

Determination of Air Quality Index Status in Industrial areas of Visakhapatnam, India

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Abstract

The present investigation was carried out to significant of air pollutant concentrations at industrial area of Visakhapatnam. $PM_{2.5}$, PM_{10} , sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) were collected over six (6) sites in Visakhapatnam. First sampling station location at Coromandal fertilizers, second sampling station location at Hindustan petroleum chemicals ltd, third sampling station location at Hindustan Polymerisation, fourth sampling station location at Hindustan zinc, fifth sampling station location at Vizag Steel plant and sixth sampling station location at Hindustan ship yard. All the sampling stations selected are located in industrial areas. Meteorological parameters like Temperature, Relative humidity, Wind speed, Wind direction & Rain fall data were also recorded simultaneously during the sampling period. Monthly and seasonal variation of these pollutions have been observed and recorded. The annual average and range values have also been calculated. It has been observed that the concentrations of the pollutants are high in winter in comparison to the summer or the monsoon and post monsoon seasons. In the present study, it was noticed that the $PM_{2.5}$ and PM_{10} levels at all selected sites exceeds the prescribed limits as stipulated by Central Pollution Control Board (CPCB) New Delhi. A part from this the SO_2 and NO_x levels in industrial areas remain under prescribed limits of CPCB.

Keywords: Air quality index, $PM_{2.5}$ particles, PM_{10} particles, air pollution, industries, sampling stations.

Introduction

In India the ambient atmospheric conditions have progressively deteriorated due to urbanization, industrial development, lack of awareness, poor maintenance of motor vehicles and poor road conditions. Transport vehicles and industrial emissions are the major sources of pollutants in the Visakhapatnam atmosphere, a problem that has been aggravated by the tremendous increase in the number of mobile sources. So, there is need to evaluate the air quality improvement in Visakhapatnam, Andhra Pradesh, India. Among the particles, those having median diameters higher than $10 \mu\text{g}/\text{m}^3$ are stopped in the upper areas of the respiratory system. Air pollution concentration in Haryana sub region, India¹. In Visakhapatnam surroundings the concentration of SO_2 and NO_x is always under the Indian air quality standard. But the concentration of $PM_{2.5}$ and PM_{10} exceeds the Indian air quality guideline in this area^{2,4}.

The WHO⁵/UNEP⁶ report reveals air pollution problems in metropolitan cities of India as some of these are among the most polluted cities of the worlds. India has 23 major cities of over 1 million people and ambient air pollution levels exceed the WHO⁵ standards in many of them. The main reason for deterioration of air quality in the cities is the growing number of vehicles urban air pollution poses a significant threat to human health, property and the environment throughout the developing and developed parts of the world. Over the years there has been a tremendous increase in human population, road transports,

vehicular traffic and industries in Visakhapatnam region, has lead to increases in the concentration of gaseous and particulates pollutants in the ambient air. This paper is an attempt to investigate the air quality status and air quality index (AQI) at selected monitoring sites of Visakhapatnam.

Material and Methods

Study Area: Visakhapatnam city is located at latitude $17^\circ 43'$ N and longitude $83^\circ 17'$ E in North Eastern Coast of Andhra Pradesh with a topography like a spoon shaped basin surrounded by hill ranges on three sides and sea on the other side and is often called as bowl area for assessment of environmental related issues. Since, the city is growing very rapidly, it is necessary to check air quality at regular intervals.

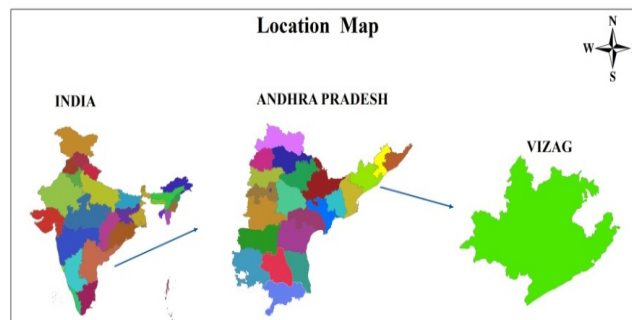


Figure-1
The Location map of the study area

Visakhapatnam is presently witnessing a boom in industrialization and a consequent explosion in population. The establishment of industries like Hindustan shipyard, HPCL, Steel plant, Hindustan Polymers, Coromandal Fertilizers, and Hindustan zinc, APIIC Industrial parks, BHPV etc. Besides this, eastern naval command Head quarters, the submarine base, Harbour, port, railway networks etc.

Study Sites: The total six sampling monitoring sites were selected in the study area. i. Coromandal fertilizers, ii. Hindustan petroleum chemicals ltd, iii. Hindustan Polymerisation, iv. Hindustan zinc, v. Steel plant, vi. Hindustan ship yard.

The present stations were monitored in March, 2011 to February, 2012. The study was carried out by means of sensitive diffusion samples in ambient air during the period March, 2011 to February, 2012 (Summer to Monsoon). Total six (6) sampling stations were exposed during the period for monitoring of PM_{2.5}, PM₁₀, SO₂, NO_x and meteorology data.

The present study deals with the effect of industrialization emission on ambient air quality in Visakhapatnam.

