Evaluate the Pollution Levels with PM2.5 Concentrations During Coronavirus Pandemic (Covid-19) in Green Zone in Baghdad City/Iraq

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Abstract

Descriptive and evaluative study is achieved on PM2.5 dataset hourly from February 18th, 2019 to July 30th, 2020 from a monitoring station in the Green Zone in Baghdad city and explores its correlation with metrological variables. The results showed that the air quality in the Green Zone is unhealthy which contribute to increase COVID-19 incidences. PM2.5 concentrations exhibited a high variation that exceed the EPA and WHO standards on weekdays compared to weekends (Friday and Saturday). The most frequent distribution of PM2.5 was 57% (276 Days) in the moderate level of air quality, 25.5% (124 Days) in unhealthy conditions for sensitive groups of people to air pollution. November month was the most polluted month while April month was the least polluted month. An hourly high variation of PM2.5 concentrations was in winter in most hours of day and its low in spring. Local weather conditions with high PM2.5 concentrations are generally characterized as warmer, less humid and less windy, but colder and more humid in autumn.

Keywords: PM2.5, Meteorological Variables and The Green Zone.

تقييم مستويات التلوث بتراكيز PM2.5 أثناء جائحة فيروس كورونا (كوفيد -19) في المنطقة الخضراء في مدينة بغداد/ العراق

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الخلاصـــة

اجريت دراسة وصفية وتقييمية على مجموعة بيانات PM2.5 كل ساعة للفترة من 18 فبراير 2019 إلى 30 يوليو 2020 في محطة المراقبة في المنطقة الخضراء ببغداد واستكشاف ارتباطها بمتغيرات الارصاد الجوية. أظهرت النتائج أن جودة الهواء في المنطقة الخضراء غير صحي والتي ساهمت في زيادة الاصابات بفايروس كوفيد-19. أظهرت تراكيز PM2.5 اختلافات عالية حيث تجاوزت معايير وكالة حماية البيئة ومنظمة الصحة العالمية في أيام الأسبوع مقارنة في بومي عطلة نهاية الأسبوع (الجمعة والسبت). التوزيع الأكثر شيوعا لجسيمات PM2.5 كان 57% (276 يوماً) في مستوى معتدل من جودة الهواء و25.5٪ (124 يومًا) في حالة غير صحية بالنسبة للمجموعات الحساسة من الأشخاص لتلوث الهواء. كان شهر تشرين الثاني هو الشهر الأكثر تلوثًا بينما كان شهر نيسان هو الاقل تلوثاً. كان التباين في تراكيز PM2.5 لكل ساعة في فصل الشتاء أعلى من الفصول الأخرى في معظم الساعات وكان الأقل في فصل الربيع. تتميز الظروف الجوية المحلية في المنطقة الخضراء ببغداد ذات التراكيز العالية من PM2.5 بأنها أكثر دفئًا وأقل رطوبة والأقل ريحاً ولكنها أكثر برودة ورطوبة في الخريف.

الكلمات المفتاحية: PM2.5، متغيرات الارصاد الجوية والمنطقة الخضراء.

