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ASSESSMENT OF AMBIENT AIR QUALITY AND AIR QUALITY INDEX IN GOLDEN CORRIDOR OF GUJARAT, INDIA: A CASE STUDY OF DAHEJ PORT

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Abstract

Clean air is the basic requirement of all living organisms. In recent times, due to population growth, urban sprawl, industrial development, and vehicular boom, the quality of air is deteriorating and being polluted. Pollutants of major public health concerns include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide, which pose serious threats to human health and hygiene. In the present study, prime particulate pollutants (PM_{10}, $PM_{2.5}$), and gaseous pollutants (SO_2 and NO_2) were estimated at seven stations in and around Dahej Port, Gujarat, India. The obtained values of PM_{10}, $PM_{2.5}$, SO_2, and NO_2 in all the studied stations (seven) ranged from 67.39 to 98.75, 29.57 to 45.79, 17.76 to 22.29 and 28.29 to 32.42 $\mu g/m^3$, respectively. The level of PM_{10} at all sampling locations, and that of $PM_{2.5}$ at Station A3 (Lakhigam) were found little higher than prescribed permissible limits of CPCB standards, while SO_2 and NO_2levels were within the acceptable range. The Air Quality Index (AQI) score was found to be ranged from 76.50 to 97.75, which is at satisfactory level as per CPCB standards. Further, precautionary measures and management strategies to minimize the effect of particulate as well as gaseous pollutants have also been suggested for achieving its ambient levels in and around Dahej Port, Gujarat, India.

Keywords: Ambient Air Quality, Air Quality Index, Golden Corridor, Dahej Port, Gujarat, India

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Introduction

In addition to land and water, air is the prime resource for sustenance of life. For better human health and wellbeing of the humanity, clean air is one of the main basic requirements. Clean air is deteriorating day by day, and being polluted by variety of sources e.g. household combustion devices, motor vehicles, industrial facilities, and forest fires (the common sources of air pollution) that change the composition of atmosphere, affecting the biotic environment adversely. The concentration of air pollutants depends not only on the quantities that are emitted from the polluting sources, but also on the ability of the atmosphere to either absorb or disperse such emissions **(USEPA, 2008)**.

The population growth, urban development, and vehicular boom have deteriorated the ambient air quality in recent industrial era. Particulate and gaseous pollutants of major public health concerns pose a serious threat to human health, if exceed the permissible limits prescribed by the regulatory authorities **(WHO, 2000; USEPA. 2008)**. More than two million premature deaths per year are attributed to the effects of urban (outdoor /indoor) air pollution that is mainly caused by burning of solid unburned fuels **(WHO, 2005)**. More than half of the air pollution driven diseases is borne by the population of developing countries **(WHO, 2005)**. The relationship between the occurrence of respiratory and cardiovascular diseases and cardiopulmonary mortality with exposure to air pollutants are well documented in the published literature in the past **(Dockery *et al*., 1994; Koken *et al*., 2003)**.

Major sources responsible for higher level of SPM (Suspended Particulate Matter), RSPM (Respirable Particulate Matter), SO_2, NO_2 and other organic and inorganic pollutants in environment are incurred through partial combustion of motor vehicle fuels **(Sharma *et al*., 2006; Jayaraman, 2007; Barman, *et al*., 2010).** In addition, 60 to 70% of the air pollution found in the urban environment is also due to the use of old or pre-owned automotives and locomotives **(Panday *et al.*, 1988; Singh *et al*., 1995)**. The public health implications due to the emission of CO, O_3, SO_2, NO_2 and particulates are very well known in most of the developed countries **(Yadav *et al*., 2012)**. Among particulate pollutants, particulate matter (PM) is a ubiquitous entity, and is especially a grave problem due to its higher suspension rate into the atmosphere, and adverse health effects on plants, animals, humans, and materials in the form of visibility reduction, soiling of buildings, etc. **(Horaginamani and Ravichandran, 2010; Chaurasia *et al*., 2013)**.

In the same context, Central Pollution Control Board (CPCB), India, initiated National Ambient Air Quality Monitoring (NAAQM) program in the year 1984 at Agra and Anpara, Northern India. Subsequently, in 1998-99 the program was renamed as National Air Monitoring Program (NAMP). The number of monitoring stations under NAMP has been increased steadily up to 295 by 2000-01, covering

98 cities/towns in 29 States and 3 Union Territories of India. Under NAMP, four air pollutants *viz*. sulfur dioxide (SO_2), oxides of nitrogen (NOx) as NO_2, particulate matter ($PM_{2.5}$) and respirable suspended particulate matter (RSPM/PM_{10}), have been identified for regular monitoring of air quality **(CPCB, 2006)**.

