Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.2, 2019

Threat to Ambient Air Quality Due to Poor Municipal Solid Waste Management: A Case Study in and Arround Vuasuni Dumping Site, Bhubaneswar, Odisha , India

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Abstract
The objective of this study is to assess the state of air quality near municipal solid waste dumping site of the smart city Bhubaneswar, Odisha,India. Air Quality Index (AQI) in the study area has been calculated by measuring parameters like particulate matter (PM_{10}, $PM_{2.5}$), sulphur dioxide (SO_2), oxides of nitrogen (NOx) and carbonmonoxide (CO). Air status from AQI study depicts moderately pollution at dumping site (AQI=51.9). Corelation study shows a strongly direct relation among AQI and PM_{10} (r=0.964). Regression study reflects PM_{10} is good at predicting AQI (R^2=0.93065, p<0.0001). Multiple linear regression (MLR) study predicts AQI with very less error(rss=0.0003) where PM_{10}, $PM_{2.5}$, SO_2, NOx and CO are independent variables. This study also identifies potential sources of pollution and the extent of air pollution. In addition, management strategies have been proposed to minimize the effects of pollutants.
Keywords: AQI, Air Pollution, PM_{10}, MLR, Wind rose
DOI: 10.7176/JEES/9-2-02

1. Introduction

In the last decades, growing population, urbanization and rising living standards have increased the amount and diversity of waste produced worldwide (Gidde *et al*. 2008; Rathi 2007). It is becoming a difficult task for municipal solid waste management (MSWM) authorities to deal such quantity of solid waste.The indiscriminate dumping of municipal solid waste is increasing because governance is poor, environmental awareness is low and it is not possible to install suitable municipal waste treatment facilities to handle municipal solid waste (MSW) generated daily in major cities(Rachel *et al.* 2009). Some researchers from various cities in developing countries have reported inappropriate handling of municipal solid waste (Mohanty *et al*. 2014; Das and Bhattacharya 2013; Noorjahan *et al.* 2012; Jafari *et al*. 2010; Chatterjee 2010; Imam *et al.* 2008; Chung and Carlos 2008; Berkun *et al.* 2005). Open dumping of municipal solid wastes is a pre-dominant waste management option in most developing countries with little regard to the health and environmental impact. There are potential risks to health and all component of environment from such solid wastes management practice (Gupta *et al*. 2007; Rathi 2006; Ray *et al.* 2005; Sharholy *et al.* 2005; Jha *et al*. 2003). These area becoming a source of air pollution resulting from the decomposition of organic materials and open burning of wastes which pose a threat to environment by emitting toxic pollutants into the air.Similar type of scenario has seen in developing countries like India, where rapid industrial growth and population explosion has led people to migrate from villages to cities, producing thousands of tons of municipal solid waste every day (Gupta *et al.* 2015). Every city dweller generates between 350 and 1000 grams of solid waste per day. Indian urban areas produces 188,500 tons of solid urban waste in a day or 68,8 million tons in a year (Gupta *et al.* 2015) . It has seen that to deal with such amount of MSW, the most common practice in developing countries like India are open dumping and few times open burning at dumping site (Sarkar 2016). This releases immense amounts of air pollutants into the atmosphere, including particulates, nitrogen oxides (NOx), sulfur dioxide (SO_2), and dioxins and furans.

The Bhubaneswar (BBSR) city is not excluded from this.The city, which was designed earlier for 40,000 people with an area of 16.84 Sq. Km of land is now accommodating about more than 8 lakhs people with an area of about 135 sq. km. As per provisional reports of Census of India Population of Bhubaneswar in 2011 was 837,737. Presently Bhubaneswar is generating 400 ton per day of MSW (REF). To deal the such amount of MSW, Bhubaneswar municipality corporation (BMC) has been allotted 61.485 acer of land in village- Bhuasuni in the year 2008 by Govt. of Odisha. The site is sorrounded by villages: Bhuasuni, Daruthenga, Tulasadeipur, Jujhagada, Krushnanagar, sunderpada, Chandaka etc. Open dumping is the major activvity i.e.practiced for Bhubaneswar MSWM (Mohanty *et al.* 2014). Some time open burning approaches is allso taking place at the dumping site to deal the huge volume of combustible MSW (Mohanty *et al.* 2014; Riyan 2018) .It may pose threat to health. As the human health is prone to various diseases such as shortness of breath, sore throat, chest pain, nausea, asthma, bronchitis and lung cancer due to inhaling of such air quality around the world (Dockery and Pope 1994, US EPA