Introduction

The problem of particle pollution began to appear with the emergence of the industrial revolution in the world, the tremendous increase in population, the increase and development of transportation means (Yang, 2014), in addition to excavation, maintenance and construction work, dust, sandstorms, pollution from refining operations oil extraction, conversion and filtration (Bozlaker, *et al*., 2013). All these processes resulted in the emission of quantities of particles from diesel vehicle, black carbon, organic carbon compounds, and sulfate from agricultural activities. Suspended particle likes soil dust, sea salt from geogenic sources that causes air pollution and health effects (Guevara, 2016), (Pope III, *et al*., 2011; 2002). (Particulate Matter Sensor/ PM2.5, PM10) have attracted a lot of attention due to its effect on environment (Zhang, *et al*., 2014; Yadav, *et al*., 2003). PM came in a wide range of sizes due to their toxicities which effect on human health (Halonen, 2009; Eatough, *et al*., 2003; Ruuskanen, *et al*., 2001; Pope III, 2000). The smallest particle with a diameter of 2.5 µm or less called fine particles (Xing, *et al*., 2016; Cao, *et al*., 2014). There are several sources of PM2.5 in the surrounding air. In addition to natural sources, these particles are emitted from transportation, especially diesel-powered, and smoke emitted from various combustion sources, fires (AQI, 2014). Vehicle emissions, fossil fuels burning, pollution from power generators are contributed to poor air quality in Baghdad. The effects of exposure to these particles usually appear through coughing and excite the trachea and eyes, and since the particles are small enough to penetrate into the tiny parts in the lungs, which are considered the most dangerous to the lungs. It is considered people who suffer from certain chronic respiratory diseases such as asthma are more sensitive to exposure to these particles. Emissions from road traffic contribute to total PM concentrations in urban areas and have impacts on human health (Du and Varde, 2016; Pant and Harrison, 2013; Masiol, *et al*., 2012; Rissler, *et al*., 2012, Buckeridge, *et al*., 2002). The Iraqi capital, Baghdad, crowded with population and traffic, suffers from multiple environmental problems, but increase in recent years with the lack of solutions to them by successive Iraqi governments. The toxic gases that are emitted from power stations, the Dora refinery and other industrial facilities, which, after the population expansion within the basic design of the capital, have become a major threat to public health and the lives of thousands of Baghdadis because they have become close to their homes, restaurants and daily life. PM is a key environmental indicator of air quality that affecting health and associated with increased deaths (Schwartz, *et al*., 1996). It can exacerbate and damage respiratory, cardiovascular and lung tissue that lead to early mortality (Bernard, *et al*., 2001). Both short- and long-term exposure of lead to health damages (Kappos, *et al*., 2004). Groups sensitive to air pollution include people with heart or lung disease. Therefore, the risk of particles pollution may begin as early as the mid-40s for men and to the mid-50s for women. (AQI, 2014). PM concentrations have strongly affected by meteorology, but there few researches on how concentrations depend on meteorological parameters in different regions (Elminir, 2005). Particulate matter (PM2.5) describes the inhalable particles with diameter that are generally 2.5 micrometer.

The main objective of this study is to analyzing particles pollutant PM2.5 over Green Zone/ Baghdad city to understand the behavior of pollutant PM2.5 during the hour of day, weekdays and weekend and investigate the effect of the curfew during

COVID-19 time on reducing the concentration of PM2.5. It will also investigate correlation between PM2.5 and meteorological variables during the period 18 February 2019 to 30 Jun 2020.

Materials and Methods

Hourly concentration PM2.5 data from 18 February 2019 to 30 Jun 2020 were collected from the air quality station in Baghdad. This monitoring station was located in the US Embassy in the Green Zone neighborhood Iraqi government as shown in Figure (1). This data measured by GAIA air quality monitoring station that using high-tech laser particle sensors to measure in real time PM2.5 pollution. Also, meteorological variables including temperature (T), relative humidity (RH) and wind speed (WS) are taken from US Embassy meteorological monitoring system. The Environmental Protection Agency (EPA) providing standards and rules affecting the environment. The Air Quality Index (AQI) developed by the EPA was classified from 0 to 500 with increasing concentrations of pollutants. Table (1) show the category of air quality index divided into six levels by color and the corresponding lower and upper values of the 24-hour average of pollutant PM2.5 concentration limits (EPA, 2018; Mintz, 2009). Ambient air quality standards provide by the US EPA for 24-hr average and the annual mean concentration of PM2.5 are 35µg/m^3 and 12 µg/m^3 respectively (EPA, 2020).

Figure (1) Site of Air Quality Station in Green Zone (Red Square).

The World Health Organization's (WHO) air quality guidelines recommend that the annual mean concentrations of PM2.5 should not exceed 10µg/m^3, while the 24-h mean concentration of PM2.5 should be below 25µg/m^3 (WHO, 2006).
Descriptive and evaluative study for hourly, daily, monthly PM2.5 pollutant concentration at the Green Zone/Baghdad city achieved using statistical analyses. The concentrations of PM2.5 of 2019 and 2020 calculated from the hourly data and then grouped into four seasons. PM2.5 concentrations compared during the curfew during Corona-19 time. Correlation between PM2.5 and meteorological parameters also calculated to understand the interrelationship between them.

Table (1) AQI Developed by EPA for PM2.5 Pollutant

AQI Category	24-hr Average PM2.5 Concentration µg/m^3
Good	0.0-12.0
Moderate	12.1-35.4
Unhealthy for Sensitive Groups	35.5-55.4
Unhealthy	55.5-150.4
Very Unhealthy	150.5-250.4
Hazardous	250.5-350.4
	350.5-500

Results and Discussion

Daily Average PM2.5 Variation in Green Zone/ Baghdad City

This study deals with air pollutant PM2.5 over Baghdad for the period starting from February 2019 to Jun 2020 and then the results obtained were analyzed. The daily average of PM2.5 measurements in the Green Zone station is presented in Figure (2). Overall, daily PM2.5 concentration ranged between 7.9 to 164.9µg/m^3, with 69% of the dataset exceed the daily average of WHO PM2.5 guideline (25 µg/m^3) and 43% dataset exceed the 24h average EPA PM2.5 concentration (35 µg/m^3) (EPA, 2020).

