The inferences drawn in this study are the views of the authors and not of the West Bengal Pollution Control Board

Fine Particulates in Ambient Air
And
Its Organic Component

Project carried out at the
West Bengal Pollution Control Board
Salt Lake, Kolkata – 700 098

Authors:
Sourav Dasgupta
Subrata Roy
Subhankar Debnath
Ujjal Kumar Mukhopadhyay

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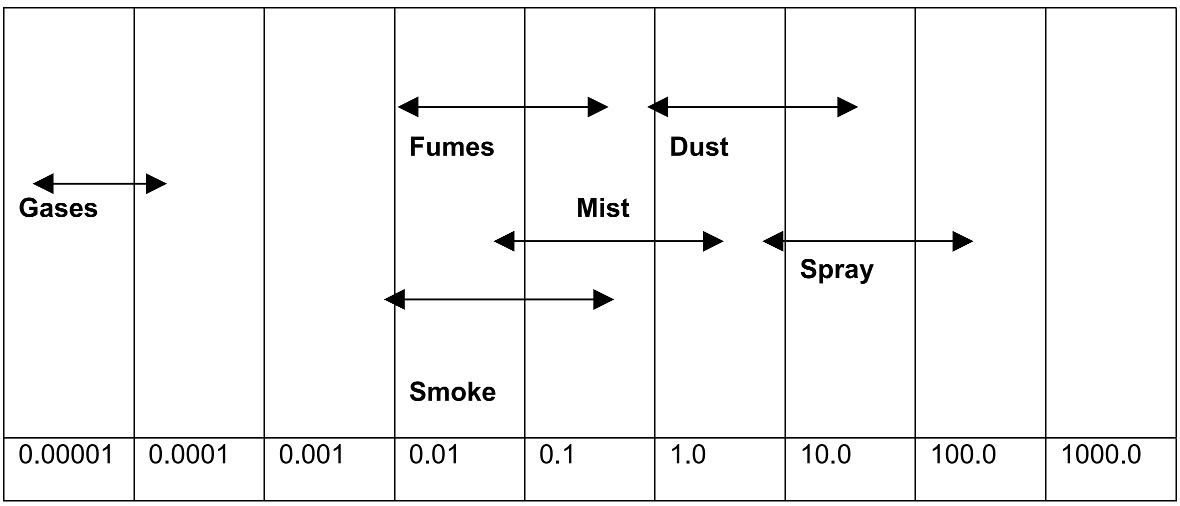
INTRODUCTION

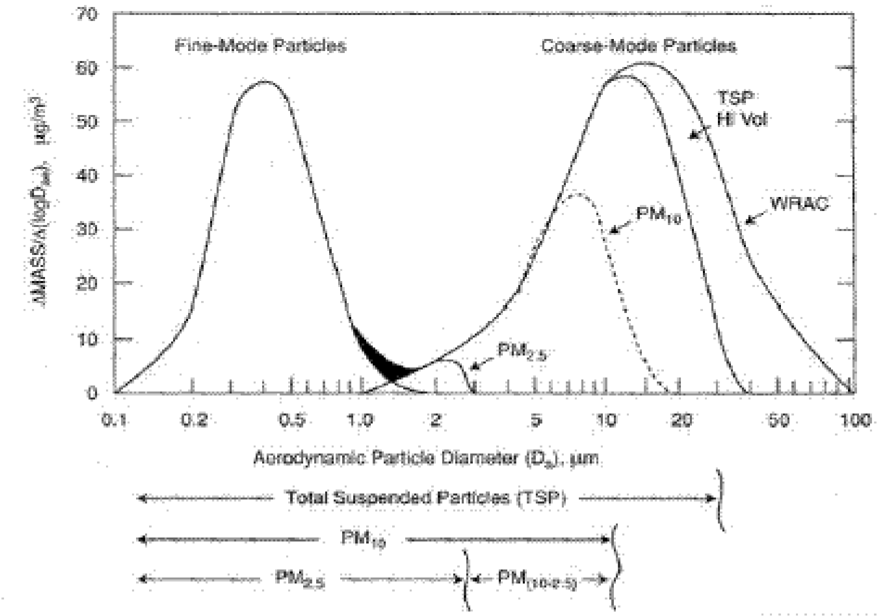
Many have little doubt that the troposphere of our earth is predominantly polluted by particulates, both nonfibrous and fibrous in nature, of anthropogenic origin. Airborne particulate matter represents a complex mixture of organic and inorganic substances. The composition of urban atmospheric particulates tend to be divided into two principal groups: coarse and fine particles, the barrier being between 1 μm and 10 μm as per different literatures whenever the aerodynamic diameters of the particulates are referred. Most recently however, the limit between coarse and fine particles has been accepted by many to be 2.5 micro-meter (μm) which is popularly referred to by $PM_{2.5}$ for both reference and measurement purposes. The whole gamut of concern for aerosol particulates is however its impact on human health. The focus of controlling airborne particles as such changed since it was established that particles below 10 micrometer diameter only are the ones that enter the human respiratory tract during normal respiration and causes all detrimental effect.

The aerosol particulates in urban atmosphere may vary in number from several hundred per cubic centimeter, in very pure air, to more than $10^5/cm^3$ in highly polluted air. Their size is in the range of 0.001-10 μm & more (Tab-1). The particulate mass level ranges from 10 μg/m^3 in clean air to 2000 μg/m^3 in the polluted air in urban areas especially on the busy roads with high traffic density. Classification of air particulates are generally done in a way depicted below in tabular form.