1999, Jeff and Hans 2004, Clean Air 2007). It is there fore in this study an attempt has been made to find out the quality of ambient air in and arround the dumping site with a radious of 10Km

2. Study area

Bhubaneswar is located between 85°44' E to 85°55' E longitude and 20°12' N to 20°25' N latitude in Khordha district of Odisha. It is situated in the eastern coastal plains, along the axis of the Eastern Ghats. It has an average altitude of 45m (148 ft.) above sea level (JNNURM 2013). The city lies on the southwest of the Mahanadi River and within its delta and forms the northern boundary of Bhubaneswar metropolitan area, where as the MSW dumping site of BBSR, Bhuasuni is situated north east of Bhubaneswar city and 20 KM from Bhubaneswar station(Figure 1).The site is geographically located at 20^0 23' 30.28"N and 85^0 47' 18.20"E at Bhuasuni village and is covering an area of 61.485 Acres . It is situated in bhuasuni mouza , chandaka of khurda district having khata no. 232, plot no. 539, 541, 543, 549 and 313. A few villeges near dumping site are Bhuasuni village ,Daruthenga, Tulasadeipur, Jujhagada, Krushnanagar, Sunderpada, Chandaka etc.

3. Materials and methodology

To determine the ambient air quality in and around the Bhubaneswar municipal solid waste dumping site, an area of 10 km. radius, monitoring stations were installed and examination of air status has been carried out at 10 locations (L1, L2,L3,L4, L5,L6,L7,L8, L9,L10) given in Table 1, during the year 2015.

Table 1: Details of Ambient Air Quality Monitoring Stations

Station code	Sampling locations	Coordinate	Distance in (km.)	Direction	Location type
			w.r.t. Project Site		
L 1	Dumping Site	20° 23' 32.62"N 85° 47' 20.08"E	-	-	-
L 2	Sundarpur	20° 21' 49.91"N 85° 47' 39.49"E	3.22 Km	S	Location having urban type settlement
L 3	Daruthenga	20° 22' 50.19"N 85° 47' 37.38"E	1.41 Km	SSE	Location having urban type settlement
L 4	Kujimahal	20° 21' 10.96"N 85° 45' 04.73"E	5.89 Km	SW	Location is near the Khurda-Chandaka road
L 5	Darhapatana	20° 24' 35.72"N 85° 49' 56.74"E	4.94 Km	NNE	Location is near the Baranga nala.
L 6	Ramdaspur	20° 27' 00.93"N 85° 47' 00.02"E	6.44 Km	N	Location having urban type settlement
L 7	Trisulia	20° 25' 56.28"N 85° 49' 56.04"E	6.32 Km	NE	Location having settlement & road infrastructure with urban type settlement
L 8	Chandaka	20° 22' 07.60"N 85° 45' 49.57"E	3.72 Km	SW	Location having urban type settlement
L 9	KIIT Campus	20° 21' 24.43"N 85° 49' 17.66"E	5.21 Km	SE	Location near Sikharchandi Road
L 10	Bharatpur	20° 18' 29.06"N 85° 46' 41.89"E	9.42 Km	S	Location near by Khandagiri-Chandaka road

For air pollutant (PM_{10}, $PM_{2.5}$, SO_2, NO_X) samples has been collected twenty four hourly basis continuous in a day while CO has been sampled for eight hourly continuous thrice in 24 hour duration. The sample collection has been conducted for two days in a week for three months (March ot May). During sampling few points has taken in to consideration like height of the inlet of sampler (3 – 10 m) above the ground level and the sampler distance from trees (>20m). A detailed methodology for air sampling, analysis and instrument used are presented in the Table 2. PM_{10} and $PM_{2.5}$ has been collected using Fine Particulate(FP) Sampler SLE- 105 at these sampling stations .

Table 2: Details Methods of Measurement and Technical Protocols used for Ambient Air Pollutant.

