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Determination of Air Quality Index Around a Thermal Power Plant-A Case Study of RWPL at Bhadresh, Barmer

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Abstract: This paper presents a case study on determination of Air Quality Index for a Thermal Power Plant known as Raj West Power Limited (RWPL), situated at Bhadresh in Barmer district of Rajasthan state. Air pollutant concentration were measured in the prevalent windward direction, leeward direction, and in the crosswind directions at both left and right to the prevalent windward direction around the plant. Method for calculation and experimentation was based on the basis of guidelines given by Central Pollution Control Board of India. Five criteria pollutants i.e., PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO were chosen for AQI determination at the given locations. Pollutants concentrations were found different in different directions. Maximum AQI was observed in the windward direction and minimum in leeward direction.

Key words: Air Quality Index, PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO, Thermal Power Plant, Air pollution.

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I. INTRODUCTION

Raj West Power Limited (RWPL) is a part of JSW Group and the project consist of 8x135 MW Thermal Power Plant at village Bhadresh in Barmer District of Rajasthan state. Geographically the Plant is located at 26° 02' 34.7" N Latitude & 71° 15' 24.76" E Longitude having an elevation of ~184 meter above MSL, which is suitable for installation of 8x135MW considering the availability of all the basic requirement. The plant is operational under environmental clearance (EC) granted by Ministry of Environment and Forests and consent to operate (CTO) granted by Rajasthan state pollution control board[9]. Purpose of this study is to measure the Air Quality Index in surrounding area of Thermal Power Plant as many villages are situated in its nearby areas. Thermal power plants are well known for its pollutant emissions like oxides of sulfur, nitrogen and carbon along with particulate matters[7]. Sulphur dioxide pollution, which takes a major toll on public health, including by contributing to the formation of small acidic particulates that can penetrate into human lungs and be absorbed by the bloodstream. SO_2 also causes acid rain, which damages crops, forests, and soils, and acidifies lakes and streams. A typical uncontrolled coal plant emits 14,100 tons of SO_2 per year[6]. NOx pollution causes ground level ozone, or smog, which can burn lung tissue, exacerbate asthma, and make people more susceptible to chronic respiratory diseases. A typical uncontrolled coal plant emits 10,300 tons of NOx per year. Particulate matter (also referred to as soot or fly ash) can cause chronic bronchitis, aggravated asthma, and premature death, as well as haze obstructing visibility. A typical uncontrolled plan emits 500 tons of small airborne particles each year[8]. Incomplete burning of fuel produces carbon monoxide which has more affinity towards hemoglobin than oxygen in our blood streams. Therefore, an attempt has been made to calculate the concentration of all these pollutants as per the guidelines of Central Pollution Control Board, India. NAQI system in India has started reporting air quality for some large cities of India which are 16 in number and it is considerably low by seeing huge population of Indian cities[3].

II. MATERIAL AND METHODOLOGY

For analysing air pollution and determining air quality index around the area of Raj West Power Limited, four stations were established in the each direction (i.e., prevalent windward direction, leeward direction, and in the crosswind directions at both left and right to the prevalent windward direction around the plant upto 1,880 m in windward direction, upto 1,550 m in leeward direction, upto 2,060 m in crosswind (left of the windward direction) and upto 1,310 m in crosswind (right of the windward direction) from central point of stacks). The nomenclature of the ambient air stations have been done on the basis of their respective directions in which they occur, i.e., WW_1, WW_2, WW_3, WW_4, LW_1, LW_2, LW_3, LW_4, CL_1, CL_2, CL_3, CL_4, CR_1, CR_2, CR_3, and CR_4 respectively in the windward, leeward, and crosswind directions both to the left and right of wind ward direction. The details of all the above ambient air stations are shown in table no -1. Five ambient air pollutants (i.e. PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO) were determined

using Respirable Dust Sampler, Fine Particulate Sampler, gaseous sampling attachment (EPA modified-West and Gaeke method for SO_2 and Modified Jacobs Hochheiser method for NO_2) and CO meter respectively[5, 1]. Air quality Index has been designed in such a manner that any of three parameters i.e., PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, O_3, Pb and NH_3 are sufficient to calculate AQI. Sub-Indices of each selected pollutants were calculated.And highest value from all of the sub-indices calculated above was considered as AQI for that particular area.

