A Critical Assessment of PM$_{10}$ (Carbonaceous Aerosol) and Ions from Biomass Burning on the Rural Side of Jamshedpur (TATA), India

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Abstract—*Biomass burning in the present scenario is one of the significant global sources of carbonaceous aerosols which have significant impact on the earth radiative balance of the atmosphere and human health Global. Emission flux estimates by tropical and Savanna forest biomass burning which shows that biomass burning could be an important source of Particulate matter (PM), Ions, Elemental carbon(EC) and Organic carbon(OC) to the atmosphere. Studies on PM in India are sporadic and mostly concentrated in large cities. Also studies on PM$_{10}$ are few in Northern India. With this background we had chosen a rural receptor site for the study of PM$_{10}$. The present study was conducted rural site near to NIT, Jamshedpur, India. PM$_{10}$ samples were collected using High Volume Sampler (Envirotech APM 460 BL). Whatman Glass Fibre Filter paper was used for PM$_{10}$ collection and samples were collected in Aluminium foil and stored in refrigerator for further analysis. For elemental analysis, samples were acid digested with standard methods and analysed in ICP (Perkin Elmer, OPTIMA-2100 DV). PM$_{10}$ was monitored for a period of a year (2014). The average PM$_{10}$ was 178.75±153 µg/m^3 which was nearly 3 times higher than the annual National Ambient Air Quality Standards (NAAQS) of 60µg/m^3. Among the analysed ions SO$_4^{2-}$ was maximum and F$^-$ was minimum. Most of the ions were maximum during the winter and minimum during monsoon season. The annual trend of ions was SO$_4^{2-}$ > NO$_3^-$ ≈ Ca^{2+} > Cl$^-$ > Na$^+$ > K$^+$ > NH^{4+} > Mg^{2+} > F$^-$. Annual average of TC was 24.53±10 µg/m^3 contributing 44% of PM$_{10}$. EC was 4.30±4 µg/m^3, whereas OC was 20.225±8 µg/m^3. An air-mass pathway traced with HYSPLIT model over the given study location illustrates the nature of the particulate.*

Keywords: *PM$_{10}$. Biomass burning. Water soluble ions. EC. OC. NAAQS. HYSPLIT model.*

1. INTRODUCTION

Biomass burning, both of anthropogenic and natural origin are a major source of gases and particles to the global atmosphere. Biomass fuels account for approximately 14% of the world's energy consumption [1]. In India, biomass burning (including wood, agricultural residues and dung cakes) is considered to be a major source of energy [2] and has major source of pollution [3]. Biomass burning sources include open burning of agricultural fires, savannah, tropical forests and the burning of domestic fuels such as wood, charcoal, crop residues and dung. Biomass combustion in household stoves and small-scale industrial facilities as per [4] recorded the highest emission rates of carbonaceous aerosols, on the order of 0.1-1.5 g/kg of black carbon and 0.3-8 g/kg of organic carbon. Residential wood combustion carried out in cold climate uses wood log stoves. These are batch fired, which gives varying emissions during different phases in the combustion cycle. Increased emissions of particles containing carbonaceous material occur at poor combustion conditions. [5] estimated that hot burning resulted in 20-60% of carbon (primarily elemental carbon) in the PM, while cool burning resulted in 55-60% of carbonaceous PM (almost entirely organic carbon). [6] Found 40-60% of fine particle mass as OC for hardwood species and 40-80% for softwood species and 3-23% as EC and 8-22%, respectively.

Water-soluble inorganic species (WSIS) are one of the significant components of atmospheric aerosol. They are influenced mainly by factors such as top geographic conditions, meteorological factors, and particle emissions like agricultural activities, emissions from industries, traffic and natural sources. The typical properties of atmospheric aerosols is because of their water soluble components, for example: Mg^{2+}, Na$^+$, K$^+$, Ca^{2+}, NH$_4^+$, NO$_3^-$, S0$_4^{2-}$, Cl$^-$ [7], elemental carbon and metals [8], organic compounds that has the origin from a distinct range of sources through a series of complex reaction mechanisms and the aerosol particles are introduced directly into the environment from natural causes, like sea spray and erosion, volcanic eruptions or from anthropogenic pollution sources [9].