Pollutant ($\mu g/m^3$)	Methods of Measurement	Instrument Name	Model	Technical Protocol	Minimum Detection Limit
PM_{10}	FP Sampler (Gravimetric Method)	Electronic Balance	APX 200	IS: 5182 Part II	0.1 µg
$PM_{2.5}$	FP Sampler (Gravimetric Method)	Electronic Balance	APX 200	IS: 5182 Part VI	0.1 µg
SO_2	Improved West and Gaeke	Spectrophotometer	DR2000;Sl No.91101634	IS: 5182 Part IV	2.0 µg
NO_X	Modified Jacob & Hochheiser (Na-Arsenite)	Spectrophotometer	DR2000;Sl No.91101634	IS: 5182 Part IV	2.0 µg
CO	Non dispersive Infra Red (NDIR) spectroscopy	Gas Chromatograph with NDIR	CP-3800-44;Sl.No.8094	IS: 5182 Part X	0.01 (ppm)

The FP sampler SLE- 105 has been used followed by cyclonic and impactor based tech-nique for measurement of PM_{10} and $PM_{2.5}$ respectively. The sampler has been operated at maximum rate of 1.2 m^3/min for collection of PM_{10} particle on a preweighed Glass Fiber Filter (GFF) paper, whereas for $PM_{2.5}$ the air sample has been drawn through Poly Tetra Fluoro Ethylene (PTFE) filter paper at a flow rate of 16.2 L/min. The mass concentrations of particulate pollutants has been estimated by taking the difference of the final and initial of the filter paper used for air sampling.

Gaseous pollutants has been collected using the FP sampler SLE-133 having impingers arrangement (bubbler trains) in series containing absorbents sodium tetrachloromercurate for SO_2 and sodium hydroxide solution for NO_X. The samples collected in the impinger were stored in ice boxes soon after sampling and transferred to a refrigerator prior to analysis. The samples were analysed spectrophotometrically using West and Gaeke (1956) method and Jacob and Hocheiser (1958) modified method for analysis of SO_2 and NO_X respectively (Kartz K: APHA 1977) . For measurement of SO_2 and NO_X by spectrophotometrically, the used wavelength are 560 and 540 nm respectively.

For carbon monoxide monitoring sample of the ambient air has been taken from the sampling tube and injected into a gas chromatograph where it is routed from one end of the column to the other. During the movement, the carbon monoxide is converted to methane and the sample is dispensed at different speeds to eventually separate. The separated components are detected as different peaks in the tracer.

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)and the recorded value of meteorological parameter has been used to draw winnd rose diagram. Also these data has been used for various statistical analysis like co-relation study, regression study, multiple regression study to find out the closeness among air quality parameter, meteorological parameter and that of with calculated AQI. While regression study examines the best approach to predict AQI with the help of single independent parameter and multiple independent parameter.

4. Result and discussion

4.1 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 in Table 3 and results are mentioned below.

Table 3: Measured Values (in μg/m3) of Air Pollutants, AQI at Ten Sampling Station

Location		L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Standard (NAAQS)
PM_{10} (μg/m^3)	Max	71.3	68.7	69.6	54.8	59.7	62.9	69.2	61.7	63.8	59.4	100 (μg/m^3)
	Min	52.6	50.1	48.4	39.5	41.2	38.9	54.3	49.8	52.3	49.7	
	Avg	61.95	59.4	59	47.15	50.45	50.9	61.75	55.75	58.05	54.55	
$PM_{2.5}$ (μg/m^3)	Max	41.2	39.6	40.8	30.7	34.8	30.2	34.2	35.1	38.5	36.2	60 (μg/m^3)
	Min	28.7	28.1	27.9	25.2	24.1	26.7	25.3	27.4	29.4	26.4	
	Avg	34.95	33.85	34.35	27.95	29.45	28.45	29.75	31.25	33.95	31.13	
SO_2 (μg/m^3)	Max	9.1	8.9	9.2	8.8	9.1	9.5	8.9	10.2	9.7	9.5	80 (μg/m^3)
	Min	7.3	6.9	7.1	6.8	7.2	7.1	6.8	7.5	6.9	7.4	
	Avg	8.2	7.9	8.15	7.8	8.15	8.3	7.85	8.85	8.3	8.45	
NO_X (μg/m^3)	Max	12.4	11.8	12.1	13.2	10.9	13.4	12.7	13.9	12.1	11.9	80 (μg/m^3)
	Min	9.2	8.9	9	10.4	8.4	10.2	9.9	11.2	9.8	9.6	
	Avg	10.8	10.35	10.55	11.8	9.65	11.8	11.3	12.55	10.95	10.75	
CO (μg/m^3)	Max	371	360	331	398	392	489	501	453	415	384	4000 (μg/m^3)
	Min	283	271	289	302	299	326	409	312	356	288	
	Avg	327	315.5	310	350	345.5	407.5	455	382.5	385.5	336	
AQI		51.9	50.02	50.31	43.56	44.7	45.76	50.07	49.24	50.62	47.49	-

