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Spatial and Temporal Variation of Particulate Matter with Height in Residential and Sand Mining Areas in Ganjam district of Odisha, India

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Abstract

Particulate Matter concentrations were analyzed from Ganjam district of Odisha during January – December, 2010.The average concentration of PM_{10} in sand mining area at 1 and 4 metre height were observed to be 56.6±2.2 and 34.0±5.0 $\mu g.m^{-3}$respectively.The seasonal variation of SPM and PM_{10} levels at study sites are visible in the order of winter > summer > rainy season. The PM_{10} levels in the month of January and February were lowest as compared tothe whole year of 2010.This may be due to dew factor in the winter season. After the apportionment, it is found that even though the SPM concentrationsare well below the standards set bynational environmental agency,PM_{10} concentrations also appears to be well within the limit. However, there are obvious differences in the occurrence time of the minimum concentration among of particulate matters. The differences in the occurrence time of minima between SPM and PM_{10} are due to their diffusion behaviour in the atmospheric boundary layer.

Keywords: Air pollution, SPM, PM_{10}, variation.

Introduction

Particulate matter is a prominent air pollutant in most of the Indian cities. Particulate matter size generally ranges from 0.01 to 100 µm. Based on size, Particulate matter can be defined as Suspended particulate matter (SPM), and PM_{10} particle with aerodynamic diameters of less than 100 and 10 µm respectively. Concentration of these in atmospheric environment of urban centers is found to be exceeding the national and international guideline / prescribed limits forming a major air pollution problem[1].

The increase in particulate pollution is a potential human health risk particularly, respiratory system[2, 3]. Although its content in the atmosphere is very limited, particulate matter attracts more and more attention due to its important role in atmospheric processes. Particulate matter can affect air quality, human health and climate changes directly and indirectly. Particulate matter toxicity may change due to seasonal shifts in composition or particle size distribution that, in turn, affect respiratory deposition efficiencies[3].

In recent years the role of desert particulate matter has become increasingly important not only in global climate change[4]but also in human health[5]. Recently, particulate matters are usually studied by observing particulate matter in the atmosphere. Natural particulate matter come from volcanoes, dust storms, grassland and forestfires, spores and pollen released by salt and plants particles from breaking waves[6]. Anthropogenic sources related to industrialization, urbanization and exploitation of natural resources also generate aerosols such as dust, haze, smoke and rain and fog droplets.

In this study, the concentrations of two kinds of particulate matter have been simultaneously observed during January – December, 2010 in Odisha, India. The present study is also to detect seasonal and annual variation of the concentration of particulate matter in different sizes and height, correlation studies and environmental impact assessment on the particulate matter concentration in Odisha, India.

Material and Methods

Study area: Orissa Sands Complex has mineral separation plant for the separation of valuable rare earth elements and other chemical plants for processing and separation of thorium. Beach sand of Bay of Bengal is the raw material, which contains many minerals of rare earth elements, thorium, titanium and zirconium. Various physical properties such as electrical conductivity, magnetic susceptibility, surface characteristics, specific gravity etc. of the minerals are used for the separation of these constituents. The important minerals obtained from the mineral separation plant are ilmenite, rutile, monazite, zircon, sillimanite and garnet. The latitude and longitude of the place are 19^0 18' (North) and 84^0 57' (East), respectively.The sampling location is shown in Fig. 1.In the present study, suspended particulate matter and $PM_{10}$are collected around OSCOM. The spatial and temporal variation of SPM and PM_{10} with correlation studies and environmental impact assessmentin the atmospheric environment around Orissa Sand Complex are given here.

