

Preliminary Study on Air Quality of Srinagar, (J&K), India

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Abstract

The present work was carried out to study the air quality of Srinagar city and the samples were collected from five different sites which includes commercial area (site-I), industrial area (site-II), residential area (site-III), ecologically sensitive site (site-IV) and sensitive area (site-V). During the study samples were taken on monthly basis and were analyzed for nitrogen dioxide (NO₂), sulphur dioxide (SO₂) and respirable particulate matter (PM₁₀). Significant variation was recorded within and among the sites in NO₂ ($F_3 = 3.82$; $F_4 = 115$, $P < 0.05$), whereas among the sites in SO₂ and PM₁₀ ($F_4 = 167$, $P < 0.05$) and ($F_4 = 72.55$, $P < 0.05$) respectively. The study revealed higher concentration of NO₂ at Lal chowk which is commercial area and vehicular emission could be the one of the reason for higher value of NO₂. SO₂ exhibited high concentration at industrial area and could be attributed to burning of fossil fuels in industries and use of generator sets. PM₁₀ was also found higher in industrial area due to presence of cement industries in addition to burning of coal as fuel. The overall concentration of NO₂ and SO₂ were found within the permissible limits for all sites as per National Ambient Air Quality Standards (NAAQS) except for PM₁₀ at site-I and site-II. The overall air quality index of site-I and site-II falls within “Moderate” category and for site-III, IV and V falls within “Good” category.

Keywords: air pollution, air quality, sites, srinagar

1. Introduction

Air is one of the vital components of environment that human beings have to live in throughout their life and affect the quality of life. The advent of technological and scientific innovations in various fields and diverse anthropogenic activities have put extra load on the atmosphere by way of releasing air pollutant like suspended particulate matter (SPM), respirable suspended particulate matter (RSPM), sulphur dioxide (SO₂), oxides of nitrogen (NO_x), carbon monoxide (CO), unburned hydrocarbon (HC), hydrogen fluoride (HF) and other organic as well as inorganic pollutants including trace metals.

Urban air quality is one of the most serious issues, receiving attention in developing as well as developed countries (Dadhich et al., 2017). In India, pollution has become a great topic of debate at all levels and especially the air pollution because of enhanced anthropogenic activities such as burning fossil fuels (coal and petroleum) and vehicle emission due to its adverse effect on health. Among the different harmful chemical compounds, the pollutants of concern are carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO₂) and suspended particulate matter, including lead from gasoline. Nitrogen dioxide (NO₂), sulphur dioxide (SO₂) and suspended particulate matter (SPM) are regarded as prime air pollutants in India (Rai & Chutia, 2014; Kishore & Deswal, 2017). In many Indian cities, the levels of particulate pollutants in the ambient air have been found to be above the permissible limit (Meenakshi & Saseetharan, 2003). SO₂ is a prime pollutant which is released directly to the atmosphere from domestic and industrial processes, particularly those using petroleum and coal combustion (Wellburn, 1998; Emberson et al., 2001). Coal-fired power plants and vehicles are the largest sources of NO_x and are produced in high temperature combustion processes (Memon, 2000). SPM are finely divided solids or liquids that are dispersed throughout the air and are produced from combustion processes, domestic and industrial activities, as well from natural sources such as volcanoes, dust and forest fires (Emberson et al., 2001). According to international agency for research on cancer (2013), outdoor air pollution is carcinogenic to humans, with the particulate matter (PM) component of air pollution most closely associated with increased cancer incidence, especially cancer of the lung (Loomis et al., 2013). Other pollutants, such as nitrogen oxides (NO_x),

sulphur dioxide (SO₂) and ammonia (NH₃) contribute to the acidification of soil, lakes and rivers, causing the loss of animal and plant life, in addition to the adverse effects on human health.

