Trend Analysis of PM 10 Aerosol Data in A Metropolitan City in India

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Abstract Extreme weather events are likely to have negative effects on the life of human beings on earth. There is an increase in heavy rainfall events and no rainfall at some other place. Anthropogenic aerosols play a vital role in either increasing or decreasing monsoon rainfall. [1] The purpose of this study is to investigate the trend in aerosol data using Man - Kendall test for Chennai region. The Mann-Kendall test was run at 5% significance level on time series data for the year 2007 – 2014.PM 10 was used for the study. PM 10 data for the Chennai region for the winter, pre-monsoon, monsoon and post-monsoon was analysed using Mann-Kendall Test. The PM 10 aerosol showed no trend for winter, pre-monsoon and post-monsoon but for monsoon season showed a positive trend. Time series analysis is a useful tool for better understanding, cause and effect relationship of environmental pollution. Understanding the trends of aerosols can pave the way to a better perspective of climate change.

Keywords: Aerosols, Anthropogenic Emissions, PM - Particulate Matter, Pollution, Time series, Trend Analysis

I. Introduction

Atmospheric aerosols are particles of solid or liquid phase dispersed in the atmosphere [2] Particulate matter (PM) is the term used to describe fine solid or liquid particles suspended in the atmosphere.

Among all the criteria air pollutants, particulate matter (SPM and RSPM) has emerged as the most critical pollutant in almost all urban areas of the country [3]

Chennai is a coastal city. The area of Chennai is 176 km^2. According to the 2011 census, 4.64 million is the population of Chennai region. Urbanisation and industrialisation have resulted in increased vehicular traffic in cities, increasing automobile emissions and toxic smoke emissions. Weather is typically hot and humid. There is only a small variation between the seasons. Due to the location and proximity to the Indian Ocean Max. Temp. 42° C and Min Temp: 20 C• These sources include large, medium and small-scale industries, household fuel use for cooking and heating, reuse burning, vehicular emissions, resuspended road dust. construction activities, agricultural activity, naturally occurring dust and transboundary migration from other regions, etc. Diesel vehicles are known to be significant emitters of PM 10.

The first step in time series analysis is to draw a time series plot that provides a preliminary understanding of the time behaviour of the series [4] Currently the regulatory standards, for PM10 in ambient environments in India are 100 $\mu g/m^3$ [5]

In Chennai the contribution of PM 10 is due to is mainly due to transport to dust and coal. Concerning PM 10, it was found that resuspension of unpaved and paved road dust contributed close to 68%, while vehicles contributed 12% to the pollution levels in Chennai.

II. Data and Methodology

A. Data

The data used for the time series analysis is PM 10 Aerosol data in a metropolitan city of Tamil Nadu, Chennai for the period of 2007 – 2014. Tamil Nadu Pollution Control Board is operating eight ambient air quality monitoring stations in Chennai under the National Air Quality Monitoring Programme (NAMP) funded by the Central Pollution Control Board. The samples collected from NAMP stations are analysed for the Respirable Suspended Particulate Matter (RSPM) (RSPM is particulate matter less than 10 microns). The data for the study is taken from the Tamil Nadu Pollution Control Board, https://tnpcb.gov.in/air-quality.php.The analysis was carried out using XLSTAT software.

