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Effects of Seasonal Differences on Particulate Matter in Mediterranean Area

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Abstract— The aim of this study was to investigate the temporal and spatial distribution of the PM_{10} and $PM_{2.5}$ concentrations in Mediterranean area. PM_{10} and $PM_{2.5}$ level were monitored for shorter time periods at twelve different sites that located near congested area in Gaza strip, Palestine. The measurements were carried out using hand help particulate matter instruments during fall, winter and spring seasons from October 2011 to May 2012.Meanwhile, meteorological parameters such as temperature, relative humidity, and wind speed were recorded during sampling period. It was found that all PM_{10} and $PM_{2.5}$ concentrations were exceeding the standard value of 50 μg/m^3 and 25 μg/m^3 respectively in winter season. The ratios between $PM_{2.5}$ and PM_{10} were found to be in the range of 0.21 to 0.55 which indicates the coarse particles (>2.5 μm) originated from road dust, and soil re-suspension are the dominated fractions of PM. Concentrations of PM_{10} and $PM_{2.5}$ showed temporal and spatial variations during fall, winter and spring. Statistical analyses have shown a positive correlation between PM_{10} and $PM_{2.5}$ and the highest correlation (0.91) was obtained between PM_{10} and $PM_{2.5}$ at fall season. The negative correlation was observed between particulate matter (PM_{10} and $PM_{2.5}$) and wind speed in spring season where a positive correlation was observed between particulate matter and wind speed in winter..

Index Terms— air pollution, meteorological parameters, $PM_{2.5}$, PM_{10} , seasonal differences.

1 Introduction

Many epidemiological studies that have been conducted around the world have established a strong correlation between ambient particle concentrations and increasing rates of mortality, morbidity, respiratory and cardiovascular problems [1],[2],[3]. Moreover a short-term increase of 10 mg/m^3 of PM for several days is associated with more coughing, lower respiratory symptoms, and an increase in hospital admissions due to respiratory problems [4].

Aerosol particle concentrations in Mediterranean area are governing by several important phenomena's which may makes the concentration of particulate matter exceed the standards limit that have established by different international organizations and governments worldwide to reduce emissions and human exposure to PM_{10} and $PM_{2.5}$.

Aerosol transportation in Mediterranean basin considered one of the main source of particulate matter due to its location at the intersection of air masses circulating among the three continents [5]. Seasonal dust storms that mainly formed in winter and spring seasons come from northern Africa and Arabian Peninsula desert inducing the transport of mineral dust to the region [6] . It has been estimated that70 million tons of the Saharan dust transported every year and 20-30 million tons of these amounts are deposited in eastern Mediterranean area [7]. Therefore, Dayan et al [8] study estimated that 60%–80% of the coarse particulate fractions of the aerosols in the area are from Saharan dust outbreaks transported in the lower free troposphere.In addition to that Mediterranean region located south of highly industrialized European continent as a result long-range transport of pollutants coming from central Europe increased particulate matter concentrations in the air [9].

In Matvev et al [10] study which used sulphur dioxide and particulate sulphate as markers showed that the pollutant transport from Europe toward the Mediterranean basin depending on the season. It increases in the hot and humid summer (June, July and August) due to the enhancement of photochemical oxidation of SO2, and drops in the rainy winter (December, January, and February) [11]. Furthermore sulphur accounts for up to 50% by mass of the total sulphur content in particles and contributes of 15% of the yearly flux of sulphur arriving at Israel and Palestinian coast[10].Moreover, the emission of sea salt aerosol and their reaction with local pollutant at coastal region result in a unique environment that defines urban marine aerosol. Sea breezes leads to a change in the wind direction from east to west as well as an increase in the trapping of pollutants which renders PM rich in sea salt [12]. Lelieveld et al [13] study reported that coastal site is most frequently associated with sea salt carrying a substantial amount of ammonium bisulphate and nitrate.