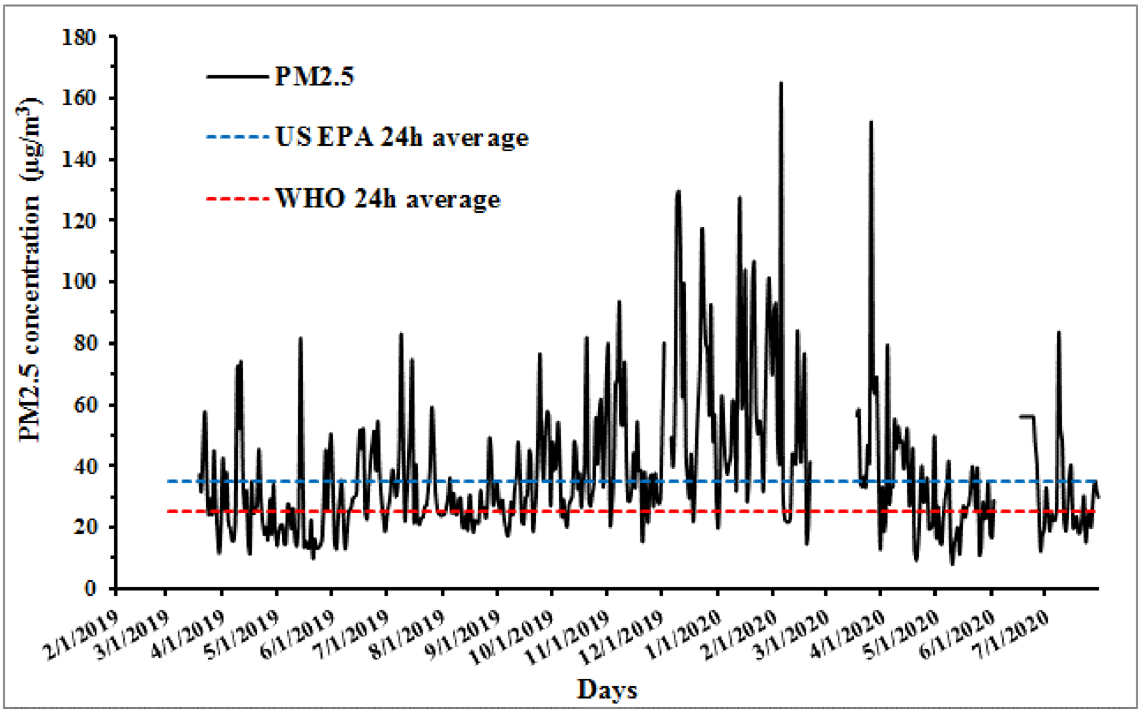

Figure (2) Daily Variations of PM2.5 (Black Line) for the Period from 18 Feb 2019 to 30 July 2020, 24h Average WHO PM2.5 Standard (Red Dashed Line) and 24h Average US EPA PM2.5 (Blue Dashed Line).