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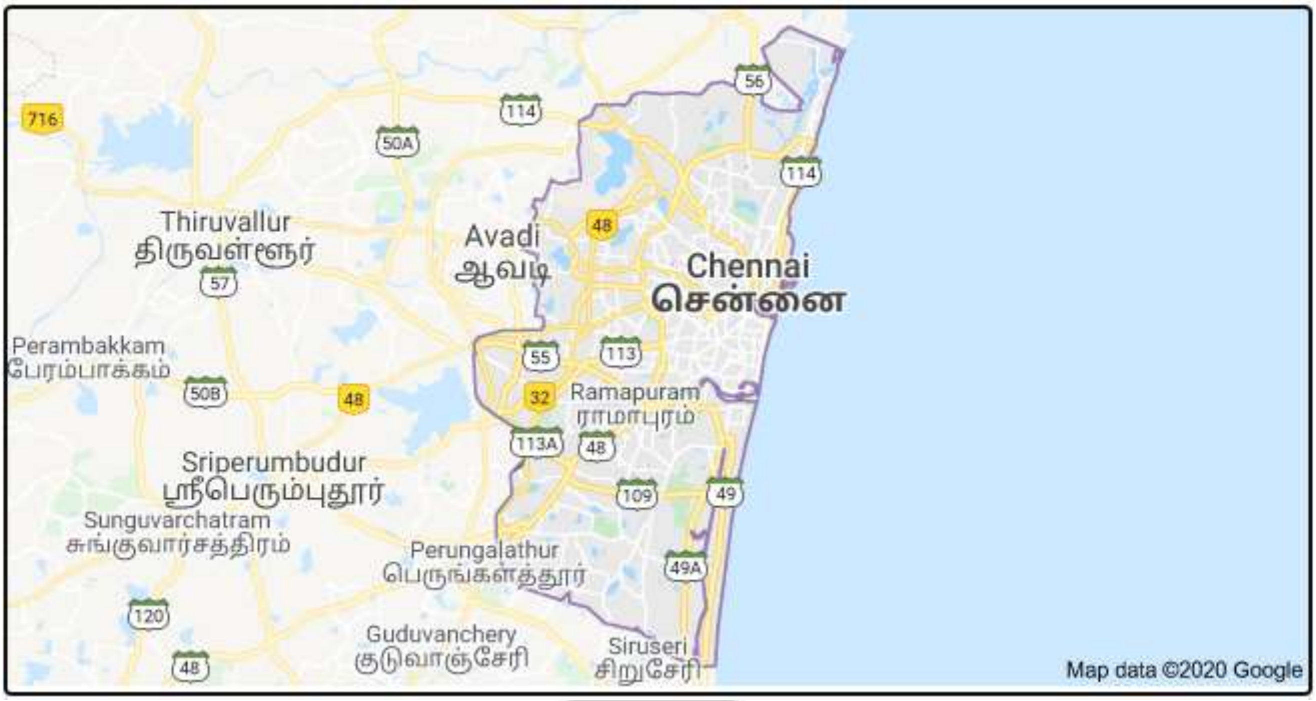

Figure1: A Geographical Map of Chennai [11]

B. *Methodology*

The nonparametric test can be employed to study the trend [6]. The Mann-Kendall statistical test is used to assess whether a set of data values is increasing or decreasing over time and whether the trend in either direction is statistically significant. The Mann-Kendall test does not however assess the magnitude of change. This test is ideal to determine the trend as it can be performed even when there are missing values in the set.

The MK test verifies the null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend. The statistics (*S*) is defined as [7]

The procedure for the Mann Kendall test considered is that the time series of n data points and Xi and Xj as two subsets of data where i = 1,2,3,…, n-1 and j = i+1, i+2, i+3, …, n. The data values are estimated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a succeeding period is higher than a data value from an earlier period, the statistic S is incremented by 1. On the other hand, if the data value from a succeeding period is lower than a data value sampled earlier, S is decremented by 1. The outcome of all such increments and decrements yields the conclusive value of S [8]

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \text{sign}\,(x_j - x_i)$$

Where *N* is the number of data points. Assuming $(x_j - x_i) = \theta$, the value of sign (θ) is estimated as

$$sign(\theta) = \begin{cases} 1 \; if \; \theta > 0 \\ 0 \; if \; \theta = 0 \\ -1 \; if \; \theta < 0 \end{cases}$$

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (*N* > 10), the test is conducted using a normal distribution15, with the mean and the variance as follows: E[S] =0

$$Var(S) = \frac{N(N-1)(2N+5) - \sum_{xi}(i)(i-1)(2i+5)}{18}$$

Where *N* is the number of tied (zero difference between compared values) groups and x_i the number of data points in the *k*th tied group. The standard normal deviate (*Z*-statistics) is then estimated as [9]

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \; for \; S > 0 \\ 0 \quad for \; S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} \; for \; S < 0 \end{cases}$$

If the computed value of $|Z| > Z_{\alpha/2}$, the null hypothesis (*H*0) is rejected at α level of significance in a two-sided test. The null hypothesis is tested at 95% confidence level for PM 10 data for Chennai. The Statistical results are given in Table 1. On

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running the Mann-Kendall test PM 10 Aerosol for Chennai Region for the year 2007 to 2014, the following results were obtained. If the p-value is less than the significance level α (alpha) = 0.05, H0 is rejected. Rejecting H0 symbolises that there is a trend in the time series while accepting H0 symbolises no trend was detected.