Furthermore, the final two resources that may contribute with an increasing of particulate matter background levels in the area are the low rainfall rates and anthropogenic resources. On one hand, the low rainfall rates in the area usually coupled with weak advections of air masses increase the resuspention rate of natural and accumulated road traffic dust [7]. On the other hand, the anthropogenic source likes power generators, unburned lubricant oil, automobile exhaust contributed with a percent of the elevation level of PM. The objective of this study is to determine the spatial variations of PM_{10} and $PM_{2.5}$ at the monitoring site that located in Gaza strip during fall, winter and spring seasons.

2 Methodology

2.1 Description of Study Area

Gaza strip (365 km², 40 km long and between 6 to 12 km wide) is located on the eastern coast of the Mediterranean sea. The area forms a transitional zone between the sub-humid coastal zone of Israel in the north, the semiarid plains of the northern Negev Desert in the east and the arid Sinai Desert of Egypt in the south [14].

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The climate in Gaza strip is characterized by mild and humid winter (December–February) which dominated by rainfall. The summer months (June–September) are characterized by high humidity and the lack of wet precipitation. The spring season (March–May) is characterized by unsettled winter type weather for the first month, associated with North African cyclones; the rest of this period is very similar to that in the summer. Fall season (October –December) usually characterized by an abrupt summer type weather in the first month; the rest of this period is characterized by the unsettled weather of winter [5],[14].

2.2 Sampling Sites

Twelfth locations were selected in order to obtain a realistic diagnosis of the temporal variation and spatial distribution of PM_{10} and $PM_{2.5}$ in area as seen in Fig 1 and Table 1.

2.3 Selection of Monitoring Instruments

The mass concentration of particles ($PM_{2.5}$ and PM_{10}) has been monitored using handheld optical particle counter (HAL-HPC300). The monitor performs particulate size measurements by using laser light scattering. Air with multiple particle sizes passes through a flat laser beam produced by an ultra-low maintenance laser diode. A 3–channel pulse height analyser for size classification detects the scattering signals. The particle counter was factory calibrated, prior to the sampling campaign and the calibration was repeated every week using Zero-Count Filter. A Kanomax IAQ Monitor was used for temperature, relative humidity measurements and Smart Sensor Electronic Anemometer was used for wind speed.

2.4 Sampling Method

A particulate monitoring program started from October 2011 to May 2012 at the twelve monitoring sites as a part of project to assess the indoor air quality in several schools in order to cover fall, winter and spring seasons. The measurements were taken place outside each site for three consecutive days from 7:00 am to 12:00 pm in winter and spring seasons and from 12:00 pm to 5:00 pm in fall season during the schools hours. The devices were relocated after 3 days in order to measure continuously at each of twelve selected sites.

3RESULTS AND DISCUSSION

3.1 Temporal Variation of PM_{10} and $PM_{2.5}$

The daily PM_{10} and $PM_{2.5}$ average concentrations for all the sites are presented in Fig 2 (a, b) . The average concentrations of PM_{10} and $PM_{2.5}$ for all the sites during the study period were 149.5μg/m^3 and 60.49 μg/m^3 The maximum and minimum concentration of PM_{10} was 839.4 μg/m^3 and 16.33 μg/m^3 respectively. The maximum and minimum concentration of $PM_{2.5}$ was 464.8 μg/m^3 and 6.33 μg/m^3 respectively.

3.2 Spatial Variation of PM_{10} and $PM_{2.5}$

Fig 3 (a, b) present the average concentration of PM_{10} and $PM_{2.5}$ at all the twelve monitoring sites during the study period. The average concentration of PM_{10} and $PM_{2.5}$ was the highest during the winter season reflecting the high emission sources (e.g. dust storm, the high dispersion from sea wind and vehicular emission exhaust) around these sites. The highest daily mass concentrations of PM_{10} and $PM_{2.5}$ were observed at MCB site in winter (431 μg/m^3 and 226.9 μg/m^3 respectively), The WHO PM_{10} and $PM_{2.5}$ limit (50 μg/m^{3}and 25 μg/m^3 respectively) were exceeded during winter season in all the monitoring sites. Some exceedances occurred also during fall and spring season for PM_{10}. The reason for the increasing of particulate matter concentration could be the dust storm that originated from Arabian Peninsula desert and attacked the area during the sampling periods. Moreover, studies show that average particle matter concentration tend to be higher in winter, the season with the lowest ventilation capability [15], comparing to the remaining seasons. This can be supported by the fact that the particles formation increase by lower temperatures, high relative humidity, and available organics emitted from vehicles and decreased atmospheric mixing height [16].