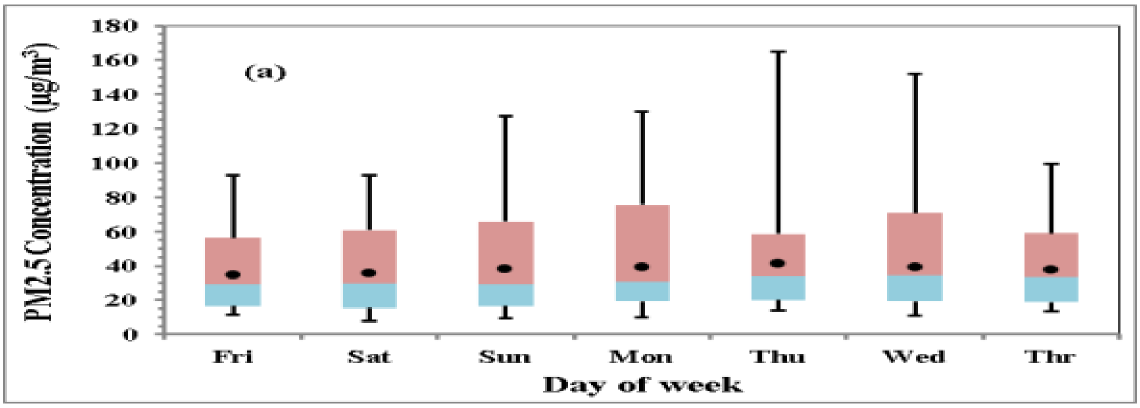

Figure (3) PM2.5 Concentrations Boxplot on Weekdays

The highest daily value 164.9 μg/m^3 is measured during January; six times more than the daily WHO guideline and four times more than the US EPA standard. This value was recorded when columns of smoke were rising from bombs and burned tires during Tahrir Square demonstrations. The annual mean concentration of PM2.5 in the Green Zone/ Baghdad city is 38 μg/m^3 which is more than three times of the recommended US EPA annual mean of 12 μg/m^3 and WHO annual mean of 10 μg/m^3 (EPA, 2020).

Weekly Average PM2.5 Variation in Green Zone/ Baghdad city

Figure (3) shows visual representation of the average weekday's variations of PM2.5 for the study period in the Green zone/ Baghdad city. PM2.5 concentrations exhibited high variations on weekdays compared to weekends (Friday and Saturday) and exceed EPA and WHO standards. For weekdays, the highest average value of PM2.5 at 41.2 μg/m^3 recorded in Tuesday, while the lowest was on Friday 34.8 μg/m^3.

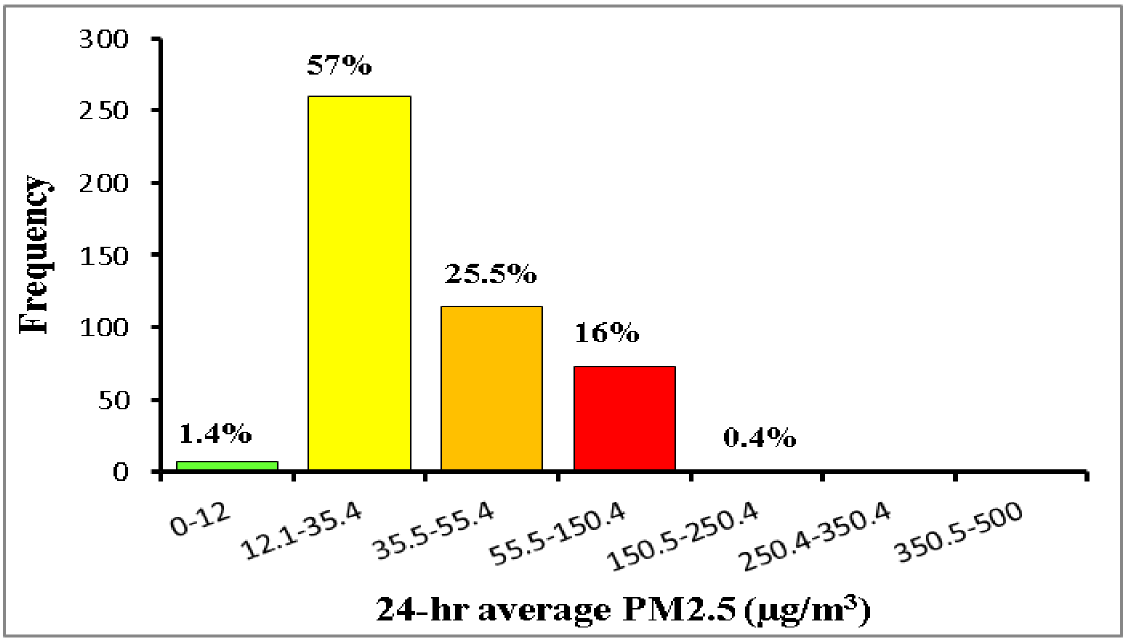

Figure (4) Frequency Distribution of 24-hr Average PM2.5 According EPA Standards for Air Quality Index for Fine Particle Pollution in Green Zone.

Frequency Distribution of PM2.5

Figure (4) shows more detail on full distribution of different air quality levels for 24-hr, average PM2.5 in the Green Zone/ Baghdad city during the study period. When the AQI value of PM2.5 scaled from 0 to 12 µg/m^3, that indicates the air quality was good and there was no fine primary pollutant. Only 1.4% of the study period is in good air level at the Green Zone/ Baghdad city, also it could be seen from Figure (4) that the most frequent distribution of PM2.5 pollutant was 57% in moderate level of air quality that mean the fine particulate matter dominated air pollution over the Green Zone/ Baghdad city. 25.5% of study period are unhealthy for sensitive groups of people, while 16% of study period was unhealthy. 0.4% of dataset conditions are very unhealthy so high PM2.5 levels negatively impacted COVID-19 incidence and spread (Kotsiou, *et al.*, 2021).