Sample collection: The sampling was carried out from January – December, 2010 by High Volume Air Particulate sampler for SPM and PM_{10} (Polltect make). The average flow rate of suction pump was maintained at $1m^3$/minute. The sampling were carried out for 24-h. The sampling substrate used was 10×8 inch glass fiber filters, due to its high efficiency. In addition, air particulate load was measured using a microbalance (Sartorius, CP225D). The filter papers were weighed under controlled conditions of temperature and humidity after and before collection of particulate matter. Prior to weighing, all filter papers were left to equilibrate their humidity (around 50%) and temperature conditions (25 ±1°C) for at least 24 hours. The collected particle mass was calculated by subtracting after and before weight of the filter papers.

Results and Discussion

Variation of SPM and PM_{10} concentrations: Particulate matter concentration data measured inresidential and sand mining areas of Ganjam district of Odisha during January – December, 2010 as shown in table 1. The ratios between PM_{10} and SPM are stablethen the quality of the data can ordinarily be assured.The data ratios have relatively stable seasonally. The ratios between PM_{10} and SPM in residential area varying from 0.32 – 0.45 at 1 metre height, 0.22 – 0.33 at 4 metre height and 0.17 – 0.21 at 7 metre height. Similarly, the ratios between PM_{10} and SPM in sand mining area vary from 0.31 – 0.36 at 1 metre height and 0.22 – 0.27 at 4 metre height. In case of sand mining area, sampling was carried out only at 1m and 4m height as there are no activities or population were not occupying the heights more than four metres (table 1).

Table-1
Ratio between PM_{10}/SPM of Monthly Average Concentration with Heights

	Residential Area			Sand Mining Area	
	1 Metre	4 Metre	7 Metre	1 Metre	4 Metre
Jan	0.35	0.22	0.17	0.31	0.22
Feb	0.32	0.24	0.19	0.29	0.21
Mar	0.33	0.20	0.21	0.32	0.21
Apr	0.44	0.23	0.16	0.36	0.26
May	0.43	0.25	0.17	0.34	0.26
Jun	0.42	0.31	0.19	0.35	0.24
Jul	0.45	0.33	0.21	0.34	0.20
Aug	0.43	0.28	0.20	0.32	0.20
Sep	0.45	0.29	0.21	0.35	0.27
Oct	0.38	0.25	0.20	0.36	0.22
Nov	0.43	0.26	0.18	0.34	0.25
Dec	0.43	0.26	0.20	0.33	0.23

There are some differences in the annual distribution of the concentration of particulate matter with height. The annual distribution of the average concentration ofSPM in residential area was observed to be 112.9 – 140.1 $\mu g.m^{-3}$ at 1 metre height, 120.3 – 139.2 $\mu g.m^{-3}$at 4 metre height and 130 – 139.6 $\mu g.m^{-3}$at 7 metre height respectively. Similarly, the annual mean concentration of SPMin sand mining area was observed to be 170±7.5 $\mu g.m^{-3}$at 1 metre height and 146±2.9 $\mu g.m^{-3}$at 4 metre respectively (table 2). In table 3, theannual mean concentration of PM_{10}in residential area at 1, 4 and 7 metre heights were found to be 48.9 ± 4.7, 33.6±5.3 and 25.9±2.9 $\mu g.m^{-3}$ respectively. Similarly, the annual mean concentration of PM_{10} in sand mining area at 1 and 4 metre heights were found to be 56.6±2.2 and 34.0±5.0 $\mu g.m^{-3}$ respectively.

Table-2
Annual Average Concentration ($\mu g.m^{-3}$) of SPM in Heights

	Residential Area			Sand Mining Area	
	1 Metre	4 Metre	7 Metre	1 Metre	4 Metre
Minimum	112.9	120.3	130.1	163.8	140.5
Maximum	140.1	139.2	139.6	185.2	149.4
Mean	121.4	129.2	134.6	170.1	146.8
Standard Deviation	7.7	7.3	3.6	7.5	2.9

Table-3
Annual Average Concentration ($\mu g.m^{-3}$) of PM_{10} in Heights

	Residential Area			Sand Mining Area	
	1 Metre	4 Metre	7 Metre	1 Metre	4 Metre
Minimum	36.2	25.9	21.1	52.6	29.8
Maximum	53.8	42.6	29.8	59.3	40.0
Mean	48.9	33.6	25.9	56.6	34.0
Standard Deviation	4.7	5.3	2.9	2.2	3.5

