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VARIATION OF FINE PARTICULATE MATTER IN THE DIFFERENT INDIAN CITIES

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Abstract
Particulate matter is mentioned many times as the most serious pollutant in the cities of India. Hence, the specific objectives of the study were to quantify particulate matters in the atmosphere along with their variations in size and number, over time and space, and to investigate the proportions of PM $_{10,}$ $PM_{2.5}$ and PM_1 in different cities such as Darjeeling, Kolkata, Chandigarh and Delhi. At Darjeeling and Kolkata mass fraction of PM_1 to $PM_{2.5}$ at various sites is above 80 % and 69 % respectively, whereas in Delhi during the day time it is above 40 % .$PM_{2.5}$ and PM_1 fractions are more in Darjeeling and Kolkata which are indicative of the presence of higher mass fractions of fine particulate in these cities.
Keywords: PM_{10}, $PM_{2.5}$, PM_1.

Introduction
Lately particulate matter, and more particularly fine particles <10 µm in size, are getting increasing attention because of their associated environmental and health impacts. Thus, it is imperative to carry out PM measurements in terms of both PM_{10} and $PM_{2.5}$, which can further be extended to $PM_{0.1}$ in the case of specific case studies. For this purpose it is necessary to have continuous real time measurements along with other analytical techniques. The main objective of this preliminary study was the continuous measurement of particulate matters (TSP, PM_{10}, $PM_{2.5}$ and PM_1) in different Indian cities, using dust monitor system (Envirocheck Model 1.107, Grimm Aerosol Technik Gmbh & Co. KG, Germany) with weather housing.

Monitoring and Sampling Technique
Field sampling site
The sampling was carried out during the summer months in the four cities like, Darjeeling, Kolkata, Chandigarh and Delhi. In Darjeeling, the sampling site was Bose Institute, located in the vicinity of valley and mountain. In Kolkata, the sampling site chosen was Victoria Memorial. In Chandigarh, the campus of the Institute of Microbial Technology (IMTEC) was chosen as sampling site for the present study, which is located in the vicinity of small industries. In Delhi, Central Road Research Institute was chosen as a sampling site located on National Highway 2, Delhi-Mathura Road.

Results and Discussion
Continuous measurements of particle concentrations
Results of the particle mass concentrations at each of the cities were obtained as TSP, PM_{10}, $PM_{2.5}$, and PM_1 along with temperature, humidity and wind speed are shown in Table 1.

Table 1: Statistical Summary of Particulate Measurements in Different Cities

Parameters/Cities	Darjeeling	Kolkata	Chandigarh	Delhi
Size (µm)	Unit Mean ± SD(Max,Min)	Mean ± SD(Max,Min)	Mean ± SD(Max,Min)	Mean ± SD(Max,Min)
TSP (µg/m^3)	126± 26(176,11)	131± 73(531,42)	101±48(530,34)	820± 278(1856,512)
PM_{10} (µg/m^3)	77± 14(115,40)	80± 52(323,27)	54±20(147,21)	456± 127(1128,344)
$PM_{2.5}$ (µg/m^3)	47± 7(60,24)	43± 20(127,13)	35±13(80,16)	80±13(111,61)
PM_1 (µg/m^3)	40± 7(52,19)	33± 6(43,8)	27±12(68,11)	32± 5(45,25)
Temperature °C	15± 5(29,10)	31±4.2(39,25)	29±3(38,25)	36±2(48,28)
Humidity %rH	71± 16(95,39)	86±10(97,61)	80±15(98,49)	28± 4(32,15)
Wind speed m/s	0.5±0.3(1.1,0.0)	1.0±0.3(1.6,0.1)	-	0.8±0.4(2.8,0.1)

Diurnal variation of particulate matter

TSP, PM_{10}, $PM_{2.5}$ and PM_1 show the significant diurnal variations in all the cities where measurement were carried out depending on the topographical, climatic, micro-meteorological and other emission sources in the vicinity of the sampling locations. At Darjeeling fine particulates were higher during the evening hours.

