International Journal of Pharmacy and Biological Sciences
ISSN: 2321-3272 (Print), ISSN: 2230-7605 (Online)
IJPBS | Volume 9 | Special Issue 2 | 2019 | 20-25
Research Article | Biological Sciences |Open Access |MCI Approved|
|UGC Approved Journal|

$PM_{2.5}$ Bound Carbon Fractions Over Tiruchirappalli City (India) and Influence of Meteorological Factors

Arun Marimuthu[1*], Mohamed Sihabudeen[1], Asrar Ahamed. A[1], Hariharan. G [2]

[1]Post Graduate and Research Department of Chemistry, Jamal Mohamed College, Bharathidasan University Tiruchirappalli 620020 Tamilnadu, India.
[2]National Centre for sustainable coastal management, Ministry of Environment, Forest and Climate Change, Anna University, Chennai, Tamilnadu, India.

Received: 30 Jan 2019 / Accepted: 20 Feb 2019 / Published online: 01 Apr 2019
Corresponding Author Email: ceo@orchard.edu.in

Abstract

This study investigated $PM_{2.5}$ bound carbonaceous species in order to determine the seasonal changes and to identify contamination sources over the urban sites of Tiruchirappalli. Elemental Carbon (EC) and Organic Carbon (OC) were analyzed with Thermal/Optical transmittance analyzer following the temperature program outlined in the NIOSH 5040 method. It is found that average concentration of EC and OC at Tiruchirappalli was the highest during cold months and lowest during warm months. Furthermore, the annual concentrations of OC and EC were 8.9 µg/m^3 and 4.1 µg/m^3 respectively. On seasonal average, the OC and EC concentrations ranked in the order of monsoon> winter>pre-monsoon > summer, which could be attributed to the combined effects of changes in local emissions and seasonal meteorological conditions. The distribution of eight carbon fractions (OC1, OC2, OC3, OC4, EC1, EC2, EC3 and OP) was also reported and found that the motor-vehicle exhaust and biomass burning, were the major contributors to the carbonaceous particles in Tiruchirappalli city.

Keywords
Organic carbon, Elemental carbon, Air pollution, vehicle exhaust

*****

INTRODUCTION

Atmospheric aerosols, derived from natural and anthropogenic sources, play an important role in balancing the Earth's radiation budget by scattering and absorbing the solar radiation. Many studies have focused on carbonaceous aerosol in recent years. Carbon is one of elements in atmospheric particulate matter, which occupies about 20–60% of $PM_{2.5}$ concentration and mainly exists in the form of organic carbon (OC) and element carbon (EC). Atmospheric EC is directly emitted from primary anthropogenic sources, while OC can be directly emitted from sources

such as primary particulates and secondary organic carbon can be formed from the products of atmospheric chemical reactions through the low vapor pressure, proper temperature and sunlight in the atmosphere. OC and EC in particulate matter play important roles in global climate effects, visibility degradation and human health [1,2]. Particulate-phase pollutants emitted by motor vehicles (especially diesel vehicles) consist mostly of carbonaceous aerosol, with its two components elemental carbon (EC, also referred to as black carbon) and organic carbon (OC) [3].

Motor vehicular emissions are a major source of fine particles in ambient air, especially in urban areas [4]. Road-traffic emission is also an important contributor to the global anthropogenic aerosol burden [5]. It has been estimated that in developed countries traffic-related air pollution constitutes more than 50% of the total particulate air pollution. Under certain conditions of gross domestic product growth and related transportation activities, the global vehicle population and traveled kilometers are projected to grow extensively in the near future, especially in Asia. It is expected that particulate emissions from vehicles will decrease in developed countries and increase in developing countries (APEG, 1999). This stresses the necessity to conduct more studies about vehicular emissions in the developing countries like India, because India is expected to play an ever-increasing role in future global economic activities.

