

## SIZE DISTRIBUTION AND CHEMICAL COMPOSITION OF AIRBORNE PARTICLES AT AKROTIRI RESEARCH STATION, CRETE, GREECE

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### ABSTRACT

Particulate matter measurements were performed at the Akrotiri research station on the island of Crete (Greece) using an 8-stages Andersen non-viable impactor. The main purpose of the current work was to measure the ambient levels of PM<sub>10</sub> particulate matter as well as the concentrations of metals and ions in 8 different PM size fractions with aerodynamic diameter cutoff at 9, 5.8, 4.7, 3.3, 2.1, 1.1, 0.7, 0.4 and a back-up filter for particles below 0.4 µm.

The mean PM<sub>10</sub> concentration during the first sampling period of August 2007 was equal to  $28.2 \pm 14.0 \mu\text{g m}^{-3}$  (10/08/2007 – 26/08/2007), whereas during the second sampling period (09/07/2008 – 16/07/2008) was  $40.2 \pm 16.9 \mu\text{g m}^{-3}$ . Moreover, mean concentrations of PM<sub>2.1</sub> particulate matter were measured on the average equal to a 41.0 % and 37.2 % of PM<sub>10</sub>, respectively for the two corresponding sampling periods. The measurements showed high concentration of fine particles (with aerodynamic diameter less than 0.9 µm), whereas the mass concentration peak was located at an aerodynamic diameter close to 4 - 5 µm. Sulphate was the most abundant anion PM<sub>10</sub>, whereas sea production ions, such as chlorine, sodium and nitrate, were also in elevated concentrations presented. In addition, the crustal element Fe was in higher concentrations in comparison to the measured heavy metals.

**KEYWORDS:** atmospheric aerosols, metals, ions, PM<sub>10</sub>, Andersen impactor.

### 1. INTRODUCTION

The main focus of the current study is on PM mass size distribution ambient levels at the Akrotiri research station. Secondly, another objective is the determination of its chemical composition, mainly on concentration levels of metals and ions.

Atmospheric aerosols play an important role in atmospheric chemistry, human health and climate, especially to the global mean radiative forcing in the climate system (Novakov and Penner, 1993). Recent studies have shown that there is a strong correlation between aerosols, particularly fine and ultrafine particles, and health effects. Atmospheric aerosols contain hundreds of chemical species (organic compounds, metals, ions etc.). Many studies are focusing on measuring aerosol size distributions in urban, rural, and remote sites around the world (Morawska *et al.*, 2002; Stanier *et al.*, 2004). However, only very few size distribution measurements have been performed in the Eastern Mediterranean (Lazaridis *et al.*, 2008; Bardouki *et al.*, 2003; Koulouri *et al.*, 2008).

Particulate matter ambient concentrations were measured at the Akrotiri coastal site, on the north-west of the island of Crete (Greece). Furthermore, in the current study, results on measurements of the ambient PM<sub>10</sub> fraction are presented along with their chemical analysis in order to evaluate the ambient concentration of metals and ions. The main purpose was to measure the particulate matter distributions and the corresponding chemical speciation. In order to accomplish that, an 8-stages sampler has been used (non-viable Andersen impactor).

The current measurements reveal that the mean PM<sub>10</sub> concentration levels are in agreement with previous measurements in the Akrotiri station (Lazaridis *et al.*, 2008).and other studies in the eastern Mediterranean (Bardouki *et al.*, 2003; Koulouri *et al.*, 2008).

## 2. SITE DESCRIPTION AND METHODS

Two measurement campaigns took place at the Akrotiri station. The station (35°31'48"N, 24°03'36"E), which has been established in the region of Akrotiri in 2003, is a typical urban background station. It is located 7 km away from the town of Chania (60,000 inhabitants) at an elevation of 137 m from sea level (Lazaridis *et al.*, 2008).

Sampling was carried out on the roof of a small building, with the Andersen impactor to be positioned at a height of about 2.5 m above the ground level. The first campaign took place from August 10<sup>th</sup> to August 26<sup>th</sup>, 2007 using GF (Glass Fiber) filters as substrate to collect atmospheric aerosols, and the second one was performed during the period 9<sup>th</sup> – 16<sup>th</sup> July 2008 using QF (Quartz Fiber) filters. The sampling time for each series of filters lasted 48 h in the first campaign, whereas in the second one lasted 24 h. On the total, fifteen series of filters (each series consisted of 9 filters) were collected during the two campaigns. During the sample collection, the ambient air flow rate was equal to 28.3 L min<sup>-1</sup>. In addition a dry gas meter was connected between Andersen impactor and the pump for the calibration of the flow rate.