Monitoring and Analysis: Air pollutants (SO₂, NO_x, PM_{2.5} and PM₁₀) monitoring data for site was measured with the help of RDS APM 460 NL by sucking air into appropriate reagent for 24 hours at every 30 days and after air monitoring it procured into lab and analysis for the concentration level. The PM_{2.5} and PM₁₀ were analyzed using Respirable Dust Sampler (RDS) APM 460 and operated at an average flow rate of 1.0-1.5 m³ min⁻¹. Preweighed glass fiber filters (GF/A) of what man were used as per standard methods. SO₂ and NO_x were collected by bubbling the sample in a specific absorbing (sodium tetrachloromercuate of SO₂ and sodium hydroxide for NO_x) solution at an average flow rate of 0.2-0.5 min⁻¹. The impinger samples were put in ice boxes immediately after sampling and transferred to a refrigerator until analyzed. The concentration of NO_x was measured with standard method of Modified Jacobs - Hochheiser method. SO₂ was measured by Modified West and Geake method, PM_{2.5} and PM₁₀ using filter paper methods. The apparatus was kept at a height of 2 meters from the surface of the ground. However air pollutants data for site was collected from Andhra Pradesh Pollution Control Board, Hyderabad. The street level concentration of nitrogen dioxide and suspended particulate matter observed in Hong-Kong⁷.

AQI (air quality index) is then calculated with the concentration values using the equation of⁸.

Results and Discussions

The present study deals with the air pollutants concentrations and air quality index (AQI) at six monitoring sites of Visakhapatnam. Table-1 represents the characterization of six selected monitoring sites. Figure 2 to figure 7 represents the seasonal variation of

PM₁₀, PM_{2.5}, NO_x and SO₂ at six monitoring sites. The table 2(a) to table 7(b) represents seasonal variation of PM₁₀, PM_{2.5}, NO_x, and SO₂ at monitoring sites. It was observed from (table – 9) the meteorological data that the highest temperature attained was during the month of May at site 1, 2, 3, 4, 5, 6, whereas the lowest temperature was recorded in the month of December at site 1, 2, 4 and 6. While lowest during January at site S3, and S5. Where as Highest humidity (table – 10) was recorded during the month of November and December at site 1, 2 and 3 and lowest in the month of April at site 4, 5 and 6. The highest rainfall (table-11) was recorded during July at site 1, 3 and 4, and September at Site 2, 5 and 6. In the case of wind speed (table – 12) highest observed during June-July at site 1, 2, 3 and 6, while at site 4, 5 lowest during April.

Site-Specific Variations: The ambient air concentration of PM₁₀ was observed more than the stipulate standard values at the 1 to 6 sites. It ranged from 78.80 to 178.90 µg/m³, 56.99 to 180.99 µg/m³, 22.90 to 160.80 µg/m³, 55.98-177.80 µg/m³, 29.30 to 175.90 µg/m³ and 26.30 to 178.80 at Site 1, 2, 3, 4, 5 and 6, respectively. Further it was observed that average concentrations of SPM ranged from 250.82 to 450.98 µg/m³, 290.36 to 440.90 µg/m³, 250.51 to 496.40 µg/m³ and 250.90 to 600.01 µg/m³, 100.80 to 490.60 µg/m³, and 98.99 to 440.36 at site 1, 2, 3, 4, 5 and 6 respectively. The highest concentration of PM₁₀ exceeding 250 µg/m³ was observed in Kolkata and New Delhi, WHO⁴. The highest concentrations of PM₁₀ and PM_{2.5} have been reported in various part of India.

According to the present study, annual NO_x and SO₂ concentrations at the monitoring station (table - 1) were well below the maximum allowed limit of National Ambient Air Quality Standards (NAAQS) for different areas. The concentration of NO_x ranged 38.80 to 76.69 µg/m³, 15.98 to 79.60 µg/m³, 22.99 to 78.80 µg/m³, 17.92 to 75.60 µg/m³, 18.82 to 70.91 µg/m³, 17.96 to 72.96 µg/m³, at site 1, 2, 3, 4, 5 and 6 respectively. The concentration of SO₂ ranged between 33.02 to 80.91 µg/m³, 14.08 to 80.08 µg/m³, 31.01 to 80.00 µg/m³, 18.90 to 80.96 µg/m³, 35.90 to 74.96 µg/m³ and 18.80 to 76.96 µg/m³, at site 1, 2, 3, 4, 5 and 6 respectively. Site 1 to Site 6 are present in industrial areas and some of the industries and high traffic load throughout day and night. The high SO₂ concentrations of about 14 to 80 µg/m³ in most of the cities of the developing countries, and the daily average values rarely exceed 125 µg/m³ and annual mean concentration of NO_x recorded in most cities across the globe, not exceeding 40 µg/m³. The highest concentrations of RSPM and SPM have been reported in various part of India.

Seasonal Variations: It is observed from Table 3 (a) to 7 (b) that the concentration of PM₁₀ during summer was recorded as 160.96 to 178.90 µg/m³, 120.80 to 149.92 µg/m³, 89.96 to 111.38 µg/m³ and 78.80 to 130.82 µg/m³ during Winter, Monsoon, Post monsoon at site 1; Site – 2 at Summer was recorded as 166.96 to 150.80 µg/m³, winter was recorded as 130.81 to 150.80 µg/m³; Monsoon was recorded as 56.99 to 89.30 µg/m³; Post monsoon was recorded as 88.81 to 130.80 µg/m³.

Site-3 at summer was recorded as 120.99 to 130.80 $\mu\text{g}/\text{m}^3$, winter was recorded as 135.99 to 160.80 $\mu\text{g}/\text{m}^3$, and Monsoon was recorded as 82.91 to 132.96 $\mu\text{g}/\text{m}^3$ respectively.