Aerodynamic diameter of Particle in micro-meter

The distribution of particulates of concern are distributed in a typical fashion described in Fig. 1. The relative abundance of the particles suspended in air show this typical distribution absence of acceptable and plausible explanation notwithstanding. The typical



Source: USEPA, 1996

Legend (Fig. 1.): Distribution of airborne particulates in urban atmosphere.

bimodal distribution however is sort of uniquely acceptable phenomena in many a city atmosphere around the globe. All the particulate measurement strategies and the monitoring methods and instrumentation however have been developed on the basis of this distribution.

The particles suspended in air vary in size, composition and origin. It is convenient to classify air-particles by their aerodynamic properties because: (a) these properties govern the transport and removal of particles from the air; (b) they also govern their deposition within the human respiratory system and (c) they are associated with the chemical composition and sources of particles. These properties are conveniently summarized by the aerodynamic diameter, that is the size of a unit-density sphere with the same aerodynamic characteristics. Particles are sampled and described on the basis of their aerodynamic diameter, usually called simply the particle size.

The chemical nature and size of the particles are more important than the particulate matter load in the atmosphere. Particles in the size range 0.001-1μm exert several important effects

- They are responsible for electrical phenomena in the atmosphere, cloud and fog formation.
- They play an important role in determining the heat balance of the earth's atmosphere through light reflection.
- They serve as nuclei for the formation of ice crystals and water droplets.
- They are involved in several chemical reactions in the atmosphere, such as
  - ✓ Neutralization reactions in water droplets.
  - ✓ Catalytic effects of small particles of metal oxides on oxidation reactions.
  - ✓ Photochemical oxidation reactions.

Air-borne particles are usually classified according to their chemistry and pathway. The predominant classifications are:

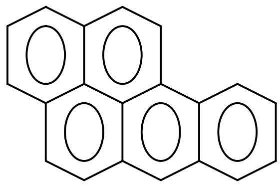
1. Organic particulate matter
2. Inorganic particulate matter
3. Inhalable particles
4. Thoracic particles
5. Respirable particles

We, in our present study, will focus mainly of the first of the above categories, i.e., the organic particulate matter.

Importance of the Present Study

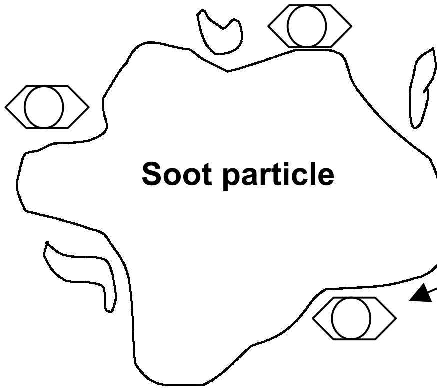
Particulate matter suspended in urban ambient air that has a possibility to enter the respiratory tract through inhalation are created with various types of nucleation centers, e.g., acid particles, metals and carbon. Most of these are byproducts of fossil fuel burning through different combustion technologies. Of these types of particles, the carbon centered ones has the highest probability of having simple long-chain or complex Polycyclic Aromatic Hydrocarbons associated with the core. This is so because of the very high surface area offered by the fine and ultra-fine carbon centered particulates for the hydrocarbons, both being non-polar in nature. The source of these hydrocarbons are also the combustion centers of fossil fuel.

Particles created in this way are generally referred to as “Organic Particulate Matter”. They occurs in a wide variety of compounds in atmosphere. The most popular and standardized method to investigate the organic components associated with air particulates is in the form of a benzene extractable fraction of the particulate sample. A typical such study, performed from 200 samples in USA showed an average formula of the hydrocarbon as $\mathbf{C_{32.4}H_{48}O_{3.8}S_{0.083}Halogen_{0.065}Alkoxy_{0.12}}$. The most vulnerable of these Polycyclic aromatic hydrocarbons (**PAH**) is **Benzo(α)pyrene (BαP)** that is having the carcinogenic potential to the highest degree amongst the environmentally abundant compounds that can likely affect human beings. The salient structural feature of this monstrous molecule is provided below.



Benzo(α)pyrene

Most of the PAH compounds remain adsorbed on soot particles that are formed as a residue of combustion of fuel in power plants and automobiles. To some estimate, it accounts for 50% of the particulate load in urban areas. Chemically it is highly condensed product of polynuclear aromatic hydrocarbons (PAH), consisting of several thousand interconnected crystallites, i.e. graphic platelets each have about 100 condensed aromatic rings.



Obviously of course the surface area is more the less the particle size. for a given total mass of the collected particulates. Thus monitoring for $PM_{2.5}$ is always more important than PM_{10} firstly as the former ones penetrate deeper into the respiratory tract and secondly and more importantly they act more efficiently in delivering the toxic and carcinogenic organic air pollutants to the interior of human respirator.

