

# Assessment of Air Quality in Two Cities of Kerala based on AQI by USEPA Method and Factor Analysis

Asha J.S.<sup>1</sup>, Sindhu P.<sup>2</sup>

Post Graduate Scholar, Department of Civil Engineering, College of Engineering Trivandrum,  
Thiruvananthapuram, India.

Assistant Professor, Department of Civil Engineering, College of Engineering Trivandrum,  
Thiruvananthapuram, India

**ABSTRACT:** Air pollution is one of the major environmental problems nowadays. Air Quality Index (AQI) is a number which helps public to know the level of air quality status in an area. The Kerala state pollution control board has established the ambient air quality monitoring stations throughout the state and monitor the four criteria pollutants such as Suspended particulate matter (SPM), Respirable suspended particulate matter (RSPM), Sulphur dioxide (SO<sub>2</sub>) and Nitrogen dioxide (NO<sub>2</sub>). As per USEPA, AQI was evaluated for all the monitoring stations in Thiruvananthapuram and Ernakulam, which are the two important cities in Kerala. Factor analysis was done and principal components were extracted and new air quality index (NAQI) was calculated based on that also. The temporal variation of AQI in all the monitoring stations was also carried out.

**KEYWORDS:** AQI, USEPA method, Factor analysis, Temporal variation.

## I. INTRODUCTION

Air pollution is one of the major environmental problems all over the world, which affects human health, vegetation, materials and ecosystems as a whole. Rapid urbanization, industrialization, vehicular growth and population growth are responsible for the increase in air pollutants namely sulphur dioxide, oxides of nitrogen and suspended particulate matter in ambient air. The concentration of air pollutants depends not only on the quantities that are emitted from these sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration varies spatially and temporarily due to changes in meteorological and topographical conditions.

The general public needs information on the air pollution levels and potential health risks associated with air pollution in a simple understandable form. Air quality index (AQI) is a number used by governmental agencies to indicate how clean or polluted our air is. As per USEPA, air quality index is divided into six categories indicating increasing levels of health concerns. But it is based on the maximum operator concept and does not account for synergic effects of the pollutants. A factor analysis will help to extract principal components, which can then be used for evaluating new AQI.

## II. RELATED WORKS

Air quality index can be used to indicate the level of air quality status in an area. Biswanath et al., (2009) evaluated the Air Quality Index based on USEPA method and factor analysis<sup>[1]</sup>. Daily monthly and seasonal air quality indices were evaluated. Various seasons were ranked according to air quality index. The high value of air quality index

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

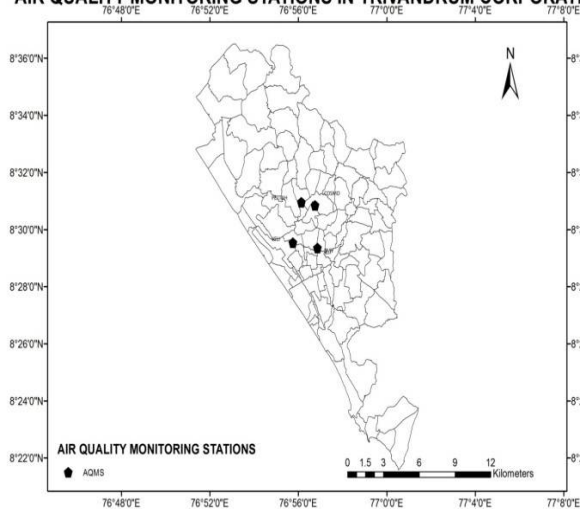
indicates more pollution in relative terms. Prakash and Jassin (2010) carried out a study on the analysis of the ambient air quality in Delhi using IND-AQI procedure<sup>[2]</sup>. Most critical pollutant was Suspended Particulate Matter. It has been observed that the calculated AQIs values of SO<sub>2</sub> and NO<sub>2</sub> fall under 'good' and 'good-to-moderate' categories. The calculated AQIs values of SPM and RSPM fall under all the four categories with varying percentages. For RSPM and SPM, the overall AQI was found to be under the category 'poor' and 'very poor' respectively. Sadhana et al., (2013) carried out a study on the assessment of ambient air quality status in Bhopal city using the air quality index<sup>[3]</sup>. The concentrations of SO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> were taken for the study. Significant positive correlation was found among all the pollutants. Gyaneswar et al., (2014) carried out a study for analysing the ambient air quality status in Cuddalore region, Tamilnadu using the air quality index<sup>[4]</sup>. The concentration of SO<sub>2</sub> and NO<sub>2</sub> levels exceed the permissible limit of National Ambient Air Quality Standards for residential area. There is a significant correlation of SPM with NO<sub>2</sub> (r = 0.53), and SO<sub>2</sub> (r = 0.46) using linear regression was also analysed. Prathipa and Sahaya, (2015) carried out a study for finding the ambient air quality in Dindigul Town, Tamil Nadu<sup>[5]</sup>. Air quality index was calculated in different areas based on USEPA method and factor analysis. The concentrations of four major criteria pollutants such SPM, RSPM, SO<sub>2</sub> and NO<sub>2</sub> have been considered for this analysis. The suspended particulate matter was mainly responsible for maximum AQI value in all three sites. Ranking of different locations were done based on AQI. The Commercial cum traffic and tannery area are found to be unhealthy and the higher ranking showed the increased pollution levels.