An 8-stages non-viable Andersen impactor was used to collect particulate matter. The Andersen sampler is a cascade impactor which consists of 9 stages (8 aluminium plates and one back-up stage) with aerodynamic diameter cutoff at 9, 5.8, 4.7, 3.3, 2.1, 1.1, 0.7, 0.4 µm and 0 µm. GF and QF filters with 1.6 µm pore size and 81 mm diameter were used for the gravimetric Andersen sampler. Filters were dried before and after weighting, in a laboratory room with approximately constant temperature and relative humidity conditions for a 24-h period. A Sartorius balance with mass resolution of 0.01 mg was used for the weighing of the filters, before and after the sampling.

After the sampling and before the analysis, each filter was divided into two pieces, the masses of which were determined accurately, in order to be used for atomic absorption spectrometry (AAS) and ion chromatography (IC) analysis. Chemical analysis was performed on GF and QF filters in order to evaluate the concentration of various heavy metals (Fe, Cr, Cu, Ni and Pb) and anions and cations (Cl<sup>-</sup>, Br<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, PO<sub>4</sub><sup>3-</sup>, SO<sub>4</sub><sup>2-</sup>, C<sub>2</sub>O<sub>4</sub><sup>2-</sup>, NH<sub>4</sub><sup>+</sup>, K<sup>+</sup>, Mg<sup>2+</sup> and Ca<sup>2+</sup>).

In order to analyze metals, loaded GF filter samples were digested in an ultrasonic bath with 8 ml nano-pure water, 2 ml HCl and a small amount of HNO<sub>3</sub> (3 drops). Furthermore, loaded QF filters were transferred to Teflon vessels and digested with 5 ml HNO<sub>3</sub> (65 % v/v) and 5 ml nano-pure water in a microwave oven for 8 minutes. The determination of elements in atmospheric aerosols was conducted by Atomic Absorption Spectrometry (AAS). Flame was used for Fe determination, whereas for Cr, Cu, Ni and Pb, electrothermal atomization in graphite furnace was used.

The other half of the filter was extracted with 15 ml nano-pure water in an ultrasonic bath for 45 minutes. Extracts, after the addition of 150 µl CHCl<sub>3</sub> were stored at 4°C and were further analyzed for the determination of the concentration of ions by Ion Chromatography (IC).

In addition, during the July 2008 an additional measurement campaign was performed using a beta radiation attenuation monitor (FH 62 I-R, Beta gauge, ESM Andersen Instruments GmbH, Erlangen, Germany) and a gravimetric Andersen impactor, in order to find the correlation between the two different sampling techniques. The monitor used the radiometric dust measurement with a two beam-compensation method for the continuous mass

determination of the dust sample on the filter. Simultaneously, during the sampling, the accumulated particle mass on the filter was measured. The airflow rate was recorded both on-line and off line. A data logger was storing the beta monitor data every 15 minutes.

Furthermore, the origin of the aerosols on the Akrotiri station was studied using the HYSPLIT4 Model of the Air Resources Laboratory of the National Oceanic and Atmospheric Administration (NOAA) (Draxler R.R., 1994; NOAA-ARL., 2002). The 3-dimensional trajectories were computed for the coordinates 35.53N, 24.06E, which are the coordinates of the Akrotiri region, for 12:00 am for each day of measurements. The trajectories were 120h (5 days) long. Each trajectory was divided into five segments. Each segment was assigned to one of the eight sectors (north, north-east, east etc.).

### 3. RESULTS AND DISCUSSION

#### 3.1. Aerosol measurements

In the present work, the PM<sub>2.1</sub> fraction incorporates the sum of the 4 filters with the lower cut-offs (below of 2.1  $\mu\text{m}$ ), whereas the PM<sub>10</sub> fraction is the sum of the 9 collected filters. As it depicted from the Tables 1 and 2 the mean concentration for PM<sub>10</sub> and PM<sub>2.1</sub> for the whole measuring time period was  $28.2 \pm 14.0 \mu\text{g m}^{-3}$  (PM<sub>10</sub>) and  $12.4 \pm 10.2 \mu\text{g m}^{-3}$  (PM<sub>2.1</sub>), for the first measurement period respectively (August 2007). The concentrations during the second measurement period (July 2008) were  $40.2 \pm 16.9 \mu\text{g m}^{-3}$  (PM<sub>10</sub>) and  $14.1 \pm 6.5 \mu\text{g m}^{-3}$  (PM<sub>2.1</sub>) respectively. There is a high variability of the PM<sub>10</sub> measurements with concentrations ranging from  $14.0 \mu\text{g m}^{-3}$  to  $57.4 \mu\text{g m}^{-3}$  and from  $21.3 \mu\text{g m}^{-3}$  to  $66.4 \mu\text{g m}^{-3}$ , for the first and second sampling periods, respectively. Mean concentration of PM<sub>10</sub> during the second period is higher compared to the first measurement period. During the first campaign the PM<sub>10</sub> concentration exceeded the 24-h limit value of  $50 \mu\text{g m}^{-3}$  only once (22-24/08/2007), whereas during the second campaign (9-10/07/2008 & 15-16/07/2008) the European PM<sub>10</sub> limit exceeded two times.

