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AMBIENT AIR QUALITY IN NAGOTHANE INDUSTRIAL AREA, RAIGARH DISTRICT, WESTERN INDIA

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Abstract
To assess the ambient air quality in the Nagothane industrial area in Raigarh district, Western India 12 sampling locations were identified within 7 km aerial distance of the industrial area. The ambient air quality monitoring was carried out in the winter season by continuous monitoring for Suspended Particulate Matter, Respirable Particulate Matter, Sulphur dioxide and Oxides of nitrogen by using High Volume Air Sampler and per the prevailing Central Pollution Control Board's guidelines. In addition, hydrocarbon and carbon monoxide were also measured. The particulate matter was analyzed by gravimetric method, whereas wet chemical analysis for sulphur dioxide and oxides of nitrogen. The micrometeorological data about wind speed, wind direction, ambient air temperature and atmospheric relative humidity was measured by employing mechanical weather monitoring the situation. The mixing height was measured by the minisonde system. The results revealed the average air pollutant concentrations were within the permissible limit of National Ambient Air Quality Standards except for Suspended Particulate Matter. The Air Quality Index in all the sampling locations was in 'good' status thus minimal or no health impacts on the inhabitants of the study area. It is concluded that the industrial contribution to ambient air pollution is minimal. However, the calm conditions during the night time, inversion and valley-like terrain in the area may pose a threat by forming an air pollution episode-like condition and accumulation of air pollutants over the industrial area from night till morning. Further industrial expansion should be carried out by assessing the carrying capacity of the industrial area.

Key Words: *Air quality, Industrial area, Nagothane, Raigarh, Western India*

Introduction

One of the most significant natural resources is air and it is necessary for human life. In perfect circumstances, the air one breathes has a balance of qualities and quantities that keep one healthy. An individual may breathe up to 22,000 times each day and consume 16 kg of air. Man can survive for five weeks without food and five days without water, but only for a few seconds without air (Rao and Rao, 2001). Due to the rapid growth of the human population, industry, urbanisation,

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vehicle use, and other factors, the problem of air pollution has grown rapidly.

Industrial clusters in India have resulted in an adverse impact on the environment especially air quality in the middle of the 20th century (Parveen *et al*., 2021, Xiao *et al*., 2021). Despite the use of cleaner technologies and the implementation of strong legislation, the adverse effect of air pollution on human health in industrial areas remains a major threat (Shen *et al*., 2021). Studies carried out in European Union's 200 urban clusters (Xiao *et al*., 2021), and Bangladesh (Qiu *et al*., 2021), highlighted that the air quality in the industrial cluster deteriorated which had an adverse health impact on inhabitants living in the vicinity of these clusters (Simpson *et al*., 2013).

Short and long-term exposure to industrial area's air quality can result in higher hospital administration, greater mortality rates, and increased outpatient visits (Parveen *et al*., 2021). A study conducted in Taiwan reported pregnant women give premature delivery of babies due to exposure to industrial air pollution (Bergstra *et al*., 2021). The inhabitants living in the downwind direction of a petrochemical industry increased the rate of melanoma and genotoxicity was observed (Thepanondh *et al*., 2011). The respiratory patients are reported to be 12 times higher than the national average in Delhi, despite of relocation of industries (Parveen *et al*., 2021). Of the world's top 25 polluted cities, 10 are in India (Bera *et al*., 2021).

Gaseous and particulate pollutants are significant contributors to atmospheric air pollution. According to Environment Canada (2001), the industrial sector is responsible for the largest emissions of sulphur dioxide (SO_2) in Canada where the smelting of metal concentrates and power generation are important contributors. In Alberta, the industrial activities leading to the largest releases of SO_2 are upstream oil and gas activities (which include natural gas processing), electric power generation and oil sands activities. The air quality assessment of industrial clusters thus becomes pertinent to ensure sustainable development of society with optimum utilization of natural resources.