### III. METHODOLOGY

The pollutants concentrations for the four years in all the monitoring stations were collected from the Kerala state pollution control board. The AQI was evaluated based on the USEPA method. Factor analysis was conducted to extract principal components and the new AQI was then evaluated. The temporal variation of two AQIs was also studied.

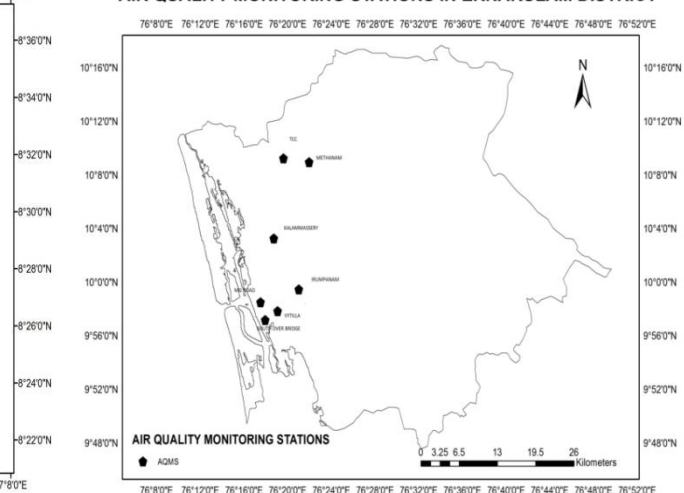
The pollutant concentration for all the monitoring stations in Thiruvananthapuram and Ernakulam for the period 2011-2014 was collected from Kerala State Pollution Control Board (KSPCB). The location of the monitoring stations is shown in fig. 1 (a) and (b).

**AIR QUALITY MONITORING STATIONS IN TRIVANDRUM CORPORATION**



(a)

**AIR QUALITY MONITORING STATIONS IN ERNAKULAM DISTRICT**



(b)

Fig.1. Air quality monitoring stations in (a) Thiruvananthapuram corporation (b) Ernakulam district.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

Various monitoring stations and the station codes provided for them are shown in the table 1 and 2.

Table 1. Air quality monitoring stations in Thiruvananthapuram

Sl. No	Station code	Station	Category
1	T1	Cosmo	Sensitive
2	T2	SMV	Sensitive
3	T3	Veli	Industrial
4	T4	Plamood	Residential

The different air quality monitoring stations in Thiruvananthapuram includes Cosmo, SMV, Veli and Plamood. Cosmo and SMV are the sensitive locations due to the presence of Hospital and school respectively.

