MEASUREMENTS OF PM2.5 PARTICLE CONCENTRATIONS AND BLACK CARBON ANALYSIS DURING THE COLD PERIOD IN THE CITY OF RION IN GREECE

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ABSTRACT

Particles less than 2.5 micrometers in diameter (PM2.5) are referred to as "fine" particles and are believed to pose the greatest health risks. Because of their small size, fine particles can penetrate deeply into the lungs. In the present study, the PM2.5 mass concentrations were measured in Rion, Greece during the cold period of 2013-2014 (from 2 October 2013 to 28 March 2014). Specifically, daily PM2.5 samples were collected onto Teflon membrane filters (47 mm in diameter, 1 μm pore size) using a low volume sampler (Partisol®-FRM Model 2000 operated at 16.7 L/min) that was installed 12 m above ground in the University of Patras Campus. The average PM2.5 mass concentration for the sampling period was 9.17±4.25 μg/m^3, which is lower than the PM2.5 annual target value of 25 μg/m^3 (as limit value enters into force 1.1.2015), according to WHO (World Health Organization) and the Air quality Guidelines for Europe. In order to investigate further the air quality of this rural area, Black Carbon (BC) analysis was performed using a Model 43 Smoke Stain Reflectrometer (Diffusion Systems). The average BC concentration was found 0.66±0.35 μg/m^3. Additionally, the correlation coefficients between meteorological conditions (wind speed, relative humidity and ambient temperature) and PM2.5, BC concentrations were also examined. Finally, in order to identify the potential sources of PM2.5 and Black Carbon, the method of Conditional Probability Function (CPF) was used, which relates the concentrations to wind directions. The results have shown as possible sources for PM and BC the city of Patras and the highway. In addition, the port in Rion is also a possible source for Black Carbon.

Keywords: PM2.5, Black Carbon, Fine Particles, Conditional Probability Function, CPF, Rion, Greece

1. Introduction

Atmospheric particulate matter (PM) is nowadays one of the most challenging environmental issues, because of its impacts on climate change, visibility and mostly because of its effects on human health. Thus, since the early 2000s, much research attention has focused on determining which physico-chemical properties of particulate matter with diameter lower than 2.5 μm (PM2.5) are mostly associated with a wide range of health end points, including cardiovascular diseases and even mortality. (Pope & Dockery 2006), (Rohr & Wyzga 2012), (Salameh *et al*. 2015). Therefore, the monitoring and the improvement of air quality is an urgent need.

2. Methodology

2.1. Study Area

Sampling took place in Rion, which is located in the Prefecture of Achaia. It is a small urban, coastal region, northeast of Patras center with a population of 4,664 residents according to the census of 2011. In the area of Rion is also located the University of Patras, where at the roof of the Chemistry Department building, at height of 12 m, the sampler for the particulate matters was installed.

2.2. Sampling

The PM2.5 sampling campaign (on 24h basis) took place during the cold period of 2013-2014 (from 2 October 2013 to 28 March 2014). The samples were collected onto Teflon membrane filters (47 mm in diameter, 1 μm pore size) using a low volume sampler, Partisol®-FRM Model 2000, at an operational flow rate of 16.7 L/min. (Manual 2004)

A total of 59 PM2.5 samples were collected for this study which were weighed before and after sampling in an analytical balance (accuracy, 0.1 μg) after 48h equilibration at a temperature of 20±1°C for the gravimetric determination of PM2.5. After the gravimetric analysis the filters were stored at 4°C. Additionally, the filters were kept into clean polystyrene petri dishes throughout the course of the experimental procedure.

2.3. Black Carbon Method

In the collected filters the concentration of Black Carbon was also measured by optical analysis using a Smoke Reflectrometer (Model 43 Smoke Stain Reflectometer, Diffusion Systems LTD). Calibration of the reflectrometer is provided by the manufacturer. Nevertheless, in order to have results equivalent to those of the modern methods a new calibration was established by parallel measurements of Teflon filter samples and real time monitoring of black carbon by a 7 wavelength aethalometer at the Demokritos GAW urban background site in Athens. As a result, an exponential relationship was established between black carbon mass concentration and reflectance response by the Smoke reflectometer. (Manousakas 2013)

3. Results

Table 1 presents the monthly and total variation of PM2.5 (μg/m^3) and BC (μg/m^3) mass concentrations, whereas, Figure 1 presents the data series of daily PM2.5 and BC concentrations for the sampling period.