Table 1. Summary Statistics

Season	Observations	Obs.with missing data	Obs.without missing data	Maximum	Mean	Std. deviation
Winter	50	1	49	217.9400	22.8853	45.9007
Pre-monsoon	75	0	75	251.4400	30.5568	54.5028
Monsoon	101	2	99	498.3500	115.4149	77.2318
Post-monsoon	76	0	76	815.5900	258.3941	186.2619

Table 2. Mann-Kendall trend test / Two-tailed test

Season	P-value	Alpha value	Var(S)	Test Interpretation
Winter	0.9652	0.05	-6.0000	Accepts H0
Pre-monsoon	0.5261	0.05	-138.0000	Accepts H0
Monsoon	0.0473	0.05	657.0000	Rejects H0
Post-monsoon	0.6150	0.05	-165.0000	Accepts H0

Table 3. Seasonal Mann-Kendall Test Results

Season	Kendall's tau	S	Var(S)	Sen's slope
Winter	-0.0053	-6.0000	13119.3333	-
Pre-monsoon	-0.0518	-138.0000	46690.0000	-
Monsoon	0.1355	657.0000	109413.0000	0.5252
Post-monsoon	-0.0579	-165.0000	106328.2620	-0.7149

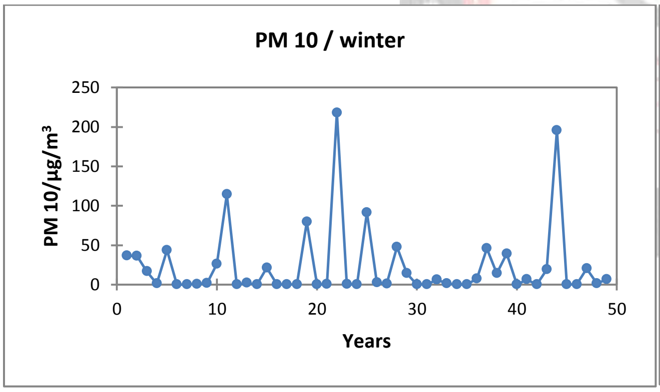

Figure 2: Plot of variation in PM 10 during Winter

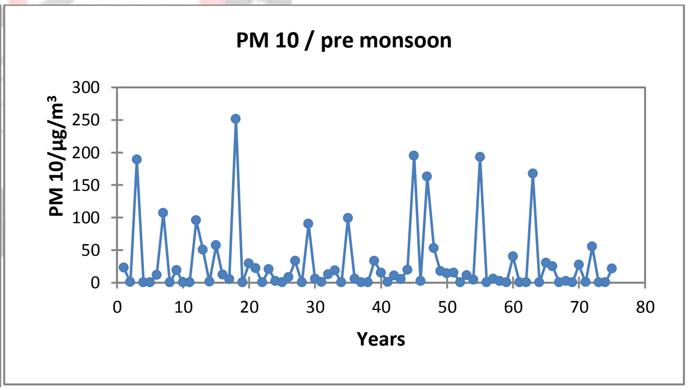

Figure 3: Plot of variation in PM 10 during Pre-Monsoon

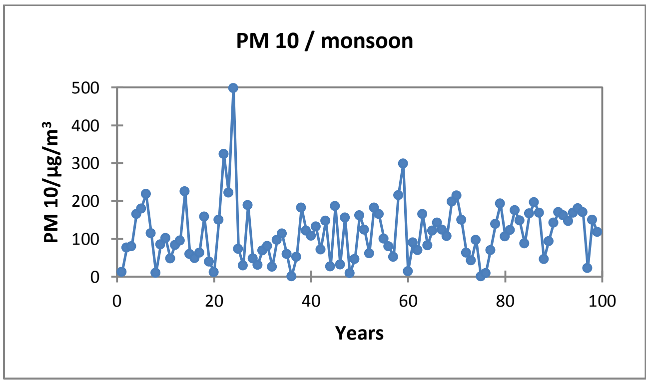

Figure 4: Plot of variation in PM 10 during Monsoon

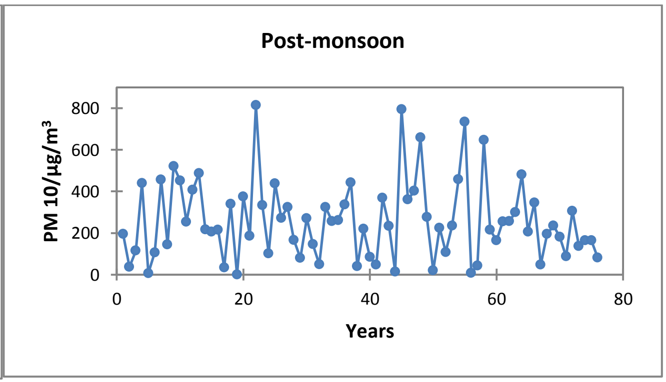

Figure 5: Plot of variation in PM 10 during Post-Monsoon

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On rejecting the null hypothesis, the result is said to be statistically notable. Table 1 indicates statistical results whereas Table 2 and 3 gives the Mann-Kendall trend test / Two-tailed test. From the observation, it is clear that there is the trend in PM 10 for the Monsoon season for Chennai, whereas there is no trend seen in the PM 10 time series for the Winter, Pre-monsoon and Post-monsoon seasons of Chennai. The positive value for Sens slope also indicates a positive trend in PM10 for monsoon season in Chennai. Aerosols play a significant role in cloud microphysics. A better insight in PM10 can make a significant breakthrough in rainfall study.

Though post-monsoon season accepts the null hypothesis and it is true for 61.78%, the Sen's slope indicates a negative trend which means the PM 10 is decreasing possible due to rain. A better understanding is required further. The lack of uniformity in data can influence the quality of recorded data. A better result can be obtained may be by increasing more data points considerably carrying it for more number of years. A study on the trend condition of rainfall in Chennai districts showed that drought intensity has decreased in the central region compared with the past during 1980 till 2010[10]. The cause needs to be investigated at a significant level.