Monthly Average PM2.5 Variation in Green Zone

As shown in Figure (5), November 2019 was the most polluted month with value 64.4±16.7µg/m^3. The monthly average of PM2.5 exceed the WHO (25 µg/m^3) and the US EPA (35 µg/m^3) standards during period from September 2019 to February 2020 with monthly value from 37.6±10.6 µg/m^3 to 58±16.4 µg/m^3 due to demonstrations in Tahrir Square and the riots that is occurred in these months. According to Figure (5), the monthly mean of daily PM2.5, April was the cleanest month with value 21.6±3.9 µg/m^3 in year 2019 and 23.96±3.5 µg/m^3 in year 2020 which is lower than WHO and US EPA standards. It notes high decreasing in PM2.5 variation after the period of demonstrations and imposes curfew due to Coronavirus Pandemic (Covid-19) which reduced the traffic in the Baghdad city. Decreasing in PM2.5 pollution and people's mobility in Baghdad at total and partial curfew contributed to decrease injuries and mortality (Halos, *et al.*, 2021). The evidence indicates that PM2.5 and PM10 can affect COVID-19 epidemiology in various geographical regions (Meo, *et al.*, 2021).

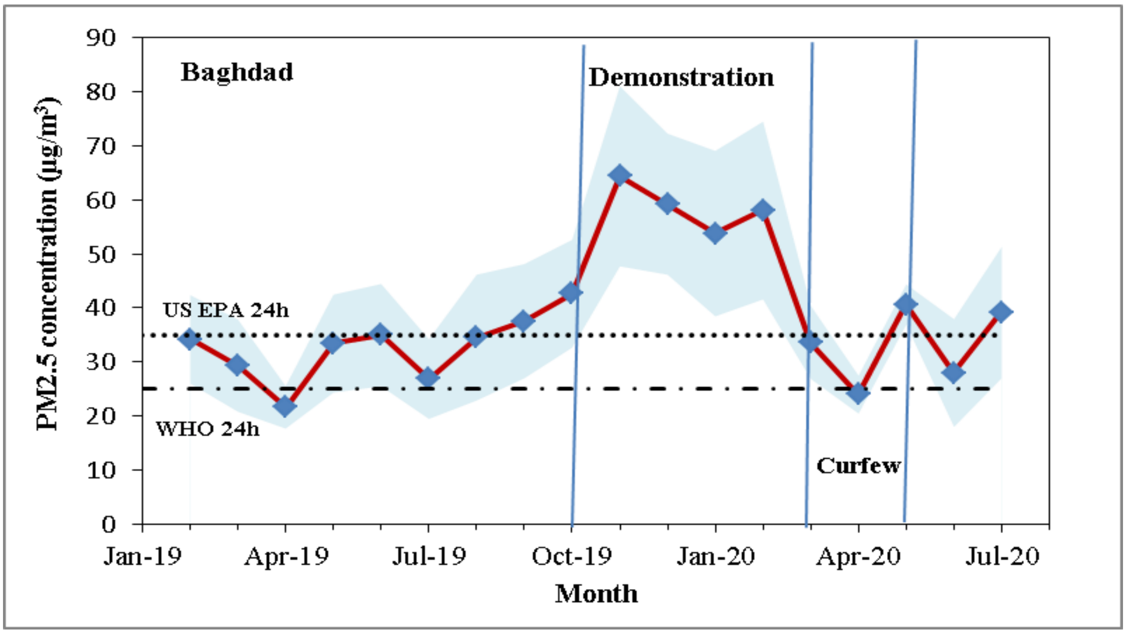

Figure (5) Monthly Variations of PM2.5 (Red Line with Blue Square), Standard Deviation (Shading) Over Green Zone, 24hr Average of PM2.5 for WHO (Black Dashed Dot Line) and for the US EPA (Black Dots Line).