The literature review revealed that no study was carried out on the air quality of the Nagothane industrial area. Thus, no information is about the ambient air quality of the study area. This is the identified knowledge gap in the subject domain. To overcome this knowledge gap and to fill it with new knowledge this study was carried out with objective to assess the ambient air quality from the study area for particulate matter such as suspended and respirable and gaseous pollutants viz. sulphur dioxide, oxides of nitrogen, hydrocarbons and carbon monoxide. In addition, average ambient air quality and Air Quality Index of the study area. The study outcome will add a new understanding of the air quality from an industrial area, the air quality index and its associated health impact. The health impact on the inhabitants of the study area from Air Quality Index can be assessed.

Study Area

The Nagothane (Latitude 18°32′40.62″ N and Longitude 73°8′11.17″ E, elevation 18.94 m above mean sea level) industrial area is located in the Roha administrative block, Raigarh district of Maharashtra state in Western India (Figure 1). The settlement is located between the Poynad-Nagothane portion of State Highway (SH 86) (East side) and the villages of Kuhire

(North side) and Vadvani (South side). The study area is essentially in the Western Ghats' foothills. The Kokan Railway line, the Amba River estuary zone, and the Vadi-Nagothane stretch of National Highway (NH 17) all lie on the east side at a distance of around 1-2 kilometres. The study area's geography had complicated terrain in the form of valleys. In the study region, there are few industrial sources, such as Indian Petrochemicals Corporation Limited's Maharashtra Gas Cracker Complex, Supreme Petrochemicals, Ispat Ltd., etc. The catchment from the adjacent hills and higher reaches streams run across the study area before draining to the Amba River. The annual rainfall in the study area varies from 721 mm to 3394 mm with an average of 2177 mm/year.

