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Fathi Zereini · Clare L.S. Wiseman (*Eds.*)

Urban Airborne Particulate Matter

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Volume Editors

Urban Airborne Particulate Matter

Origin, Chemistry, Fate and Health Impacts

Springer

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Preface

Particles have been a recognized ingredient in polluted air for decades if not centuries. Despite the fact that their atmospheric concentrations have decreased substantially in developed countries over the last 50+ years, due to government policies and evolving technologies, particles continue to be a high priority environmental issue. This is because of growing evidence, starting in the early 1990s, of significant health effects at lower ambient concentrations than expected and because of the recognition that our understanding of their net effect in regulating the Earth's climate is insufficient. In particular, the magnitude and direction of their indirect effect on the radiation budget and the extent to which particles will play a role in positive or negative climate feedbacks are not known. Geoengineering responses to climate change may also involve atmospheric particles, but much more information is needed before the risks and benefits of such measures can be properly evaluated. Engineered nanoparticles represent another pressing environmental issue for which our knowledge is incomplete.

There are many directions in need of research to further our understanding in support of wise environmental and public health management pertaining to particles. In this book readers will find unique contributions to our knowledge on atmospheric and indoor particles and related pollutants or exposures. The context for much of what is presented is geared towards pollution issues and health effects as opposed to climate and engineered nanoparticles. However, many of the methods developed and/or applied in the papers in this book are quite relevant to particle research related to these latter two issues. For example, there are several papers that describe and apply advanced particle measurement methods, including chemical analysis techniques, for trace and ultra-trace metals and gas/particle phase organics. While these methods are shedding new light on the chemical characteristics and sources of particles to the benefit of risk assessment and exposure reduction strategies, they can be turned towards studying particle properties related to global aerosols and climate. Other papers in this book present new data on concentrations and important chemical constituents, including levels in the biota, indoor dust and other microenvironments. These are helping to complete the picture for particles, their sources and sinks across the globe, and human and

biological exposures. Yet other papers focus on quantifying exposure to combustion nanoparticles or studying the fate of motor vehicle exhaust catalyst materials, both of which provide scientific insights that will benefit efforts to study the potential impacts of engineered nanoparticles. Rounding out this book are a number of subject reviews from health effects and the mechanisms of oxidative stress, to persistent organic pollutants and motor vehicle emissions and to the challenges of setting ambient and emissions standards.

PM2.5 and/or PM10 levels exceed current standards or guidelines in many countries and are they alarmingly high in several megacities, particularly in some developing nations. Solving these public health problems represents a tremendous scientific challenge as well as an economic one. This is especially the case in countries where the 'easier' policies have been implemented so the options that remain are potentially more complex and more costly to undertake. Therefore, in addition to scientific research to quantify, by size, concentrations of total mass, chemical constituents and the main sources contributing to the problem, devising more cost-effective ways to achieve maximum benefits to public health is important. This necessitates, as one of the papers in this book discusses, that research continues working towards identification of the types and/or sources of particles that pose greater risk, including consideration of the combined effects of particles and gaseous co-pollutants. While this seems to be a straightforward endeavour, there is more than one particle type and or pollutant mix that can be considered 'most harmful' given the range of acute and chronic health outcomes linked to particle exposure. Consideration of environmental impacts further expands the list of emission sources and subsequent particle types that might warrant preferential control. I am sure that readers will find that this book provides a diverse, yet complementary range of information helpful in gaining the insight needed to make further headway on the challenges posed by particulate air pollution.