4.1.1 Findings from Particulate Matter

Throughout the study period, the concentrations of PM_{10} found between minimum value of 38.9 μg/m^3 to maximum value of 71.3 μg/m^3. The highest value was found to be 71.3μg/m^3 at the dumping site and lowest value was found to be 38.9 μg/m^3 at the Ramdaspur. While the average values for PM_{10} at ten sampling location were found to be varried between 47.15 (at L4) to 61.95 (at L1). While the recorded values for $PM_{2.5}$ varies between 24.1 μg/m^3 (at L5) to maximum value of 41.2 μg/m^3 (at L1). The average value for $PM_{2.5}$ varries from 27.95 μg/m^3 (at L4) to 34.95 μg/m^3 (at L1). The result indicates that the observed PM_{10} and $PM_{2.5}$ value at ten location are well below the standard as per national ambient air quality standards (NAAQS, 2009). The slight higher PM_{10} and $PM_{2.5}$ values at the MSW dumping site (at L1) has been observed due to local phenomena viz. unpaved roads, heavy vehicular traffic, burning of MSW and heavy vehicle movement for dumping of MSW. Though the PM_{10} value has increased a little but it is within the permissible limit of NAAQS which is shown in Figure 2a. It is there fore proper management of MSW and frequent sprinkling of water are required to suppress the emission of these particulate matter.

4.1.2 Findings from NO_X Pollutant

NO_X found to be minimum of 8.4μg/m^3 at L5 to highest value of 13.9 μg/m^3 at L8. 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 location were may be due to vehicular movemments. The highest and lowest average value for NO_X was found to be 12.55μg/m^3 (at L8) and 9.65μg/m^3 (at L5) respectively.

4.1.3 Findings from SO_2 Pollutant

SO_2 found to be minimum of 6.8 μg/m^3 at L4 to maximum of 10.2 μg/m^3 at L8. While the recorded average values at these ten locations are varried from 7.8 μg/m^3 at L4 to 8.85 μg/m^3 at L8. The recorded values are staying below the standard.

4.1.4 Findings from CO Pollutant

The study shows that CO level in ambient air is also well below the NAAQ standard. The recorded values for CO were varrying between 271 at L2 to 501 at L7. While the average values for CO at these ten location were found to be lowest of 310 at L3 to highest of 455 at L7.

The findings from above air quality parameters (PM_{10}, $PM_{2.5}$, SO_2, NO_X, CO) has been found bellow the NAAQ 2009 standard values which is there in Figure 2a-h. Even the data of all air quality parameters at all locations and during entire monitoring period do not exceed the NAAQ standard limits.

