Concentration and Composition Of Fine Particulate Matter ($PM_{2.5}$) In Hebron City, Palestine

By:

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ABSTRACT

Suspended Particulate matter $PM_{2.5}$ is one of the pollutant that pollute air and has adverse health effect. $PM_{2.5}$ are particles from various sources with a wide range of structure and chemical composition.

This study aims to investigate the mass concentration of $PM_{2.5}$ and its chemical composition at Hebron city.

Weekly $PM_{2.5}$ samples were collected in Hebron City, West bank, at one site, Hebron governmental Hospital. Sampling was started in January 2007 and continued for one year. The ambient mass concentration and chemical composition of the $PM_{2.5}$ were determined, chemical analysis includes organic and inorganic carbon, metal elements, crustal materials, and water soluble ions (SO_4^{-2}, NO_3^-), were conducted.

Our data showed that annual average mass concentration of $PM_{2.5}$ was $22.8 \pm 11.1 \mu g/m^3$. Seasonal variation of $PM_{2.5}$ concentration was detected with the highest concentration observed in summer, and the lowest in winter.

Carbonaceous materials accounted for 33.2% of the $PM_{2.5}$ mass, OC alone accounting 24.9%, crustal materials averaged 17.9% of the $PM_{2.5}$ mass. SO_4^{-2} accounted for 17.1% of the $PM_{2.5}$ mass, higher concentration occur in summer, and from May to November, while NO_3^- accounted for 4.69% from the total $PM_{2.5}$ mass, and the highest concentration occur in winter.

Abbreviations:

TSP: Total suspended particulate.

PM: Particulate matter.

PM_{10} : Suspended particulate matter that have 10µm in diameter.

$PM_{2.5}$: Suspended particulate matter that have 2.5 µm in diameter.

EPA: Environmental Protection Agency.

USEPA: United State Environmental Protection Agency.

List of Contents:

List of Figures:

List of Tables

1.INTRODUCTION

Air pollution is the human introduction into the atmosphere of chemicals, particulate matter, or biological material that cause harm or discomfort to humans or other living organisms, or damage the environment (Webster Online Dictionary www.merriam-webster.Com/org-bin/dictionary).

There are many substances in the air which may impair the health of plants and animals (including humans) or reduce visibility (DeGaetano et al., 2004). These arise both from natural processes and human activity, substances not naturally found in the air or at greater concentrations or in different locations from usual are referred to as pollutants. Pollutants can be classified as either primary or secondary, an important example of a secondary pollutant is ground level ozone - one of the many secondary pollutants that make up photochemical smog, note that some pollutants may be both primary and secondary, that is, they are both emitted directly and formed from other primary pollutants (Streen et al., 1984).

Major primary pollutants produced by human activity include: sulfur oxides (SO_x) especially sulfur dioxide are emitted from burning of coal and oil; nitrogen oxides (NO_x) especially nitrogen dioxide are emitted from high temperature combustion; carbon monoxide which is colourless, odourless, non-irritating but very poisonous gas, it is a product of incomplete combustion of fuel such as natural gas, coal or wood, vehicular exhaust is a major source of carbon monoxide; carbon dioxide (CO_2), a greenhouse gas emitted from combustion, volatile organic compounds (VOC), such as hydrocarbon fuel vapours and solvents (Streen et al., 1984; Scheffe et al., 1993; Kim et al., 2004).

Particulate matter (PM) measured as smoke and dust, PM_{10} is the fraction of suspended particles 10 micrometers in diameter and smaller that will enter the nasal cavity, $PM_{2.5}$ has a maximum particle size of 2.5 μm and will enter the bronchus and lungs (WHO, 2005).

Increased awareness of health problems related to air pollution increased especially during the last two decades, gradually created a demand for more efficient emission controls, especially in developing country. Recently, problems caused by atmospheric particulate matter in urban air have received greater attention. The majority of recent health studies suggest that fine particles ($PM_{2.5}$) are more harmful than coarse particles (Pope, 2000; Schwartz et al., 1999; Holgate et al., 1999; NRC, 2004). Therefore it is very important to study their concentration, variation, and chemical composition, and then sources, in order to control their emission. However this is the first time that the fine particulate matter will be investigation in the West bank.

In the 1960s, 70s, and 90s, the United States Congress enacted a series of Clean Air Acts which significantly strengthened regulation on air pollution. Individual U.S. states, some European nations and eventually the European Union followed these initiatives, the Clean Air Act sets numerical limits on the concentrations of a basic group of air pollutants and provide reporting and enforcement mechanisms (USEPA).

In 1999, the United States EPA replaced the Pollution Standards Index (PSI) by the Air Quality Index (AQI) to incorporate new $PM_{2.5}$ and Ozone standards (EPA).

Study objectives:

The overall objective of this study was to add to current knowledge on the characteristics and sources of urban ambient particulate matter.

The specific aims of the study were to

1. Determine $PM_{2.5}$ levels and concentrations in Hebron City, including background and urban locations.
2. Study the impact of meteorology on pollutant patterns throughout the area.
3. Characterize the chemical composition of $PM_{2.5}$.

2. literature Review:

2.1 Particulate matter:

Particulate matter (PM) is a complex mixture of organic and inorganic substances, present in the atmosphere as both liquids and solids (U.S. Environmental Protection Agency (EPA), 2002). These suspended particulate vary in size, shape composition and origin, which can be classified in several ways (WHO, 2005). Firstly, PM can be classified as primary and secondary, depending on the compounds and processes involved during its formation. Primary particles are emitted directly as particles, for example dust from roads or elemental carbon (soot) from wood combustion, where secondary particles formation result from a series of chemical and physical reactions involving different precursor gases, such as sulphur and nitrogen oxides and ammonia reacting to form sulphate, nitrate and ammonium particulate matter (Waverley Bourough Council, 2007; Poschl, 2002; Zheng et al., 2002).

Secondly, particles can be classified by their physical size, particles can range in size from a few nanometers (nm) to ten micrometer (µm) in diameter, size is one of the major characteristic of particles and it has implication on formation, physical and chemical properties, transformation, transport, health effect, and removal of particles from the atmosphere, particles have irregular shapes and their aerodynamic behavior is expressed in terms of the diameter of an idealized sphere (Vallius, 2005). The sampling and description of particles is based on this aerodynamic diameter, which is usually simply refer to as " particle size". Particles having the same aerodynamic diameter may have different dimensions and shapes. The notation PM_X refers to particulate matter comprising particles less than x µm in diameter, particles greater than 2.5

micrometer (PM_{10}) are generally referred to as coarse particles, and particles less than 2.5 μm ($PM_{2.5}$) and 1μm as fine particles and ultrafine particles, respectively. The term total suspended particulate matter (TSP) refers to airborne particulate matter with an upper size limit of approximately 100 μm in aerodynamic equivalent diameter (Streen et al., 1984; Seinfeld and Pandis, 1998; Heal et al., 2005).

2.2 Air quality and particulate matter standards:

1n 1970 the standard for particulate pollutant was based on Total Suspended Particulate (TSP), the standards were set at 260 $\mu g/m^3$ (24-hour) and 75 $\mu g/m^3$ (annual geometric mean). In July 1987, EPA began using a new indicator, the TSP standard was replaced by the PM_{10} standard, the PM_{10} standard were set at 150 $\mu g/m^3$ (24-hours) and 50 $\mu g/m^3$ (annual arithmetic mean), this fraction of TSP is responsible for most of the adverse health effects of PM because of the particles ability to reach the lower regions of the respiratory tract. In 1997, the USEPA established a standard for $PM_{2.5}$ of 65 $\mu g/m^3$ for 24-hours and 15 $\mu g/m^3$ for an annual arithmetic mean, average concentration based on assessment of three consecutive years, USEPA based this standard on an extensive review of numerous epidemiological studies (EPA´s air quality standards, 1997). Recent study suggest that $PM_{2.5}$ is more strongly correlated with adverse health effects than particles in other size range, these health effects range from slight respiratory symptoms to increased mortality rates (WHO, 2005). In a study of six eastern U.S. cities Schwartz et al., (1999) reported a $10g/m^3$ increase in the two –day mean $PM_{2.5}$ concentration associated with a 1.5 percent increased in total daily mortality.

Israel began to monitor fine particulate matter smaller than 2.5 micrometer at the end of 1998, the result for 2001 showed an annual exceedance of the proposed Israeli target standard (15µg/m^3) for this pollutant throughout the country. In addition, dozens of exceedance of the proposed diurnal average (65µg/m^3) were noted in the Ashkelon area, Kiryat Malachi and Sderot (Kardova, 2001).

In 2003 and also in 2005 annual exceedances of the proposed Israeli target standard for $PM_{2.5}$ (15µg/m^3) in all monitoring stations (Haifa, Hadera, Tel Aviv Metropolitan area, Ashdod, and Ashkelon) range between 122%-177% of the annual target (Air quality monitoring, management and awareness, 2005). Israeli Environment Ministry website reported annual average concentration of $PM_{2.5}$ 23-34 µg/m^3 and 45-67 µg/m^3 across the country with the highest levels recorded in the largest population centers. Particulate air pollution in Israel is high compared to European and North America levels but less than those measured in Sao Paulo (Brazil, 30 µg/m^3 for $PM_{2.5}$), Kangwha (background site for urban area in South Korea, 29.1 µg/m^3 for $PM_{2.5}$), Kaohsiung (Taiwan, 68 µg/m^3 for $PM_{2.5}$) (Zhang et al., 2004), and in Darjeeling (India, 24.19± 15.53 µg/m^3 for $PM_{2.5}$ that obtained in 2005) (Singh et al., 2006). Particulate air pollution monitoring studies conducted in Jordan have measured mainly dry deposition and total suspended particles with annual geometric mean of TSP concentration was 101-227 µg/m^3 that measured in Amman during 1986-1987 (Jaradat et al., 1997), according to our knowledge there was no measurement of Jordanian PM_{10} or $PM_{2.5}$.

According to the Applied Research Institute –Jerusalem (ARIJ) the total emission for PM_{10} was 374 ton from solid waste in West Bank (ARIJ, 1999).

Zhang et al., (2004) found that the concentration of $PM_{2.5}$ gradually increased along the wind direction, which illustrates regional transport of aerosol. Cheung et al., (2005) found that in the coastal area of southern China the high $PM_{2.5}$ concentrations were generally associated with the northerly and northeasterly winds, low $PM_{2.5}$ concentration were mostly associated with easterly wind or with heavy rain.

2.3. Health effects:

Studies of air pollution on health have linked particulate matter with a number of significant health effects, these include increased mortality and respiratory and cardiovascular disease, as evidenced by increased hospitalization, school absences and lost work days (Bell et al., 2004).

The health effect of atmospheric particulate matter are related to its ability to penetrate the respiratory system, in general, respiratory defense mechanisms are able to remove 99 percent of particles larger than 10µm from inhaled air stream, smaller particles (>2.5 µm) called "inhalable" can cling to protective mucous and removed in the upper respiratory system, fine particles (<2.5 µm) are called "respirable" can enter the lungs and end up in lung capillaries and air sacs (alveoli) penetrate and accumulate there (Scoditti and Olivieri, 2005).

Numerous epidemiological studies found associations between ambient fine particles ($PM_{2.5}$) concentrations and a wide variety of cardio-respiratory health outcomes, including premature mortality and lung cancer, have been documented in numerous studies (Schwartz et al., 1999; Pope, 2000; Pope et al., 2002).

A survey obtained in Tel Aviv in Israel found a greater frequency of respiratory symptoms was noted in central-north Tel Aviv- an area exposed to vehicular pollution - in comparison to the northeast (Goran, et al., 1999). Other study in 2005 in Ashkelon show that lung function of asthmatic children is negatively associated with air pollution by fine particles (PM_{10} and $PM_{2.5}$) (Peled et al., 2005).

Scientific studies estimate that all people may suffer from exposure to particulate matter, but the elderly people, individuals with preexisting heart or lung disease, children, asthmatics and asthmatic children are the most at risk from exposure to fine particulate (EPA, office of air and radiation, health and environmental effects of particulate matter, fact sheet, 1997).

Adams et al., (2001) concluded that the occurrence of higher wind speeds was strongly associated with a decrease in personal exposure levels.

2.4. Ecological effects :

Particulate matter cause damage and soiling to materials, and is a major cause of visibility impairment in many part of the US, also it affect our ability to see by scattering and /or absorbing light, certain particles such as sulfates and nitrates, grow in size as humidity increases, making them more effective in improving visibility (Zhang et al., 2004; Chung et al., 2002). High $PM_{2.5}$ levels have been shown to reduce visibility (DeGaetano and Dohary, 2004). Zhang et al., (2004) mentioned that the visibility decreased rabidly with increasing in $PM_{2.5}$ contraction from 12-260 $\mu g/m^3$, and the same $PM_{2.5}$ concentration leads to different visibility in summer and in winter indicating that visibility depends on other factors beside $PM_{2.5}$.

Particulate matter can damage vegetation both directly and indirectly when exposed to particulate. Plant may suffer from increased disease, leaf cells may be damaged, yield and growth rates may be reduced and plants may even die. Dust on the leaves of crops, trees and shrubs inhibits photosynthesis and plant growth, particulate carrying heavy metals can contaminate soil and vegetation in urban area, in addition, particulate matter can scatter sunlight and cause a reduction in solar radiation, thereby crop productivity (Charlson et al., 1992; Malm et al., 1994; Seinfeld and Pandis 1998; Chameidies et al., 1999; Cheung et al., 2005)

2.5 Sources of particulate matter:

Particulate matter originates from a variety of sources, these sources are both primary and secondary in origin. $PM_{2.5}$ are primarily from anthropogenic combustion sources, although natural sources contribute significantly as well, and secondary sources of PM that produced by reaction in the air. Important sources of $PM_{2.5}$ include diesel vehicles (transportation emission), power plant (especially those burning high sulfur fuel), biomass combustion (e.g., fireplaces and forest fires), resuspended road dust and windblown, and mechanical processes (e.g. quarrying and agricultural harvesting) in addition to other natural resource such as volcanoes and sandstorm (Kim and Hopke, 2004; Marmur et al., 2005; EPA, Arizona Department of Environmental Quality, 2006; Waverley Borough Council, UK, 2007).

Eight sources of particles are identified, in a study obtained in some Chinese cities, which including coal burning, soil dust, construction dust, road dust, vehicle exhaust, biomass burning, organics, and secondary sulfate and nitrate. Approximately 53% of $PM_{2.5}$ mass is assigned to primary sources, eight sources apportionment of ambient $PM_{2.5}$ in Beijing were 6% vehicle, 10% road dust, 14%soil dust, 3%construction activity , 15%coal burning, 14%organic, 5% biomass burning, 16% secondary and 17% unknown (Zhang et al., 2004).

Other study focused on $PM_{2.5}$ organic carbon sources in the southeastern United State, the major contributors were wood combustion (25-66%), diesel exhaust (14-30%), meat cooking (5-12%) and gasoline –powered motor vehicle exhaust (0-10%), as well as smaller but statistically significant contribution from natural gas combustion, paved road dust, and vegetative detritus (Zheng et al., 2005). In an examination of the ratio of secondary organic carbon to total organic carbon suggested that approximately 34% of organic carbon was of secondary origin (Cheung et al., 2005).

Formation and growth of fine particulate are influenced by several processes including ; nucleation in which gas molecule coming together to form a new particles, condensation of gas onto existing particles, coagulation of particles, the weak bond of two or more particles into one large molecule, gas phase reaction which form secondary PM (Stern et al., 1984; Poschl, 2002).

Removal processes of particles depend on their size; in general, the smaller and lighter a particle is, the longer it will be stay in the air, large particles tend to settle to the ground by gravity in a matter of hours where is the smallest particles can stay in the atmosphere for weeks and are mostly removed by precipitation (Stern et al., 1984; Yu et al., 2008).

2.6. Chemical composition of Particulate matter :

Air samples of particulate matter from urban areas around the world typically show the same major components, although in considerably different proportions according to the sample location (Harrison and Yin, 2000). Because of the large number of sources, particulate matter may contain hundreds of different chemical substances (Poschl, 2002).

According to Polissar and Hopke, 2000; Kim et al., 2003; Cheung et al., 2005, there are eight major components namely:

1) Elemental carbon (EC) known as black carbon, which formed during high temperature combustion of fossil fuels and biomass fuels.
2) Organic carbon (OC): OC primarily comes from traffic or industrial combustion sources while secondary OC comes from the oxidation VOCs (volatile organic carboceous).
3) Sulphate: derived predominantly from sulpher dioxide oxidation in the atmosphere to form sulphuric acid, which can react with ammonia to give ammonium sulphate.
4) Nitrate: formed by the oxidation of nitrogen oxides to form nitric acid, which can react with ammonia to give ammonium nitrate, also present as sodium nitrate.
5) Sodium chloride : main sources are sea spray in addition to other secondary sources.
6) Trace metal : these metals are present at very low concentrations, it include lead, cadmium, nickel, chromium, zinc, and manganese, they are generated by metallurgical processes (e.g. steel making), from impurities in fuel additives and from mechanical abrasion processes (e.g. break and tyre wear on vehicle) .
7) Crustal material : soil dust and wind blown crustal material; are quite diverse in composition reflecting local geology and surface condition; their concentration is dependant on climate and the processes which suspend them into the atmosphere, these particles are found in coarse dust from quarrying, construction and demolition work and form wind driven dust, includes aluminum, silicon, iron and calcium.
8) Water: some particulate take up water from the atmosphere.

Zheng et al., (2005) found that sulfate, nitrate and ammonium constitute 88% of $PM_{2.5}$ mass on average, and dust is one of the major sources, accounting for 36 % of $PM_{2.5}$ in April 2000, and OC concentration ranged from 13 $\mu g/m^3$ in summer to 31 $\mu g/m^3$ in winter.

Cheung et al., (2005) says that the chemical composition of $PM_{2.5}$ showed changes with different wind flows, a larger fraction of OC was often observed in northerly and northeasterly winds while a higher content of sulfate was indicated under easterly winds.

Hogrefe et al., (2006) mentioned that during summertime, sulfate is the strongest contributor, while in wintertime nitrate to be the strongest contributor.

3. Materials and Methods:

3.1. Site description

Hebron city is located at the southern part of the Central Highland region to of West Bank. Its topography is mountainous with elevation about 950 m above sea level. It is characterized by the Mediterranean climate, with rainy, humid, and moderately cold winter, long, warm and dry summer, the average temperature is 22ºC in summer, and from 7º C to 10 ºC in winter. Humidity range from 60-75% in winter, and precipitation range from 200-1027mm/y (Meteorological station in Hebron City, 2007).