Highest concentration of $\text{PM}_{2.5}$ was recorded during winter at Site 1 and 4; Where as Site 2 and 6, the highest concentration was recorded during summer.

Highest levels of NO_x were observed during winter at all four monitoring sites and lowest levels of NO_x were observed during summer at six monitoring sites.

Highest concentrations of SO_2 were recorded during winter at total 6 sites. However the lowest concentrations of SO_2 were recorded during the summer at all six selected monitoring sites.

Air Quality Index (AQI): Air Quality Index (AQI) is developed to provide the information about air quality. Air Quality Index (AQI) was introduced by the Environmental Protection Agency (EPA) in USA to measure the levels of pollution due to major air

pollutants. It is one of the important tools available for analyzing and representing air quality status uniformly. The concentrations of the major pollutants are monitored and subsequently converted into AQI (Table - 13 to 18) using standard formulae and rating scale was also calculated (Table - 8). The higher value of an index refers to a higher level of air pollution. In the present investigation, the SPM, NO_x and SO_2 levels at all six selected sites have been used to calculate AQI.

Air quality index (AQI) varied from the concentration of PM_{10} high value 110 $\mu\text{g}/\text{m}^3$ (Summer) observed in S_2 Sampling station and AQI Category is “Unhealthy for Sensitive Groups” during study period. Air quality index (AQI) varied from the concentration of SPM high value 457 (Monsoon) observed in S_5 Sampling station, AQI Category is “Hazardous” during study period. Air quality index (AQI) varied from the concentration of NO_x high value 77 (winter) observed in S_2 Sampling station, AQI Category is “Moderate” during the study period. Air quality index (AQI) varied from the concentration of SO_2 high value 102 observed in the winter season of S_1 and S_2 sampling stations, AQI Category is “Unhealthy for Sensitive Groups” during study period.

Table-1
Characterization of Six sampling sites

S. No	Sampling Sites	Zonal Activities
1	Site – 1- Coromandal Fertilizers	1) Construction works. 2) Developed road condition. 3) Transportation of vehicles.
2	Site – 2 - Hindustan Petroleum Chemicals Ltd.,	1) Developed road condition. 2) Transportation of vehicles.
3	Site – 3 - Hindustan Polymers	1) Developed road condition. 2) Transportation of vehicles.
4	Site – 4 - Hindustan Zinc	1) Construction works. 2) Developed road condition. 3) Transportation of vehicles.
5	Site – 5 - Steel Plant	1) Developed road condition. 2) Transportation of vehicles.
6	Site – 6 - Hindustan Ship Yard	1) Construction works. 2) Developed road condition. 3) Transportation of vehicles.

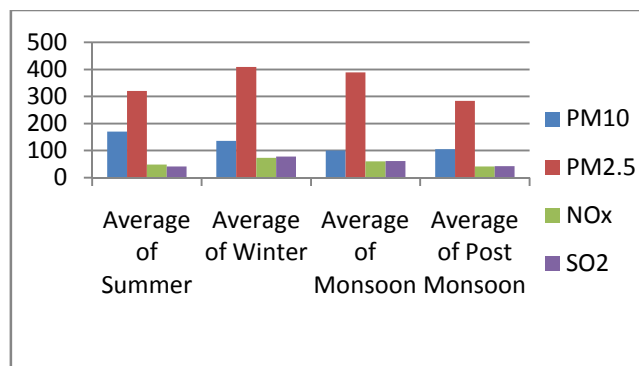
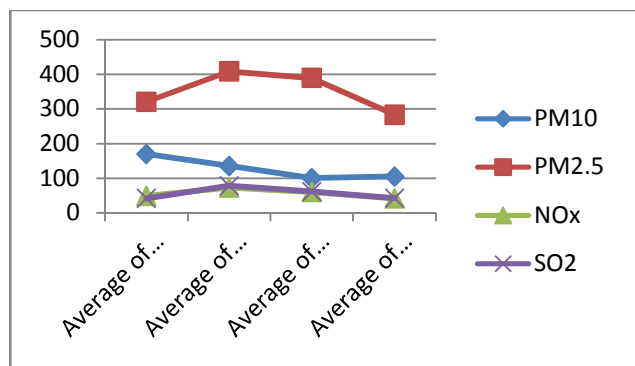


Figure-2
Seasonal variation of PM_{10} , $\text{PM}_{2.5}$, NO_x , SO_2 , at Six selected sites in Visakhapatnam
Two types of Graph showing - Coromandal Fertilizers – Site -1

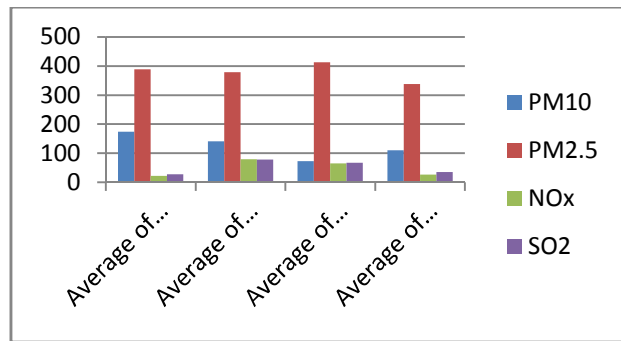
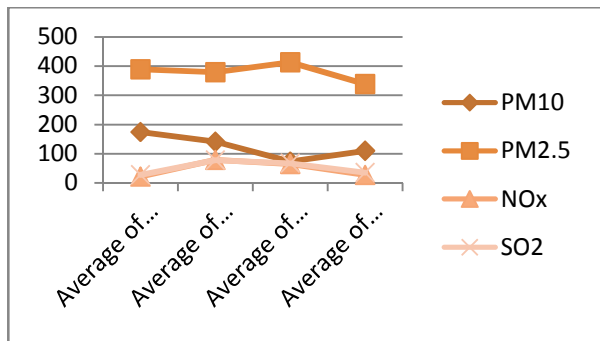