The sub-index (I_p) for a given pollutant concentration (C_p) is calculated as[1]

$$I_P = \left\lceil \left\{ \frac{I_{HI} - I_{LO}}{B_{HI} - B_{LO}} \right\} \times (C_P - B_{LO}) \right\rceil + I_{LO}$$

Where,

B_{HI}= Breakpoint concentration greater than or equal to given concentration

B_{LO}= Breakpoint concentration smaller than or equal to given concentration

I_{HI}= AQI value corresponding to B_{HI}

I_{LO}= AQI value corresponding to B_{LO}, subtract one from I_{LO} if I_{LO} is greater than 50

C_p= Pollutant concentration

Finally, AQI = Max (I_p) (where, p = 1, 2, 3 …denotes n pollutants)

III. OBSERVATION AND ANALYSIS

Observations were taken in all the monitoring stations as per the standard guidelines prescribed by Central Pollution Control Board of India[2, 4]. Carbon mono oxide concentration in each monitoring station was found 'Below Detection Limit' (BDL). Station name and location of stations is given in table-1. Observed average concentrations of various pollutants, calculated sub index and air quality index (AQI) for sampling stations are given from table-3 to table-18.

Table -1: Location of Different Monitoring Stations

S.NO.	STATION NAME	LOCATION	
		LATTITUDE	LONGITUDE
1	WW1	$25^0$53'56.90'' N	$71^0$20'20.66'' E
2	WW2	$25^0$53'57.88'' N	$71^0$20'24.96'' E
3	WW3	$25^0$54'2.49'' N	$71^0$20'32.57'' E
4	WW4	$25^0$54'5.07'' N	$71^0$20 38.03'' E
5	LW1	$25^0$53'10.37'' N	$71^0$19'8.75'' E
6	LW2	$25^0$53'6.51'' N	$71^0$19'3.56'' E
7	LW3	$25^0$53'3.78'' N	$71^0$18'57.63'' E
8	LW4	$25^0$53'0.02'' N	$71^0$18'51.13'' E
9	CL1	$25^0$54'24.39'' N	$71^0$19'16.44'' E
10	CL2	$25^0$54'26.55'' N	$71^0$19'10.57'' E
11	CL3	$25^0$54'28.46'' N	$71^0$19'3.87'' E
12	CL4	$25^0$54'30.40'' N	$71^0$18'57.96'' E
13	CR1	$25^0$53'11.85'' N	$71^0$20'20.87'' E
14	CR2	$25^0$53'8.13'' N	$71^0$20'26.24'' E
15	CR3	$25^0$53'4.56'' N	$71^0$20'32.25'' E
16	CR4	$25^0$53'2.51'' N	$71^0$20'36.27'' E

Table -2: Breakpoints for AQI Scale 0-500 (Units: µg/m^3 unless mentioned otherwise)

AQI Category	**PM_{10}**	**$PM_{2.5}$**	**NO_2**	**CO**	**SO_2**
(Range)	**24-hr**	**24-hr**	**24-hr**	**8-hr (mg/m^3)**	**24-hr**
Good (0-50)	0-50	0-30	0-40	0-1.0	0-40
Satisfactory(51-100)	51-100	31-60	41-80	1.1-2.0	41-80
Moderately polluted(101-200)	101-250	61-90	81-180	2.1-10	81-380
Poor(201-300)	251-350	91-120	181-280	10-17	381-800
Very poor(301-400)	351-430	121-250	281-400	17-34	801-1600
Severe(401-500)	430+	250+	400+	34+	1600+

Table -3: Observed Pollutant Concentrations and AQI Values At Sampling Station Name: WW_1, in windward direction

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	237.03	191	191
2	$PM_{2.5}$	$\mu g/m^3$	59.63	99	
3	SO_2	$\mu g/m^3$	26.53	33	
4	NO_2	$\mu g/m^3$	13.71	17	
5	CO	mg/m^3	BDL	-	