In India, mostly three seasons are experience predominantly i.e. summer, rainy and winter. For this area, March, April, May and June months can be termed as summer season, July, August, September and October as rainy season, and November, December, January and February as winter season. The twelve months divided into these three seasons and seasonal variation of SPM and PM_{10} levels at both residential and mining areas are shown in figure 2. The impact of different seasons on SPM as well as PM_{10} level is visible from thisFig. i.e. winter > summer > rainy. In winter season, due to temperature inversion, dry condition and low humidity, the SPM and PM_{10} levels are higher as compared to other seasons. In summer season, due to higher temperature and mixing height, the SPM and PM_{10} levels were lower. The values are lowest in the rainy season due to removal of particulates due to precipitation. Shaofeireported that for a coastal site of Tianjin, China, SPM and PM_{10} maximum levels were observed in autumn, followed by summer and winter seasons. This is due to thermal inversion and fog situations on ground levels causing accumulation of air pollutants[7]. For an urban site like Hyderabad and Chennai city, India, the average PM_{10} levels were observed maximum in winter, followed by monsoon and summer[8,9]. Similarly trends (i.e. winter > summer > rainy) were also observed in an urban and rural site around Agra city, India for PM_{10}[10].

Variation of Spatial and temporal of SPM and PM_{10} was studied in the present study. Therefore sampling of SPM and PM_{10} was carried out with increasing heights i.e. 1 metre (1m), 4 metres (4m) and 7 metres (7m). As the study site was a rural site, either single storied or double storied houses were occupied by the members of the public residing around the site. Therefore, to make a realistic assessment of the distribution of particulate matter content in atmospheric environment such heights were selected i.e. ground floor (1m), first floor (4m) and second floor (7m) were selected in the residential area. But in case of mining area, sampling was carried out only at 1m and 4m heights as there are no activities or population were not occupying heights more than four metres. Monthly average variations of SPM and PM_{10} levels with increasing height at residential and mining area are graphically represented in figure 3 and 4. It is evident that the PM_{10} level at 1m height is marginally less than 4m and 7m height. Similar observations were reported[11,12]. PM_{10} levels in the month of January and February were lowest as compared to other month. This may be due to dew factor in the winter season.

Correlation study was carried out on SPM and PM_{10} fractions in the study area. Correlation coefficients between various components are indicators of possible common sources. Elements which are strongly correlated at a receptor site indicate a like hood of similar originating source or transporting agencies from source to receptor site. The Pearson correlation of $PM_{10}$is better correlated with increasing height as compared to SPM.

Environmental impact Assessment: The adverse environmental effects of aerosols are well recognized. Though both thenatural and anthropogenic aerosols contribute to degradation of visibility and other optical and radioactive effects, it is the anthropogenic source that is more relevant for air qualityassessment from the health perspective and also to adopt and plan mitigation strategieswhen its level reaches dangerously high. Examining from this perspective, it is theexposure to the respirable particles (PM_{10}) that is responsible for observed association ofparticulate matter induced health related problems. In India, Central Pollution Control Board has recommended National Ambient Air Quality Standards limit values for PM_{10} as 100 $\mu g.m^{-3}$ for a 24-h average and $60 \mu g.m^{-3}$ for the annual meanconcentration to reduce the human healthrisk. These standards of mass concentration are set at 50% relative humidity. In figure 5, the distribution of the frequency of occurrence of $PM_{10}$is shown in database insteps of $5 \mu g.m^{-3}$. The distribution is skewed, spanning a range from 21.1 to$55 \mu g.m^{-3}$, with the values lying in the range 35.1 to $40 \mu g.m^{-3}$. Consideringthe entire database of 12 months the mean valuewas $36.1 \mu g.m^{-3}$for PM_{10} and $128.4 \mu g.m^{-3}$ for SPM in residential area. Similarly, that the mean value was $45 \mu g.m^{-3}$ for PM_{10} and $158 \mu g.m^{-3}$ for SPM in sand mining area, which are high, in case of PM_{10}. However, most of theenvironmental standards are specified for fixed Relative humiditycondition (RH = 50%), whereas themeasurements relating to this work are for the ambient RH conditions. So, these have to be reduced to thereference RH level, before a proper assessment is made, particularly, because the coastalaerosols are hygroscopic.