Figure-3
 Seasonal variation of PM₁₀, PM_{2.5}, NO_x, SO₂, at Six selected sites in Visakhapatnam
 Two types of Graph showing - Hindustan Petroleum Chemicals Ltd., – Site -2

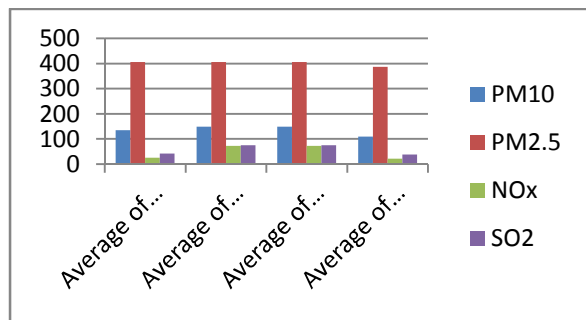
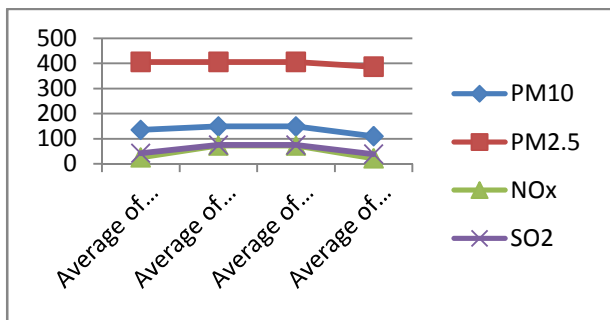


Figure-4
 Seasonal variation of PM₁₀, PM_{2.5}, NO_x, SO₂, at Six selected sites in Visakhapatnam
 Two types of Graph showing - Hindustan Polymers – Site -3

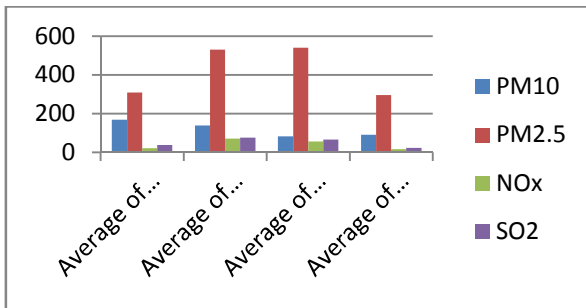
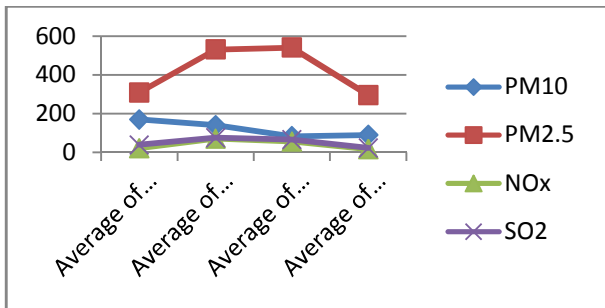


Figure-5
 Seasonal variation of PM₁₀, PM_{2.5}, NO_x, SO₂, at Six selected sites in Visakhapatnam
 Two types of Graph showing - Hindustan Zinc – Site -4

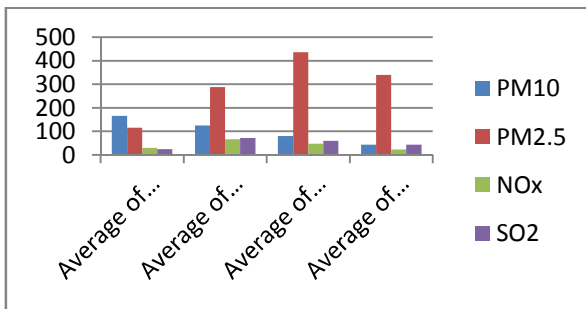
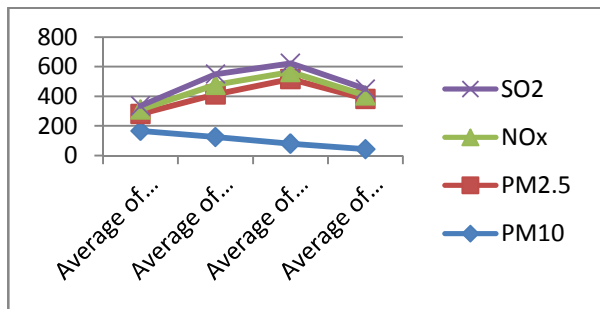


Figure-6
 Seasonal variation of PM₁₀, PM_{2.5}, NO_x, SO₂, at Six selected sites in Visakhapatnam
 Two types of Graph showing - Steel plant – Site -5

