Status of Particulate Matter in Industrial city Bhilai

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ABSRACT

The atmospheric concentration of the particulate trace elements was determined at specially chosen reference sampling station located at Bhilai (C.G.), which is an urban industrial location. Sampling site was free from any near source effect. Twenty-four hours particulate samples were collected twice in every month by a high volume sampler on a glass micro fiber filter paper between November 2006 to October 2008. The samples extracted by employing an automatic digestion system. Moreover, collected particulates were determined in samples by various methods. Monitoring of the total pollutants showed that the concentration of respirable particulate matter (RPM) was more than suspended particulate matter (SPM). The level of many trace elements was higher than obtained in various other parts of the world. Aluminium, zinc, iron, sodium, potassium and copper dominate the trace composition and reaching abnormlly high level. The intend of this paper is to assessment and standard monitoring of SPM, RPM heavy and toxic metals present in the SPM and RPM in the ambient air and in rain wter samples. This topic is very broad, briefly concerned with the different toxic metals, its health effects and regular monitoring.

Key Words: Contamination, Respirable Particulate Matter (RPM), Suspended Particulate Matter (SPM), Total Suspended Particulate Matter (TSPM), Heavy metals and toxic metals.

INTRODUCTION

The Earth is one of the eight planets orbiting the sun. It holds environment with various life saviour gases, plenty of water and land. These things provide all-important circumstances for survival of life. The atmosphere is a blanket of gases, suspended liquid and solids that entirely envelops the earth. It is a dynamic system, which steadily absorbs various pollutants from natural as well as manmade sources, thus acting as a natural sink. The atmospheric air is a colourless, odourless and tasteless mixture of gases consisting mostly of nitrogen (N_2) and oxygen (O_2), where humans and all other animals breathe in order to obtain the oxygen needed to sustain life.

Contamination

"Contamination is the presence of substance in any segment of the environment in excessive concentration that adversely affect the well-being of the individual organism or cause damage to property"[1]. Contamination of environment has mainly caused by particulate, which are classified according to their size as follows:

Coarse particulates (PM_{10}-$PM_{-2.5}$).
Fine particulates ($PM_{2.5}$-$PM_{0.1}$).
Ultrafine particulates ($PM_{<0.1}$).

The environment of Bhilai has still getting contaminated from various sources of pollution as discussed below.

- **Emission from integrated steel plant**

An integrated steel plant is working at Bhilai and producing large quantity of steel by using blast furnace. This excellent plant has the capability of producing various by-products by various units. These units are emitting various types of pollutants by different ways such as stack emissions, fugitive emissions, cancer causing emissions, water pollutants, solid wastes etc.[2]. Thus, Bhilai Steel Plant is the main factor for the deterioration of quality of environment of this area.

- **Pollution potential of the foundries**

There are numerous foundries are working in and around Bhilai. The stacks are not heighted in these foundries, which cause the dispersal of the smoke and fume approximately the work area. The atmospheric pollutants are generally the particulate matters (dust, fly ash etc.) and the gaseous pollutants (SOx, NOx, CO etc.)[2].

- **Emission from vehicles**

The increasing number of vehicles is a matter of great concern as it adds to the ever-increasing pollution problem. Total no. of vehicles are 2.1 lakh, out of which 1.3 lakh two wheelers, 70,000 big cars, and 10, 000 lightweight cars have been registered in twin city (data collected from city reporter Dainik Bhaskar daily news paper 1/11/2010). Adulterate of fuel and fuel products result in high emissions from vehicles.

In recent years, atmospheric particulate aerosols have been under intense consideration. Review of literature reveals that many studies concerning the air pollution have reported recently. The number of researches and their publications has added a new dimension in this area. Particulate matter especially the RPM, is more dangerous for human health and responsible for several cardiovascular and respiratory diseases[3-12]. About 7,34,000 tones of heavy metals are released into the atmosphere, 1,108,000 tonnes of heavy metals in water, and 6,209,000 tonnes of heavy metals enter the soil every year worldwide[13]. Uncontrolled emissions from electric arc furnaces are also reports to pollute the environment[14].

Major and trace elements

About ninety elements have been detected in the earth crust, out of which a mere nine elements (viz. Al, Fe, Ca, Mg, O, Si, Na, K, and Ti) only account for over 99% by weight. These elements are called major elements[15].

A term trace elements commonly used to describe substances, which cannot be precisely defined, but most frequently occur in the environment in concentration of a few ppm or less[13]. These elements occur in living tissues in such minute amounts that the early workers with the analytical techniques then available could not measure their precise concentration. About 40 elements (metals and non-metals) detected in living organisms, about 30 of them seem to be highly essential for the higher animals and humans it will become toxic at a little higher level. Sixteen trace elements have been identified as being essential for good health. These, collectively, have five general physiological roles:

- Bone and membrane structure
- Water and electrolyte balance
- Metabolic catalysis
- Oxygen binding and transport
- Hormone effects

Some of the body symptoms affected more severely in a poisoning situation by different chemical pollutants. The target organs affected by different heavy metals pollutants reported in Table-1[15].

Table 1: The target organs affected by heavy metal pollutants

S. No.	Heavy metal pollutants	Target organs
1.	(As), Hg, Mo, Se	Liver
2.	(As), Hg, Cd, Pb	Blood

3.	(As), Hg, Pb	Brain
4.	(As), Hg, Cd	Lungs
5.	(As), Hg, Pb, Cd	Kidney
6.	Cd, Se	Bones and teeth

Toxic metals

Toxic metals form poisonous soluble compounds and have no biological role, some heavy metals are toxic, but a few of them are essential, have a low toxicity and some are non-toxic. Oxidation state of a metal also decides its toxic behavior. Such as chromium(III) is essential nutrient for human beings in traces but chromium(VI) reported to be carcinogenic. Toxicity is also a function of solubility. Insoluble compounds as well as the metallic forms often exhibit negligible toxicity. Various sources are responsible for environmental pollution due to the presence of toxic metals in effluents that are released from various industries presenting in Table-2[15].