Table 1. Concentration levels of PM<sub>10</sub> and PM<sub>2.1</sub> during the measurement period from 10/08/07 to 26/08/07 at the Akrotiri research station

Date	Volume of air (m <sup>3</sup> )	PM10 ( $\mu\text{g m}^{-3}$ )	PM2.1 ( $\mu\text{g m}^{-3}$ )
10 - 12/08/07	80.9	17.0	5,4
12 - 14/08/07	96.2	24.7	6,2
14 - 16/08/07	96.3	14.0	7,1
16 - 18/08/07	96.3	23.9	11,3
18 - 20/08/07	96.0	28.3	14,7
20 - 22/08/07	95.7	21.1	7,9
22 - 24/08/07	94.0	57.4	36,5
24 - 26/08/07	96.4	39.0	10,3
<b>Mean values of GFFs</b>		<b>28.2 <math>\pm</math> 14.0</b>	<b>12.4 <math>\pm</math> 10.2</b>

Table 2. Concentration levels of PM<sub>10</sub> and PM<sub>2.1</sub> during the measurement period from 09/07/08 to 16/07/08 at the Akrotiri research station

Date	Volume of air (m <sup>3</sup> )	PM <sub>10</sub> ( $\mu\text{g m}^{-3}$ )	PM <sub>2.1</sub> ( $\mu\text{g m}^{-3}$ )
09 - 10/07/08	50.8	55.0	19,1
10 - 11/07/08	51.4	47.5	20,2
11 - 12/07/08	51.6	32.0	12,0
12 - 13/07/08	52.9	36.9	13,6
13 - 14/07/08	48.8	22.4	6,8
14 - 15/07/08	51.5	21.3	5,4
15 - 16/07/08	51.4	66.4	21,4
<b>Mean values of QFFs</b>		<b>40.2 <math>\pm</math> 16.9</b>	<b>14.1 <math>\pm</math> 6.5</b>

Moreover, the  $PM_{2.1}$  fraction (the sum of the last 4 filters) constitutes the 25.1 – 63.5 % of the  $PM_{10}$  during the first measurement period (August 2007), and 25.3 – 52.3 % during the second sampling period (July 2008), with a mean value equal to 41.0 % in the first period and 37.2 % in the second one. Therefore, about 40 % of the whole mass of  $PM_{10}$  atmospheric particulate matter is in the form of fine particles with aerodynamic diameter less than 2.1  $\mu m$ . Those are in agreement with other studies in Greece (Koulouri *et al.*, 2008a). In addition, the  $PM_{2.1}$  levels are well correlated with the corresponding concentrations of  $PM_{10}$  ( $R^2$  (2007) = 0.89 and  $R^2$  (2008) = 0.86).