Table 2. Air quality monitoring stations in Ernakulam

Sl No	Station code	Station	Category
1	E1	Ernakulam south	Residential
2	E2	M G Road	Residential
3	E3	Vyttila	Residential
4	E4	Irumpanam	Industrial
5	E5	Kalamassery	Industrial
6	E6	Eloor 1	Residential
7	E7	Eloor 2	Industrial

Only two type of categories such as residential and industrial air quality monitoring stations are in the Ernakulam district. The air pollutants considered include Sulphur dioxide, Nitrogen dioxide, Suspended particulate matter and Respirable suspended particulate matter for the last four years. The air quality index by USEPA method involves the calculation of subindex for each pollutant followed by selecting maximum value as AQI. The sub index can be evaluated using the Equation 1<sup>[1]</sup>.

$$I_p = \frac{(I_{Hi} - I_{LO})}{(BP_{Hi} - BP_{LO})} (C_p - BP_{LO}) + I_{LO}$$

Where,

- $I_p$  - Index value for pollutant P
- $C_p$  -Actual ambient concentration of pollutant P
- $BP_{Hi}$  -The upper end break point concentration greater than or equal to  $C_p$
- $BP_{LO}$  -The lower end breakpoint concentration less than or equal to  $C_p$
- $I_{Hi}$  -The AQI value corresponding to  $BP_{Hi}$

Table 3 shows the sub index and break point pollutant concentration for AQI by USEPA<sup>[6]</sup>.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

Table 3. Sub Index and Break Point Pollutant Concentration for AQI  
(Source: Guidelines for the reporting of daily air quality-the Air quality index)

<i>Sub-Index</i>	<i>Category</i>	<i>Pollutants (µg/m<sup>3</sup>)</i>			
		<b>SO<sub>2</sub></b>	<b>NO<sub>x</sub></b>	<b>SPM</b>	<b>RSPM</b>
		24-h <sub>avg</sub>	24-h <sub>avg</sub>	24-h <sub>avg</sub>	24-h <sub>avg</sub>
0-100	Good	0-80	0-80	0-200	0-100
101-200	Moderate	81-367	81-180	201-260	101-150
201-300	Poor	368-786	181-564	261-400	151-350
301-400	Very poor	787-1572	565-1272	401-800	351-420
401-500	Severe	>1572	>1272	>800	>420

The maximum index value among the subindices is selected as EPAQI. AQI was categorised according to the levels of health concern. Table 3 shows the colour code for air quality index<sup>[6]</sup>. Air quality index is in the good category, there will be no health problems for the entire public. In the moderate range of air quality, the sensitive group may experience health effects. In the third group, the air quality is unhealthy for sensitive groups. In the higher groups, air quality will badly affect the health of general public and also the sensitive groups.

Table 4. Colour code for air quality index  
(Source: A guide to air quality and your health, USEPA)

<b>Air Quality Index (AQI) Values</b>	<b>Levels of Health Concern</b>	<b>Colors</b>
<i>When the AQI is in this range:</i>	<i>...air quality conditions are:</i>	<i>...as symbolized by this color:</i>
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

The factor analysis was done using SPSS software. The concentrations of SPM, RSPM, SO<sub>2</sub> and NO<sub>2</sub> were used in this study. PCA was done using the SPSS software. Using the eigen values and factor loadings obtained, the principal components were extracted. The principal components with eigen values greater than 1 was selected for the calculations. The principal component is obtained using equation 2<sup>[1]</sup>.

$$P_t = \sum_{j=1}^n \frac{a_{tj} X_j}{\lambda_t} \tag{2}$$

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

- $P_i$  is the  $i^{\text{th}}$  principal component
- $a_{ji}$  - factor loading of the  $j^{\text{th}}$  variable on the  $i^{\text{th}}$  principal component
- $\lambda_i$  is the eigen-value associated with  $P_i$
- $X_j$  is the various pollutants concentrations.

NAQI will be calculated by using the equation 3<sup>[1]</sup>.

$$NAQI = \frac{\sum_{i=1}^m (P_i E_i)}{\sum_{i=1}^m E_i} \quad (3)$$

$P_i$  is the Principal components and  $E_i$  is the Intialeigen values.

## IV. RESULTS AND DISCUSSION

The air quality index by the USEPA method and the factor analysis were calculated for all the monitoring stations in Ernakulam and Thiruvananthapuram during the four years. The results are shown in Fig. 2 and 3.