3.3 Seasonal differences of PM_{10} and $PM_{2.5}$

The PM_{10} average concentrations at winter, spring, and fall seasons were 248.2 μg/m3,102.2 μg/m^3 and 98.1 μg/m^3 respectively. The $PM_{2.5}$ average concentrations at winter, spring, and fall seasons were 134.7 μg/m^3, 20.1 μg/m^3 and 26.5 μg/m^3 respectively. Fig 4 shows that during winter season, concentration of PM_{10} and $PM_{2.5}$ exceeded the standard value of 50 μg/m^3 and 25 μg/m^3 respectively. Moreover, it was found that most of sites exceeded the standard limit of PM_{10} concentration during spring and fall seasons except MCG site.

In order to investigate the effect of seasonality on ambient air quality, winter to fall , spring to winter and spring to fall average ratios were calculated, and the results are shown in Table 2. It is apparent that there was a general pattern of increasing levels of outdoor PM_{10} and $PM_{2.5}$ from fall to winter and decrease from winter to spring. Moreover, the pattern of outdoor PM_{10} and $PM_{2.5}$ from fall to spring increased for $PM_{2.5}$ and decreased for PM_{10}. The difference between the three seasons result may be due to the fact that dust storms occur mostly from December to April (full winter and the 1st month of spring season). The relatively high contribution of mineral dust from natural origins is reflected in the elevated PM_{10} yearly mean concentration which exceeds the values obtained for such big cities [6].

3.4 Relationships between PM_{10} and $PM_{2.5}$

The mean ratio $PM_{2.5}/PM_{10}$ ranged from 0.21 to 0.55 as shown in Table 3. This suggests that the contributions of $PM_{2.5}$ to PM_{10} were not similar in the three seasons and indicates that in all monitoring site , coarse particles (>2.5 μm) originated from road dust soil re-suspension and abrasion processes are the dominating fraction in PM . Similar results have been reported from the US-Canadian 24-cities study [17] and Santiago de Chile study [18] which have shown ratios of $PM_{2.5}$ to PM_{10} varying from 0.30 to 0.70 depending on location of measurement.