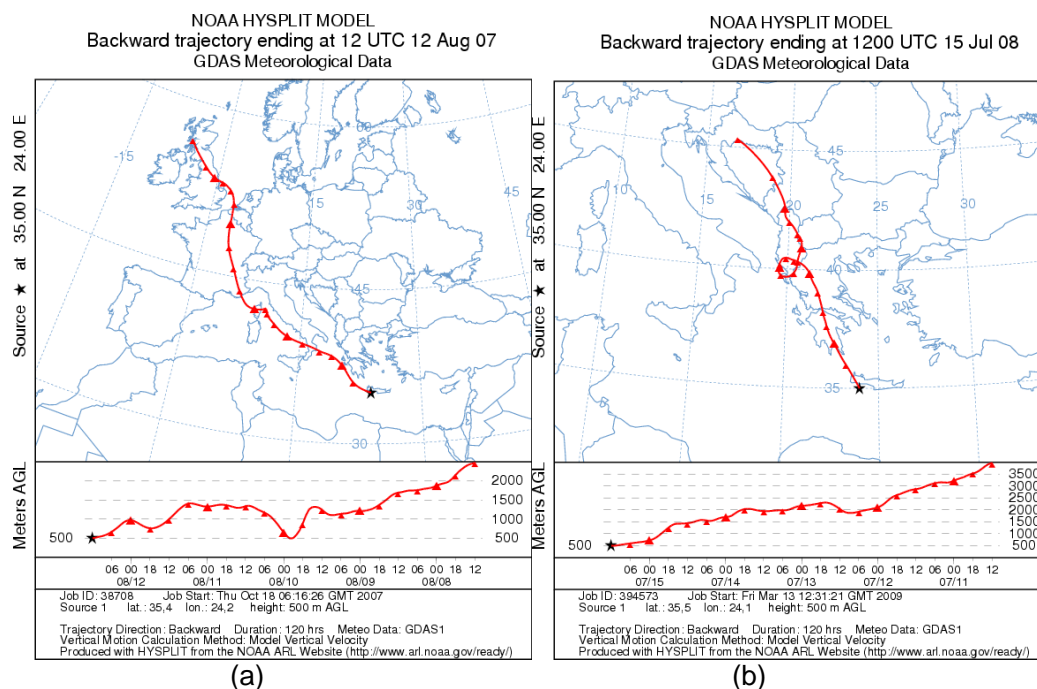
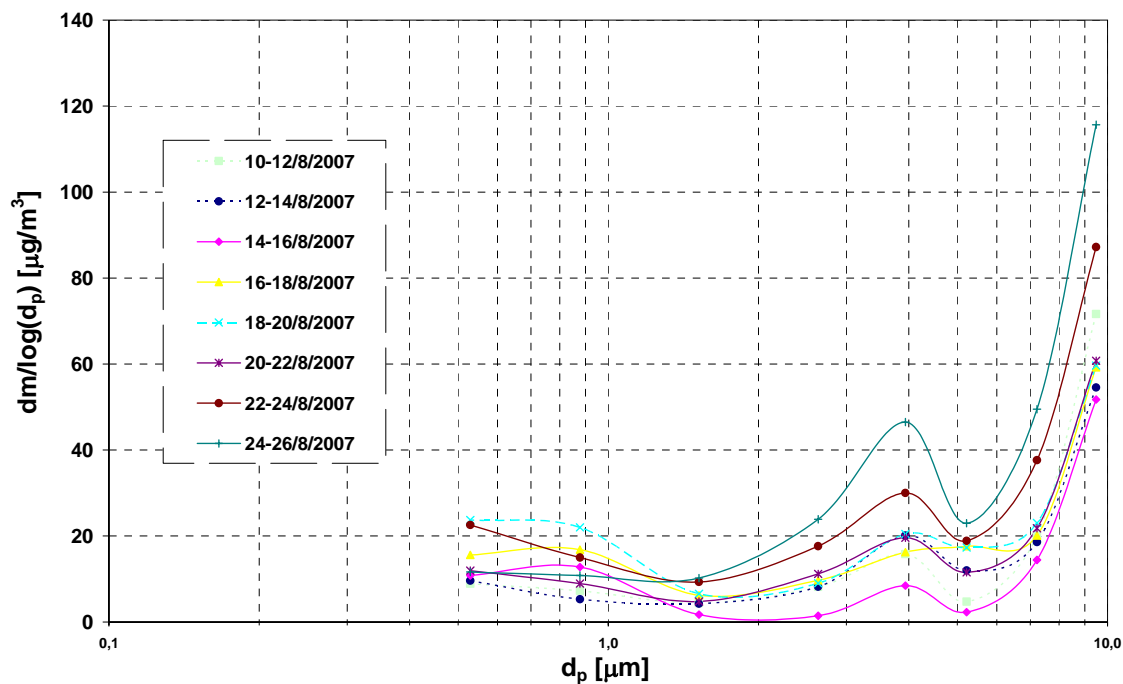


Figure 1. Characteristic back trajectories calculated by HYSPLIT4 Model (NOAA, 2002) for (a) August 2007, and (b) July 2008