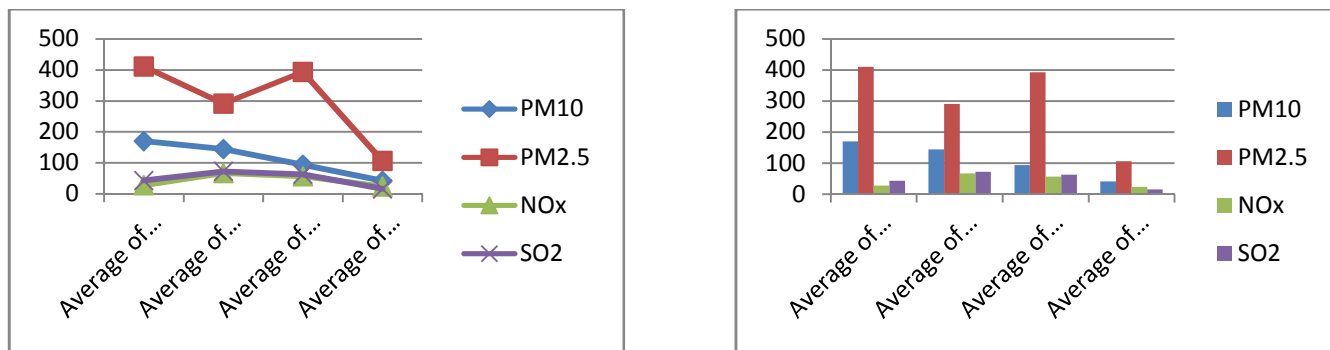


Figure-7
Seasonal variation of PM10, PM_{2.5}, NO_x, SO₂, at Six selected sites in Visakhapatnam
Two types of Graph showing - Hindustan Ship Yard – Site -6

Table-2(a)
Seasonal variation of PM10, PM_{2.5}, NO_x, SO₂, and AQI at Six selected sites in Visakhapatnam –
Coromandal Fertilizers – Site -1

S. No	Pollutants	Permissible Limit Value	Summer	Winter	Mon Soon	Post Monsoon
1	PM ₁₀	60	160.96 to 178.90	120.80 to 149.92	89.96 to 110.38	78.80 to 130.82
2	SPM	100	250.82 to 390.60	365.98 to 450.98	366.81 to 411.90	256.99 to 309.30
3	NO _x	80	44.99 to 52.68	68.90 to 76.69	49.68 to 70.30	38.80 to 43.96
4	SO ₂	80	33.02 to 50.90	75.09 to 80.91	57.76 to 65.50	39.06 to 45.90

Table-2(b)
Seasonal average values of PM10, PM_{2.5}, NO_x, SO₂, and AQI at Six selected sites in Visakhapatnam –
Coromandal Fertilizers – Site -1

Pollutants	Summer	Average of Summer	Winter	Average of Winter	Mon Soon	Average of Monsoon	Post Monsoon	Average of Post Monsoon
PM ₁₀	160.96 to 178.90	169.93	120.80 to 149.92	135.36	89.96 to 110.38	100.17	78.80 to 130.82	104.81
PM _{2.5}	250.82 to 390.60	320.71	365.98 to 450.98	408.48	366.81 to 411.90	389.35	256.99 to 309.30	283.14
NO _x	44.99 to 52.68	48.83	68.90 to 76.69	72.79	49.68 to 70.30	59.99	38.80 to 43.96	41.38
SO ₂	33.02 to 50.90	41.96	75.09 to 80.91	78	57.76 to 65.50	61.63	39.06 to 45.90	42.48

Table-3(a)
Seasonal variation of PM10, PM_{2.5}, NO_x, SO₂, and AQI at Six selected sites in Visakhapatnam –
Hindustan Petroleum Chemicals Ltd., – Site -2

S.No	Pollutants	Permissible Limit Value	Summer	Winter	Mon Soon	Post Monsoon
1	PM ₁₀	60	166.96 to 180.99	130.81 to 150.80	56.99 to 89.30	88.81 to 130.80
2	PM _{2.5}	100	366.90 to 411.12	356.98 to 400.00	384.84 to 440.90	290.36 to 386.30
3	NO _x	80	15.98 to 26.99	77.90 to 79.60	60.66 to 68.99	20.99 to 32.60
4	SO ₂	80	14.08 to 40.90	76.00 to 80.08	65.08 to 70.06	30.06 to 40.98

Table-3(b)
Seasonal average values of PM10, PM2.5, NOx, SO2, and AQI at Six selected sites in Visakhapatnam – Hindustan Petroleum Chemicals Ltd., – Site -2

Pollutants	Summer	Average of Summer	Winter	Average of Winter	Mon Soon	Average of Monsoon	Post Monsoon	Average of Post Monsoon
PM ₁₀	166.96 to 180.99	173.97	130.81 to 150.80	140.8	56.99 to 89.30	73.14	88.81 to 130.80	109.8
PM _{2.5}	366.90 to 411.12	389.01	356.98 to 400.00	378.49	384.84 to 440.90	412.87	290.36 to 386.30	338.33
NO _x	15.98 to 26.99	21.48	77.90 to 79.60	78.75	60.66 to 68.99	64.82	20.99 to 32.60	26.79
SO ₂	14.08 to 40.90	27.49	76.00 to 80.08	78.04	65.08 to 70.06	67.57	30.06 to 40.98	35.52

Table-4(a)
Seasonal variation of PM10, PM2.5, NOx, SO2, and AQI at Six selected sites in Visakhapatnam – Hindustan Polymers – Site -3