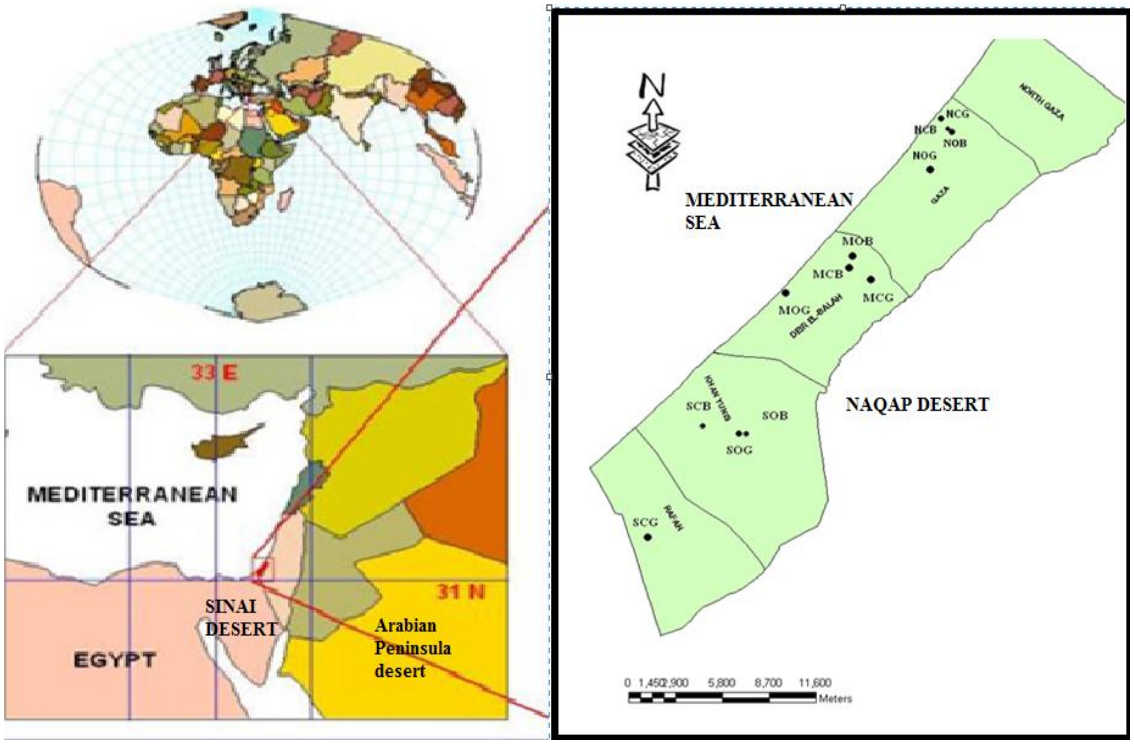
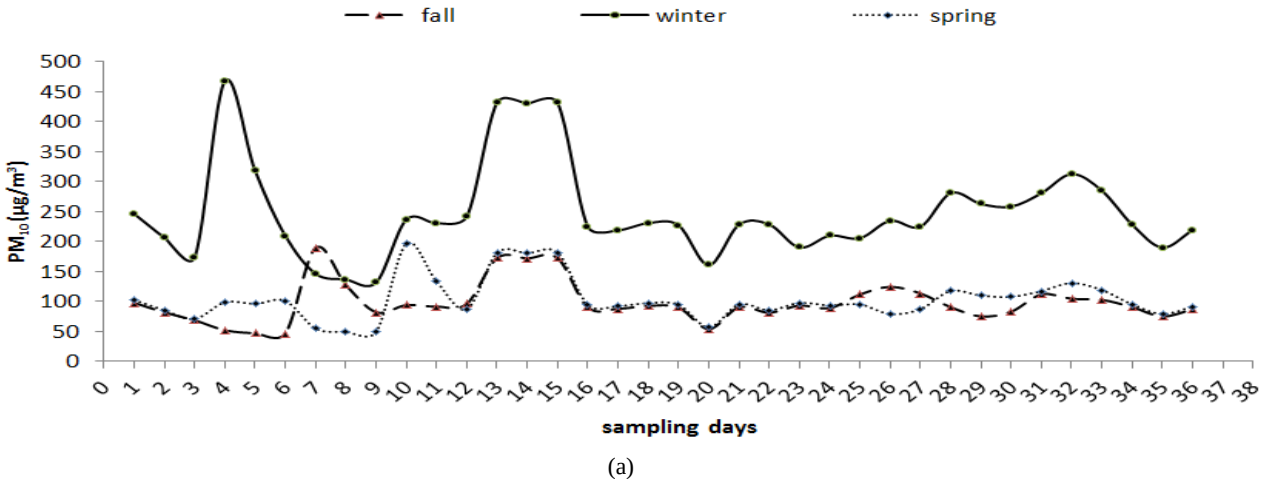


Fig 1 Location map of the monitoring sites in Gaza strip.