Table 2: Heavy metals found in the effluents from some major industries

S. No.	Industry	Heavy metals present in the effluents
1.	Chlor alkali	Cd, Cr, Cu, Pb, Zn, Hg, Se.
2.	Electroplating	Cu, Cr, Zn, Ni
3.	Leather	Cr
4.	Batteries	Pb, Cd, Hg.
5.	Paints and dyes	Cd, Cr, Cu, Pb, Hg, Se.
6.	Textile	Cr
7.	Paper and pulp	Hg
8.	Petroleum	Cd, Cr, Cu, Pb, Zn.
9.	Fertilizers	Cd, Cr, Cu, Pb, Zn, Hg, Mn, As.
10.	Motor vehicles	Cd, Cr, Pb, Hg, Se, Zn.
11.	Pharmaceuticals	As, Hg
12.	Mining and metallurgy	As, Hg, Cd, Cu, Se
13.	Explosives	As, Hg, Cu, Pb
14.	Pesticides	As, Hg, Se, Pb

Effect of RPM in heavy metals on human being

The effect of Particulate matter depends on the mass shape and size, the composition and concentration of other inorganic and organic pollutants associated with it. Correlation of metals showed that the RPM has significant correlation with metals like Pb, Mn, Cu and Cr, this indicates that the same sources might be due to the vehicular pollution[16].

In addition to this a great research has been done to analyse the deteriorating condition of environment, factors responsible for it, and the way it is going to harm the ecosystem, the threat it's going to pose to our future generations. It is very well prominent from the listed references. Pollution from CO, aerosol, SO_2 and NO_2[17,18,19,20,] pollution from SPM, RPM, Lead, metallic pollutants, acid rain[21,22,23,24,25,26,27,28,29,30,31,32,33,34].

Exposure can occur from various routes; but Inhalation of particles (<10 µm) is one of the important routes. The inorganic components constitute a small portion by mass of the particulates; however, it contains some trace elements such as As, Cd, Co, Cr, Ni, Pb and Se, which are carcinogen even in trace amounts[35,36,37]. Here some harmful effects of heavy metals having PM are showing below.

- The increased heavy metal exposure constitutes a direct risk for people with asthma, metal allergies and chemical sensitivities. Infants and children are particularly vulnerable and may suffer permanent damage.
- Heavy metal overload can lead to unresponsiveness of diabetics to their medications. Heavy metal overload can lead to neurological diseases such as depression and loss of thinking power.
- It can also aggravate conditions such as osteoporosis and hypothyroidism. For obvious reasons, removing metals from the body safely has been a concern of physicians for many years.
- Chronic symptoms frequently associated with excessive accumulation of heavy metals include fatigue, musculoskeletal pain, neurological disorders, depression, failing memory, and allergic hypersensitivity. Heavy metals disrupt a vast array of metabolic processes.
- Most heavy metals are readily transferred across the placenta, found in breast milk, and are well known to have serious detrimental effects on behaviour, intellect and the developing nervous system in children.

METHODS AND MATERIALS

Common explanation of the study region

The twin city of Bhilai-Durg (81.2^0 E longitudes, 21.3^0 N latitudes, and M.S.L. 380 meters) is situated in Mahanadi (Great River) basin in Chhattisgarh (India). Durg district is one of the urbanized industrial districts among the total 27 districts of Chhattisgarh. According to the census of 2001, it had a population of 753,837. The city is located 35 km. west of the capital Raipur, on the main Howrah–Mumbai rail line, and national highway 6. There are a large number of industries located in this twin city with a large manufacture capacity. One large integrated steel plant, refractory plant, host of metal working industries, cement mills, chemical industries, timber, cotton, plastic, rubber, glass, coal and a great number of small-scale industries in different area of operation are located here.

The residents and a large volume of transport activities through and in the area and large number of industries are liable for ever increasing pollution load on urban air in this city. As per the Comprehensive Environmental Pollution Index (CEPI), Bhilai-Durg is the severely polluted areas in Chhattisgarh after Korba and Raipur.

Meteorological details of site

Bhilai has a classic humid monsoon climate with very scorching summer intense rains and sound cold in winters. During the study period, a highest temperature of 48.3^0C recorded in May and the least possible temperature of 11.5^0C was in January. Maximum rainfall and comparative humidity have noticed in the monsoon season from June to September. Lower atmospheric pressures and subsequently higher wind speed (>21-61 Km/h) have been observed in the summer- rainy season (May – September). The meteorological data also shows that the most predominant wind direction in south-west (17%) and west (14%) during the rainy season: northeast (12%) and north (9%) during the rest of the year. Percentage of calm has been distinguished on 32% days of the year[2].

Study area and sampling site

The sampling site BIT as shown in Figure-1 chosen at Bhilai house located at the threshold of Durg city besides NH-6 or grand eastern highway GE road in Chhattisgarh state (India). The whole area covers 0.28 sq. Km area. The BIT is located in this premises and one of the buildings used as sampling location. The size fractionated sampling device kept on the roof at a height of 10 meter.

Sampling of air

Sampling of air was carried out at Bhilai Institute of Technology Bhilai house Durg. The station was selected keeping the population density and wind directions under consideration in order to obtain a representative sample. The high volume sampler (Figure-2) at BIT kept on the rooftop at a height of about 10 meter in order to reduce the likelihood of larger particulate collection. Ambient air samples were collected using high volume air samplers during a period of 24 hours. Sampling was carried out from November 2006 to October 2008 at least twice in each month at the location. The frequency of sampling was somewhat less during the rainy season. The samples collected on what- man glass micro fibre filter papers GF/A 20.3 x 25.4 cm. After loading, the filter papers they were kept in desiccators and weighed by digital electronic balance.