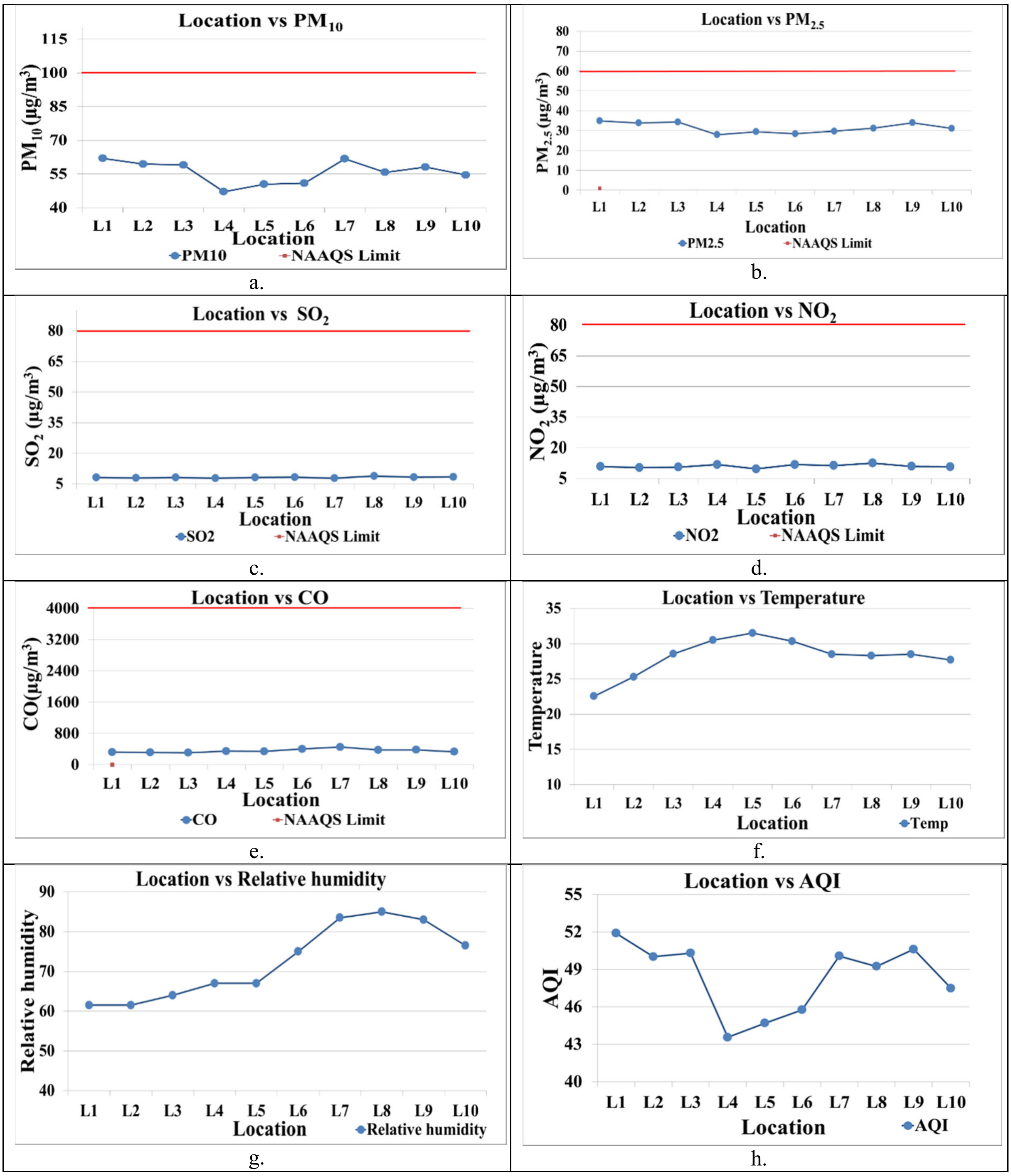

Figure 2a-h: Trend of Air Pollutant, Meteorological Parameter and AQI t ten Locations.

4.2 Results from AQI

Result from AQI from ten sampling location given in Table 3 depict that the ambient air quality is ranging from light air pollution (LAP) to moderate air pollution (MAP) as shown in Table 4. It has seen that except location L1and L9, the calculated AQI for rest eight locations are falling in the category of low air pollution (LAP) while at L1it is falling in the category of moderately (MAP). Even though at locations L2, L3, L7, L8 the quality of air is LAP but the calculated AQI reveals that the AQI values of these locations are very nearrer to the MAP category of air quality. The highest AQI of 51.9 is registered at location L1 and next to it the highest AQI value of 50.62 is observed at L9. The higher values of AQI were expected at these location because of higher values of observed particulate matter concenration as given in Table 3. Study founds a lowest value of AQI (43.56) at location L4.

Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.2, 2019

Table 4: Air Quality Index and Corresponding Air Quality Status (Panda and Panda 2012)

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

4.3 Findings from Corelation

Table 5 presents the correlation matrix between weather parameters and air quality parameters. Temperature (T) is positively correlated with NO_X having correlation coefficient, r = 0.0.0287. Except NO_X temprature is negatively correlated with other AQP parameter. The meteorological parameter, relative humidity (RH) is strongly correlated with CO (r = 0.8112) and is directly proportional. While

Table 5: Correlation Coefficient Matrix of Air Quality Parameter, Meteorological Parameter and AQI.

	PM_{10}	$PM_{2.5}$	SO_2	NO_X	CO	TEMP	RH	AQI
PM_{10}	1	0.768	-0.014	-0.177	0.028	-0.747	0.033	0.964
$PM_{2.5}$		1	0.132	-0.355	-0.505	-0.757	-0.288	0.858
SO_2			1	0.374	0.026	-0.021	0.485	0.154
NO_X				1	0.507	0.118	0.56	-0.078
CO					1	0.352	0.788	-0.042
TEMP						1	0.324	-0.768
RH							1	0.068
AQI								1

the least influence of relationship has been observed with SO2 having correlation coefficient, r = 0.1247 and also is directly proportional relationship. The relative humidity is also positively correlated with NO_X and temprature with r = 0.4364 and 0.3766 respectively. The relationship between particulate matter and relative humidity is found inversely proportional. The correlation study shows a significant correlation among PM_{10}, $PM_{2.5}$ (r=0.768) and among CO,NO_X (r=0.507). The tested correlation study between AQI and other observed parameter in Table 5 depicts that AQI is significantly influenced by particulate matter. The correlation coefficient, r=0.964 and 0.858 is found among AQI with PM_{10} and $PM_{2.5}$ respectively. Except particulate matter and SO_2, AQI is negatively corelated (r=-0.078, -0.042, -0.53, -0.15) with all other studied parameter (NO_X , CO, temperature, RH) respectively as shown in Table 5.

4.4 Findings fom Regression and MLR

In regression study when R^2 value is closure to one, the prediction is better (Field, 2009). It can also be explained as a measure of asociation between the dependent and independent variable (Field, 2009). Regression study in Table 6 and Figure 3a-h reveals that PM_{10} and $PM_{2.5}$ are positively regressed with AQI and are good regressor towards AQI (Figure 3a) with regression coefficients between them: k = 0.53869 and 0.93223 respectively (Table 6). It is cleared from regression study (Table 6) that PM_{10} is best at predicting AQI (R^2= 0.93065, p= <0.0001, rss=4.98). $PM_{2.5}$ is also good at predicting AQI next to PM10 (R^2= 0.0.73686, p= 0.00148, rss=18.91). The regression study between AQI and meteorological parameter (T, RH, Wind speed) depicts that temprature is good at at predicting AQI (Figure 3f). While MLR study examines the best equation between dependent parameter (AQI) and all studied independent air quality parameter (PM_{10}, $PM_{2.5}$, SO_2, NOx, CO) which is there in Table 6, where the coefficient of determination is found to be, R^2=0.9999 and rss=0.0003. From MLR study (Table 6) values of residuals revealed that the equation in Table 6 is good at predicting WQI for the study area.

Table 6:Regression Study of AQI with AQP and Meteorological parameter.

Regression study of AQI with AQP and meteorological parameter				
Regression	k	R^2	rss	p
AQI= 0.020808261* RH + 46.8604819	0.020808261	0.0047	71.508	0.85031
AQI= -0.82872*Temp + 71.71618	-0.7275268986	0.58969	29.48	0.00949
AQI= -0.002647356*CO + 49.32388686	-0.002647356	0.00184	71.71	0.90632
AQI=-0.2643650794*NO_X + 51.28823413	-0.2643650794	0.00613	71.41	0.8298
AQI=1.393992632*SO_2 + 36.94323038	1.393992632	0.02386	70.13	0.67004
AQI=0.9322307283*$PM_{2.5}$ + 18.99427421	0.9322307283	0.73686	18.91	0.00148
AQI=0.5386938261*PM_{10} + 18.25670859	0.5386938261	0.93065	4.98	< 0.0001
Multiple linear regression study of AQI with AQP				
AQI = 0.3327547934*PM_{10} + 0.5480183909*$PM_{2.5}$+ 0.4208193927*SO_2+ 0.4136342662*NO_X				
rss	R^2			
$3.118485367 \cdot 10^{-4}$	0.9999			

