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A Comparative Study on Seasonal Variations of Air Quality Index (AQI) in Sanathnagar area of Hyderabad City, India

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Abstract*: A comparative study on air quality indices using three different formulae was aimed at in the present work. The raw data were collected from CPCB and AQI was computed, displayed along with possible health effects in the tables. The result showed that AQI-CPCB method is more applicable to the air urban pollution scenario. The Primary pollutants were PM, SO_2, NO, O_3 and CO. Data was divided by season-wise, which showed that pollution was maximum in winter, and followed by monsoon, pre-monsoon and minimum in the summer season.*

Key words: Air pollution, Air quality Index, Sub- indices, Pollution index, PM, Hyderabad.

1. INTRODUCTION

The Air pollution (Particulate matter) level rapidly increased in India over the last decade. The most polluted city in the world is New Delhi, located in Northern India. In 2015, 1.09 million deaths related to ambient air pollution were recorded in India. The statistics of deaths were given by the Lancet Commission [4] on pollution and health, making major Indian cities as the most polluted in the world.

In Southern India, Hyderabad is one of the prominent cities which has seen rapid urbanization leading to an increase in the levels of ambient air pollution over the last decade. One of the major sources of ambient air pollution has been identified as Vehicular emissions, releasing pollutants such as Hydrocarbons, Lead, Benzene, Carbon-monoxide, Sulphur dioxide, Nitrogen dioxide and Particulate matter of which PM contributed to the majority of air pollution in Hyderabad city, capital of Telangana Sate [1].

1.1Literature Review:

Air quality index: AQI is used as a communication tool to inform the public about the level of ambient air quality in an area, and possible health risks from the exposure of hazardous air pollutants. The complex air quality data on various pollutants are converted and displayed as a single number, and colour. Several equations have been developed to calculate the AQI.

1.2 Continuous Ambient Air quality monitoring systems (CAAQMS):

CAAQMS is an automated air quality monitoring system which records data by hourly, monthly, and yearly. The parameters such as gases and volatile organic compounds quality is displayed directly by the monitoring system in a real time format. For computation of AQI at least three major pollutants are required, in which the Particulate Matter (PM) is a mandatory input.

2. METHODOLOGY:

Study area and Data: Data on the ambient air for particulate matter and gaseous pollutants in the time period of 2007-2017 was collected from Sanathnagar control board station (Telagana State pollution control board) established in 2005. The study station is located in the center of Hyderabad city and equipped with CAAQM system, which has a 24 hour recorded data in all the seasons, throughout the year.

2.1*Calculation of AQI:* AQI was calculated by three different methods and a comparison was made between them. The following text presents the classification of AQI by a) CPCB method, b) PI method and c) Tiwari and Ali method and the calculation of AQI for the study area as cited above. A comparative study of the results from these three methods is also presented here under.

Method I: CPCB method

Central pollution control board (CPCB), India monitors the ambient air continuously and has been using EPA-US method to calculate the Air quality indices (AQI) [10] [26]. Formation of Sub-indices for each individual pollutant and then the aggregation of break point values (sub-indices), which depend upon the Indian National Ambient air quality standards (NAAQS) are the two steps involved in AQI calculating. The Maximum value of the sub-indices is taken as the AQI. The AQI is displayed in number form and the color code is given to it which also describes the Quality rating (potential health effects) as shown in Table-1. It is calculated as

$$I_p = \left[\left\{\frac{(I_{HI}-I_{LO})}{(B_{HI}-B_{LO})}\right\}\times(C_p-B_{LO})\right]+I_{LO}$$

Where *Ip*= Sub Index for a given pollutant concentration

BHI = Break point concentration greater or equal to given concentration (CP)

BLO= Break point concentration smaller or equal to given concentration (CP)

IHI = AQI value corresponding to BHI

ILO = AQI value corresponding to BLO; subtract one from ILO, if ILO is greater than 50

CP = Pollutant concentration

AQI = Max (Ip) (where p = 1, 2…n; whereas 'n' denotes no. of pollutants)

Table-1: National Air Quality Index, CPCB, October 2014) (Units: µg/m3) [14]