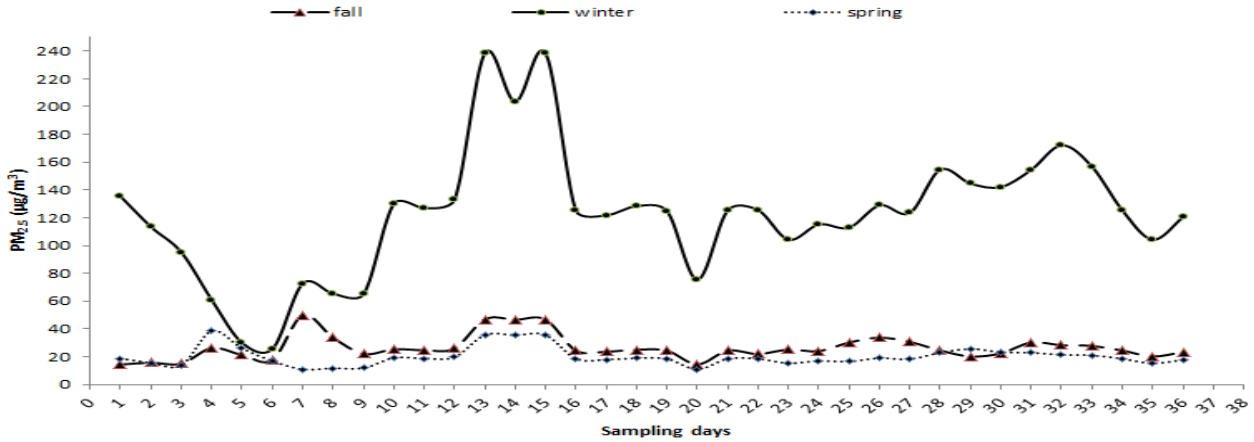
TABLE 1

CHARACTERISTICS OF MONITORING SITES

Site name	Site code	Distance from main road (m)	Location in Gaza strip	Land use
Nusirate Prep Boys A	MCB	43	Middle (Nusurate camp)	Over populated camp
Nusirate Prep Boys D	MOB	65	Middle (Nusurate camp)	Over populated camp
Elburaj Prep Girls B	MCG	50	Middle (Buraj camp)	Over populated camp
Dier Elbalah Prep Girls B	MOG	50	Middle (Dier Elbalah City)	Small town
Bany Suhiela Prep Boys B	SOG	40	South (Khanyouis city)	Urban area
Bany Suhiela Prep Girls B	SOB	55	South (Khanyouis city)	Urban area
Ahmad Abed Elaziz Prep Boys B	SCB	50	South (Khanyouis city)	Urban area
Rafah Prep Girls B	SCG	55	South (Rafah city)	Over populated camp
Elzaytoon Prep Girls B	NOG	58	North (Gaza city)	Urban area
New Gaza Prep Boys A	NCB	30	North (Gaza city)	Urban area
Beach Prep Girls B	NCG	50	North (Beach camp)	Over populated camp
Salah Eldien Prep Boys B	NOB	43	North (Gaza city)	Urban area

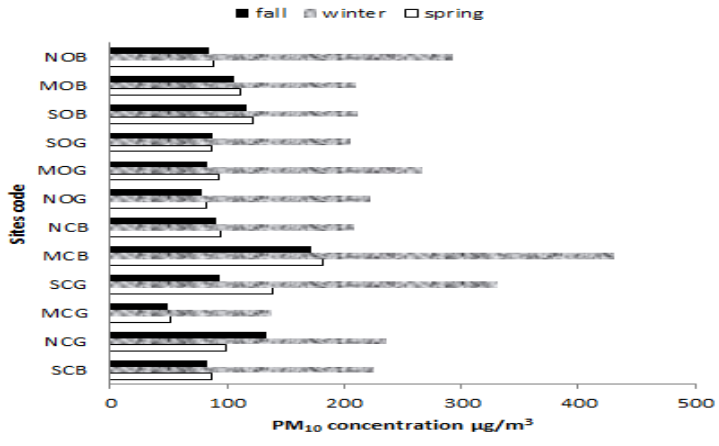


(a)