An air quality index (AQI) is one of the important tool available for analyzing and interpreting air quality status uniformly (Swami & Tyagi, 1999; Taieb & Brahim, 2013). An air quality index is defined as an overall scheme that transforms the weighed values of individual air pollution related parameters into a single number or set of numbers (Ott, 1978). There have not been significant efforts to develop and use AQI in India, primarily due to the fact that a modest air quality monitoring programme was started only in 1984 and public awareness about air pollution was almost non-existent. The challenge of communicating with the people in a comprehensible manner has two dimensions as translate the complex scientific and medical information into simple and precise knowledge and to communicate with the citizens in the historical, current and futuristic sense. Addressing these challenges and thus developing an efficient and comprehensible AQI scale is required for citizens and policy makers to make decisions to prevent and minimize air pollution exposure and ailments induced from the exposure. Briefly, an AQI is useful for general public to interpret air quality in a simplified way, a politician to invoke quick actions, a decision maker to know the trend of events and to chalk out corrective pollution control strategies, a government official to study the impact of regulatory actions and a scientist who engages in scientific research using air quality data.

2. Materials and Methods

2.1 Study Area

The Valley of Kashmir is a lacustrine basin of the intermountain depression existing between the Lesser and Greater Himalayas characterized by numerous aquatic ecosystems of great ecological and economic importance (Najar & Khan, 2012; Ishtiyag et al., 2017). It is located within the geographical coordinates of 33.7782°N, 76.5762°E and lies in the temperate zone, characterized by wet and cold winter and relatively dry and moderate hot summer. The hottest months are July and August, when the maximum temperature rises above 30°C (Najar & Khan, 2011). September has cooler nights and the severe winter sets in about the middle of December (Najar & Khan, 2014). The coldest month is January, with temperature falling below freezing point (Najar & Khan, 2013). The winters vary from year to year; some are severe with very heavy snowfall, while others are mild with moderate snowfall (Najar et al., 2015).

Srinagar is the summer capital of Jammu and Kashmir. It is located within the Geographical Coordinates of 34°5'24"N 74°47'24"E, with the mean elevation of 1585m. The area of Srinagar has increased from 83km² in 1971 to 103.81km² in 1987. It further expanded to 117km² in the later years. With further expansion of the city the area increased to 300km². The master plan (2000-2021) has termed the Srinagar city as Greater Srinagar and placed the area measurement to 416.25km².

2.2 Study Sites

For the study of air quality of Srinagar 5 sites were selected across the study area with different characteristics. The details about the sites are given in Table 1.

Table 1. Description of the study sites

Site	Site location	Geographical coordinates	Elevation (masl)	Nature of site
Site-I	Lal chowk	34°09'00"N 74°79'00"E	1563	Commercial area
Site-II	Khanmoh	34°03'27"N 74°57'80"E	1638	Industrial area
Site-III	Rainawari	34°05'52"N 74°49'18"E	1575	Residential area
Site-IV	Nehru Park	34°05'21"N 74°50'43"E	1565	Ecologically sensitive
Site-V	SMHS	34°05'09"N 74°47'49"E	1586.4	Sensitive

2.3 Air Sampling

Air sampling was carried out by using air sampler of Envirotech. At each site samples were collected on monthly basis, by keeping the sampler at a height of 2 meter above ground level. SO₂ was determined by using Modified West and Gaeke method (1956). The determination of NO₂ is carried out by using Jacob and Hochheiser method (1958). PM₁₀ was determined by Gravimetric method. Air quality index was calculated using IND-AQI by the following formula:

$$I_p = [I_{HI} - I_{LO} / BP_{HI} - BP_{LO} (C_p - BP_{LO})] + I_{LO}$$

Where:

I_p = Index for pollutant “p”.

B_{HI} = Break point concentration greater or equal to given concentration.

B_{LO} = Break point concentration smaller or equal to given concentration.

I_{HI} = AQI value corresponding to BHI.

I_{LO} = AQI value corresponding to BLO.

C_p = Pollutant concentration.