Hebron city is one of the largest cities in West Bank with an area of about 997 Km², and 166,003 inhabitant (Palestinian Center bureau of statistics, 2006). Hebron city is the center of a large district which has a population about 551.130 inhabitants (Palestinian Center bureau of statistics, 2007). It has a high traffic, about 31124 cars, (21168 car gasoline, 9889 car diesel, 64 others) (Traffic unit and licensing, 2007). There are about 576 small, medium and large scale industries, and 28 quarries which are surrounding the city nearly from all directions (Chamber of commerce and industry, 2007).

Sampling was conducted on the roof of a three story building, the Governmental Hebron Hospital with height about 12m from the ground surface (longitude 35º 05´ 56´´ altitude 31º 31´ 46´´), which located at the center of Hebron city. The measurement site is surrounded by heavy traffic, shops, and the market located nearby, as seen in photo (1) below. It is surrounded by several buildings. The nearest major street was 100 meters away with heavy traffic, in addition there are two minor street, the first in the south belong to the hospital and the second 50 m in the east. There was a parking lot at more than 500 m south of the site, in addition to some temporally parking.

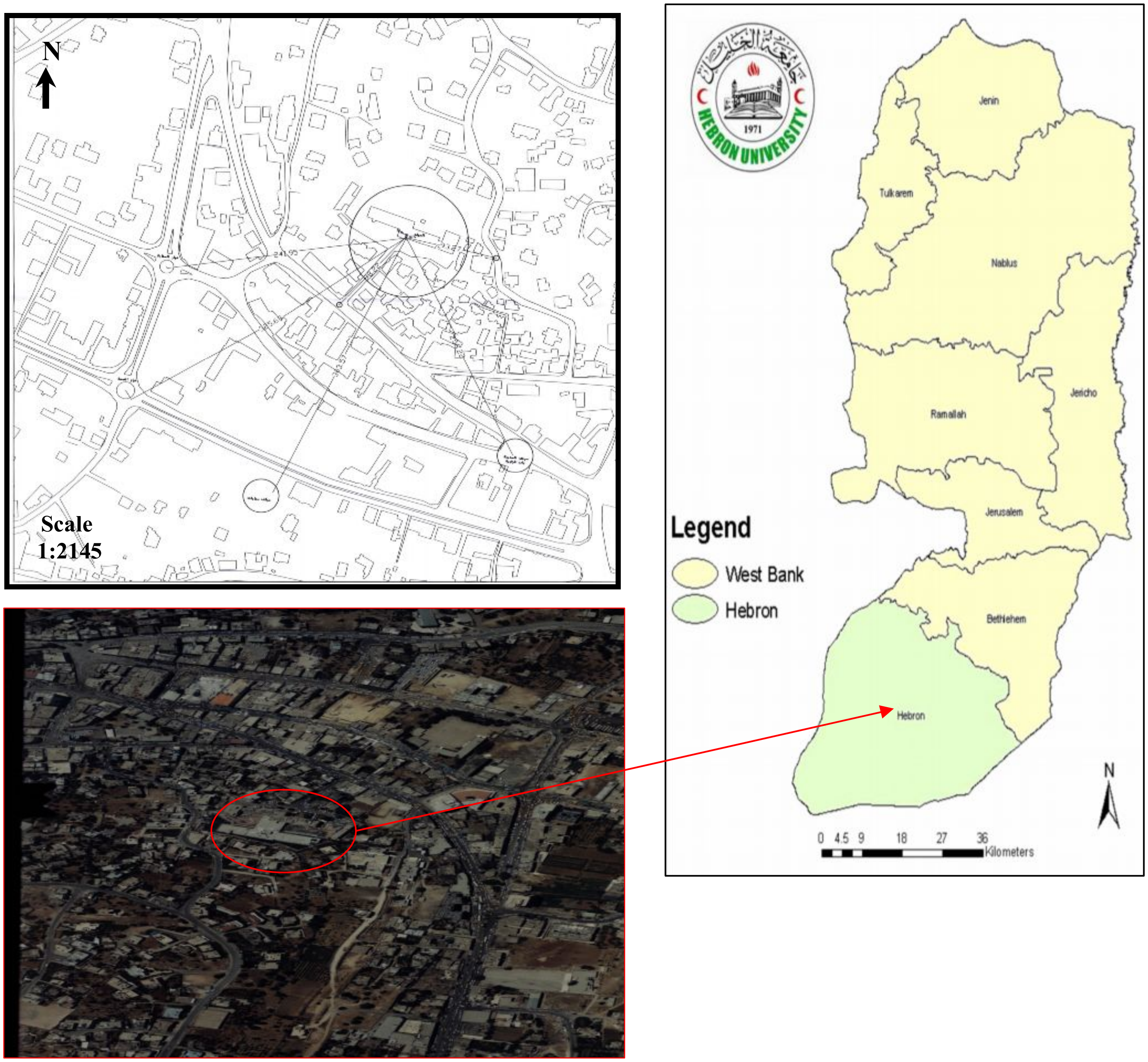

Photo (1) Sampling area from above.

3.2. Sampling equipment and methods :

At the $PM_{2.5}$ monitoring site, 24-hour filter collections were performed every 6th day in the months January 2007- December 2007, yielding a total of 60 sampling days using the Harvard impactor of $PM_{2.5}$ chemical speciation sampler. A schematic of the sampler set-up is shown in photo (2). The sampler use cyclone separators to remove particles of diameter greater than 2.5 µm (Marple et al. 1987), with particles collected downstream on filter in four channels (two 47 mm quartz fiber filters, two 47mm Teflon filters).The sampler had two flow lines of 24 L/min, which included a $PM_{2.5}$ cyclone followed by a manifold splitting each flow line into a quartz filter channel (12.5 channel (7.3 L/min for RAAS $PM_{2.5}$, 10.0 L/min for Caltech Gray Box) and a Teflon filter channel (7.3L/min for RAAS $PM_{2.5}$, 10.0 L/min for Caltech Gray Box). Flow rates were controlled by critical orifices located upstream of a vacuum pump were measured periodically with a calibrated dry gas mater. After each sampling period, filter samples were sealed in Petri dishes and stored under freezing temperatures to minimize the loss of volatile species. Samples were later transported in ice-packed coolers to their eventual destinations at Al-Quds University and Wisconsin University for mass measurement and chemical analyses. To track any contamination due to handling, four field blanks (one per sampling month) was taken at the site.

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3.3. Concentration calculation :

Gravimetric method was used to calculate mass concentration of $PM_{2.5}$, can be described as follows:

Gravimetric Methods - exchangeable filters (FRM)

Basis: An air pump draws ambient air at a constant flow rate into a specially shaped inlet where particulate matter is separated into size fractions. Particulate matter is then collected on a filter, and one of the Teflon filters is weighed before and after use, to determine the net mass gain due to collected matter. The total volume of air filtered is known from the constant air flow and rotometer reading by using this equation (Total volume =LPM reading* site's rotometer factor * sampling time[Minute]*(10^-3)[m^3/L]). The difference in filter weights is used to calculate the particulate matter concentration in micrograms per cubic meter ($\mu g/m^3$) of air volume. Before the calculation of atmospheric concentration, each filter loading were blank correct, using net work wide average loading from field blank, blank corrected filter loadings were then divided by sample volume (volume of air). (The Gravimetric weighing lab is placed at the Earth Science Institute, Hebrew University of Jerusalem (HUJI)).

3.4.Chemical analysis:

After sample collection, one Teflon filters were analyzed for $PM_{2.5}$ mass concentration, (explain previously), major ions (sulfate and nitrate), and trace elements. Analysis of the quartz fiber filters included organic carbon (OC), and elemental carbon (EC). $PM_{2.5}$ mass measurements were conducted via a microbalance (Mettler Instruments) following the guidelines laid out in the

EPA Quality Assurance Document 2.12 (EPA,1998), with repeat measurements performed on all samples to ensure accurate results. Concentrations of sulfate and nitrate were determined using ion chromatography, comparing sampled concentrations with laboratory standards prepared from ACS grade analytical reagents. Specific elements were detected using X-ray fluorescence (XRF)(Watson et al., 1996).

Quartz fiber filters were measured for EC and OC using a carbon analyzer (Wisconsin Laboratory) following the NOISH protocol of thermal evolution and combustion (Birch and Cary, 1996).

3.2.6. Meteorological data :

The meteorological data namely temperature, wind speed, wind direction, relative humidity, and precipitation were obtained from Meteorological station in Hebron city, about 4 km a way from the measurement site. The maximum, minimum and average temperature for each day of sampling were obtained, for wind speed, relative humidity, the average for each day were taken. For each factor there were 8 readings each day.

4. Results :

4.1. Mean $PM_{2.5}$ mass concentration :

The average annual mass concentration of $PM_{2.5}$ in this study (for Hebron city) was 22.8±11.1µg/m^3, with the concentration of individual samples ranging from 8.1 to 65 µg /m^3 (Appendix A). This is higher than 15 µg /m^3, the recommended $PM_{2.5}$ standard in the United States (EPA).

4.2. Relationship of $PM_{2.5}$ concentration with the meteorological factors:

4.2.1. Ambient temperature and $PM_{2.5}$ concentration :

The highest $PM_{2.5}$ concentration was when average temperature 28 ºC (35.25 µg /m^3 ±1.48) and followed by values when temperature was equal 20 ºC (33.25 µg /m^3 ±19.93), while the lowest $PM_{2.5}$ concentration was detected when average temperature was 6 ºC (12.35 µg /m^3 ±0.07) (Figure 1). Generally, it was shown that $PM_{2.5}$ concentration increased as the temperature increased with r^2 value of 0.65 (Figure 1).

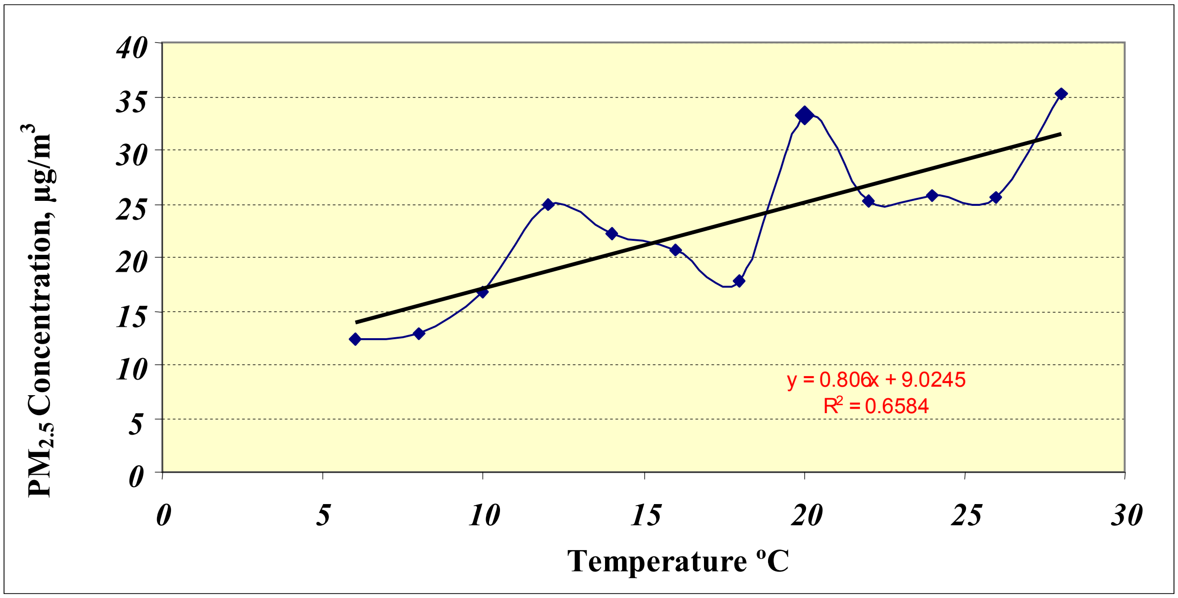

Figure 1: Relationship between Temperature and $PM_{2.5}$ concentration, Hebron City/2007.

4.2.2. Relative humidity (RH%) and $PM_{2.5}$ concentration :

Data in Figure (2) show that most of the high $PM_{2.5}$ concentration was when the RH below 80% but above that the concentration decrease, with the highest $PM_{2.5}$ concentration was when RH 27% (61.3µg /m^3), and the lowest value at 97% (4.5µg /m^3). When RH 100% the $PM_{2.5}$ concentration was 10.4µg/m^3.

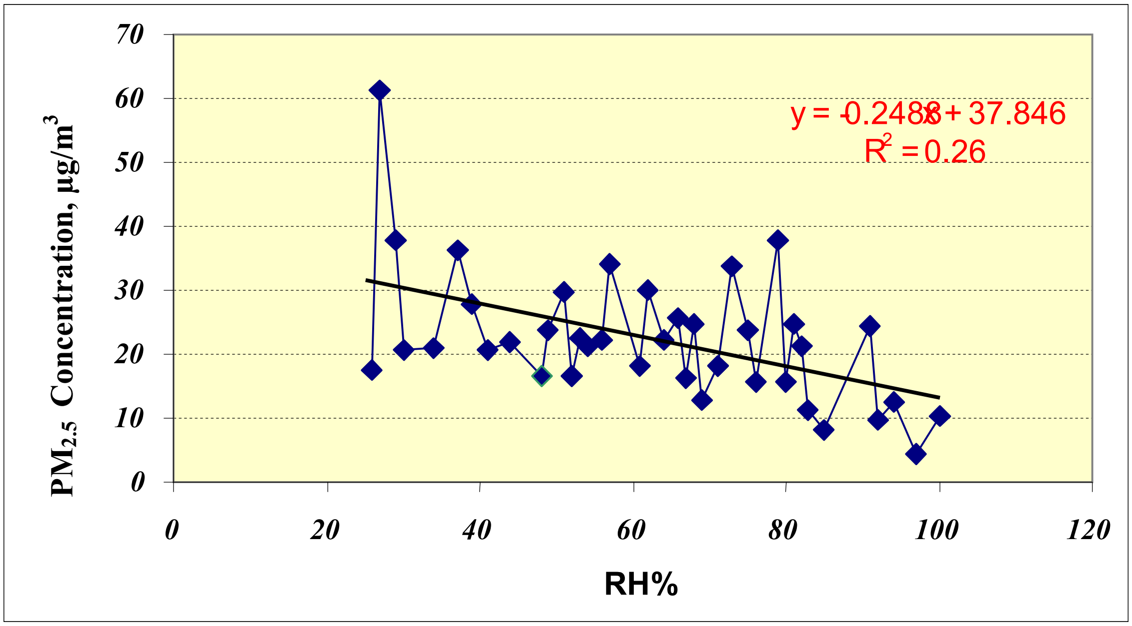

Figure 2: Relationship between relative humidity and $PM_{2.5}$ concentration, Hebron City/2007.

4.2.3. Wind speed and $PM_{2.5}$ concentration :

Data in Figure (3) show a decrease in $PM_{2.5}$ concentration as wind speed increased, the higher $PM_{2.5}$ concentration was when the wind speed 4km/h (36.7µg / m^3 ±0.07), then when wind speed 6km/h (28.4µg / m^3 ± 14.27), when wind speed around 7km/h and above the concentration was decrease, at 9km/h the concentration was 17.5µg/m^3 ±17.53, but the concentration increase when the wind speed was 10km/h (23.2 µg / m^3 ± 9.78). The lowest $PM_{2.5}$ concentration was when wind speed 11km/h (4.5µg / m^3 ± 0.07).

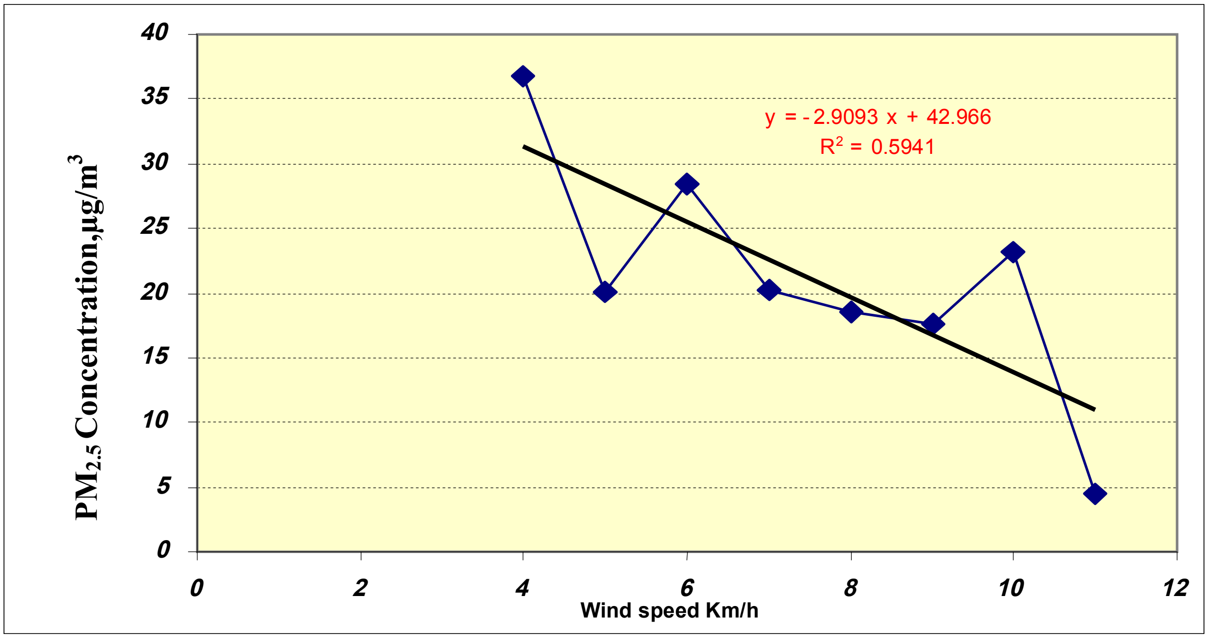

Figure 3 : Relationship between wind speed and $PM_{2.5}$ concentration, Hebron City/2007.

4.2.4. Wind direction and $PM_{2.5}$ concentration :

The result obtained from Figure (4) and (5) show that $PM_{2.5}$ concentration affected by wind direction. Most $PM_{2.5}$ became from south east (26.95 µg/m^3 ±13.95), then north west (26.33 µg/m ^{3} ±11.95), then north east (19.06 µg/m ^{3} ±2.69), and the least come from south west (17.67 µg/m^3 ±8.45).