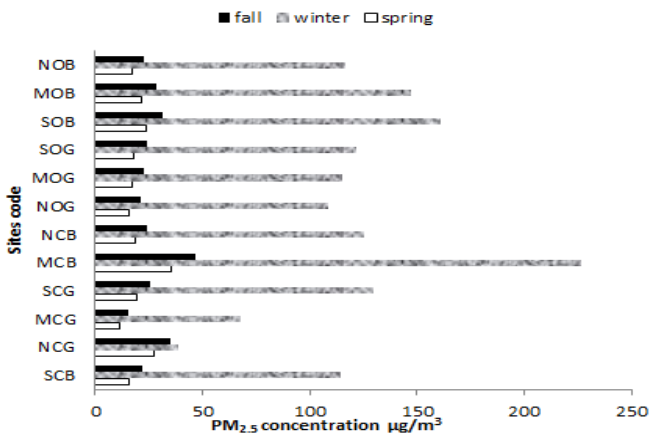


(b)

Fig 2 Seasonal variation of (a) PM_{10} and (b) $PM_{2.5}$



(a)



(b)

Fig3 Concentrations of (a) PM_{10} and (b) $PM_{2.5}$ at all the twelve monitoring sites

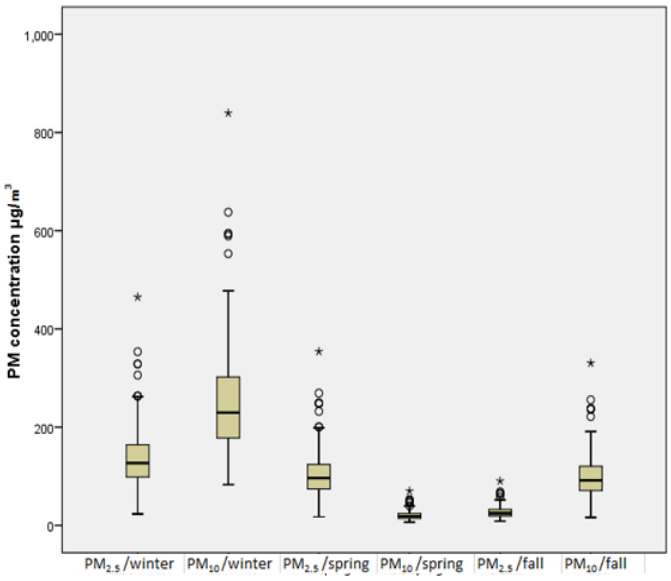


Fig 4 Box plot of PM_{10} and $PM_{2.5}$ concentration for all sites

3.5 Correlation between particulate data sets

Correlation analyses of the data have been carried out using Pearson correlation coefficient from the commercial package SPSS (SPSS, 2012). Table 4 shows the correlation between PM_{10} and $PM_{2.5}$ data sets during the study period. The results showed showed different trend during the three seasons. The correlation between PM_{10} and $PM_{2.5}$ during fall was positive and robust (r = 0.91) as given in Table 4, which was reduced to (r=0.51) and (r= 0.47) between PM_{10} and $PM_{2.5}$ in winter and spring seasons respectively.

TABLE 2

EFFECT OF SEASONALITY ON PM_{10} AND $PM_{2.5}$

	PM_{10}	$PM_{2.5}$
winter/fall	2.52	5.00
spring /winter	0.41	0.14
spring /fall	1.04	0.75

TABLE 3

EFFECT OF SEASONALITY ON $PM_{2.5}/PM_{10}$ RATIO

	Winter	Spring	Fall
	Outdoor $PM_{2.5}/PM_{10}$	Outdoor $PM_{2.5}/PM_{10}$	Outdoor $PM_{2.5}/PM_{10}$
Min	0.40	0.12	0.20
Max	0.76	0.31	0.52
Mean	0.55	0.21	0.28
Std. Dev.	0.11	0.05	0.08

TABLE 4.