Air pollution has emerged in the past few decades, that poses a critical health problem to the human population and the whole ecosystem **(Tripathee *et al*., 2016)**. Various studies in this regard have been undertaken all over the world and also in India **(Katsouyanni *et al*., 2001; Afroz *et al*., 2003; Yang *et al*., 2004; Samoli *et al*., 2005; Analitis *et al*., 2006; Kaushik *et al*., 2006; Barman *et al*., 2010; Yadav *et al*., 2012; Mukhopadhyay and Mukherjee, 2013; Rai *et al*., 2013; Barman *et al*., 2015)**. The aim of the present study was to assess the Ambient Air Quality (AAQ) ($PM_{10,}$ $PM_{2.5}$, $SO_{2,}$ and NO_2) and measurement of Air Quality Index(AAQ) in Golden Corridor of Gujarat, Dahej Port, District Bharuch, Gujarat State, India.

Methods

Study Area**:** Dahej ($21^0$68' 35" N and $72^0$49' 65" E) is a cargo port situated about 45 km from Bharuch Town on the South-West coast of Gujarat, India. It is an all-weather, direct berthing, multi-cargo port on the west coast of India, situated on the Gulf of Khambhat. The port provides import and export services to the Indian States (Gujarat, Maharashtra and Madhya Pradesh). It is a natural deep-water port with two deep draft berths capable of accommodating cape-size vessels. It operates the coal import terminal with the capacity to handle 20 million tons of coal per year, which has a fully mechanized conveyor system for receiving imported coal, which can be unloaded at the rate of 4200 tons per hour.

Study Sites**:** Based on the standard site selection criteria, and reduced interference of local public, the study sites (sampling stations) were chosen in and around Dahej Port for intensive investigation with the help of an air quality measurement device (Omron Digital Arm Bp Monitor HEM-7120). The concentration of PM_{10}, $PM_{2.5}$, Sulphur dioxide (SO_2), and Nitrogen dioxide (NO_2), was measured from selected monitoring stations *viz*. Station A1 (Project Site of Rallis India Pvt. Ltd.– RIPL: SEZ-2), Station A2 (Jolwa Village), Station A3 (Lakhigam Village), Station A4 (Rahiyad Village), Station A5 (Jageshwar Village), Station A6 (Suva Village), and Station A7 (Ambetha Village) **(Fig. 1)**.

Fig. 1. Study Area and Study Sites (Dahej Port, Gujarat, India)

Ambient Air Quality Monitoring

The quality of PM_{10} and $PM_{2.5}$ was determined with the help of Combo PM_{10} and $PM_{2.5}$ Respirable Dust Sampler (Envirotech APM 460 BL), with the airflow rate of 2.3 m^3/hr and 1.0m^3/hr, respectively. The concentration of Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2) was measured by gaseous pollutant sampler (LES 411) using specific absorbing solutions (Potassium tetrachloromercuate for SO_2, and Sodium hydroxide and Sodium arsenite for NO_2). The sampling was carried out consecutively for three months (December, 2014 to February, 2015) at the interval of one week. The average values of all readings were taken into consideration for final output of the results. The apparatus was kept at a height of 5 m from the ground surface for eight (8) hours per day. Once the sampling was over, the samples were immediately kept in icebox, brought to the laboratory, and preserved in refrigerator prior to analyses. Later, the concentrations of different air pollutants in samples were analyzed spectrophotometrically (VARIAN Cary 50 Bio UV-Visible Spectrophotometer) **(USEPA, 2000a; 2000b; 2008)**. The concentration of gaseous pollutants (SO_2 and NO_2) was analyzed using Modified West and Gaeke Method **(West and Gaeke, 1956)**, and Modified Jacob Hochheiser Method **(Jacob and Hochheiser, 1958)**, respectively, and the quantity of particulate pollutants ($PM_{2.5}$ and PM_{10}) was measured by Gravimetric Method **(CPCB, 2013)**.