S. No	Pollutants	Permissible Limit Value	Summer	Winter	Mon Soon	Post Monsoon
1	PM ₁₀	60	120.99 to 148.02	135.99 to 160.80	22.90 to 85.30	82.91 to 132.96
2	PM _{2.5}	100	350.50 to 460.90	350.50 to 460.90	380.66 to 440.30	386.30 to 386.30
3	NO _x	80	22.92 to 27.30	65.60 to 78.80	52.80 to 60.91	15.90 to 26.91
4	SO ₂	80	35.061 to 49.02	69.00 to 80.00	57.98 to 66.90	31.01 to 45.96

Table-4(b)
Seasonal average values of PM10, PM2.5, NOx, SO2, and AQI at Six selected sites in Visakhapatnam – Hindustan Polymers – Site -3

Pollutants	Summer	Average of Summer	Winter	Average of Winter	Mon Soon	Average of Monsoon	Post Monsoon	Average of Post Monsoon
PM ₁₀	120.99 to 148.02	134.5	135.99 to 160.80	148.39	22.90 to 85.30	54.1	82.91 to 132.96	109.43
PM _{2.5}	350.50 to 460.90	405.7	350.50 to 460.90	405.7	380.66 to 440.30	410.48	386.30 to 386.30	386.3
NO _x	22.92 to 27.30	25.11	65.60 to 78.80	72.2	52.80 to 60.91	56.85	15.90 to 26.91	21.4
SO ₂	35.06 to 49.02	42.04	69.00 to 80.00	74.5	57.98 to 66.90	62.44	31.01 to 45.96	38.48

Table-5(a)
Seasonal variation of PM10, PM2.5, NOx, SO2, and AQI at Six selected sites in Visakhapatnam – Hindustan Zinc – Site – 4

S. No	Pollutants	Permissible Limit Value	Summer	Winter	Mon Soon	Post Monsoon
1	PM ₁₀	60	160.92 to 177.80	121.99 to 156.98	55.98 to 110.96	81.80 to 98.49
2	PM _{2.5}	100	250.90 to 366.96	510.99 to 550.80	480.80 to 600.01	240.88 to 350.98
3	NO _x	80	17.92 to 25.30	66.98 to 75.60	50.90 to 61.21	13.20 to 20.91
4	SO ₂	80	34.08 to 42.96	70.90 to 80.96	57.96 to 75.60	18.90 to 26.51

Table-5(b)
Seasonal average values of PM₁₀, PM_{2.5}, NO_x, SO₂, and AQI at Six selected sites in Visakhapatnam – Hindustan Zinc – Site – 4

Pollutants	Summer	Average of Summer	Winter	Average of Winter	Mon Soon	Average of Monsoon	Post Monsoon	Average of Post Monsoon
PM ₁₀	160.92 to 177.80	169.36	121.99 to 156.98	139.48	55.98 to 110.96	83.47	81.80 to 98.49	90.14
PM _{2.5}	250.90 to 366.96	308.93	510.99 to 550.80	530.89	480.80 to 600.01	540.4	240.88 to 350.98	295.93
NO _x	17.92 to 25.30	21.61	66.98 to 75.60	71.29	50.90 to 61.21	56.05	13.20 to 20.91	17.05
SO ₂	34.08 to 42.96	38.52	70.90 to 80.96	75.93	57.96 to 75.60	66.78	18.90 to 26.51	22.7

Table-6(a)
Seasonal variation of PM₁₀, PM_{2.5}, NO_x, SO₂, and AQI at Six selected sites in Visakhapatnam – Steel plant - Site – 5

S. No	Pollutants	Permissible Limit Value	Summer	Winter	Mon Soon	Post Monsoon
1	PM ₁₀	60	155.96 to 175.90	118.96 to 130.22	70.80 to 89.96	29.30 to 56.90
2	PM _{2.5}	100	100.80 to 130.81	275.80 to 300.33	380.80 to 490.60	312.30 to 366.91
3	NO _x	80	18.82 to 41.96	60.90 to 70.91	41.92 to 52.90	15.92 to 30.80
4	SO ₂	80	16.90 to 30.91	69.08 to 74.96	57.90 to 60.91	36.91 to 49.90

Table-6(b)
Seasonal average values of PM₁₀, PM_{2.5}, NO_x, SO₂, and AQI at Six selected sites in Visakhapatnam Steel plant - Site – 5

Pollutants	Summer	Average of Summer	Winter	Average of Winter	Mon Soon	Average of Monsoon	Post Monsoon	Average of Post Monsoon
PM ₁₀	155.96 to 175.90	165.93	118.96 to 130.22	124.59	70.80 to 89.96	80.38	29.30 to 56.90	43.1
PM _{2.5}	100.80 to 130.81	115.8	275.80 to 300.33	288.06	380.80 to 490.60	435.7	312.30 to 366.91	339.6
NO _x	18.82 to 41.96	30.39	60.90 to 70.91	65.9	41.92 to 52.90	47.41	15.92 to 30.80	23.36
SO ₂	16.90 to 30.91	23.9	69.08 to 74.96	72.02	57.90 to 60.91	59.4	36.91 to 49.90	43.4

Table-7(a)
Seasonal variation of PM₁₀, PM_{2.5}, NO_x, SO₂, and AQI at Six selected sites in Visakhapatnam – Hindustan Ship Yard – Site -6