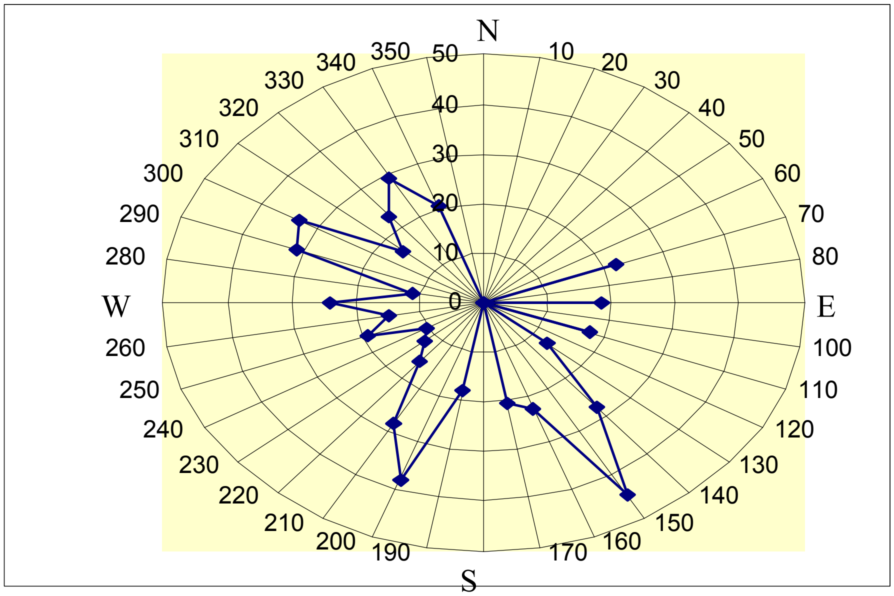

Figure 4:Wind direction and $PM_{2.5}$ concentration, Hebron City/2007.

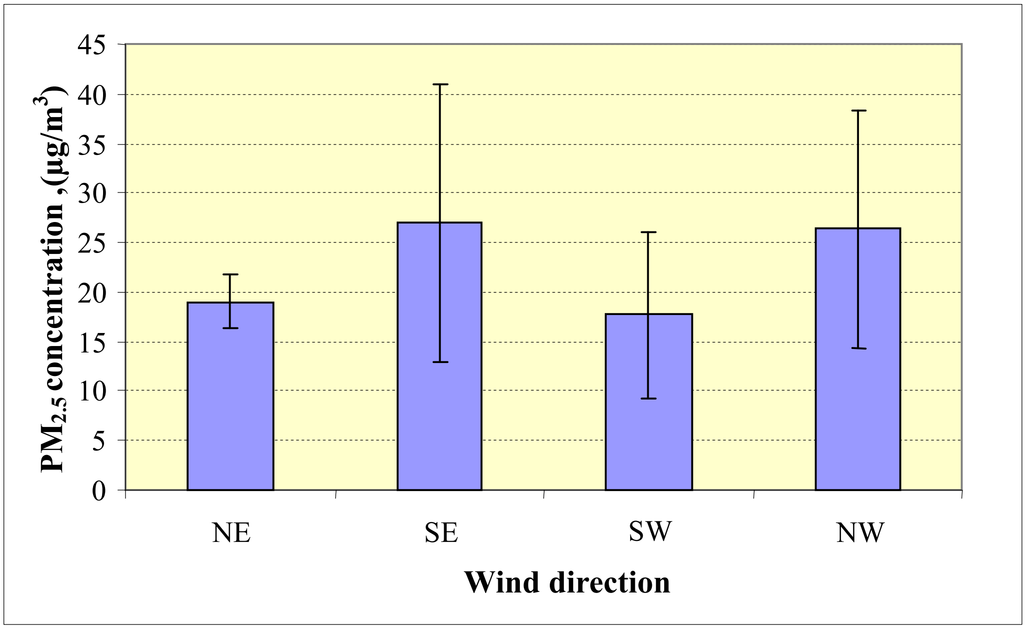

Figure 5: Relation between wind direction and $PM_{2.5}$ concentration, Hebron City/2007.

4.3. Influence of temporal variation on $PM_{2.5}$ concentration :

4.3.1. Monthly variation in $PM_{2.5}$ concentration:

Data in Figure (6) show a variation in $PM_{2.5}$ concentration between months, that the highest $PM_{2.5}$ concentration values were obtained in October with 31.4 $\mu g/m^3$ ± 21.37, the second month was May (30.7$\mu g/m^3$ ±20.63),followed by April (29.8 $\mu g/m^3$± 8.14), the low $PM_{2.5}$ concentration was occurred in December (16.8 $\mu g/m^3$ ± 7.55), and November (16.7 $\mu g/m^3$± 4.75), then January (15.4 $\mu g/m^3$ ± 4.26), and the lowest value for $PM_{2.5}$ concentration was in March (12.5$\mu g/m^3$ ± 5.85).

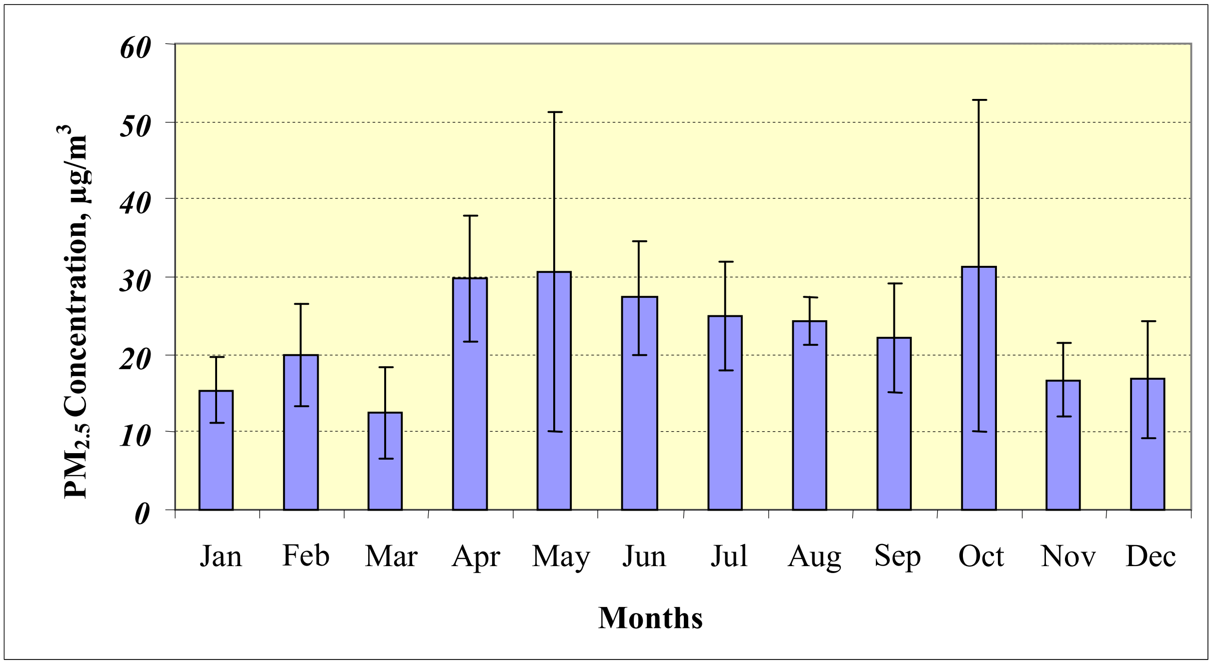

Figure 6: Variation in $PM_{2.5}$ concentration between months, Hebron City/2007.

4.3.2. Influence of seasons on $PM_{2.5}$ concentration:

Our result show that there were variation in $PM_{2.5}$ concentration between seasons. Data in Figure (7) showed high $PM_{2.5}$ concentration in Summer (25.53 µg/m^3 ± 1.56), then in Spring (23.67 µg/m^3±10.25) and Autumn (23.4 µg/m^3±7.43), and the lowest $PM_{2.5}$ concentration was in Winter (17.4 µg/m^3 ± 2.35).

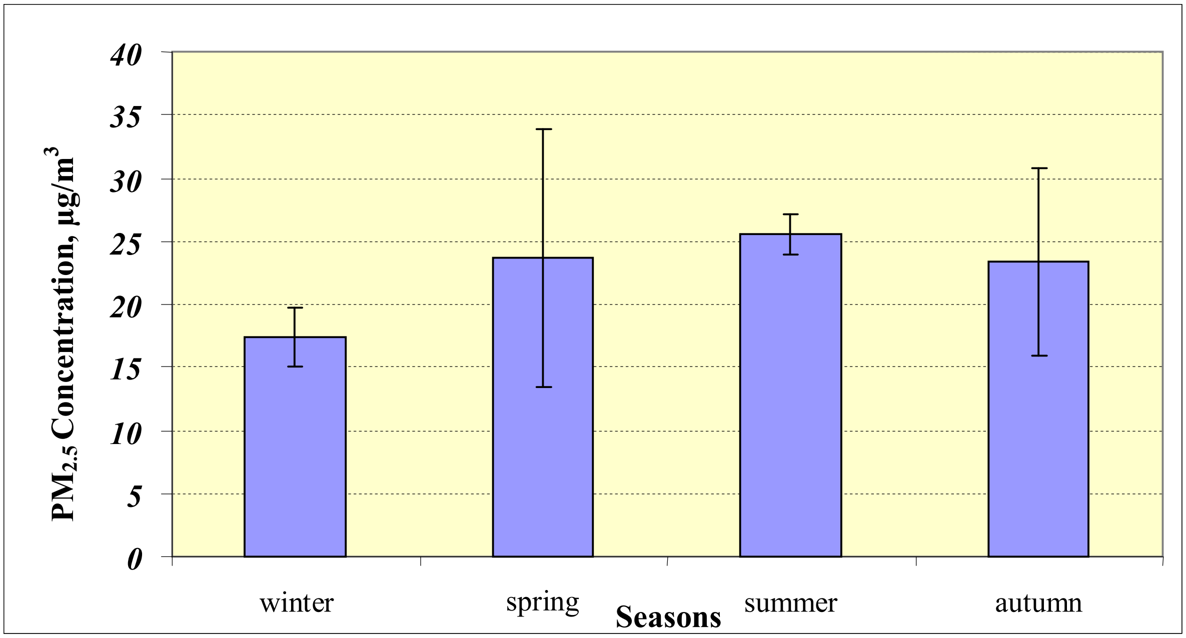

Figure 7:Influence of seasons on $PM_{2.5}$ concentration, Hebron City/2007.

4.3.3. Influence of days on $PM_{2.5}$ concentration :

Sunday (27.37 µg/m^3 ± 17.87), Wednesday (27.42 µg/m^3± 16.11), and Friday (26.1 µg/m^3± 8.38) had the highest $PM_{2.5}$ concentration, followed by Thursday (21.1 µg/m^3 ± 8.02) and Monday (20.46 µg/m^3 ± 6.95) then Saturday (19.72 µg/m^3± 5.44), while Tuesday had the lowest $PM_{2.5}$ concentration (16.82 µg/m^3 ± 6.25) (Figure 8). Even though there were variation in $PM_{2.5}$ concentration between days, on the average, weekend $PM_{2.5}$ concentration (22.91 µg/m^3 ±

4.51) and weekdays $PM_{2.5}$ concentration (22.63 µg/m^3 ± 4.64) are similar (Figure 9).

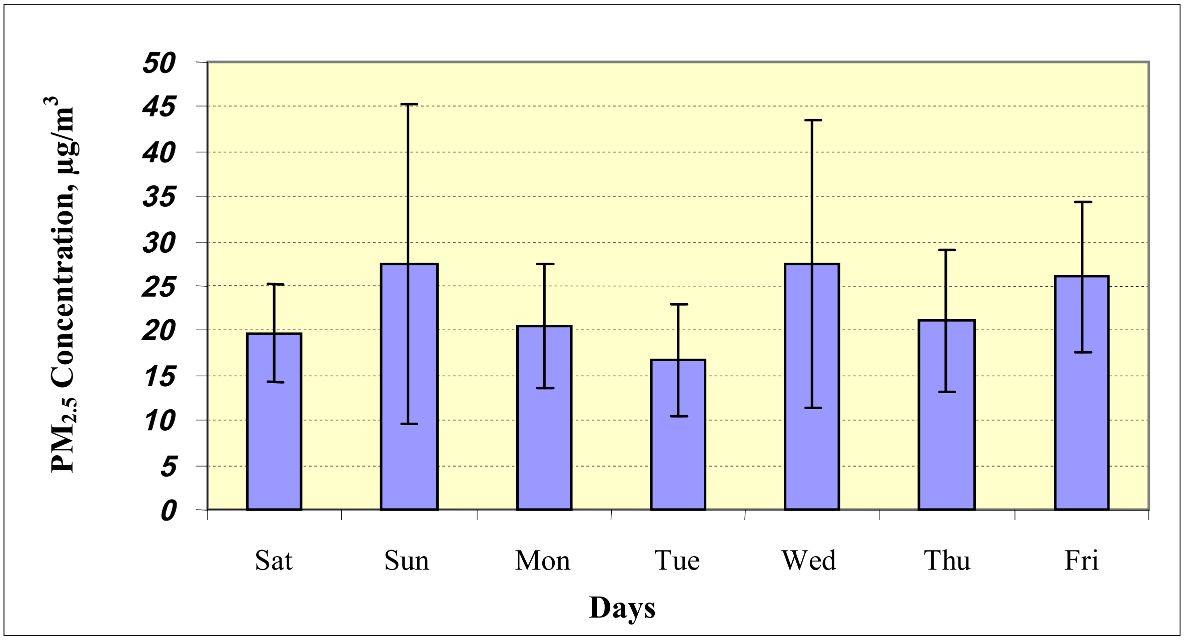

Figure 8:Influence of days on $PM_{2.5}$ concentration, Hebron City/2007.

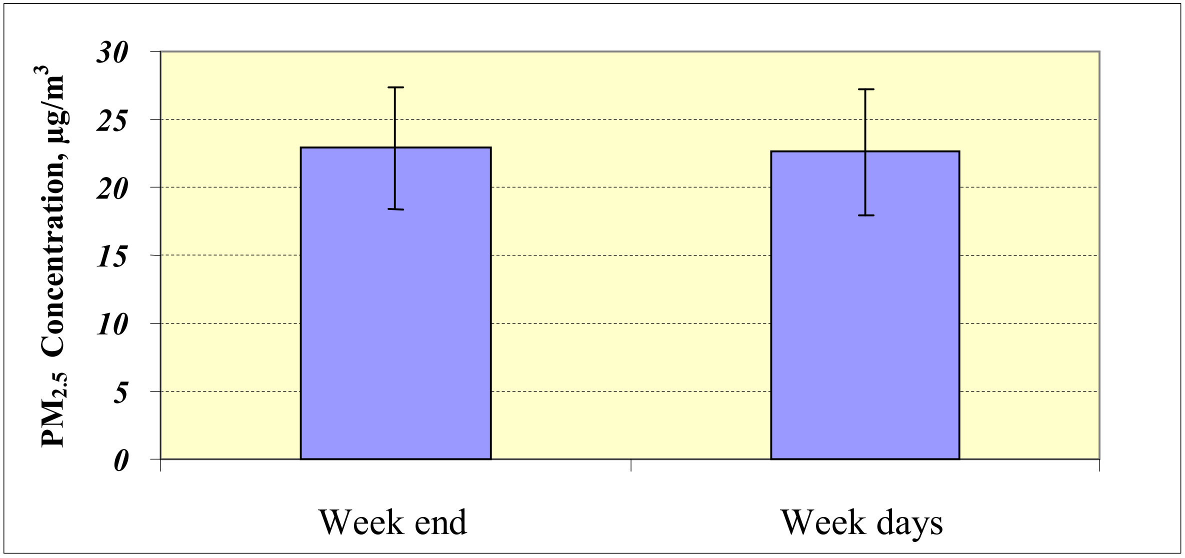

Figure 9: Variation in $PM_{2.5}$ concentration between weekend and weekdays, Hebron City/2007.

4.4. Chemical composition :

4.4.1. Main chemical composition of $PM_{2.5}$:

As shown in Table (1) and Figure (10) organic carbon (OC) (5.69µg/m^3 ± 3.39) constitute 35% of the $PM_{2.5}$ mass and crustal material (4.083 µg/m^3 ± 8.04) constitute 24% and sulfate (3.9µg/m^3 ± 2.44) constitute 23%, are the major components of $PM_{2.5}$, followed by elemental carbon (EC) (1.9 µg/m^3 ±1.1) constitute 11% from the total $PM_{2.5}$ concentration, then nitrate (1.07µg/m^3 ± 0.92) constitute 6%. Metals was present in small quantity (0.149µg/m^3 ± 0.13) and constitute only 1% from the total $PM_{2.5}$ mass.

Table 1: Main chemical composition and mass concentration of $PM_{2.5}$ in Hebron city (µg/m^3), Hebron City/2007.

	Mass of $PM_{2.5}$	EC	OC	TC	SO_4^{-2}	NO_3^-	Metals	Crustal
Annual average	22.8	1.906	5.69	7.596	3.9	1.07	0.1497	4.083
SD	±11.1	±1.11	± 3.39	±4.35	± 2.44	± 0.92	± 0.132	± 8.04

Note : SD: standard deviations, TC: total carbon.

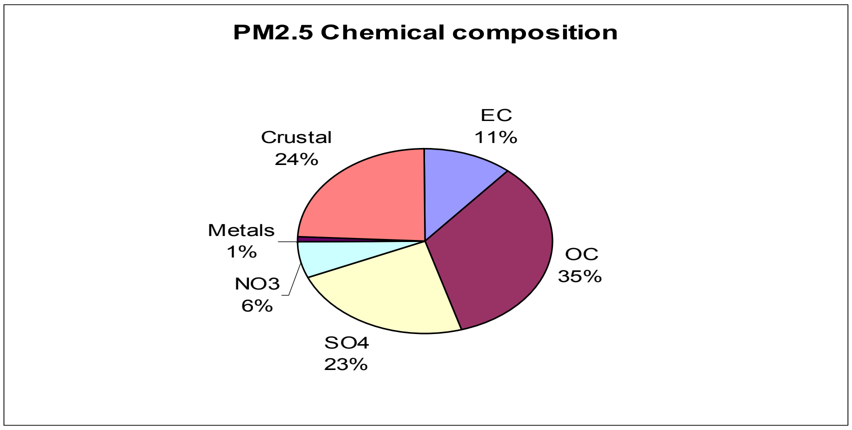

Figure 10:PM$_{2.5}$ chemical composition and its percentage, Hebron City/2007.

4.4.2. Influence of meteorological factor on concentration of chemical composition of PM$_{2.5}$:

Nearly all chemical composition of PM$_{2.5}$ increased with increase in temperatures (Appendix B Figure1), and SO_4^{-2} concentration increased (Figure 11), while NO_3^- concentration decrease with increased in temperature (Figure 12). Most of high SO_4^{-2} reading occur when temperature 20° C and above, while for NO_3^- higher reading was appeared when temperature 15 °C and below. Also the data show that large part of PM$_{2.5}$ composed of SO_4^{-2} with increase in temperature, especially in Summer.

