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Assessment of Ambient Air quality in Industrial Cluster at Paradip (India) based on Air Quality Index (AQI)

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ABSTRACT

Ambient Air Quality (AAQ) of an important industrial cluster of country, Paradip, Odisha has been assessed by monitoring of four ambient air quality parameters: particulate matter (PM_{10}, $PM_{2.5}$), sulphur dioxide (SO_2), oxides of nitrogen (NOx), carbon monoxide (CO) and by using Air Quality Index (AQI). The result revealed severe air pollution at all six sites of the town out of which highest index value of 168.62 .25 is recorded at location A3. Co-relation study shows a strongly direct relation among AQI and CO (r=0.733). Regression study reflects PM_{10} is good at predicting AQI (R^2=0.6703). This study also identifies potential sources of pollution, the extent of air pollution caused due to industrial operation & suggested mitigative measures.

Key words: *AQI, Air Pollution, PM_{10}, $PM_{2.5}$, Correlation, MLR*

Introduction

Rapid industrialization is a yardstick of development of a country. In India, there has been a fast growth in industrialization after independence. The port city of Odisha, Paradip, has attracted more industries in the last two decades, because of its convenient location and the motivational approach of government towards industrial revolution .The pace of industrialization in last decades in this area has led to population surges, urbanization, and other related developments, bringing environmental impacts closer to the limits of the tolerance threshold. Severely polluted industrial areas/clusters are not only environmental challenges, but also public health challenges. Although these heavily polluted areas pose a major threat to the environment and public health, so far, only a small number of national/international efforts have been made to curb the pollution level in these areas. Off late this has forced people to realize that it is necessary to develop an objective method to quantify the environmental conditions in the industrial clusters. Though all Indian industries function by following the rules and regulations of the Central Pollution Control Board (CPCB), but the pollution situation is still dissatisfactory. Aware of the importance of the impacts on the environment and, in particular, on the human health of air pollution (Chaurasia and Tiwari, 2016) due to industrial activity, this study was carried out to assess the quality of the ambient air in this industrial area. The critical parameters were chosen by

([1] PhD Scholar, [2]Associate Prof., [3]GM) linking the environmental issues and relevance of the parameter.

Study Area

Paradip city is a major seaport city of state of Odisha, India. Paradip town is the main outlet and inlet of the sea-borne trade of the eastern port. It also signaled the economic development of the state, giving impetus to trade and commerce. It has become the gateway of Odisha to the International community. The port town has become a hub of industrial activities varying from fertilizer making to crude oil refining and pellet making. RED category (Red-A) polluting industries, numbering at 5 followed by Red-B numbering at 10 apart from a number of small ancillary industry are situated in Industrial Area (SPCB-Odisha report, 2020).

Materials and Methodology

Determination of ambient air quality has been done in Paradip city within a 10 km radius for which monitoring stations were installed and air condition tests have been carried out at six locations (A1, A2, A3, A4, A 5, A6) which are shown in Figure 1 and listed in Table 1. For air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_X) samples has been collected continuously twenty four hour in a single day while CO has been sampled continuous eight hour and thrice in 24 hour duration. The frequency of sample collection for ambient air quality (AAQ) was conducted twice in a week during a season (i.e. the Summer season). The SLE -105 Fine Particle (FP) sampler has been used to measure PM10 and $PM_{2.5}$. The sampler has been operated at a maximum flow rate of 1.2 m^3/min. Pre-weighed glass fiber filter (GFF) paper and polytetrafluoroethylene (PTFE) filter paper were used to collect PM_{10} and $PM_{2.5}$ particle respectively, from an air sample. The gaseous pollutants were collected using the FP sampler SLE-133 with impingers arrangement (bubbler trains) containing sodium tetrachloromercurate and sodium hydroxide absorbents. Samples were analyzed spectrophoto