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Preface of the Editors

The idea for this edited volume originated in 2008, after much discourse with colleagues regarding the need for a multidisciplinary book which pulls together the most up-to-date research on the chemistry and environmental fate of airborne particulate matter (PM) and its impact on exposed populations. Over the last decade, a great deal of evidence has been gathered which shows that airborne PM plays a strong role in patterns of morbidity and mortality among urban populations. Airborne PM with an aerodynamic radius of less than 2.5 μm has been especially implicated in eliciting negative human health effects in exposed individuals, particularly in more vulnerable persons such as children, the elderly and those with compromised immune systems and/or pre-existing health problems. While it is clear that fine and ultrafine fractions of airborne PM can impact human health, however, it is not known what chemical constituents found in PM may contribute to patterns in observed morbidity and mortality. Airborne PM contains a vast number of compounds, from metals to organic constituents such as lead and polyaromatic hydrocarbons, which have the potential to negatively impact human health. The composition of airborne PM can vary significantly over time and space, depending on number of factors such as season, prevailing meteorological conditions and the time of day, week, month and year, and may be associated with certain sources such as traffic and industry or even activities in specific world regions. Currently, most countries base their air quality and emissions policies and regulations on the measured mass of ambient PM (i.e. PM_{10} and/or $PM_{2.5}$). As the toxicity of the various constituents of airborne PM are likely to significantly vary, with some of the most toxic ones contributing little to the overall PM mass, this may not be the most effective way to minimize risks among exposed populations. As we begin to shed more light on the role of specific constituents found in airborne PM in cardiopulmonary and other health effects, countries will be in a better position to regulate emission sources and shape policy in a manner that is more protective of human health.

Despite the work yet to be done, we have made progress in recent years in developing analytical methods to measure the chemical constituents of airborne

PM, determining their sources and transport pathways, identifying the processes behind their environmental fate and transformation and the toxicological mechanisms involved in their human health effects. In pulling together the research on this highly interdisciplinary topic area, we have made an attempt to be as comprehensive as possible in both disciplinary and geographical terms, involving highly respected researchers from different fields and different parts of the globe.

This edited volume has a total of eight chapters. The contributions of invited authors have been divided into six chapters which correspond to specific theme areas that relate to the topic of airborne PM and its chemical composition, environmental fate, behaviour and impact on exposed populations, as follows: 1. Airborne Particulate Matter: Sources, Composition and Concentration, 2. Metals and Organic Compounds in Airborne Particulate Matter: Analytical Methods, 3. Airborne Particulate Matter: Environmental Pathways, Behaviour and Fate in Urban Environments, 4. Bioavailability and Toxicology of Airborne Particulate Matter, 5. Airborne Particulate Matter Exposures and Health Risks and 6. Protecting Human Health: Policy Measures and Scientific Uncertainty. Chapters 7 and 8 include the author and subject indices, respectively.

The individual contributions of the authors, which number 30 in total, have been compiled and sorted accordingly. It should be noted that many of the contributions fall under two or more of the major theme areas, given the interdisciplinary nature of much of the research that has been undertaken by the authors. As editors, we attempted to assign the specific papers to certain theme areas as best we could give the foci of the respective topics.

This book has truly been a transnational effort, involving 78 individuals from Algeria, Austria, Australia, Canada, Czech Republic, Denmark, Germany, Greece, Italy, Japan, Korea, Lebanon, Morocco, Singapore, Spain, Sweden, UK and USA. The editors would like to personally thank each author for their contributions and cooperative efforts in helping us compile this book in a very timely and efficient manner.

We would also like to extend our gratitude to the reviewers and the insightful comments they provided regarding the individual contributions. Many thanks go to Dr. R. Schierl from the Institute and Clinic for Occupational and Environmental Medicine, University of Munich, Prof. Dr. S. Hann from the Department of Chemistry, University of Natural Resources and Applied Life Sciences, Vienna, Austria, Prof. Dr. E. Helmers from Applied University FH Trier, Germany, Dr. Jeffrey Brook from Environment Canada and Prof. Dr. Athanasios Valavanidis from Department of Chemistry, University of Athens, Greece.

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Part I
Airborne Particulate Matter: Sources, Composition and Concentration

Clare L. S. Wiseman and Fathi Zereini

Airborne particulate matter (PM) is a complex mixture of solid and liquid particles of primary and secondary origin, which contain a wide range of inorganic and organic components. PM mass and composition is also highly variable in spatial–temporal terms and is strongly influenced by climatic and meteorological conditions. It can be emitted from both natural and man made sources, including forest fires, dust storms, traffic and industry, and is found both outdoors and indoors. In terms of the latter, PM may be generated within the built environment or may be transported from outside via various mechanisms. Typically, PM is defined according to size or the diameter of the particles which make up a particular fraction, as this is what determines how long they will reside in the air, how far they may be transported and, in terms of health, how they will be deposited in the respiratory system. Air quality policy and emissions regulations are typically based on the mass of size fractions PM_{10} and/or $PM_{2.5}$, for these fractions are the most likely to impact human health as they are small enough to be inhaled and respired. Particles in PM_{10} are inhalable and may reach the upper part of the airways and lung, while smaller $PM_{2.5}$ particles are more able to deeply penetrate the lungs and perhaps reach the alveoli. Ultrafines, which have a cut-off of 0.1 μm, may make up a small proportion of the total mass but may have the greatest health impacts due to their ability to pass from the lung directly into the bloodstream and their larger reactive surface area which may be capable of inducing greater damage.