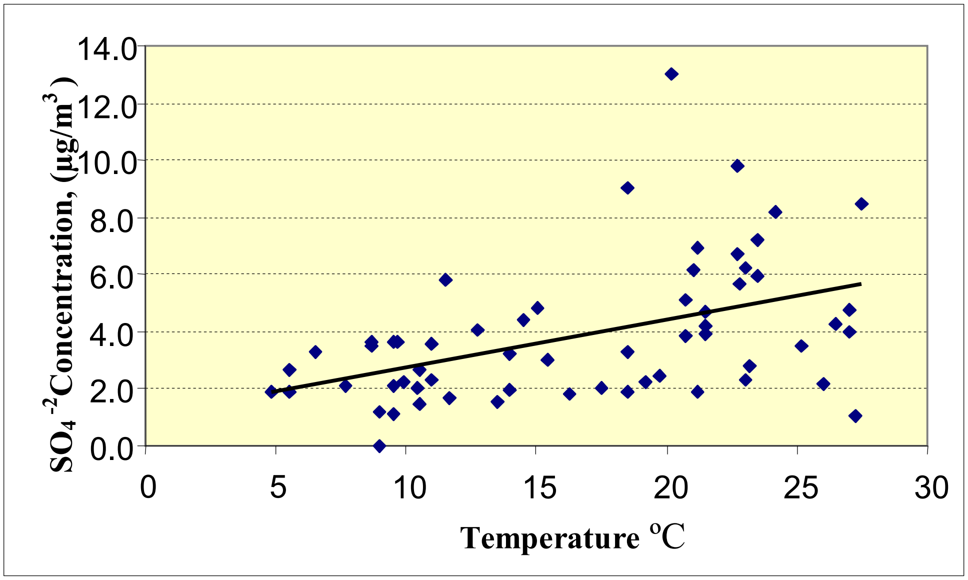

Figure 11: Influence of temperature on SO_4^{-2} concentration, Hebron City/2007.

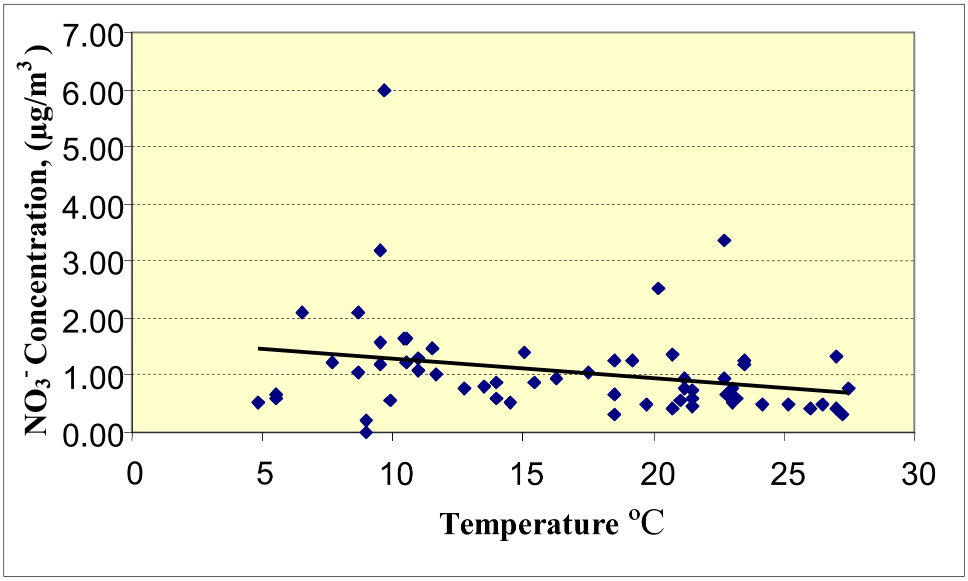

Figure 12:Influence of temperature on NO_3^- concentration, Hebron City/2007.

Figure (13) show that most of SO_4^{-2} comes from SW and NW directions, while high concentration of metals come from SE and NW direction, (Figure 14). From figure (15) most of crustal material come from SE and NW direction, and high concentration occur when wind came from NW.

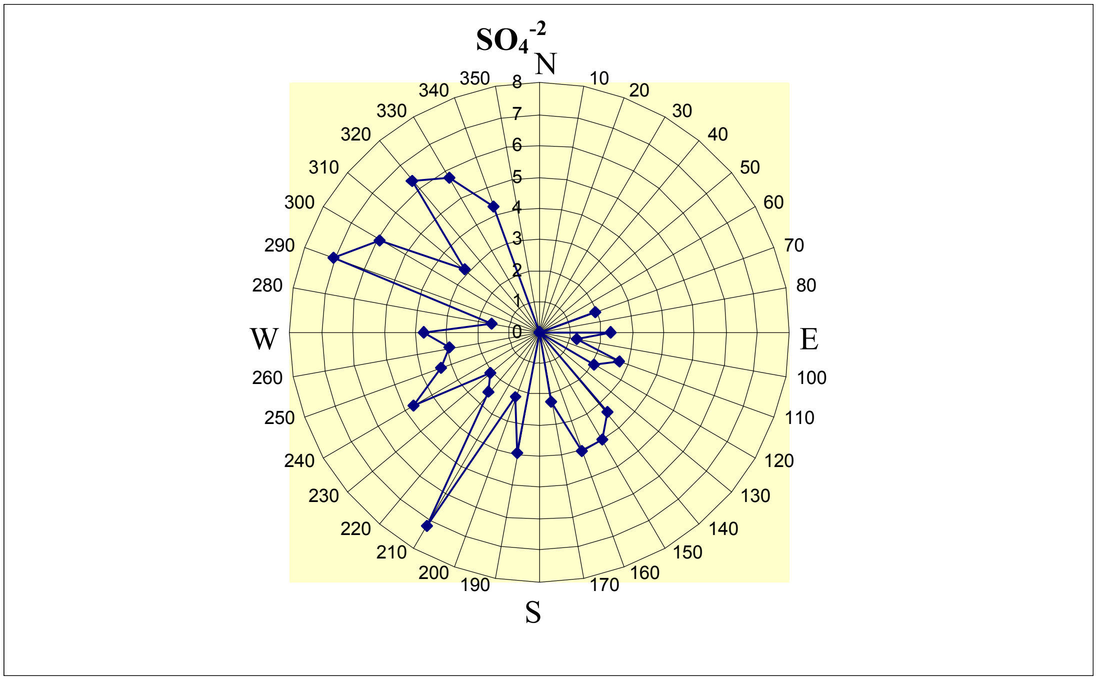

Figure 13: Influence of wind direction on SO_4^{-2} concentration, Hebron City/2007.

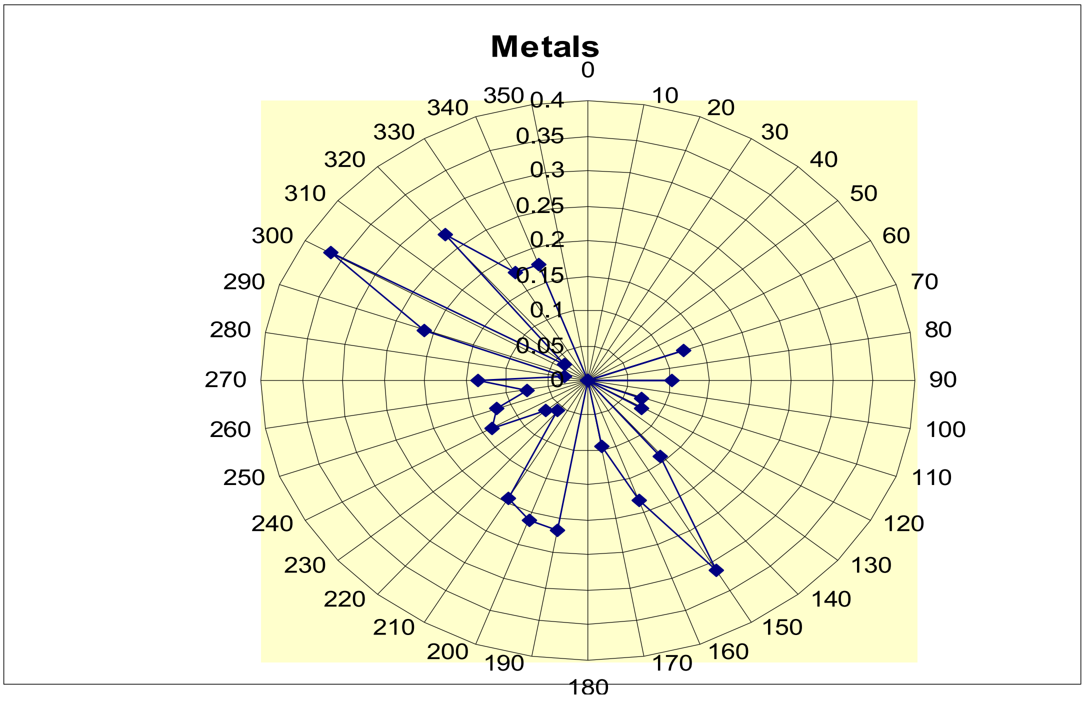

Figure 14: Influence of wind direction on Metals concentration, Hebron City/2007.

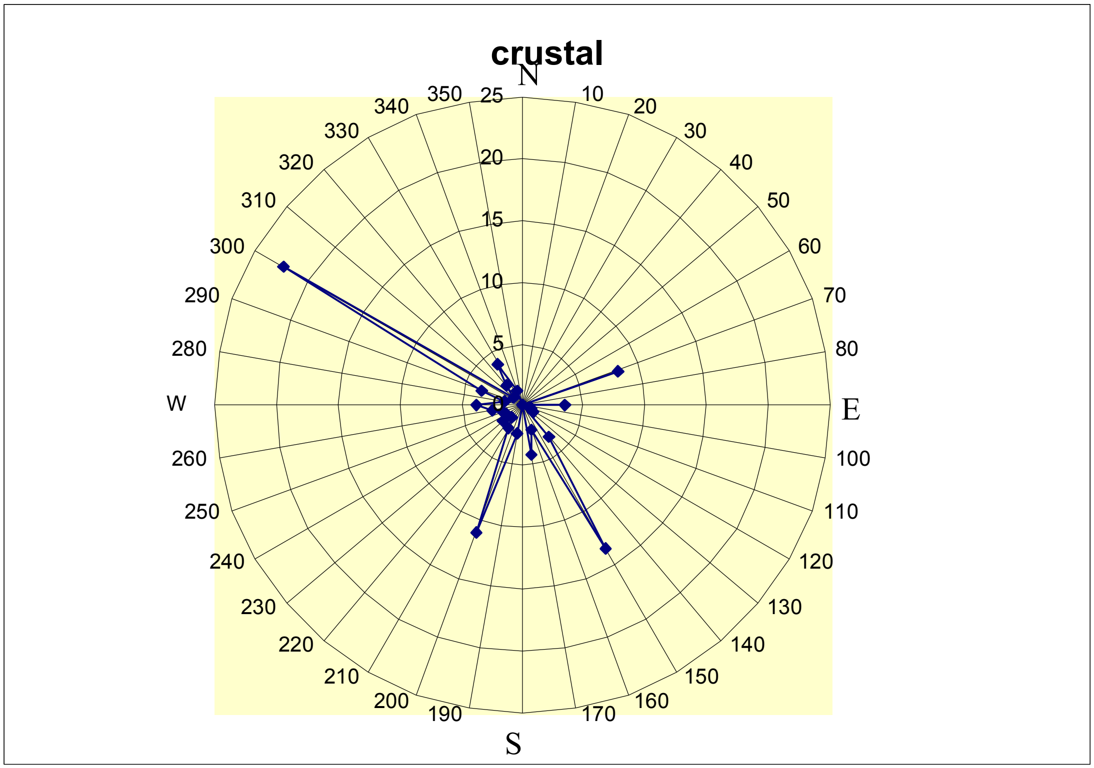

Figure 15: Influence of wind direction on crustal concentration, Hebron City/2007.

4.4.3. Influence of temporal variation on chemical composition of $PM_{2.5}$:

4.4.3.1 Variation of SO_4^{-2} concentration through months and seasons :

The highest SO_4^{-2} concentration was obtained in September (5.79 µg/m^3 ±2.45), then in October, August , July and June with nearly equal values (Figure 16). January, February, November and December months have low concentration, while March had the lowest concentration with 1.6 µg/m^3 ±1.2. So the highest concentration of SO_4^{-2} occur during Summer (5 µg/m^3 ±1.39) and Autumn (5.57 µg/m^3 ±1.59) (Summer – Autumn peak) and the lowest concentration was in Winter (2.44 µg/m^3 ±0.27). Spring had higher SO_4^{-2} concentration than winter (Figure 17).

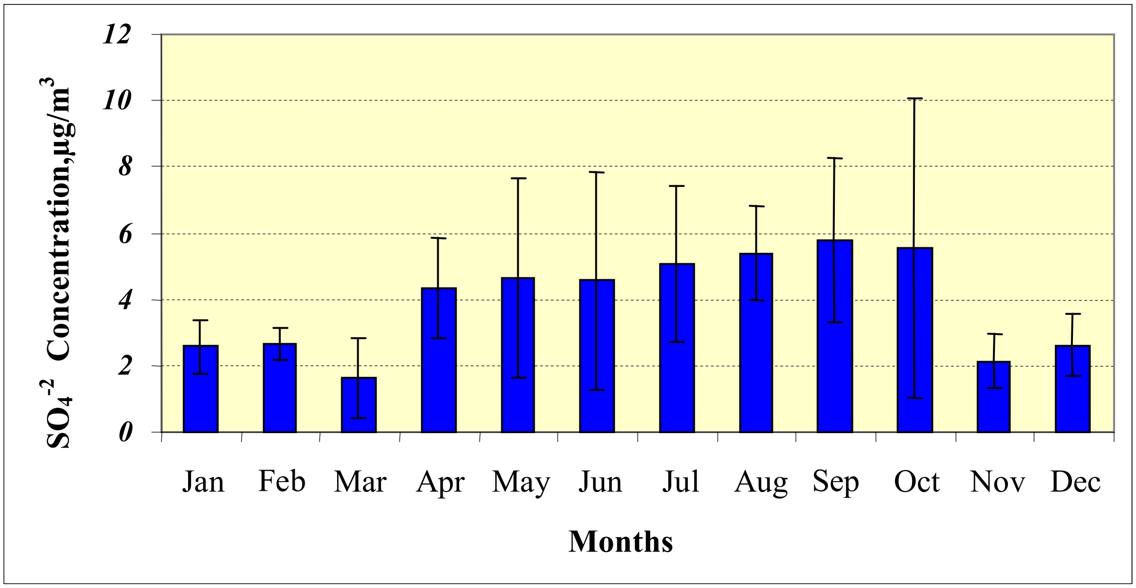

Figure 16:SO_4^{-2} mean concentration during months, Hebron City/2007.

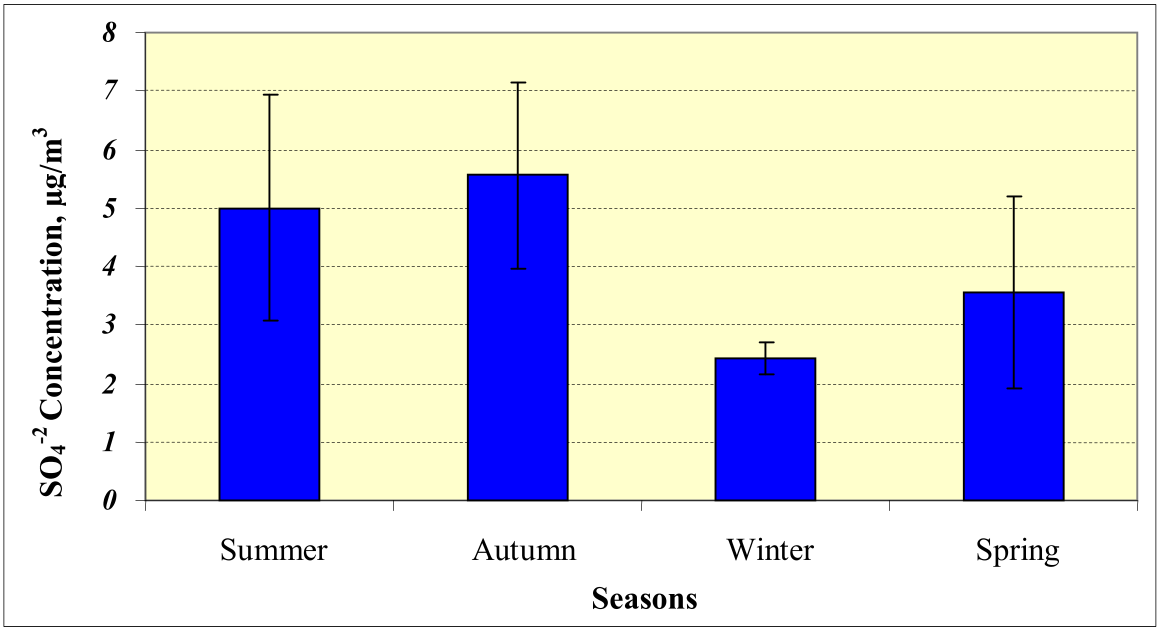

Figure 17: SO_4^{-2} mean concentration during seasons, Hebron City/2007.

4.4.3.2. Variation of NO_3^- concentration during months and season:

Data in Figure (18) show that NO_3^- concentration was very high in January (1.95 µg/m^3 ±2.36), December (1.7 µg/m^3 ± 0.79), then in October (1.25 µg/m^3 ± 0.86) and May. NO_3^- have low concentration in June, July, September and August (0.61 µg/m^3 ± 0.19). From figure (19) the high concentration of NO_3^- was in Winter (1.58 µg/m^3 ± 0.43), while Summer have the lowest concentration (0.65 µg/m^3 ± 0.03). Spring and Autumn had low NO_3^- concentration than Winter but higher than Summer.