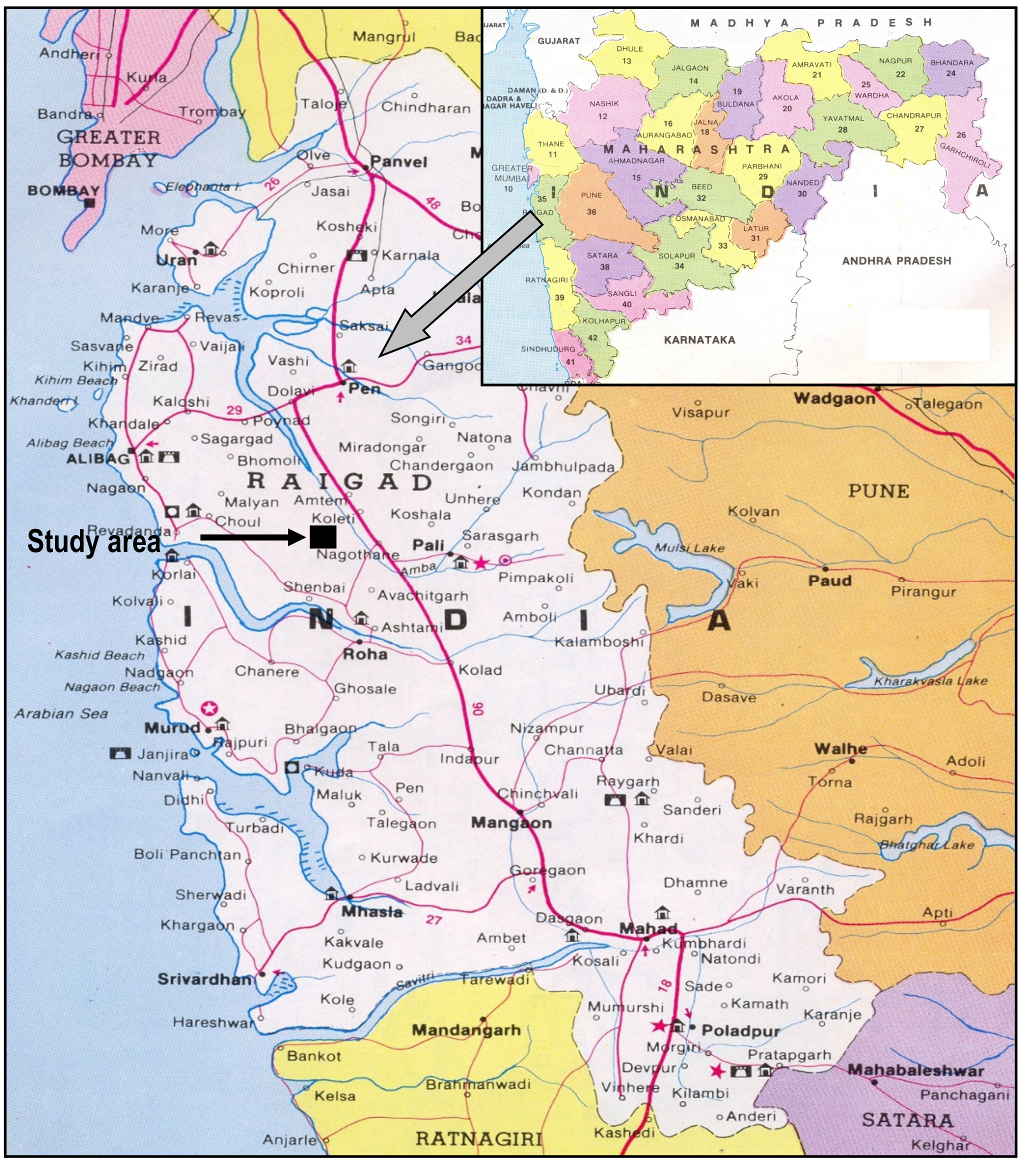

Fig. 1: Study area

Materials and Methods

The micrometeorological data from the study area was monitored continuously (30 days) by using a battery-operated mechanical weather monitoring station at an elevated position (10 m above ground level) for meteorological parameters viz. wind speed, wind direction, temperature, and atmospheric relative humidity in winter season which is most crucial for air pollution perspective.

During the winter season (December–February), onsite measurements of mixing height at the sample location, including diurnal fluctuations, were conducted using a minisonde system (model 3003 of Aero-Aqua Inc., Canada). The minisonde system uses a tiny, lightweight sonde that can be attached as a payload to a 15 cm balloon filled with hydrogen gas to monitor vertical temperature profiles up to 4 km in height in the atmosphere. This allows the sonde to be lifted at a predefined ascent rate (3 m/s). The minisonde flying kit includes a signal transmitter assembly, a temperature sensor that runs on batteries, and a balloon that is inflated with hydrogen gas. A minisonde was used to continually measure the temperature. It was then broadcast back to a receiving station at ground level at a frequency range of 400 MHz–405 MHz.

The ambient air quality status in the study area was assessed during the winter season through 12 sampling stations (Figure 2) by continuous air sampling around the clock as per the prevailing Central Pollution Control Board's guidelines for air quality monitoring. The sampling locations identified were within the 7 km aerial distance of the industrial area. The high-volume air samplers with a Respirable Particulate Matter separation facility fabricated according to the National Environmental Engineering Research Institute's design were used for ambient air quality monitoring. The significant air pollutants, viz. suspended particulate matter, respirable particulate matter, sulphur dioxide and oxides of nitrogen were monitored on a 24-hour basis. The Suspended Particulate Matter (SPM), and Respirable Particulate Matter (RPM) were analyzed by gravimetric method for deriving concentrations at each sampling location. The gaseous pollutants (sulphur dioxide and oxides of nitrogen) were analysed using standard wet chemical methods. The carbon monoxide and hydrocarbons were monitored through spot field sampling and respective instrumental analysis (hydrocarbon analyzer).

