

Distribution of PM₁₀ in Ambient Air in Two Cities of Kerala

Neethu P. S.¹, Sindhu P.²

Post Graduate Scholar, Department of Civil Engineering, College of Engineering Trivandrum,
Thiruvananthapuram, India¹

Assistant Professor, Department of Civil Engineering, College of Engineering Trivandrum,
Thiruvananthapuram, India²

ABSTRACT: Particulate matter concentration in the atmosphere has a significant effect on human health and climate change. In addition to health impacts particulate matter bring about changes in rainfall pattern, temperature levels etc. This paper investigates the annual trend of PM₁₀ concentration in Thiruvananthapuram and Ernakulam, one the city capital and the other one said to be the industrial capital of Kerala state, India for the period 2010 to 2015. The Exceedance Factor (EF) levels of PM₁₀ did not show much variation in Thiruvananthapuram and remained in the moderate range in all regions except in the industrial area. The EF values of Ernakulam showed high variation for different environmental backdrops.

KEYWORDS: Exceedance factor, NAAQS, PM₁₀.

I. INTRODUCTION

Air pollution is a major cause for deterioration of air quality in an urban atmosphere, which in turn affects environment and human health. Also, it is the major inducing factor of atmospheric climate change. PM₁₀ is that fraction of particulate matter in the atmosphere with an aerodynamic diameter less than 10 μm . It can be a suspension of solid, liquid or a combination of solid and liquid particles in the air. Sustained exposure to PM₁₀ has long been associated with effects on the respiratory system, damage to lung tissue, cancer, and premature death^[1]. There are also adverse impacts on crops, especially on small and short life cycle plants such as vegetables. PM₁₀ also leads to climate change by absorbing or reflecting solar radiation. The air quality in an area is largely controlled by the concentration and composition of fine particles. The main anthropogenic sources of PM₁₀ are vehicular emissions and from industries. The concentration of these particles may vary temporally and spatially depending on the nature of particles itself, atmospheric conditions and topography of the area. Also, air pollutant concentrations exhibit diurnal, seasonal and annual variations due to changes in meteorological parameters.

Air quality in Kerala is adversely affected by the increased usage of fossil fuels in the transportation and industrial sectors^[2]. Unplanned urban growth along with an exponential increase in vehicles has an adverse impact on the ambient air quality in Thiruvananthapuram and Ernakulam districts. In addition to these, presence of large number of industries contributes a major share in deterioration of air quality in Ernakulam. Impact of vehicular pollution is widespread in while that of the industries are localized to the areas around it. The Kerala State Pollution Control Board has set up ambient air quality monitoring stations in different environmental backdrops in each district in order to monitor air quality in these areas. Respirable Suspended Particulate Matter (RSPM or PM₁₀), Sulphur dioxide (SO₂) and Oxides of Nitrogen (NO_x) are monitored from stations located in industrial, residential and sensitive areas. In almost all stations, SO₂ and NO_x levels are observed to be within the National Ambient Air Quality Standards (NAAQS). The concentration of PM₁₀ in Thiruvananthapuram and Ernakulam was observed to vary, even exceeding NAAQS during certain times of the year.

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The main objective of the study was to determine the variation of PM_{10} concentration in Thiruvananthapuram and Ernakulam within a time period of 2010-2015. The study area was also categorised based on the exceedance factor of PM_{10} .