3. Results and Discussion

3.1 Nitrogen Dioxide (NO_2)

The concentration of NO_2 recorded at different sites and during different months is given Figure 1. NO_2 showed significant variation within ($F_3 = 3.82, P < 0.05$) and among ($F_4 = 115, P < 0.05$) the sites. At site-I, the concentration of NO_2 varied from of $17.97\mu\text{g}/\text{m}^3$ during November to maximum of $19.01\mu\text{g}/\text{m}^3$ during January and at site-II, NO_2 ranged from minimum value of $16.69\mu\text{g}/\text{m}^3$ in the month of October to maximum $17.90\mu\text{g}/\text{m}^3$ in the month of January. The site-III exhibited a mean value of $12.00\mu\text{g}/\text{m}^3$ during October to maximum of $15.80\mu\text{g}/\text{m}^3$ during January. At site-IV, NO_2 ranged from minimum of $9.97\mu\text{g}/\text{m}^3$ during October to maximum of $11.00\mu\text{g}/\text{m}^3$ during January whereas at site-V, the minimum and maximum concentrations were found to be $9.92\mu\text{g}/\text{m}^3$ during December and $11.10\mu\text{g}/\text{m}^3$ during January respectively. The mean value recorded at the different sites is given in (Figure 2) and was $10.35\pm 0.26\mu\text{g}/\text{m}^3$ (SMHS), $10.46\pm 0.23\mu\text{g}/\text{m}^3$ (Nehru Park), $14.25\pm 0.88\mu\text{g}/\text{m}^3$ (Rainawari), $17.17\pm 0.25\mu\text{g}/\text{m}^3$ (Khanmoh) and $17.17\pm 0.24\mu\text{g}/\text{m}^3$ (Lal chowk). In the present study, NO_2 ranged from $9.92\mu\text{g}/\text{m}^3$ and $19.01\mu\text{g}/\text{m}^3$. Banerjee and Srivastava (2010) also reported the values of NO_2 around this range ($21.7\mu\text{g}/\text{m}^3$). The study of Sarangi and Mishra (1997) also showed the value of NO_2 ranging from $4.39\mu\text{g}/\text{m}^3$ to $16.89\mu\text{g}/\text{m}^3$. Site-I represents the commercial area and the maximum value of NO_2 ($19.01\mu\text{g}/\text{m}^3$) was recorded. The reason attributed is vehicular emission in the area and the area being highly urbanized.