In addition to size, PM mass and number concentrations, volatility, morphology and chemical composition (e.g. organic, metal, salt content) are critical factors to be considered in the assessment of risk. The evidence regarding the relationship between airborne PM mass exposures (i.e. $PM_{2.5}$) and patterns of cardiopulmonary morbidity and mortality is quite solid. It is not clear, however, what chemical constituents may be particularly responsible for the observed effects.

This part includes six chapters which address various issues and topics which relate to how airborne PM is generated, where it comes from, its chemical composition and concentrations. In the first chapter, Saliba and Massoud summarize research on the levels and origins of airborne PM and related chemical

processes and implications for human health in the Eastern Mediterranean region. In the studies discussed, they reveal the complexity of airborne PM and how its concentrations and composition are strongly impacted by source (e.g. local industry, marine, Sahara Desert) and season. Celo and Ewa Dabek-Zlotorzynska discuss the concentration and origins of trace metals measured in collected $PM_{2.5}$ from May 2004 to December 2006 at various monitored sites in Canada as part of the Canadian National Air Pollution Surveillance network in the second chapter. They compare data collected from both rural and urban sites as a function of annual and seasonal trends and source origin and discuss how the major sources of trace metals in $PM_{2.5}$ at urban sites include natural dust resuspension processes, industrial and traffic emissions and fossil fuel refining/burning. $PM_{2.5}$ mass concentrations at rural sites were found to be most strongly impacted by season. In the third chapter, Lammel et al. also discuss the strong influence of seasonality on the concentratraion, source and mass size of polyaromatic hydrocarbons (PAHs) in ambient PM collected at urban and rural sites of central (Czech Republic) and south-eastern Europe (Bosnia and Herzegovina) in 2006–2008. In addition, they also present their results on the phase distributions of parent PAHs and their toxicity. They found that PAH levels were higher in winter compared to the summer, due to higher emissions and slower photochemical degradation and mixing during this time of year. Limbeck and Puls provide a comprehensive review of the literature on particulate emissions from on-road vehicles under real world conditions in the fourth chapter. As they argue, data on traffic emissions, as they occur under real world conditions, are critical in assessments of risk and have been shown to differ from that obtained in the lab using dynamometer-based studies. As part of this, they focus on published data on size segregated emissions factors of particle mass, elemental and organic carbon, as well as crustal components and selected trace metals. In the fifth chapter, Ki-Hyun et al. present data collected on the trace metals Pb, Mn, Cr and Cd over a 16-year period from 1991 to 2006 in 15 major cities in Korea. They discuss the temporal and spatial variability of these elements over time and how concentrations are influenced by varying environmental conditions and source–sink processes. Part I then concludes with a contribution from Marx and McGowan on the long-distance transport of urban and industrial metals and their sources and environmental fate over time (sixth chapter). Their contribution discusses the importance of historical trends in understanding regional and global patterns of metal contamination in spatial–temporal terms and the importance of considering long-range pollution sources and pathways as contributors to local pollution levels. As they point out, this is often overlooked with the result that many urban studies incorrectly ascribe pollution to local sources.

A Comparative Review of PM Levels, Sources, and Their Likely Fates in the Eastern Mediterranean Region

Najat A. Saliba and Rawad Massoud

1 Introduction

Particulate matter (PM) has become a public concern ever since the British Clean Air Act was published in 1956. The publication came after a series of pollution episodes (1930 and 1952) that led to a serious increase in mortality, hospital admissions and insurance claims (Anderson 2009; Chen et al. 2007; Greenbaum 2003; Pope 2004) (Dec. 1930 Meuse valley, Belgium; Oct. 1948 Pennsylvania, USA; Dec. 1952 London, UK). In 1969, the USA's Environmental Protection Agency issued the "Criteria Document", which summarized findings from previous studies on health effects related to exposure to PM, total suspended particles (TSP) and sulfur dioxide (SO_2) (Greenbaum 2003). This led to the establishment of the Clean Air Act in 1970 in the USA, followed by the first National Ambient Air Quality Standards (Chen et al. 2007; Greenbaum 2003). Concurrently, the World Health Organization (WHO) set in its guideline a standard for the levels of suspended particles followed by a global guideline for the levels of ambient particles (Anderson 2009). Hence, the increasing interest among scientists in PM levels and health implications culminated in an increase by almost 5,000-fold in publications between 1980 and 2008 (Scopus 2009).

