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RESEARCH ARTICLE

Source Apportionment of Particulate Air Pollution and Percentage Contribution of PM_{10} and $PM_{2.5}$ Using Chemical Mass Balance (CMB) Method

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Abstract: The study is to analyze the concentration of particulate pollutants level and its monitoring, there fore suggesting controlling measures of particulate pollution at Virudhunagar in Tamilnadu. This work summarized the results of a series of comprehensive studies on particulate matter carried out in study area from 2010 to 2011. The air quality has been categorized into four broad categories based on an Exceedence Factor (EF) of measured concentration of pollutants. It could be seen from the categorization, that all the study sites were violating the standards, although, with varying magnitude. The concentration of particulate matter PM_{10} and $PM_{2.5}$ was statistically analyzed and higher concentration of pollutants observed during the months of April and May. Overall high concentration of particulates observed during summer at site 2. There is no considerable variation of concentration of particulates was observed at site 3 during all the three seasons. In the available receptor models, chemical mass balance(CMB) method was utilized for this study. This modeling involves quantitative assessment of source contributions to the measured ambient samples based on the degree to which source profiles can be combined to produce ambient concentrations. Particulate samples collected from all the three locations were subjected to chemical speciation. The composition of the data was analyzed and divided into three categories to correlate with the sources. Sources identified as major contributors to particulate pollution were fugitive dust on roads and construction sites, vehicular exhaust, biomass burning at residential and road side trash. The monitoring and analysis results were utilized to strengthen the need for a faster and effective pollution control action plan for the study area.

Keyword: PM_{10}, CMB, Virudhunagar, Particulate matter, Exceedence factor, Critical pollution

Introduction

Changes in the gaseous composition of earth's atmosphere have become a prime concern for today's world due to human activities. According to an estimate, dust pollutants comprise around 40% of total air pollution problem in India[1]. In India the particulate matter problem is very significant due to the huge number of vehicles plying on the road, number of power plants, combustion process, dust stones and domestic emissions[2]. In the recent studies, exceeding levels of particulates are observed with serious health concern[3,4]. The distinction between the coarse and fine particles is made due to the differences in sources, formation mechanisms, composition, atmospheric life spans, spatial distribution, indoor-outdoor ratios, temporal variability in addition to size and health impacts. PM is also classified as primary and secondary in which Primary particles are direct emissions from combustion processes, whereas secondary particles are formed via chemical reactions of primary particles, such as reaction between ammonia and oxides of nitrogen or sulphur, followed by nucleation to form aerosols.

During recent years, India is experiencing unprecedented economic growth rate and rapid urbanization. This resulted in expansion of city, increase in urban population, vehicular population, vehicle kilometer traveled (VKT), traffic congestion, large scale construction activity and unsystematic land usage. The issue of urban air quality in particulate matter (PM), concentrations receiving more attention as an increasing share of the world's population lives in urban centers (UN 2004). The traffic generated emissions are accounting more than 50% of the total PM emissions in the urban areas. Rates of increase of air pollutant concentrations in developing countries such as India are higher than those in developed countries and hence atmospheric pollution is often severe in cities of developing countries all over the world[5]. Atmospheric particulate matter is the major air pollutant in India at the same time other chronic non communicable diseases such as cancer, cardiovascular disease and respiratory disorders are becoming more dominant. Approximately 50,000 prematured deaths occurred annually due to particulate pollution in India.

Experimental

Ambient air quality monitoring was conducted in three sampling stations in Virudhunagar town. The monitoring station and brief description of activities causing pollution are given in Table 1.

Table 1. Selected ambient air monitoring locations in the study area

Site no	Location of the site	Type of the site
1	Madura coats colony	Residential area
2	Pavali	Traffic area
3	Perali	Industrial area

The common air pollutants in atmospheric air had been (SO_2, NO_x, particulates) monitored at regular intervals .Concentration of particulate pollutants for selected locations (S1,S2,S3)were measured with the help of APM 460 respirable dust sampler with impinger box. And after monitoring of air it was procured into lab and analyzed for various parameters using standard methods prescribed by Central Pollution Control Board.

Measurement of PM_{10} and $PM_{2.5}$

A known amount of the air drawn through the pre weighed filter paper. The amount of the air was calculated from the hours the instrument worked and the average of the initial and final flow. (Hours and flow rate are recorded in the data sheet, which was carried with instrument while sampling) For the measurement of $PM_{2.5}$ Whatmann filter paper 46.2 mm. The filter paper was previously checked for pores and dried in oven and weighed. The processed filter paper was carried to the sampling site in the polythene cover. After sampling the amount of $PM_{2.5}$ collected on the paper was measured for concentration[6].