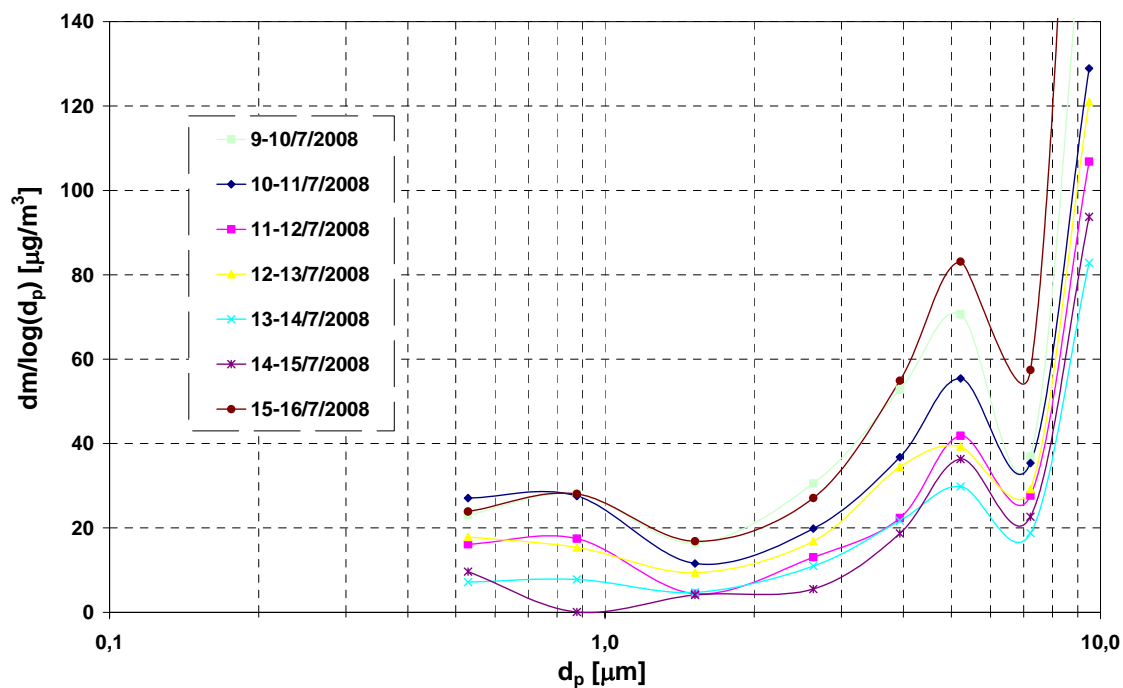
This analysis of the origin of the aerosols on the Akrotiri station showed that in both periods winds from North – Northwest directions were dominant. The air masses passed over the Mediterranean Sea for more than 48 hours prior to coming over the monitor station (see Figure 1). This fact can explain the observed  $PM_{10}$  concentrations (absence of a Saharan dust episode) (Lazaridis *et al.*, 2008).

In Figure 2, where all the 24h or 48h values of the 9 collected fractions of the whole  $PM_{10}$  are depicted, two main peaks are clearly evident. At aerodynamic diameter less than 1  $\mu m$ , nanoparticles showed an increased concentration, whereas a second mass concentration peak was observed at aerodynamic diameters close to 4  $\mu m$  in August 2007 and 5  $\mu m$  in July 2008 measurement period. These results are in agreement with recent research findings in other studies (Jaworski *et al.*, 2002). In the present work, a third maximum was observed, corresponding to the first two stages, where the impactor collected the largest atmospheric particles, with aerodynamic diameter larger than 5.8  $\mu m$ .

Furthermore, during July 2008, from 09/07/2008 to 16/07/2008, continuous concurrent measurements of particulate matter ( $PM_{10}$ ) were performed using a beta radiation attenuation monitor (sampling flow rate 1  $m^3 h^{-1}$ ,  $PM_{10}$  head, glass fiber filter, it measures the attenuation of a beam of beta particles generated by a source) and a gravimetric Andersen sampler (collision of airborne particles on a paper plate), in order to find the correlation between the two different sampling techniques. As it is depicted in Table 3, the mean average concentration of  $PM_{10}$  was  $40.4 \pm 13.7 \mu g m^{-3}$  for beta monitor and  $40.2 \pm 16.9 \mu g m^{-3}$  for the sequential Andersen impactor whereas the Pearson' coefficient for the two measurement methodologies was  $r = 0.69$ .



(a)



(b)

Figure 2. Mass concentration distribution of Andersen impactor vs. aerodynamic mass diameter for (a) August 2007, and (b) July 2008

### 3.2. Ions and metals concentrations

In Table 4 are presented the results from the ion chromatography analysis. In general, sulphate seems to be the most abundant anion with average concentrations of 18.4 and 6.8  $\mu\text{g m}^{-3}$  for the first and second measurement periods, respectively. It has been measured also that the air masses arrive at east Mediterranean contain appreciable quantities of Gypsum, a common mineral, and other sulphate salts. It has been confirmed from chemical analysis of air samples of the region after rain events (winter season), concentration of sulphates is lower as a consequence of deposition of water-soluble sulphates (data not shown). The above

observations are in agreement with other studies done in east Mediterranean which show elevated concentrations of sulphates (Bardouki *et al.*, 2003), especially into fine particles (Mamane *et al.*, 2008).