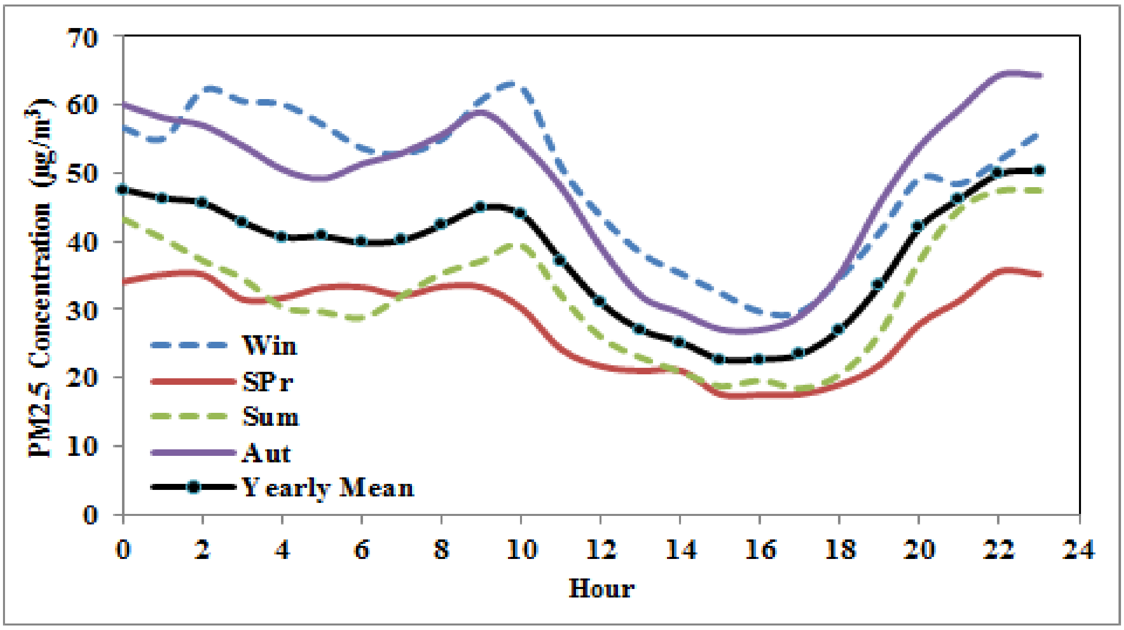

Figure (6) Hourly Seasonal Variation of PM2.5 for Green Zone.

Variations of Seasonal PM2.5

Figure (6) shows hourly mean of PM2.5 for the period from February 2019 to July 2020 in the Green Zone/ Baghdad city for different seasons. The hourly variation of PM2.5 was high in most hours in winter than other seasons. Hourly average PM2.5 patterns have two peaks appear at hour 2:00 AM and 10:00 AM (Baghdad Time) and the minimum value occurred at 16:00 PM. In autumn, the lowest hourly average PM2.5 concentration is in the afternoon at 16:00 PM, while the heavier concentration in the middle night at 22:00 and at 9:00 on morning. In summer, the peak hour was found in the middle night at 23:00. The second peak hour was in the morning at 10:00 and PM2.5 has a few changes at other times of the day. The lowest concentration was at afternoon at

15:00. In spring, the PM2.5 concentration of each hour was clearly lower than in other seasons. This confirms that the air quality in this season is good. Overall average, it’s clarified that the hourly seasonal mean of PM2.5 has a significant bimodal pattern represented by morning and evening peaks. This may be attributed to enhanced anthropogenic activity contribution during the rush hours. The low value occurred at afternoon which was mainly attributed to a higher mixing layer of atmosphere. The presence of the peak in midnight can be attributed to the low air temperature and the stability of the atmosphere during the night hours to the trapping of pollutants in the atmosphere near the ground.

Correlation PM2.5 with Meteorological Variables

The mean of PM2.5 and metrological variables vary as season as shown in Table (2) where in winter PM2.5, humidity and pressure have high mean than other seasons. Summer is witnessing an increase in both temperature and wind speed than other seasons.

Correlation PM2.5 with Air Temperature

In Figure (7a), daily median PM2.5 has a positive correlation with daily median temperature in winter, spring and summer while in autumn season PM2.5 has a negative correlation. The correlation coefficients have high values in spring and summer than in winter and autumn seasons as shown in Table (3).

Correlation PM2.5 with Humidity

There is a negative correlation in Figure (7a) between daily median humidity and PM2.5 (r = -0.42, r = -0.09, -0.06) in spring, winter and summer. Weak positive correlation (r= 0.17) in autumn as display in Table (3). When the humidity is high enough especially in spring season, the particles will be too heavy to stay in the air therefore it precipitates in the ground and its number will decrease in the air and the concentration of PM2.5 will decrease.

