$PM_{2.5}$ Water-soluble Ionic Composition and Trace Gases over Adityapur Industrial Zone, (Tata Nagar) India, during Winter Time

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Abstract—*$PM_{2.5}$ and trace gases (SO_2 and NO_2) sample were collected from Dec 2014 to March 2015. The $PM_{2.5}$ was collected by high volume sampler and trace gases (SO_2 & NO_2) were collected with impinger equipped with PM sampler. The average winter time $PM_{2.5}$ mass concentrations from Industrial (A-1), Traffic (A-2), Academic (A-3) and Rural (A-4) sampling sites of Adityapur industrial zone, Tata nagar are 178±68 µg/m^3, 102 ± 56 µg/m^3, 174.5 ±84 µg/m^3 and 88.25±37 µg/m^3 respectively. Water soluble ionic species ions (Na^+, NH_4^+, K^+, Mg^{2+}, Cl^-, NO_3^- and SO_4^{2-}) were analyzed with ion chromatography. The three most abundant ions were SO_4^{2-}, NO^{3-}, and NH_4^+ with average concentrations of 6.41±1.5, 2.40±0.30 and 2.96±0.62 µg/m^3, respectively. The trace gaseous present in study area having average concentrations of SO_2 and NO_2 were 38.25±4.55 and 52.18±4.85 µg/m^3, respectively. The total average concentration of SO_2 and NO_2 were much lower than the average guideline values of the world health organization (WHO). The evolution patterns clearly show the winter time of $PM_{2.5}$ with impaction low temperature. An air-mass pathway traced with HYSPLIT model over the study area illustrates the nature of the particulate.*

Keywords*: $PM_{2.5}$, Trace gases. Water soluble ions. WHO. HYSPLIT model.*

1. INTRODUCTION

The $PM_{2.5}$ study of atmospheric aerosols is gaining importance in scientific world as lot of studies have shown their association with health-related problems [1] (Laden *et al* 2000) and climate changes [2] (Ramanathan *et al* 2001). As from the previous literature studies it has been well established the deleterious impact of ambient particulate matter (PM) on human, animal as well as plants health and the World Health Organization (WHO) from time to time publishes suggested air quality guidelines for mass concentrations of $PM_{2.5}$ size fractions (particles with aerodynamic diameters smaller than 2.5 µm). Due to increasing anthropogenic activities such as increasing vehicular traffic, biomass burning, increased industrial related activities, forest burning, fuel wood and cow dung burning for cooking may alter the pollutants level in the region.

A large portion of aerosol particles comprise of water-soluble ions (WSI) which plays an important role in the atmospheric chemistry. The factors which influence the mass concentrations of aerosol particles are meteorological factors, geographic conditions and particle emissions sources. The chemical characteristic properties of aerosols are due to their water soluble components, e.g. potassium, magnesium, calcium, sodium, ammonium, chloride, nitrate, sulphate [3] (Tsai and Kuo, 2005) and metals [4] (Mariani & Mello, 2007) that originate from the different sources through a series of complex mechanisms [4] (Mariani & Mello, 2007).

Meteorology plays an important role in ambient distributions of PM in atmosphere. The variations of meteorological variables for example temperature, wind speed and direction, humidity, mixing height and precipitation modulate the air quality which plays a major role in determining the levels, transport and diffusion of pollutants [2] (Ramanathan et al. 2001). The inflowing of pollutants from the ground surface, their residence time and the formation of secondary pollutants in the atmosphere are not only controlled by rate of emission of the reactants from the source, but also by wind speed, turbulence level, air temperature and precipitation [5] (Malm et al. 1994). Thus, it is very important to understand and to study the physical phenomena like meteorological factors to determine the pollutant levels and their relationship with meteorological parameters.

2. EXPERIMENTAL

2.1 Study area

Tata nagar is 86º04' to 86º54' east Longitude and 22º12' to 23º01' North latitude. It has an average elevation of 40 metres (131 feet). The city is situated 1400 km from New Delhi and a little less than 300 km north-west of Kolkata on the(NH-33) and Eastern Railway. The chief rivers are the swarnrekha and Kharkai. Tata nagar is located in the southern east region of Jharkhand. The city is located in the Chhota Nagpur plateau and covers an area of 3533 km^2. Sampling site is close to state

highway Jamshedpur kandra road, Godowns of Food Corporation of India, hotels, bakeries and Adityapur railway station also exist in the vicinity of sampling area. Tata nagar is one of the major industrial centres of Eastern India. It houses companies like Tata Steel, TCE, Lafarge, Tata Motors, BOC Gases, Tata Power, Cement, Telcon, Praxair, TCS, Timken, TRF, Tinplate and many more. It homes to one of the largest industrial zones of India known as Adityapur which houses more than 1,200 small and medium scale industries and has a SEZ named AIDA in the Adityapur. The details of sampling sites for the collection of $PM_{2.5}$ are shown in table 1.