Fig. 2.EPAQI graph for Thiruvananthapuram

Good to moderate level of air quality exists in all the monitoring stations in Thiruvananthapuram for the entire study period. Except in 2014, the air quality is in the moderate level in Veli. But in 2014 the air quality is improved and it

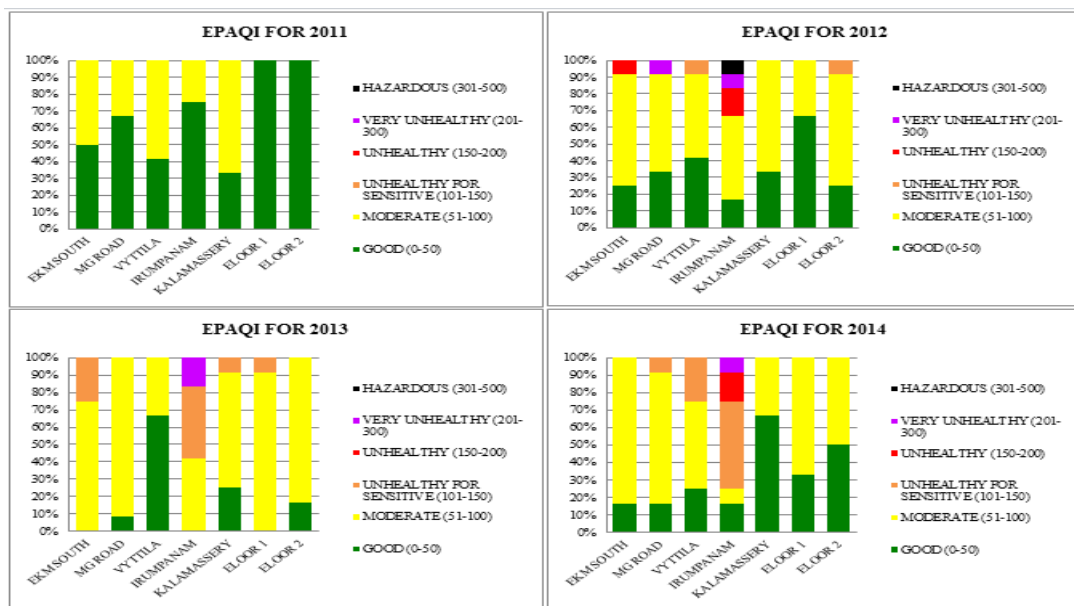
## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

became good in half of the months. From the graph it is clear that the air quality is improved in 2014 in all the monitoring stations compared to the previous years.



**Fig. 3.EPAQI graph for Ernakulam**

In Ernakulam, the highest air quality index was recorded at station Irumpanam, coming under very unhealthy category. Irumpanam is home to large petroleum companies as well as numerous small scale and cottage industries. The air quality is unhealthy for sensitive groups in the monitoring stations like M G Road and Vyttila. Good to moderate level of air quality exists in stations Eloor 1 and Eloor 2. Over the years the air quality is deteriorating in stations like Irumpanam and Vyttila.

Two principal components were extracted in nine of the air quality monitoring stations and only one principal component for the remaining two stations. A typical example of factor analysis and principal component extraction for the station Cosmo is shown in table 5 and 6.

Table 5. Eigen values in factor analysis for station T1

Component	Total Variance Explained			Extraction Sums of Squared Loadings		
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.400	60.001	60.001	2.400	60.001	60.001
2	1.146	28.643	88.644	1.146	28.643	88.644
3	.329	8.226	96.870			
4	.125	3.130	100.000			

Extraction Method: Principal Component Analysis.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

The eigen values greater than 1 were selected for the study. The eigen values less than 1 explain less variance and discarded. In the station Cosmo, the selected initial eigen values were 2.4 and 1.146. These eigen values were used for the calculation of principal components and new air quality index. In this station two principal components were extracted for calculating the new air quality index.