Air Quality Index (AQI)

The Air Quality Index (AQI) is an environmental index, which describes the overall ambient air status and trend of a particular place based on specific standard. It is a tool that transforms the (weighted) values of individual air pollutants (parameters) into a single number or set of numbers **(Rao, 1991)**. The overall ambient air quality of a specified area can be assessed in a better way and quantified in terms of AQI since it represents the cumulative effect of all the pollutants. AQI can also enable one to formulate the alternative policies for prevention of air pollution or to design control equipment, which, for instance, will reduce the level of certain pollutants while increasing the levels of others. There are several methods and equations used for determining the AQI. However, here the below mentioned formula **(Zlauddin and Siddiqui, 2006: Joshi and Semwal, 2011)** has been used for computation of AQI value:

$$AQI = \frac{1}{4} \times (IPM_{10}/SPM_{10} + IPM_{2.5}/SPM_{2.5} + ISO_2/SSO_2 + INO_2/SNO_2) \times 100$$

Where, SPM_{10}, $SPM_{2.5}$, SSO_2 and SNO_2 represent the revised Ambient Air Quality Standards (AAQS) as prescribed by Central Pollution Control Board of India (2013), and IPM_{10}, $IPM_{2.5}$, ISO_2 and SNO_2 represent the actual values of pollutants obtained at the time of sampling. Based on AQI range, AQI categories have been framed to determine the overall health status of an environment **(CPCB, 2013) (Table 1)**.

Table 1. AQI Range and Category

AQI Range	AQI Category
0-50	Good
51-100	Satisfactory
101-200	Moderate
201-300	Poor
301-400	Very Poor
401-500	Severe

Results and discussion

Ambient Air Quality (AAQ)

Table 2 depicts the obtained values of air pollutants (PM_{10}, $PM_{2.5}$, SO_2 and NO_2) at seven selected sampling stations. The concentration of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 at all the locations were ranged from 67.39 to 98.75, 29.57 to 45.79, 17.76 to 22.29, and 28.29 to 32.42 µg/m^3, respectively.

Table 2. Concentration of Air Pollutants (PM_{10}, $PM_{2.5}$, SO_2 and NO_2) at Sampling Stations, Dahej Port, Gujarat, India (@ 8 hours / day)

Station	PM_{10} µg/m^3	$PM_{2.5}$ µg/m^3	SO_2 µg/m^3	NO_2 µg/m^3
A1	98.75	40.45	22.29	32.42
A2	76.28	30.48	20.84	30.88
A3	83.82	36.67	18.73	29.17
A4	67.39	29.57	19.80	32.33
A5	78.56	33.64	17.89	31.04
A6	86.70	45.79	21.59	28.79
A7	97.44	42.50	17.76	30.18
CPCB*	100	60	80	80
Mean Conc.	84.13	37.01	19.84	30.69
S.D.	11.33	6.17	1.80	1.42

** CPCB Standards (2013) @ 24 hrs /day*

The primary sources of PM_{10} in the atmosphere are incomplete combustion, automobile emissions, industrial dust, unburned cooking methods, and secondary sources e.g. chemical reactions in the atmosphere **(USEPA, 2008; WHO, 2000)**. In case of PM_{10}, stumpy amount (67.39 µg/m^3) was reported at A4 (Rahiyad), and 76.28 µg/m^3 at A2 (Jolwa), followed by modest concentration (78.56 µg/m^3) at A5 (Jageshwar), 83.82 µg/m^3 at A3 (Lakhigam), 86.70 µg/m^3 at A6 (Suva), accentuated quantity (97.44 µg/m^3) at A7 (Abmetha), and peak amount (98.75 µg/m^3) of PM_{10} at A1 (RIPL). Overall, the mean concentration of PM_{10} was 84.13 µg/m^3, with an average deviation of 11.33 µg/m^3. The present study reveals that the level of PM_{10} was within the prescribed permissible limits of CPCB standards (100 µg/m^3) at all the selected study sites (except at A1 and A7: nearby stations with marginal values) in and around Dahej Port. Trace metals concentration in PM_{10} at different locations of Lucknow city was studied by **Sharma *et al*. (2006).** The influenced localities with heavy loads of PM_{10} suggested the preventive measures for safe health and secure hygiene of locales in and around Lucknow, Uttar Pradesh, India. The trend observed in the present study was due to the fact that in winter, anti-cyclonic condition prevailed, which was characterized by calm or very low wind, there was little dispersion or dilution of pollutants which caused marginal levels of PM_{10} **(Panda and Panda, 2012)** as observed during the present study.