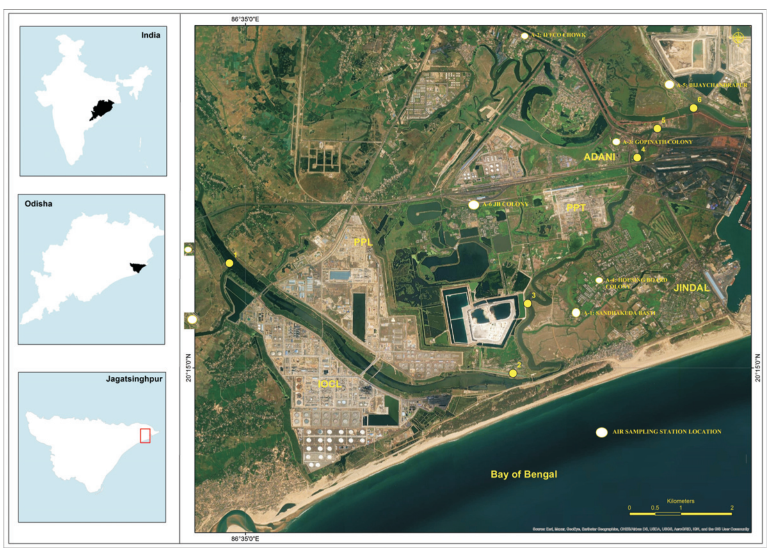

Fig. 1. Location of six sampling pont

Table 1. Locations of Ambient Air Quality Monitoring station

Code	Location	Coordinates	Terrain Features
A1	SandhakudaBasti	20°15’4.30"N86°38’26.20"E	Flat, Residential area. Near to Gypsum pond of PPL.
A2	IFFCO Chowk	20°18’10.45"N86°38’24.11"E	Commercial area, Residential area Near industry IFFCO, Mittall steel
A3	Gopinath Colony	20°17’20.13"N86°38’48.99"E	Residential area Near paradip port.
A4	Housing Board colony	20°15’30.91"N86°38’24.00"E	Residential area Near PPL Gypsum pond
A5	Bijaychandrapur	20°17’50.38"N86°39’35.50"E	Residential area Near IFFCO Gypsum pond
A6	JB colony	20°16’10.38"N86°37’49.96"E	Residential area near IOCL Oil terminal & PPL gypsum pond

metrically (at wavelengths of 560 and 540 nm respectively) using the methods of West and Gaeke (1956) and the modified method of Jacob and Hocheiser (1958) for the analysis of SO_2 and NO_X respectively. For carbon monoxide analysis, the collected sample was analyzed by gas chromatography with NDIR spectroscopy.

The obtained value of five major air quality parameters (PM_{10}, $PM_{2.5}$, SO_2, NOx and CO) from air sample analysis has been used to evaluate the quality of air by using Oak Ridge National Air Quality Index (ORNAQI) given in equation 1 (Bhuyan *et al.*, 2010). Also these data has been used for various statistical analysis like co-relation study, regression study to find out the closeness among air quality parameter, meteorological parameter and that of with calculated AQI. The regression study examines the best approach to predict AQI with the help of single independent parameter and multiple independent parameters.

Results and Discussion

Findings of pollutant

The average value of ambient air quality parameters (PM_{10}, $PM_{2.5}$, NO_X, CO and SO_2) at selected stations and their respective air quality index has been studied which is found in Table 2 and results are mentioned below.

Throughout the study period, the average values for PM_{10} at six sampling location were found to varied between minimum value of 95.37 mg/m^3 at A4 to maximum value of 123.67 mg/m^3 at A3. The average values for PM_{10} in study area are found to stays above the NAAQ limit (100 mg/m^3). Same trend has been seen for PM $_{2.5}$ also. In 66% of sample case, the PM $_{2.5}$ concentration were detected above the NAAQ limit (60 mg/m^3) except sample from A4 and A6. But the average values for $PM_{2.5}$ in the study area staying much above the NAAQ limit of 60 mg/m^3 which is a matter of concern.

The result indicates that the observed PM_{10} and $PM_{2.5}$ value in the study area are found well above the national ambient air quality standards (NAAQS, 2009) which are shown in Figure 2a. The higher PM_{10} and $PM_{2.5}$ values in the study area have been observed due to heavy vehicle movement for industrial operation and industrial activity including manufacturing process. The city is facing a grave problem of air pollution with iron, coal dust, gypsum dust and other pollutants getting diffused in the atmosphere due to 'dirty cargo' such as coking coal and thermal coal being handled at the port. The issue is compounded by transportation of gypsum by two fertilizer units. Trucks carrying gypsum waste & iron ore to port are often overloaded as a result of which the dust spills onto the road causing air pollution. Apart from the above, the fugitive emissions from the burning of coal as domestic fuel, also contribute to air pollution in the area.