Table 3. Concurrent daily values using a beta radiation monitor and a gravimetric sampler

Date	PM <sub>10</sub> of Beta radiation attenuation monitor ( $\mu\text{g m}^{-3}$ )	PM <sub>10</sub> of Andersen impactor ( $\mu\text{g m}^{-3}$ )
09-10/07/08	59.0	55.0
10-11/07/08	44.2	47.5
11-12/07/08	29.8	32.0
12-13/07/08	30.8	36.9
13-14/07/08	20.6	22.4
14-15/07/08	46.6	21.3
15-16/07/08	51.5	66.4
<b>Mean values</b>	<b>40.4 ± 13.7</b>	<b>40.2 ± 16.9</b>

Moreover, chlorine, potassium and sodium ions have predictable increased concentrations as an effect of the small distance of the Akrotiri research station from the coast. The phosphate concentration values were extremely high in July 2008, a result which was quite unusual, whereas during the first sampling period (August 2007) the concentration is fluctuated close to normal levels observed in the Mediterranean region (Bergameti *et al.*, 1992). The elevated concentrations of phosphate, as well as nitrate, may be associated with agricultural activities in the region of Chania (use of artificial fertilizer).

As it depicted in Tables 4(a) – 4(d), the sum of measured anions is about six times higher than the sum of cations in each fraction during the first campaign, whereas only two times higher during the second campaign. Additionally, sea production ions as chlorine and nitrates have higher concentrations in the first stages of the Andersen impactor which corresponded in airborne particles with larger aerodynamic diameter (coarse particles). This is in agreement with the source and formation mechanism of those ions (Mamane and Gottlieb 1992; Pakkanen *et al.*, 1999). Moreover, the low concentrations of nitrates in the fine particles show the insignificant participation of anthropogenic activities (Bardouki *et al.*, 2003, and references therein). On the other hand, other species as sulphates and ammonium show increased values of concentration in the last stages of the sampler where the fine and ultrafine particles are present (Koulouri *et al.*, 2008). In general, high ion concentration is observed in the area, and there is a need for additional measurements in order to determine the variability of their concentrations (Zhang *et al.*, 2007).

Additionally, sea production ions as chlorine and nitrates possess higher concentrations in airborne particles with larger aerodynamic diameters from 2.1 to 10  $\mu\text{m}$  (coarse particles). This is in agreement with the source and formation mechanism of those ions (Mamane and Gottlieb 1992; Pakkanen *et al.*, 1999). On the other hand, other species as sulphates and ammonium show increased values of concentration in the fine and ultrafine particles with aerodynamic diameters below the 2.1  $\mu\text{m}$  (Koulouri *et al.*, 2008). In general, high ion concentration is observed in the area, and there is a need for additional measurements in order to determine the variability of their concentrations (Zhang *et al.*, 2007).

Moreover, the atomic absorption spectrometry results are presented in Table 5. In general, the concentrations of anthropogenic elements (Cu, Cr, Pb and Ni) are low, as compared to the concentrations of Fe (crustal element). Both are shown decreased concentrations in fine fraction with on average a percentage of 36.6 % of metals into particles with diameter lower than 2.1  $\mu\text{m}$ . These results are in agreement with previous studies on the SE Mediterranean Sea region (Smolik *et al.*, 2003; Karanasiou *et al.*, 2007) and elsewhere (Gerab *et al.*, 1998). The concentration of Fe, a soil dust characteristic element, is greater in the coarse fraction compared to the fine mode aerosols, indicating the contribution of soil dust resuspension (illite etc.).

Table 4. Mean averaged concentrations of anions and cations ((a) and (c)) of PM<sub>10</sub> and concentrations of ions of the 9 collected PM fractions ((b) and (d)) (in ng m<sup>-3</sup>)