Table 6. Component matrix for the station T1

	Component	
	1	2
SO2	.763	-.500
NO2	.234	.936
RSPM	.956	.046
SPM	.922	.129

The above table explains the factor loading for the principal components. Using the principal components and the eigen values, New Air Quality Index was calculated. Table 7 shows a comparison of EPAQI and NAQI for the monitoring stations in Thiruvananthapuram for the year 2011.

Table 7. Two Air quality indices in Trivandrum (2011)

STATION	AQI	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
T1	EPAQI	50.55667	53.25	54.25125	51.33125	50.9575	50.70222	44.88889	52.44444	49.81444	48.03556	50.08125	49.11
	NAQI	40.97966	42.91195	43.45727	42.05798	41.72512	40.44187	39.68532	41.45712	39.99397	38.68149	40.13614	39.77656
T2	EPAQI	58.07444	52.75	50.88889	49.99889	47.03778	50.29556	49.22333	52.99889	48.03667	64.51889	60.91625	54.89
	NAQI	60.14431	57.91718	53.31183	52.84415	49.87539	53.51795	52.22549	56.06104	51.14434	61.31207	55.79296	57.8883
T3	EPAQI	69.67667	69.68	59.25	74.99875	65.3325	64.37	61.36889	63.92556	66.20875	64.66667	59.966	61.467
	NAQI	41.96404	41.96586	39.75366	44.48408	37.64648	38.55078	37.74314	39.28119	39.92594	39.40402	38.82811	38.96917
T4	EPAQI	49.58222	49.58	52.08375	49.29125	45.43875	48.07333	53.20333	51.53	48.466	48.668	49.70875	51.25889
	NAQI	43.40225	43.79837	45.48424	41.97975	40.08282	42.04058	45.4689	43.8686	41.98882	42.38197	42.91684	44.20895

Similarly the steps were followed and EPAQI and NAQI for all the monitoring stations for the study period were also evaluated. The temporal variation of EPAQI and NAQI was also plotted. A sample of the same for the stations T1 and E1 is shown in the fig. 4 and 5.

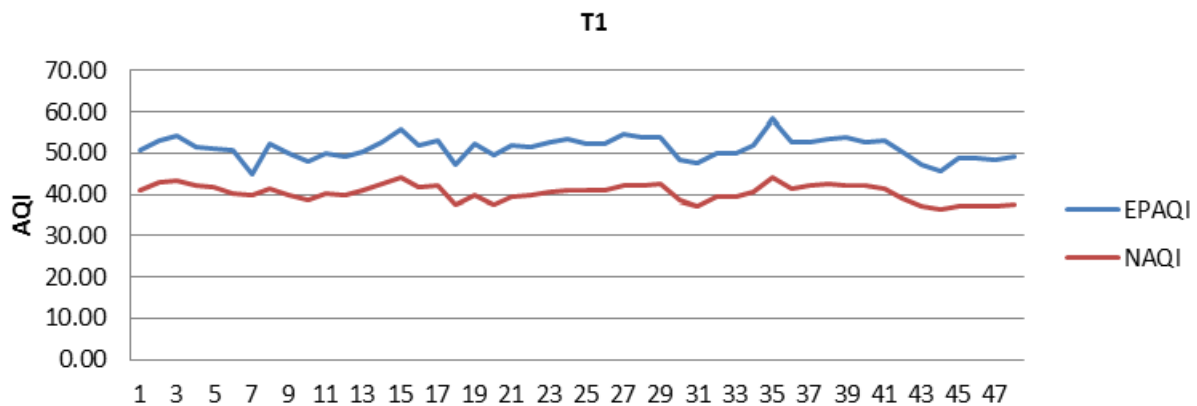


Fig.4. Monthly variation of two AQI in station T1 over the four years

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

New air quality index was found to be less than the EPAQI. A small difference exists between the new air quality index and the EPAQI. Two AQI follows the similar trends over the four years. The fig. 5 shows the variation of the NAQI and EPAQI in the station Ernakulam south.