Particulate matters are classified in different types, depending on their origins. While marine aerosols are formed of sea salt particles, remote continental aerosols are of primary particles (like dust, pollens and plant waxes), as well as secondary oxidation products. Moreover, desert aerosols, which resemble remote continental aerosols in their shape and size, are found over deserts and adjacent regions and strongly depend on the wind velocity. Urban aerosols are then considered a

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mixture of biogenic (natural sources), primary anthropogenic (vehicle emission, industrial processes, combustion of fuel, domestic heating, power plants, and road dust resuspension) and particulate emissions, and of secondary material (gas-to-particle conversion) (Seinfeld and Pandis 1998).

Aerosol fates are not confined to a particular source or local region, and so a better understanding of their transformation processes should be addressed at a global scale and calls for the understanding of the local sources and the multi-processes the aerosol undertakes once emitted into the atmosphere. The emission of sea salt aerosol and their reactions with local pollutants at coastal regions result in a unique environment that defines urban marine aerosols (Kerminen et al. 1997; Kocak et al. 2004a, b; Niemi et al. 2005; Pathak et al. 2004; Zhuang et al. 1999). On the other hand, particles emitted from deserts can also react with nearby city pollutants like acid precursors (NOx and SO_2) and acids (HNO_3, and H_2SO_4) to produce airborne pollutants highly loaded with crustal and non-crustal elements. Sources of these pollutants can be attributed to vehicle emission, industrial processes, combustion of fuel, domestic heating, power plants, and road dust resuspension.

2 PM in the Eastern Mediterranean Region

2.1 Climate

The Eastern Mediterranean area including Cyprus, Egypt, Palestine, Israel, Jordan, Syria, Lebanon and Turkey (Fig. 1) is characterized by winters with abundant precipitation and summers with nearly no precipitation at all, separated by short transition seasons: spring and autumn. The thermal variations can be large without being excessive (Combier 1945). Rain is especially abundant during 4 or 5 months of winter; however, during hot summers; the air remains humid despite the absence of rain.. These low rainfall rates coupled with weak advections and frequent recirculation episodes of air masses result in frequent regional pollution events that increase the aerosol's residence time in the region and give rise to high PM background levels recorded in summer. This specific setting of the Eastern Mediterranean (including the high radiation intensity) enhances the formation of secondary aerosols and ozone (Kostopoulou and Jones 2007).

In addition, there are other features favoring the occurrence of higher ambient air concentrations of mineral dust in the Mediterranean basin. First, the Mediterranean is frequently affected by African dust outbreaks. Second, because of the low precipitation rates in the Eastern Mediterranean, soils exhibit a poor vegetal coverage in such a way that resuspension of natural and accumulated road traffic dust is enhanced with respect to cities located in more rainy regions (Graham et al.