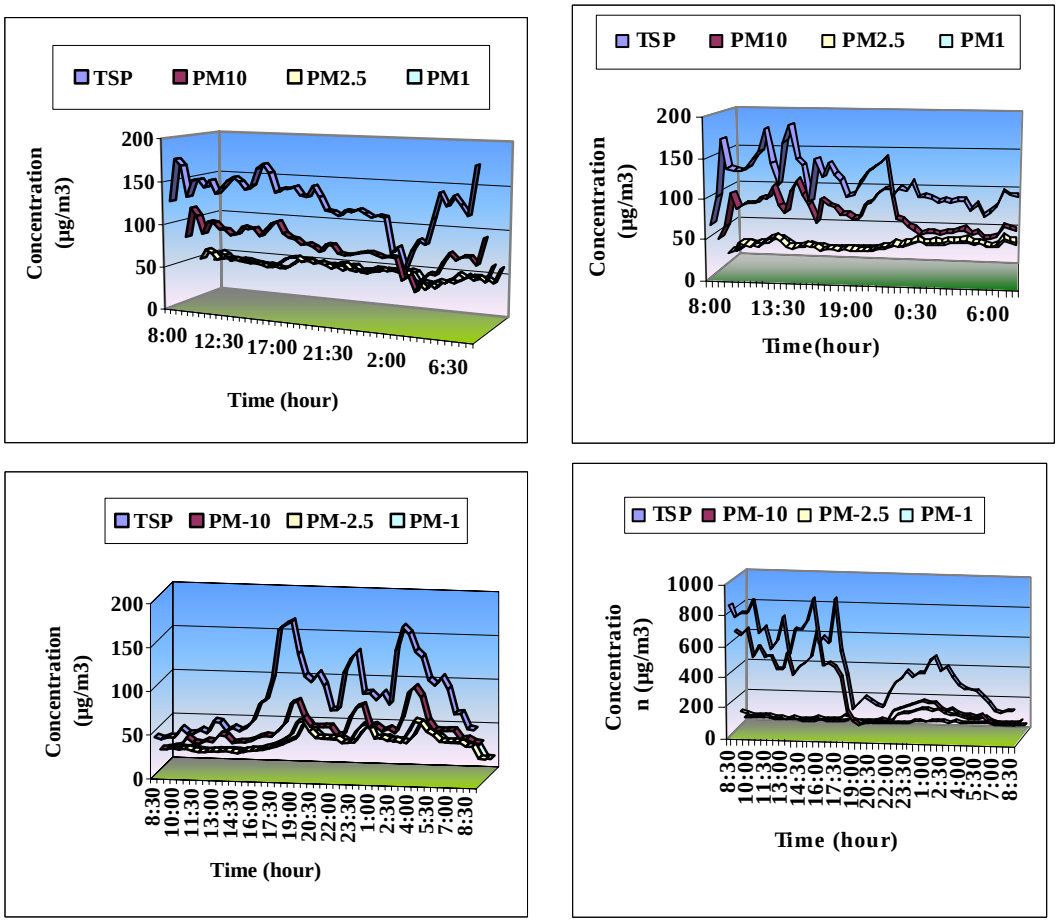

Fig 1(a): Diurnal Variation of Particulates in Darjeeling (b) Kolkatta (c) Chandigarh (d) Delhi

After 01:30 hours in the night-time (18:00 hours to 06:00 hours) sharp dip was observed and again concentrations increased after 03:00 hours in the early morning which may be due to the change in wind speed and mountain-valley circulations (Fig 1a). In Kolkata (Fig 1b) the increase in concentrations of $PM_{2.5}$ and PM_1 was found after 21:00 hours in the night which may be due to transport of sea salt aerosols and agglomeration of the ultra fine particulates from diesel emissions as the humidity increases during the night time. In one

of best architectured city of India, Chandigarh (Fig1c), the concentrations of the particulate matter was lesser than the other observed cities in the summer season. In Delhi the mass concentration of particulates (TSP, PM_{10}, and $PM_{2.5}$) were much higher, because apart from contribution from vehicular and industrial activities, significant amount of soil particles and re-suspended dust are generated by strong winds and construction activities (Fig1d).

Mass percentage of particulate matter

Table 2 for the measured cities indicated the fraction of fine particulate matter to the coarse particulate matter.

Table 2: Particulate Mass Ratio of Different Cities

City	Mass Ratios							
	$PM_1/PM_{2.5}$		PM_1/PM_{10}		$PM_{2.5}/PM_{10}$		PM_{10}/TSP	
	Day	Night	Day	Night	Day	Night	Day	Night
Darjeeling	0.850	0.856	0.517	0.566	0.607	0.661	0.606	0.573
Kolkata	0.718	0.712	0.226	0.407	0.315	0.563	0.635	0.587
Chandigarh	0.719	0.812	0.419	0.532	0.581	0.654	0.648	0.512
Delhi	0.588	0.836	0.205	0.467	0.346	0.533	0.683	0.400

Regression Analysis

3.4.1 Correlation between meteorological parameters and PM concentration

Correlation between meteorological parameters and PM concentration was also found, so to understand there chemistry, dispersion and dilution in the atmosphere.

3.4.2 Multivariate analysis

Multivariate analysis was performed and it was found that as we proceed from univariate model to bivariate model and than to multivariate analysis, the regression coefficient (R^2) keep on increasing. For high R^2 accuracy is high and error is least.

3.4.3 Model Validation

Different model validation methods were applied to observed and predicted concentration of PM and meteorological parameters, which define the possible fate of pollutants in the atmosphere for all the four locations.

Conclusions

Continuous hourly measurements of particulate as has been carried out in four different cities in India, elucidate the diurnal variation of the concentration. In Darjeeling and Kolkata, the total mass concentrations were higher during the day time and the mass fraction of coarse and fine particulate were more or less similar during the day and night time in Darjeeling but varies significantly in Kolkata. In Chandigarh, particulate mass concentrations were higher during the night time, whereas in Delhi fine particulates were higher during the night time. Average mass concentration of fine particulates ($PM_{2.5}$) was found to be higher in Delhi whereas PM_1 concentrations were observed to be higher at Darjeeling and Kolkata. The concentration of all particulate matter was observed to be lesser in Chandigarh. This preliminary study with limited data shows potential of using particulate data from continuous measurements to address certain policy issues.

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