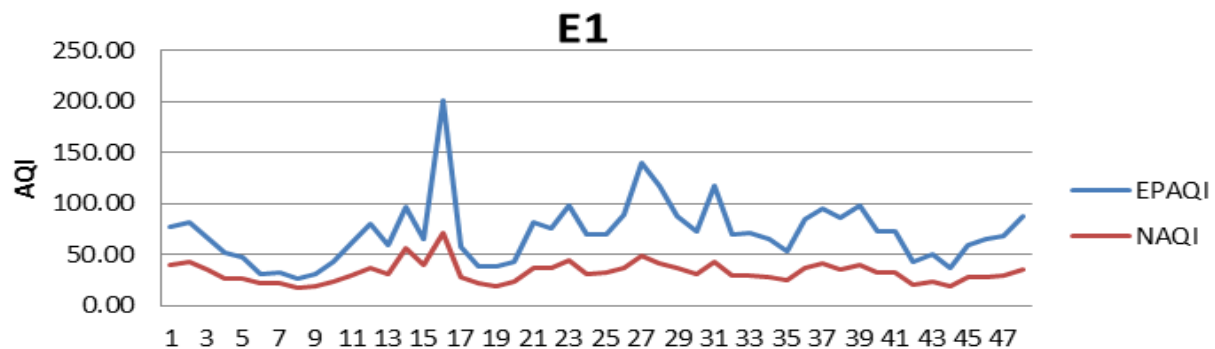


Fig.5. Monthly variation of two AQI in station E1 over the four years

The magnitude of the EPAQI is determined by the maximum value of a subindex of a given pollutant, the value of NAQI considered the variances of concentrations in different pollutants. In this study only the dominant pollutant is respirable suspended particulate matter. Thus when considering the combined effects of pollutants the new air quality index was less than the EPAQI.

## V. CONCLUSION

The air quality index is a health protection tool by reducing exposure to air pollution. AQI was lowering in Thiruvananthapuram and in most of the stations, it lies in good to moderate level of air quality. All the stations in Ernakulam, except Irumpanam and Vyttila, the air quality were not much affected. In Irumpanam the air quality changed from moderate to very unhealthy category over the years.

NAQI follows the similar trend as that of EPAQI. But NAQI was found less than EPAQI, even if it considered the synergic effects of pollutants. This may be due to the fact that, in all cases single pollutant RSPM was responsible for high AQI and all the other pollutants are much below the national ambient air quality standards.

## ACKNOWLEDGEMENT

The authors thank the Department of Civil Engineering of College of Engineering Trivandrum for providing the necessary facilities for carrying out the study. The authors are grateful to the Kerala State Pollution Control Board for providing pollutant concentration data used in the study.

## REFERENCES

- [1] Biswanath Bishoi, Amit Prakash, and Jain, V.K., "A Comparative Study of Air Quality Index Based on Factor Analysis and US-EPA Methods for an Urban Environment", *Aerosol and Air Quality Research*, Vol. 9, pp. 1-17, 2009.
- [2] Prakash, M., and Bassin, J.K., "Analysis of ambient air quality using air quality index – a case study", *International journal of advanced engineering technology*, Vol. 1, pp.106-114, 2010.
- [3] Sadhana Chaurasia, Pragya Dwivedi, Ravindra Singh, and Anand Dev Gupta, "Assessment of ambient air quality status and air quality index of Bhopal city (Madhya Pradesh), India", *International journal of current sciences*, Vol. 1, pp. 96-101, 2013.





ISSN(Online) : 2319-8753  
ISSN (Print) : 2347-6710

## International Journal of Innovative Research in Science, Engineering and Technology

*(An ISO 3297: 2007 Certified Organization)*

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

- [4] Gyaneswar, B., Anamdhan, R., and Kavitha, V., "Measurement and statistical analysis of ambient air quality status in Cuddalore region, Tamilnadu, India", Journal of Biological and scientific opinion, Vol. 2, pp. 177-180, 2014.
- [5] Prathipa, V., and Sahaya Raja, A., "Air Quality Assessment and Air Quality Index of Dindigul Town (Tamil Nadu), India– A Case Study", International Journal of PharmTech Research, Vol. 8, pp. 45-55, 2015.
- [6] EPA., Guideline for Reporting of Daily Air Quality –Air Quality Index (AQI), EPA-454/B-06-001, 2006.