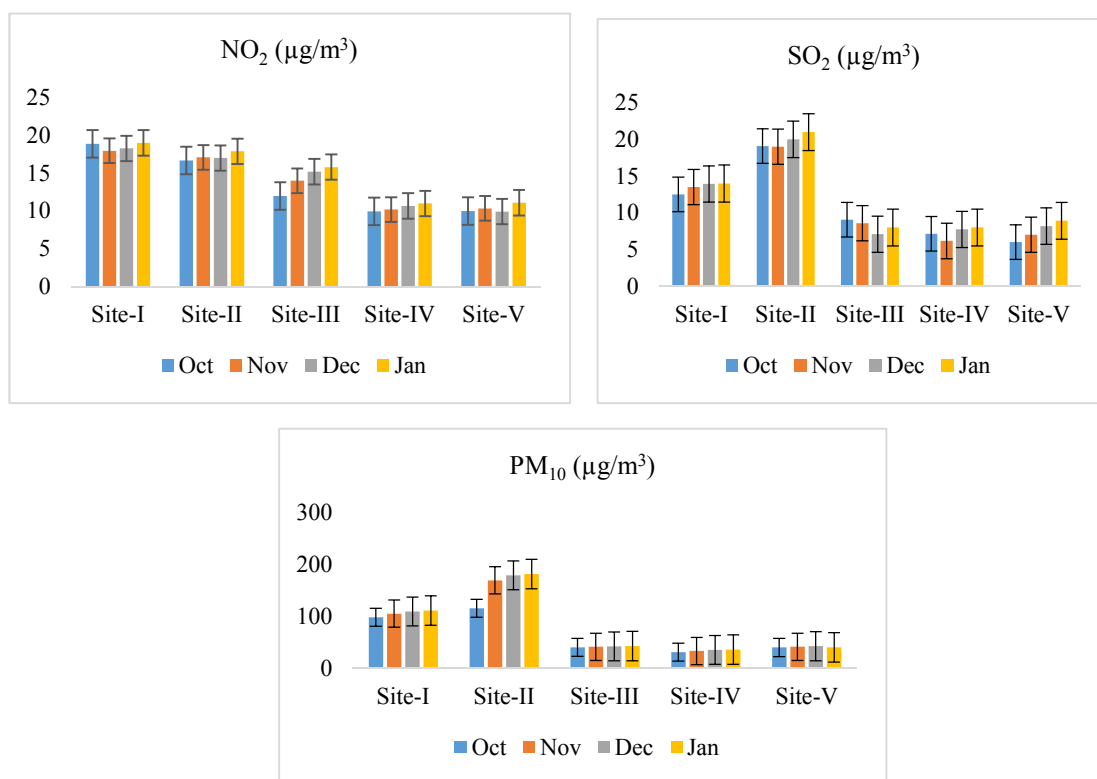


Figure 1. Monthly variation in NO_2 , SO_2 and PM_{10} at different sites

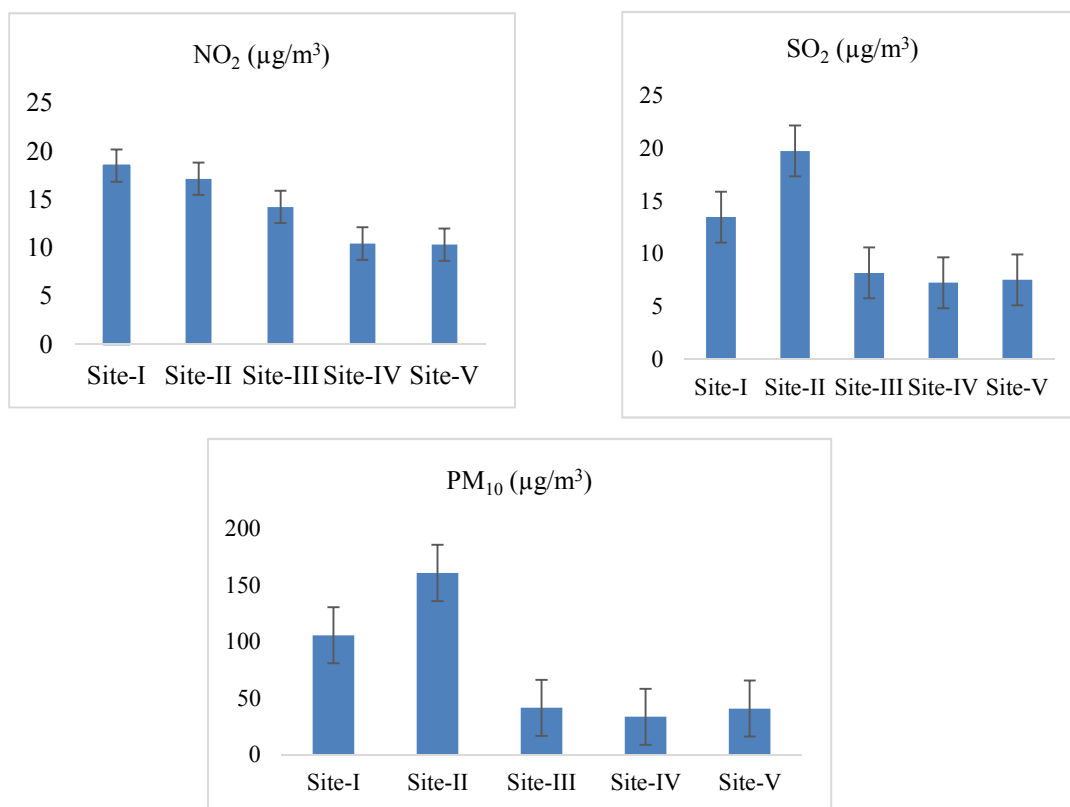


Figure 2. Mean value of NO₂, SO₂ and PM₁₀ at different sites

The study of Hussan et al. (2013) reported that vehicular exhaust is the main cause of NO₂. Aneja et al. (2001) also reported the mobile sources as the predominant contributor of NO₂. According to Panda and Panda (2012) the main factor responsible for the higher level of NO₂ is transportation. Mandal (2000) revealed in its study that NO₂ is found higher in near highly urbanized areas. The concentration is higher in the areas where tree density is low according to the study of Grundström and Pleijel (2014).