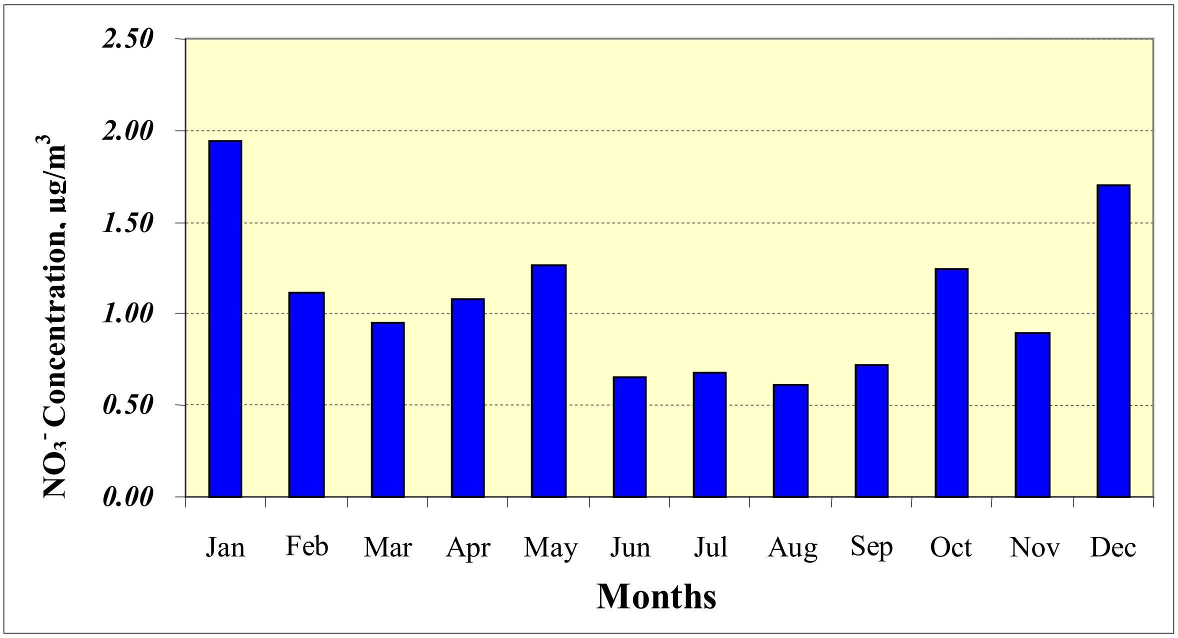

Figure 18: NO_3^- mean concentration during months, Hebron City/ 2007.

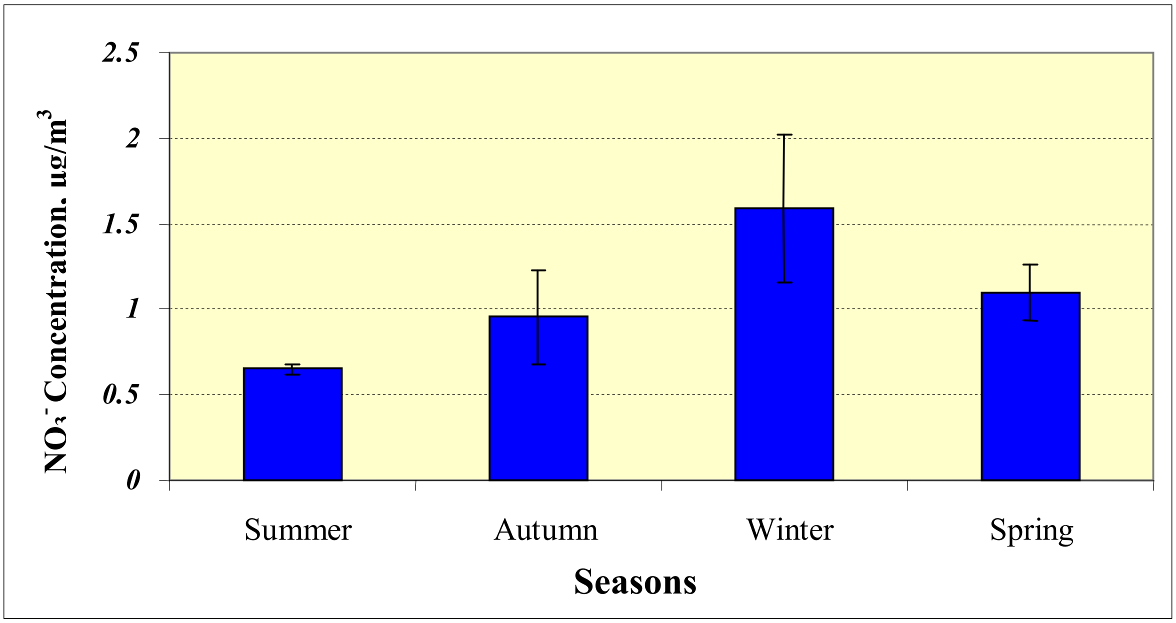

Figure 19:NO_3^- mean concentration during seasons, Hebron City/2007.

4.4.3.3. Influence of months and season on crustal concentration:

From figure (20) it is clear that May has the highest concentration of crustal material (17.55 μg/m^3 ±23.09), then October (6.1 μg/m^3 ±5.39), while the other months have very low concentration in comparison with May.

Figure (21) show that Spring has the highest concentration of crustal material (8.1 μg/m^3 ±8), followed by Autumn (3.6 μg/m^3 ±2.2). Summer (2.21 μg/m^3 ±11.4) and Winter (2.07μg/m^3 ±0.46) had the lowest concentration.

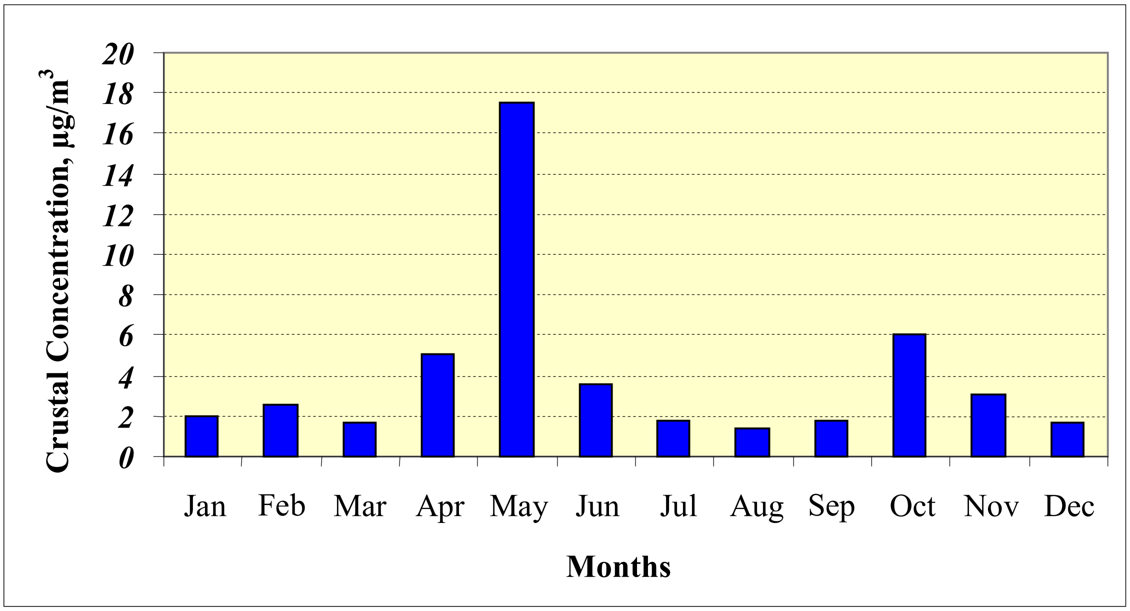

Figure 20: Crustal mean concentration through months, Hebron City/2007.

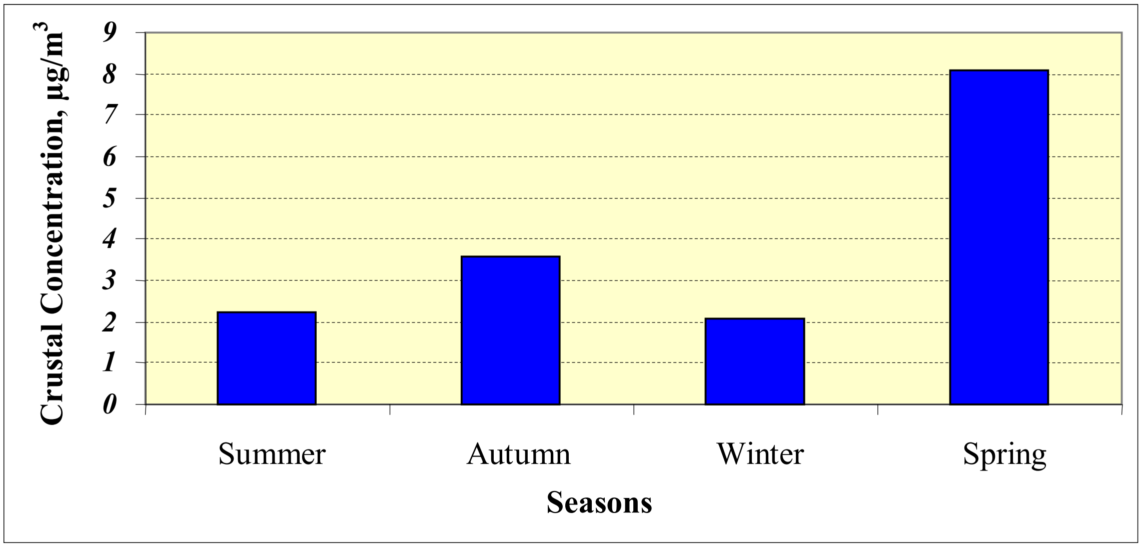

Figure 21:Crustal mean concentration through seasons, Hebron City/2007.

5. Discussion:

5.1. $PM_{2.5}$ Concentration :

The USEPA has set a strict $PM_{2.5}$ limit value of 15 $\mu g/m^3$ (annual average) and the same value has been recommended by Palestinian and Israeli standards, while a lower annual $PM_{2.5}$ limit of 20 $\mu g/m^3$ has been recommended by the European Committee for standardization (CEN) (Vallius, 2005). The mean annual value of $PM_{2.5}$ concentration (22.8±11.1$\mu g/m^3$) in this study was higher than the USEPA standard but close to CEN limit value. The result of $PM_{2.5}$ annual mean concentration in our study generally was much lower than some Chinese cities in which $PM_{2.5}$ annual mean concentration varies from 50- 140 $\mu g/m^3$ (Zhang et al., 2004), and those measured in Sao Paulo (Brazil, 30.2 $\mu g/m^3$), in South Korea (29.1 $\mu g/m^3$), and in Taiwan (68 $\mu g/m^3$) and lower than that was measured in India (33.93±25.1 $\mu g/m^3$) (Singh et al., 2006). However it was higher than $PM_{2.5}$ annual mean concentration in Amsterdam (The Netherlands) (19.9± 13.21$\mu g/m^3$) and Helsinki (Finland) (12.8 ±6.74 $\mu g/m^3$) that measured between 1998-99, and moderately equal to $PM_{2.5}$ concentration in Erfurt (Germany) which is about 22.3±17.4 $\mu g/m^3$ (Vallius, 2005).

In our study the sources of $PM_{2.5}$ could be from the quarries that surrounded the Hebron city nearly from all direction, the fuel from the cars since the measurement area is located in the center of the city, and or from cross border.

5.2.Influence of meteorological factors on $PM_{2.5}$ concentration :

Jung et al., (2002) found that high $PM_{2.5}$ concentrations were often associated with high daily temperatures. Our data shows that generally the $PM_{2.5}$ concentration increased as the temperature increased, the highest $PM_{2.5}$ concentration was when average temperature 28ºC (35.25 µg /m^3 ±1.48) and there was also other high value when temperature was equal 20 ºC (33.25 µg /m^3 ±19.93), the lowest $PM_{2.5}$ concentration was when average temperature is about 6 ºC (12.35 µg /m^3 ±0.07) (Figure 1). In other related study (DeGaetano et al., 2004) it was found that high summer $PM_{2.5}$ concentration caused under moderately strong southwesterly winds, under these conditions temperature typically exceed 29 °C, and high winter $PM_{2.5}$ concentrations are associated with similar condition (a southerly wind component and relatively high temperature) and low concentration in summer associated with low temperature. Some studies suggested that in summer and under high temperature the SO_4^{-2} formation from precursor gas by photochemical activity (conversion of sulfur dioxide mainly from automobiles to sulfate) increase (Zhang et al., 2004; Hogrefe et al., 2006), the current research result showed that SO_4^{-2} concentration is higher in summer and autumn (Figure 17) than other seasons, mainly during the period of high temperatures (Figure 11), in autumn 2007 the average temperatures was 19°C for the sample days, and also it contain the day that has the highest concentration which is 10/10, in addition, weather fluctuation in autumn.

Hartog et al., (2005) found that concentration decreased with increasing relative humidity. From figure (2) most of the highest $PM_{2.5}$ concentration was when the RH below 80% but above that the concentration decreased, the highest $PM_{2.5}$ concentration when RH 27% (61.3µg / m^3), and the lowest value at 97% (4.5µg /m^3), when RH 100% the $PM_{2.5}$ concentration was 10.4 µg/m^3 . Even though there was a fluctuation in $PM_{2.5}$ concentration values with increase in RH. In general the researcher found that $PM_{2.5}$ concentration decrease with increase in relative humidity, this may be due to high RH with low temperatures which lead to condensation of vapor and then precipitation of $PM_{2.5}$ occur ; which is the removal process of $PM_{2.5}$ from the atmosphere. Low $PM_{2.5}$ levels were mostly associated with heavy rain, where rainfall is the most effective sink for fine PM, especially the water soluble components (Cheung et al., 2005).

The concentration of air pollutants is always inversely proportional to wind speed (Duijm, 1994; Chung and Cheng, 2002; Hartog et al., 2005). Figure (3) show that higher PM $_{2.5}$ concentration when the wind speed 4km/h (36.7µg / m^3 ±0.07), then when speed 6km/h (28.4µg / m^3 ± 14.27), then the concentration decrease with increase in wind speed, especially when wind speed around 7km/h and above, at 9km/h the concentration was 17.5µg /m^3 ±17, but the concentration increase when the wind speed 10km/h (23.17µg/m^3 ± 9.78) there could be other factors that might affect the $PM_{2.5}$ concentration rather than wind speed lead to increase the concentration. The lowest $PM_{2.5}$ concentration was detected when wind speed 11km/h (4.5µg / m^3 ± 0.07). DeGaetano and Doherty (2004) found that the lowest particulate concentration occurs with relatively strong wind. Baltrenas and Markuniene (2005) consider that increase in PM concentration was caused by onset of wind that stirred dust on a gravel road, dust deflation occurs in a sources region when the surface wind speed exceeds a threshold velocity, which is a function of surface roughness elements, grain size, and soil moisture (Climate change, 2001).

Previous studies showed that $PM_{2.5}$ concentration influenced by wind direction (Cheung et al., 2005; DeGaetano and Doherty, 2004; Heal et al., 2005). And there were a clear differences in hourly level of air pollution related to wind direction (Hartog et al., 2005). The results from figures (4) and (5) show that $PM_{2.5}$ concentration affected by wind direction. The high $PM_{2.5}$ concentrations in Hebron city were generally associated with the southeasterly (26.95 $\mu g/m^3$ ±13.95) and northwesterly winds (26.33 $\mu g/m^3$ ±11.95), this might be because the presence of quarries in this two directions and the desert in the south, and due to Alkhamasine wind that originated from south and east. Low $PM_{2.5}$ concentration was mostly associated with southwesterly wind (17.67 $\mu g/m^3$ ±8.45). Wind direction was fluctuating (i.e. not from any specific sector during a day). In a study done in Europe the result showed that $PM_{2.5}$ concentration was higher for days with air originating from continental Europe than those days air originated from the Athletic and the Arctic (Heal et al., 2005).

5.3. Temporal $PM_{2.5}$ concentration patterns:

Photochemical reactions and mixed- layer variations together have been the major contributor to the temporal variations of atmospheric pollutants (Demerjian and Jin, 1993). DeGaetano and Doherty (2004) mentioned that $PM_{2.5}$ concentration was influenced by seasons, and found that high $PM_{2.5}$ concentration was in summer (June- August), and minimum $PM_{2.5}$ concentrations occurring during the winter (December –March), the result in figures (6) and (7) show that there were monthly and seasonally variation in $PM_{2.5}$ concentration, and there were two high concentration peaks, the first one from April- August (Spring –Summer peak) and the second one in October, and the highest $PM_{2.5}$ concentration was in Summer (25.53 $\mu g/m^3$±1.56), and the lowest $PM_{2.5}$ concentration was in Winter (17.4 $\mu g/m^3$± 2.35), also the Summer months has higher $PM_{2.5}$ concentration than Winter months, in Summer there were calm wind, low relative humidity and high temperature, the high temperature increased $PM_{2.5}$ concentration (Figure 1), high temperature lead to formation of these particles in the atmosphere by conversion SO_X and NO_X to sulfate and nitrate which are the main components of $PM_{2.5}$ particles (Zhang et al., 2004). Hogrefe et al., (2006) mentioned that sulfate peak in summer higher than in winter, in June sulfate peak is high which caused by strong photochemical activity and fast conversion of sulfur dioxide to sulfate in summer time, in December lower than that in June. Cox and Chu (1996), suggesting that atmospheric chemistry, rather than transport, may be responsible for these high summer concentrations, also with decreased relative humidity and wind speed in summer $PM_{2.5}$ concentration increased (figure 2 and 3), in winter the high RH and low temperature lead to many precipitation events this led to low $PM_{2.5}$ concentration, Zhang et al., (2004) says that the low concentrations are largely due to meteorological conditions, especially precipitation. Zheng et al., (2005) found that the low level of fine particulate matter in January is possible due to frequent snow and reduced activities in cold season, in Spring $PM_{2.5}$ concentration was (23.67 $\mu g/m^3$±10.25), even though average temperature is low and relative humidity is high in most days of Spring, there were two months having high $PM_{2.5}$ concentration which are May (30.7$\mu g/m^3$ ±20.63) and April (29.8 $\mu g/m^3$ ± 8.14), in which there were normally Alkhamassen sand storm coming from the desert in the south, and in these two months most of the wind was came from SE and SW (Appendix A), the directions of sand storm. In addition, high biogenic and plowing action mainly in spring. The result of crustal material shows Spring season

(Appendix C) mainly May (Figure 19) had the highest concentration of crustal material, this corresponding well to the finding by Zheng et al., (2005) who reported that the highest $PM_{2.5}$ mass concentration was found in April, however, it is mainly attributed to dust Spring.

Between months, the highest $PM_{2.5}$ concentration was in October with 31.4 µg/m^3 ± 21.37, this month contains the day that has the highest $PM_{2.5}$ concentration (65µg/m^3), (Appendix A) this was 10/10 /2007, two days before Eid Alfeter which were characterized by highly traffic and shopping to the last hour of the day, since it is the tradition that most people go to the market in these days, the OC concentration was high in this day 9.6 µg/m^3, OC is one of the major components of $PM_{2.5}$, originated from mobile source. the lowest month was March (12.5µg/m^3 ±5.85) this might be attributed to high relative humidity and low temperature in this month and many precipitation events (the removal process of PM) in the day of sampling or before, and snow event that occurd in this month.