There are many sources of emissions of $PM_{2.5}$ at source level, which includes wood-burning stoves, forest fires, diesel engines, natural sources, non-road vehicles, agricultural burning, and fugitive emissions of industries **(Simon *et al*., 2008; WHO, 2000; 2005)**. Contrary to PM_{10}, low concentration of $PM_{2.5}$ was recorded at A4 (29.57 μg/m^3), and A2 (30.48 μg/m^3), whereas medium quantity was observed at A5 (33.64 μg/m^3), A3 (36.67 μg/m^3), and A1 (40.45 μg/m^3), with an accentuated amount at A7 (42.50 μg/m^3), with maximum concentration at A6 (45.79 μg/m^3). As a whole, the average concentration of $PM_{2.5}$ documented at Dahej Port was 37.01 μg/m^3, with an average deviation of 6.17 μg/m^3 from observed values. During the present study, the amounts of $PM_{2.5}$ were found within the standard limits prescribed by CPCB (60 μg/m^3) in and around Dahej Port. The exposure to particle pollution is a grave public health hazard. When inhaled, particulate pollution ($PM_{2.5}$) can travel deep into the lungs, and cause or aggravate heart and lung diseases. This increases in doctor and emergency room visits, hospital admissions, use of prescription medication, and absences from work and school **(Yang *et al*., 2004)**. The slightly higher value may be mainly due to the massive transportation of cargo, raw materials, and finished products.

SO_2 is emitted primarily from stationary sources, power plants, and refineries that burn fossil fuels. Other sources are smelters, steel mills, and pulp and paper mills. Wood, natural gas, propane, and other common fuels used for home heating do not contain significant quantities of sulfur and, therefore, are not considered to be the major sources of SO_2. On the contrary, diesel fuel, and to a lesser extent gasoline, contain sulfur, and contribute to SO_2emission in the ambient air **(West and Gaeke, 1956)**. The concentration of SO_2 recorded was very high at A1 (22.29 μg/m^3), and A6 (21.59 μg/m^3), as compared to moderate quantity at A2 (20.84 μg/m^3), followed by A4 (19.80 μg/m^3), and A3 (18.73 μg/m^3). On the other hand, very low amount of SO_2 was reported at A5 (17.89 μg/m^3), and the least concentration was observed at A7 (17.76 μg/m^3). Overall, the mean concentration of SO_2 reported was 37.01 μg/m^3 with an average deviation of 1.80 μg/m^3 at Dahej Port, and was within the CPCB limits (80 μg/m^3). This slightly higher concentration may be related to the prevalence of high speed wind and frequent precipitations over the sampling sites. Further, it was observed that SO_2 emission, though insignificant, was more at non-industrial sites in comparison to industrial sites. This is an indication that existing industries are not abusive, as far as SO_2 emission is concerned **(Zlauddin and Siddique, 2006)**.

Among all the sampling stations at Dahej Port, the highest concentration (32.42 μg/m^3) of NO_2 was recorded at A1, and A4 (32.33 μg/m^3), followed by modest amount at A5 (31.04 μg/m^3), A2 (30.88 μg/m^3), and A7 (30.18 μg/m^3). However, the low concentration of NO_2 was observed at A3 (29.17 μg/m^3), with the lowest at A6 (28.79 μg/m^3). The overall mean concentration of NO_2 observed was 30.69 μg/m^3, with an average deviation of 1.42 μg/m^3 at Dahej Port, within the CPCB limits (80 μg/m^3).

Compared to SO_2, an average concentration of NO_2 was a bit higher, which could be explained by frequent transportation of cargo vehicles, automotive, and locomotives in and around Dahej Port **(Panda and Panda, 2012)**.

Site fidelity

The cumulative results clearly reflect that at most of the sampling stations (A1, A3, A5, A6, A7), the amount of particulate pollutant (PM_{10}) was a bit higher than that of $PM_{2.5}$, except at stations A2 and A4, where the trend of concentration gradient was bit different i.e. PM_{10} was found more than $PM_{2.5}$. Similarly, the amount of NO_2 was more than SO_2 at most the sampling stations (A1, A3, A5, A6, A7), except at stations A2 and A4, where the concentration of $PM_{2.5}$ was found a bit higher than that of SO_2. However, considering the mean concentration of gaseous as well as particulate pollutants, it was clear that the amount of PM_{10} was always higher than that of $PM_{2.5}$, followed by moderate concentration of NO_2, with low amount of SO_2. Thus, the overall scenario depicts that the Dahej Port and its adjoining areas are heavily influenced by more dispersal of PM_{10}, followed by $PM_{2.5}$, NO_2, and SO_2. As a whole, the concentration gradient of air pollutants is represented as $PM_{10} > PM_{2.5} > NO_2 > SO_2$. Moreover, the air quality in and around Dahej Port is disseminated in the form of dispersal ratio, which is represented by 1.00: 0.44: 0.36: 0.24 for PM_{10}, $PM_{2.5}$, NO_2 and SO_2 **(Table 3, Fig. 2)**. Similar trend was observed by **Yadav *et al.* (2012)** in urban residential areas of Jhansi city and rural residential areas of adjoining villages of Madhya Pradesh, India.