And measurement of PM_{10} was carried out by flowing air through a preweighed a glass micro fiber filter paper (47 mm, GF/A) on 8 hourly basis for 24 hours. Then the amount of particulates were calculated using the formula;

$$\text{Weight } (\mu g\ m^{-3}) = [M2\text{-}M2/V]*10^{6}$$

M2-Final weight of the filter paper, M1-initial weight of the filter paper, V-average flow rate

Exceedence factor

The air quality has been categorized into four broad categories based on an Exceedence Factor (EF) of measured concentration of pollutants[7]. The four air quality categories for Exceedence Factor values are given in Table 2. It is calculated as follows:

$$\text{Exceedence Factor} = \frac{\text{Observed annual mean concentration of criteria pollutant}}{\text{Annual standard for the respective pollutant}}$$

Table 2. Categorization based on exceedence factor of pollutant concentration

Exceedence Factor values	Categories
> 1.5	Critical pollution
1.0 – 1.5	High pollution
0.5 – 1.0	Moderate pollution
< 0.5	Low pollution

Source profiling

Minor chemical components, constituting less than 1 percent particle mass are needed for quantitative apportionment as they more likely to occur with patterns that allow differentiation among sources[8].

Table 3. Marker elements associated with various emission sources

Emission source	Marker elements
Soil	Al, Si, Sc, Ti, Fe, Sm, Ca
Road dust	Ca, Al, Sc, Si, Ti, Fe, Sm
Oil burning	Na, Cl, Na^{+}, Cl^{-}, Br^{-},I^{-}, Mg, Mg^{2+}
Coal burning	V, Ni, Mn, Fe, Cr, As, S, SO_4^{2-}
Iron and steel industries	Mn, Cr, Fe ,Zn, W, Rb
Non ferrous metal industries	Zn, Cu, As, Sb, Pb, Al
Glass industry	Sb, As, Pb
Cement industry	Ca
Refuse incineration	K, Zn, Pb, Sb
Biomass burning	K, Cele, Corg, Br
Automobile gasoline	Cele,Br,Ce,La,Pt,SO_4^{2-},NO_3^{-}
Automobile diesel	Corg, Cele,S, SO_4^{2-},NO_3^{-}
Secondary aerosols	SO_4^{2-},NO_3^{-},NH_4^{-}

**Marker elements are arranged by priority order*

Chemical analysis

The filters from ambient particulate sampling are analyzed for mass, elements, ions and carbon. Elements, organic carbon (OC) and black carbon (BC) are sufficient to account for the most of the particle mass, with reasonable assumptions. A more detailed description of chemical analysis methods is presented in Chow *et al*.[9].

Receptor modeling

A variety of receptor models and methodologies are available with varying levels of benefits and limitations. In the available methods, Chemical mass balance (CMB) method was utilized for this study[10]. This modeling involves quantitative assessment of source contributions to the measured ambient samples based on the degree to which source profiles can be combined to produce ambient concentrations. The quantitative assessment of the primary particles to their source types and determines the chemical form of secondary aerosol when the appropriate chemical components have been measured.

Results and Discussion

Excedence of particulates

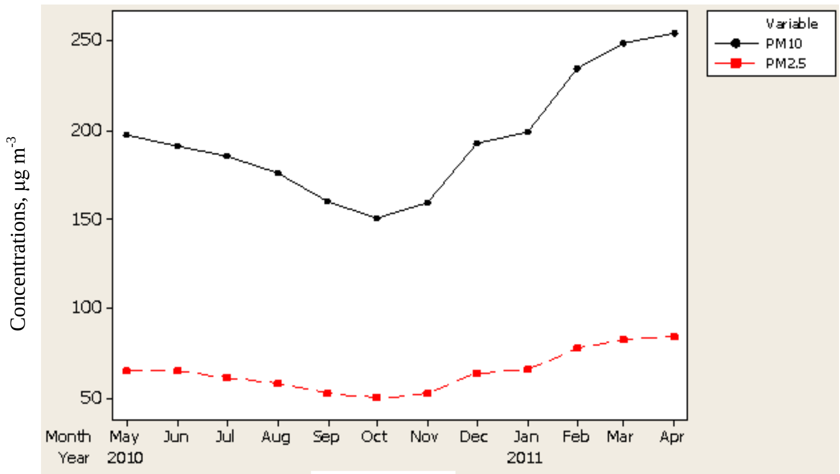
It could be seen from the categorization, that all the study sites were violating the standards, although, with varying magnitude. Computed Exceedence Factor categories for various pollutants at three sampling areas are tabulated in Table 4.