The minimum values are recorded in SMHS Hospital being a sensitive area. The low values are due to the reason that the vehicular density in the hospital is very low and no industrial setup is located in the vicinity of the area. The study of Sharma and Raina (2015) also reported that NO₂ exhibited its low values at residential area as compared to commercial and traffic crossing.

During the study, the higher values of NO₂ were recorded during the winter months (January) as compared to other months and might be attributed to the fact that winter months have comparatively calm weather conditions, facilitating more stability to atmosphere and thus slow dispersion of pollutants resulting in higher concentration of pollutants in ambient air. The study of Lakshmanarao and Satish (2014) also reported maximum values during winter season. Panda and Panda (2012) also record relatively higher levels of NO₂ during winter in comparison to summer and monsoon.

3.2 Sulphur Dioxide (SO₂)

The concentration of SO₂ recorded at different sites and during different months is given Figure 1. SO₂ exhibited significant variation among ($F_4 = 167$, $P < 0.05$) the sites whereas no significant variation was recorded within ($F_3 = 2.29$, $P < 0.05$) the sites. At site-I, the minimum and maximum concentration of SO₂ were found to be 12.51 μg/m³ in the month of October and 14.00 μg/m³ in the month of January respectively. At site-II, mean value was found to be varied from 19.00 μg/m³ during November and to 21.00 μg/m³ during January. At site-III, SO₂ exhibited concentration from minimum of 7.09 μg/m³ during December to maximum of 9.06 μg/m³ during October and at site-IV, SO₂ ranged from 6.17 μg/m³ (minimum) during November to 8.00 μg/m³ (maximum) during January. The concentration of SO₂ varied from minimum of 6.00 μg/m³ in the month of October to maximum of 8.92 μg/m³ in the month of January at site-V. The mean value (Figure 2) recorded at sites was 19.99±0.46 (Khanmoh), 13.49±0.34 (Lalchowk), 8.19±0.42 (Rainawari), 7.53 ± 0.06, (SMHS) and 7.26±0.40 (Nehru park).

The recorded concentration of SO₂ varies from 6.00µg/m³ to 21.00µg/m³ during the study. Sarangi and Mishra (1997) and Saksena et al. (2003) also reported the values of SO₂ ranging from 4.62µg/m³ to 25.74µg/m³ and 8.4µg/m³ to 51.2µg/m³ respectively.

The maximum concentration of SO₂ (21.00µg/m³) was found at Site-II and could be attributed to emission from different industrial units as the site represents the industrial area. The maximum concentration is due to the fact that the area is highly industrialized and burning of fuel emissions from industries is prominent resulting in increase in concentration of SO₂. Further the use of generator sets, poorly maintained roads, frequent traffic jams and slow speed of vehicles also contribute to the high levels. The study of Banerjee and Srivastava (2003) also revealed the value of SO₂ to be 21.1µg/m³ which collaborates with the present study. Barman et al. (2010) also reported the value of SO₂ within the range of 18.0µg/m³ to 25.7µg/m³ for industrial area. According to Hussan et al. (2013), fuelling material contributes to higher values of SO₂. Limbochiya and Patel (2013) reported higher concentration of SO₂ in areas close to industrial establishment. Sharma and Raina (2015) also recorded higher SO₂ in areas using diesel generator sets.

The minimum concentration of SO₂ is recorded for Site-V which represents the sensitive area-SMHS Hospital (6.00µg/m³). Minimum values are attributed to the fact that use of fuel and generators sets in the area is less and no industrial setup is located in the vicinity of the area.

Since the study was carried from October to January, the higher values recorded was for January because of calm weather conditions during winter season leading to more stability, slow dispersion of pollutants in the atmosphere and inversion factor causing higher concentration of pollutants in atmosphere. The study of Lakshmanarao and Satish (2014) also reported maximum values during winter season. Panda and Panda (2012) also record relatively higher levels of SO₂ during winter in comparison to summer and monsoon. According to Rai and Chutia (2014), air pollutants tend to concentrate in winter season due to high atmospheric stability and inversion factor.