Figure 1: Location of Bhilai Institute of Technology

Sampling of ambient air for collection of SPM and RPM was carried out as per Indian Standard 1S: 5182 (part IV)-1973. The larger particles were collected in a cyclone and the smaller fractions captured through the filter paper. Filter papers having RPM and SPM samples digested by aquaregia on a hot plate in beaker covered with watch glasses. After complete digestion the samples were filtered by glass micro fibre filter papers and then diluted up to 50 ml volumetric flask by 1:1 HCl.

Figure 2: High volume sampler

Analytical procedures

Various equipments are used for the analysis of different metals. Fast Sequential Atomic Absorption Spectrometer (AA240FS) (Figure-3) analyzed most of the elements. This spectrophotometer was controlled by Varion's innovative AA worksheet software. The system has been designed with four hollow cathode-lamps with the capability that detects four elements at a time while conventional AAS detect only once. The wavelength of desired element has been achieved by high-speed wavelength drive operating under intelligent software control. The samples were only aspired once and all elements were measured before progressing to the next sample. The system improves precision and accuracy with online internal standard correction.

Some other equipment was also used such as turbidity meter, ion selective electrode meter and flame photometer (TMF 4) for determining sulphate, fluoride, sodium and for potassium respectively. Simple visible spectrophotometer with a range of wavelength between 340 nm to 960 nm was use for elemental analysis that was not amenable to AAS like aluminium, nitrate, arsenic (Gudzet method).

Figure-3 Fast Sequential Atomic Absorption Spectrometer

RESULT AND DISCUSSION

Status of ambient pollution in various environmental matrices
The atmospheric concentrations of SPM and RPM in the air for the period of two years are explained through graphs and tables.

Annual involvement of pollutants in study area
Annual average of RPM was found 191.37µg/m^3. The seasonal variation of RPM during winter, summer and rainy season ranges from 195.62 to 510.65, 76.25 to 130.19 and 42.91 to 104.16 µg/m^3, respectively (Table-3). There is a wide range of variation in the SPM concentration in the study area. Annual average of SPM has been found 87.69 µg/m^3. The seasonal average variation of SPM during winter, summer and rainy season ranges from 59.88 to 116.66, 51.09 to 132.77 and 49.72 to 95 µg/m^3, respectively. The seasonal average variation of TSPM during winter, summer and rainy season ranges from 255.50 to 627.31, 127.34 to 262.96, and 92.63 to 199.16 µg/m^3, respectively.

Table 3: Annual involvement of pollutants in the study area

Pollutants	Annual (µg/m^3)		Winter (µg/m^3)		Summer (µg/m^3)		Rainy-season (µg/m^3)	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
RPM- (PM_{10}& < PM_{10})	510.65	42.91	510.65	195.62	130.19	76.25	104.16	42.91
SPM- (>PM_{10})	132.77	49.72	116.66	59.88	132.77	51.09	95	49.72
TSPM -(RPM + SPM)	643.42	92.63	627.31	255.50	262.96	127.34	199.16	92.63

Annual elemental distribution in TSPM at the monitored sites (TSPM = SPM+RPM)

Collected data represented that average concentration of (TSPM) varied from 127.77 in the month of April and 570.55µg/m^3 in October. Figure-4 representing the higher TSPM found in the month of October. Almost all the elements have shown higher enrichment factor values. For RPM, metal concentration higher spatial variability values obtained than SPM metal[31 &38.].

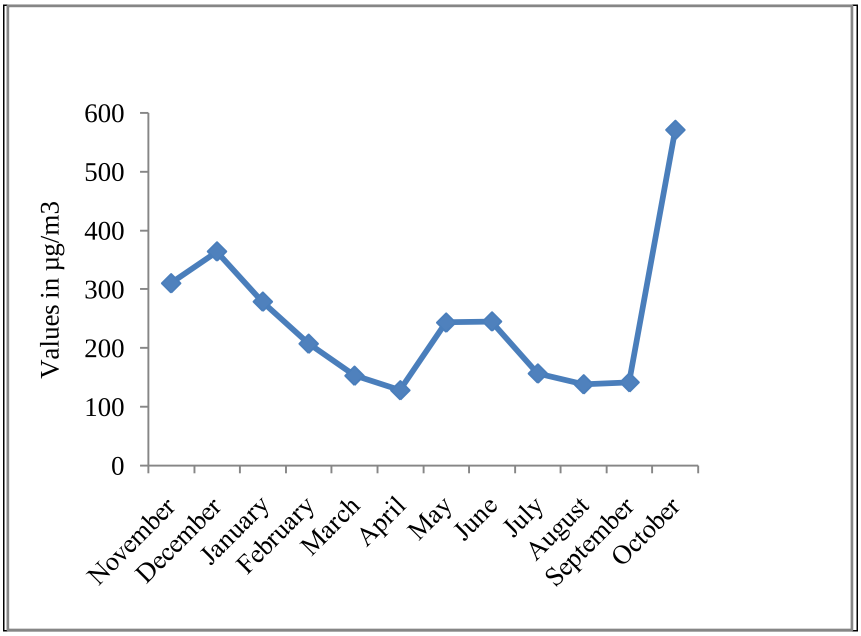

Figure 4: Monthly distribution of total particulates in Bhilai

Suspended particulate matter (SPM)

It is noticed that maximum SPM was found in summer season during the month of May but minimum SPM level noticed in the rainy season in the month of September. The results found from elemental analysis of SPM are presented by Table-4 and Figure-5. it is shown that zinc, copper, aluminium, iron, and fluoride were present in high level in winter as well as in summer season. Aluminium and silica are soil-originated elements so it shows high concentration in summer season. In the summer season, SPM loaded with high nickel and sulphate than other season. Presence of Arsenic was in negligible amount in winter season whereas Cd, Cr, Mn, Pb found in countable amount in SPM. High concentration of Fe, Zn, Cr, and Mn in winter season in SPM shows these affected from industrial effluents. SPM values in winter at most of the sites and in summer at few sites are exceeding the prescribed standards[39]. A trend of elements in SPM represents Al>F^->Zn>Fe>Cu>SO_4^{-2}>Na>Cr>K>Ni>Pb>Mn>Cd>As in winter season. Whereas In summer season, SPM gave different trend such as Al>Fe>SO_4^{-2}>Ni>Zn>Cu>K>Na>Pb>Cd>Mn>Cr~F^->As. The SPM concentration observed was higher than the permissible limits for sensitive area.