Scope of the Present Work

Albeit the policies, practices and regulations in our country for control of air pollution are as old as of the industrially developed ones, practice of monitoring and preparing standard guidelines for ambient air pollutants in our country suffered from timely interventions all through. We have ambient air standards for SO_2, NO_2, Suspended Particulate Matter (SPM), Respirable Particulate Matter (RPM), Lead, Ammonia and Carbon Monoxide (CO). Very little data is available from monitoring experiments done on Indian soil on the concentrations of $PM_{2.5}$ and the extremely toxic hydrocarbons associated with PM_{10} and/or $PM_{2.5}$. Thus it is not possible to estimate the exposure, for either fine particulates or the organic portion associated with them, of an average Indian living in the city area. Such estimates are required as the basis of the epidemiological health effect studies or policy backgrounds for setting up standards and taking appropriate measures to achieve the target standards. The monitoring PM_{10} is done employing sort-of modified High Volume Samplers (the samplers most popularly used are HVSs associated with a cyclone separator at the entry point) all over the country. The main drawback for this instrument appears sustainable maintenance of the air sampling rate (not less than 1.1 m^3 / min), especially during the winter days when the particulates in ambient air reach their yearly high. Secondly, on the cut-off diameter for the collected particulates (<10 micrometer predicted) as the separation is based on the principle of cyclone separator and not impactors. A PM_{10} or $PM_{2.5}$ sampler with an appropriate impactor head for defined aerodynamic particle size and the suction system that can maintain constant and required flow rate is the right choice for determination of PM_{10} or $PM_{2.5}$ that can be compared with similar data collected at other cities of the world.

With this backdrop, the following were set to be the scope of the present work.

1. Estimation of PM_{10} and $PM_{2.5}$ and comparing the results collected by both cyclone-separator based and impactor-separator based samplers.

2. Estimation of Benzene soluble fraction of the PM_{10} and $PM_{2.5}$ fractions and compare them with the particulate concentrations.

Outlines of the Study

- The study included sampling of ambient air employing the following samplers.

Manufacturer	Model	Type	Special feature
M/s. Andersen Instruments Inc., U.S.A.	FM-TSP-MB-SP	High Volume Flow Manager with brushless blower motor assembly	PM_{10} entry head (Impactor Type); Automatic flow controller
M/s. Andersen Instruments Inc., U.S.A.	FM-TSP-MB-SP	High Volume Flow Manager with brushless blower motor assembly	$PM_{2.5}$ entry head (Impactor Type)
M/s. Envirotech Pvt. Ltd.	APM – 460 - DX	Brushless blower motor assembly with flow controller	Cyclonic separater at the entry for PM_{10}
M/s. Envirotech Pvt. Ltd.	APM 550	Brushless blower motor assembly with flow controller	$PM_{2.5}$ separator

- The time period of the study was for 1 month and a half – starting during middle of October and finishing early December of the year 2003.

- Air samples were collected mostly at an ambient position in side the office premises of the West Bengal Pollution Control Board. This sampling station was situated near the crossing of North Eastern Bypass and Beliaghata Main Road, towards the eastern end of the Kolkata city. All the air samples collected at this station were for 24 hours duration.

- Air samples were collected at four different sampling points in the city. Samples at these points were collected in three eight hourly shifts in a day. These sampling points may be named as: (1) Minto Park – Central to the city and having huge traffic density all around, (2) Ultadanga – Northern side of the city and having fairly high traffic population around, (3) Mominpur – Centre to western side and with moderate traffic and industrial activity around, and (4) Baishnabghata – Deep in the south and preferentially a residential area. These samples were used mostly for the purpose of BSOF study.

- All measurements in relation to particulate concentration were done gravimetrically employing a five(5) figure analytical balance after at least 18 hours of conditioning of the filter paper inside desiccators. Benzene soluble organic fraction was computed extracting 10 cm^2 of the deposited area of the filter paper in benzene. Extensive ultrasonication was employed for extraction of the organic phase solubles from the particulates and the estimate was done gravimetrically evaporating out the benzene and conditioning the container in desiccators for at least 18 hours.

Materials and Methods

The following materials were required for the experiments reported I this study.

- Hi-volume air sampler (Make – M/s. Instruments Inc., USA and M/s. Envirotech India vt. Ltd.)
- Glass fibre filter paper (GF / A of M/s. Whatman Inc.)
- Scale/ruler.
- Scissor
- 25ml reagent bottle.
- Forceps
- Pipette & Pipetter.
- Beaker.
- Benzene.
- Ultrasonicator
- Water.
- Filtration assembly.
- Glass tubes.
- Desiccators.

- Totary Vacuum Concentrator (Make – M/s. Thermo Savant, USA).
- Permanent marker.
- Balance (Sensitivity 10 µg, Make – M/s. Mettler Toledo, Germany).
- Test-tube rack.
- Micropipette.
- Waste disposal basket.
- Cloth/soft rag.
- Organic waste disposal bottle.

All chemicals used in this study were of analytical grade and the Benzene used were of HPLC grade of M/s. Merck Ltd.

Method

The experiment can be divided into two parts:-

a. The study of particulate matter (PM) from sampler.

b. Chemical analysis of the collected particulates.

(A).The study of particulate matter (PM) from sampler

Procedure:

The glass fiber filter papers (GF/A) are kept in a desiccators for conditioning for at least 4hrs. After conditioning the filter papers are taken out and weighed on an electronic balance. These filter papers are now set up on the particular positions of three different samplers Anderson PM 2.5, Anderson PM 10and Envirotech PM 10. The sampling is now carried out for a period of 24hrs. After24hrs, when sampling is completed, the filter papers are taken out , folded and placed in the respective envelope. The time of introduction, removal time, date, duration of sampling, total volume of air sucked and the average air flow rate- all these information's are recorded The filter papers are now placed in a desiccators and allowed to be conditioned overnight. After complete conditioning the filter papers are weighed again and the difference in weight is noted.