Correlation PM2.5 with Wind Speed

Figure (7b) shows that PM2.5 is inversely correlated with wind speed for each season during study period. The high range of wind speed was recorded in spring with the range between 1.5 and 11.3 m/s while the low wind speed was in autumn with range 1.5-6.1 m/s. That mean when the wind speed is high enough, it can transfer and spread pollutants to far places, which makes their concentration low.

Table (2) Daily Median of PM2.5 and Metrological Variables in Seasons.

Mean	PM2.5	Temp	Humidity	WS
Spring	77.6	22.0	39.5	3.8
Summer	84.7	36.0	20.7	4.4
Autumn	110.9	25.2	37.6	2.8
Winter	122.0	12.2	69.9	3.0

Table (3) Seasonal Correlation Coefficients of Daily Median PM2.5 with Metrological Variables.

	Winter	Spring	Summer	Autumn
Temperature	0.15	0.49	0.43	-0.23
Humidity	-0.09	-0.42	-0.06	0.17
Wind Speed	-0.22	-0.23	-0.62	-0.59

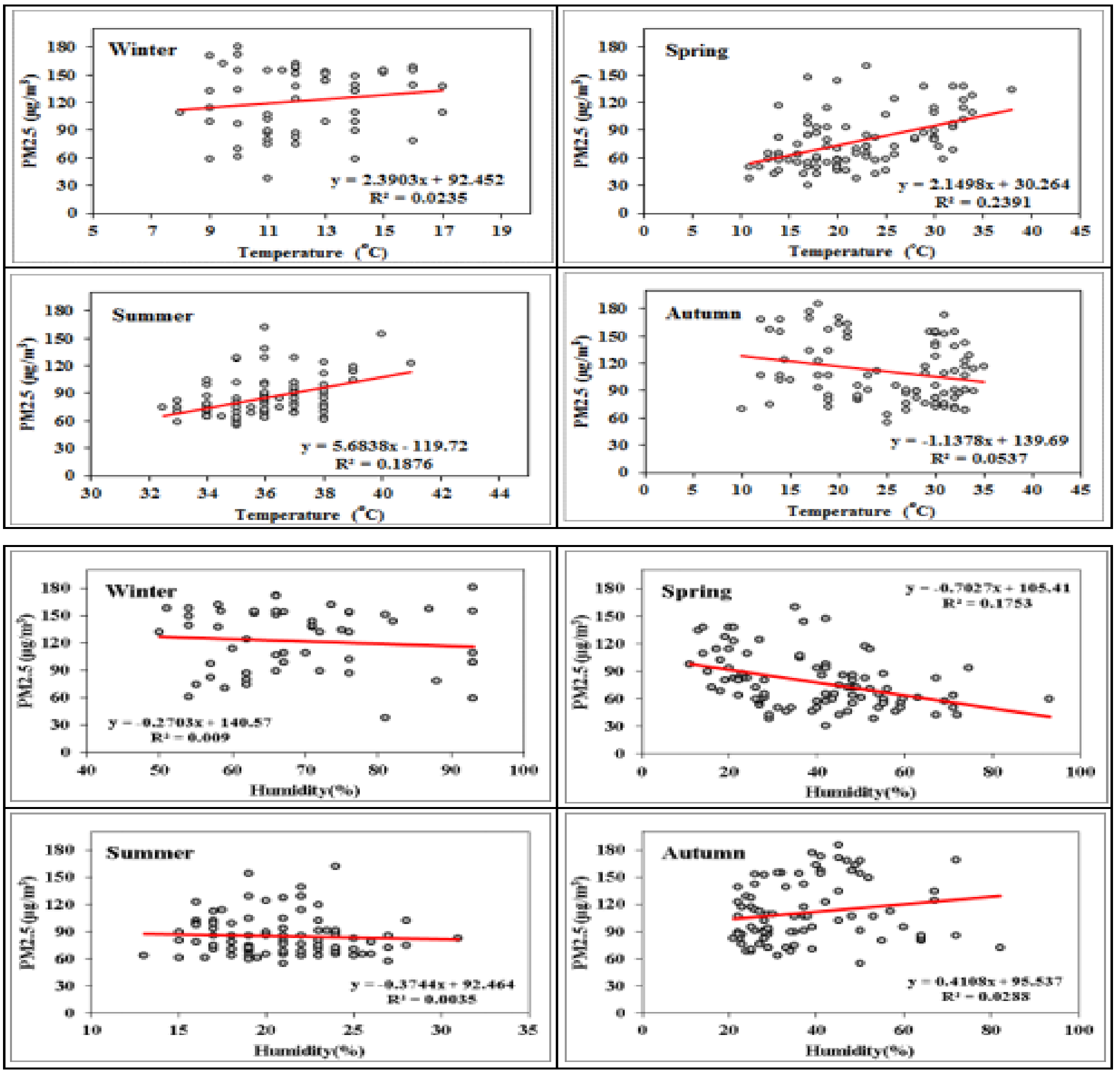

Figure (7a) Seasonal Correlations of Daily Median PM2.5 Concentration and Daily Median Temperature and Humidity in the Green Zone/ Baghdad city.