S. No	Pollutants	Permissible Limit Value	Summer	Winter	Mon Soon	Post Monsoon
1	PM ₁₀	60	160.66 to 178.80	132.86 to 155.56	56.99 to 130.26	26.30 to 56.99
2	PM _{2.5}	100	380.91 to 440.36	281.80 to 300.11	364.91 to 420.98	98.99 to 112.80
3	NO _x	80	22.91 to 32.80	60.88 to 72.96	50.02 to 62.91	17.96 to 29.38
4	SO ₂	80	35.90 to 49.90	68.02 to 76.96	56.90 to 68.96	18.80 to 12.96

Table-7(b)

Seasonal average values of PM₁₀, PM_{2.5}, NO_x, SO₂, and AQI at Six selected sites in Visakhapatnam - Hindustan Ship Yard–Site-6

Pollutants	Summer	Average of Summer	Winter	Average of Winter	Mon Soon	Average of Monsoon	Post Monsoon	Average of Post Monsoon
PM ₁₀	160.66 to 178.80	169.73	132.86 to 155.56	144.21	56.99 to 130.26	93.62	26.30 to 56.99	41.64
PM _{2.5}	380.91 to 440.36	410.63	281.80 to 300.11	290.95	364.91 to 420.98	392.94	98.99 to 112.80	105.89
NO _x	22.91 to 32.80	27.85	60.88 to 72.96	66.92	50.02 to 62.91	56.46	17.96 to 29.38	23.67
SO ₂	35.90 to 49.90	42.9	68.02 to 76.96	72.49	56.90 to 68.96	62.93	18.80 to 12.96	15.88

Table-8

Air Quality Index scale and its categories (Source: Environmental Protection Agency (EPA))

S. No	Category	Scale
1	Good	0-51
2	Moderate	51-101
3	Un Healthy for Sensitive groups	101-151
4	Un Healthy	151-201
5	Very Un Healthy	201-301
6	Hazardous	301 and Above

Table-9

Monthly Variation in Temperature (°C) as recorded Study sites during 2011 March to February 2012

S. No	Months	Site - 1	Site - 2	Site - 3	Site - 4	Site - 5	Site - 6
1	March - 2011	22.8	22.9	21.2	22.8	23.6	24.8
2	April - 2011	33.2	32.1	25.6	30.1	27.3	28.2
3	May - 2011	35.9	36.2	29.1	36.1	28.1	30.2
4	June - 2011	36.3	38.1	33.2	30.2	39.0	36.1
5	July - 2011	30.2	31.0	29.0	32.8	33.3	29.6
6	August - 2011	26.8	30.1	32.8	30.2	34.4	28.3
7	September - 2011	30.1	29.8	28.6	30.2	31.6	29.8
8	October - 2011	32.8	28.3	29.6	31.1	32.8	30.3
9	November - 2011	22.8	22.0	21.0	23.0	21.0	19.6
10	December - 2011	13.0	15.0	11.0	12.0	10.0	15.0
11	January - 2012	15.1	15.8	16.0	13.6	12.6	14.6
12	February - 2012	20.0	19.0	18.1	20.6	22.1	20.1

Table-10

Monthly Variation in Humidity (%) as recorded Study sites during 2011 March to February 2012

S. No	Months	Site - 1	Site - 2	Site - 3	Site - 4	Site - 5	Site - 6
1	March - 2011	72	70	73	58	60	63
2	April - 2011	55	42	53	52	55	56
3	May - 2011	60	62	59	60	56	52
4	June - 2011	61	66	62	70	68	73
5	July - 2011	72	70	81	82	78	73
6	August - 2011	81	79	82	81	76	73
7	September - 2011	79	81	76	80	82	77
8	October - 2011	80	77	78	72	81	69
9	November - 2011	72	70	71	70	75	73
10	December - 2011	91	90	80	62	70	81
11	January - 2012	92	91	82	70	74	70
12	February - 2012	91	73	93	92	77	80

Table-11
Monthly Variation in Rainfall (m. m.) as recorded Study sites during 2011 March to February 2012

S. No	Months	Site - 1	Site - 2	Site - 3	Site - 4	Site - 5	Site - 6
1	March - 2011	0.00	0.00	0.00	0.00	0.00	0.00
2	April - 2011	23.3	25.3	25.2	23.1	23.1	25.3
3	May - 2011	77.4	77.6	77.9	77.4	81.1	0.7
4	June - 2011	76.3	96.6	76.3	96.6	76.0	96.0
5	July - 2011	127.9	130.4	131.8	127.3	128.0	131.5
6	August - 2011	155.3	161.2	161.1	160.0	157.4	160.2
7	September - 2011	116.8	130.6	141.8	116.9	125.4	141.9
8	October - 2011	228.4	230.6	232.1	229.4	230.9	234.7
9	November - 2011	0.00	0.00	0.00	0.00	0.00	0.00
10	December - 2011	15.2	16.8	15.9	18.4	18.9	19.2
11	January - 2012	12.4	12.8	19.2	12.9	19.0	19.6
12	February - 2012	8.9	10.4	9.4	9.9	8.9	10.7

Table-12
Monthly Variation in Wind speed (m/sec) recorded Study sites during 2011 March to February 2012