II. RELATED WORK

Ambient aerosols with mass median aerodynamic diameter less than $10\mu m$ are of concern owing to their effect on human health and climate change. Several studies have been carried out all over the world to study the distribution of PM_{10} in ambient air. But in Kerala such studies were less reported and the few studies reported concentrated on the adverse health effect of PM_{10} and did not include any study on its relation with climate change. Sivaramasundaram and Muthusubramanian (2010) made an assessment of PM_{10} and total suspended particulate matter (TSP) concentrations in ambient air of Tuticorin^[1]. Statistical analysis was carried out to determine the frequency distribution and to analyse seasonal variability of both pollutants. The seasonal PM_{10} and TSP concentrations showed a well-defined variation and were relatively lower in post-monsoon and higher in summer. Tiwari et al. (2012) studied the temporal variation of PM_{10} in Delhi and was observed to be maximum during winter and minimum during monsoon seasons^[3]. Entrapment of pollutants in lower layers of atmosphere during winter caused greater exposure risks. A correlation study with meteorological parameters showed negative correlations with temperature, wind speed and rainfall supporting the seasonal variation pattern. Wang et al. (2013) studied the variation characteristics of PM_{10} in Xingtai, China during 2009-2012^[4]. The annual variation showed a weak downward trend whereas the seasonal variation was much significant with a higher level in winter and fall and a lower level in spring and summer. Correlation of PM_{10} with meteorological factors were also determined and was observed to be different during various seasons. Leni et al. (2015) conducted a study on the ambient air quality of Ernakulam by measuring five pollutant parameters^[2]. The Air Pollution Index obtained was in the light to moderate category. Prathipa et al. (2015) made an assessment of air quality in Dindigul based on exceedance factor, Indian AQI and a newly developed AQI based on factor analysis^[5]. The exceedance factor values obtained was always less than 0.5 during both summer and winter indicating low pollution level in the area.

III. METHODOLOGY

The study of temporal variation of PM_{10} in the study area required air quality monitoring daily data which was collected from the National Ambient Air Quality Stations at Thiruvananthapuram and Ernakulam over a period of six years from 2010 to 2015. The details of monitoring stations are shown in Table 1.

Table 1. Details of Monitoring Stations

District	Station Name	Category	Latitude	Longitude
Thiruvananthapuram	Veli	Industrial	8°29'52.9"N	76°55'7.64"E
	SMV	Sensitive	8°36'29.9"N	76°56'7.59"E
	COSMO	Sensitive	8°31'000"N	76°56'15.9"E
	Plamood	Residential	8°29'6.51"N	76°55'7.61"E
Ernakulam	Ernakulam South	Residential	9°57'09" N	76°17'57" E
	M.G. Road	Residential	9°58'29" N	76°17'31" E
	Vytilla	Residential	9°57'49" N	76°19'05" E
	Irumpanam	Industrial	9°59'26" N	76°21'01" E
	Kalamassery	Industrial	10°03'14" N	76°18'44" E
	Eloor I	Residential	10°04'29.6"N	76°18'23.8"E
	Eloor II	Industrial	10°04'31.3"N	76°18'09.7"E

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Annual variation of PM₁₀ in the residential, industrial and sensitive areas of Thiruvananthapuram and Ernakulam was studied and graphs were plotted. The amount by which PM₁₀ exceeded the annual NAAQS was determined using Exceedance Factor. It was calculated using the equation given below ^[5,6].

$$\text{Exceedance Factor} = \frac{\text{Observed annual mean concentration of criteria pollutant}}{\text{Annual standard for the respective pollutant and area class}} \quad (1)$$

The PM₁₀ concentration for the monitoring stations were compared with the National Ambient Air Quality Standards and was categorised into different air quality categories based on the Exceedance Factor (EF) as shown in Table 2.

Table 2. Air Quality Categories Based on Exceedance Factor

Category	EF
Critical Pollution (C)	>1.5
High Pollution (H)	1.0-1.5
Moderate Pollution (M)	0.5-1.0
Low Pollution (L)	<0.5

From the above categorization it is clear that the locations in either of the first two categories are actually not meeting the standards. The locations falling in the third category are meeting the standards as of now but are likely to exceed the standards in future if pollution continues to increase and is not controlled. However, the locations in low pollution category have a rather clean air quality.

The seasonal variation of PM₁₀ for all the monitoring stations whose EF showed high variation was evaluated. Seasons were classified based on classification given by the Indian Meteorological Department as shown in Table 3.