(B). Chemical analysis of the collected particulates

Procedure:

From each of these filter papers 10 x 10 sq.cm are cut out. The cut out squares are further cut into smaller pieces and placed in a separate 25ml reagent bottle by means of forceps. To each of these reagent bottles 20ml of benzene is added through a pipette and shaken well. The reagent bottles are now placed in a container and water is poured up to the neck of the bottle. The above set up is now allowed to be ultrasonicated for 10mins, with a pulse of 5sec and an amplitude of 50 to separate out the particulate from the filter paper more stringently and bringing them into liquid (benzene) phase. After sonication the set up is kept for a period of ½-1hr for the proper settling of the particulates . The liquid in the reagent bottles is now filtered through GF/A filter paper and the filtrate is collected in small tubes.

From the filtrate 5ml is transferred to the preweighed tubes by means of a micropipette. The tubes are then placed in a concentrator for 1-1½hrs for benzene to evaporate, forming a pellet of solubilised particulate at the bottom of each tube. After complete evaporation of benzene the tubes are taken out and placed in a desiccators for an hour.

The desiccated tubes are now weighed, the difference in weight recorded and total benzene soluble organic fraction (BSOF)/m^3 is calculated out.

OPERATIONAL DETAIL OF ANDERSON SAMPLER

The sampler consists of an inlet, a filter holder, a flow control system, a pump and a flow manager control system.

The inlet provides a precipitation shield and an insect shield , in some case. In some systems the inlet provides size selectivity so that the sampler can discriminate one size fraction of the ambient particulate. For size selective inlets, sampling is independent of wind speed and direction. A number of inlets are available.

WORKING PRINCIPLE OF ANDERSON SAMPLER

The ambient air is sucked out as the motor is started, at a certain flow rate. The sucked out air inserted into the sampler from the bottom of the lid at an angular direction . The air entered, then passes through the impactor which arrest the particulates larger than the desired size (e.g. PM10 & PM 2.5). The air containing particulates of desired size get deposited upon it, as the pore size of the filter – paper is necessarily smaller than the aerodynamic diameter of the particulates being sampled. The passed out air free from particulates is evacuated from the sampler by means of an a brush less motor through the exhaust – pipe.

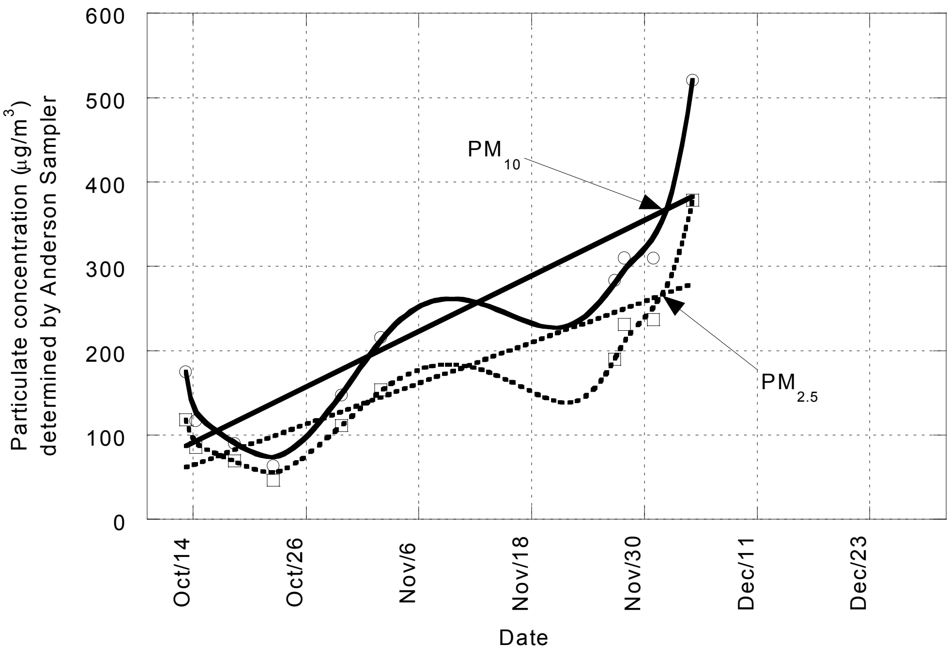
PRINCIPLE OF OPERATION OF ENVIROTECH PM10 SAMPLER

Ambient air laden with suspended particulates enters the system through the inlet pipe. As the air passes through the cyclone coarse, non respirable dust is separated from the air stream by centrifugal force acting on the solid particulates. These separated partculates fall through the cyclone's conical hopper and collect in the sampling bottle fitted at its bottom. The fine dust forming the respirable fraction of the TSP, passes through the cyclone and is carried by the air stream to the filter paper clamped between the top cover and fitter adapter assembly. The Respirable Dust (RSP) is retained by the filter of the carrier air exhausted from the system through the blower.

Results and Discussion

The west Bengal Pollution Control Boad has been monitoring the ambient air quality of Kolkata and other important cities of he State, especially during winter, since early 80s of the previous century. That the concentration of particulate matter in the ambient air increases as we move towards colder days after the monsoon, is an established fact. This increment is further assisted by less and less velocity of the wind which ensures lowering of the inversion layer and less possibility of diffusion of aerosols. To speak about the results from the Anderson samplers, this fact was further confirmed by the present study and the linear fits to the data establishes further a steady increment in concentration of both PM_{10} and $PM_{2.5}$ in ambient air of Kolkata (Fig. 1). Further to this the slopes of the fits of Fig. 1. Speaks about same rate of increment of both the size fractions under study at the same rate. The same conclusions could be drawn from the data obtained when the Envirotech samplers were employed for sampling of air particulates. Although with much less data points, the trend lines corroborated well with the same ones obtained from Anderson samplers.