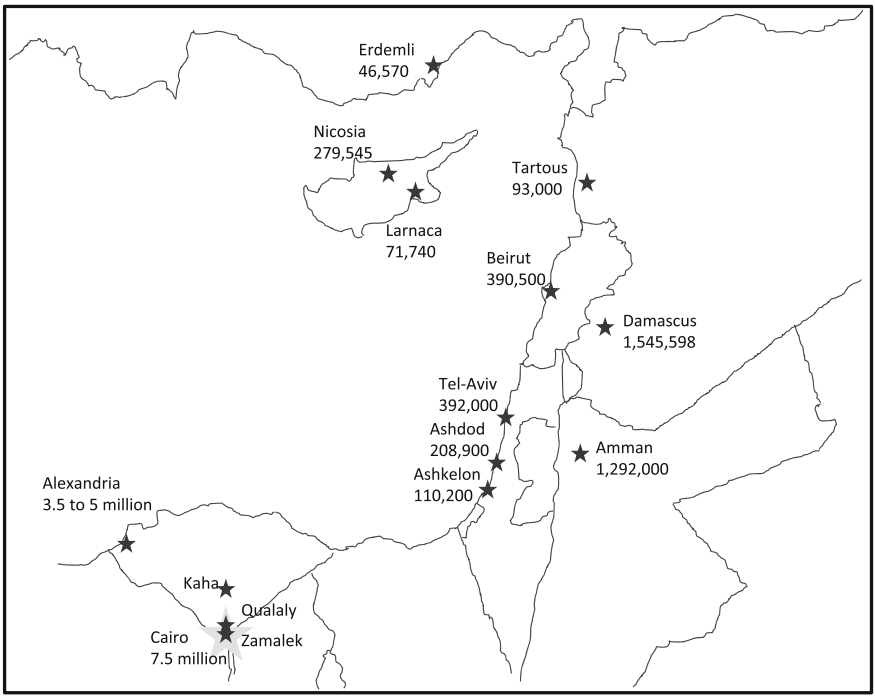

Fig. 1 Map of the Eastern Mediterranean region showing the reported cities lying along the Mediterranean coast. Numbers below the name of each city represent the city's population

2004; Millan et al. 1997, 2002; Rodriguez et al. 2001, 2003). Third, weak prevailing winds from sea breezes are formed due to the high pressure build-up some hours after sunrise during the warm season (summer and late spring). This leads to a change in the wind direction from east to west as well as an increase in the wind speed and the trapping of pollutants which renders PM rich in sea salt (Bleeker et al. 1960).

Several studies in the Eastern Mediterranean region have emphasized the effect of the aforementioned factors in affecting the type and level of pollutants in the region. During the ADIOS-EU funded program, Guieu et al. (2009) established a comparison between fluxes of metals of biogeochemical interest in the Western and Eastern Mediterranean regions. The Fe/Al ratio was found slightly higher in the Eastern region, due to its proximity to the Saharan desert. In non-dusty days, and during the summer, particles over the Eastern Mediterranean are found to be mainly composed of SO_4^{2-} and carbonaceous materials. They originate from the Balkans, Turkey and Central/Eastern Europe (Bryant et al. 2006; Vrekoussis et al. 2005). Additional sources could be attributed to extensive forest fires from southern Europe and desert dust plumes from North Africa (Bonnet and Guieu 2006; Guieu et al. 2005).

2.2 PM Levels

Despite the low recirculation probability of pollutants in the Eastern Mediterranean due to its geographical setting, and the consequences of such geography on the chemical composition and levels of aerosols, the literature review reveals a serious gap in long term air quality monitoring data along the Eastern Mediterranean coast (Levy et al. 2008). With the exception few articles (Elbir et al. 2000; Im et al. 2008; Kleanthous et al. 2008; Kocak et al. 2004a, b; Kubilay et al. 1997; Levy et al. 2009; Middleton et al. 2008; Tasdemir et al. 2005; Yuval and Broday 2006), reports in the region are restricted to short term measurements (Abed et al. 2009; Abu-Allaban et al. 2002, 2006, 2007a, b, 2008; Akkoyunlu and Tayanc 2003; Al-Masri et al. 2006; Al-Momani et al. 2005; Arafa et al. 2002; Asaf et al. 2008; Borai and Soliman 2001; Erel et al. 2002; Falkovich et al. 2001; Freiman et al. 2006; Ganor et al. 1998; Genc et al. 2009; Griffin et al. 2007; Kocak et al. 2007a, b, 2009; Kouyoumdjian and Saliba 2006; Mamane et al. 2008; Matvev et al. 2002; Othman and Al-Masri 2007; Perrino et al. 2009; Saliba et al. 2006, 2007; Schlesinger et al. 2006; Shaka and Saliba 2004; Tecer et al. 2008; Vrekoussis et al. 2005; Waisel et al. 2008a, b; Yatkin and Bayram 2008; Zakey 2008).