Table 4: Annual trace elemental distribution in SPM in study area

Elements in SPM	Winter (ng/m^3)		Summer (ng/m^3)	
	Max.	Min.	Max.	Min.
Cd	0.06	0	2.08	0.04
Cu	68.04	1.04	56	2.29
Zn	363.12	0.46	178.35	8.97

Cr	8.78	0.38	1.86	0.29
Mn	3.24	0.99	2.75	1.00
As	0.21	0.01	0	0
Fe	91.88	15.36	261.55	81.89
Al	955.3	74.82	749.36	28.49
Na	15	1.8	19.39	3.61
K	6.51	0.46	22.99	2.37
Pb	4.20	1.24	10.79	0.62
SO_4^{-2}	71.48	1.61	199.07	7.07
F^-	371.39	0.11	1.89	0.13
Ni	4.43	0.34	126.3	0.77

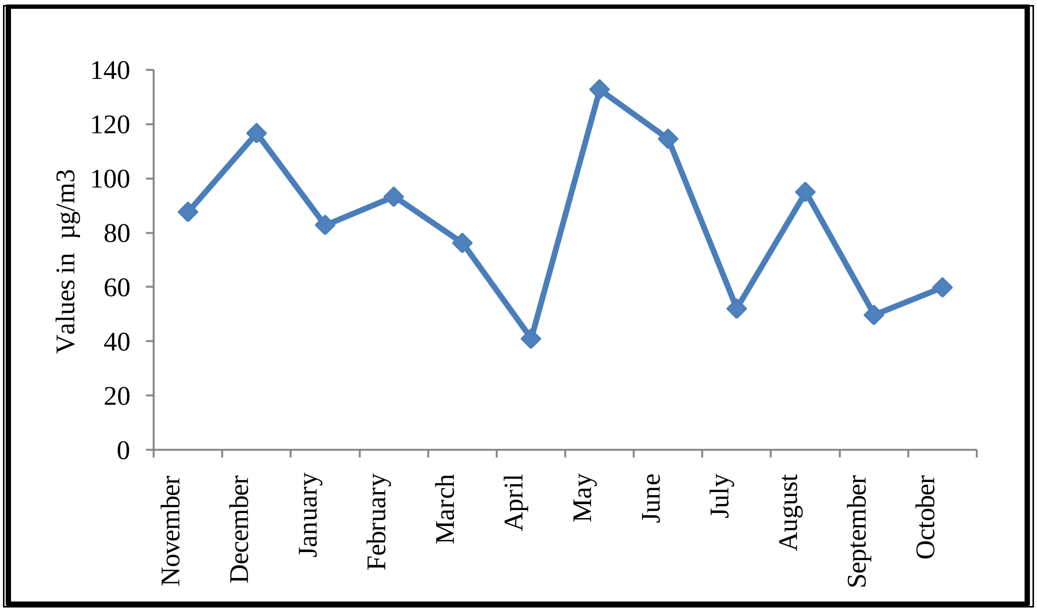

Figure 5: Monthly distribution of SPM in Bhilai

Respirable particulate matter (RPM)

Analysis of RPM sample shows maximum RPM found in winter season in the month of October and minimum RPM level found in the month of August, presented a clear trend of lowering of atmospheric levels during rainy season (Figure-6). Trends of elements in RPM shows Al>K>Zn>Na>Cu>Fe>F^->Ni>SO_4^{-2}>Mn>Pb>Cr>Cd>As in winter season but in the summer season it shows little different trend Al>Zn>K>Na>Fe>SO_4^{-2}>Ni>F^->Cu>Pb>Mn>Cr>Cd>As. Elemental analysis of RPM shown by Table-5 that Cu, Zn, Fe, Al, Na, K were present in high concentration during winter season and Al, Zn, Fe, Ni, were also found in high concentration in summer season that of winter. It is very important that Zn shows its higher concentration in RPM in the month of July (rainy season) than August and September. The participation of arsenic and cadmium were not much observed than chromium, manganese, and lead.

Table 5: Annual trace elemental distribution in RPM in study area

Elements in RPM	Winter (ng/m^3)		Summer (ng/m^3)	
	Max.	Min.	Max.	Min.
Cd	0.11	0.023	0.20	0
Cu	164.56	5.35	70.92	9.4
Zn	305.75	73.76	1765.24	900.13
Cr	1.12	0.33	3.54	1.29
Mn	8.10	1.31	3.83	1.71
As	0.066	0	0	0
Fe	42.31	8.15	283.66	65.31
Al	3788.52	137.27	3782.1	317.63
Na	294.33	73.9	494	367
K	761.5	182.9	949	363
Pb	3.23	0.46	4.46	1.89
SO_4^{-2}	17.51	2.00	270.9	2.21
F^-	163.9	1.26	82.49	10.22
Ni	19.84	0.53	189.11	0.60