AQI	Remark	Colour Code	Quality rating
0-50	Good	Dark Green	Minimal impact
51-100	Satisfactory	Light Green	Minor breathing discomfort to sensitive people
101-200	Moderate	Yellow	Breathing discomfort to the people with lungs, asthma and heart diseases
201-300	Poor	Light Orange	Breathing discomfort to most people on prolonged exposure
301-400	Very Poor	Dark Orange	Respiratory illness on prolonged exposure
401-500	Severe	Red	Affects healthy people and seriously impacts those with existing diseases

Method II: PI method

Pollution Index was first used by Cannistraro, et al, [15] in 2009 for computing and reporting the AQI of Naples city in Italy. It indicates air quality, with a numeric index stating the potential health effects. Calculation is based on weighted mean values of the sub-indices of most critical pollutants. PI is calculated by arithmetic average of sub-indices of two most critical pollutants. This is given by an equation:

$$I = \frac{(I_1 + I_2)}{2}$$

Where I = Pollution index, I_1 & I_2 = Sub-indices calculated for two most critical pollutants having the highes concentrations.

And the Sub-Indices are calculated by the following equation:

$$I_x = \frac{V_{max\ hx}}{V_{rif}} * 100$$

Where, I_X = sub-index of critical pollutant

$V_{max\ hx}$ = the maximum 1 hour mean value of the critical pollutant in a day in all the monitoring stations of the area.

V_{rif} = maximum 1-hour limit value of the critical pollutant for protection of human health.

Table-2: Values, Index and Health Risks for Pollution Index method [4].

Numeric value	Numeric index	Quality Rating
0-50	1	Health risks
51-75	2	No risks for people
76-100	3	No risks for people
101-125	4	No risks for people
126-150	5	Generally, there aren't risks for people. People with asthma, chronic bronchitis, cardiopathy, may feel light respiratory symptoms only during an intense physical activity
151-175	6	There risks for people with heart diseases, olds and children
>175	7	Many people may feel light adverse symptoms, however reversible. Weak people may feel gravest symptoms

Method III:

This AQI formula was first used by Tiwari and Ali I in 1987 [18], later on popularized by Rao and Rao in 1989 [19] and AQI is devised by Mundri in 1990 [20]. This Formula was used by CPCB until 2009 to calculate the AQI. The AQI is calculated by using as Arithmetic expression as:

AQI = ¼ [$\sum^n (C_i / C_{si})$] ⍰ 100

Where C_i/C_s = q; and q = air quality rating of any individual pollutant, C_i= Observed value of the parameter, C_s= Standard value of recommended parameter, n = number of parameters considered.

Based on the above AQI is calculated as follows:

$$AQI = ⍰ \left[\frac{IPM}{SPM} + \frac{ISO_2}{SSO_2} + \frac{INO}{SNO} + \frac{IO_3}{IO_3}\right] \times 100$$

I = Observed value, S = Standard value given by CPCB, PM_{10} or $PM_{2.5}$ can be used as major pollutants to calculate the AQI. The Air quality categories with respect to the Air quality index values as given in Table-5.

Table-3*:* Air Quality categories based on Air quality index, Tiwari and Ali [19].

Index values	Quality Category
Below 10	Very clean
10-25	Clean air
26-50	Fairly clean
51-75	Moderately polluted
76-100	Polluted
>100	Heavily polluted

3. RESULTS AND DISCUSSION:

Variation in Ambient Air quality: Data acquired from CPCB was used for computation of AQI. The raw data composed of missing values were modified by using IBM SPSS 26 software. After the complete data was acquired (in 24-hour format), AQI was computed season-wise by using the above three mentioned methods, illustrated above and a comparison was made between them. As the comparison is between seasons, the average value of observed value in a month was taken into account.

3.1Air quality index by method I:

Table-4: AQI values by CPCB method in Sanathnagar Area, Hyderabad.