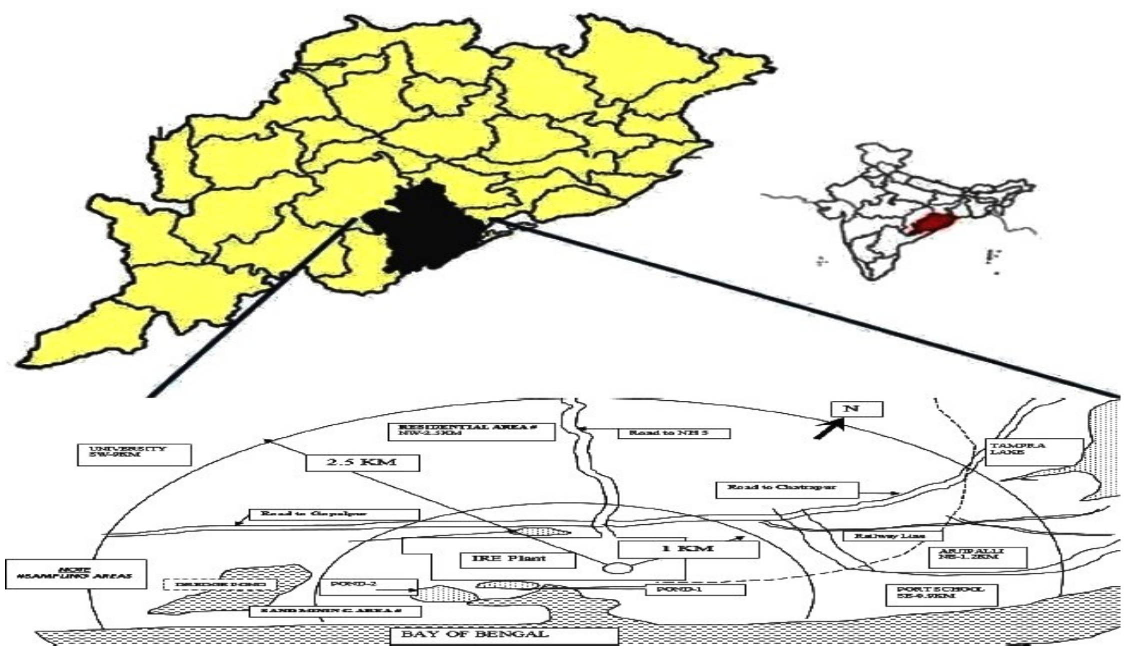

Figure-1
Map of the sampling location

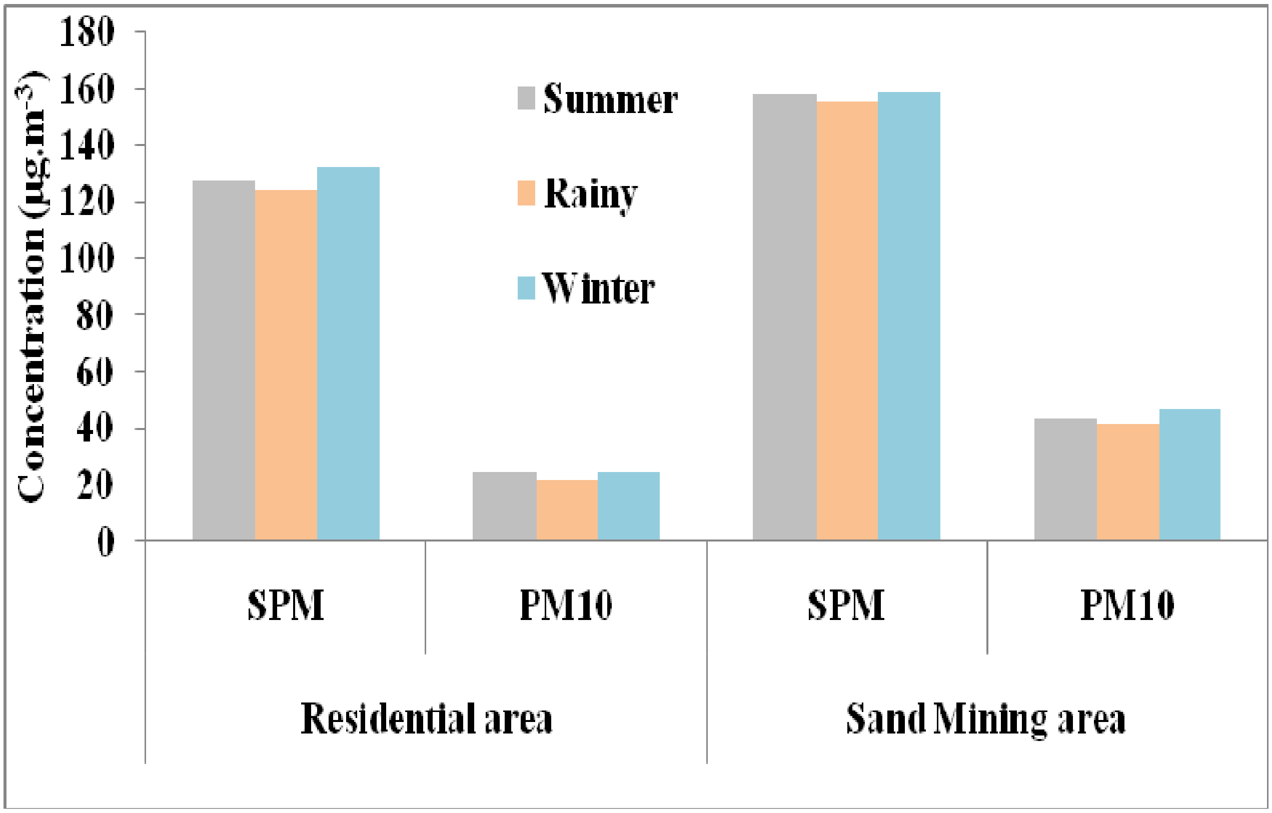

Figure-2
Seasonal Variation of SPM and PM_{10} in Residential and Sand Mining Area