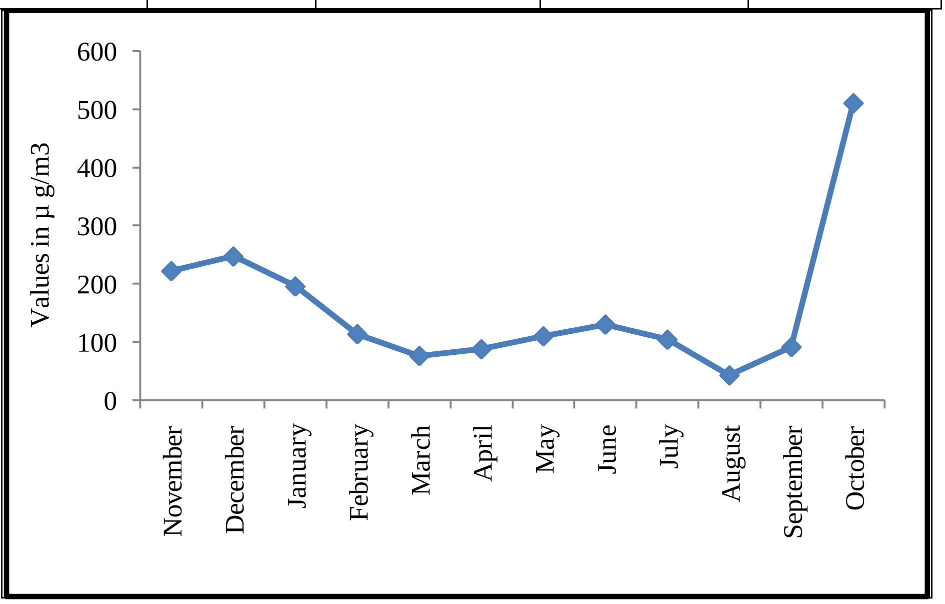

Figure 6: Monthly distribution of RPM in Bhilai

Comparison between different particulates

During metallurgical operations the emitted elements form metallic fumes. These fumes got convert into fine respirable particles on condensation. The concentration of RPM shows higher than SPM concentrations (Figure-6).

Average elemental distribution in SPM at the monitored site

The elemental distribution in SPM shown in Figure-7 the Aluminium, Iron, and Zinc are the most dominant elements whereas Fluoride and Sulphate are dominating anions. It was observed in the samples collected from the site that it has a greater percentage of Copper and Nickel as compared to other metals.

Average elemental distribution in RPM at the monitored site

The elemental distribution in RPM shows that Aluminium and Zinc are the most dominant elements whereas Fluoride and Sulphate dominating anions explained by Figure-8. The sampling site also has shown a greater percentage of Iron, Copper, Sodium, and Potassium as compared to other metals because this site is not much affected by the direct industrial and vehicular emission sources RPM shows high concentration of Sodium and Potassium due to oceanic effect.