Moreover, the higher concentration of NO_2 could be due to high fuel usage and trapping of the pollutants in the boundary layer due to frequent temperature inversions in and around study area. Further, it could probably due to intense solar radiation and increased photochemical activity. Overall, NO_2 showed higher values than SO_2, which could be due to more vegetation and favorable conditions for microbial activity in and around Dahej Port (SEZ: Special Economic Zone) **(Jacobs and Hochheiser, 1958; Joshi and Semwal, 2011)**.

Table 3. Concentration Gradient of Air Pollutants

Station	Concentration Gradient
A1	$PM_{10} > PM_{2.5} > NO_2 > SO_2$
A2	$PM_{10} > NO_2 > PM_{2.5} > SO_2$
A3	$PM_{10} > PM_{2.5} > NO_2 > SO_2$
A4	$PM_{10} > NO_2 > PM_{2.5} > SO_2$
A5	$PM_{10} > PM_{2.5} > NO_2 > SO_2$
A6	$PM_{10} > PM_{2.5} > NO_2 > SO_2$
A7	$PM_{10} > PM_{2.5} > NO_2 > SO_2$
Mean	$PM_{10} > PM_{2.5} > NO_2 > SO_2$

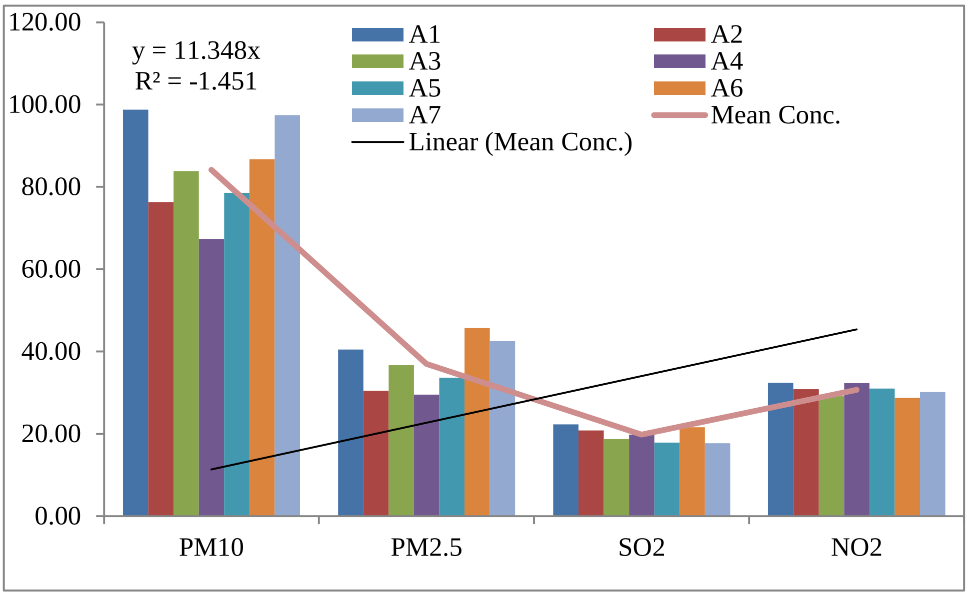

Fig. 2. Ambient Air Quality at Sampling Stations (Dahej Port, Gujarat, India)