Fig. 1

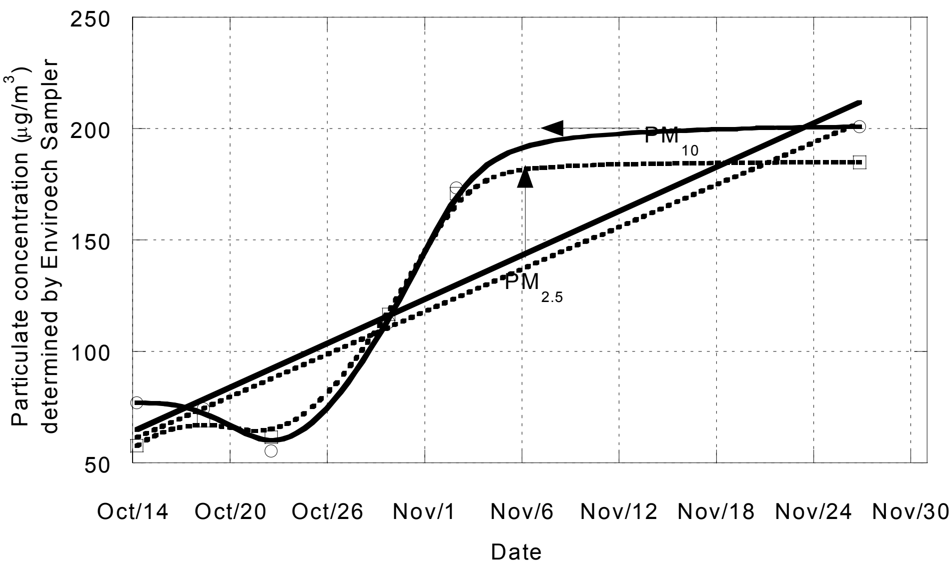


Legend (Fig. 1): Variation of particulate matter below aerodynamic diameter of 10 and 2.5 micrometer with date. Place of air sampling is Salt Lake (WBPCB office). Linear fit equations are displayed below.

——— y = -2.0726e+05 + 6.5846e-05x   R= 0.86991

-------- y = -1.5244e+05 + 4.8429e-05x   R= 0.87616

Fig. 2



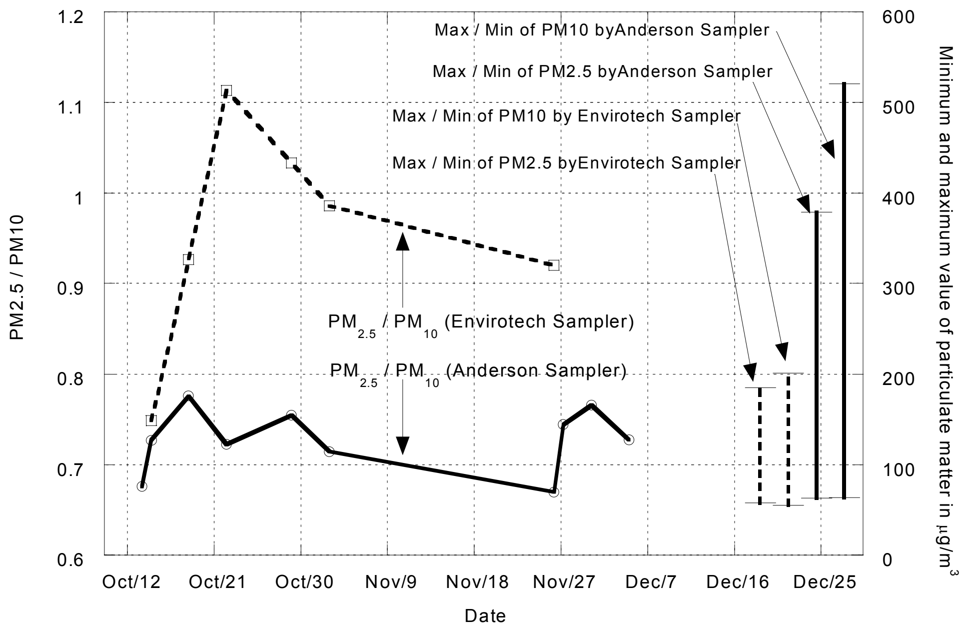
Legend (Fig. 2): Variation of particulate matter below aerodynamic diameter of 10 and 2.5 micrometer with date. Place of air sampling was Salt Lake (WBPCB office). Linear fit equations are displayed below.

——— y = -1.2431e+05 + 3.9498e-05x   R= 0.89235

-------- y = -1.195e+05 + 3.7968e-05x   R= 0.89191

The ratios of $PM_{2.5}$ and PM_{10} however presented a completely different scenario when the two samplers were compared. $PM_{2.5}$ is supposed to maintain a defined ratio with PM_{10} in case the composition of air and the source of the particulates remain invariant which is of course the case for the samples under study.

Fig. 3.