Fig. 2: Ambient air quality sampling locations

The Air Quality Index (AQI) at sampling locations was calculated by using the Central Pollution Control Board India's formula which was based on a minimum of three air pollutants from the mentioned eight in the National Ambient Air Quality Standard with particulate matter 10 or particulate matter 2.5 as one of them. The data reading is divided by the national standard of the respective pollutant in consideration and multiplied by 100. The AQI ranges from 0-500 with 0 being good and 500 severe.

Results and Discussion

Micrometeorology

The micrometeorological data from the study area was recorded continuously during the study period (winter season) using a battery-operated mechanical weather monitoring station. Hourly averages of wind speed, wind direction, ambient temperature and relative humidity were derived from continuous data. The hourly record of wind speed and wind direction data during the study period were used for computing the relative percentage frequencies of occurrence in 16 cardinal directions and 5 wind speed classes. These frequencies were computed on 8 hourly as well as 24-hour basis and the corresponding results were used to draw windroses for 00-08 hrs, 08-16 hrs, 16-24 hrs, and 00-24 hrs for the winter season as shown in Figure 2. The 8 hourly windroses during the study period showed predominantly calm conditions. Wind from N, NW and W directions were observed, with a dominant wind speed class of 1-5 kmph. During the daytime (08-16 hrs) and evening hours (16-24 hrs), there were no significant diurnal variations in wind directions. During night time it was purely calm conditions while during day time, wind speed was recorded mostly in the range of 1-10 kmph. The calm condition varied from 35.8% to 99% (8 hourly) with an average of 66.3% (00-24 hrs.) of time during the study period (Figure 3). The channelling effect on wind flow was observed near the study area as it was located at the foothills of the Western Ghats (a wide valley along the course of the Amba River). The daily minimum temperature varied between 14°C and 22.5°C while the maximum temperature varied between 22°C and 33.5°C during the study period. The relative humidity was observed in the range of 60-85% during the study period.

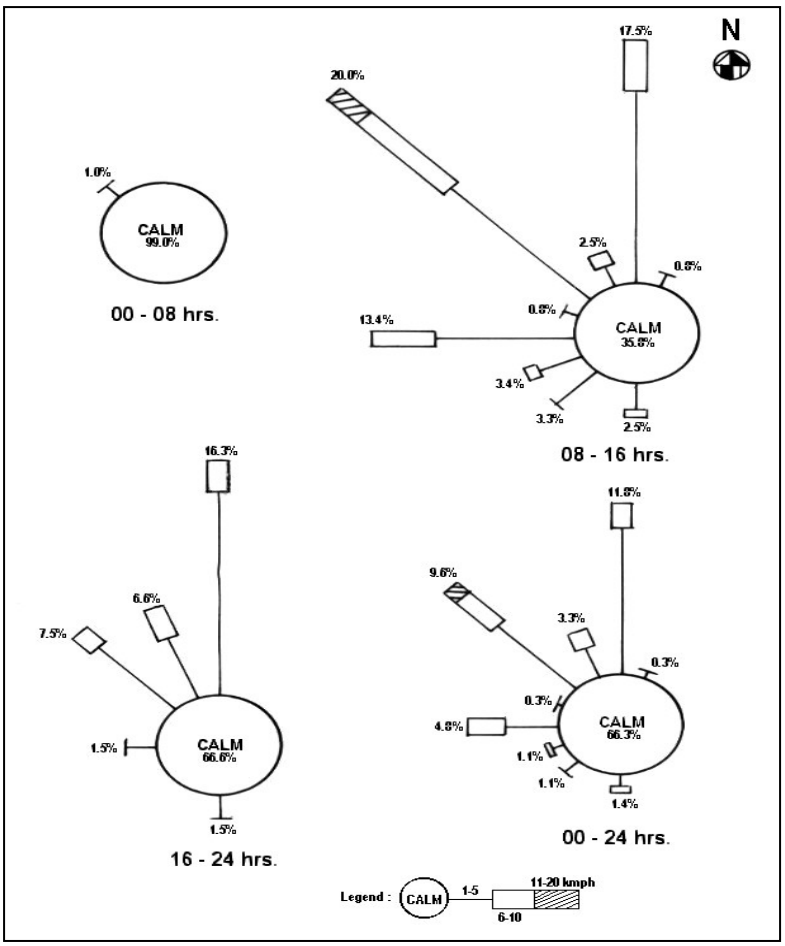

Fig. 3: Windrose from the study area (Winter season)