Our study reflects that the concentration of PM_{10} was ranged from 67.39 to 98.75 µg/m^3 with an average concentration of 84.13 µg/m^3, which was a bit marginal, tended to reach its recommended limit (100 µg/m^3), prescribed by Central Pollution Control Board (CPCB), India, especially for residential areas as well as industrial units. Moreover, the standard limit for $PM_{2.5}$ in human populated areas is 60 µg/m^3 **(CPCB, 2013)**, and our study delineated its substantial amount at A1 (40.45 µg/m^3), A6 (45.79 µg/m^3) and A7 (42.50 µg/m^3), with a mean concentration of 37.01 µg/m^3. This clearly depicts that the concentrations of PM_{10} and $PM_{2.5}$ were within the prescribed standards of CPCB at Dahej Port, but its adjacent areas are little bit affected by marginal dispersal of such particulate pollutants. The present scenario might be owing to downwind pattern of obnoxious pollutants from core region (Dahej Port) towards its buffer and fringe areas (sampling stations). Fortunately, the concentration of SO_2 (Range: 17.76 to 22.29 µg/m^3; Mean Conc. 19.84 µg/m^3) and that of NO_2 (Range: 28.79 to 32.42 µg/m^3; Mean Conc. 30.69 µg/m^3) was within the prescribed limits (80 µg/m^3 for SO_2 and NO_2 each) **(CPCB, 2013)**. This could be due to effective control methods for pollution abatement at source, process, and receptor levels at Dahej Port, Gujarat, India.

Air Quality Index (AQI)

The Air Quality Index (AQI) may act as a valuable tool, and a proxy assessment of ambient air quality to determine the healthy status of environs **(Zlauddin and Siddique, 2006)**. The values of AQI in our study were derived using the concentration of PM_{10}, $PM_{2.5}$, SO_2, and NO_2. The AQI values were ranged from 76.50 to 97.75 in all sampling stations in and around Dahej Port, which are categorized as "Satisfactory level" (50 to 100), designated by **CPCB (2013)**. The outranged results of AQI in and around study area may cause minor breathing discomfort to sensitive people as a temporary uneasiness or momentary anomaly, which can be ameliorated within a short-time period, based on individuals' health and hygiene, susceptibility counterforce, and immunity capacity **(Panda *et al.*, 2011)(Table 3)**.

Table 3. Air Quality Index of Sampling Stations

Station	AQI	AQI Range	AQI Category
A1	97.75	50-100	Satisfactory
A2	82.50	50-100	Satisfactory
A3	85.25	50-100	Satisfactory
A4	76.50	50-100	Satisfactory
A5	82.25	50-100	Satisfactory
A6	93.75	50-100	Satisfactory
A7	94.75	50-100	Satisfactory
Mean	87.54	50-100	Satisfactory

Correlation Coefficient (r)

Correlation is the mutual relationship between two variables. Direct correlation is said to exist when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of the other. Correlation is considered positive when increase in one parameter causes increase in other parameter and is said negative when increase in one parameter causes decrease in the value of the other and *vice versa*. The correlation coefficient (r) ranges between +1 and –1. When it is in the range of +0.8 to 1.0, the correlation is characterized as strong, is moderate in the range of +0.5 to +0.7, and is weak in the range of +0.1 and +0.4, it is characterized as weak. The correlation coefficient value among the parameters is given in **Table 4**. It is seen that PM_{10} and $PM_{2.5}$ are strongly and positively correlated (r = 0.812) with each other, indicating that their sources are the same, having uniform dispersal pattern into atmosphere. Besides, the AQI is also having strong as well as positive correlation with PM_{10} (r = 0.959) and $PM_{2.5}$ (r = 0.898). This indicates that PM_{10} and $PM_{2.5}$ concentrations squarely influence the value of AQI, as well as air quality of the environs.

Table 4. Correlation Coefficient Values among Parameters

Correlation	PM_{10}	$PM_{2.5}$	SO_2	NO_2	AQI
PM_{10}	1.000				
$PM_{2.5}$	0.812	1.000			
SO_2	0.136	0.196	1.000		
NO_2	-0.175	-0.527	0.203	1.000	
AQI	0.959	0.898	0.341	-0.227	1.000

Conclusion

The present study revealed that PM_{10} and $PM_{2.5}$ are the causative air pollutants at all sampling points. However, gaseous pollutants (SO_2 and NO_2) are well within the permissible limits. The study clearly indicated that it would be more appropriate to consider AQI rather than individual air pollutant level, while planning prevention of air pollution in and around industrial areas. From AQI values, it was found that there was controllable air pollution at all locations. It was also observed that particulate emission was an outside factory phenomenon, and was basically a transport related phenomenon, and their levels were relatively high during winter period owing to particles' suspension into air for a shorter period, influenced by less wind flow, low cloud formations, and humid atmospheric conditions.