NO_X concentration is found to be minimum of 34.17 mg/m^3 at A1 to highest value of 69.9 mg/m^3 at A2. These results are well below the NAAQ standard value. Even the average values for NO_X also staying below the standard. The higher values of NO_X at different locations may be due to vehicular movements. While for SO_2 the recorded average values at these eight locations are varied from 55.3 mg/m^3 at A1 to 86.73 mg/m^3 at A5. The recorded values are staying below the standard except for 33% of samples from A3 and A5. In these two locations the recorded SO_2 values stays above the NAAQ limit of 80 mg/m^3. The study shows that CO level in ambient air is also well below the NAAQ standard (4000mg/m^3) except at location A3(4833.3 mg/m^3). The recorded values of CO also staying below the standard. CO value varies between 1833.3mg/m^3 at A5 to 4833.3 mg/m^3 at A3.

Table 2. Air pollutants values (µg/m^3), meteorology data and AQI at six sampling location

Location	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (µg/m^3)	NOx (µg/m^3)	CO (µg/m^3)	Temp	RH	AQI
A1	117.43	71.87	55.3	34.17	2767	32.5	82	137.97
A2	104.37	72.7	69.9	69.5	3166.7	28.85	80.5	157.26
A3	123.67	72.27	80.5	39.37	4833.3	25.6	75	168.62
A4	95.37	55.6	56.83	34.97	2266.7	31	62.5	119.15
A5	102.53	74.57	86.73	51.33	1833.3	28.15	64	146.54
A6	111.67	52.47	68.47	48.87	2800	25.3	67	137.16
NAAQ standard	100	60	80	80	4000	-	-	-

Results from AQI

It has observed that in all six locations the calculated AQI are falling in the category of severe air pollution (SAP). The highest AQI of 168.62 is calculated at location A3 and next to it, the highest AQI value of 157.26 is observed at A2. The higher values of AQI were expected at these locations because of higher values of observed particulate matter concentration and Sox as given in Table 2. Study founds a lowest value of AQI (119.15) at location A4.

Findings from co-relation

Table 4 presents the correlation matrix between different studied parameters and the result reveals a strong positive correlation in between PM_{10} and CO with correlation coefficient $r = 0.764$ while strong negative correlation is obtained between $PM_{2.5}$ and NOx (r =-0.746). Meteorological parameter, temperature has the least influence of relationship with studied air quality parameter and is inversely proportional. The tested correlation study between AQI