Regardless of months and seasons, $PM_{2.5}$ concentrations are low on Tuesday and uniformly high on the other days of the week. The pattern of mean concentrations for specific days of the week is shown in figure 8. Here the mean concentrations rise to high peak on Wednesday and Sunday before falling to a Tuesday minimum. There was no difference between weekdays (22.63µg/m^3± 4.64) and weekend (22.91 µg/m^3 ±4.51) in $PM_{2.5}$ concentration (Figure 9). The high concentration in Sunday might be because it is the beginning of the week where there is high motion and traffic, that the traffic influence and increased $PM_{2.5}$ concentration, Eerens et al., (1994) found that CO, NO_2, black smoke, lead, benzene, fine particle, benz (a)pyrene, SO_2 are a major substances that emitted to the atmosphere from traffic, McMurry et al., (2002) suggested that concentration increased and tend to occur at rush hour, that they are associated with vehicular emissions. Even though Friday and Saturday are holiday they consider as shopping days and are characterized by high traffic and movement especially Saturday, and Friday it is holiday in our region but not in Israel. In a study they found that $PM_{2.5}$ concentrations are significantly lower on Saturdays and Sundays and uniformly high on the other days of the week, and also tend to be the lowest during the weekends (DeGaetano et al., 2004), which are the opposites of our results .

In our study the sources of $PM_{2.5}$ could be from the exhaust vehicles, road conditions (minimal silt loading) and or from cross border, Pohjola et al., (2002) say that large fraction of $PM_{2.5}$ concentration originates from regional or long- scale sources, (40% of $PM_{2.5}$ of the $PM_{2.5}$ concentration originated from local sources, and the rest of the $PM_{2.5}$ mass from regional or long-range transported pollution border), also vehicle type affect the $PM_{2.5}$ concentration that is light duty gasoline vehicle emit less fine particles than heavy duty diesel vehicles (Abu- Allaban et al., 2003).

5.4. Chemical composition of $PM_{2.5}$:

The chemical composition of $PM_{2.5}$ changes with different wind flow (Cheng et al., 2005), Appendix B and Figures (13, 14, 15) show the same result, in a related study done in China, they found that organic carbon and sulfate then EC and nitrate are the major components, in addition to crustal and trace elements, in one city they found that sulfate is almost twice than other cities, which might be attributed to large emissions from both anthropogenic and natural (seawater) sources (Zhang et al., 2004).

Table 2:Comparison of chemical composition of $PM_{2.5}$ in this study with other studies .

Location	$PM_{2.5}$ µg/m^3	SO_4^{-2} µg/m^3	NO_3^- µg/m^3	OC µg/m^3	EC µg/m^3	Reference
Hebron city	22.8	3.9	1.07	5.69	1.9	This study
Shanghai	91.2	18.5	9.9	28.6	8.1	Ye, et. al (2003)
Beijing	136	20.4	10.9	40.8	3.5	Bergin, et. al. (2001)
Atlanta	34.4	11.0	0.7	10.5	0.7	Baumann. et. al.(2003)
Philadelphia	17.4	4.1	3.8	6	2.5	Tolocka, et. al. (2001)

Organic carbon OC which counted about 35 % of $PM_{2.5}$ mass compared to 36% of $PM_{2.5}$ in Beijing (Zhang et al., 2004) and 42%in Tai O (17.4 µg/m^3 ± 8.5) (Chung, 2005). In winter OC concentration (7.68 µg/m^3 ± 1.05) constitutes about 47% of the total $PM_{2.5}$ mass concentration, higher than in summer (5.5 µg/m^3 ± 1.43) constitutes 37% from $PM_{2.5}$ mass (Appendix D), the same result found by Zheng et al., (2005) that the OC concentration in winter was higher than in summer, OC primarily comes from traffic or industrial combustion sources (directly emitted to the atmosphere in particulate form) while secondary OC comes from the oxidation VOCs (volatile organic carboceous) (produced by gas to particle conversion processes) (Cheung et al., 2005). The high concentration of OC in this study in comparison to other part of $PM_{2.5}$ may be due to large number of vehicles in the sampling region which considered as center of the district, and characterized by heavy traffic and highly motion especially in the daytime (the sum of diesel and gasoline exhaust is reported in this study), the vehicles exhaust can be considered one of the popular sources of OC in Hebron because the number of industry is low especially heavy industry. According to Zheng et al., 2005; Zheng et al., (2002) the sources of fine particulate matter are diesel and gasoline exhaust (17.3±6.9%), biomass aerosol (16.1±18.1%), dust (11.7±8.1%), coal combustion (9.8 ±3.9%), cigarette smoke (3.1±2.2%), and vegetative detritus (1.4±0.9 %).

EC concentration (1.9 µg/m^3 ±1.1) is higher than that measured in Atlanta, but lower than in Philadelphia and those measured in China (Table 2). EC concentration is higher in winter and autumn than summer and spring (Appendix B).

SO_4^{-2} had 3.9µg/m^3 ± 2.44 annual concentration and accounts for 23% of the $PM_{2.5}$ mass (Table 1). From figure (16) the highest SO_4^{-2} concentration was in September (5.79 µg/m^3 ±2.45), while March had the lowest concentration with 1.6 µg/m^3 ±1.2. The highest concentration of SO_4^{-2} occur during summer (5 µg/m^3 ±1.39) and autumn (5.57 µg/m^3 ±1.59) (Summer – Autumn peak). Zhang et al., (2004) found that a high sulfate peak in June, this caused by strong photochemical activity and fast conversion of sulfur dioxide to sulfate in summer time, and in December the peak of SO_4 concentration is lower than in June. The lowest concentration was in winter (2.44 µg/m^3 ±0.27), Spring had higher SO_4^{-2} concentration than winter (Figure 17). Stern (1984) found also that SO_2 gas is sufficiently soluble to dissolve in water associated with cloud formation of rain droplets, these soluble gases may be removed by wet deposition of liquid droplets in form of rain or fog. Sellegri et al., (2003) conclude that SO_4^{-2}, NH_4 and NO_3^{-}account for more than 80 % of total analyzed mass of ions in rain droplet > 7µm. Also SO_4^{-2} concentration had a reverse relation with wind speed (Appendix B)(Figure 17). The high concentration of SO_4^{-2}occurs in months of summer and autumn which could be related to high temperature in these period. Figure (11) shows that SO_4^{-2} concentration increase with increase in temperature. Zheng (2005) found that low SO_4^{-2} concentration in winter may be related to low vehicular emissions that is low temperatures reduce activities. The oxidation rate of SO_2 to form SO_3^{-2} and SO_4^{-2} is increased with light (Streen, 1984).

The concentration of nitrate is relatively low when compared with other components of $PM_{2.5}$, or with some part of the world (Table 2). Data in Figure (18) show that the highest NO_3^- concentration was in January (1.95µg/m^3±2.36) and December (1.7µg/m^3±0.79), and the lowest NO_3^- concentration was in June, July, September and August. From figure (19) the higher concentration of NO_3^- was in winter (1.58 µg/m^3 ± 0.43), while summer had the lowest concentration (0.65 µg/m^3 ± 0.03). NO_3^- concentration increase with decrease in temperature as shown in figure (12), the same result found by Hogrefe (2006) that is in winter time nitrate is the strongest component forcing on high $PM_{2.5}$ days, this is in part due to the increased amount of $PM_{2.5}$ emissions from wood burning during winter months, while in summer time, sulfate is the strongest contributor forcing on high $PM_{2.5}$ days. Zhang, (2004) found that highest SO_4^{-2} concentration was in May and June, and lowest concentration in September and December.

Crustal elements constitute a large part of $PM_{2.5}$ (4.083 µg/m^3 ±8.04) 24% (Table 1) from the total $PM_{2.5}$ concentration. May has the highest concentration of crustal material (17.55 µg/m^3 ±23.09) then October (6.1 µg/m^3 ±5.39), while the other months have very low concentration in comparison with May, this might be due to sand storms that occur in Spring and Autumn (as mentioned before), in winter dust removed by precipitation, mainly rain, and if it snows it reduces the resuspension, and cold temperature reduces outdoor activities and particle resuspension (Zheng, 2005). Crustal material comes mainly from SE and NW direction, these two direction (had the high crustal concentration) in which the quarries present, and desert in the south, lead to formation of dust storm mainly in April and May (Alkhamasine wind), and sometimes in autumn.

6.Conclusion :

The results give an overview on status of concentration and chemical composition of suspended fine particulate matter $PM_{2.5}$ in Hebron City :

- $PM_{2.5}$ concentration is higher than the EPA standard (15µg/m^3). The annual mean concentration was 22.8± 11.1µg/m^3 in Hebron City.
- $PM_{2.5}$ concentration is influenced by meteorological factors and temporal variations.
- Organic carbon, crustal material and sulfate are the most abundant components of $PM_{2.5}$, while nitrate, elemental carbon and metals constitute minor part of $PM_{2.5}$.
- In summertime, sulfate and OC are the major components, while in wintertime OC has the highest concentration. Crustal material constitutes about 41% of $PM_{2.5}$ mass in spring .

Policy implications:

Overall, our results suggest that fine particulate pollution in Hebron can be greatly improved by targeting emissions inside the district, both within the district and in neighboring areas. Management of emissions (biomass burning, fossil fuel combustion, and dust) in the Guangzhou vicinity would have strong positive impacts on air quality at nearby regions, including Hebron city. IN addition, it appears that air quality in the city can be improved by locally reducing emissions from vehicles.

7. Recommendation for Further Research:

Particulate matter pollution in Hebron is a challenging issue linking research disciplines such as sociology, economics, atmospheric science, epidemiology, agriculture, and engineering. To fully understand air quality in the district and the best strategies for its improvement, continuing research is needed in each of these areas. Addressing the specific focus of this thesis, suggestions for further research in the atmospheric science arena are provided here:

- **Determine spatial variability in source impacts and population exposure** closely linked with this study, expanded (spatially and temporally) field measurement of fine particulate matter in this region would provide a great deal of policy- relevant information. The limited number of measurements presented by this thesis illustrates spatially variables PM concentrations, suggesting equally variables population exposure are location-specific source impact. A greater number pf sampling locations, particularly in high concentrations areas such as in Doura vicinity, would better capture the state of particulate pollution and its associated impacts. In addition, sustaining sampling over a longer period of time would provide a higher number of data points and some sophisticated analytical tools (e.g. Positive Matrix Factorization) could e applied to drive site-specific source information. Also, extending sampling would allow for an improved understanding of the connection between particulate pollution and local human health impacts.

Characterize regional emissions magnitude, source locations, and source profiles

Emissions of fine particles and gashouse precursors are only crudely known in Hebron. Source profiles of major in the region are unknown, including coal burning, biomass burning, and vehicular emissions. Not only would these source profiles be useful in defining an emissions inventory, they would also support higher accuracy in applying receptor modeling analyses (e.g. chemical mass balance model) to apportion fine particulate `pollution to sources.

8. Suggestion for future research

The present work has several more specific implications for future research linked to the points listed above. This work has revealed the need for further characterization of the fine and coarse particles during resuspended dust episodes, including the quantification of potentially detrimental components such as transition metals and biogenic material adhering to the resuspended particles. Also the health relevance of the peak PM concentrations during these episodes should be investigated further. A sample and affordable, yet specific, measurement technique to be used in long-term monitoring of traffic related PM emissions should be developed and introduced to complement the currently used $PM_{2.5}$ measurements. As an alternative, the continuation and even wider use of Black Smoke (or absorption coefficient) measurements as an indicator of mainly traffic-related particulate matter should be considered. Finally, the uncertainties in the current estimates of population and personal exposures to particulate matter from specific sources should be reduced through application of (more than one) source apportionment methods in future exposure and epidemiological studies on PM.

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Appendix(A) : Row data of PM2.5 concentration and meteorological data.

Date	Concentration	Day	Ave. temp.	RH%	Wind speed	Wind direction
HB-240107-C	18.5	Wednesday	9.9	49	9	89
HB-300107-C	12.4	Tuesday	5.5	94	8	230
HB-050207-C	12.3	Monday	5.5	76	6	220
HB-110207-C	22.3	Sunday	10.4	64	8	120
HB-170207-C	17.8	Saturday	10.5	67	5	110
HB-230207-C	27.7	Friday	14	39	6	150
HB-010307-C	9.6	Thursday	7.7	93	9	230
HB-070307-C	16.7	Wednesday	9	54	10	100
HB-130307-C	4.5	Tuesday	9	97	11	230
HB-190307-C	19.1	Monday	8.7	80	6	230
HB-250307-C	8.1	Sunday	9.5	85	7	230
HB-310307-C	16.7	Saturday	16.3	48	5	230
HB-060407-C	37.7	Friday	19.2	29	5	200
HB-120407-C	29.9	Thursday	11.5	62	6	240
HB-180407-C	37.7	Wednesday	15	30	10	140
HB-240407-C	19.1	Tuesday	14.5	56	6	270

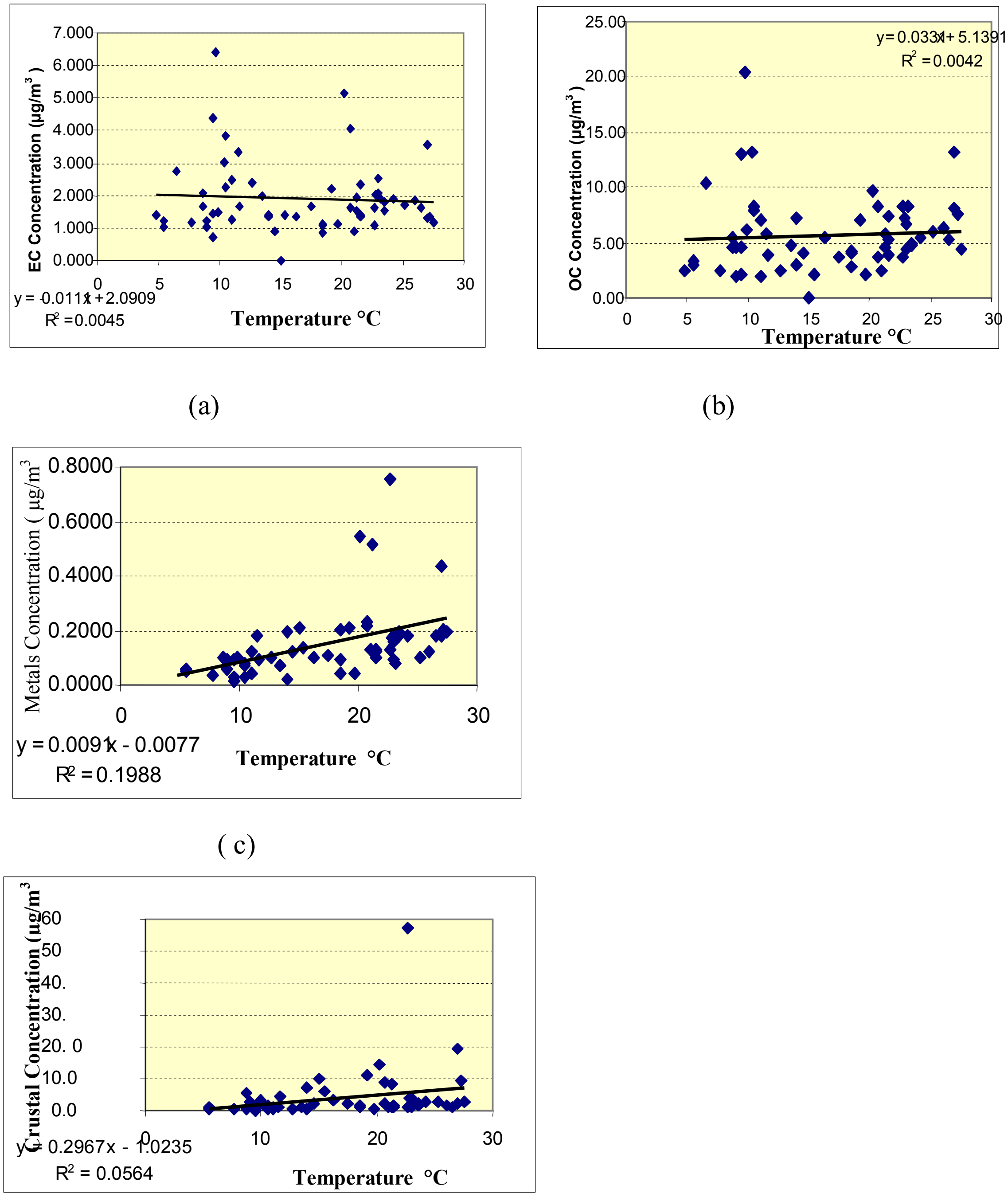
HB-300407-C	24.8	Monday	12.7	68	7	270
HB-060507-C	61.3	Sunday	27	27	6	150
HB-120507-C	24.5	Saturday	15.4	91	9	270
HB-180507-C	16.6	Friday	18.5	52	5	260
HB-240507-C	20.6	Thursday	23	30	5	170
HB-050607-C	19.3	Tuesday	23.2	34	5	220
***HB-110607-C**	24.6	Monday	21.5	81	7	290
HB-170607-C	33.7	Sunday	18.5	73	7	290
HB-230607-C	22.7	Saturday	27	34	5	160
HB-290607-C	36.3	Friday	27.2	37	6	300
HB-050707-C	22.9	Thursday	21.5	51	6	250
HB-110707-C	17.6	Wednesday	26	26	5	290
HB-170707-C	20.0	Tuesday	21.5	66	6	310
HB-230707-C	30.1	Monday	23.5	56	6	240
HB-290707-C	34.2	Sunday	27.5	57	6	320
HB-040807-C	28.8	Saturday	22.7	82	6	300
HB-100807-C	23.9	Friday	21	75	6	290
HB-160807-C	25.9	Thursday	23	54	6	290

HB-220807-C	20.6	Wednesday	26.5	41	5	340
HB-280807-C	22.4	Tuesday	25.2	53	6	320
HB-030907-C	29.0	Monday	24.2	49	5	290
HB-090907-C	12.3	Sunday	19.7	80	7	310
HB-150907-C	23.0	Saturday	21.2	76	5	320
HB-220907-C	18.0	Saturday	20.7	61	5	190
HB-270907-C	27.9	Thursday	23.5	66	5	210
HB-031007-C	29.0	Wednesday	22.8	51	5	330
HB-101007-C	65.0	Wednesday	20.2	79	6	290
HB-151007-C	11.5	Monday	18.5	76	5	270
HB-211007-C	36.7	Sunday	20.7	51	4	270
HB-271007-C	15.0	Saturday	17.5	67	5	250
HB-021107-C	22.0	Friday	21.2	44	6	70
HB-081107-C	10.9	Thursday	14	79	5	260
HB-141107-C	12.7	Wednesday	13.5	69	5	140
HB-201107-C	20.1	Tuesday	11.7	82	10	230
HB-261107-C	17.7	Monday	11	56	7	140
HB-021207-C	10.4	Sunday	11	100	8	240

HB-081207-C	11.1	Saturday	10.5	83	6	280
HB-141207-C	18.2	Friday	8.7	71	10	260
HB-171207-C	15.1	Monday	9.5	82	5	220
HB-261207-C	29.0	Wednesday	9.5	66	8	140

Appendix (B) : Influence of meteorological factor on chemical composition of $PM_{2.5}$:

Figure (1): Influence of temperature on : a) EC conc., b) OC conc., c) metals conc., d) crustal conc., Hebron city/2007.



