming level in and was many times greater in Chandrapur City than in the NAAQS and Global AQG.

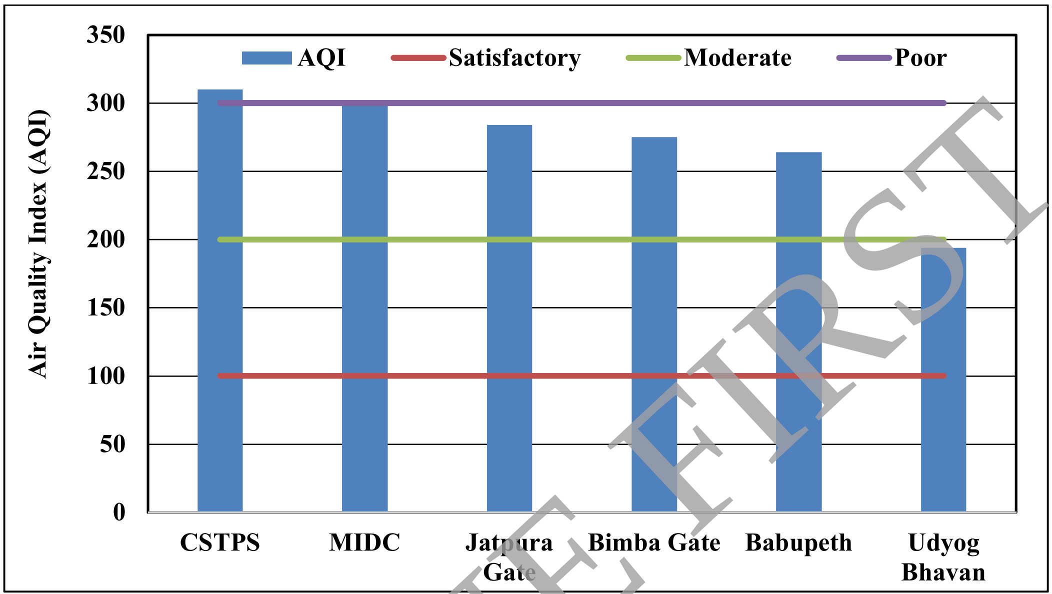

Figure 2: AQI values at different stations and levels of public health effects.

Similar observations were made for 55 to 71 μg/m^3 PM_{10} concentrations and 23 to 48 μg/m^3 $PM_{2.5}$ concentrations by the Chandrapur Maharashtra Pollution Control Board (MPCB, Feb 2018) and for 20 to 46 μg/m^3 $PM_{2.5}$ in Chandrapur by Gawai *et al.* (2014), which were lower than the observations made here, revealing an increasing trend of air pollution.

A higher $PM_{2.5}/PM_{10}$ ratio (>0.5) indicates more anthropogenic sources, while smaller ratios indicate the presence of more coarse particles generated from natural sources, such as dust storms (Fan *et al.*, 2020). The ratios in the Chandrapur dataset ranged from 0.58 to 0.72 for all monitoring stations, indicating particulate pollution from industries, mines and traffic.

Gaseous pollutants (SO_2, NO_2, and CO)

Sulfur dioxide (SO_2) is the dominant sulfur oxide in the environment. The 98th percentile concentrations of SO_2 at all the monitoring stations varied from 24.88 to 45.0 μg/m^3 (Table 2), which were much lower than the NAAQS of 80 μg/m^3 but 1.24 to 2.25 times greater than the global AQG of 20 μg/m^3. The lowest concentration (24.88 μg/m^3) was detected at the Bimba gate, and the highest concentration (45 μg/m^3) was detected near the CSTPS, followed by MIDC, the Jatpura gate and Babupeth. Similar observations have been reported in the Chandrapur city area (MPCB, February 2018). A joint committee report submitted by the CPCB in March 2020 revealed that the emission loads of SO_2 at all units of the CSTPS were two to eight times greater than the prescribed levels of SO_2, highlighting the need to retrofit these units to restrict toxic emissions (CPCB, 2021b) and to shut down old units 3 and 4, which cannot be upgraded. The ambient levels of SO_2 in Chandrapur are the third highest in India, and the National Aeronautics and Space Administration (NASA) has already warned of acid rains in Chandrapur in the future (CPCB, 2009b).