Legend (Fig. 3): Variation of the 2.5 micrometer fraction of lessthan 10 micrometer particulates with the absolute fluctuations values of PM 2.5 and PM 10

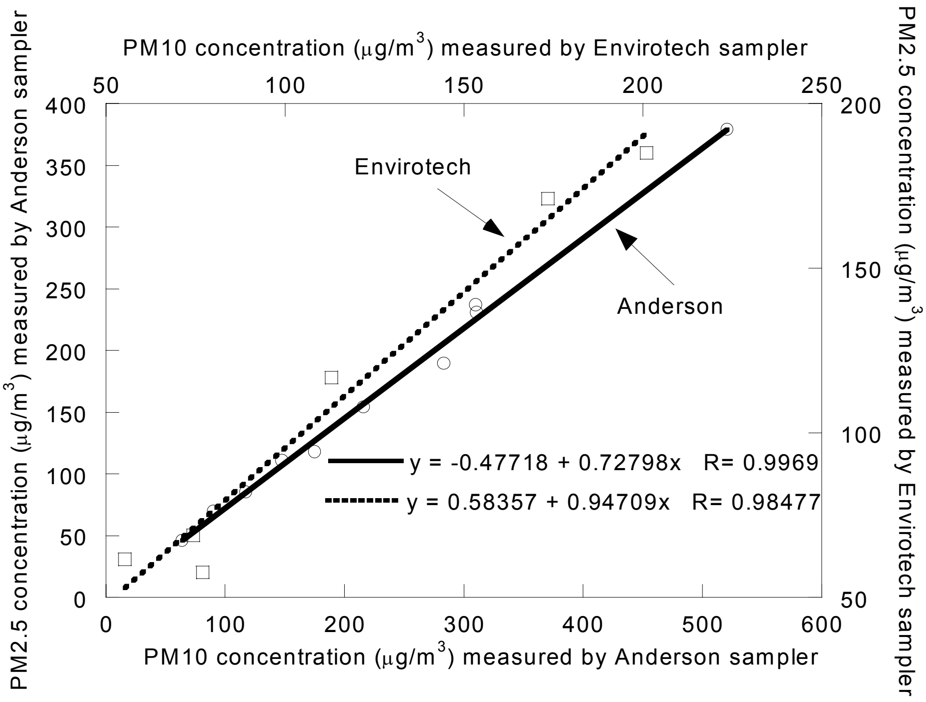
It is evident from Fig. 3. That although the absolute values of the mass of the particulates collected for both the size fractions varied widely in case of Anderson samplers, the $PM_{2.5}$ / PM_{10} ratio maintained steadiness between 0.67 and 0.78. The same for Envirotech samplers however had wider fluctuations and reached values more than unity (which is not at all acceptable) often. This phenomena may be ascribed to the two different technologies of collection of particulates and predominantly the difference in flow rates of he two samplers. When the total volume of air sampled by the Envirotech PM_{10} sampler lies over 1500 m^3 in 24 hours, the same for the $PM_{2.5}$ sampler lies below 25 m^3 for the same period of time. The $PM_{2.5}$ fraction of PM_{10} sampled by Envirotech samplers thus cannot be taken as ‘representative’ as the two samplers are not designed to sample same amount of air and thus leaving scope of error in capturing all the below-2.5 μm particles during the period of sampling. The picture could be much clearer referring to the tables 1 & 2 that represent the actual amounts of the particulates collected by Anderson and Envirotech samplers respectively.

Table 1: PM10, PM 2.5 and their ratio calculated from the data obtained by Anderson Samplers			
Date	PM10 (μg/m^3)	PM2.5 (μg/m^3)	PM2.5 / PM10
14-Oct-2003	174.95	118.20	0.675621606
15-Oct-2003	117.06	85.08	0.726806766
19-Oct-2003	89.94	69.80	0.776072938
23-Oct-2003	63.74	46.03	0.722152495
30-Oct-2003	147.44	111.20	0.7542051
3-Nov-2003	215.72	154.06	0.714166512
27-Nov-2003	283.00	189.46	0.669469965
28-Nov-2003	310.41	230.93	0.743951548
1-Dec-2003	309.59	237.08	0.765787009
5-Dec-2003	520.96	378.84	0.727195946
Mean	223.28	162.07	0.73
stdev	137.3887	100.3276	0.035079
Minimum	63.74	46.03	0.67
Maximum	520.96	378.84	0.78

Table 2: PM10, PM 2.5 and their ratio calculated from the data obtained by Envirotech Samplers			
Date	PM10 (μg/m^3)	PM2.5 (μg/m^3)	PM2.5 / PM10
15-Oct-2003	77.03	57.67	0.74866935
19-Oct-2003	74.34	68.88	0.926553672
23-Oct-2003	55.30	61.59	1.113743219
30-Oct-2003	112.96	116.73	1.033374646
3-Nov-2003	173.45	171.03	0.986047852
27-Nov-2003	201.01	184.97	0.920202975
Mean	115.68	110.15	0.95
stdev	59.11775	56.8562	0.124014513
Minimum	55.30	57.67	0.75
Maximum	201.01	184.97	1.11

This comparison of $PM_{2.5}$ and PM_{10} sampled by samplers of two different make and technology could be better understood from the correlation plots (Fig. 4). Although the $PM_{2.5}$ fraction of PM_{10} was found to correlate well when the data collected by two groups of samplers were plotted, from analysis of the correlation equations it is seen that the slopes for Anderson samplers (0.728) are much more practical than that for Envirotech samplers (0.947). Looking at the intercepts also it is seen that the same for Anderson's is negative which is obvious but is showing positive values in case of Envirotech samplers which is not a practicable proposition. The sort of analysis presented here however needs validation with more data collected during different time and weather conditions of the year.

Fig. 4.