Aim and Objective of this research work.

- The assessment of concentration and the ambient air quality with respect to $PM_{2.5}$ WSI, SO_2, & NO_2.
- Use of backward trajectory for the study of pattern of pollutants over sampling periods at Adityapur industrial zone, Tata nagar.
- To create a database for further analysis.

2.2 Meteorological details of the site

Metrology plays crucial role in the $PM_{2.5}$ studies. There is a strong reaction between winter season & change in air quality level [6] (Karar et al. 2006). 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.

2.3 Sample Collection

Samples of $PM_{2.5}$, and gaseous were collected simultaneously from Dec 2014 to March 2015 in Tata nagar. A total of 18 samplers in including 2 field sample were deployed for our study among four categories of sites: Industrial area (Adityapur, A-1), Traffic (Shire Punjab Adityapur, A-2), Academic (Nit Campus, A-3) and Rural area (Burgidih, A-4) (>100 m from the nearest building) (Fig. 1). Samples were collected (every Monday on weekly basis; 4 to 5 samples in a month) on quartz filter fibre (that were prebaked at 550 ^oC at least 5h before desiccated and sample collection) by using Particle Sampler (APM460NL, Make: M/s. Envirotech, India) at 10m height (above ground level). Through Whatman Quartz Microfiber filter (QMA; size: 20×25 cm^2) Ambient air was passed at a flow rate of 1.12 m^3 min/m (accuracy 64%) for 8 h during the sampling period (9000–1700h).The QM-A filters were weighed before and after the sampling during the experiment in order to determine the mass of the $PM_{2.5}$ collected. The amount of $PM_{2.5}$ (µg /m) was calculated on the basis of the difference between initial and final weights of the QM-A filters measured by a microbalance (M/s. Mettle-Toledo) was determined by dividing the amount of total volume passed during the sampling. After the collection of samples, filters were stored under dry condition at - 20 ^0C in the deep-freezer prior to analysis. Meteorological data such as wind speed, temperature, relative humidity, pressure, precipitation and wind direction were obtained from Weather Underground (http://www.underground.com/) and data of SO_2 and NO_x were obtained from the website http://www.gzepb.gov.cn/.

2.4 Analysis of water-soluble ionic species

For the analysis of water soluble ions (WSI) in $PM_{2.5}$ sample the filters were extracted by ultrasonic agitation for 90 min. The extract is filtered through Whatman filter paper and stored in polypropylene sample bottles (these bottles are dipped in 2% HNO_3 and then dipped in deionised distilled water overnight to eliminate any contamination on these bottles). The major WSI_s Concentrations of (F^-, Cl^-, NO_3^- and SO_4^{2-}) are determined by Ion Chromatograph (DIONEX-ICS-3000, USA) using an Ion Pac-AS11-HC analytical column (4x250 mm, Dionex, USA) with a guard column (IonPac AG11-HC, 4 x 50 mm, Dionex, USA), ASRS-300 4 mm anion micro-membrane suppressor, 20 mM NaOH (50%w/w) as effluent and triple-distilled water as a regenerator. Na^+, K^+, $Ca^{2+}$and Mg^{2+} are determined by using a separation column (IonPac CS17-HC, 4 x250 mm, Dionex, USA) with a guard column (IonPac CG17-HC, 4 x 50 mm, Dionex, USA), suppressor CSRS-300 (4 mm, Dionex, USA) and 5 mM MSA as eluent. The IC system is fitted with a 25 mL sample loop that is used to introduce the sample manually. All the standard solutions are filtered using 0.45 mm nylon membrane filters (Millipore) and degassed by ultra-sonication.