Table -4: Observed Pollutant Concentrations and AQI Values At Sampling Station Name: WW_2, in windward direction

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	233.93	189	189
2	$PM_{2.5}$	$\mu g/m^3$	60.93	103	
3	SO_2	$\mu g/m^3$	25.96	32	
4	NO_2	$\mu g/m^3$	13.23	17	
5	CO	mg/m^3	BDL	-	

Table -5: Observed Pollutant Concentrations and AQI Values At Sampling Station Name: WW_3, in windward direction

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	165.7	144	144
2	$PM_{2.5}$	$\mu g/m^3$	61.9	106	
3	SO_2	$\mu g/m^3$	13.36	17	
4	NO_2	$\mu g/m^3$	8.11	10	
5	CO	mg/m^3	BDL	-	

Table -6: Observed Pollutant Concentrations and AQI Values At Sampling Station Name: WW_4, in windward direction

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	168.7	146	146
2	$PM_{2.5}$	$\mu g/m^3$	63.43	111	
3	SO_2	$\mu g/m^3$	14.27	18	
4	NO_2	$\mu g/m^3$	7.45	9	
5	CO	mg/m^3	BDL	-	

Table -7: Observed Pollutant Concentrations and AQI Values At Sampling Station Name: LW_1, in leeward direction

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	71.8	72	72
2	$PM_{2.5}$	$\mu g/m^3$	39.9	67	
3	SO_2	$\mu g/m^3$	13.36	17	
4	NO_2	$\mu g/m^3$	18.4	23	
5	CO	mg/m^3	BDL	-	

Table -8: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: LW_2, in leeward direction

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	72.43	72	72
2	$PM_{2.5}$	$\mu g/m^3$	41.1	69	
3	SO_2	$\mu g/m^3$	12	15	
4	NO_2	$\mu g/m^3$	18	23	
5	CO	mg/m^3	BDL	-	

Table -9: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: LW_3, in leeward direction

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	73.43	73	73
2	$PM_{2.5}$	$\mu g/m^3$	36.26	60	
3	SO_2	$\mu g/m^3$	12.53	16	
4	NO_2	$\mu g/m^3$	15.76	20	
5	CO	mg/m^3	BDL	-	

Table -10: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: LW_4, in leeward direction

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	77.73	78	78
2	$PM_{2.5}$	$\mu g/m^3$	43.76	73	
3	SO_2	$\mu g/m^3$	12.36	15	
4	NO_2	$\mu g/m^3$	14.23	18	
5	CO	mg/m^3	BDL	-	

Table -11: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: CL_1, in crosswind (left of the windward) direction.

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	141.9	128	128
2	$PM_{2.5}$	$\mu g/m^3$	48.13	80	
3	SO_2	$\mu g/m^3$	13.63	17	
4	NO_2	$\mu g/m^3$	18.36	23	
5	CO	mg/m^3	BDL	-	

Table -12: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: CL_2, in crosswind (left of the windward) direction.

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	146.43	131	131
2	$PM_{2.5}$	$\mu g/m^3$	48.93	82	
3	SO_2	$\mu g/m^3$	12.66	16	
4	NO_2	$\mu g/m^3$	17.36	22	
5	CO	mg/m^3	BDL	-	

Table -13: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: CL_3, in crosswind (left of the windward) direction.

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	154.5	136	136
2	$PM_{2.5}$	$\mu g/m^3$	50.96	85	
3	SO_2	$\mu g/m^3$	11.73	15	
4	NO_2	$\mu g/m^3$	17.03	21	
5	CO	mg/m^3	BDL	-	

Table -14: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: CL_4, in crosswind (left of the windward) direction.

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	162.16	141	141
2	$PM_{2.5}$	$\mu g/m^3$	53.86	90	
3	SO_2	$\mu g/m^3$	11.73	15	
4	NO_2	$\mu g/m^3$	16.33	20	
5	CO	mg/m^3	BDL	-	

Table -15: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: CR_1, in crosswind (right of the windward) direction.