(a)

(b)

(c)

(d)

Figure (2): Influence of RH % on : a) SO_4^{-2} conc., b) NO_3^- conc., c) OC conc., Hebron city/2007.

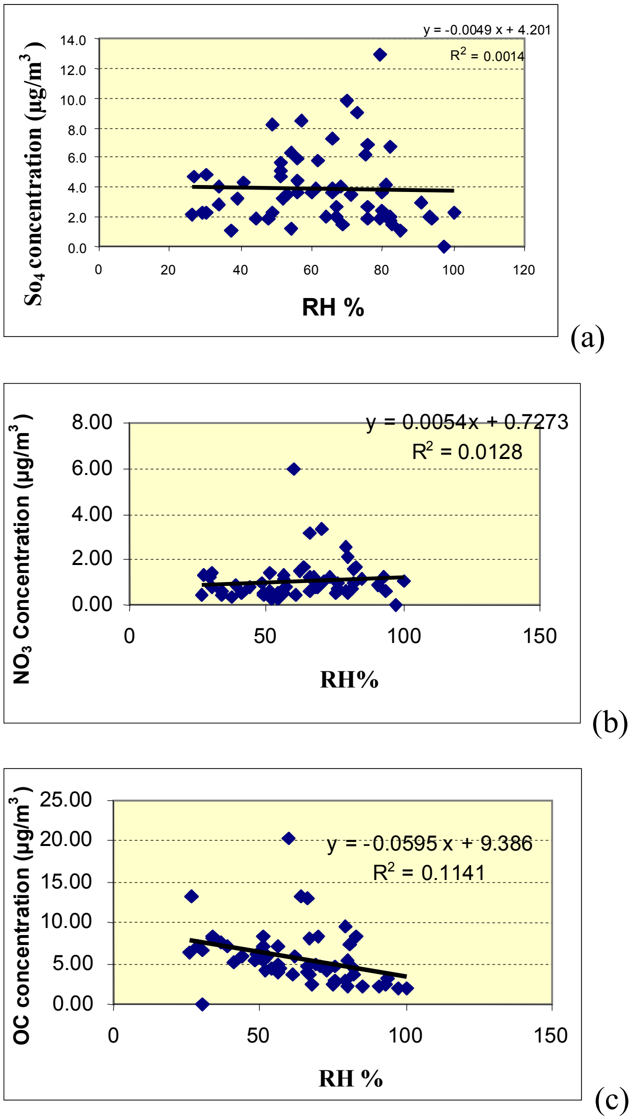
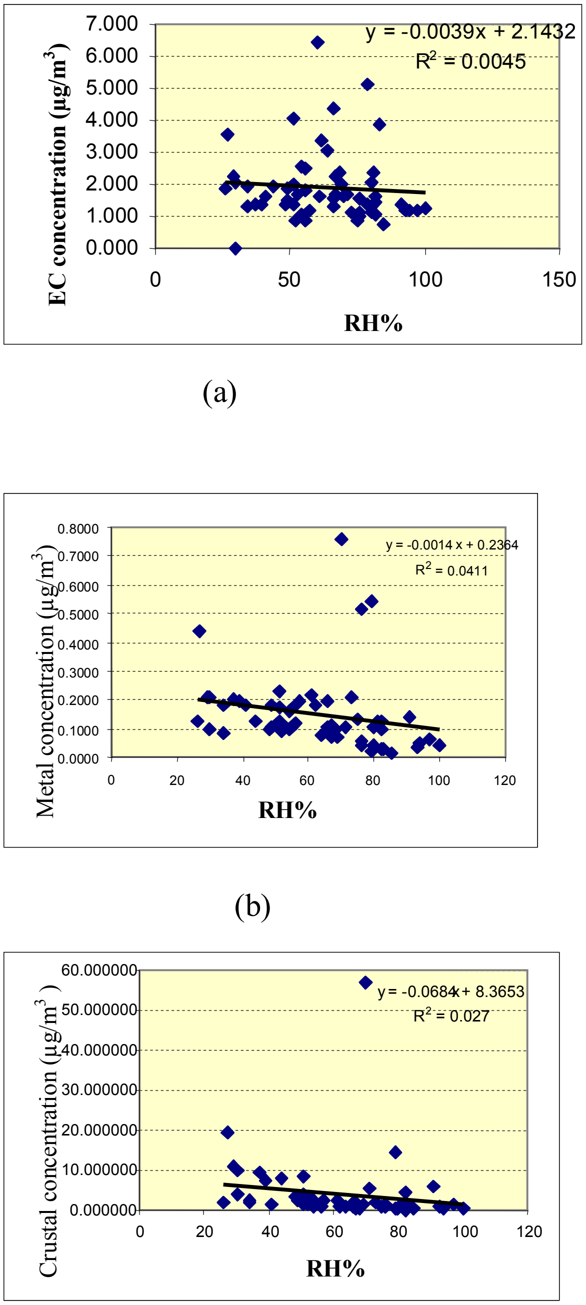


Figure (3): Influence of RH % on : a) EC conc., b) metal conc., c) crustal conc., Hebron city/2007.



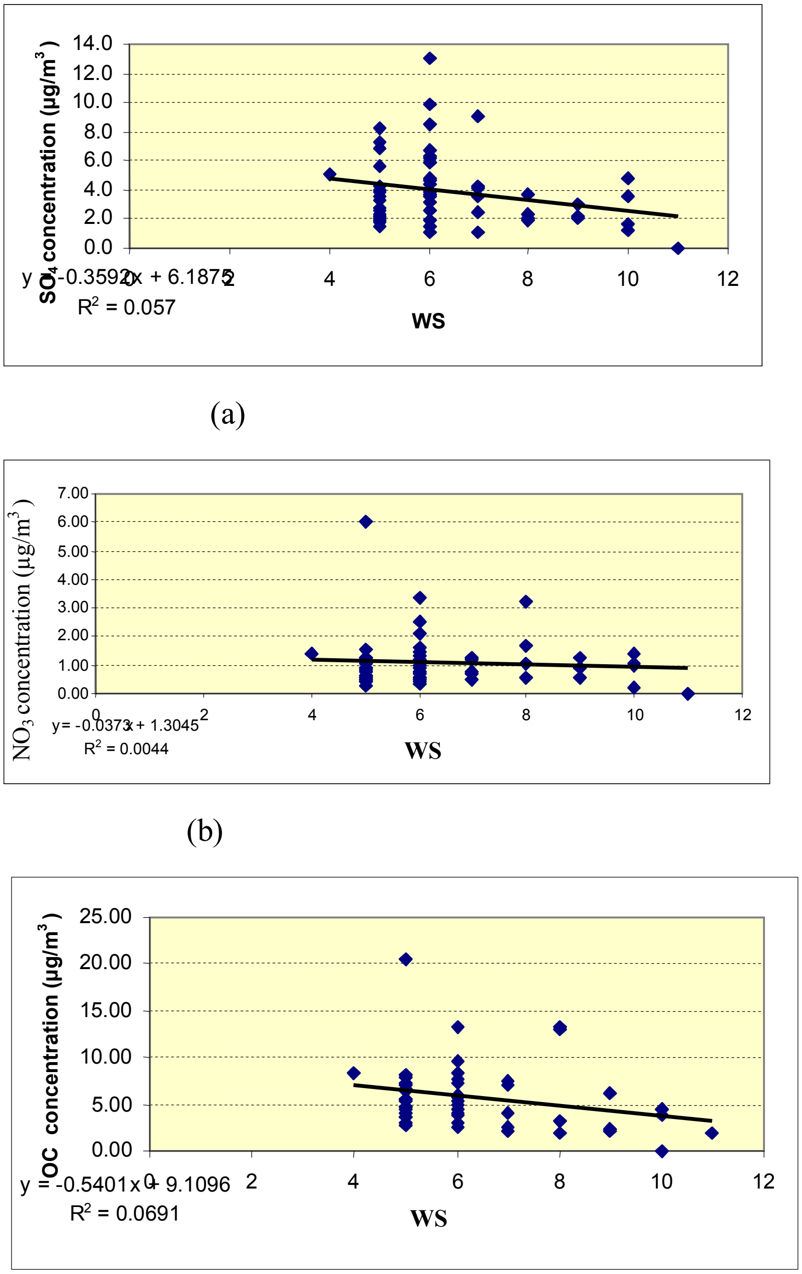
(a)

(b)

(c)

Figure (4): Influence of wind speed on : a) SO_4^{-2} conc., b) NO_3^- conc., c) OC conc., Hebron city/2007.

Note: ws : wind speed, km/h

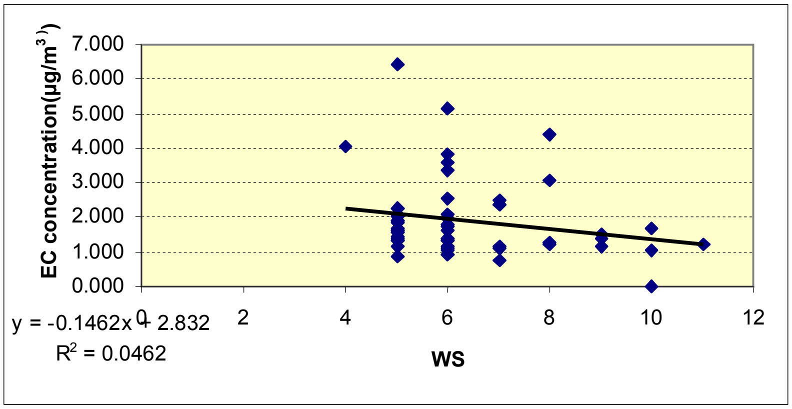


(a)

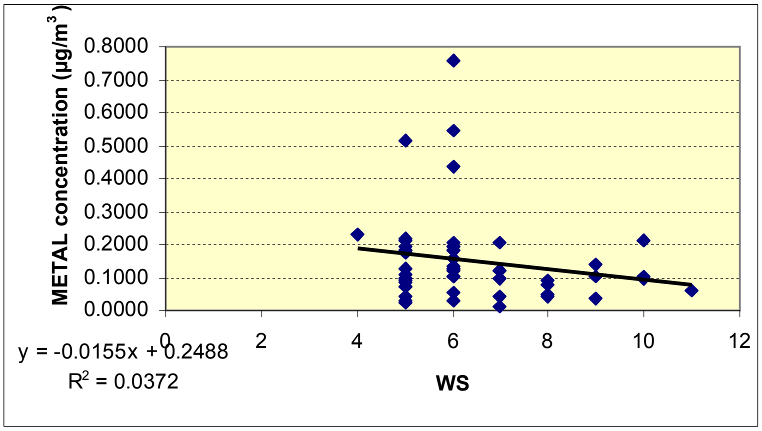
(b)

(c)

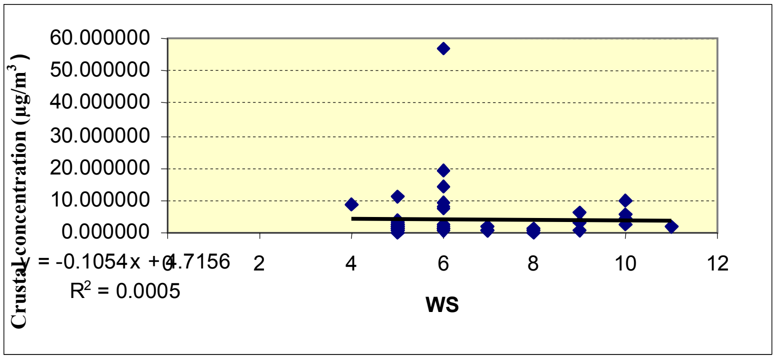
Figure (5): Influence of wind speed on :a) EC conc., b) metal conc., c) crustal conc., Hebron city/2007



(a)

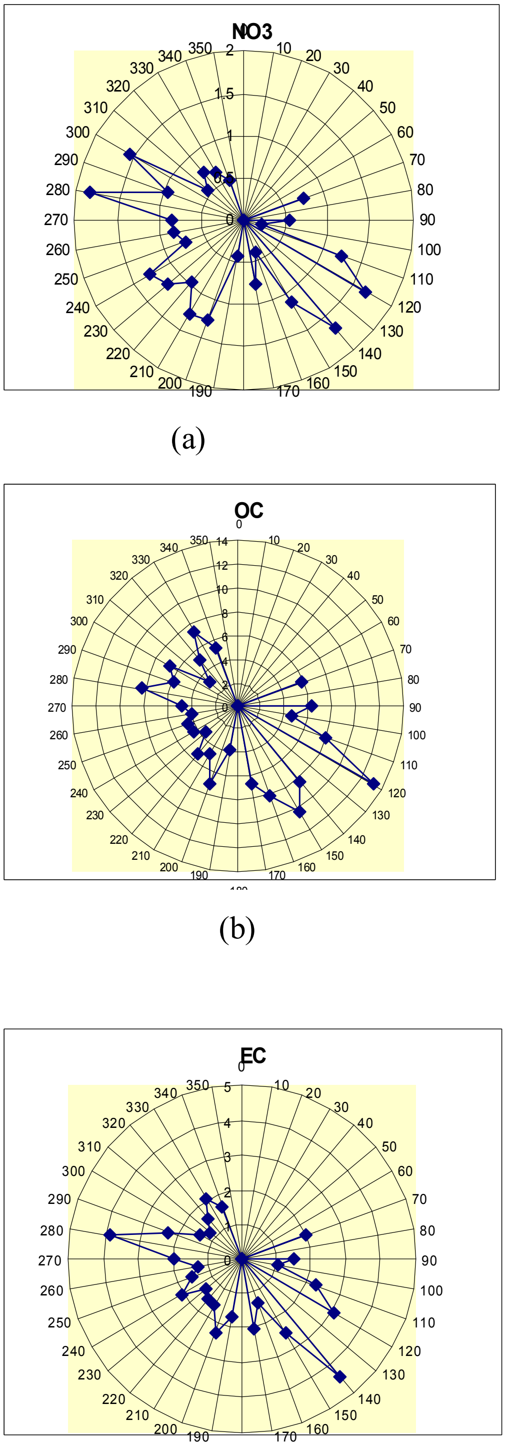


(b)



(c)

Figure(6) : Wind direction and : a) $NO3^-$ conc., b) OC conc., c) EC conc., Hebron city/2007.

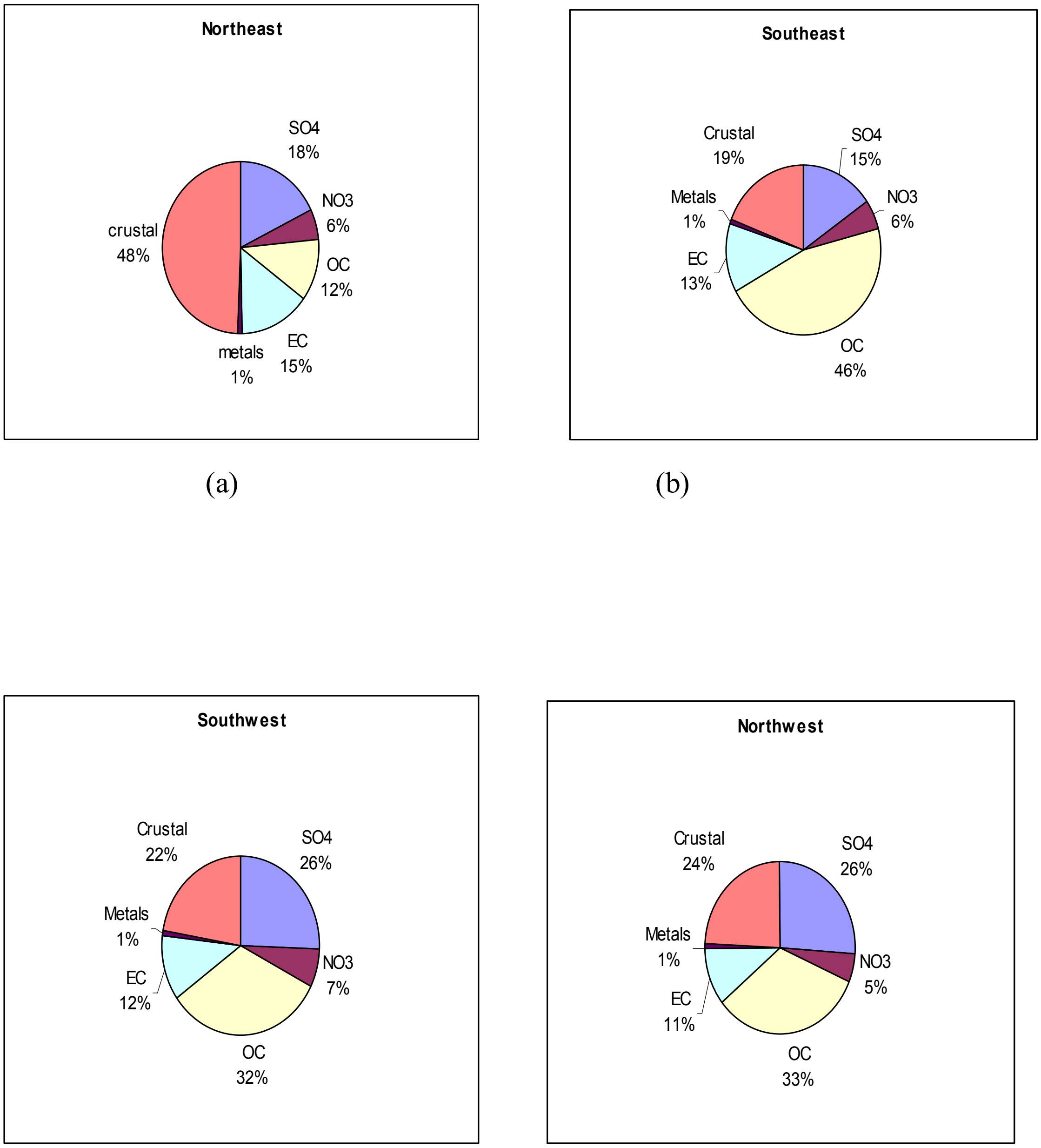


(a)

(b)

(c)

Figure (7) : Wind direction sector and percentage of each chemical composition of $PM_{2.5}$: a) Northeast, b) Southeast, c) Southwest, d) Northwest, Hebron city/2007.