Note: 'k'- rgression coefficient, 'R^2'- coefficient of determination, 'rss'- residual sum of squares

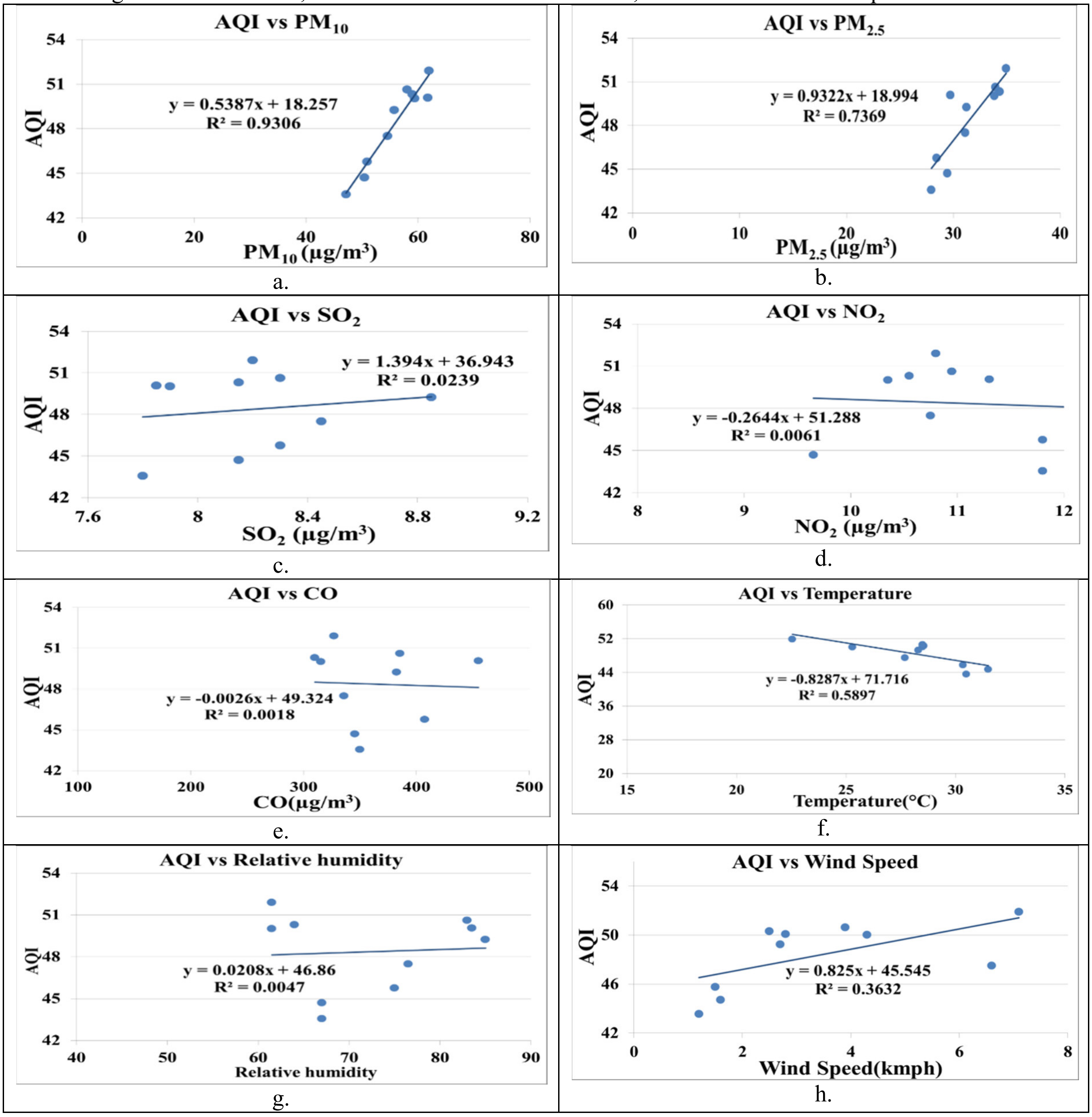

Figure 3a-h: Scatter Diagrams Showing Correlation and Regression Between AQP, Meteorological Parameter and AQI.

ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.2, 2019

4.5 Results from Meteorological Parameter Study

In meteorological parameter, temperature is ranging between 20.1° C (at L1) to 32.2° C (at L5) with average values ranging from 22.55° C to 31.5° C. While the relative humidity ranges between 50% (at L2) to 86% (at L8) i.e given in Table 7. The wind speed was mostly between 1.2 – 8.2 km/hour for all the studied period. The overal wind speed during the study period at dumping site has been presented in wind rose diagram (Figure 4). The Figure depict that the predominant wind direction is from southwest (SW) direction during allmost all studied period. During monsoon the predominant wind direction is from southwest and south. The wind direction during the study period is presented in wind rose diagram.

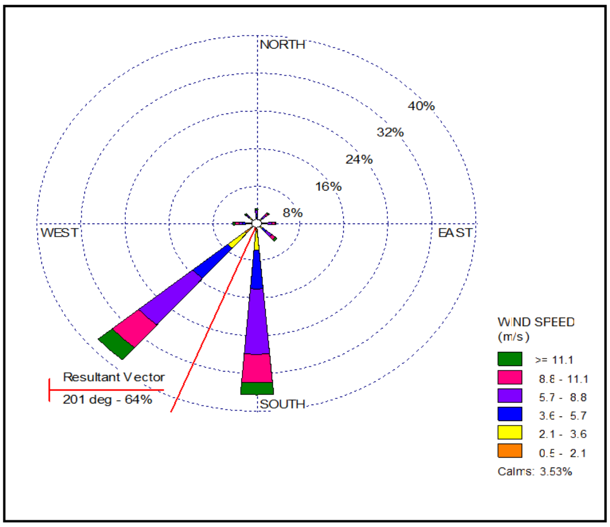

Figure 4: Overall Wind rose Pattern of the Study Area (March-May 2015)

Table 7: Measured Values of Meteorological Parammeters at Ten Sampling Station

Location	Temperature (°C)			Relative Humidity (%)			Wind speed	Direction (from)	AQI
	Max	Min	Avg	Max	Min	Avg	kmph	(from)	
L 1	25	20.1	22.55	72	51	61.5	7.1	NE, E	51.9
L 2	27.5	23.1	25.3	73	50	61.5	4.3	S, NE	50.02
L 3	30.3	26.8	28.55	74	54	64	2.5	S, SW	50.31
L 4	31.4	29.6	30.5	72	62	67	1.2	SW, S	43.56
L 5	32.2	30.8	31.5	71	63	67	1.6	SW, S	44.7
L 6	30.9	29.8	30.35	78	72	75	1.5	SW, S	45.76
L 7	28.7	28.3	28.5	85	82	83.5	2.8	SW, W	50.07
L 8	28.5	28.1	28.3	86	84	85	2.7	SW, W	49.24
L 9	28.6	28.4	28.5	84	82	83	3.9	SW, S	50.62
L 10	28	27.4	27.7	79	74	76.5	6.6	NE, E	47.49

5. Conclusion

Recorded and analyzed data revealed that all gaseous pollutants are well within the permissible limit at all locations. But the pollutant Particulate Matter (PM_{10} and $PM_{2.5}$) are mostly responsible for detarioration of ambient air quality (AAQ) which is cleared from corelation and regression study. Also the study intelligibly shows that it would be more appropriate to consider the value of AQI instead of air pollutant content when planning for prevention of air pollution. Based on the AQI values, it was found that the AAQ value is between LAP and MAP. It was observed that particulate emission was basically transport related. In order to keep the PM_{10} and $PM_{2.5}$ values within an acceptable limit, it is recommended to grow trees with high dust trapping efficiency alongside of roads and also water is to be sprinkled continuously at the source of particulate matter generation. Except these; measures such as limiting the speed of vehicle in vulnerable localities, organizing public awareness campaigns on the harmful effects of air pollution. Wind rose. A closer examination at the Bhuasuni dumping site landfill indicates that potentially hazardous foul odors are commonly experienced by passersby and inhabitants of the community especially those around the landfill. So further study is needed to address this.

Acknowledgments

We are grateful to our Department (Geography, Utkal University) and friends who provided valuable suggestions and contributions to this research.

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