To maintain the PM_{10} and $PM_{2.5}$ concentrations, it is suggested that massive green plantation must be taken up in and around the study area. Trees having high dust trapping efficiency (*Azadirachta indica, Cassia fistula, Delonix regia, Ficus religiosa, Pterocarpus marsupium*) are to be grown alongside the roads, and water is to be sprinkled continuously at the source of generation of particulate matter. Apart from this, measures like limiting vehicle speed at vulnerable localities, conducting public awareness campaigns about the harmful effects of air pollution, and educating the drivers to be more eco-friendly, are also to be implemented. Moreover, regulatory authorities must ensure that industries obey their moral and social responsibilities to protect the environment. Overall, the air quality in and around Dahej Port is in a satisfactory condition (except minor threats of PM_{10} and $PM_{2.5}$), which could be ameliorated by implementing above-mentioned managerial steps and strategic plans to live a safer and healthy life. Authors suggest the periodic estimation of air and gaseous pollutants at frequent intervals on regular basis to check the level of such obnoxious pollutants in and around Dahej Port, South-Western Gujarat, India.

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References

Afroz, R., Hassan, M.N. and Ibrahim, N.A., 2003. Review of air pollution and health impacts in Malaysia. *Environmental Research*, 92, 71-77.

Analitis, A., Katsouyanni, K., Dimakopoulou, K., Samoli, E., Nikoloulopoulos, A.K. and Petasakis, Y., 2006. Short-term effects of ambient particles on cardiovascular and respiratory mortality, *Epidemiology*, 17 (2), 230-233.

Barman, S.C., Kisku, G.C. and Khan, A.H., 2015. *Assessment of Ambient Air Quality of Lucknow City during Pre-Monsoon, 2015*. Final Technical Report: Environmental Monitoring Division, CSIR: Indian Institute of Toxicology Research, Lucknow. 26 *pp*.

Barman, S.C., Kumar, N. and Singh, R., 2010. Assessment of urban air pollution and its probable health impact. *Journal of Environmental Biology,* 31 (6), 913-920.

Chaurasia, S, Singh, S. and Gupta, A.D., 2013. Study on air quality of SKS Ispat and Power Ltd. Raipur (CG), India. *Asian Journal of Science and Technologies,* 4 (4), 48-50.

CPCB, 2006. *Annual Report of Central Pollution Control Board*. Central Pollution Control Board, India. 248 *pp*.

CPCB, 2013. *Guidelines for Manual Sampling & Analyses*. (Guidelines for the Measurement of Ambient Air Pollutants, Vol. I), Central Pollution Control Board, National Ambient Air Quality Series: NAAQMS/36/2012-13. 62 *pp*.

Dockery, D.W. and Pope, C.A., 1994. Acute respiratory effects of particulate air pollution. *Annual Review of Public Health*, 15, 107-132.

Horaginamani, S.M. and Ravichandran, M., 2010. Ambient air quality an urban area and its effects on plants and human beings: A case study of Tiruchirappalli, India. *Kathmandu University Journal of Science, Engineering and Technology*, 6 (2), 13-19.

Jacobs, M.B. and Hochheiser, S. 1958. Continuous sampling and ultra micro determination of nitrogen oxide in air analyst. *Chemosphere,* 30, 426-428.

Jayaraman, G.N., 2007. Air quality and respiratory health in Delhi. *Environmental Monitoring and Assessment,* 135, 313-325.

Joshi, P.C. and Semwal, M., 2011. Distribution of air pollutants in ambient air of district Haridwar (Uttarakhad), India: A case study after establishment of State Industrial Development Corporation. *International Journal of Environmental Sciences,* 2 (1), 237-243.

Katsouyanni, K., Touloumi, G., Samoli, E., Gryparis, A., Le, T.A. and Monopolis, Y., 2001. Confounding and effect modification in the short-term effects of ambient particles on total mortality: results from 29 European cities within the APHEA2 project. *Epidemiology,* 12, 521-531.

Kaushik, C.P., Ravindra, K. and Yadav, K., 2006. Assessment of ambient air quality in urban centres of Haryana (India) in relation to different anthropogenic activities and health risk. *Environmental Monitoring and Assessment,* 122 (1-3), 27-40.

Koken, P.J., Piver, W.T., Ye, F., Elixhauser, A., Olsen, L.M. and Portier, C.J., 2003. Temperature, air pollution and hospitalization for cardiovascular diseases among elderly people in Denver. *Environmental Health Perspectives,* 111, 1312–1317.

Mukhopadhyay, S. and Mukherjee, R., 2013. Assessment of Ambient Air Quality of Purulia Town, Purulia District, West Bengal, India. *Biolife,* 1 (4), 189-194.