As shown in Fig. 2, the reported averages range between 93 and 9.7 μg/m^3 for $PM_{2.5}$ and 202.6 and 36.4 μg/m^3 for PM_{10} with the highest values of PM_{10} and $PM_{2.5}$ being measured in a residential site in Egypt. In fact, PM_{10} levels in Egypt exceeded in residential sites by 63% the maximum level that was measured in other Mediterranean countries. This could be attributed to the high population (7.5 million in Cairo city), its proximity to the Arabian and Saharan deserts and

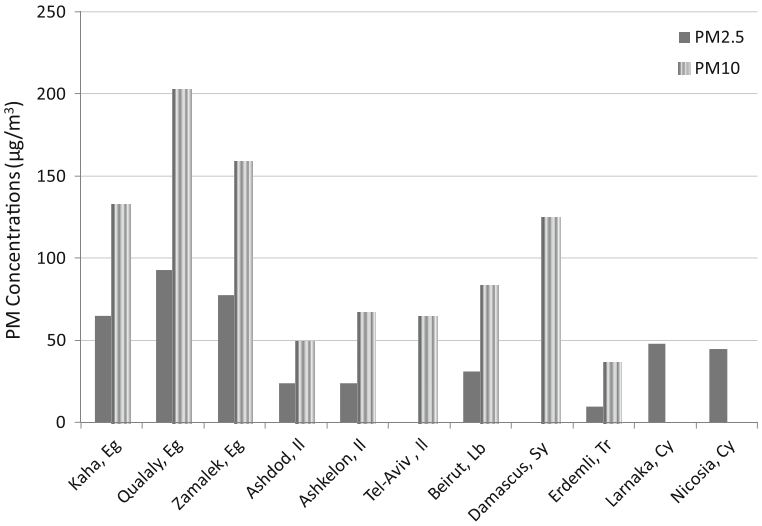

Fig. 2 Average concentrations of PM_{10} and $PM_{2.5}$ in different Eastern Mediterranean cities. Outbreaks due to desert storms and local industrial activities were omitted

the small amount of precipitation in the winter season (around 24 mm yearly average).

According to Abu-Allaban et al. (2007a, b), PM levels measured in the Cairo district (also called the greater Cairo area) in several sites of various characteristics, such as industrial (Shobra; downwind of Pb smelters and El-Massara; Cement plants), traffic (El Qualaly), and residential (Helwan and Zamalek), showed a PM_{10} concentration increase by 157% in industrial sites over the background site taken in Kaha that is situated 16 km north west of Cairo city. High PM_{10} concentrations in El-Massara originated from the cement plant while in Shobra, sources were assigned to Pb smelters. In the greater Cairo, however, the major contributors to PM_{10} included geological material, mobile source emissions, and vegetative burning. $PM_{2.5}$ tended to be dominated by mobile source emissions, vegetative burning, and secondary species (Abu-Allaban et al. 2002; Borai and Soliman 2001; Zakey 2008).

Israel showed lower $PM_{2.5}$ and PM_{10} levels. While Cairo is considered a megacity with 6.8 million population, Ashdod and Ashkelon are much smaller in size (around 47 km^2 each), and for both cities $PM_{2.5}$ levels were around 30% smaller than Cairo, and 19 and 40% for PM_{10}, respectively. In the rural site in Gedara, a $PM_{2.5}$ average of 25 $\mu g/m^3$ was measured (Mamane et al. 2008). Steinvil et al. 2008 conducted a short-term exposure to air pollution and inflammation-sensitive biomarkers study in Tel-Aviv, Israel, and reported a mean PM_{10} of 64.5 $\mu g/m^3$. Due to the proximity of the cities to the Saharan and Arabian deserts, the contribution of the background was assessed by sampling during different dust episodes (Schlesinger et al. 2006). A dust storm events lasting between few hours to 1–3 days, generated PM_{10} levels from 100–200 to 300–1,500 $\mu g/m^3$ and more, respectively. On the other hand, assessment of the effect of traffic reduction volume on PM_{10} levels was studied during the military conflict in Israel in summer 2006 (Yuval et al. 2008). Results showed that PM_{10} concentrations in most stations decreased by 4–18% during the conflict when compared to data from previous dates. The very low $PM_{2.5}/PM_{10}$ ratio (0.26–0.32) for spring supports this observation, in accordance with Vallius et al. (2000) and Gehrig and Buchmann (2003). The effect of the sea breeze on TSP levels was found to be much lower than that of the land breeze (7.8 and 8.6 $\mu g/m^3$ vs. 41.3 and 116.9 $\mu g/m^3$). This reversed behavior is due to heavy industry over the land in Haifa (Ganor et al. 1998).