Table 3. Seasonal Classification

Season	Months
Winter	Jan - Feb
Pre Monsoon	Mar - May
South West Monsoon	Jun - Sep
Post Monsoon	Oct - Dec

IV. RESULTS AND DISCUSSION

The annual variation of PM₁₀ concentration for all the monitoring stations were studied for a period of six years from 2010 to 2015. PM₁₀ concentration has exceeded the National Ambient Air Quality Standards (NAAQS) in Veli (Industrial area) in Thiruvananthapuram during the initial periods of study from 2010 - 2012. But from 2013 onwards, the pollutant concentration was below NAAQS for all the stations. In Ernakulam all the stations have exceeded the NAAQS at least for one year. A comparison was made between the PM₁₀ levels of the residential, industrial and sensitive areas of both locations. The results are shown in Fig. 1 - Fig. 3.

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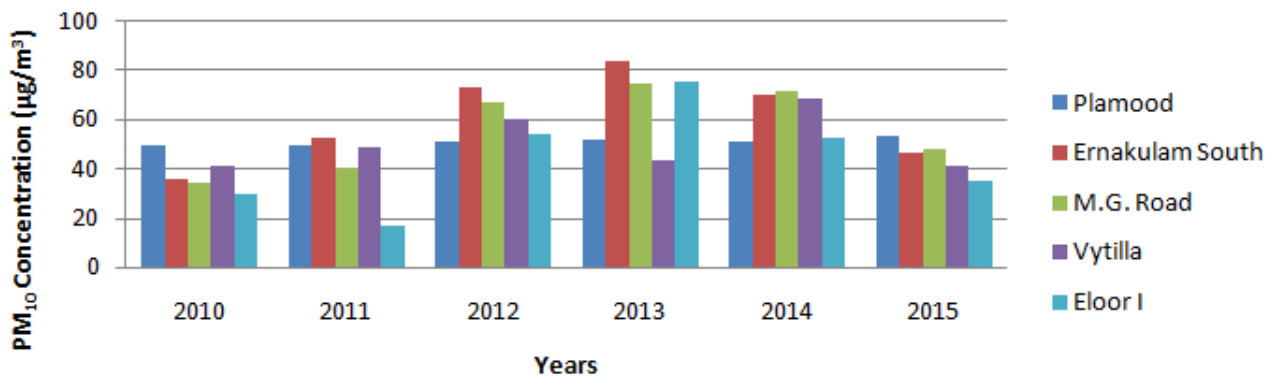


Fig.1. Annual variation of PM₁₀ levels in residential areas

The PM₁₀ levels of residential areas in Ernakulam showed high variation during the study period with all the stations crossing the NAAQS at least once. In Ernakulam South, M. G. Road and Eloor I the PM₁₀ levels have slightly increased compared to 2010. Plamood is the only residential area monitored in Thiruvananthapuram and here the PM₁₀ levels remain almost constant.