The 98th percentile NO_2 concentrations at all the sampling stations varied from 45.4 to 70.6 μg/m^3 (Table 2) and were observed to be well below the NAAQS of 80 μg/m^3. MPCB (2018) also reported similar NO2 concentrations (16.6 to 39.4 μg/m^3) in the Chandrapur city area. The highest concentrations of NO_2 (64.78 to 70.6 µg/m^3) were detected at the Jatpura gate. The main sources of NO_2 were observed to be industry and vehicle transport. Lower values of NO_2 were observed at Bimba Gate and Babupeth (4.46 and 45.4 µg/m^{3,} respectively), which are relatively far from industrial areas. Gawai *et al*. (2014) recorded the highest concentration of NO_2 above the NAAQS in Chandrapur city. A high SO_2/NO_2 ratio (>0.60) indicates significant contributions from point sources, while a low ratio (0.04~0.12) signifies more contributions from mobile sources (Halim *et al.,* 2018). The SO_2/NO_2 ratios calculated for stations A-1, A-2 and A-5 were 0.64, 0.65 and 0.61, respectively, indicating a significant contribution of point sources of gaseous pollution; however, at Jatpura and Bimba, the ratios were 0.53 and 0.46, respectively, indicating greater contributions from mobile sources, i.e., vehicular emissions. Carbon monoxide (CO) is a colorless and odorless gas. The main source of CO is burning any object or fossil fuel. The 98th percentile of carbon monoxide was observed to vary from 0.63 to 0.88 mg/m^3 (Table 2). All the CO concentrations were 4.55 to 6.35 times lower than the NAAQS (4.0 mg/m^3) concentration. The highest concentration was observed at CSTPS, and the lowest was at Babupeth. MPCB (2018) also reported lower values of Co (0.67 to 0.81 mg/m^3) in the Chandrapur city area.

Air Quality Index (AQI)

AOI is beneficial for easy and unambiguous review of air pollution. Although the ultimate aim is the same, different authors or regulatory bodies have promoted different procedures for computing AQIs. Ruhela *et al.* (2022a) calculated the AQI by aggregating the ratio of pollutant concentration in ambient air to the standard limit of pollutants in ambient air. Several researchers have calculated the AQI for different regions (Ruhela *et al*., 2022b; Yadav *et al.,* 2012; Ziauddin & Siddique, 2006).

The CPCB national AQI values calculated for the different air sampling stations are shown in Figure 2. The CSTPS station had the highest AQI (310), followed by the MIDC (AQI= 302), indicating very poor air quality, which can cause respiratory illness in people with prolonged exposure. *The* AQI for the remaining three stations, namely, the Jatpura gate, Bimba gate and Babupeth, ranged from 264 to 284 (poor air quality), indicating breathing discomfort to people during prolonged exposure. The AQI is greater at the Jatpura gate than at the Bimba gate and Babupeth gate, and a gradation of air pollution occurs in these areas due to the presence of industrial and vehicular pollution. The higher AQI at CSTPS and MIDC was due to very high levels of PM10 and PM2.5 coming from industrial, CSTPS emission, and vehicular exhaust. Jatpura Gate, Bimba Gate and Babupeth dust pollutants are generated mainly from vehicular exhaust.

Identification of Causes of Air Pollution in Chandrapur City

The major causes of air pollution in Chandrapur city were emissions from the CSTPS, industrial activity, dust from mining activity, laxity in sanitary operations and vehicular pollution. The CSTPS was commissioned in November 1984 and has old units; some can be upgraded, while others cannot be upgraded; these units are responsible for emissions higher than the standards. FGD has not yet been installed in a CSTPS to control SO_2 emissions. Dense vehicular traffic, old and untuned vehicles and truck transport through the city are responsible for serious vehicular emissions of air pollutants. Occasional unscientific solid waste management is responsible for dust and putrefying gases in the environment of Chandraour city.

Recommendations to mitigate air pollution

Based on our observations, the major approaches required to control or reduce air pollution are given below.

- Industries may be compelled to use high-quality coal and proper removal of particulate matter from stacks.
- The retrofitting of old units in CSTPS, which are responsible for air pollution;
- Shutting down older units no. 3 and 4 of the CSTPS, which cannot be retrofitted;
- The FGD in CSTPS units should be installed to reduce SO_2 emissions.
- Mandatory use of washed coal by CSTPS and coal-fired industries,
- The mandatory use of air pollution control devices in air polluting industries,

- Public awakenings for LPG use in households and restaurants
- The implementation of the Bharat Stage VI (BS-VI) emission standard for all major on-road vehicle categories occurred on April 1, 2020, in India. promotion of electric vehicles, there should be strict compliance with the emission norms through PUC checks;
- The traffic of heavy duty vehicles should be minimized through proper alternative traffic facilities, such as by passing roads.
- The need for improvements in public transport and road design and proper removal of road dust and construction and demolition waste;
- Scientific municipal solid waste management and ban on open burning of thrashes,
- The implementation of efficient dust control measures in mines,
- Personal precautionary measures for residents:
  - Wear a mask outdoors,
  - If possible, avoid visiting polluted areas in cities or avoid outdoor work during the morning and evening when pollution is very high, especially due to vehicular emissions.
  - Use an air purifier indoors