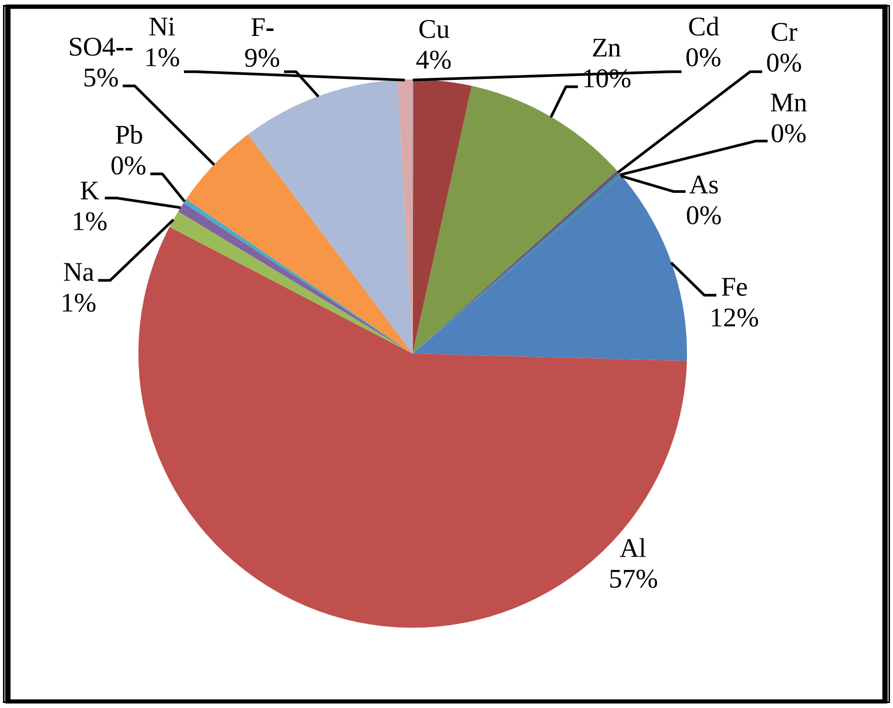

Figure 7: Average elemental distribution in SPM

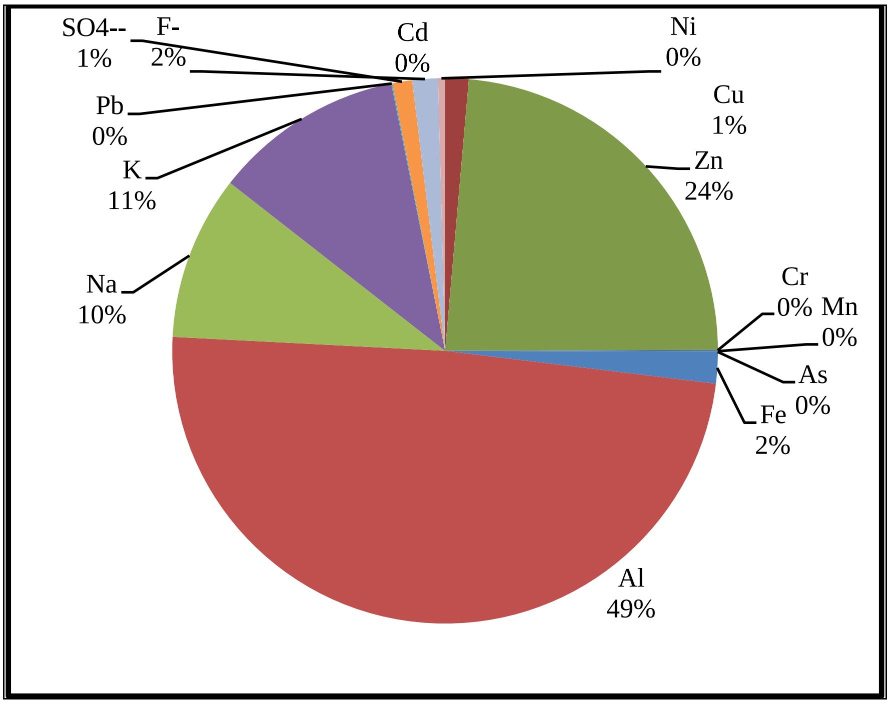

Figure 8: Average elemental distribution in RPM

Seasonal variations of trace metals in SPM

Seasonal distribution of the different monitored elements such as aluminium, copper, zinc and fluoride showed high concentration in winter season. but iron, sulphate and nickel represents high concentration in the summer season represented in figure-9. SPM levels are higher during the months of winter and were lowers during rainy season. In the winter season, average mixing height is lower as compared to other seasons, atmospheric dispersion is typically at a minimum, and therefore the pollutants will not be as widely dispersed. The monsoons results in large amount of precipitation, high wind velocities and changes in general wind direction. The large amounts of precipitation reduce atmospheric pollution by wet deposition processes. Wind velocities can also allow for pollutant transport away from sources.

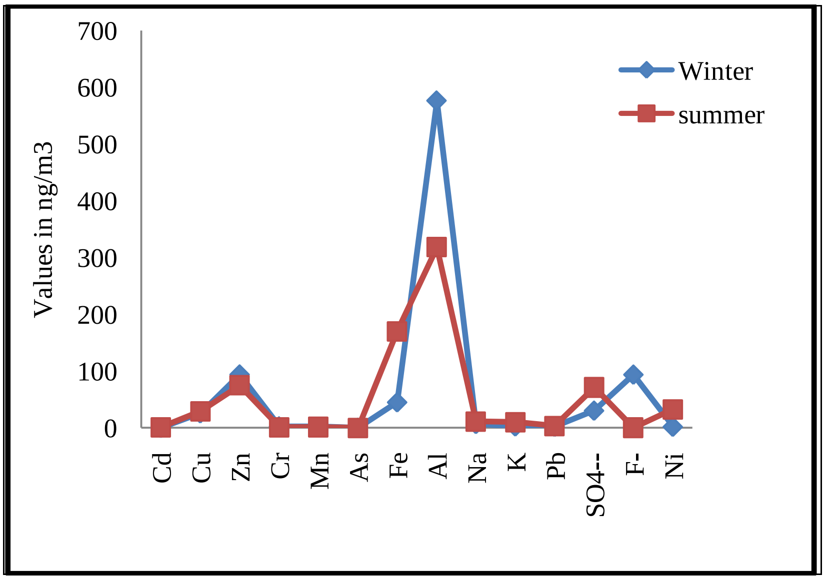

Figure 9: Seasonal distribution of elements in SPM

Seasonal variations of trace metals in RPM

Seasonal distribution of the monitored elements shows higher concentration of aluminium, zinc, and iron in the summer season. No change was establish in both summer and winter season for fluoride. But other trace elements showed higher concentration in the summer season in RPM represented by Figure-10. Zinc shows maximum concentration at sampling station due to uses of Zinc for protective coating on iron, steel etc. by the industries[40].

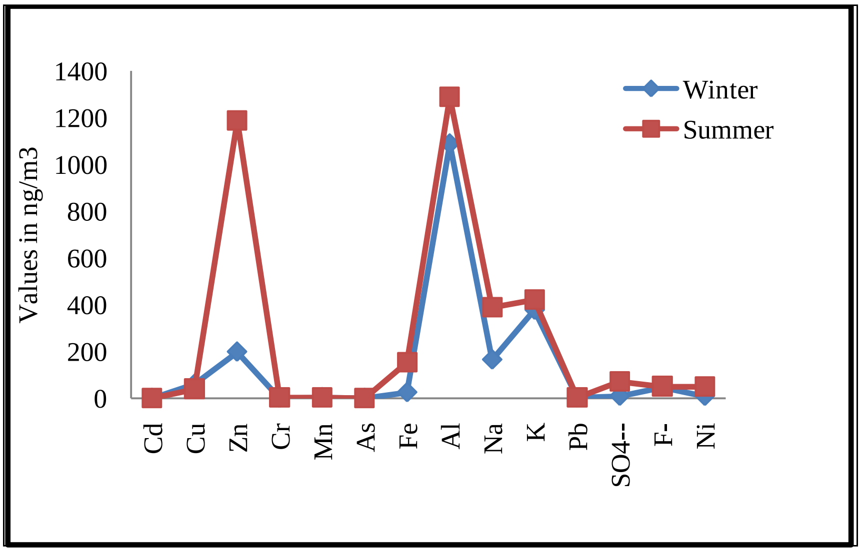

Figure 10: Seasonal distribution of elements in RPM

Seasonal distribution of trace elements in TSPM

By the analysis of total particulates it is found that aluminium, zinc, potassium and iron were in higher quantity in the summer season whereas these all elements and pollutants represent its poorer apperence in the winter season (Figure-11).