S. No	Months	Site - 1	Site - 2	Site - 3	Site - 4	Site - 5	Site - 6
1	March - 2011	0.6	0.8	0.6	0.7	0.9	0.8
2	April - 2011	0.6	0.5	0.1	0.9	0.7	0.9
3	May - 2011	0.7	0.9	0.8	0.5	0.6	0.2
4	June - 2011	1.3	1.6	1.4	0.8	1.5	0.9
5	July - 2011	1.2	1.3	1.6	1.4	0.4	1.2
6	August - 2011	0.5	0.3	0.2	0.4	0.5	0.6
7	September - 2011	0.3	0.2	0.3	0.2	0.2	0.1
8	October - 2011	0.7	0.5	0.3	0.6	0.5	0.2
9	November - 2011	0.3	0.5	0.6	0.7	0.6	0.4
10	December - 2011	0.6	0.5	0.4	0.2	0.3	0.6
11	January - 2012	0.7	0.5	0.3	0.2	0.4	0.6
12	February - 2012	0.4	0.8	0.5	0.6	0.4	0.5

Table-13
AQI Rating Scale and Category of Coromandal Fertilizers – Site -1

S. No	Pollutants	AQI Rating Scale Summer	AQI Category	AQI Rating Scale Winter	AQI Category	AQI Rating Scale Monsoon	AQI Category	AQI Rating Scale Post Monsoon	AQI Category
1	PM ₁₀	108	Unhealthy for Sensitive Groups	91	Moderate	73	Moderate	75	Moderate
2	PM _{2.5}	370	Hazardous	439	Hazardous	427	Hazardous	333	Hazardous
3	NO _x	45	Good	70	Moderate	56	Moderate	39	Good
4	SO ₂	57	Moderate	102	Unhealthy for Sensitive Groups	82	Moderate	59	Moderate

Table-14
AQI Rating Scale and Category of Hindustan Petroleum Chemicals Ltd., – Site -2

S. No	Pollutants	AQI Rating Scale Summer	AQI Category	AQI Rating Scale Winter	AQI Category	AQI Rating Scale Monsoon	AQI Category	AQI Rating Scale Post Monsoon	AQI Category
1	PM ₁₀	110	Unhealthy for Sensitive Groups	93	Moderate	60	Moderate	78	Moderate
2	PM _{2.5}	426	Hazardous	419	Hazardous	442	Hazardous	388	Hazardous
3	NO _x	20	Good	77	Moderate	62	Moderate	25	Good
4	SO ₂	39	Good	102	Unhealthy for Sensitive Groups	90	Moderate	50	Good

Table-15
AQI Rating Scale and Category of Hindustan Polymers – Site -3

S. No	Pollutants	AQI Rating Scale Summer	AQI Category	AQI Rating Scale Winter	AQI Category	AQI Rating Scale Monsoon	AQI Category	AQI Rating Scale Post Monsoon	AQI Category
1	PM ₁₀	90	Moderate	97	Moderate	50	Good	78	Moderate
2	PM _{2.5}	437	Hazardous	437	Hazardous	441	Hazardous	425	Hazardous
3	NO _x	24	Good	70	Moderate	53	Moderate	20	Good
4	SO ₂	59	Moderate	99	Moderate	84	Moderate	54	Moderate

Table-16
AQI Rating Scale and Category of Hindustan Zinc – Site -4

S. No	Pollutants	AQI Rating Scale Summer	AQI Category	AQI Rating Scale Winter	AQI Category	AQI Rating Scale Monsoon	AQI Category	AQI Rating Scale Post Monsoon	AQI Category
1	PM ₁₀	108	Unhealthy for Sensitive Groups	93	Moderate	65	Moderate	68	Moderate
2	PM _{2.5}	359	Hazardous					346	Hazardous
3	NO _x	20	Good	69	Moderate	53	Moderate	16	Good
4	SO ₂	54	Moderate	100	Moderate	89	Moderate	31	Good

Table-17
AQI Rating Scale and Category of Steel plant – Site -5

S. No	Pollutants	AQI Rating Scale Summer	AQI Category	AQI Rating Scale Winter	AQI Category	AQI Rating Scale Monsoon	AQI Category	AQI Rating Scale Post Monsoon	AQI Category
1	PM ₁₀	106	Unhealthy for Sensitive Groups	85	Moderate	63	Moderate	40	Good
2	PM _{2.5}	180	Unhealthy	338	Hazardous	457	Hazardous	389	Hazardous
3	NO _x	28	Good	63	Moderate	44	Good	22	Good
4	SO ₂	33	Good	96	Moderate	80	Moderate	60	Moderate

Table-18
AQI Rating Scale and Category of Hindustan Ship Yard – Site -6

S. No	Pollutants	AQI Rating Scale Summer	AQI Category	AQI Rating Scale Winter	AQI Category	AQI Rating Scale Monsoon	AQI Category	AQI Rating Scale Post Monsoon	AQI Category
1	PM ₁₀	108	Unhealthy for Sensitive Groups	95	Moderate	63	Moderate	38	Good
2	PM _{2.5}	441	Hazardous	341	Hazardous	429	Hazardous	174	Unhealthy
3	NO _x	25	Good	64	Moderate	53	Moderate	22	Good
4	SO ₂	59	Moderate	96	Moderate	84	Moderate	21	Good

Conclusion

The overall AQI can give clear view about ambient air and the critical pollutant mainly responsible for the quality of air quality which can be easier for a common man to understand. The AQIs were calculated to assess the ambient air quality at three different sites namely the industrial, commercial and residential sites in B during the year 2009. The AQIs were calculated according to Indian Air quality Index (IND-AQI). The AQI study reveals that Particulate matter (PM_{2.5}) was mainly responsible for maximum times in all sites in Visakhapatnam. The majority of AQI values of PM_{2.5} fell under the category of very poor.

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