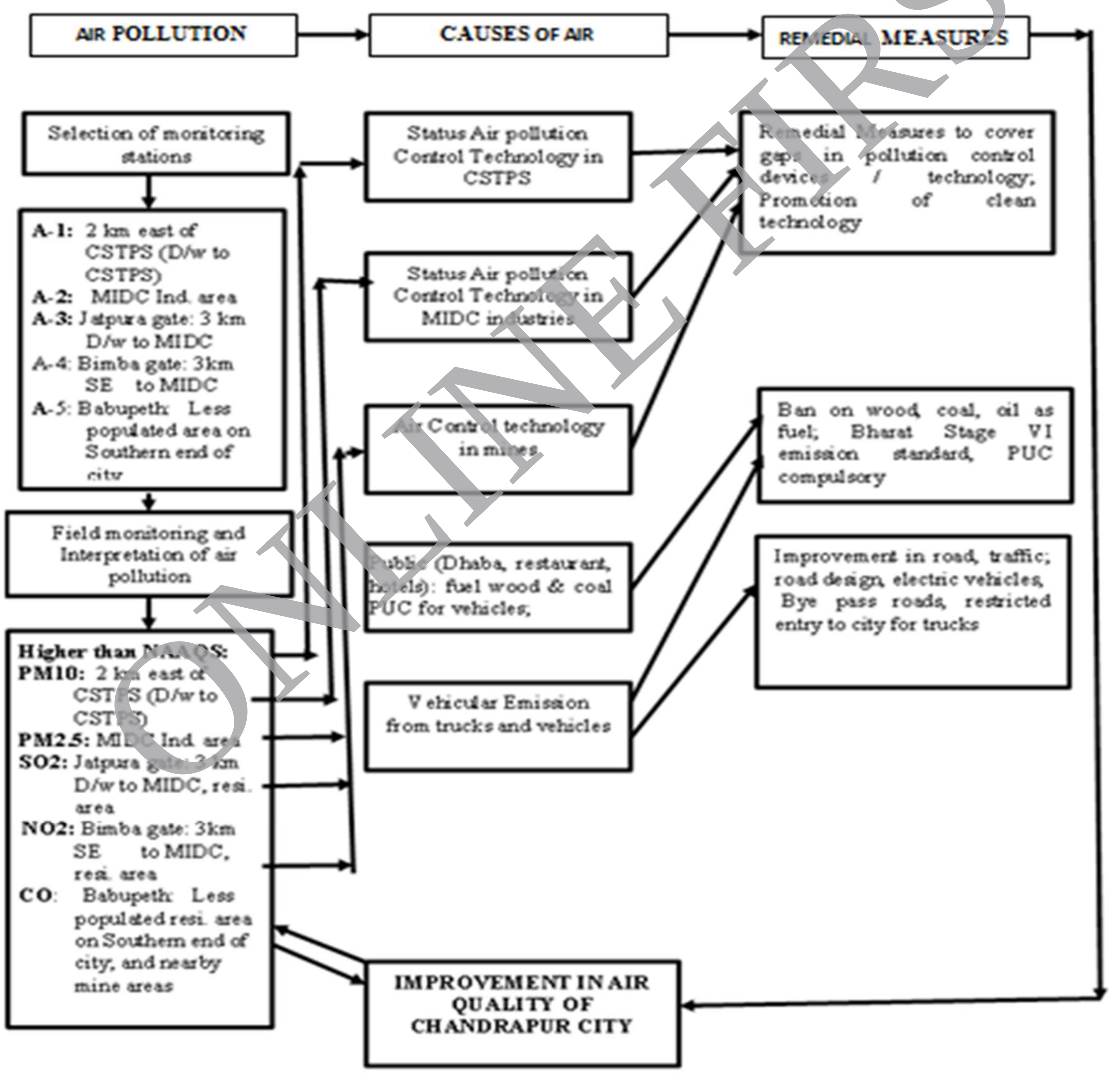

Figure 3: Assessment of the status and causes of air pollution and recommendations of remedial measures for an industrial town in Maharashtra, India

Conclusion

The present study was carried out to assess the air quality in Chandrapur city, Maharashtra State, India. The data were also analyzed for the calculation of the AQI. Observations have shown that particulate matter pollution is highly important from a public health point of view. from the deleterious effects of SO_2 and NO_2. The values of the national AQI indicated poor to very poor air quality, causing breathing discomfort to people on prolonged exposure and respiratory illness to people on prolonged exposure. The major causes of severe air pollution in Chandrapur city were identified as emissions from the CSTPS, industries, dense traffic, truck transport through the city, and dust from mining activities.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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