Date	Cl <sup>-</sup>	Br <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	PO <sub>4</sub> <sup>3-</sup>	SO <sub>4</sub> <sup>2-</sup>	C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup>	NH <sub>4</sub> <sup>+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Ca <sup>2+</sup>
10 - 12/08/07	2526.3	4.3	3261.5	0.0	9274.1	456.0	1661.7	364.3	264.7	109.8	410.9
12 - 14/08/07	3064.8	10.0	5077.2	0.0	14413.4	674.9	2470.2	261.7	224.3	120.3	193.0
14 - 16/08/07	1031.5	1.5	4318.9	0.0	25133.6	841.9	3691.6	699.7	613.1	88.6	294.3
16 - 18/08/07	2414.3	9.4	4771.9	57.6	20893.6	598.0	3412.5	533.2	616.4	92.8	340.5
18 - 20/08/07	1940.3	6.6	4410.3	31.2	23990.5	613.2	3786.6	1597.5	1084.3	107.4	823.8
20 - 22/08/07	2165.4	11.6	4394.9	15.1	13852.7	509.1	2832.4	596.5	592.8	69.7	237.8
22 - 24/08/07	3278.1	10.2	5703.8	13.7	27053.3	891.3	4485.0	1298.6	1652.2	137.1	858.2
24 - 26/08/07	9940.6	30.2	7631.0	46.8	15192.9	692.7	4838.4	410.6	444.4	364.4	926.1
<b>Mean value</b>	<b>3295,2</b>	<b>10,5</b>	<b>4946,2</b>	<b>20,6</b>	<b>18725,5</b>	<b>659,6</b>	<b>3397,3</b>	<b>720,3</b>	<b>686,5</b>	<b>136,3</b>	<b>510,6</b>
<b>St. dev.</b>	<b>2772,8</b>	<b>8,7</b>	<b>1290,2</b>	<b>22,4</b>	<b>6402,9</b>	<b>150,4</b>	<b>1048,1</b>	<b>476,2</b>	<b>472,1</b>	<b>94,4</b>	<b>305,3</b>

(a)

PM fraction (μm)	Cl <sup>-</sup>	Br <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	PO <sub>4</sub> <sup>3-</sup>	SO <sub>4</sub> <sup>2-</sup>	C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup>	NH <sub>4</sub> <sup>+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Ca <sup>2+</sup>
<b>9.0-10</b>	964,1	1,2	765,0	4,4	1648,2	43,9	523,7	32,4	95,2	11,3	86,4
<b>5.8-9.0</b>	1265,2	1,3	1381,6	6,6	1855,5	66,3	700,3	27,2	128,7	43,5	262,3
<b>4.7-5.8</b>	199,3	0,6	284,0	5,3	1048,1	26,3	63,4	19,8	13,4	5,6	21,9
<b>3.3-4.7</b>	484,1	0,8	1104,3	0,0	1273,0	64,9	531,2	17,4	3,6	23,3	79,6
<b>2.1-3.3</b>	219,3	0,7	798,5	2,1	1137,0	77,5	232,5	20,7	2,1	11,7	13,0
<b>1.1-2.1</b>	116,3	0,9	440,0	0,0	1436,7	93,6	191,2	23,2	0,0	9,4	2,7
<b>0.7-1.1</b>	2,6	1,5	78,6	2,1	3446,9	88,9	363,5	160,5	161,4	8,5	17,8
<b>0.4-0.7</b>	4,4	2,0	48,3	0,0	4437,0	109,0	517,2	372,7	254,3	9,5	23,8
<b>0.0-0.4</b>	39,9	1,5	45,9	0,0	2443,2	89,1	274,2	46,4	27,9	13,5	2,9
<b>Total</b>	<b>3295,2</b>	<b>10,5</b>	<b>4946,2</b>	<b>20,6</b>	<b>18725,5</b>	<b>659,6</b>	<b>3397,3</b>	<b>720,3</b>	<b>686,5</b>	<b>136,3</b>	<b>510,6</b>

(b)

Date	Cl <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	PO <sub>4</sub> <sup>3-</sup>	SO <sub>4</sub> <sup>2-</sup>	C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup>	NH <sub>4</sub> <sup>+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Ca <sup>2+</sup>
09 - 10/07/08	1838.7	3024.4	3779.8	9816.3	482.5	3760.1	2481.9	926.9	395.6	3143.7
10 - 11/07/08	2084.8	1514.8	5752.8	8509.5	382.6	5229.2	2179.4	701.8	324.0	2626.6
11 - 12/07/08	3222.7	1474.2	3944.5	6907.9	320.2	3821.8	1592.6	688.1	323.9	1999.4
12 - 13/07/08	3135.4	1461.1	2735.3	4392.7	222.6	3698.8	927.2	497.9	290.1	1566.7
13 - 14/07/08	3613.1	1496.2	2821.1	3447.1	180.4	4855.6	686.4	874.0	277.9	1548.9
14 - 15/07/08	2006.8	1410.0	3879.3	4827.9	255.2	3579.0	993.0	770.4	265.6	2120.0
15 - 16/07/08	2641.2	961.7	3875.0	6573.2	286.4	6081.6	1402.2	222.0	320.9	4208.8
<b>Mean value</b>	<b>2649,0</b>	<b>1620,3</b>	<b>3826,8</b>	<b>6353,5</b>	<b>304,3</b>	<b>4432,3</b>	<b>1466,1</b>	<b>668,7</b>	<b>314,0</b>	<b>2459,2</b>
<b>St. dev.</b>	<b>693,1</b>	<b>648,4</b>	<b>994,4</b>	<b>2295,4</b>	<b>102,4</b>	<b>968,3</b>	<b>668,7</b>	<b>241,3</b>	<b>43,1</b>	<b>958,2</b>