3.3 PM₁₀

The PM₁₀ recorded at different sites is given in Figure 1. No significant variation in PM₁₀ was recorded within the sites ($F_3 = 1.90$, $P < 0.05$) whereas significant variation was recorded among ($F_4 = 72.55$, $P < 0.05$) the sites. At site I, II, III and IV the minimum concentration of PM₁₀ was found to be 98µg/m³, 115.1µg/m³, 40µg/m³ and 31µg/m³ in the month of October and maximum to be 111µg/m³, 181µg/m³, 42.8µg/m³ and 35.5µg/m³ in the month of January respectively. While at site-V, PM₁₀ exhibited minimum concentration of 39.8µg/m³ in the month of October and 42.3µg/m³ in the month of December. The mean value recorded (Figure 2) was 105.75±2.87 (LalChowk), 161.025±15.53 (khanmoh), 41.475±0.62 (Rainawari), 33.625±1.03 (Nehru Park) and 40.8±0.58 (SMHS).

PM₁₀ exhibited a range of 31µg/m³ to 181µg/m³ among different sites. The maximum concentration was recorded for site-II which represents the Industrial area (181µg/m³) and minimum concentration was recorded for site-IV which represents ecologically sensitive area (31µg/m³). The higher ranges of PM₁₀ in industrial area have key contributions from the cement factories and other industrial processes. High vehicular traffic, increasing number of heavy vehicles, unpaved roads, and resuspension of dust from roads contribute to the high levels of PM₁₀ in the area. Bhaskar and Mehta (2010) reported that particulate pollutant concentration is higher in industrial and traffic areas and less in residential area. According to Lamare and Chaturvedi (2014), elevated PM₁₀ concentrations are attributed mainly to increasing number of vehicles. Limbochiya and Patel (2013) also reported higher concentration of particulate in and around industrial areas. According to Meenambai and Akil (2000), higher values of PM₁₀ are due to traffic congestion and increased human activity such as construction. Bhuyan et al. (2014) also revealed that the traffic system, road construction, burning of municipal wastes and unpaved roads are the main cause of higher levels of particulate matter (PM₁₀).

The national ambient air quality standards (NAAQS), 2009 of Central Pollution Control Board (CPCB) is given in Table 2. From the table it is clear that the concentration of different pollutants at different sites falls within the permissible limits except for the PM₁₀ at site-II (Khanmoh) followed by Site-I (Lalchowk). The site-II being the industrial area with cement factories could be the reason for the higher PM₁₀ whereas the Site-I which is having higher vehicular load results in higher concentration of PM₁₀.

Table 2. Comparison of observed concentration of different pollutants at different sites with National Ambient Air Quality Standard (NAAQS), 2009

Pollutant	Observed concentrations at different sites					Weighted Average	Prescribed limits	
	Site-I	Site-II	Site-III	Site-IV	Site-V		Rural and other areas	Sensitive area
Sulphur Dioxide ($\mu\text{g}/\text{m}^3$)	13.49	19.77	8.19	7.26	7.53	Annual 24 Hours	50 80	20 80
Nitrogen Dioxide ($\mu\text{g}/\text{m}^3$)	18.54	17.17	14.25	10.46	10.35	Annual 24 Hours	40 80	30 80
Particulate Matter (< 10 μm) $\mu\text{g}/\text{m}^3$	105.75	161.02	41.47	33.62	40.8	Annual 24 Hours	60 100	60 100

3.4 Air Quality Index (AQI)

The air quality index (AQI) of different pollutants at different sites based on the concentration in Table 3. For site-I, the air quality index for PM₁₀, SO₂ and NO₂ is 104.14, 16.68, and 23.16 respectively. At site-II, AQI for PM₁₀ is 140.62, SO₂ is 24.71 and NO₂ is 21.46. For site-III, PM₁₀, SO₂ and NO₂ exhibited values of 41.48, 10.24 and 17.81 respectively. For site-IV, the value of PM₁₀ is 33.63, SO₂ is 9.075 and NO₂ is 13.08. For site-V, the value is 40.8, 9.41 and 12.04 for PM₁₀, SO₂ and NO₂ respectively. The percent contribution of pollutant at different sites is given in Figure 3.