Seasonal Variation of AQI (cpcb method) values at Sanathnagar (Hyderabad) w.r.t Gasesous paramters of the Ambient air quality for period 2007-2017									
S.NO	Year	Summer		Pre-Monsoon		Monsoon		Winter	
		AQI	Quality Rating	AQI	Quality Rating	AQI	Quality Rating	AQI	Quality Rating
1	2007	42	Good	101	Moderate	126	Moderate	118	Moderate
2	2008	59	Satisfacotry	105	Moderate	150	Moderate	127	Moderate
3	2009	59	Satisfacotry	113	Moderate	113	Moderate	145	Moderate
4	2010	39	Good	94	Satisfactory	131	Moderate	101	Moderate
5	2011	75	Satisfacotry	134	Moderate	102	Moderate	120	Moderate
6	2012	54	Satisfacotry	122	Moderate	133	Moderate	150	Moderate
7	2015	54	Satisfacotry	86	Satisfactory	153	Moderate	141	Moderate
8	2016	35	Good	85	Satisfactory	134	Moderate	137	Moderate
9	2017	43	Satisfacotry	90	Satisfactory	154	Moderate	203	Poor

Seasonal variations in AQI by CPCB method (Table- 4) state that AQI for the winter season (2007-17) ranged from 118 to 203, and worsened from moderate to poor, causing adverse health effects such as breathing discomfort to most people on prolonged exposure. In pre-monsoon, index ranged from moderate to satisfactory. The monsoon season had a quality rating of moderate throughout the study period and an increase in AQI. Summer monsoon has shown as AQI range of 42-75 and quality rating from good to satisfactory.

3.2 Air quality index method II:

The results using Pollution Index (PI) method of the period 2007-2012 (Table-5) gives us a brief idea that AQI was more in winter season and quality rating ranged from 81 to 137 and the rating varied from moderate to mediocre with numeric index varying from 3 to 5, whereas pre-monsoon and summer had AQI of 111-175, and respectively 28-53 with quality rating as Good-mediocre, Optimum - good with a numeric index varying from between 3-5.

Table-5: AQI values by Pollution Index (PI) method in Sanathnagar, Hyderabad.

Seasonal Variation of AQI (Pollution Index method) values at Sanathnagar (Hyderabad) w.r.t Gasesous paramters of the Ambient air quality for period 2007-2017													
S.NO	Year	Summer			Pre-Monsoon			Monsoon			Winter		
		AQI	Quality Rating	Numeric Index	AQI	Quality Rating	Numeric Index	AQI	Quality Rating	Numeric Index	AQI	Quality Rating	Numeric Index
1	2007	39	Optimum	1	78	Good	3	113	Mediocre	4	97	Moderate	3
2	2008	48	Optimum	1	100	Moderate	2	142	Not much healthy	5	111	Mediocre	4
3	2009	43	Optimum	1	104	Mediocre	4	95	Moderate	3	137	Not much healthy	5
4	2010	35	Optimum	1	88	Moderate	2	82	Mediocre	3	91	Moderate	3
5	2011	53	Good	2	110	Mediocre	4	124	Moderate	4	118	Mediocre	4
6	2012	47	Optimum	1	111	Mediocre	4	94	Moderate	3	117	Mediocre	4
7	2015	43	Optimum	1	76	Moderate	2	79	Moderate	3	91	Moderate	3
8	2016	28	Optimum	1	74	Good	3	90	Moderate	3	89	Moderate	3
9	2017	34	Optimum	1	75	Good	3	92	Moderate	3	108	Mediocre	4

3.3 Air quality index method III:

The seasonal variation of AQI (Table-6) as calculated by Tiwari method let to following observation during study period 2007-17: In winter season AQI ranged in between 56-84, which were categorized as moderate to heavy. The AQI in pre-monsoon ranged between 50-62 and quality rating was light to moderate air pollution. Monsoon recorded a maximum AQI of 90 in 2007, 104 in 2008 with quality rating of heavy air pollution, though the rest of the years rated as moderate air pollution. Lowest AQI reading were observed during summer season with a range of 21-32, which was categorized as clean to light air pollution.

Table-6: AQI values obtained by Tiwari and Ali method for Sanathnagar, Hyderabad.