One of the major components of atmospheric aerosol is carbonaceous aerosol, which is contributing 20–50% of atmospheric aerosol in heavy polluted atmosphere [10]. It is produced mainly as combustion and the aerosol may be of primary and secondary origin. Further the carbonaceous aerosol is usually classified into two main components: one is referred to as the **organic carbon (OC)** and the other as the **elemental carbon (EC) or black carbon (BC) [11]**. OC,

which is maximum fraction component of the carbonaceous aerosol, may be directly discharged into the environment in particulate form (primary) or may condense into the gas to particle conversion in the volatile anthropogenic and biogenic precursor compounds involving reactive organic gases [12]. OC represents a large variety of organic compounds. Elemental carbon (EC) or black carbon (BC) is produced exclusively by incomplete combustion of fossil and biomass fuels and, therefore, it is used as a tracer for combustion. EC is primarily considered as the only component in aerosol phase which strongly absorbs light and hence it strongly contributes a positive radiative force to the climate system [13].

Objectives

In the present work,

- Emission and distribution of the PM and associated species such as TC, OC, EC, Ions (i.e. Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+}, Ca^{2+} and F^-) during burning are described.
- To study the mass size distribution of aerosols and its variations during burning periods.
- To evaluate the relative impact on the ambient aerosols concentrations arising out of the burning of biomass.

2. EXPERIMENTAL

2.1 Study area

Bargidih is situated on the outskirts of Tatanagar Jamshedpur on the acres of 320 which has sprawling, rolling hills, and wooded land. There is the combination of natural beauty of countryside along with urban glamorization of an industrial area. It is at a distance of 2 km away from the state national highway (Tata-Seraikela Road). The nearest railway station is 3 km which is Adityapur railway station and a distance of 11 km from main Tatanagar railway station. The Kharkai River flows 2 kilometres away from the sampling site. The village is at the centre of the industrial belt of Adityapur industrial zone (AIDA). The main market place, Bistupur which is known as mini Mumbai, is around at a distance of 5 km from the study site. The sampling location site is combination of picturesque with greenery, trees and thick foliage, and mountains in the backdrop. There is a CBSE school named (DAV Public School and NIT Campus) located in the vicinity of sampling site. The sampling site diagram has been shown in Fig. 1.

Fig. 1: Diagram of sampling sites location

2.2 Meteorological details of the site

Metrology plays crucial role in the PM studies. There is a strong reaction between different season and change in ambient air quality slandered [14]. The Tata nagar has a temperate type climate. The temperature during study period varies between 8–41ºC. The minimum temperature recorded in Dec and Jan is 8º C. The climate of Tata nagar is marked by south-west monsoon. The details metrological data are shown in table 2.

Table 2: Average meteorological parameters at sampling sites during January-December 2014.

Month↓	Temp (0C)	Wind speed (Km/h)	Relative humidity (%)	Visibility (km)	Solar Radiative Flux (Watt/m2)
J	18.625	2.125	60.25	1.875	15.63
F	21.5	3.375	53	2.25	15.63
M	24.375	2.5	58.125	2.625	20.82
A	31.5	2.75	30.875	3	22.1
M	32.375	4.75	43.875	3.375	21.19
J	32.625	4.25	56	2.625	16.75
J	29.25	2.5	75	2.375	14.5
A	28.625	4	81	2.625	13.89
S	28.75	3.375	76	2.875	14.9
O	27.25	1.25	68.125	2.375	15.76
N	22.75	0.625	61.625	2.375	15.34
D	19.5	0.75	61	2.125	14.68

2.3 Sample Collection

The air sampler (i.e. Thermo Scientific Partisol, USA) was used for collection of coarse particulate material (PM_{10}) on 47-mm quartz fibre filters (Whatman, QMA) housed in the molded filter cassettes. The air sampler used for the sampling was installed at the ground level and operated at flow rates of ten l/min. we have used one blank filter paper to correct for the background values. The filters paper were heated to 600^oC for constantly 6 h. prior to use for the sampling for reducing the carbon blank values, and stored in clean polyethylene petri dishes. The weighted filters paper after heating were put in the sampler and were run for the duration of the burning process. The loaded filters were removed from the sampler and brought to the laboratory, and again heated up to 50^oC for 6 h so that the moisture contents are removed. The filters were transferred into the desiccators, and finally weighted to measure the particulate mass load. Each loaded filter was kept in a petri dish, and dispatched to the different laboratories for the analysis of the chemical constituents. A total of forty eight PM samples were collected in 2014.