Table 1: Monthly and total variation (Arithmetic mean ± Standard deviation) of PM2.5 and BC mass concentrations for Rion during the cold period 2013-14

Month	PM2.5 (μg/m^3)	BC (μg/m^3)
October 2013	9.45±4.08	0.78±0.41
November 2013	10.00±4.60	0.60±0.27
December 2013	7.53±3.37	0.72±0.29
January 2014	7.13±4.76	0.61±0.37
February 2014	9.96±3.39	0.65±0.28
March 2014	9.00±5.59	0.59±0.44
AVERAGE	9.17±4.25	0.66±0.35

As shown in Table 1, the average PM2.5 concentration was 9.17±4.25 μg/m^3. The highest monthly concentration was at November 2013 (10.00±4.60 μg/m^3) and the lowest at January 2014 (7.13±4.76 μg/m^3). The average concentration of BC was 0.66±0.35 μg/m^3.

Furthermore, the Spearman correlation coefficients between the day of the week, the wind speed (WS), relative humidity (RH), ambient temperature (T) and PM2.5, BC concentrations were examined (Table 2), in order to investigate the dependence of PM2.5 from meteorological conditions. (Tai *et al*. 2010), (Pateraki *et al*. 2012)

As shown in Table 2, the PM2.5 mass concentrations presented moderate, but significant correlation with BC, suggesting that it is possible BC and PM2.5 to have common sources. As it is well known, BC originates from combustion processes and this indicates that combustion processes are a major source of PM2.5 too. Also, a moderate, but significant negative correlation between BC and PM2.5 with wind speed was observed, whereas BC presented a small but significant positive correlation with RH. It is also worth noting the absence of any correlation of both PM2.5 and BC with the day of week.

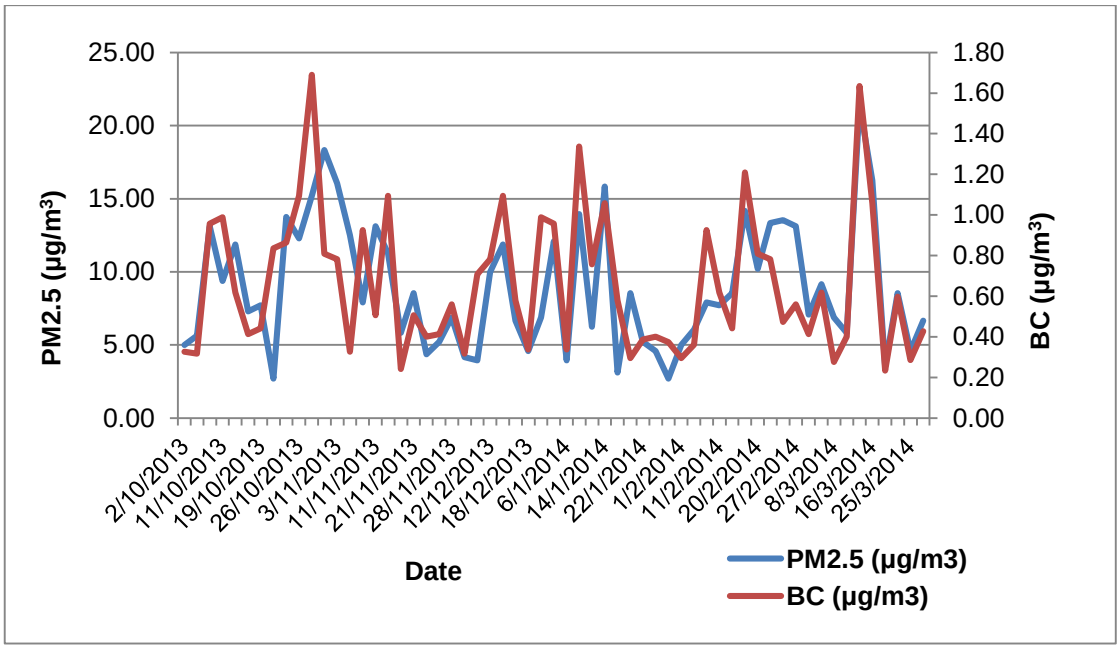

Figure 1: Data series of daily PM2.5 (µg/m^3) and BC (µg/m^3) concentrations for Rio during the cold period.