III. Conclusion

An attempt was made in this study to investigate the persistence behaviour and trend in the aerosol time series of Chennai. .Mann Kendall trend test was used .for this purpose. Mann Kendall trend analysis of PM10 showed no trend for winter figure 2, pre-monsoon figure 3 and post-monsoon figure 5 and an increasing trend for the monsoon period figure 4. The Mann-Kendall test (MK) gives an interesting insight into the trend in PM 10 data during the monsoon season of Chennai region. The above result is of immense importance.

This analysis can be increased further by analysing the data until 2020. The rainfall of Chennai has been high in 2015 to no rain in 2016, 2017, 2018. This research may help to comprehend further if there is any relation between PM10 data and rainfall by progressing with the Spearman's correlation. Hence the trend in monsoon data of PM10 helps to go one step ahead in time series analysis of the PM10 data of Chennai region.

It is crucial to understand here that these empirical evaluations should be analyzed from a global perspective and no conclusions should be drawn for the local level. In other words, the trend should be analysed for various regions and for more data points, which would help in understanding the rainfall patterns in the urban region as there is a change in the pattern of rainfall in the urban region. The study, therefore, offers remarkable insights and a new perspective for policymakers and planners in helping them take proactive measures in the context of climate change. Chennai is located in the southern part of India and has an important role in the socio-economic development of India which is one of the metropolitan city of the country. This region is prone to drought phenomenon. In the other words, this region can be confronted by water supply stress. Thus for better management, But of late extreme rainfall events are also a matter of serious concern and hence programming, suitable studies related to rainfall and PM 10 are necessary for this region. These results can be used for local and regional programmings of water resources sections and help governors for selecting optimum strategies related to water management. The goal of the study is determining the trend of PM 10 could help in opening the understanding of the rainfall pattern of Chennai.

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