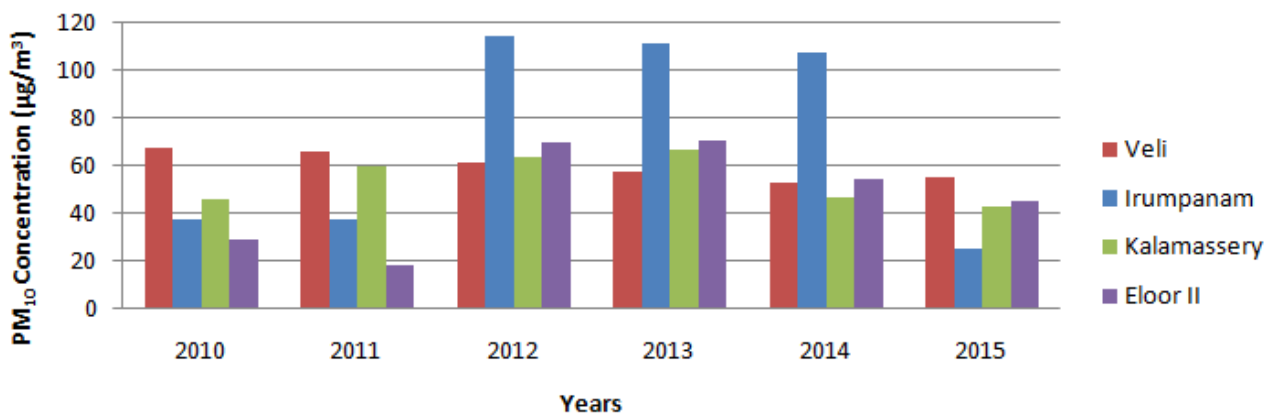


Fig.2. Annual variation of PM₁₀ levels in industrial areas

Deterioration of air quality over the years was observed in industrial areas of Ernakulam in the initial period of study. A sudden improvement in PM₁₀ levels were observed towards the end of study period and this improvement was very drastic in case of Irumpanam. The PM₁₀ levels of Irumpanam has exceeded the NAAQS by almost 1.8 times in three consecutive years and suddenly got reduced to well below the standards. Several chemical manufacturing and metal fabricating industries located in Irumpanam contributes to high PM₁₀ levels. Adoption of stringent measures by the Pollution Control Board regarding industrial emissions may have helped in reduction of PM₁₀ levels in industrial areas. In Thiruvananthapuram, Veli was the only industrial area monitored and it showed slight improvement in PM₁₀ levels over the years.

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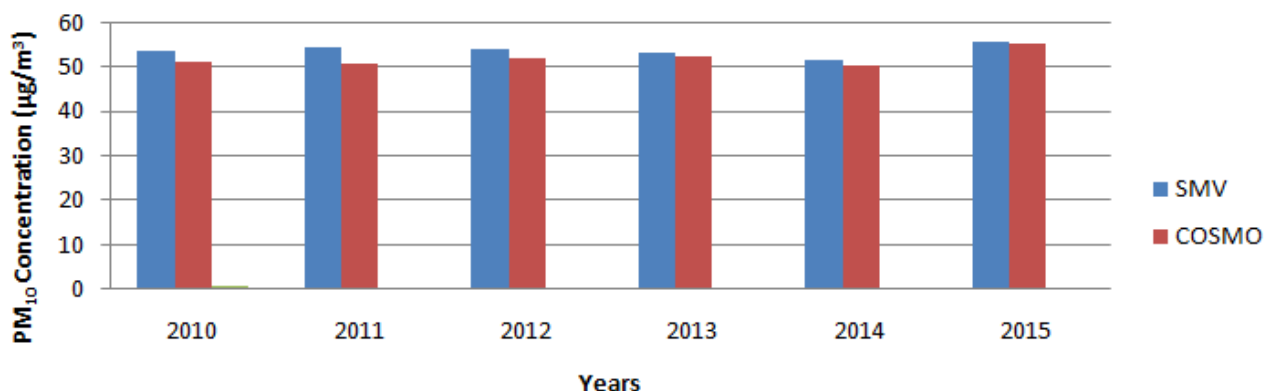


Fig.2. Annual variation of PM₁₀ levels in sensitive areas

In Thiruvananthapuram for both SMV and COSMO the PM₁₀ concentration level was almost constant and was less than the NAAQS during the entire study period. This may be because of strict regulatory measures taken in these areas as they belong to the ecologically sensitive areas.

The exceedance factor was calculated based on the PM₁₀ concentration levels for all the monitoring stations of Thiruvananthapuram and Ernakulam and is shown in the Table 4 where C stands for critical pollution, H stands for high pollution, M stands for moderate pollution and L stands for low pollution.

Table 4. Exceedance Factors for the Monitoring Stations.

District	Station Name	Exceedance Factor					
		2010	2011	2012	2013	2014	2015
Thiruvananthapuram	Veli	H	H	H	M	M	M
	SMV	M	M	M	M	M	M
	COSMO	M	M	M	M	M	M
	Plamood	M	M	M	M	M	M
Ernakulam	Ernakulam South	M	M	H	H	H	M
	M.G. Road	M	M	H	H	C	M
	Vytilla	M	M	M	M	H	M
	Irumpanam	M	M	C	C	C	L
	Kalamassery	M	M	H	H	M	M
	Eloor I	L	L	M	H	M	M
	Eloor II	L	L	H	H	M	M

The air quality of Thiruvananthapuram was consistent during the study period considered. The air quality of Veli, industrial area has improved from highly polluted to moderately polluted category. This may be due to the establishment of strict norms for the industries and development of green manufacturing technologies. The monitoring stations of Ernakulam showed high variability in their air quality. In Eloor I and Eloor II air quality has deteriorated whereas in Irumpanam it has improved drastically from critical pollution level in 2014 to low pollution in 2015. M. G. Road and Irumpanam has maximum variation in the air quality and hence their seasonal variation was studied in detail.