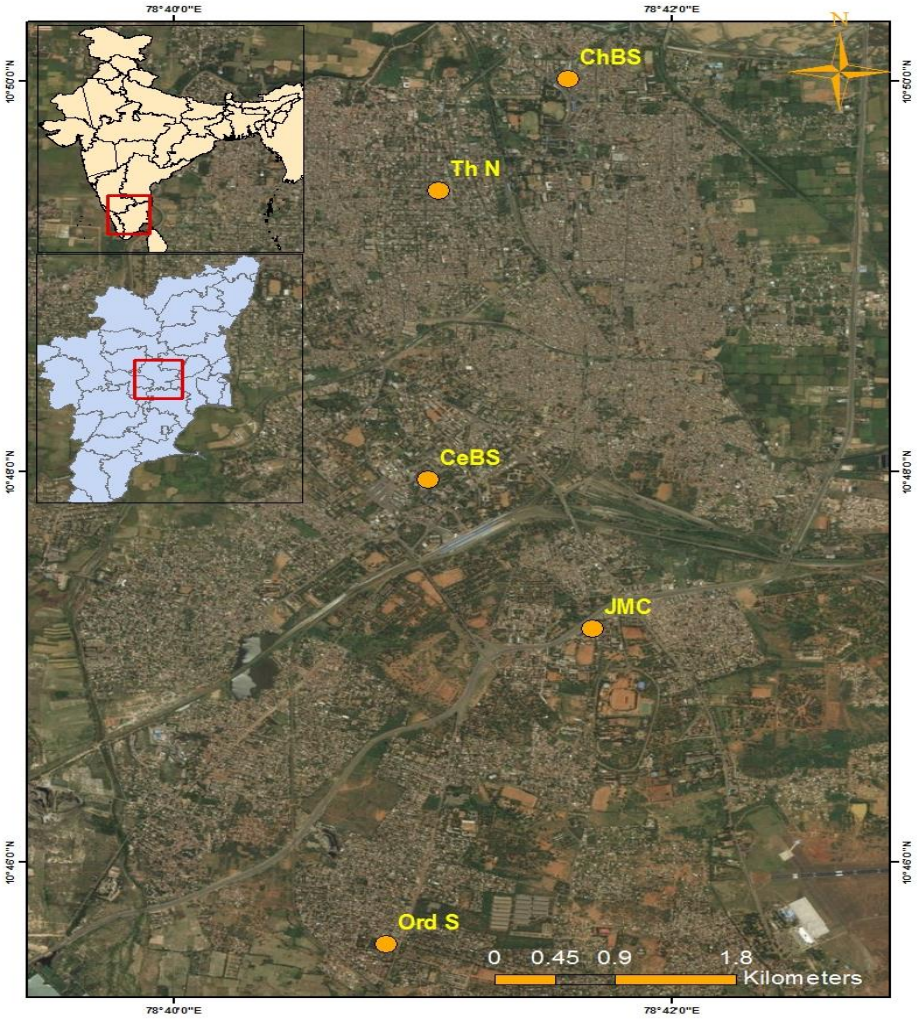
In this context, the current study focused on the assessment of the influence of $PM_{2.5}$ bound carbon fractions and influence of metrological factors in an urban city like Tiruchirappalli. Tiruchirappalli was chosen as the sampling location as it is listed as one of the most polluted cities of Tamil Nadu, with a global ranking of 370 according to the new global urban ambient air pollution ranking released by WHO. It is also the fourth largest city of South India, rapidly growing in terms of population density and vehicular pollution; Tiruchirappalli city is currently facing the challenge of severe air pollution [6], which has already led to numerous adverse impacts on the atmospheric environment and public health. Transport ministry of Tamil Nadu specified that vehicular population has touched 1.71 crore as on March 2013 As per the Directorate of Census Operations reports states that the population in Tiruchirappalli gets increased by 12.57 % within a short span of ten years from 2001 to 2011. Due to the increase of human population and vehicular population, the volume of traffic has increased by about 35.08% on the roads of Tiruchirappalli district in the past ten years *(Citizen Services of Tamil Nadu Government, Department of Transport- 2016).*The purposes of the study are to obtain the profile of eight carbon fractions and to characterize the source apportionments of carbon fractions of fine particles in Tiruchirappalli city.

MATERIALS AND METHODS

Sampling site:

The Tiruchirappalli City (10.5°N, 78.43°E, 78.8 MSL) is situated on the banks of the River Cauvery Tamil Nadu, South India. Sampling was conducted at five sampling sites, located in distinctly different over the Tiruchirappalli city and Figure 1 shows the location of all sampling sites. The sampling locations were selected at Jamal Mohamed College –TVS Tollgate (JMC), Orchard school- KK.Nagar (OrdS), Central Bus stand (CeBS), Thillai Nagar (ThN) and Chathiram Bus Stand (ChBS). The samplers were placed on the rooftop of buildings in all sampling sites, about 15m height from the ground level.