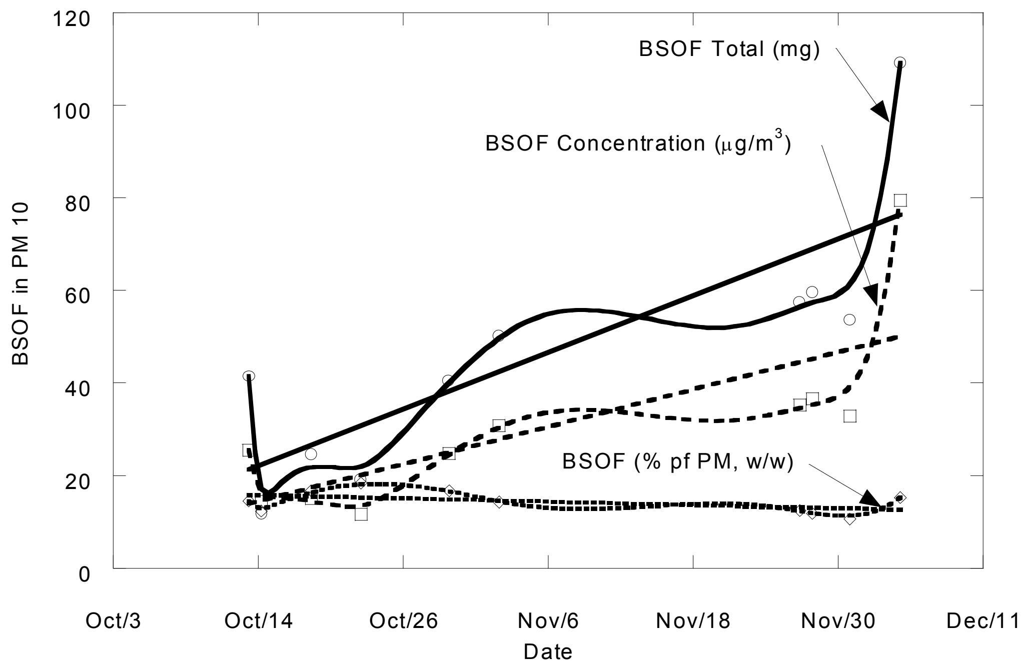
Legend (Fig. 4): Correlation between PM10 and PM2.5 measured by different samplers

Benzene soluble fractions of the particulate matters collected employing both Anderson and Envirotech air samplers were estimated as described in "Materials and Methods". Tables 3 and 4 present the various data in this relation for Anderson PM_{10} and $PM_{2.5}$ respectively. The maximum, minimum and mean of the results show higher values for $PM_{2.5}$ fractions over PM_{10}. The variations of BSOF with time however corroborated well with the variations of particulate concentrations. Although steady increases of total BOSF parameters could be observed from the linear fit lines (Fig. 5 and Fig. 6), the mass fractions of BSOF were found to maintain rather steadiness with winter setting in, i.e., with increase in the particulate concentration in the ambient air. A closer inspection of the variations of BSOF fractions (w/w) with time, total mass of particulates in other sense (as the mass of particulates kept increasing with days), however narrated about the extent of organic composition with size fraction of the particulates. The linear fit equations for the BSOF fractions (w/w) with time are as follow.

$$y = 2201.3 - 6.9408e\text{-}07x \qquad (A)$$

$$y = -1822.9 + 5.8364e\text{-}07x \qquad (B)$$

Fig. 5.



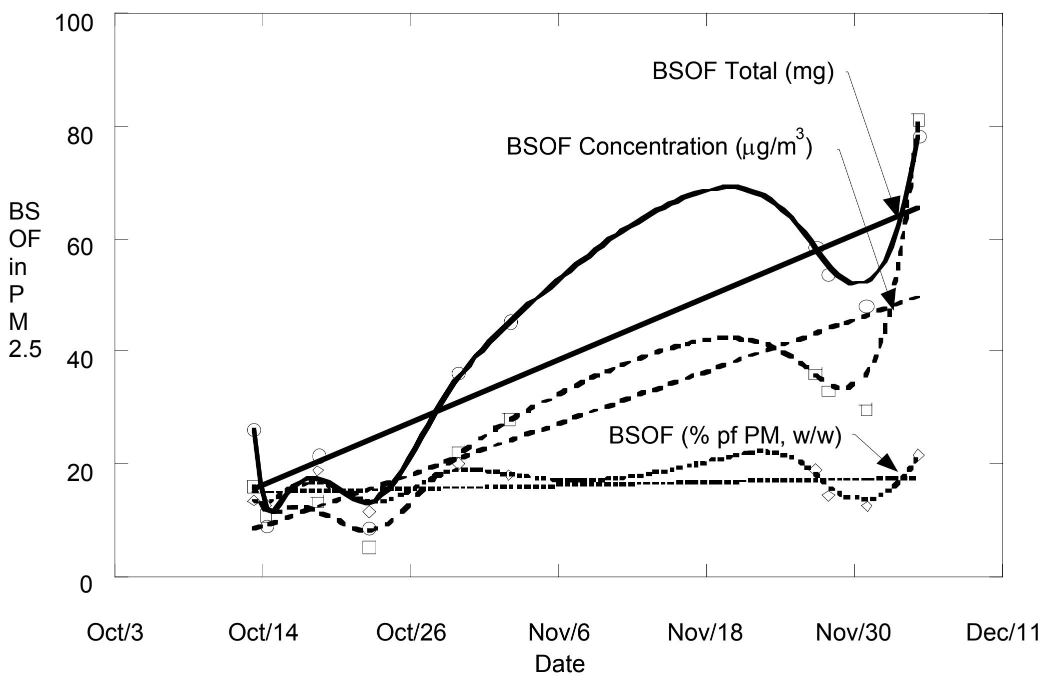
Legend (Fig. 5.): Variation of BSOF parameters of PM10 with date. The linear fit equations are provided below.