2.4 Analysis

Analysis of carbons

A standard thermal method was used for the analysis of elemental carbon (EC) and organic carbon (OC) content by measuring the formation of CO_2 when heating (in pure

helium) and burning (in pure oxygen) the quartz filter samples. At least 3 pieces from each of the sample taken and blank filters paper were punched out and was analysed. The cut filter pieces were feed into a stainless steel gas cylinder which was kept in an oven purged with pure helium. The temperature of the oven were uniformly increased stepwise from room temperature to a level of 350°C and then again increased to 650°C. An oxidizing catalyst converted all carbon into CO_2 which was then measured with the help of a non-dispersive infrared detector (NDIR). The fraction which was volatilized up to the temperature of 650°C in pure helium was defined as OC fraction and the fraction volatilized in a second step at 650°C in pure oxygen was defined as EC. However, the sum of OC and EC contents in this Work was considered as total carbon (TC).

Analysis of ions

The PM content was extracted with 15 ml of de-ionized water (0.054 μS/cm) with sonication for 15 min and heated at 60ºC for approximately 24 hrs. The extracts were filtered through 0.45 μm tracer filters and its 200 μl aliquot was injected. The ion chromatograph (DX120, Dionex, USA) equipped with anion separation column (AS9-HC, 250x4mm), cations separation column (CS12A, 250x4mm) and conductivity detector was used for analysis of the ions.

3. RESULTS AND DISCUSSION

3.1 PM₁₀ concentration

PM₁₀ samples were collected at Bargidih for the year 2014. The average mass concentrations were recorded are 178.75 ± 153 μg/m³. This may be attributed to increased emissions from various types of biomass burning. From Fig. 2 it is clear that the concentration of PM₁₀ vary in the order as

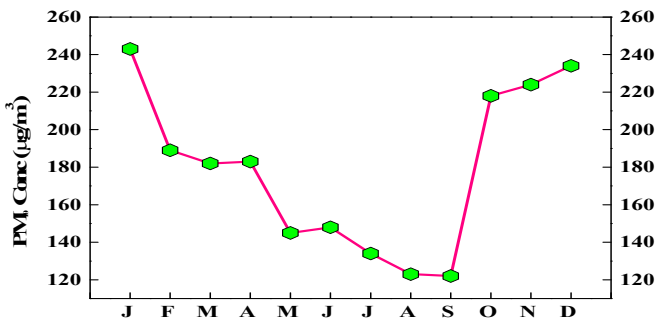Jan > Dec > Nov > Oct > Feb > Apr > Mar > Jun > May > Jul > Sep > Aug

Fig. 2 PM₁₀ Concentration of sampling sites from the month of (January–December) 14.

As it is clear that during winter month (Nov-Jan) due to low temperature there is increased in burning of biomass. The maximum and minimum concentration of PM₁₀ was 234 ± 102 and 123 ± 89 μg/m³ respectively. The average daily mass

concentration of PM during the measurement period exceeded the 24 hour National Ambient Air Quality Standard of India (60 μg/m³ for PM₂.₅ NAAQS, 2009) and WHO (25 μg/m³ for PM₂.₅ whqlibdoc.who.int/hq2006/WHO_SDE_PHE_OEH_06.02_eng.pdf) 24–h guidelines 100% of the time, respectively.

3.2 OC and EC

Two types of carbon i.e. elemental carbon (EC) and organic carbon (OC) were quantified in the PM₁₀ emitted from the burning processes. The sum of total concentration of EC and OC is considered as total carbon (TC) in the present work. The EC, OC and TC concentration for the biomass smoke was ranged from 7.2-1.2, 26.3–11.3 and 33.5–12.5 μg/m³ with mean value of 4.30 ± 321, 20.22 ± 1607 and 24.53 ± 1884 μg/m³, respectively.