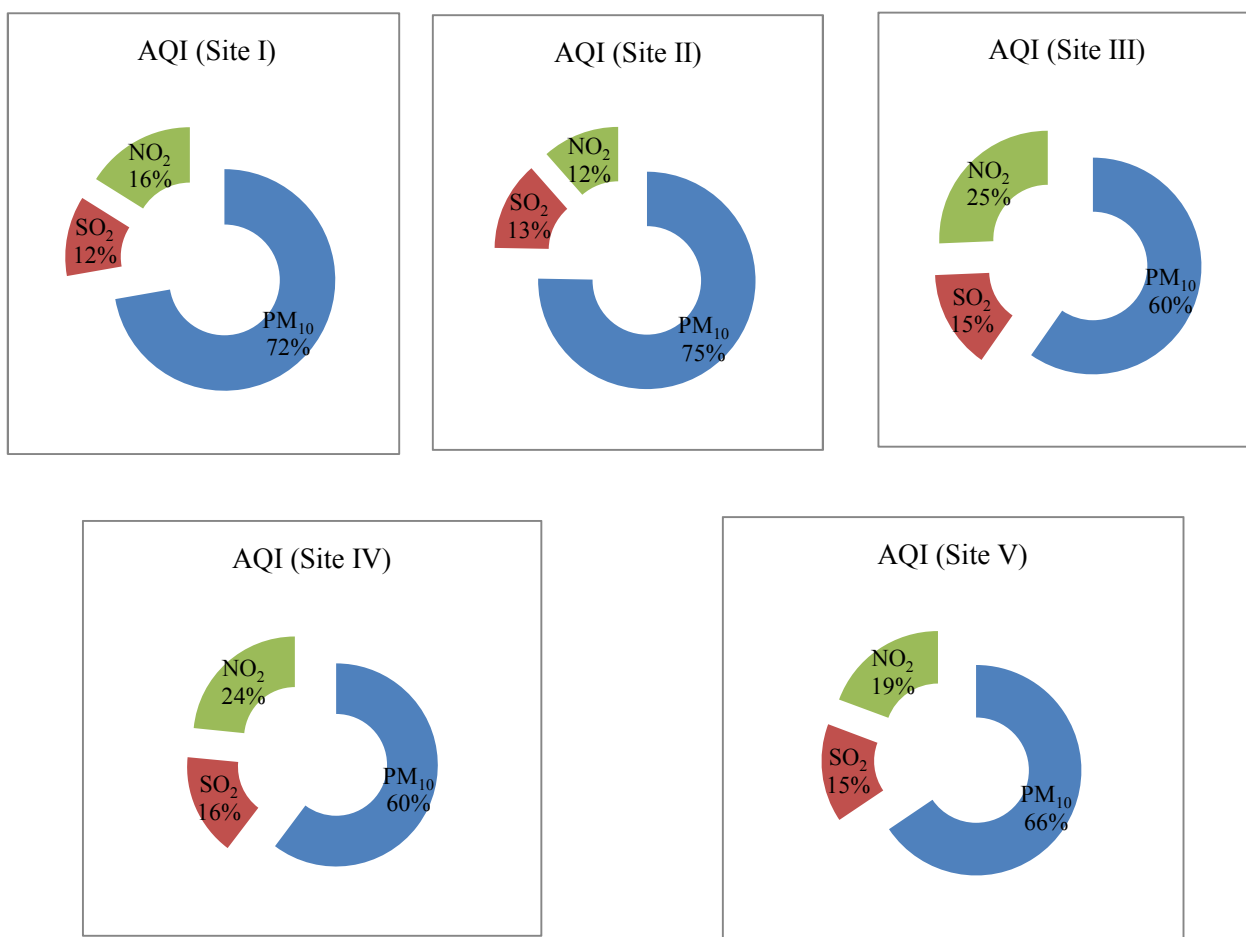


Figure 3. Air quality Index (AQI) of different pollutants at different sites and their percent contribution