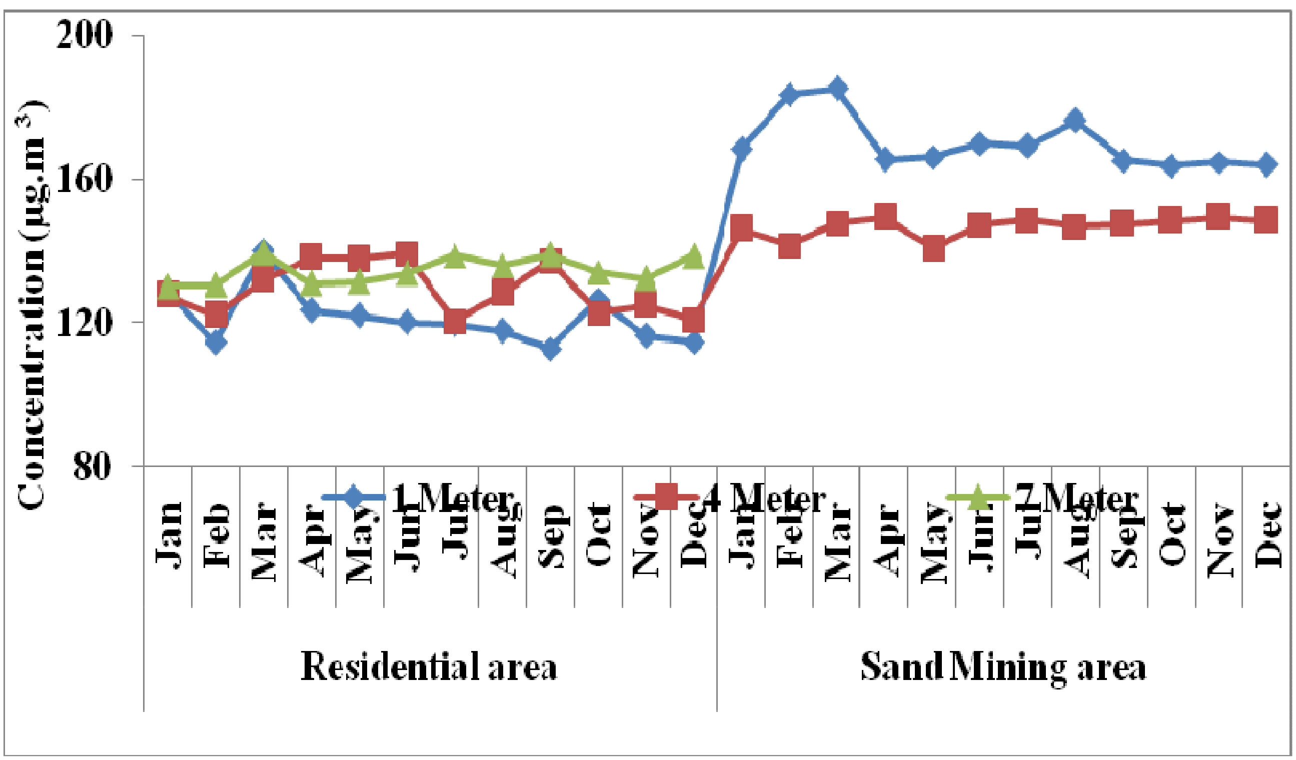

Figure-3
Monthly Variation of SPM with Heights

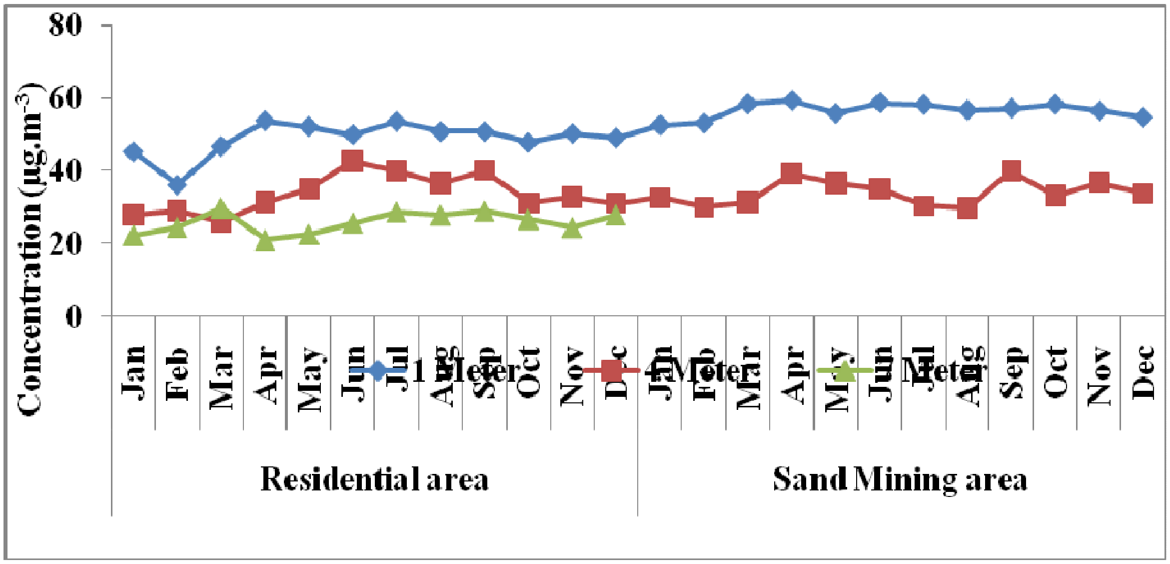

Figure-4
Monthly Variation of $PM_{10}$with Heights

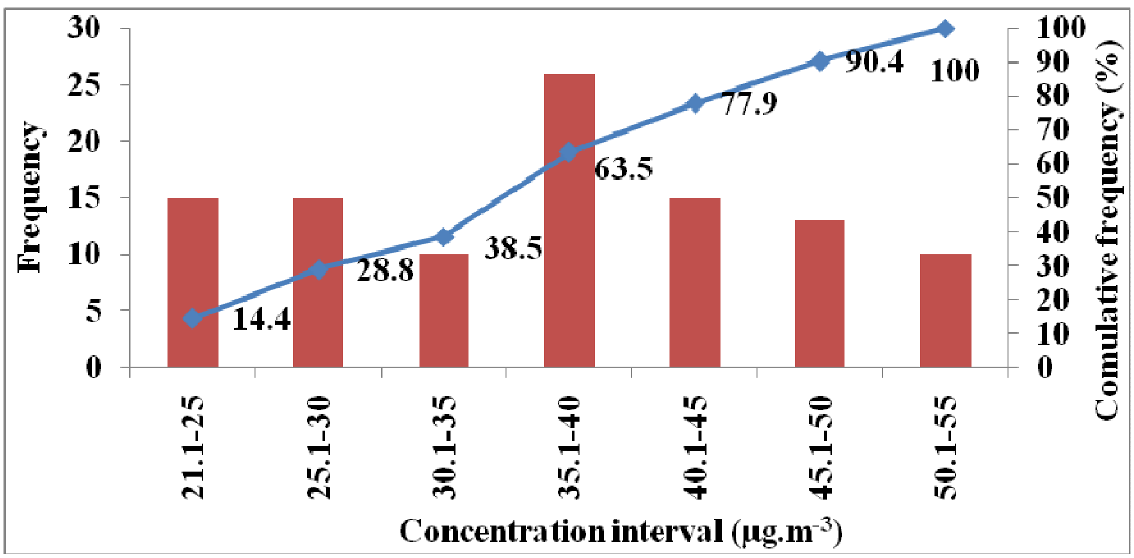

Figure-5
Frequency of Occurrence PM_{10} Concentration in Residential Area

Conclusion

Based on the study, the following conclusion aredrawn – i. The ratios between PM_{10} and SPM in residential area vary from 0.32 – 0.45 at 1 metre height, 0.22 – 0.33 at 4 metre height and 0.17 – 0.21 at 7 metre height. Similarly, the ratios between PM_{10} and SPM in sand mining area vary from 0.31 – 0.36 at 1 metre heightand 0.22 – 0.27 at 1 metre height. ii. The annual distribution of the average concentration of SPM in residential area is observed to be 112.9 – 140.1 µg.m^{-3} at 1 metre height, 120.3 – 139.2 µg.m^{-3}4 metre height and 130 – 139.6 µg.m^{-3} at 7 metre height. iii. The seasonal variation of SPM and PM_{10} levels in residential and mining areasare visible in the order winter > summer > rainy. iv. The distribution of PM_{10} is skewed, spanning a range from 21.1 - 55 µg.m^{-3}, with the values laying in the range 35.1 - 40 µg.m^{-3}.

Finally, it must be pointed out that the effects of different weather processes and their relevant environmental impacts on particulate matter concentrations should be different. In order to fully understand this problem, the behaviour of particulate matter concentration during certain typical weather processes need to be studied in the future.

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