3. RESULTS AND DISCUSSION

3.1. Ambient air $PM_{2.5}$ concentrations

$PM_{2.5}$ samples were collected at A-1, A-2, A-3 and A-4 during winter season. At these sites, the average mass concentrations ranked in the order of A-1 (178±68 µg/m^3) > A-3 (174±84µg/m^3) > A-2 (102±56 µg/m^3) > A-4 (88.25±37 µg/m^3) sites. This may be attributed to increased emissions from vehicular, construction and industrial exhaust. Fig. 5.2 compares the $PM_{2.5}$ with different sites of India. On comparison, the average mass concentrations of $PM_{2.5}$ was found to be lower than reported at other cities of India: [7] Kanpur (154 µg/m^3; Behara and Sharma, 2010), [8] Raipur (185.9 ± 66.9 µg/m^3; Deshmukh et al., 2012b), and [9] Agra (170.4 ± 54.9 µg/m^3; Kulshrestha et al., 2009) but found to be higher than reported at [10] Lucknow (101 µg/m^3; Pandey et al., 2011), [11] Mumbai (42 µg/m^3; Kothai et al., 2011) and [12] Ahmedabad (55.7 ± 17 µg/m^3; Rengarajan et al., 2011a). The average daily mass concentration of PM during the measurement period exceeded the 24 hour National Ambient Air Quality Standard of India (60 µg/m^3 for $PM_{2.5}$ NAAQS, 2009) and WHO (25 µg/m^3 for $PM_{2.5}$ whqlibdoc.who.int/hq2006/WHO_SDE_PHE_OEH_06.02_eng.pdf) 24–h guidelines 100% of the time, respectively.

3.2 WSI composition

WSI comprise a large part of aerosol particles and play an important role in the atmosphere. In this study, seven major water-soluble inorganic components were detected (Cl^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg_2^+). From Fig-6, also presents the mean water soluble ionic concentrations in A-1 site as follows:

$$SO_4^{2-} > NH_4^+ > K^+ > NO_3^- > Cl^- > Na^+ > Mg^{2+}$$

The mean water soluble ionic concentrations in A-2 site as follows:

$$SO_4^{2-} > K^+ > NH_4^+ > NO_3^- > Cl^- > Na^+ > Mg^{2+}$$

The mean water soluble ionic concentrations in A-3 site as follows:

$$SO_4^{2-} > NH_4^+ > K^+ > NO_3^- > Cl^- > Na^+ > Mg^{2+}$$

The mean water soluble ionic concentrations in A-4 site as follows:

$$SO_4^{2-} > K^+ > NH_4^+ > NO_3^- > Cl^- > Na^+ > Mg^{2+}$$

High concentrations in winter may probably be attributed to the enhanced emissions from heating sources and stagnant atmospheric conditions (low temperature, low wind speed, low mixing height). The ionic constituents (Cl^-, NO_3^-, SO_4^{2-}, NH_4^+ and K^+) showed high mass concentrations in winter. . The variation in ionic constituents is due to the change in meteorological parameters and physico-chemical transfer processes arising in the atmosphere.

3.3 Gaseous (SO_2 and NO_2)

As per the National Ambient Air Quality Standards (NAAQS), the limit for NO_2 and $S0_2$ are 80 ug/m^3 is respectively. The concentration of NO_2 and SO_2 are 38.25±4.55 and 52.18±4.85 µg/m^3, respectively. The NO_2 and SO_2 levels were found to be below the permissible limit as prescribed by NAAQS. The conc of NO_2 are higher than SO_2 at the sampling site on all days of sampling. High levels of SO_2 are particularly dangerous in the presence of particulate matter because it slowly adhere on $PM_{2.5}$ atmospheric particles and can be transported very deep into lungs and therefore staying inside for a long duration of time. Because of their very long habitation time and acidic behaviour, they cause serious harm to the lung tissue (oedema). [13] (WHO 2000).

3.4 Hysplit

These climatic conditions i.e. less dispersion and low mixing heights or lower boundary layer height, typically 500m [14] (Nair et al., 2007) during winter months help the ambient particles to remain for longer time in the atmosphere. These stagnant meteorological conditions is also supported by the results of back trajectory analysis that shows that the site is under the influence of different local emissions and account for increased levels of particulate mass. The effect of localized sources during the months of December, January, February and March can be seen in Fig. 7.1 and 7.2.

4. CONCLUSION

At Tata nagar, higher level of $PM_{2.5}$ may be attributed to the combined impact of climatic conditions and anthropogenic emissions by various local sources such as vehicular exhaust, waste incineration, coal and biomass combustion in various small scale industries (petha, iron casting, electroplating etc.), resuspended road dust as well as growing rate of construction activities refuse dust. In winter season, temperature generally drops up to 2°C so people use combustible materials, such as fire wood and cow dung cakes in open fires for heat generation in winter. Due to this massive biomass burning activity (especially during night time) results in the release of significant quantities of airborne smoke particles. In addition to these anthropogenic emissions, the stable meteorological conditions during winter season (i.e. less dispersion and low mixing heights and low wind speed) favour the accumulation of pollutants.