Maximum mixing height was measured during the study period at 2.30 pm, which was 903 m above ground level. Diurnal variation showed that there was ground-based inversion up to a height of approximately 500 m above ground level, which is nil mixing height during late night (11.30 pm and 2.30 am) to early morning (5.30 am) hours. The research area's highest mixing height of 903 metres above sea level suggested the existence of both thermal and mechanical turbulence. This demonstrates the upward diffusion of air pollutants; as a result, the afternoon will have the lowest ground level. Therefore, in the afternoon, mechanical and thermal turbulence will thoroughly mix up any air pollutants emitted during the day into the volume of air that is accessible to them in the lower atmosphere (Kamble, 2014).

Ambient Air Quality

The ambient air quality status (24 hourly concentrations) observed during the winter season from the study area is presented in Table 1. The average concentrations of SPM at different sampling locations varied between 119 and 239 μg/m^3 and the 98th percentile values ranged between 144 and 408 μg/m^3. The 24 hourly average concentrations of RPM varied between 41 and 117 μg/m^3 while the 98th percentile values ranged between 58 and 179 μg/m^3.

Table 1: Ambient air quality

Sampling location	*SPM*	*RPM*	*SO_2*	**NO_x**
	Average ± Standard deviation (Range)			
Kuhire	180 ± 56 (79 – 270)	117 ± 37 (51 – 176)	3 ± 2 (2 – 11)	14 ± 11 (2 – 42)
Vadvani	132 ± 59 (61 – 282)	60 ± 25 (24 – 98)	3 ± 3 (2 – 14)	7 ± 3 (3 – 13)
Kadsure	169 ± 55 (87 – 267)	109 ± 36 (60 – 174)	3 ± 3 (2 – 15)	10 ± 11 (2 – 40)
Gandhe	199 ± 52 (112 – 298)	70 ± 18 (39 – 104)	3 ± 1 (2 – 6)	10 ± 5 (3 – 18)
Bendse	193 ± 111 (42 – 332)	93 ± 49 (22 – 186)	3 ± 2 (2 – 10)	15 ± 13 (2 – 37)
Nagothane	191 ± 40 (121 – 308)	61 ± 14 (36 – 97)	3 ± 3 (2 – 11)	20 ± 17 (2 – 46)
Warvatane	164 ± 64 (73 – 277)	85 ± 31 (36 – 139)	4 ± 3 (2 – 10)	18 ± 11 (7 – 45)
Patansai	169 ± 65 (93 – 277)	51 ± 20 (28 – 83)	5 ± 5 (2 – 18)	11 ± 7 (2 – 22)
Balsai	201 ± 98 (102 – 393)	60 ± 29 (31 – 118)	3 ± 1 (2 – 6)	10 ± 11 (2 – 28)
Amdoshi	239 ± 44 (174 – 298)	72 ± 13 (52 – 89)	16 ± 10 (2 – 28)	6 ± 3 (2 – 10)
Bhise	229 ± 37 (161 – 290)	51 ± 19 (27 – 87)	5 ± 5 (2 – 11)	17 ± 18 (4 – 38)
Medha	119 ± 23 (92 – 146)	41 ± 7 (33 – 58)	3 ± 2 (2 – 6)	5 ± 2 (3– 9)

(in µg/m^3, sampling period 24 hours)

The average ambient air quality for SPM, RPM, SO_2, and NO_x is presented in Table 2. The minimum, maximum, average and standard deviation of these average concentrations of the air pollutants are also presented. These values are compared with the NAAQS of India for respective air pollutants. From the comparison, the maximum RPM (117 µg/m^3) was above the NAAQS whereas for SO_2, and NO_x they were within the respective standard. The standard deviation (± 5) for SO_2 and NO_x indicates the findings are in proximity to each other. However, opposite observations were drawn for SPM and RPM.