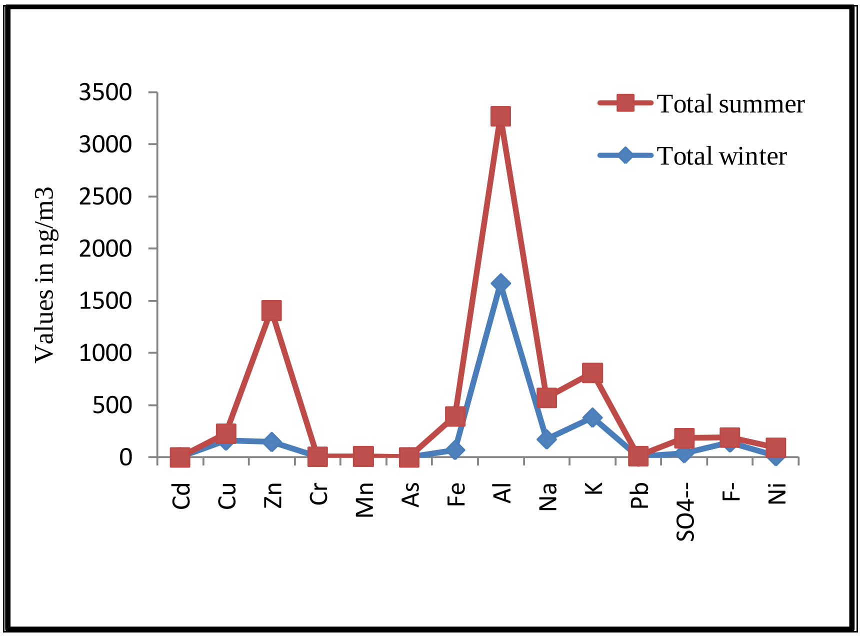

Figure 11: Seasonal distribution of elements in TSPM

Correlation matrix in suspended particulate matter and respirable suspended particulate matter

Table-6 and Table-7 represent the correlation matrix of SPM and RPM. Correlation studies of the RPM show the strong positive correlation of Copper with Aluminium, Zinc with Chromium, Arsenic and Lead, Chromium with Lead, Lead with Potassium, Mangnese with Potassium, Arsenic with Nickel and Sulphet, Iron with Nickel, Aluminium with Fluoride, and Nickel with Potassium. In these combinations strong correlation of many elements with Potassium indicates the probability of long range transport of the contaminants. The strong correlation between Lead, Chromium and Lead, indicates the probability of a common origin for these elements. Metallurgical operations act as the source of these elements In Bhilai**.** This association is missing in case of SPM. Reason for such phenomenon lies in the fact that these elements are emitted in substantial quantity in the form of metallic fumes during the metallurgical operations and get converted into fine respirable particles on condensation. Concentration of Aluminium, Iron is high which appears to be contributed by crustal sources and industrial emissions both.

Table 6: Correlation matrix in suspended particulate matter

	Cd	Cu	Zn	Cr	Mn	As	Fe	Al	Na	K	Pb	SO_4^{-2}	F-	Ni
Cd	1.00													
Cu	-0.01	1.00												
Zn	-0.13	0.24	1.00											
Cr	-0.05	-0.10	-0.21	1.00										
Mn	-0.25	-0.39	0.05	0.43	1.00									
As	-	-1.00	0.57	-0.96	0.16	1.00								
Fe	0.18	0.00	-0.23	0.32	0.06	0.83	1.00							
Al	0.29	0.40	-0.05	-0.30	-0.28	0.07	-0.33	1.00						
Na	0.31	0.46	-0.19	0.29	0.05	-1.00	0.83	-0.26	1.00					
K	-0.43	0.32	-0.32	-0.47	0.28	-1.00	0.21	-0.03	0.09	1.00				
Pb	0.08	0.10	-0.08	0.00	0.05	-1.00	0.38	0.11	0.28	0.15	1.00			
SO_4^{-2}	-0.13	-0.24	0.04	-0.18	-0.16	-1.00	-0.06	-0.05	-0.05	0.04	-0.14	1.00		
F^-	0.13	0.80	0.55	-0.14	-0.01	0.68	-0.13	0.16	-0.69	-0.35	0.48	-0.15	1.00	
Ni	-0.10	-0.19	-0.09	-0.17	0.17	1.00	0.05	-0.21	-0.07	0.99	-0.13	-0.06	-0.06	1.00

Table 7: Correlation matrix in Respirable suspended particulate matter

	Cd	Cu	Zn	Cr	Mn	As	Fe	Al	Na	K	Pb	SO_4^{-2}	F-	Ni
Cd	1.00													
Cu	-0.23	1.00												
Zn	0.49	0.06	1.00											
Cr	0.41	0.14	0.61	1.00										
Mn	0.06	-0.12	0.08	0.19	1.00									
As	-0.14	-0.69	0.63	0.39	0.91	1.00								
Fe	0.16	-0.16	0.22	0.26	0.01	1.00	1.00							
Al	-0.25	0.54	0.02	0.03	-0.19	-0.11	0.17	1.00						
Na	0.77	0.20	0.12	0.28	0.31	-1.00	0.63	0.06	1.00					
K	0.01	0.17	0.11	0.66	0.55	1.00	0.68	0.46	0.00	1.00				
Pb	0.32	0.49	0.51	0.58	0.34	-0.42	-0.08	0.20	0.45	0.41	1.00			
SO_4^{-2}	0.25	-0.06	0.26	0.22	0.01	0.98	-0.03	0.32	-0.16	-0.17	-0.02	1.00		
F^-	-0.18	0.19	-0.04	0.10	-0.10	-0.29	-0.07	0.64	0.33	0.45	0.17	-0.03	1.00	
Ni	-0.19	-0.20	-0.05	0.20	0.03	0.99	0.62	0.10	0.37	0.62	-0.16	-0.09	-0.14	1.00

Comparison of pollutants of different cities (µg/m^3)

The comparison of pollutants of Bhilai with other cities is shown in Table-8. Bhilai has maximum RPM concentration but SPM is present in high amount in Tughalakabad city. NO_2, and SO_2 are also present in maximum concentration in Bhilai. Comparative study of SPM and SO_2 at Bhilai with other major industrial cities of India is represented in Table-4.8. From this study, the result found that Bombay has high SO_2 pollution and Bhilai has fifth rank after New Delhi, Calcutta, and Kanpur.