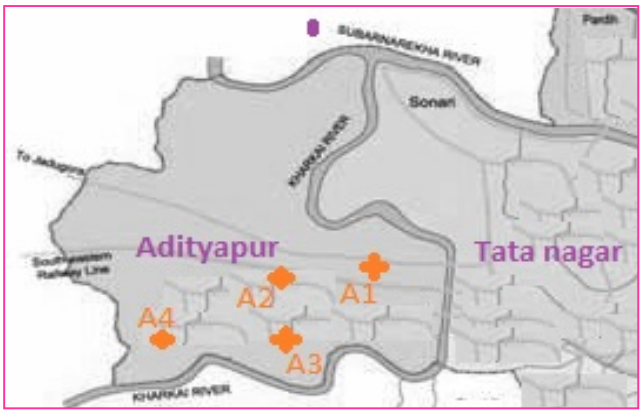

Fig. 1: Diagram of sampling sites location of (A-1, A-2, A-3, and A-4).

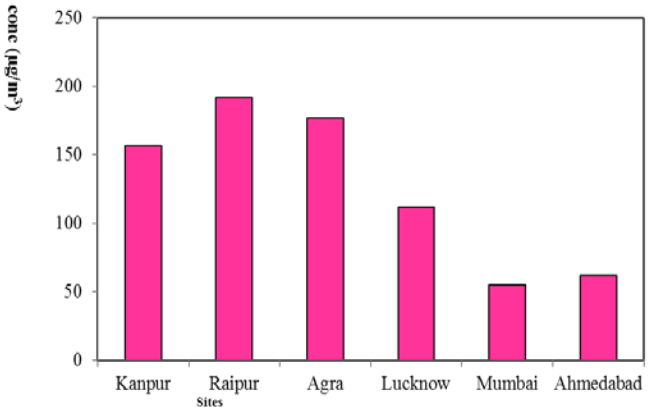

Fig. 2: Showing $PM_{2.5}$ Concentration of different study.

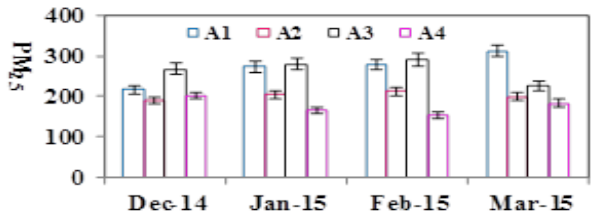

Fig. 3: $PM_{2.5}$ Concentration of four different sampling sites in the month of December 14 – March 15.

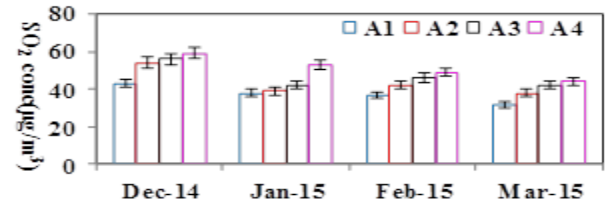

Fig. 4: SO_2 Concentration of four different sampling sites in the month of December 14 – March 15.

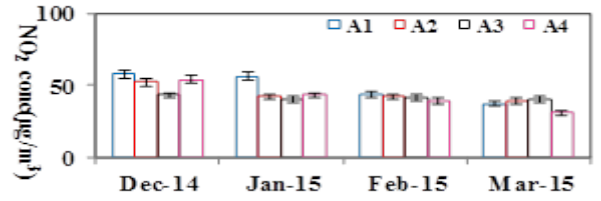

Fig. 5: NO_2 Concentration of four different sampling sites in the month of December 14 – March 15.

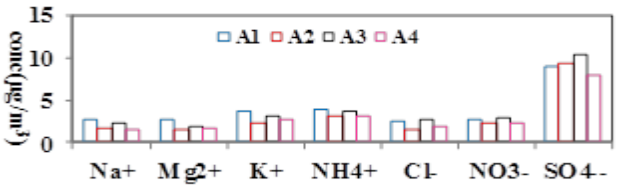

Fig. 6: WSI Concentration of four different sampling sites in the month of December 14 – March 15.

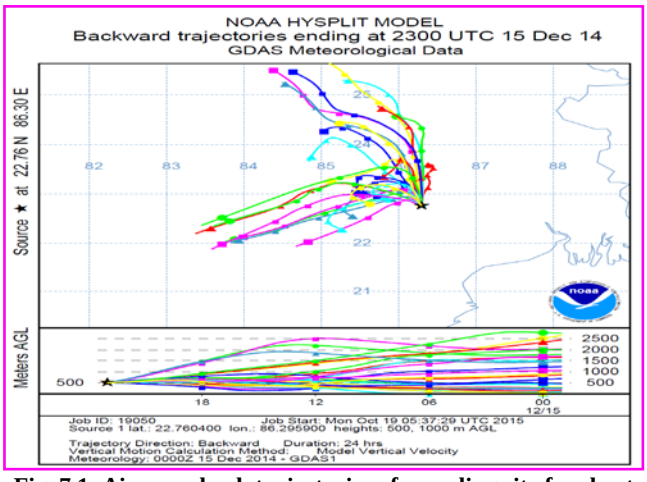

Fig. 7.1: Air-mass back trajectories of sampling site for short range transport of aerosols (dust) during Jan and contribution from localized sources.