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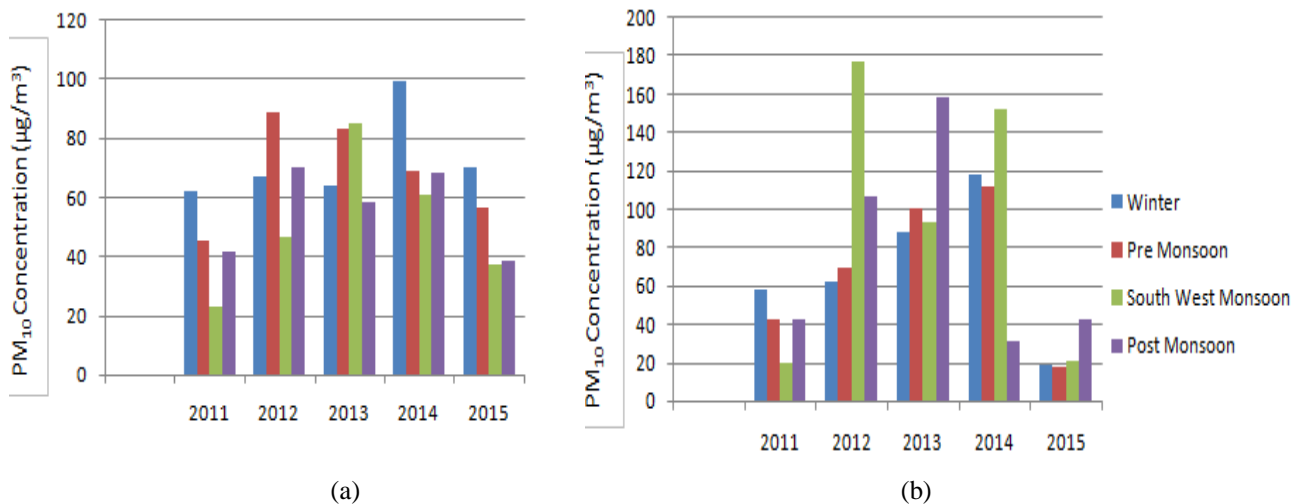


Fig. 4, Seasonal Variation in (a) M. G. Road and (b) Irumpanam

M.G. Road followed the general pattern of seasonal variation having maximum concentration in winter and pre monsoon and minimum concentration in south west monsoon. But in 2013 maximum concentration was observed in south west monsoon. But in Irumpanam the seasonal variation did not follow any peculiar pattern and the PM₁₀ concentration was found to be high in the south west monsoon season. The particulate matter usually gets washed off due to the monsoon showers and very low concentration of PM₁₀ were observed during this season. But the contradictory observation in Irumpanam gives an indication that the season despite being named monsoon did not actually receive much rainfall and points towards the changing rainfall pattern in the area.

V. CONCLUSION

The assessment of concentration of PM₁₀ in ambient air in Thiruvananthapuram and Ernakulam for a period of six years revealed that the concentration of PM₁₀ exceeded the NAAQS in one monitoring station of Thiruvananthapuram and all the monitoring stations of Ernakulam during the study period. Air quality in Ernakulam shows high variability whereas in Thiruvananthapuram it remains in the moderate category. There has been a deterioration of air quality in two regions of Ernakulam - Eloor I which is a residential area and Eloor II which is an industrial area. In all other stations the air quality has improved due to decrease in PM₁₀ concentration. The enforcement of stringent vehicle registration rules, new fuel efficient technologies in vehicles, improved road conditions which limits re-suspension of suspended particulate matter are all reason for the improved air quality considering PM₁₀ concentration for Thiruvananthapuram. In the case of Ernakulam, besides the above said factors, steps taken by industries to reduce air pollution has limited the increase in PM₁₀ concentration.

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