Table 3. Calculated air quality index (AQI) of different pollutants at different sites and overall air quality index of each site based on the color coding system of Indian standard (CPCB)

Sites	Pollutant with their AQI			Overall AQI	Overall Category
	PM ₁₀	SO ₂	NO ₂		
Site-I	104.14	16.86	23.16	104.13	Moderate
Site-II	140.62	24.71	21.46	140.62	Moderate
Site-III	41.48	10.24	17.81	41.48	Good
Site-IV	33.63	9.075	13.08	33.63	Good
Site-V	40.8	9.41	12.04	40.8	Good

The Table for air quality index with range and color coding as per Central Pollution Control Board (2014) is given in Table 4 and its associated health statements in Table 5. From the table it is clear that the air quality index of all sites based on their respective concentration of PM₁₀, SO₂ and NO₂ showed varied index. For SO₂ and NO₂, the air quality falls within “Good” air quality index category for all sites except for the PM₁₀, the index falls within the “Moderate” category for site-I and site-II and whereas for site III, IV and V the index falls within “Good” air quality index category. Since the air quality index values of PM₁₀ are higher than the air quality index values for SO₂ and NO₂, thus PM₁₀ determines the overall air quality index of all sites (Figure 3). Thus, the air quality of site-I and site-II is “Moderate” and site III, IV and V has “Good” air quality according to India Air quality Index (IND-AQI). Thus it is clear that the air quality of site-I and Site-II is unhealthy for sensitive group and may cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults (Table 5).

Table 4. Air quality index (AQI) system with range, categories and color coding as per CPCB, 2014

AQI Category (Range)	PM ₁₀ 24-hr	PM _{2.5} 24-hr	NO ₂ 24-hr	O ₃ 8-hr	CO 8-hr (mg/m ³)	SO ₂ 24-hr	NH ₃ 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6-1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201-300)	151-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430+	250+	400+	748+	34+	1600+	1800+	3.5+

Table 5. Health statements for AQI Categories as per CPCB, 2014

AQI	Associated Health Impacts
Good (0-50)	Minimal Impacts
Satisfactory (51-100)	May cause minor breathing discomfort to sensitive people
Moderate (101-200)	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201-300)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease with short exposure
Very Poor (301-400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe (401-500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

Neelima et al. (2014) also reported SO₂ and NO₂ concentration and their respective value of AQI within “Good” and “good to moderate” while for PM₁₀ and SPM as “Unhealthy to Very poor” category. Panda and Panda (2012) reported that high values of AQI are mainly due to SPM and RSPM. According to Mamta and Bassin (2010), suspended particulate matter (SPM) is mainly responsible for higher values among different pollutants and determined the overall AQI category of “Very poor”. Sharma and Raina (2013) and Goyal (2001) also reported SPM as the dominant pollutant determining the overall air quality index.

4. Conclusions

The present study revealed that the concentration of NO₂ was found to be higher in commercial area and is contributed to vehicular emission and the area being highly urbanized. SO₂ concentration was found to be higher in industrial area due to burning of fuels in industrial units and use of diesel generator. PM₁₀ exhibited higher values in industrial area due the presence of cement industries and burning of coal as fuel in different industrial units, in addition to the poorly maintained roads and heavy vehicular movement. However, the overall concentration of different pollutants (SO₂ and NO₂) was within the permissible limits of National Ambient air Quality standards (NAAQS) at all sites except for particulate matter (PM₁₀) at site-I and site-II. The overall concentration of all the pollutants was found higher in the month of January because of calm weather conditions and stagnant air leading to more stability and slow dispersion of pollutants within the atmosphere. The air quality index (AQI) was contributed by PM₁₀ because of higher value of PM₁₀ at all sites. The Air quality index of commercial and industrial site falls within “Moderate” category and for residential and ecologically sensitive site it falls within “Good” category.

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