Table 4. Categorization of study sites based on excedence factor of particulates

Particulate		Exceedence factor	Category
PM_{10}	S1	1.77	Critical pollution
	S2	4.85	Critical pollution
	S3	3.16	Critical pollution
$PM_{2.5}$	S1	0.98	Moderate pollution
	S2	4.58	Critical pollution
	S3	1.21	High pollution

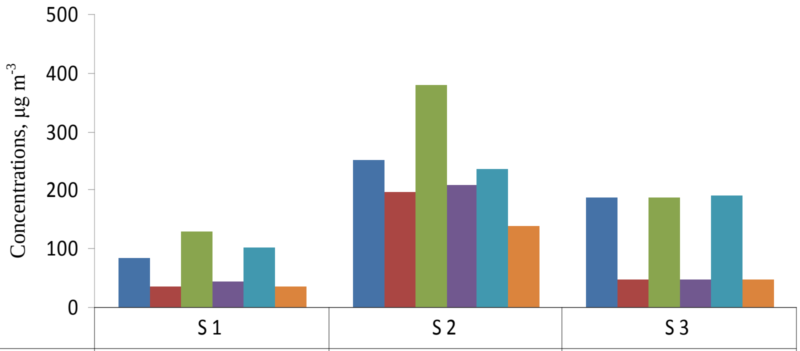
**S1, S2, S3:Site 1, Site 2, Site 3 respectively*

The concentration of particulate matter PM_{10} and $PM_{2.5}$ was higher during the months of April and May. And a drop of particulates concentration observed during the months September and October. So the people of Virudhunagar can breathe easy in these months. The variation of particulate concentrations followed a similar pattern. The Figure 2 shows the seasonal variation of particulates concentration and it shows overall high concentration of pollutants observed during summer at site 2. There is no considerable variation of concentration of particulates was observed at site 3 during all the three seasons.



Time series plot

Figure 1. Time series of measured particulate concentrations (µg m^{-3}) during the study period



	S 1	S 2	S 3
Win PM 10	85.4	253.325	187.975
Win PM2.5	35.525	198.525	48.9
Sum PM 10	129.8	381.5	189.35
Sum PM 2.5	46.25	211.575	48.875
Mon PM10	104.725	238.7	191
Mon PM2.5	36.4	140.025	48.7

Figure 2. Seasonal variation of concentration of particulates in Virudhunagar
**Win, Sum, and Mon: Winter, Summer, Monsoon seasons respectively, *Concentration measured in µg m^{-3}*

Chemical speciation and source apportionment

Particulate samples collected from all the three locations were subjected to chemical speciation as outlined in the Table 3. The composition of the data was analyzed and divided into three categories to correlate with the sources. The first category consists of elemental Carbon (EC), organic Carbon (OC) and sulphates and nitrates whose fractions are dominated by direct vehicle exhaust emissions. The second category is related to resuspended dust lofted by natural wind and movement of vehicles from paved and unpaved roads. This constitutes mainly silicon (Si), aluminium (Al), calcium (Ca), potassium (K), (Mg) and iron (Fe). The third category consists of soluble K and OC and is related to biomass burning[11].

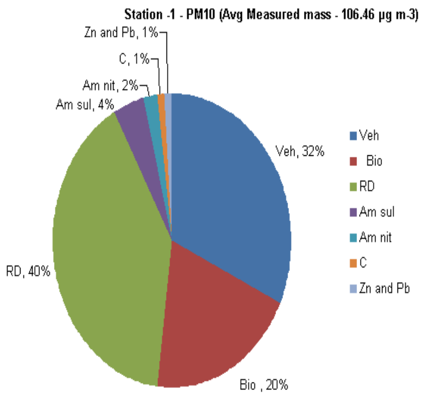


Figure 3(a)

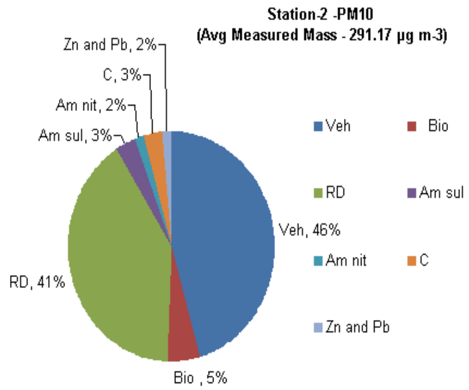


Figure 3(b)

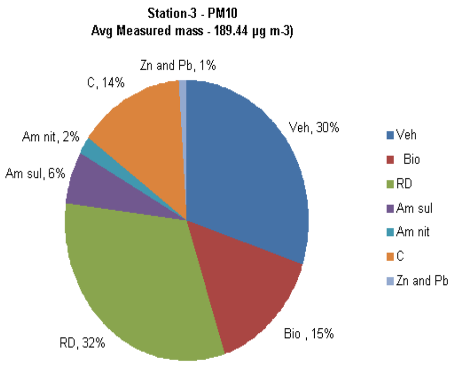


Figure 3(c)