Panda, B.K. and Panda, C.R., 2012. Estimation of ambient air quality status in Kalinga Nagar industrial complex in the district of Jajpur of Odisha. *International Journal of Environmental Sciences,* 3 (2), 767-775.

Panda, R.B., Panda, G., Amitshreeya, R. and Sahu, S.K., 2011. Air quality index of Balasore town, Orissa. *Pollution Research,* 30 (2), 131-133.

Panday, P.K., Patel, K.S. and Subart, P., 1988. Trace element composition of atmospheric composition of atmospheric particulate at Bhilai in central east India. *Science of Total Environment,* 21, 123-134.

Rai, P., Panda, L.L., Chutia, B.M. and Singh, M.M., 2013. Comparative assessment of air pollution tolerance index (APTI) in the industrial (Rourkela) and non-industrial area (Aizawl) of India: An eco-management approach. *African Journal of Environmental Science and Technology,* 7 (10), 944-948.

Rao, C.S., 1991. *Environment Pollution Control Engineering*. Wiley Eastern Ltd., New Delhi. 431 *pp*.

Samoli , E., Analitis, A., Touloumi, G., Schwartz, J., Anderson, H.R. and Sunyer, J., 2005. Estimating the exposure-response relationships between particulate matter and mortality within the APHEA multicity project. *Environmental Health Perspectives,* 113, 88-95.

Sharma, K., Singh, R., Barman, S.C., Mishra, D., Kumar, R., Negi, M.P.S., Mandal, S.K., Kisku, G.C., Khan, A.H., Kidwai, M.M. and Bhargava, S.K., 2006. Comparison of trace metals concentration in PM_{10} of different location of Lucknow city. *Bulletin of Environmental Contamination and Toxicology,*77, 419-426.

Simon, H., Allen, D.T. and Wittig, A.E., 2008. Fine Particulate Matter Emissions Inventories: Comparisons of Emissions Estimates with Observations from Recent Field Programs. *Journal of the Air and Waste Management Association,* 58 (2), 320-343.

Singh, N., Yonus, M., Srivastav, K., Singh, S.M. and Panday, V., 1995. Monitoring of autoexhaust pollution by roadside plant. *Environmental Monitoring and Assessment,* 34, 1325.

Tripathee, L., Kang, S., Rupakheti, D., Zhang, Q., Huang, J. and Sillanpaa, M., 2016. Water-Soluble Ionic Composition of Aerosols at Urban Location in the Foothills of Himalaya, Pokhara Valley, Nepal. *Atmosphere,* 7, 102.

USEPA, 2000a. Code of Federal Regulations, Title 40, Part 60, Appendix A, Method 301: *Field validation of pollutant measurement methods from various waste media*, US Environmental Protection Agency, Washington, DC. 42 *pp*.

USEPA, 2000b. Code of Federal Regulations, Title 40, Part 60, Appendix A, Method 5: *Determination of particulate emissions from stationary sources*, US Environmental Protection Agency, Washington, DC. 41 *pp*.

USEPA, 2008. *Air Quality Index: A Guide to Air Quality and Your Health*. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, USA. 12 *pp*.

West, P.W. and Gaeke, G.C., 1956. Fixation of sulphur dioxide as sulfitomercurate (11) and subsequent colorimetric determination. *Annals of Chemistry*, 28, 1916-1819.

WHO, 2000. *Air Quality Guidelines for Europe*. 2nd Ed., *Reg. Publ. Eur. Ser.* 91: 288. World Health Organization (WHO) Reg. Off., Europe, Copenhagen. 273 *pp*.

WHO, 2005. *Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide*. Global Update 2005. Summary of Risk Assessment, World Health Organization, WHO/SDE/PHE/OEH/06.02. 22 *pp*.

Yadav, S.K., Kumar, V. and Singh, M.M., 2012. Assessment of ambient air quality status in urban residential areas of Jhansi city and rural residential areas of adjoining villages of Madhya Pradesh. *International Journal of Advanced Engineering Technology*, 3 (1), 280-285.

Yang, C.Y., Chang, C.C., Chuang, H.Y., Tsai, S.S., Wu, T.N. and Ho, C.K., 2004. Relationship between air pollution and daily mortality in a subtropical city: Taipei Taiwan, *Environment International*, 30 (4), 519-523.

Zlauddin, A. and Siddique, N.A., 2006. Air quality index (AQI) - A tool to determine ambient air quality. *Pollution Research*, 25, 885-887.