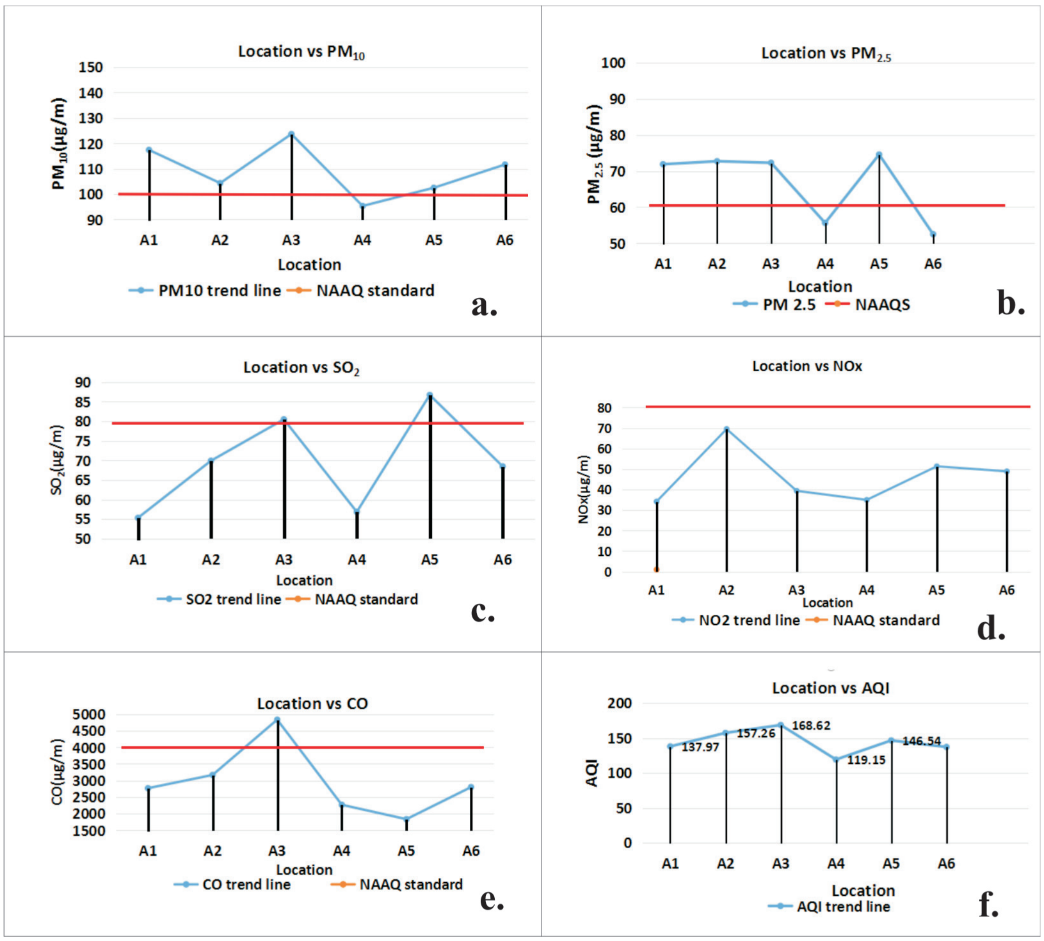

Fig. 2a-f: Trend of Air Pollutant and AQI at six Locations.

Table 3. Air Quality Index and Corresponding Air Quality Status

AQI Value	Remark	Health risk
0-25	Clea air (CA)	None/minimal health effect
26-50	Light air pollution (LAP)	Possible respiratory or cardiac effect for most sensitive group
51-75	Moderately air pollution (MAP)	Increasing symptoms of respiratory and cariovascular illness
76-100	Heavy air pollution (HAP)	Aggravation of heart and lung diseases
>100	Severe air pollution (SAP)	Serious aggravation of heart and lung diseases Risk of death in children

(Panda and Panda, 2012)

and other observed parameter in Table 4 depicts that AQI is significantly influenced by CO and $PM_{2.5}$. The correlation coefficient, r = 0.641, 0.684, 0.674, 0.733 is found among AQI with $PM_{10,}$ $PM_{2.5,}$ SO_2, CO respectively as shown in Table 4.

Findings from regression and MLR

In regression study when R^2 value is closure to one, the prediction is better (Field, 2009). Regression study in Figure 3a-d reveals that PM_{10}, $PM_{2.5}$, SO_2 and CO are positively regressed with AQI and are good regressor towards AQI (Figure 3a-b) with regression coefficients between them: k = 0.5725, 1.2, 0.9308 and 0.0122 respectively . It is cleared from regression study (Table 5) that PM_{10} is best at predicting AQI (R^2= 0.6703). CO is also good at predicting AQI next to PM_{10} (R^2= 0.5381).

Results from meteorological parameter study

In meteorological parameter, temperature is ranging between 25.3°C (at A6) to 32.5°C (at A1) while the relative humidity ranges between 62.5% (at A4) to 80.5% (at A2). The recorded wind direction is predominantly from southwest (SW) direction during almost all studied period. During monsoon the predominant wind direction is from southwest and south.