Table 8: Comparison of particulates of different cities (µg/m^3)

City	RPM		SPM	
	Max	Min	Max	Min
Bhilai[a]	510.65	42.91	132.77	49.72
Chennai[b]	240	20	-	-
Dhanbad[c]	82.5	52.4	212.4	132.4
Dehradun[d]	53.76	-	322.58	-
Govt. polytechnic college Nagpur[e]	52.47	-	-	-
MysureK.R. circle[f]	-	-	457	-
Tughlakabad[g]	180	-	501.9	-

([a]present study. [b41], [c42], [d 43], [e] from Central poiiution control (CPC), [f44],[g45],)

Comparison of the results with previous studies

Comparative study of recent results (2006-2008) with previous studies (1998) is presented in Table-9 and Figure-12. The comparison of our present results with those obtained in the year 1998 at the same location show a decreasing trend in the level of elemental pollutants in the atmosphere. This could be attributed to two following fact. (1) The sampling stations in the previous study were located in predominating polluted areas whereas in the present study the sampling station is away from any near source effects. (2) The second reason could be a general lowering in the pollution levels at the studied site due to phasing out of leaded petroleum fuels. However, it is interesting to know that the trend and type of elements present in air have not much varied in last 10 years.

Table 9: Comparison of the results (ng/m^3) with previous studies

Elements	TSPM[b]	SPM[a]	RPM[a]	TSPM[a]
Cd	0.53	2.08	0.20	2.28
Cu	771.42	68.04	164.56	232.59
Zn	6263.13	363.12	1765.24	2128.36
Cr	16.67	8.78	3.54	12.32
Mn	154.06	3.24	8.10	11.34
As	7.85	0.21	0.07	0.28
Fe	5263.5	261.55	283.66	545.21
Al	-	955.3	3788.52	4743.82
Na	-	19.39	494	513.39
K	-	22.99	949	971.99
Pb	690.39	10.79	4.46	15.25
SO_4^{-2}	5292.38	199.07	270.9	469.97
F^-	158.58	371.39	163.92	535.31
Ni	24.04	126.3	189.11	315.49

[a]Present study 2006-2008. [b 46],

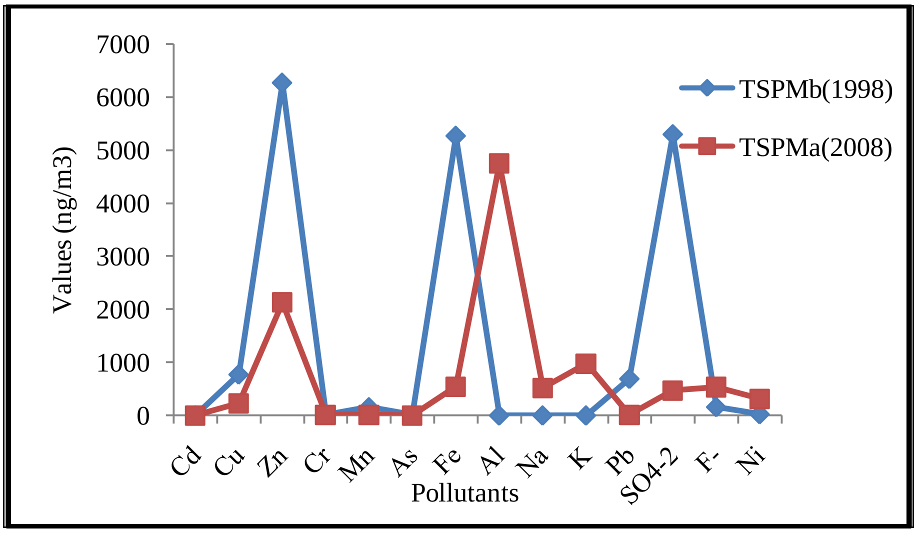

Figure 12: Comparison of present studies (ng/m^3) with previous studies

CONCLUSION

- The high levels of total particulate found in winter season which is major health concern because of their synergistic action. Al, Zn, Fe, Na , K and Cu dominate the trace composition reaching abnormlly high level. Secondary sulphates also are shown at higher level.
- Pb with a yearly mean of 10.246 ng/m^3 and high 6.86 ng/m^3 in the month of July in RPM and 10.79 ng/m^3 in summer season in SPM shows the effect of transport sector.

- The high trace composition in this area may affect the ecosystem and the public health of the region. Metallic comparison in SPM and RPM shows that SO_4^{2-}, K, Na, Al, Zn, Mn, Cu, Ni were higher in RPM whereas Pb, F^-, As, Cr, Cd, were higher in SPM. On the other hand, Iron showed its equal presence in SPM as well as in RPM both.
- The trend of elements in SPM represents Al>F^->Zn>Fe>Cu>SO_4^{-2}>Na>Cr>K>Ni>Pb>Mn>Cd>As in winter season. Whereas In summer season, SPM gave different trend such as Al>Fe>SO_4^{-2}>Ni>Zn>Cu>K>Na>Pb>Cd>Mn>Cr~F^->As.
- The SPM concentration observed was higher than the permissible limits for sensitive area.
- Trends of elements in RPM shows Al>K>Zn>Na>Cu>Fe>F^->Ni>SO_4^{-2}>Mn>Pb>Cr>Cd>As in winter season but in the summer season it shows little different trend Al>Zn>K>Na>Fe>SO_4^{-2}>Ni>F^->Cu>Pb>Mn>Cr>Cd>As.
- The levels of RPM and SPM levels exceeded the prescribed National Ambient Air Quality Standards for sensitive areas.
- The reason for high respirable particulate matter levels may be vehicles, large and small scale industries, biomass incineration, boilers, resuspension of traffic dust, commercial and domestic use of fuels, etc. the presence of high vegetation in the study area plays an important role to maintain the air quality status.
- The comparison of present results with those obtained in the year 1998 at the same location show a decreasing trend in the level of elemental pollutants in the atmosphere.
- This could be attributed to two following fact.
- The sampling stations in the previous study were located in predominating polluted areas whereas in the present study the sampling station is away from any near source effects.
- The second reason could be a general lowering in the pollution levels at the studied site due to phasing out of leaded petroleum fuels. However, it is interesting to know that the trend and type of elements present in air have not much varied in last 10 years.

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