Seasonal Variation of AQI (Tiwari & Ali method) values at Sanathnagara (Hyderabad) w.r.t Gasesous paramters of the Ambient air quality for period 2007-2017									
S.NO	Year	Summer		Pre-Monsoon		Monsoon		Winter	
		AQI	Quality Rating	AQI	Quality Rating	AQI	Quality Rating	AQI	Quality Rating
1	2007	22	Clean air	55	Moderate air pollution	90	Heavy air pollution	63	Moderate air
2	2008	25	Clean air	62	Moderate air pollution	104	Heavy air pollution	67	Moderate air
3	2009	27	Light air pollution	67	Moderate air pollution	71	Moderate air pollution	77	Heavy air pollution
4	2010	21	Clean air	58	Moderate air pollution	58	Moderate air pollution	56	Moderate air
5	2011	27	Light air pollution	69	Moderate air pollution	67	Moderate air pollution	72	Heavy air pollution
6	2012	25	Clean air	58	Moderate air pollution	56	Moderate air pollution	84	Heavy air pollution
7	2015	32	Light air pollution	57	Moderate air pollution	55	Moderate air pollution	57	Moderate air
8	2016	23	Clean air	50	light air pollution	73	Moderate air pollution	57	Moderate air
9	2017	27	Light air pollution	56	Moderate air pollution	69	Moderate air pollution	76	Heavy air pollution

4. COMPARISON OF DIFFERENT AIR QUALITY INDICES:

The comparative study of AQI obtained in the three different methods is presented in the following figures. The figures 1 to 4 are in accordance with the seasonal variations i.e., winter, summer, pre-monsoon and monsoon. CPCB has defined AQI of 50 as fairly clean atmospheric conditions and it was observed that AQI calculated three methods are above this value of the entire study period in all the seasons except in summer season. The lower temperatures and the stable atmospheric conditions in the study area could be the reasons for the accumulation of pollutants and thereby yielding more AQI values.

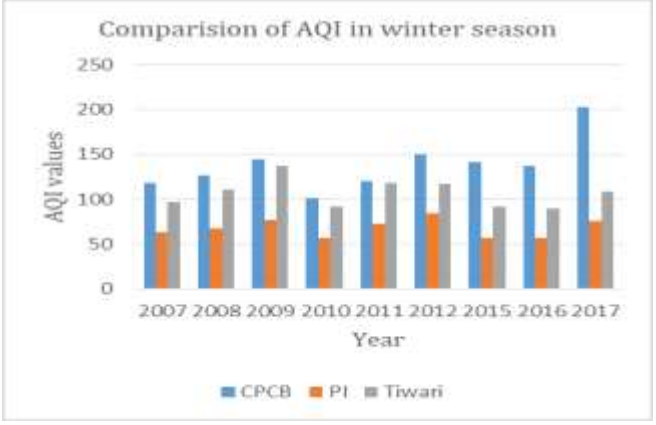

Fig-1: Comparison of AQI for winter season

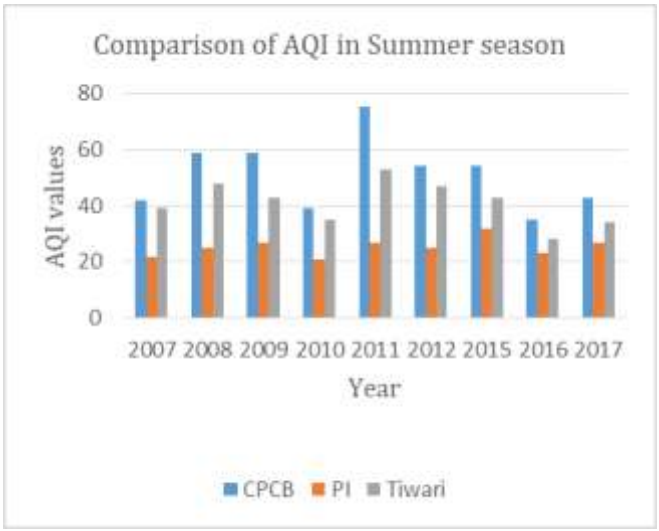

Fig- 2: Comparison of AQI for summer season.