Figure 1. Location of the sampling site at Tiruchirappalli, India, (M.Arun et all, 2018).



Sample collection:

$PM_{2.5}$ samplers (TH100-PM2.5 medium flow impact samplers, Wuhan Tianhong Instruments, Wuhan, China) were deployed at each site. The samples were collected from June 2015 to July 2016, January-February, March-May, June - September and October - December were defined as winter, summer, pre-monsoon and monsoon, respectively. Samples were collected for 24 hours continuously in each station and the flow rate was maintained at 100 ± 2 L min^{-1}. In this study, quartz filters – Whatman, QM-A quartz filters 90 mm (Quartz microfiber filters: Whatman, GE Healthcare Life Sciences, UK.) were used for the analyses of gravimetric and carbons. The quartz filters were pre-heated in a muffle furnace at 800°C for three hours before sampling to remove the residual carbon. $PM_{2.5}$ mass concentration was obtained by gravimetric method with an analytical microbalance (Mettler Toledo, Switzerland) after being conditioned under constant temperature and relative humidity. Each filter was stored in a separate sealed Petri dish.

Thermal /Optical Carbon Analysis:

OC and EC were analyzed by Desert Research Institute (DRI) Model 2001 transmittance analyzer (TOT, Sunset Laboratory Inc., USA) following the temperature program outlined in the NIOSH 5040 method (Birch and Cary, 1996).. In the analysis procedure, a punch from the filter was analyzed and the four OC fractions (OC1, OC2, OC3, and OC4) were respectively obtained at 140°C, 280°C, 480°C, and 580°C in a Helium atmosphere; In the present work the pyrolyzed OC is not shown separately but added to OC4. And three EC fractions (EC1, EC2, and EC3) were respectively obtained at 580°C, 740°C, and 840°C in a 2% O2/98% Helium atmosphere. In the all procedure, the blank filters were also analyzed to get the blank OC and EC concentrations. The average blank concentrations were used to correct the sample results. The detection limits of OC and EC were 0.98 and 0.02 µg C/punch and

the LODs are 0.474 (OC) and 0.015 (EC) µg C.m^3 respectively. Seven temperature fractions, as well as the TOR and TOT charring correction, are individually quantified and reported when the IMPROVE_A [7] temperature protocol is applied.

RESULTS AND DISCUSSIONS:

PM2.5 concentration:

The annual average concentrations of $PM_{2.5}$ in Tiruchirappalli was observed in the range of 74.1±23.3µg/m^3. Moreover, in the study area CeBS (99.8 µg/m^3) and ChBS (92.9 µg/m^3) stations were observed significantly higher than other stations. Equally, other stations also observed higher concentrations of 44.8 µg/m^3, 57.0 µg/m^3, and 76.0 µg/m^3 in OrdS, ThN and JMC respectively. The present study signified that the mass of $PM_{2.5}$ in Tiruchirappalli exceeded the NAAQS (40 ug/m^3) and WHO (10 ug/m^3) standards [6] . Overall results shows that concentrations of $PM_{2.5}$ ranked in the order of CeBS>ChBS>JMC>ThN>OrdS. The present higher concentrations of $PM_{2.5}$ would cause potential adverse effects to human health.

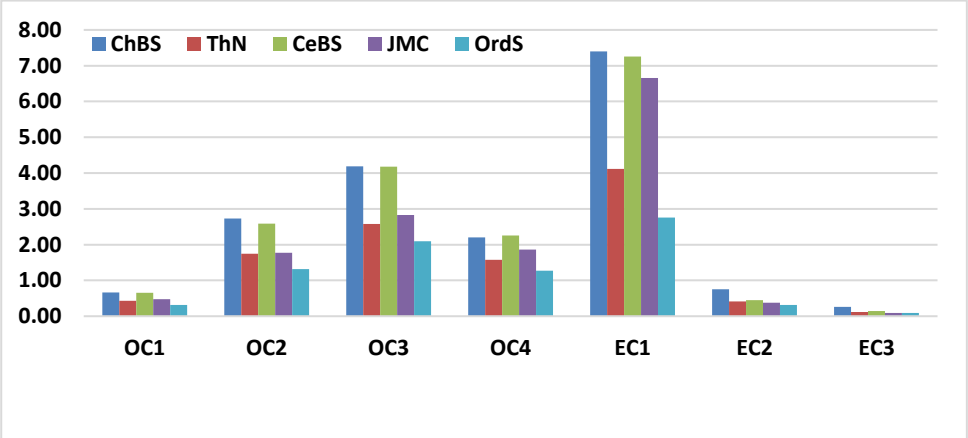
Concentrations and seasonal variation of eight carbon fractions:

The IMPROVE- A temperature protocol method step by step upgraded the temperature to measure each sample, and eight carbon fractions (OC1、OC2、OC3、OC4、EC1、EC2、EC3、OP) were provided. Carbon abundances in each of these fractions differed from carbon sources [8, 9]. The abundance of eight carbon fractions in the source sample showed certain character of source composition. Eight carbon fractions had been used to identify the source apportionment of carbonaceous aerosol [10, 11] For example, OC1 was abundant in the sample of biomass burning. OC2 was abundant in the sample of coal-combustion. The abundance of OC3 and OC4 relatively were in the road dust profile [12]. EC1 was enriched in motor-vehicle exhaust sample [13]. EC2 and EC3 were carbon fractions of coal–combustion and motor-vehicle exhaust. A larger OP fraction for polar organic compounds was extracted in water [14].

Table 1. Seasonal variation and site wise of eight carbon fractions in PM2.5 samples (µg/m^3).

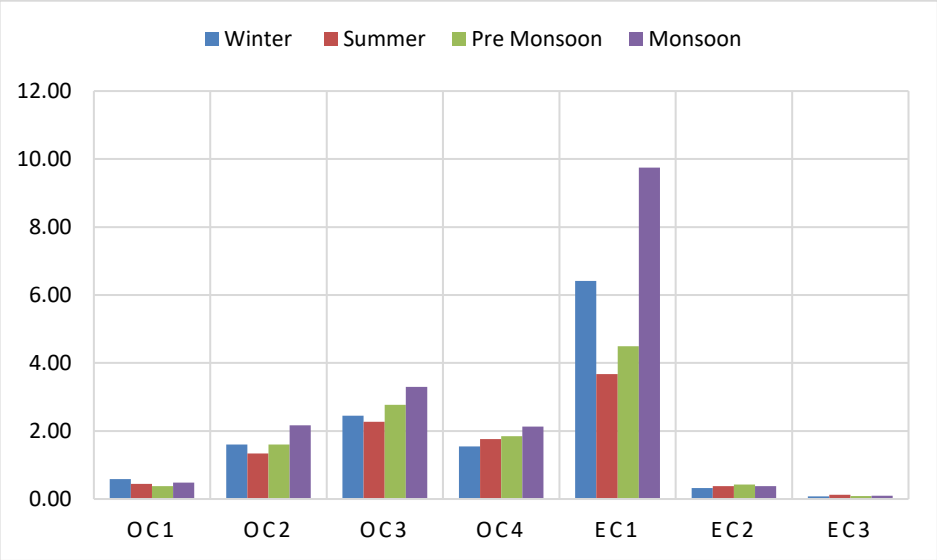
Sampling Sites	OC1	OC2	OC3	OC4	EC1	EC2	EC3	Total OC	Total EC	Total carbon
ChBS	0.67	2.73	4.19	2.20	7.40	0.75	0.26	12.79	5.41	18.20
ThN	0.43	1.75	2.58	1.58	4.12	0.41	0.12	7.66	3.33	10.99
CeBS	0.65	2.58	4.18	2.26	7.25	0.45	0.14	12.21	5.31	17.52
JMC	0.47	1.77	2.82	1.86	6.66	0.38	0.09	7.91	6.15	14.06
OrdS	0.32	1.31	2.10	1.27	2.75	0.32	0.09	6.16	2.00	8.16
Seasons										
Winter	0.58	1.61	2.45	1.55	6.42	0.33	0.08	6.19	6.82	13.02
Summer	0.44	1.34	2.28	1.77	3.68	0.38	0.13	5.82	4.18	10.01
Pre-Monsoon	0.38	1.60	2.77	1.85	4.49	0.43	0.09	6.60	5.00	11.61
Monsoon	0.48	2.17	3.29	2.13	9.74	0.38	0.10	8.08	10.22	18.30
Average	0.47	1.68	2.70	1.82	6.08	0.38	0.10	6.67	6.56	13.23
% in PM2.5 TC	3.58	12.69	20.39	13.78	45.97	2.84	0.75			

Figure 2. The abundance of eight carbon fractions of 2015-16 sampling site wise.