PEARSON CORRELATION COEFFICIENT FOR $PM_{2.5}$ AND PM_{10}

Season	Pearson coefficient (r)	p-value
Fall	0.91**	0.00
Winter	0.51**	0.00
Spring	0.47**	0.00

** Correlation is significant at the 0.01 level (2-tailed).

3.6 Influence of Meteorological Parameters on Particulate Matter

The air quality varies at any place from season to season because the dynamics of the atmosphere and the meteorological conditions play a very important role in governing the fate of air pollutants. In this study, the relationship between ambient particulate matter data and meteorological factors, such as temperature (TEMP), relative humidity (RH), and wind speed (WS) is statistically analysed. Table 5 shows the descriptive statistics of meteorological factors during the three seasons

TABLE 5

DESCRIPTIVE STATISTIC FOR METEOROLOGICAL PARAMETERS

season	Parameters	Minimum	Maximum	Mean	Std. Deviation
Fall	Temperature °c	24.80	32.60	27.50	1.70
	Relative Humidity (RH)	47.30	71.00	58.80	5.00
	Wind speed (m/s)	0.10	7.00	3.50	1.50
Winter	Temperature °c	8.30	21.30	14.00	2.40
	Relative Humidity (RH)	27.60	89.40	62.20	14.30
	Wind speed (m/s)	0.10	13.00	3.20	2.50
Spring	Temperature °c	9.00	33.80	18.20	3.70
	Relative Humidity (RH)	15.00	100.00	73.10	18.10
	Wind speed (m/s)	0.10	9.00	2.60	2.00

Table 6 presents the relationship between particle concentrations (PM_{10} and $PM_{2.5}$) and meteorological parameters (temperature, relative humidity and wind speed). The PM_{10} and $PM_{2.5}$ is found to be positively correlated with wind speed in winter and negatively correlated with wind speed in spring and fall seasons. A positive correlation was observed between $PM_{2.5}$ and relative humidity in winter season. Further, a positive correlation was found between PM_{10} and relative humidity in in the three seasons. Moreover, the negative relationship between temperature and $PM_{2.5}$ and PM_{10} concentration were observed. This inverse relationship supported by fact as temperature is decreasing in winter season this will result in stable conditions that will increase outdoor concentrations of such pollutant.

TABLE 6

CORRELATION BETWEEN $PM_{2.5}$ AND PM_{10} WITH METEOROLOGICAL PARAMETERS

	$PM_{2.5}$			PM_{10}		
	Spring	Fall	Winter	Spring	Fall	Winter
Temp	- 0.05	0.14*	- 0.35**	- 0.09	- 0.05	- 0.29**
RH	0.13	0.11	0.19**	0.22*	0.19**	0.16*
WS	- 0.08	- 0.10	0.24**	- 0.15*	- 0.05	0.24**

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level .

4 CONCLUSION

The results of a field campaign that took place in Mediterranean area - Gaza strip as a case study- are presented and analyzed. The total data were analyzed to investigate spatial and temporal variation and correlation in order to gain more understanding on their variability and interrelations. Several meteorological and particulate matter measurements (the fine and coarse fractions) at several sites in the area were carried out during three season's period. The PM_{10} average concentrations at winter, spring, and fall seasons were 248.2 $\mu g/m^3$, 102.2 $\mu g/m^3$ and 98.1 $\mu g/ m^3$ respectively. The $PM_{2.5}$ average concentrations at winter, spring, and fall seasons were 134.7 $\mu g/m^3$, 20.1 $\mu g/m^3$ and 26.5 $\mu g/m^3$ respectively. The daily limit for PM_{10} and $PM_{2.5}$ exceeded the standard value of 50 $\mu g/m^3$ and 25 $\mu g/m^3$ during winter season. It was found that most of sites exceeded the standard of PM_{10} during spring and fall season. As regards the spatial distribution, a consistent pattern among the sites was observed. Moreover, $PM_{2.5}/PM_{10}$ ratio appears to be a constant fraction (0.21 – 0.28) in fall and spring season indicating common influences of meteorology and sources. Average diurnal patterns of PM_{10} and $PM_{2.5}$ show a clear seasonal variation. Concentrations in winter were in average 2.5 and 5 times higher than in fall for PM_{10} and $PM_{2.5}$ respectively. There are clear associations between PM_{10} and $PM_{2.5}$ data sets at all the measured sites. The highest correlation (0.91) was obtained between PM_{10} and $PM_{2.5}$ during fall season.

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