The average concentrations of 24-hourly sulphur dioxide (SO_2) at individual sampling locations varied from 3 to 16 µg/m^3 and the 98th percentile values were in the range of 6 to 27 µg/m^3. The mean concentrations of oxides of nitrogen (NO_x) at all sampling locations varied between 5 and 20 µg/m^3 whereas the 98th percentiles were in the range of 8-44 µg/m^3. The cumulative percentile levels of SO_2 and NO_x show that 98th percentile concentrations of SO_2 and NO_x were well within the stipulated National Ambient Air Quality Standards (80 µg/m^3) for residential, rural and other areas at all the sampling locations during the study period (winter season).

Table 2: Average ambient air quality

Sampling location	*SPM*	*RPM*	*SO_2*	**NO_x**
Kuhire	180	117	3	14
Vadvani	132	60	3	7
Kadsure	169	109	3	10
Gandhe	199	70	3	10
Bendse	193	93	3	15
Nagothane	191	61	3	20
Warvatane	164	85	4	18
Patansai	169	51	5	11
Balsai	201	60	3	10
Amdoshi	239	72	16	6
Bhise	229	51	5	17
Medha	119	41	3	5
Minimum	**119**	**41**	**3**	**5**
Maximum	**239**	**117**	**16**	**20**
Average	**182**	**72.5**	**4.5**	**12**
SD (±)	**40**	**27**	**5**	**5**
NAAQS	**NS**	**100.0**	**80.0**	**80.0**

SD - Standard Deviation, NAAQS - National Ambient Air Quality Standard of India (2009), NS - No Standard (in µg/m^3, sampling period 24 hours)

The spot concentrations of hydrocarbons are converted into three hourly averages following the standard method. The three hourly total hydrocarbon concentrations at all sampling locations have been observed in the range of 0.7-2.4 ppm out of which, the non-methane hydrocarbons are in the range of 0.1-1.1 ppm in ambient air during the study period. The carbon monoxide (CO) was not detectable at most of the sampling locations; however, along the national highway in Nagothane town as well as state highways (SH-86 and SH-92) the spot CO concentrations were recorded in the range of 1.1–2.3 mg/m^3. The status of ambient air quality w.r.t. all gaseous pollutants, was observed well within the prescribed standards in the study period (winter season).

The Air Quality Index of the sampling locations from the study area is presented in Table 3. From the table, it can be seen that the minimum AQI is 17.00 (Medha) and the maximum 46.08 (Kuhire). Based on Indian Air Quality Index (Table 4) the AQI from the study area falls in the category of ‘Good’ status. As mentioned in Table 4 Indian Air Quality Index range and probable health impact can be arrived at the health impact due to air quality from the study area having minimal or no health impact. Thus, it can be concluded that the inhabitants of the Nagothane industrial area have no immediate health impact or disease burden due to industrial air pollutant emissions. However, long-term impacts on them need to be ascertained, with special emphasis on children and elderly persons with co-morbidity.