The percentages of carbon fractions collected at Tiruchirappalli city during the sampling periods were shown in Table 1. The annual average abundances of OC1, OC2, OC3, OC4, EC1, EC2 and EC3 were 3.58%, 12.69%, 20.39%, 13.78%, 45.79%, 2.84%, and 0.75% respectively, in PM2.5 TC. EC1 was found to be the major contributor of EC fraction in all the sampling sites. It contributed 87 - 93% over all sampling site (OrdS,ThN , ChBS, CeBS and JMC).EC1 contribution was very high in all sampling sites (figure.2). The contribution of EC1 found to be less (37%) in warm months and high (51%) in cold months, the contribution of EC2 and EC3 found very low in all seasons. The major source of EC1 is reported to be motor vehicle exhaust and vegetative burning [12, 13]. Hence this suggests that major EC subtractions over all the sampling sites are vehicular exhaust. The abundance of EC1, mainly from motor-vehicle exhaust, was relatively stable in all the seasons. The percentages of EC2 were the secondary lowest of EC fraction. Because the gasoline-fueled vehicle was the one of the sources in Tiruchirappalli, While EC2 was the most abundant species in the exhaust of diesel-fueled vehicles. In the sub components, it is found that OC2, OC3 and OC4 are the major OC components, contributing up to 93% of total OC concentration. EC1 was found to be major EC component contributing to the EC concentration 93%.

Figure 3. The seasonal abundance of eight carbon fractions of 2015-16 in Tiruchirappalli city



Carbon content in each of these fractions differs by carbon sources [8]. The reason for lower concentrations of OC1 could be associated with the highly volatile nature of this component. OC3, OC4 and OC2 found to be the major contributor to OC concentrations over Tiruchirappalli. OC3 was found to contribute 40% during all seasons (figure.3). However, the contribution of OC4 was found to vary from 25 to 35% during all seasons. The contribution of OC2 was found to be around 25% in all seasons. Seasonal variation shows that concentrations of ECs and OCs ranked in the order of monsoon>winter>pre-monsoon>summer and the carbon fractions in the order of EC1>OC3>OC2>OC4.The major source for OC3 was found to be enriched in cooking exhaust (43%) as well as in vegetative burning and motor vehicle exhaust (> 10%) Paved dust and unpaved road dust contributes 1 to 10% of the OC3 mass [12].

CeBS, ChBS sites are entitled to very heavy traffic as they are the major bus stations of the city while JMC site marks the cross-section of major highways and hence prone to intermittent traffic at all times. ThN and OrdS are subject to lower traffic than other three sites but enclosed by numerous road side restaurants. All these sites experience emission on and off due to solid waste burning. The study shows that the concentrations of EC1, OC3, OC2 and OC4 in the order of ChBS, CeBS > JMC> ThN > OrdS. The major sources contributing to OC and EC were determined earlier by OC/EC ratio method by Arun et al (6), according to the

study OC/EC ratio varied from 1.21 to 4.55 within an average of 2.51, which indicates that the impact of vehicular emission and biomass burning were the most prominent in Tiruchirappalli City. The variation of eight carbon fractions shows that the clear picture of the pollution sources and confirm that vehicular pollution and biomass burning are the main sources for the carbonaceous pollution in Tiruchirappalli city.

CONCLUSIONS:

The characteristics of eight carbon fractions and seasonal variations were investigated. EC1 was the dominant elemental carbon fraction at all sites in the present study. In the sub components, it is found that OC3, OC4 and OC2 are the major OC components, contributing up to 93 % of total OC concentration. EC1 was found to be major EC component contributing to the EC concentration (up to 93) contributor to PM2.5 in Tiruchirappalli city. Although there was a substantial seasonal variety of eight carbon fractions in PM2.5, the EC1, OC3, OC4 and OC2 were generally the most abundant species, accounting for over 12.0%. This indicated that motor-vehicle exhaust and biomass burning were all contributed to the high carbon species in Tiruchirappalli city.