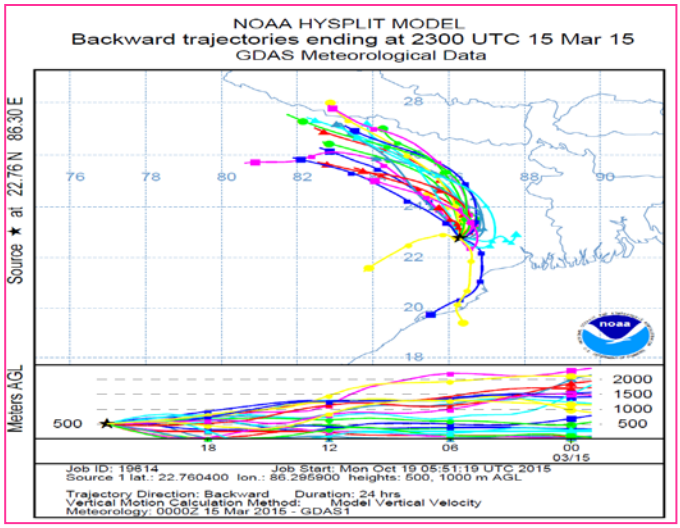

Fig. 7.2: Air-mass back trajectories of sampling site for short range transport of aerosols (dust) during March and contribution from localized sources.

Table 1: Sampling sites description for the collection of $PM_{2.5}$ site at Adityapur industrial zone (Tata nagar).

Sampling location	Site code	Description of the site	Type of sources
Adityapur Industrial (SEZ) Area	A-1	Industrial and Traffic area	Industries, road dust, vehicles, Domestic cooking, DG sets, garbage burning.
Shire Punjab Adityapur	A-2	Commercial and Traffic cum residential area	DG sets, vehicles, road dust, garbage burning, Domestic cooking, restaurants.
Nit Campus	A-3	Institutional cum residential area	Domestic cooking, light vehicle.
Burgidih	A-4	Rural Residential area	Domestic cooking, vehicles, road dust.

Table 2 The Ranges and Average meteorological parameters at sampling sites during Dec 2014 to March 2015.

Month→ parameter↓	Dec (2014)	Jan (2015)	Feb (2015)	March (2015)
Temp (°C) (Max–Min) Average	(30-9) 19	(28-8) 19	(39-9) 21	(39-9) 21.4
Pressure (hpa) (Max–Min) Average	(1025-1009) 1017	(1021-1012) 1016	(1024-1007) 1015	(1020-1003) 1021
Precipitation (mm) (Max–Min) Average	(0-0) 0	(2-0) 0.1	(17-0) 0.9	(10-0) 0.6

Humidity (%) (Max –Min) Average	(34-98) 68	(31-90) 71	(33-91) 66	(31-98) 75
Wind speed (km/h) (Max –Min) Average	(37-0) 2	(11-0) 2	(159-0) 3	(11-0) 2
Wind direction	W-N	W-N	W-N	W-N

Table 3: Comparative table of WSI of present study with previous study

←Site	Type	Cl^-	NO_3^-	SO_4^{2-}	NH_4^+	Na^+	K^+	Mg^{2+}	Ref.
Present study	$PM_{2.5}$	2.1	2.40	6.41	2.96	2.05	2.9	1.9	Present study
Raipur (India)	$PM_{2.5}$	6.8	8.1	46.5	8.7	7.4	5.9	1.6	[22
New Delhi (India)	$PM_{2.5}$	12.7	6.41	19.8	-	9.8	4.8	0.9	[21]
Mumbai (India)	$PM_{2.5}$	4.6	0.9	11.4	3.7	3.1	2.8	0.9	[20]
Kanpur (India)	$PM_{2.5}$	0.6	5.7	13.5	5.2	0.2	2.4	0.04	[19]
Taichung (Taiwan)	$PM_{2.5}$	1.5	10.5	12.6	7.8	0.2	0.5	0.7	[18]
Shanghai (China)	$PM_{2.5}$	3.0	6.2	10.4	3.7	0.5	0.6	0.2	[17]

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