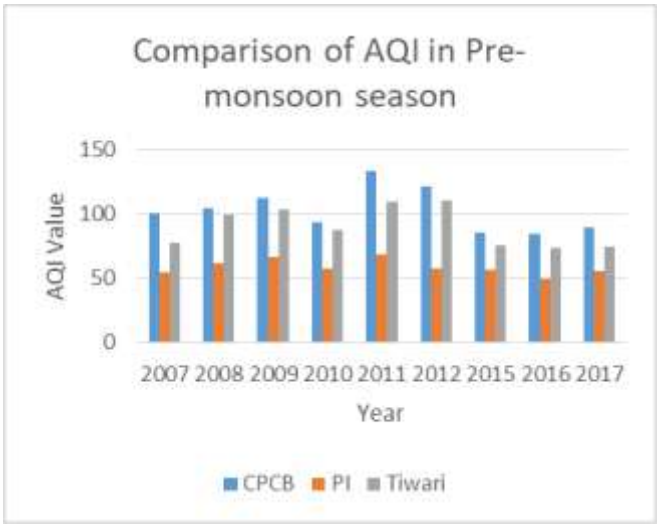

Fig-3: Comparison of AQI for Pre-monsoon season

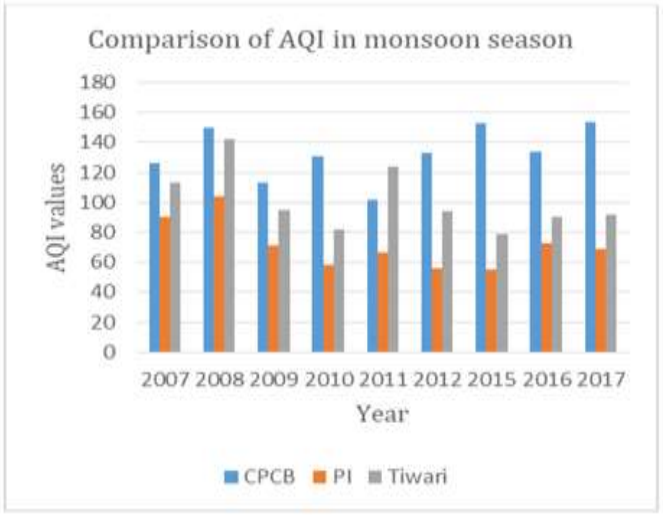

Fig-4: Comparison of AQI for monsoon season

5. REGRESSION ANALYSIS:

The regression analysis of AQI values with time obtained seasonally shows that there exists a non-linear variation. Among all the three methods in which AQI values are evaluated, the CPCB yielded better R^2 values [30] indicating more appropriateness over the other two methods.

Table-7: Regression Analysis of AQI.

Season	Index	Regression equation	R^2	Standard deviation	Coefficient of variance
Summer	CPCB	$y = -0.6529x^2 + 2626.5x - 3E+06$	R²= 0.3235	11.864	0.232
	PI	$y = -0.3982x^2 + 1601.3x - 2E+06$	R²= 0.4401	3.131	0.123
	Tiwari	$y = -0.0655x^2 + 264.12x - 266079$	R²= 0.2032	7.415	0.180
Post-monsoon	CPCB	$y = 0.7794x^2 - 3134.4x + 3E+06$	R²= 0.3704	16.816	0.127
	PI	$y = 0.4412x^2 - 1778.6x + 2E+06$	R²= 0.3686	15.356	0.215
	Tiwari	$y = 1.1272x^2 - 4538.5x + 5E+06$	R²= 0.4225	19.680	0.194
Monsoon	CPCB	$y = -0.9542x^2 + 3837.7x - 4E+06$	R²= 0.4999	15.958	0.154
	PI	$y = -1.092x^2 + 4392.3x - 4E+06$	R²= 0.6633	5.626	0.095
	Tiwari	$y = -0.1973x^2 + 793.92x - 798508$	R²= 0.4225	14.750	0.163
Winter	CPCB	$y = 1.0159x^2 - 4082.8x + 4E+06$	R²= 0.5402	27.166	0.197
	PI	$y = -0.4109x^2 + 1651.9x - 2E+06$	R²= 0.1641	9.592	0.142
	Tiwari	$y = -0.1973x^2 + 793.92x - 798508$	R²= 0.0363	15.174	0.142

6. CONCLUSIONS:

1. The AQI values evaluated using three different methods viz., CPCB, PI and Tiwari & Ali, for the study area are found to be in the rating of moderate to poor in all the seasons.

2. The regression analysis of AQI values has shown that the evaluation by CPCB method proves to be yielding better results when compared with others.

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