Table 2: Spearman correlation coefficients for Rio during the cold period.

	PM2.5	BC	WS	T	RH	Day
PM2.5	1.000	0.667**	-0.341**	0.203	0.136	0.119
BC		1.000	-0.504**	0.059	0.273*	0.043
WS			1.000	0.164	-0.583**	-0.045
T				1.000	-0.131	0.119
RH					1.000	0.053
Day						1.000
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).						

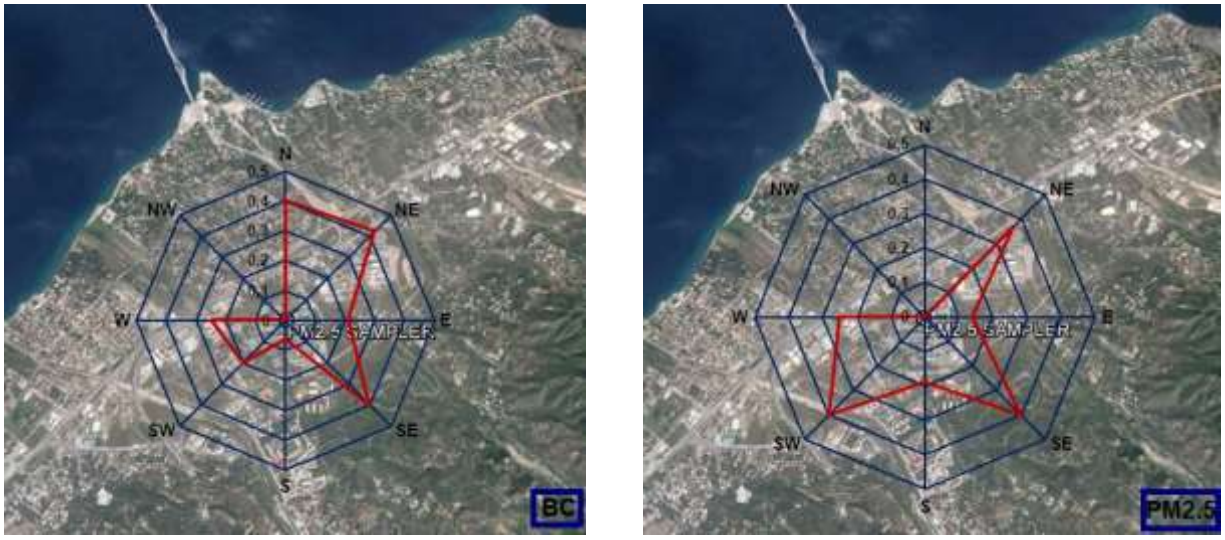

Figure 2: CPF results for BC and PM2.5

Moreover, to analyze point source impacts from various wind directions, the Conditional Probability Function (CPF) was calculated using the daily concentration of PM and BC coupled with the wind direction. (Manousakas 2013), (Uria-Tellaetxe & Carslaw 2014). The results from CPF analysis are presented in Figure 2. The CPF shows that the possible sources for both BC and PM2.5 are mainly the highway which is northeast and also west of the sampler and the city of Patras located southwest of the sampler. There is also a possible source southeast of the sampler for both PM and BC, probably due to the combustion processes, that are taking place in this location, especially in the winter. Moreover, the port of Rion located in the north of the sampler, is a possible source for BC.

4. Conclusions

The average mass concentrations of BC and PM2.5, during the cold period of 2013-14, were found 0.66±0.35 μg/m^3 and 9.17±4.25 μg/m^3, respectively. It is important to note that the average PM2.5 mass concentration is lower than the PM2.5 annual target value, (25 μg/m^3) according to WHO (World Health Organization) and the Air quality Guidelines for Europe.

Spearman correlation coefficients have shown a moderate, but significant correlation between BC and PM2.5, which indicates their common sources.

Moreover, the Conditional Probability Function (CPF) has shown as possible main sources of both of BC and PM2.5 in the examined area the Patras center, the highway and additionally for Black Carbon the port in Rion.

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