$y = -38578 + 1.2258e\text{-}05x$ R= 0.80919

$y = -25337 + 8.0507e\text{-}06x$ R= 0.75442

$y = 2201.3 - 6.9408e\text{-}07x$ R= 0.50204

Fig. 6.



Legend (Fig. 6.): Variation of BSOF parameters of PM2.5 with date. The linear equations are provided below.

$y = -34993 + 1.1117e\text{-}05x$ R= 0.89346

$y = -28836 + 9.1599e\text{-}06x$ R= 0.77632

$y = -1822.9 + 5.8364e\text{-}07x$ R= 0.29127

The marked difference in equations (A), representing the mass-% BSOF in PM_{10} and (B), representing the same in $PM_{2.5}$ is the signs of slope. The positive slope in case of $PM_{2.5}$, in contrast to the negative for PM_{10} flatly speaks about 'more BSOF more $PM_{2.5}$'. In other words, the 2.5 fraction of PM_{10} constitutes much higher

Table 3: BSOF parameters derived from air particulates sampled by Anderson sampler with PM10 head

Date	Sampler	BSOF in total particulates (mg)	Mass of particulate (mg)	BSOF (µg/m³)	BSOF (% of PM, w/w)
14-Oct-03	AndersonPM10	41.395536	284.87	25.42	14.5313778
15-Oct-03	AndersonPM10	11.75	95.36	14.43	12.3217282
19-Oct-03	AndersonPM10	24.53	146.74	15.03	16.7166417
23-Oct-03	AndersonPM10	19.08	104	11.64	18.3461538
30-Oct-03	AndersonPM10	40.37	240.56	24.74	16.7816761
3-Nov-03	AndersonPM10	50.25	351.97	30.8	14.276785
27-Nov-03	AndersonPM10	57.432	283	35.2	12.44
28-Nov-03	AndersonPM10	59.61	506.16	36.56	11.7769085
1-Dec-03	AndersonPM10	53.58	504.81	32.86	10.6138943
5-Dec-03	AndersonPM10	109.296	716.22	79.49	15.26
		↓	↓	↓	↓
	Mean	46.7293536	323.369	30.617	14.3065165
	stdev	26.08469563	190.4628933	18.37554301	2.38058836
	Minimum	11.75	95.36	11.64	10.6138943
	Maximum	109.296	716.22	79.49	18.3461538

Table 4: BSOF parameters derived from air particulates sampled by Anderson sampler with PM2.5 head

Date	Sampler	BSOF in total particulates (mg)	Mass of particulate (mg)	BSOF (µg/m³)	BSOF (% of PM, w/w)
14-Oct-03	AndersonPM2.5	26.106444	192.86	16	13.5364741
15-Oct-03	AndersonPM2.5	8.86	69.4	10.86	12.7665706
19-Oct-03	AndersonPM2.5	21.46	113.89	13.15	18.842743
23-Oct-03	AndersonPM2.5	8.52	75.1	5.22	11.3448735
30-Oct-03	AndersonPM2.5	36.114624	181.44	22.13	19.9044444
3-Nov-03	AndersonPM2.5	45.31	251.36	27.77	18.0259389
27-Nov-03	AndersonPM2.5	58.604	189.46	35.92	18.96
28-Nov-03	AndersonPM2.5	53.75	376.57	32.96	14.2735746
1-Dec-03	AndersonPM2.5	48.22	386.61	29.57	12.4725175
5-Dec-03	AndersonPM2.5	78.3288	365.47	81.19	21.43
		↓	↓	↓	↓
	Mean	38.5273868	220.216	27.477	16.1557137
	stdev	21.42637504	115.1127308	20.3174162	3.45039476
	Minimum	8.52	69.4	5.22	11.3448735
	Maximum	78.3288	386.61	81.19	21.43

amount of benzene soluble organics than the coarser particulate fractions. More importantly since the mass of $PM_{2.5}$ increases absolutely linearly with that of PM_{10} (as evident from the correlation coefficients of the linear fits of Fig. 4), the fact that the finer particles harbor the most toxic organics to a greater extent creates the scope of reduction and control of finer particulates in the air we breadth.

Conclusion

- Particulate matter in ambient air below 2.5 μm dimension is **73 percent of the PM_{10}**
- Anderson air samplers produce steady and representative mass fraction of air particulates both for PM_{10} and $PM_{2.5}$.
- $PM_{2.5}$ fraction of PM_{10} derived from Envirotech samplers produced unacceptable results as in some cases it crossed unity. The fact, that $PM_{2.5}$ sampler samples only a very small (about 1.5%) volume of air compared to PM_{10} sampler, may be the reason for such result. The fact that the pressure drop in the RDS sampler of Envirotech falls much below the set value (after 24 hours of sampling period) could be the other reason also as well. It needs however more experiments for comparison with the results obtained from Anderson samplers that showed very good correlation during this study period.
- Benzene soluble organic fraction (BSOF) comprises about **14.3% of the RSPM (PM_{10}) and 16.1% of $PM_{2.5}$ masses.**
- Highest concentration of BSOF in ambient air is **79.49 μg/m^3** with a range of **11.64 to 79.49 μg/m^3.** The average concentration of BSOF in ambient air is **30 μg/m^3** considering the respirable particles.
- The BSOF percentage in PM_{10} decreases with increase in mass density of the particulates. The same increases with increase in $PM_{2.5}$ mass density in ambient air.
- Finer particles in the Respirable fraction of the aerosol contributes more in respect of toxic and carcinogenic components and thus actions for reduction of finer particulates are necessary.