REFERENCES:

1. Menon, S., Genio, A.D., Koch, D. and Tselioudis, G. GCM Simulations of the Aerosol Lndirect Effect: Sensitivity to Cloud Parameterization and Aerosol Burden. J. Atmos. Sci. 59: 692–713,2002.
2. Watson, J.G., T. Zhu, J.C. Chow, J. Engelbrecht, E.M. Fujita and W.E. Wilson, Receptor modeling application framework for particle source apportionment. Chemosphere, 49(9), 1093-1136 ,2002.
3. Funasaka, K., Miyazaki, T., Kawaraya, T., Tsuruho, K., Mizuno, T., Characteristics of particulates and gaseous pollutants in a highway tunnel. Environmental Pollution 102 (2e3), 171e176 ,1998
4. Harley, R. A., Marr, L. C., Lehner, J. K., and Giddings, S. N.: Changes in motor vehicle emissions on diurnal to decadal time scales and effects on atmospheric composition, Environ. Sci. Technol., 39, 5356–5362, 2005.
5. Kohler, I., Dameris, M., Ackerman, I., and Hass, H.: Contribution ¨ of road traffic emissions to the atmospheric black carbon burden in the mid-1990s, J. Geophys. Res., 106, 17997–18014, 2001.
6. Arun Marimuthu, Mohamed Sihabudeen, Shuiping Wu, Hariharan.G; Pollution characteristics of organic, elemental carbon and water soluble organic carbon in PM2.5 a Tropical City Tiruchirappalli, Tamil Nadu, India. ISROSET-Journal (IJSRBS) Vol.5 Issue.6, pp.44-55, 2018.
7. I.H.S. Chow, V.P. Lau, T.W.C. Lo, Z. Sha, H. Yun Service quality in restaurant operations in China: Decision and experience Oriented perspectives Hospitality Management, 26 (3) pp. 698-710, 2007.
8. Watson, J.G., Chow, J.C., Lowenthal, D.H., Pritchett, L.C., Frazier, C.A., Neuroth, G.R. and Robbins, R. Differences in the Carbon Composition of Source Profiles for Diesel- and Gasolinepowered Vehicles.Atmos. Environ. 28: 2493–2505,1994.
9. Chow, J.C., Watson, J.G., Kuhns, H.D., Etyemezian, V., Lowenthal, D.H., Crow, D.J., Kohl, S.D., Engelbrecht, J.P. and Green, M.C.Source Profiles for Industrial, Mobile, and Area Sources in the Big Bend Regional Aerosol Visibility and Observational (BRAVO) Study. Chemosphere 54: 185–208,2004b.
10. Kim, E., Hopke, P.K. and Edgerton, E.S.Source Identification of Atlanta Aerosol by Positive Matrix Factorization. J. Air Waste Manage. Assoc. 53: 731–739,2003a.
11. Kim, E., Larson, T.V., Hopke, P.K., Slaughter, C., Sheppard, L.E. and Claiborn, C. Source Identification of PM2.5 in an Arid Northwest U.S. City by Positive Mmatrix Factorization. Atmos. Res. 66: 291–305,2003b
12. Yu, J.Z., Xu, J.H. and Yang, H. Charring Characteristics of Atmospheric Organic Particulate Matter in Thermal Analysis. Environ. Sci. Technol. 36: 754–761, 2002.
13. Chow, J.C., Watson, J.G., Chen, L.-W.A., Arnott, W.P., Moosmüller, H. and Fung, K.K. Equivalence of Elemental Carbon by Thermal/Optical Reflectance andTransmittance with Different Temperature Protocols. Environ. Sci. Technol. 38: 4414–4422,2004.
14. Cao, J.J., Chow, J.C., Lee, S.C., Li, Y., Chen, S.W., An, Z.S., Fung, K., Watson, J.G., Zhu, C.S. and Liu, S.X. Characterization and Source Apportionment of Atmospheric Organic and Elemental Carbon during Fall and Winter of 2003 in Xi'an, China. Atmos. Chem. Phys.5: 3127–3137.2005.
15. Barnett, T. P., Adam, J. C., and Lettenmaier, D. P.: Potential impacts of a warming climate on water availability in snow-dominated regions, Nature, 438, 303-309, 10.1038/nature04141, 2005.
16. Kim, E. and Hopke, P.K. Improving Source Identification of Fine Particles in a Rural Northeastern US Area Utilizing Temperature Resolved Carbon Fractions. J. Geophys. Res. 109: D09204, 2004.