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	119.56	113	113
2	$PM_{2.5}$	$\mu g/m^3$	52.06	87	
3	SO_2	$\mu g/m^3$	14.36	18	
4	NO_2	$\mu g/m^3$	17.7	22	
5	CO	mg/m^3	BDL	-	

Table -16: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: CR_2, in crosswind (right of the windward) direction.

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	123.7	116	116
2	$PM_{2.5}$	$\mu g/m^3$	53.63	89	
3	SO_2	$\mu g/m^3$	12.6	16	
4	NO_2	$\mu g/m^3$	18.26	23	
5	CO	mg/m^3	BDL	-	

Table -17: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: CR_3, in crosswind (right of the windward) direction.

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	125.86	117	117
2	$PM_{2.5}$	$\mu g/m^3$	52	87	
3	SO_2	$\mu g/m^3$	12.2	15	
4	NO_2	$\mu g/m^3$	19.83	25	
5	CO	mg/m^3	BDL	-	

Table -18: Observed Pollutant Concentrations and AQI Values
At Sampling Station Name: CR_4, in crosswind (right of the windward) direction.

S. No	Pollutants	Units	Average Ground level Concentration	Sub-Index Considering all parameters	AQI
1	PM_{10}	$\mu g/m^3$	91.06	91	91
2	$PM_{2.5}$	$\mu g/m^3$	38.90	65	
3	SO_2	$\mu g/m^3$	12.2	15	
4	NO_2	$\mu g/m^3$	19.13	24	
5	CO	mg/m^3	BDL	-	

It can be concluded from the observations and calculated values of AQI in cross wind (right of the windward) varies from 113 to 91 and in cross wind (left of the windward) varies from 128 to 141. Similarly calculated values of AQI in leeward direction varies from 72 to 78 and AQI in windward direction varies from 191 to 146. The difference in AQI between values of windward direction and leeward direction is significant and this indicates that the increase in AQI value in windward direction is because of emissions from thermal power plant and governing pollutant was PM_{10} at all the sampling stations. Air quality in the leeward direction falls in the category of satisfactory but in the wind ward direction falls in the category of moderate polluted and is in the verge of poor category. In crosswind (right of the windward) direction, the concentration of both PM_{10} and $PM_{2.5}$ are little high as compared to the leeward direction mainly due to the presence of sand dunes in the surrounding area. The gaseous pollutants i.e., SO_2 and NO_2 are in the good category whereas CO concentration is below detection limit at all the stations due to the absence of vehicular movement. So, It can also be concluded that in almost all direction AQI is decreasing with the increase of sampling distance from centre of stacks.

IV. CONCLUSION

Study of above area reveals that maximum AQI was observed in windward direction. Primary pollutant responsible observed to be is PM_{10}. The main factors that contribute to high concentrations of PM_{10} in this area are: maximum dispersion of stacks plume occurs in this area, presence of lignite yard, presence of lignite belt that transports crushed coal from lignite mines to the plant, and the coal handling activities in the lignite yard occurs in the open atmosphere without any cover mechanism. It is clear from the observations that the AQI values are in the decreasing order for the starting three stations, this is mainly due to the coarse dust that spread from the lignite yard and belt which was high in weight and hence travels less distance before the settlement on the ground as compared to the stack's plume. Air quality of this area belongs to moderate air quality as all the AQI values are laying among 100 to 200. In the leeward direction, pollutant dispersion occurred in this area is less as compared to the windward direction. The concentrations of PM_{10} and $PM_{2.5}$ pollutants are nearly constant at all the four stations and it was found mainly due to the presence of sand storms and other natural activities. The ambient air was clean as compared to the windward direction i.e., it belongs to satisfactory category as AQI value varying from 51 to 100. In crosswind (left of the windward) direction, it is clear that the sub index values for both PM_{10} and $PM_{2.5}$ are in the increasing order. This is merely due to the presence of mines area in this monitoring zone. The concentration of SO_2 and NO_2 are low, as there is absence of any vehicular movement while the concentration of CO is below detection limit (BDL). It can be said that air quality around thermal power plant cannot be said to be good as its air quality is lying in moderate category. If effective measures are not taken to control these emissions then, air quality may also be turned to be poor also.

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