From Fig. 3 and 4 it is clear that the concentration vary as

EC – Feb > Jan > Dec > Nov > Oct > Mar > Apr > May > Jun > Jul > Aug > Sep

OC – Feb > Jan > Dec > Mar > Apr > Nov > Oct > May > Jun > Jul > Aug > Sep

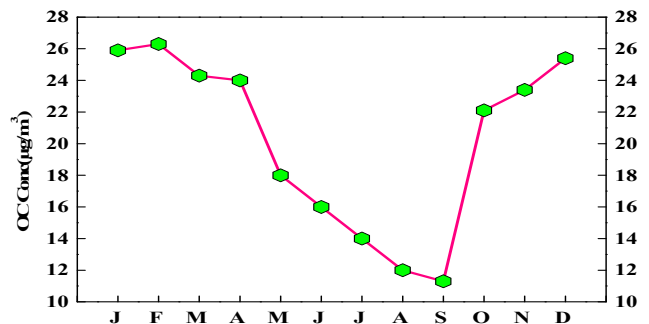TC – Feb > Jan > Dec > Nov > Mar > Oct > Apr > May > Jun > Jul > Aug > Sep

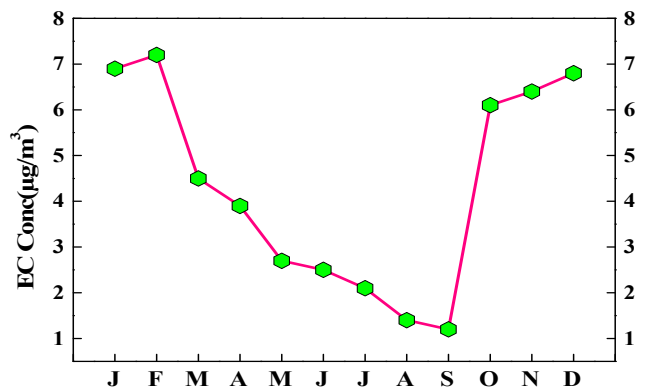**Fig. 3: OC Concentration of sampling sites from the month of (January- December) 14**

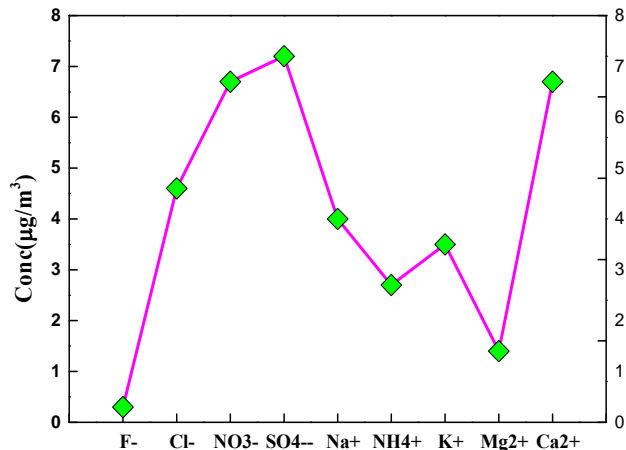**Fig. 4: EC Concentration of sampling sites from the month of (January-December) 2014**

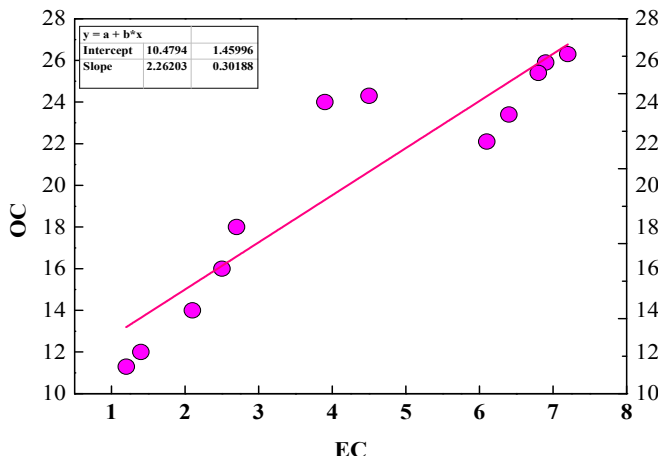**Fig. 5: Mean concentrations of Ions in PM_{10} in during burning of biomass.**
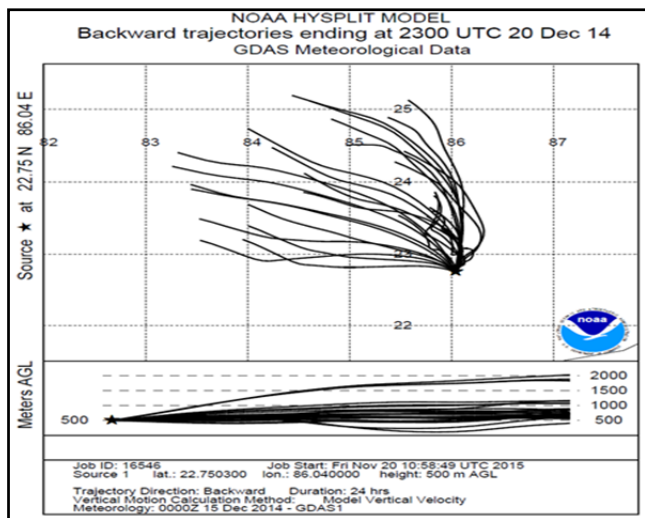

Fig. 6: Air mass back trajectories during December winter 2014 at altitudes (500 m) ending at 2000m.