Conclusion

The study has found out that concentrations of all

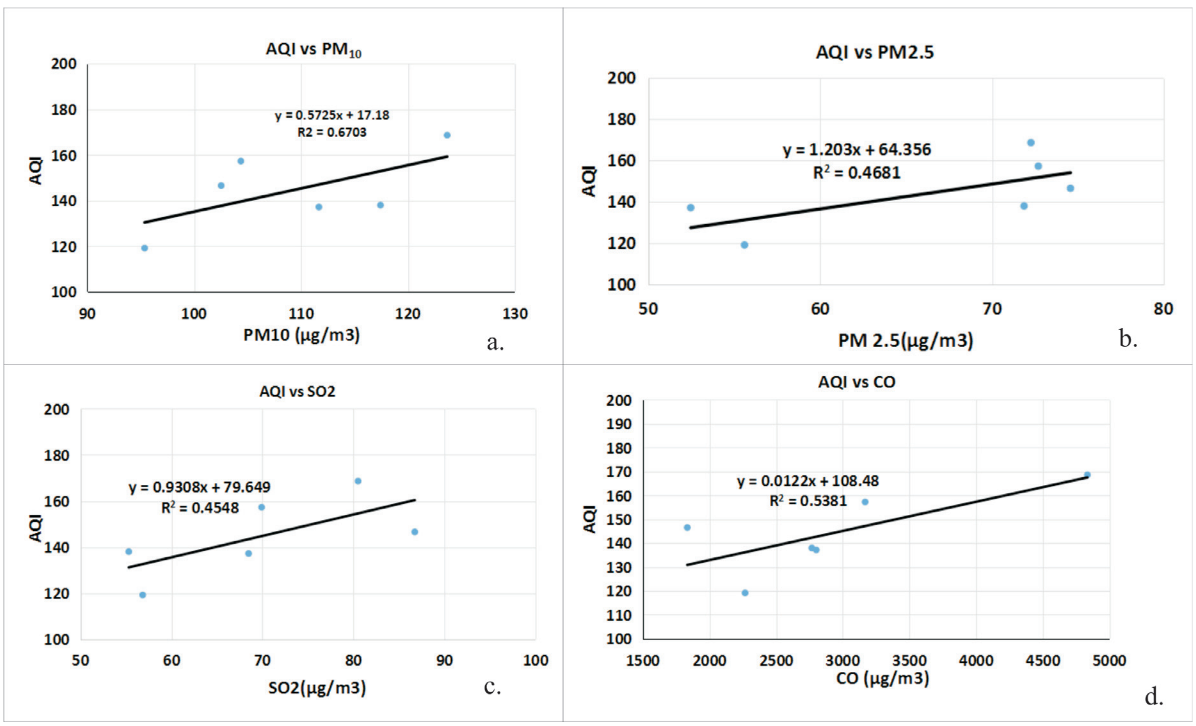

Fig. 3a-d: Scatter Diagrams Showing Correlation and Regression between AQP, Meteorological Parameter and AQI.

Table 4. Correlation Coefficient Matrix among Air Quality Parameter, Meteorological Parameter and AQI

Parameter	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	TEMP	RH	AQI
PM_{10}	1	0.313	0.15	-0.262	**0.764**	-0.34	0.581	**0.641**
$PM_{2.5}$		1	0.458	**0.254**	0.231	0.154	0.559	0.684
SO_2			1	**0.398**	0.2	-0.686	0.222	**0.674**
NOx				1	-0.058	-0.305	0.193	0.422
CO					1	-0.468	0.496	**0.733**
TMP						1	0.241	-0.534
RH							1	**0.513**
AQI								1

gaseous pollutants are well above the permissible limit at all six locations. The Particulate Matters pollutant (PM_{10}, $PM_{2.5}$) is mostly responsible for deterioration of ambient air quality (AAQ) which is cleared from co-relation and regression study. The study intelligibly shows that it would be more appropriate to consider the value of AQI instead of air pollutant content during planning for prevention of air pollution in this industrial cluster. Based on the AQI values, it was found that the AAQ values lies in the category of SAP (severe air pollution) category. It was observed that particulate emission was basically caused due to transportation and industrial operation related. In order to keep the PM_{10} and $PM_{2.5}$ values within an acceptable limit, measurements like frequently sprinkling of water on road, plantation of trees with high dust trapping efficiency alongside of roads needs to be done. The transportation of iron ore and gypsum in roads and overloading should be banned district administration. Except this, measures such as limiting the speed of vehicle in vulnerable localities, organizing public awareness campaigns on the harmful effects of air pollution should be carryout by industries and government agencies. Frequent monitoring of air quality and its results should be displayed at strategic location of the city in order to make industries and regulatory agencies more vigilant and responsive to pollution.

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