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Origin and variability of particulate matter (PM10 and PM2.5) mass concentrations over an Eastern Mediterranean city

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ABSTRACT

Being a semi-enclosed area, the Eastern Mediterranean region experiences high Particulate Matter (PM) levels that could be attributed to sources originating from the region and from long-range transported pollutants. In this study, a long-term evaluation of PM10 and PM2.5 mass concentrations reveals that averages of PM10 and PM2.5 concentrations collected between 2003 and 2007 in several different sites in Beirut exceeded the World Health Organization (WHO) PM10 and PM2.5 annual averages (20 and 10 μg m^{-3}, respectively). When compared to other sites in the region, levels fell in general outside the usual range for most other urban sites that are not directly affected by industrial activity. The average PM2.5/PM10 ratios were about 0.42, a value that is typical of urban sites. The overall averages for different seasons were higher in fall and summer as a result of low precipitations, the increase of dust storm activities in fall and the enhancement of sea and land breezes in summer, along with the increase in traffic activities (summer is a high touristic season). Using the HYSPLIT model for about 500 sampled days in Beirut, Lebanon, it was found that 60% of the wind comes from the N, NW and NE, while the remaining 40% comes from the S, SW and SE. Comparing the sources assigned to the pre- (BH) and post- (HH) 2006-war sites, it was found that aged dust increased by 64% in total PM10 and secondary aerosols by 150% in fine PM in HH over BH. Furthermore, much higher average percentages of sulfates and nitrates were determined in fine PMs in HH, indicating increased levels of their precursors NO_x, SO_x and Ca generated from a higher density of gasoline, diesel vehicles and construction debris.

1. Introduction

The Eastern Mediterranean region is a semi-enclosed area surrounded by the Mediterranean Sea and the Arabian and Saharan Deserts. This region is characterized by a wet winter and a dry summer. Compared to other countries in the Western Mediterranean, precipitation in the Eastern part is low. Spring and fall are very short transitional seasons during which most dust outbreaks occur. The latter usually originate from the Saharan and Arabian deserts.

It is evident from the few studies conducted in the Eastern Mediterranean region that Particulate Matter (PM) levels are much higher than in other regions, even when compared to the Western Mediterranean. In the Western Mediterranean region, PM levels were reported between 28.00–75.50 μg m^{-3} for PM10 and 20.00–40.20 μg m^{-3} for PM2.5, whereas in the Eastern Mediterranean, they ranged between 36.40–184.15 μg m^{-3} for PM10 and 23.90–86.24 μg m^{-3} for PM2.5. Nevertheless, there are remote or rural sites that show much lower PM values (especially PM2.5), like Erdemli, a rural site in Turkey, where the PM2.5 level was 9.7 μg m^{-3} (Table 1). High PM background levels in most Eastern Mediterranean cities could be attributed to several factors like high population density, low recirculation probability of pollutants because of

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Table 1
PM levels and PM2.5/PM10 ratios in some Western and Eastern Mediterranean cities.

Country	Site	Year	PM2.5	PM10	PM2.5/PM10	Reference
Spain	Barcelona	2003–2004	25.00	39.00	0.64	Pey et al. (2008)
Spain	Tarragona	2001	22.20	37.40	0.59	Moreno et al. (2006)
Spain	Barcelona	1995–2005	26.50	43.00	0.62	(Querol et al. (2008)
	Onda		20.00	28.00	0.71	
	Alcora		24.00	35.00	0.69	
	Cartagena		22.00	46.00	0.48	
	Mallorca		20.00	28.00	0.71	
Greece	Athens	1999–2000	40.20	75.50	0.53	Chaloulakou et al. (2003)
Greece	Akrotiri (Crete)	2004–2006 (PM2.5) 2003–2004 (PM10)	25.40	35.00	0.73	Lazaridis et al. (2008)
Greece	Finokalia	2004–2006	18.2	30.8	0.63	Gerasopoulos et al. (2007)
Egypt	Cairo	1999, 2002	86.24	184.15	0.47	Abu-Allaban et al. (2007)
Israel	Ashod Urb	1999	23.9	48.73	0.49	Peled et al. (2005)
Israel	Ashkelon Urb	1999	24.00	67.10	0.36	Peled et al. (2005)
Israel	Sderot Urb	1999	29.20	52.90	0.55	Peled et al. (2005)
Turkey	Erdemli	2001–2002	9.70	36.40	0.27	Koçak et al. (2007)
Turkey	Izmir (Urban)	2004–2005	64.37	79.98	0.80	Yatkin and Bayram (2008)
	Izmir (Suburban)		24.11	46.9	0.51	
Lebanon	HH	2006–2007	27.63	86.81	0.32	This study
	BH	2004–2005	38.86	103.81	0.37	
	Bliss	2003	40.95	71.34	0.57	
	Seagate	2003–2004		86.90		

the geographical setting of the region, frequent dust outbreaks, proximity to the Mediterranean Sea (causing PMs to be rich in sea salt), low precipitation rates, poor vegetal coverage and, in some cases, lack of rules and regulations concerning PM levels (Gerasopoulos et al., 2006; Kocak et al., 2007a; Querol et al., 2001).

Although it is clear that PMs are a big risk in the Eastern Mediterranean, there are very few long-term studies focusing on determining PM yearly averages and their constituents ((Saliba and Massoud, in press), and references therein). Our study covers several years of PM measurements and their chemical composition in the greater Beirut area, Lebanon. The analysis of the presented data allows us to draw conclusions regarding PM seasonal and yearly variations, and the attribution of PMs to their sources.

2. Experimental procedure

2.1. Study sites and data collection

Beirut (7800 persons/km^2) is a city geographically located between the Mediterranean coast from the West and "Mount Lebanon" from the East (35°28′790″E, 33°54′139″N). The Seagate at the American University of Beirut (AUB), Abdel-Aziz (AA) and Bliss sampling sites are all located in Beirut, at a close distance from heavy traffic lines (Fig. 1), which are due to commercial and residential activities, as well as recreational activities during the summer. Sampling site descriptions and details are summarized in Table 2.

Collected Teflon filters were conditioned at room temperature and 50% relative humidity for 24 h before and after

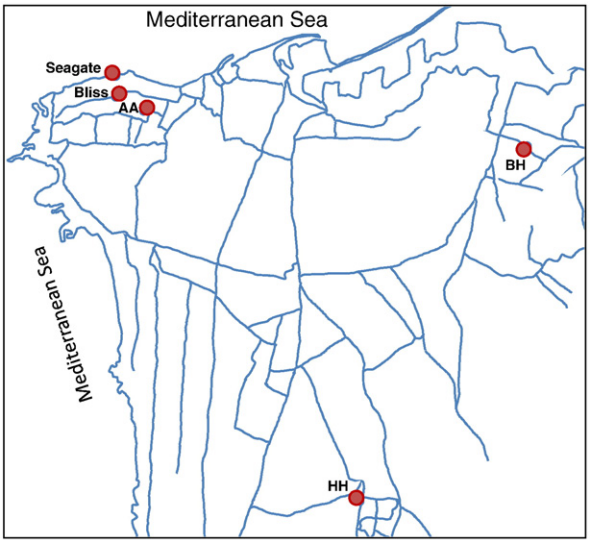

Fig. 1. Map of Beirut. The spots indicate the PM sampling sites (2003–2007).