In Jordan, high variation of PM_{10} concentrations depended on dust resuspension due to desert storms and abundant limestone quarries. Yearly averages ranging between 39 and 630 $\mu g/m^3$ were reported (Abu-Allaban et al. 2007a, b; Alsawair and Solieman 2007). No levels up to our knowledge were reported in Palestine. In Beirut, PM_{10} mean concentrations measured in various sites varied from 44 to 110 $\mu g/m^3$ (Moussa et al. 2006; Saliba et al. 2006, 2007; Shaka and Saliba 2004). Populated and inner city sites showed over 70% exceedances of the WHO PM_{10} annual average (20 $\mu g/m^3$), whereas coastal sites showed only 30%. Averages of $PM_{2.5}$ concentrations varied between 27.6 and 32.2 $\mu g/m^3$. $PM_{2.5}$ concentrations, at any given site, were usually between 36 and 51% of those of PM_{10}.

In the city of Tartous, Syria, TSP levels ranged between 171 and 397 μg/m^3 with sources attributed to traffic, a cement factory and phosphate and coal loading activities into ships. Moreover, concentrations reached 2,269 μg/m^3 during the phosphate loading around the Tartous port (Al-Masri et al. 2006; Othman and Al-Masri 2007). In Damascus PM_{10} values varied between 44 and 188 μg/m^3, levels were affected by wind direction (Meslmani 2004). PM_{10} and $PM_{2.5}$ measured at a rural site in Erdemli, Turkey, were 36.4 and 9.7 μg/m^3, respectively (Kocak et al. 2007a, b). Daily variations of PM_{10} and $PM_{2.5}$ concentrations were observed with the highest deviation from the mean due to mineral dust transported from North Africa and to sea spray generation. During summer, $PM_{2.5}$ levels exhibited higher concentrations resulting from an enhanced production of secondary aerosols due to high insolation. Similar behavior with high winter background at the traffic site, higher summer PM_{10} background levels and high seasonal influence of Saharan dust were observed at the majority of the 31 studied cities in Cyprus (Kleanthous et al. 2008; Kocak et al. 2004a, b, 2007a, b).

The low $PM_{2.5}/PM_{10}$ ratio ($\sim$0.25) in the Eastern Mediterranean region indicates that the particle size distribution has a large contribution of coarse particles which are either affected by a background level of naturally occurring dust (mineral dust particles from the Saharan Desert and sea salt particles from the Mediterranean Sea itself (Kocak et al. 2007a, b) or that the region is characterized by high levels of primary coarse PM emissions (Kocak et al. 2007a, b). Even though the $PM_{2.5}/PM_{10}$ ratio showed seasonal variations, the values remained lower than 0.5 in most cases (Abu-Allaban et al. 2002, 2007a, b; Asaf et al. 2008; Freiman et al. 2006; Kocak et al. 2007a, b; Moussa et al. 2006; Peled et al. 2005; Saliba et al. 2007; Shaka and Saliba 2004; Zakey 2008), a value that is least two times lower than those of the Western Mediterranean.

2.3 PM Chemical Profiles

In Alexandria, Egypt, the analysis of total Polycyclic Aromatic Hydrocarbons (PAH) concentrations of street dusts and particulate fallout samples revealed values that are similar to reported levels in different cities around the world. The major contributor to PAH levels is traffic, including diesel and gasoline vehicles (Barakat 2002), steel work (Mostafa et al. 2009), petroleum residues and traces of terrestrial organic compounds (Aboul-Kassim and Simoneit 1995). In addition to organic and elemental carbon, crustal components (Si, Ca, Fe, and Al) were found to be significant at various sites in Cairo. The latter exhibited higher levels in industrial and heavy traffic areas due to resuspended road dust. High levels of Pb and Cl measured in industrialized sites like Shobra area, which includes over 450 industrial units, were assigned to Pb smelters and textile factories (Abu-Allaban et al. 2002). The detected high amount of ammonium chloride in Cairo was attributed to traffic and neighboring industries (Abu-Allaban et al. 2007a, b; Borai and Soliman 2001; Zakey 2008).