(c)

PM fraction (μm)	Cl <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	PO <sub>4</sub> <sup>3-</sup>	SO <sub>4</sub> <sup>2-</sup>	C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup>	NH <sub>4</sub> <sup>+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Ca <sup>2+</sup>
<b>9.0-10</b>	447.1	175.2	53.1	290.6	18.1	514.0	47.2	48.8	39.8	310.9
<b>5.8-9.0</b>	559.1	322.6	47.9	331.4	19.1	584.6	34.8	57.1	42.0	317.4
<b>4.7-5.8</b>	366.9	262.3	344.0	306.2	19.6	474.8	35.9	38.8	41.3	320.7
<b>3.3-4.7</b>	443.5	484.3	432.8	378.8	31.1	710.1	42.4	60.4	55.1	337.7
<b>2.1-3.3</b>	225.3	250.9	449.8	365.7	34.9	431.5	42.5	45.4	37.9	231.1
<b>1.1-2.1</b>	199.9	125.1	571.8	597.4	38.1	480.8	83.4	59.4	30.8	193.2
<b>0.7-1.1</b>	128.0	0.0	640.8	1451.8	54.4	321.0	480.4	103.8	23.4	219.2
<b>0.4-0.7</b>	153.5	0.0	663.7	1724.5	52.1	547.3	549.1	183.3	24.9	295.6
<b>0.0-0.4</b>	125.8	0.0	623.1	907.0	37.0	368.1	150.5	71.7	18.7	233.2
<b>Total</b>	<b>2649,0</b>	<b>1620,3</b>	<b>3826,8</b>	<b>6353,5</b>	<b>304,3</b>	<b>4432,3</b>	<b>1466,1</b>	<b>668,7</b>	<b>314,0</b>	<b>2459,2</b>

(d)

Table 5. Mean concentrations of heavy metals in the 9 collected PM fractions during the measurement period in August 2007 (in ng m<sup>-3</sup>)

PM fraction ( $\mu\text{m}$ )	Cu	Cr	Fe	Pb	Ni
9.0-10	1.1	25.1	343.6	15.0	0.2
5.8-9.0	1.0	19.7	345.7	12.1	0.2
4.7-5.8	0.6	8.4	249.2	5.8	0.0
3.3-4.7	0.2	2.4	233.4	5.8	0.1
2.1-3.3	0.4	2.1	239.8	5.9	0.1
1.1-2.1	0.4	2.2	243.8	6.5	0.0
0.7-1.1	0.5	1.3	211.5	6.4	0.0
0.4-0.7	0.2	0.8	183.6	5.3	0.3
0.0-0.4	0.4	2.2	203.4	6.5	1.0
<b>Total</b>	<b>4.8</b>	<b>64.4</b>	<b>2254.0</b>	<b>69.3</b>	<b>1.9</b>

#### 4. CONCLUSIONS

Particulate matter measurements were performed at the Akrotiri research station on the island of Crete, Greece during two campaigns (August 2007, July 2008). Gravimetric analysis of samples has shown similar variability of the PM<sub>10</sub> values in agreement with previous studies (Lazaridis *et al.*, 2008). The PM<sub>10</sub> values ranged from 14.0  $\mu\text{g m}^{-3}$  to 57.4  $\mu\text{g m}^{-3}$  and from 21.3  $\mu\text{g m}^{-3}$  to 66.4  $\mu\text{g m}^{-3}$ , for the first and second sampling periods, respectively. The size distribution had a bimodal shape, with mass mean diameters at 0.8 and 4  $\mu\text{m}$ , and 0.8 and 5  $\mu\text{m}$ , respectively during the two measurement campaigns.

Furthermore, the chemical composition of aerosols was determined. Ions have shown very high concentrations in all 9 collected PM fractions, especially for sulphate, sodium, chloride, nitrate and phosphate ions. Finally, crustal metals as Fe have shown much higher concentrations than corresponding anthropogenic ambient concentrations, since the Akrotiri station is situated in a suburban, non industrial area in a Mediterranean island.

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