The highest concentration of BC, OC and TC was observed with the biomass burning, may be due to incomplete combustion as well as evaporation of the organic compounds. The mean [OC/EC] ratio of the biomass smokes was found to be 5.10±1.26 Fig. 7. These ratios were found several folds higher than the ambient air [OC/BC] ratio (≈ 0.6) of this region [12].

Fig. 7 Correlation of EC with OC in biomass smoke.

3.3 IONS

Nine PM_{10} samples derived from burning of biomass were analysed for determination of eight ions i.e. F^-, Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+} and Ca^{2+}. The sum of total concentration of nine ions, $\Sigma ion9$ i.e. F^-, Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+} and Ca^{2+} was ranged from $7.2 - 3$ µg/m³ with mean value of 4.12±14 µg/m³. From Fig. 6 the order of concentration is

$$SO_4^{2-} > NO_3^- \approx Ca^{2+} > Cl^- > Na^+ > K^+ > NH^{4+} > Mg^{2+} > F^-$$

3.4 Sources of PM, BC, OC and Ions

The correlation matrix of TSP and ions for the biomass smoke is summarized in Tables 1. The TSP content in the biomass smoke was well correlated Cl^- (0.64) and NO_3^- (0.61) indicating common origin during the burning processes. The ions i.e. Mg^{2+} and Ca^{2+} were well correlated with Cl^- (0.67), NO_3^- (0.78) and Cl^- (0.88), NO_3^- (0.90), SO_4^{2-} (0.74) respectively, indicating origin from the burning processes. The NH^{4+} ion had good correlation with the SO_4^{2-} (0.63), Cl^- (0.65), NO_3^- (0.74) which indicate that their possible source may be from the earth atmospheric reactions. Other ions i.e. K^+ and Cl^- (0.80) were also well correlated among themselves and with other species i.e. NH_4^+ (0.89), Ca^{2+} (0.86) and SO_4^{2-} (0.68).

Table 1: Correlation matrix of TSP and major ions of aerosols during study period.

Species	TSP	NH4+	Na+	K+	Mg2+	Ca2+	F-	Cl-	NO3-	SO42-
TSP	1									
NH4+	0.39	1								
Na+	0.58	0.53	1							
K+	0.46	0.65	0.48	1						
Mg2+	0.53	0.62	0.72	0.71	1					
Ca2+	0.50	0.68	0.40	0.86	0.75	1				
F-	0.49	0.62	0.32	0.61	0.48	0.66	1			
Cl-	0.64	0.65	0.46	0.80	0.67	0.88	0.66	1		
NO3-	0.61	0.74	0.59	0.89	0.78	0.90	0.73	0.87	1	
SO42-	0.50	0.63	0.29	0.68	0.50	0.74	0.51	0.74	0.72	1

3.5 Hysplit

In order to assign the possible movement and transport pathways of EC and OC aerosols from their potential sources of different origins to the experimental site, air mass back–trajectories were analysed using the hybrid single particle Lagrangian integrated trajectory (HYSPLIT) model of the National Oceanic and Atmospheric Administration (NOAA), USA [15]. Figure 6 shows the air mass back trajectories during winter at altitudes (500 m). It is quite discernible from the Figure 6 that air masses reaching over to great height during the winter season are mostly from the north–western, western and south–western side.

4. CONCLUSIONS

The environment is contaminated with very high content of carbonaceous PM during the burning processes, being several folds higher than in the NAAQ standard. The biomass burning air pollution is expected to be largely responsible for appearing of the respiratory disease in Human being. The release of aerosols and gases may play an important role in atmospheric chemistry and radiative forcing, thus affecting regional and global climate. Hence, it is imperative that the burning of biomass must be investigated in all its attendant aspects because of its impact in particular on rural health, environmental quality in general and climate change.

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