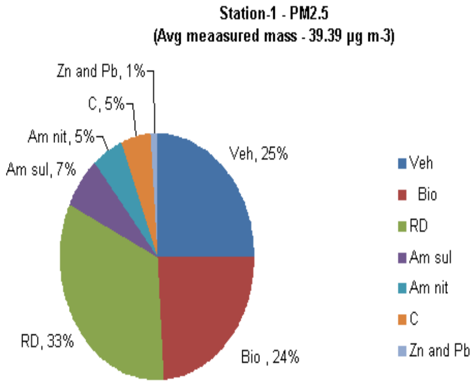


Figure 3(d)

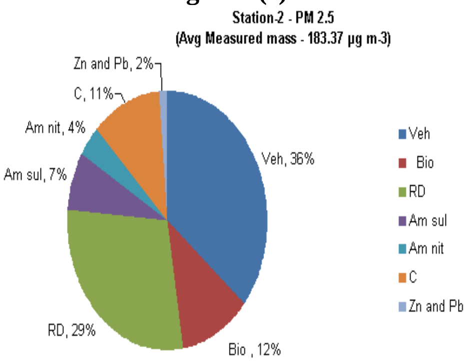


Figure 3(e)

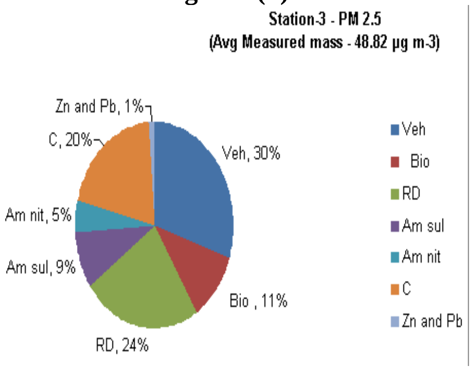


Figure 3(f)

Figure 3(a-f). Source apportionment of PM_{10} and $PM_{2.5}$ for study stations S1, S2 and S3

The main contribution to the PM_{10} is in the form of crustal elements because of their coarser nature. In the crustal elements the silica and alumina are predominant indicating soil and road dust signature[12,13]. The other markers for the resuspeded dust are Calcium and Iron Concentration of PM. In Virudhunagar dust on road is consistently high, contributing 40%, 41% and 32% in PM_{10} concentration at S1, S2 and S3 respectively. The ratios $PM_{2.5}$ / PM_{10} was very low indicating the contribution of resuspended dust to PM_{10} is more than that of $PM_{2.5}$. The highest contribution of RD was due to poorly maintained roads and geographical nature of study area.

Due to encroachment of roads by shops 30% of the available road space is lost. The lack of traffic discipline also aggravating the congestion problem. EC is mostly a by product of diesel combustion. OC is partially contributed by gasoline vehicles, diesel vehicles and biomass[14]. At Pavaly the movement density of vehicles is highest in the town. The concentration of EC was higher in site 2 when compared to other two sites. Also the EC to OC ratio in Pavaly was higher indicating the contribution mostly from diesel vehicles. Vehicular sources are the major contributor, contributing 32%, 30% of the average total mass of PM_{10} at s1, s3 respectively. At site 2 the highest mass contribution to (46%) the average mass of PM_{10} was due to vehicular sources. In the case of fine particulates ($PM_{2.5}$) the highest contribution to the average mass was due to vehicular exhausts at site 2 (36%) and site 3(30%).

Because of the smoke, air pollution and odor complaints of waste burning, many organizations prohibit residential trash burning but it is continuously unabated. Many of these pollutants become widely dispersed and persist for years in the environment[8]. Waste burning substantially contributing $PM_{2.5}$ and PM_{10} particulates. Biomass burning is characterized by high OC, EC and K. The concentration and ratio of soluble potassium and potassium and concentration of OC is higher at site 1 followed by site 3. Site 1 is categorized as residential area in which 24% of $PM_{2.5}$ and 20% of PM_{10} pollution was due to biomass burning. Sulfur in the form of ammonium sulphate, which originates from coal and diesel also a good indicator for industrial contribution to particulate pollution. The contribution of industrial activity to the particulate pollution is even though low it contributes 7-9% of $PM_{2.5}$ concentration and 4-6% of PM_{10} concentration.

Conclusion

The study focused on the quantification of contribution of various sources to the growing air pollution in this town. Sources identified as major contributors to particulate pollution are fugitive dust on roads and construction sites, vehicular exhaust, biomass burning at residential and road side trash. The monitoring and analysis results were utilized to strengthen the need for a faster and effective pollution control action plan for the study area.

- It may be conducted routine Wet Street sweeping on roads with highest traffic volume.
- It must be considered better solid waste management and the inclusion of provisions for Clean Development Mechanism (CDM).
- Industries must be fitted with Air pollution control devices such as wet scrubbers, cyclones, bag filters and dust collectors.
- Providing capacity to policy makers to support integrated policies to reduce PM emissions.

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