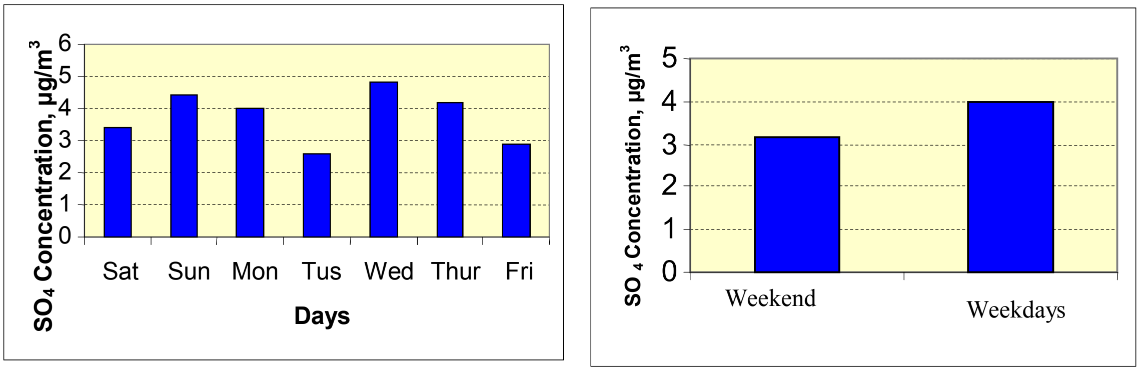


(a) (b)

(c) (d)

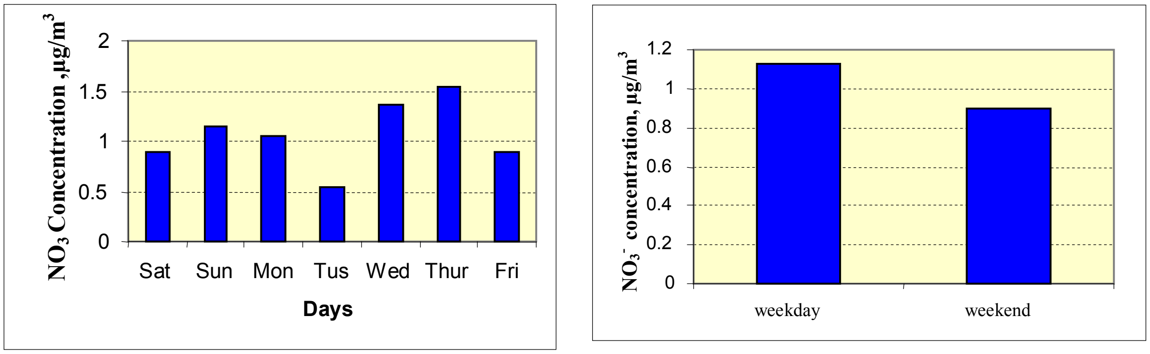
Appendix (C): Diurnal variation of chemical composition of $PM_{2.5.}$

Figure (1): Diurnal pattern of SO_4^{-2} concentration for : a) day of the week pattern of mean SO_4^{-2} conc., b) weekend and weekdays, Hebron city, 2007.



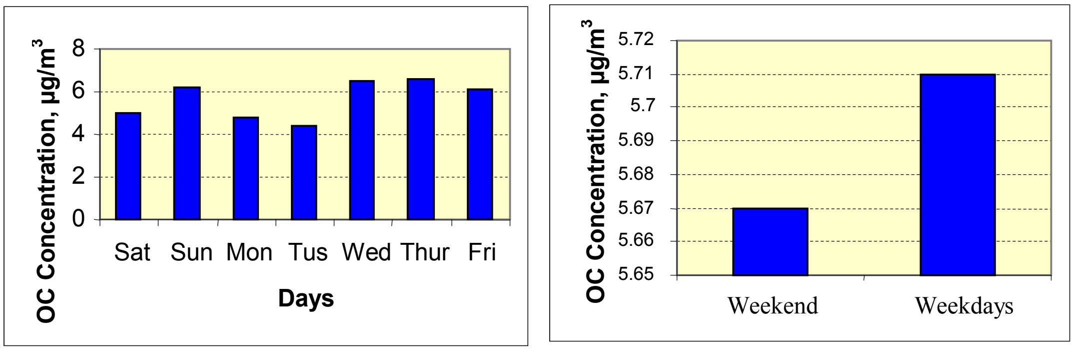
(a) (b)

Figure (2): Diurnal pattern of NO_3^-concentration for : a) day of the week pattern of mean NO_3^- conc., b) weekend and weekdays, Hebron city, 2007.



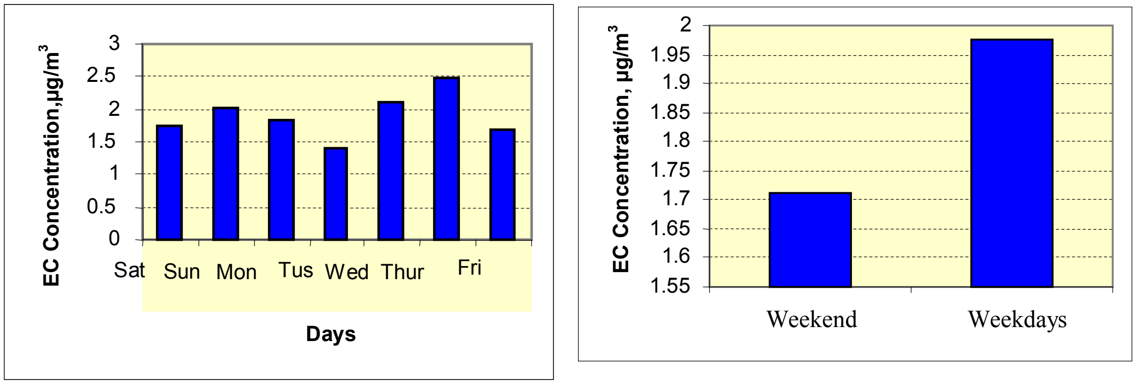
(a) (b)

Figure (3) : Diurnal pattern of OC concentration for : a) day of the week pattern of mean OC conc., b) weekend and weekdays, Hebron city, 2007.



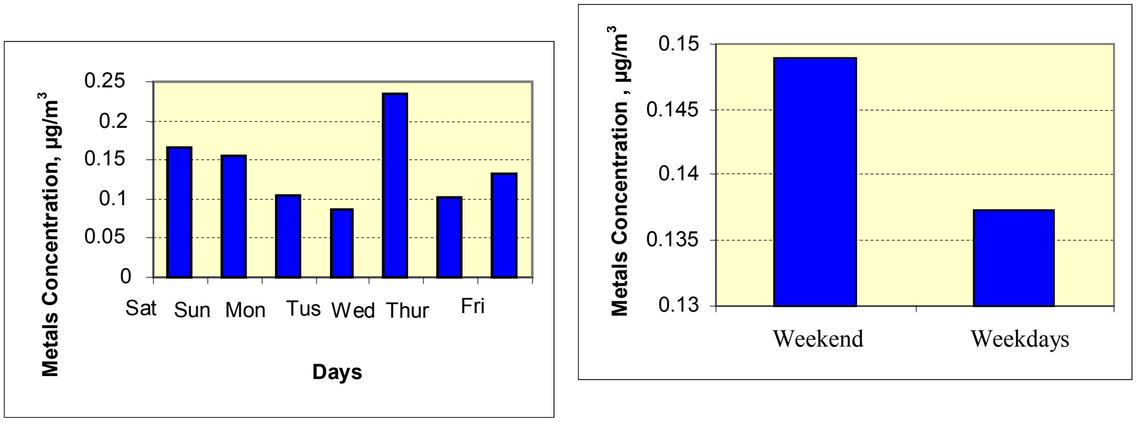
(a) (b)

Figure (4): Diurnal pattern of EC concentration for : a) day of the week pattern of mean EC conc., b) weekend and weekdays, Hebron city, 2007.



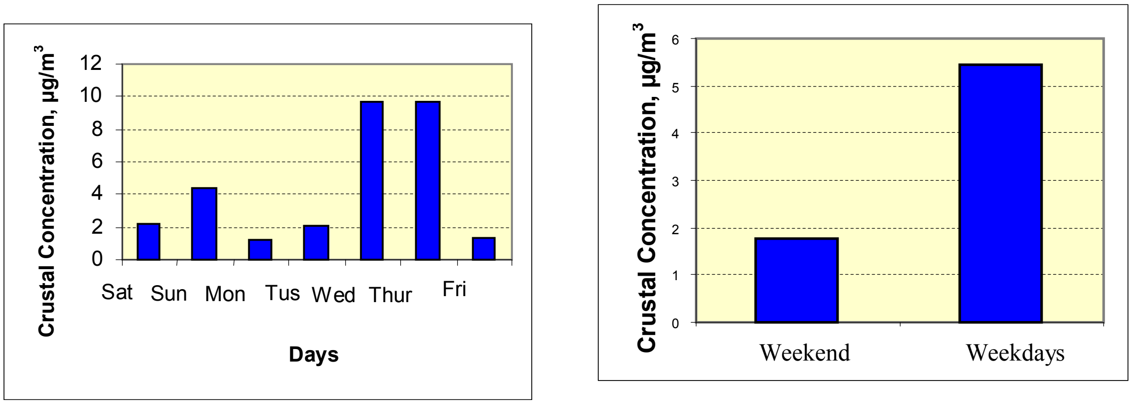
(a) (b)

Figure (5): Diurnal pattern of metals concentration for : a) day of the week pattern of mean of metals conc., b) weekend and weekdays, Hebron city, 2007.



(a) (b)

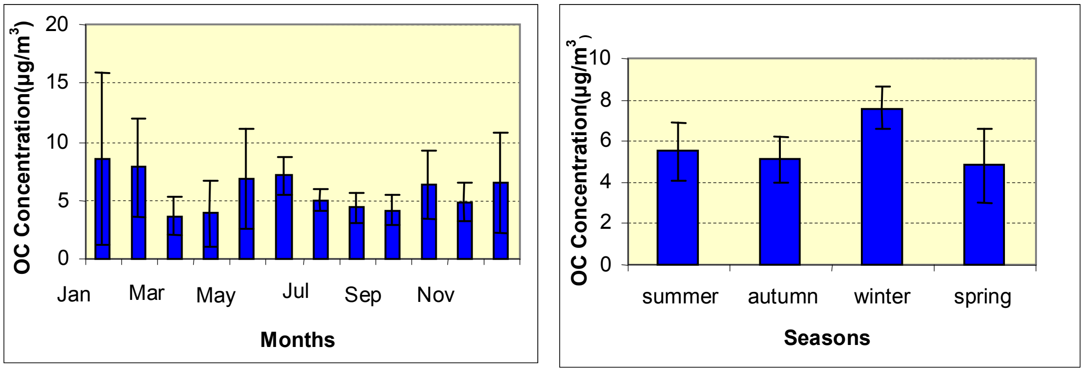
Figure (6):): Diurnal pattern of crustal concentration for : a) day of the week pattern of mean of crustal conc., b) weekend and weekdays, Hebron city, 2007.



(a) (b)

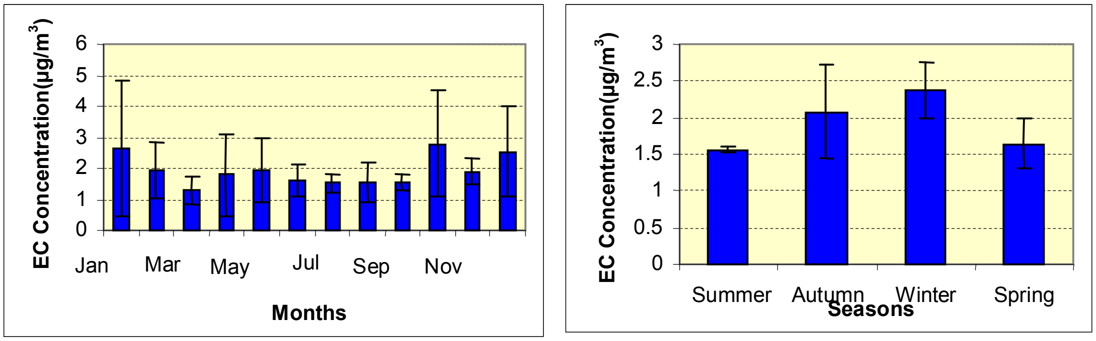
Appendix D: Variation in concentration through months and seasons of some compound that found in $PM_{2.5}$.

Figure (1): OC concentration through: a) months, b) seasons, Hebron city,2007.



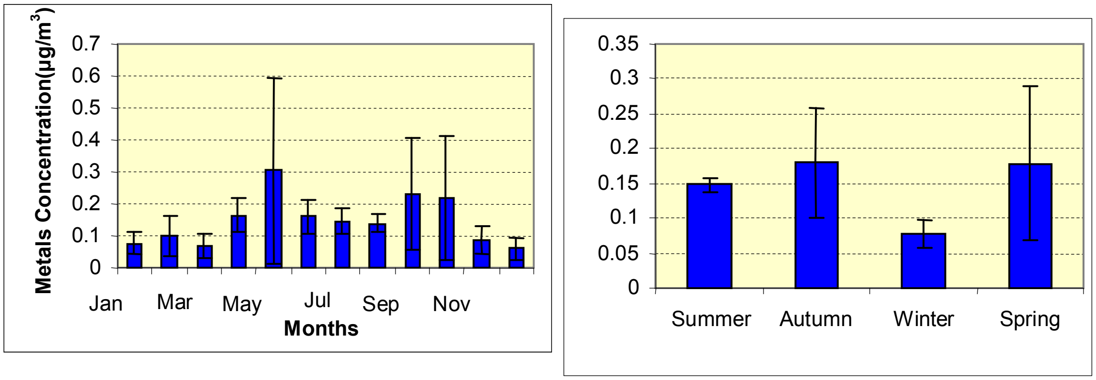
(a) (b)

Figure (2):EC concentration through : a) months, b) seasons, Hebron city/2007.



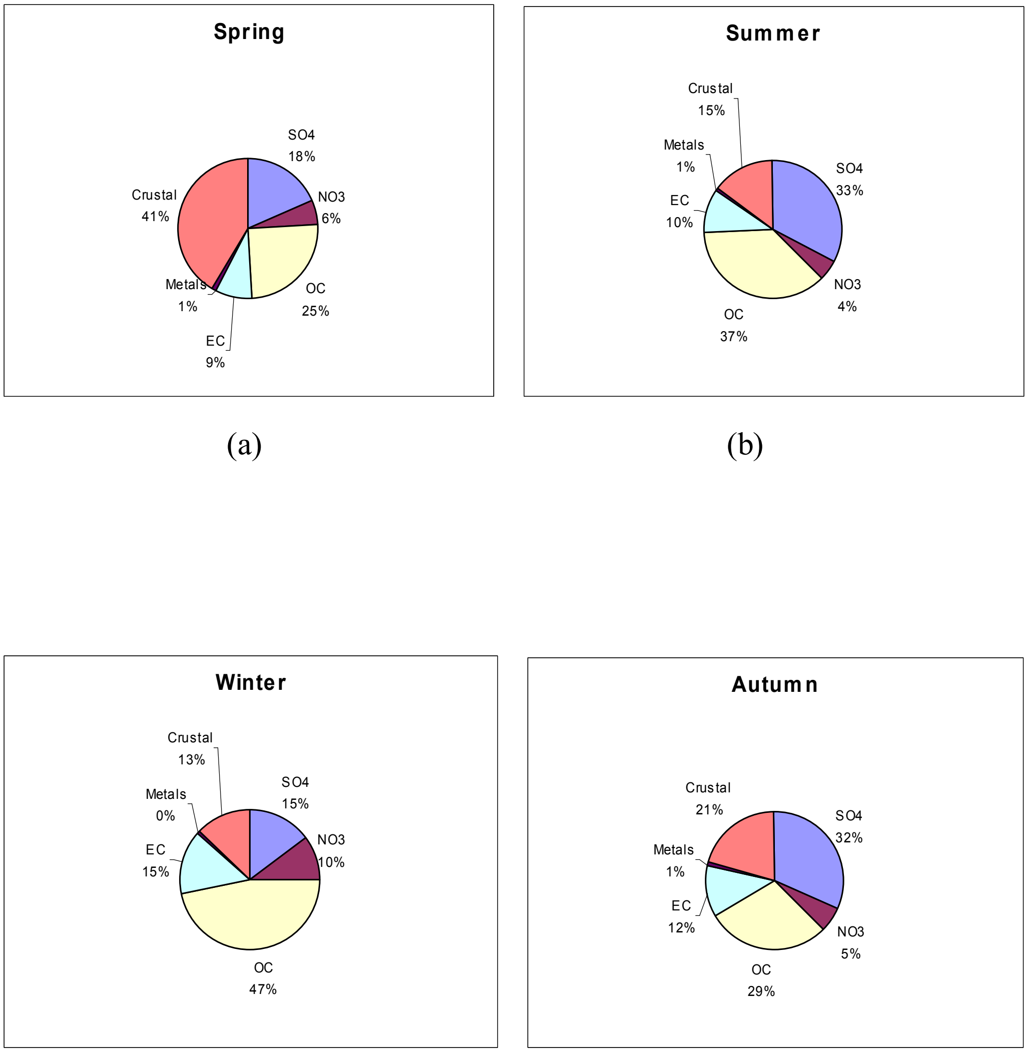
(a) (b)

Figure (3): Metals concentration through: a) months, b) season, Hebron city,2007.



(a) (b)

Figure (4) : Chemical composition and percentage of PM $_{2.5}$ in : a) Spring, b) summer, c) Winter, d) Autumn, Hebron city/2007.



(a) (b)

(c) (d)

بسم الله الرحمن الرحيم

Abstract in Arabic

التركيز و التركيب للملوثات الغبارية العالقة لحجم 2.5 ميكرون في مدينة الخليل- فاسطين

الملخص باللغة العربية:

لقد تم دراسة الملوثات الغبارية العالقة من حجم 2.5 ميكرون($PM_{2.5}$) في مدينة الخليل، في عام 2007 وذلك بأخذ عينات من منطقة مستشفى مدينة الخليل الحكومي على مدار العام.

حيث تم دراسة التركيز و التركيب الكيميائي لهذا الملوث، وتأثرهما بالعوامل الجوية (درجة الحرارة، الرطوبة، سرعة الرياح و اتجاهها) و تغيرهما بتغير الأيام و الأشهر و الفصول.

وقد أظهرت الدراسة أن التركيز الذي تم قياسه أعلى من معيار وكالة حماية البيئة الأمريكية ، ويتغير بتأثير العوامل الجوية، وكان أعلى تركيز في فصل الصيف بينما اقل تركيز فكان في فصل الشتاء. ولا يوجد فرق كبير بين أيام الأسبوع ونهاية الأسبوع.

كما أظهرت نتائج التحليل الكيميائي أن هذه الملوثات تتكون من عنصر الكربون (EC)، و مركبات عضوية (OC) و لها أعلى تركيز، ومواد من القشرة الأرضية (crustal material) وتمتلك ثاني أعلى تركيز، وSO_4^{-2} ، NO_3^- ، و بعض المعادن، وقد كان للمتغيرات الجوية و الزمنية تأثير على تركيز كل مادة.