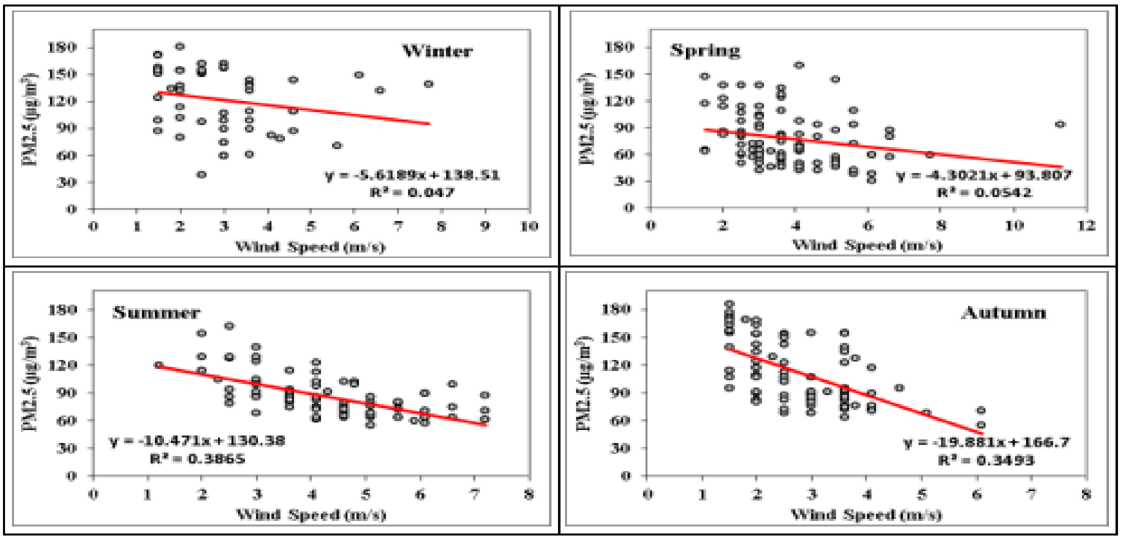

Figure (7b) Seasonal Correlations of Daily Median PM2.5 Concentration and Daily Median Wind Speed in Green Zone.

Conclusions

PM2.5 data and meteorological variables are collected and analyzed during 18 February 2019 to 30 July 2020 and concluded the following:

1- The highest daily of PM2.5 (164.9µg/m^3) was an unhealthy day measured in January month, six times more than WHO and four times more than EPA standards.

2- 68% of the dataset of daily PM2.5 concentrations during the study period exceeds WHO standard and 42% of dataset exceed the EPA standard that conclude the air quality in the Green Zone is unhealthy so reducing emissions are required by reducing the number of vehicles and increasing agriculture in Baghdad city and providing guidance for future emissions control strategies from a health protection perspective.

3- PM2.5 concentrations exhibited high variations on weekdays exceed the EPA and WHO standards compared to weekends. Tuesday recorded the highest average value of PM2.5 while lowest was on the weekend Friday.

4- The most frequent distribution of PM2.5 pollutant was in a moderate level of air quality. There may be moderate health concern for a number of people who are unusually feeling to air pollution.

5- November was the most polluted month while April was the cleanest month.

6- Seasonal hourly variations of PM2.5 concentration have the most significant bimodal pattern pronounced with obvious morning and evening peaks. The hourly PM2.5 concentrations in winter and autumn were higher than other seasons in most hours and it was lower in spring.

7- Daily median PM2.5 has a positive correlation with a daily median air temperature in winter, spring and summer while PM2.5 has a negative correlation in autumn season. The correlation coefficients are high in spring and summer than winter and autumn seasons.

8- In general, a negative correlation between daily median humidity and PM2.5 especially was in spring, winter and summer seasons and there a weak positive correlation in autumn.

9- PM2.5 is inversely correlated with wind speed for each season during study period. When wind speed is high enough, it can transfer and spread pollutants to far places, which makes their concentration low.

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