Table 3: Air Quality Index

Sampling location	*RPM*	*SO_2*	**NO_x**	**Average**	**Status**
Kuhire	117	3.75	17.5	46.08	Good
Vadvani	60	3.75	8.75	24.17	Good
Kadsure	109	3.75	12.5	41.75	Good
Gandhe	70	3.75	12.5	28.75	Good
Bendse	93	3.75	18.75	38.50	Good
Nagothane	61	3.75	25.0	29.92	Good
Warvatane	85	5.00	22.5	37.50	Good
Patansai	51	6.25	13.75	23.67	Good
Balsai	60	3.75	12.5	25.42	Good
Amdoshi	72	20.0	7.50	33.17	Good
Bhise	51	6.25	21.25	26.17	Good
Medha	41	3.75	6.25	17.00	Good

Table 4: Indian Air Quality Index range and probable health impact

AQI	Air quality status	Health impact
0-50	Good	Minimal or no health impact
51-100	Satisfactory	Breathing difficulty in sensitive group
101-200	Moderate	Breathing discomfort for the elderly and children
201-300	Poor	Adverse health effects on people. Those suffering from heart disease can experience discomfort.
301-400	Very poor	Long-term exposure causes respiratory illness
401-500	Severe	Health impacts to normal and diseased people. Severe health impact on sensitive groups

AQI – Air Quality Index (no unit)

The AQI in the study area is in ‘Good’ status owing to the maximum (99%) calm condition (wind speed <1 kmph) during night time (00-08 hours) with nil mixing height during late night to early morning hours the accumulation of air pollutants in the study area can’t be ruled out may result in the formation of an air pollution episode like condition. The valley-like geographical terrain will aggravate this air pollution problem to a higher level. The maximum mixing height of 903 m above ground level in the afternoon will also limit the vertical movement in the winter season and thus may pose a threat to the inhabitants in the case of prolonged ground-based inversion. The industrial expansion and permission to new industries should be given only after carrying out the carrying capacity of the industrial area.

In Yanbu industrial city a substantial spatiotemporal variation was observed in the gaseous contaminants. This was due to the predominance of characterized meteorological parameters interfering with contributions from existing chemical facilities and anthropogenic activities (Al Rabadi *et al*., 2023). The air quality characterization at three industrial areas in southern Italy concerning gaseous pollutants and particulate matter concentration showed a general compliance of the concentrations of some regulated species with the limits set by the EU Ambient Air Quality Directive (Perrino *et al*., 2020). Air pollution in industrial parks in Henan, China revealed power plants were the largest source of SO_2 and NO_x emissions, and industrial processes were the largest emission source of CO, PM_{10}, $PM_{2.5}$, VOCs and NH_3 (Gao *et al*., 2011). The prominent emission sources of air pollution in a critically polluted industrial city are coal burning in power plants, agricultural activities, vehicular emissions, and mining activities (Yadav *et al*., 2022).

The health impact due to industrial air pollution includes childhood-onset of asthma (Zeng and He, 2019), low birth weight of babies (Bergstra *et al*., 2021), reduced life expectancy, disability-adjusted life years, and cardiovascular problems (Vega *et al*., 2021), premature mortality, and lung cancer (Simpson *et al*., 2013), respiratory disease mortality, and otitis media infection in early childhood (Zeng and He, 2019), and cancer mortality (17% higher in industrial areas) (Fernandez-Navarro *et al*., 2017). The Air Quality Index in the study area is <50 which indicates minimal or no health impact on the inhabitants of the study area. These findings reported by authors were not observed in the study area. The plausible reason for the same can be assigned to the good Air Quality Index and less ambient air pollution in the study area. However, a long term monitoring on the health impact need to be carried out.

Conclusion

As the air pollutant concentrations in the study area are within the National standard for respective pollutants and the Air Quality Index is in 'good' status they have minimal or no health impact on the inhabitants. The micrometeorological data along with the terrain of the area in the winter season may pose a threat of air pollution episode-like conditions. The carrying capacity of the study area needs to be assessed before further expansion of the industries and permission for the new one. It is concluded that the industrial contribution to ambient air pollution is minimal in the impact zone. However, continuous monitoring of air quality needs to be carried out to maintain the 'Good' AQI status and minimize the adverse health impact on the inhabitants.

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