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Distribution of Dustfall in Selected Sites In Mosul City and around It/IRAQ

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□ ABSTRACT □

The research aimed to indicate the levels of dustfall in different areas of Mosul city, residential, commercial and industrial in addition to a selected sites of small cities in the around sub-boarder in Al-Hatra, Talkif, Sinjar, Al-Qayara, Al-Hamdania and Makhmoor. Dustfall samples were collected from the sites at a height of 4-6 m using dry polyethylene cylindrical containers for the period from December 2007 to October 2008. The collectors were exposed to the atmosphere for a sampling period of 30 days. The results of statistical analysis showed significant difference in the dustfall quantities among the studied sites in the sub-boarder and Mosul city. On the other hand, little difference was observed among different areas of Mosul city. The maximum monthly dustfall was recorded in Al-Hatra city with 185 gm/m^2.month. Additionally, the highest frequency of maximum dustfall was occurred in Al-Hatra city with 33.33%, while the highest frequency for the minimum dustfall was recorded in each of Talkif and Sinjar cities with 44.44%. The mean dustfall quantity in Mosul residential area was 16.23 gm/m^2.month. The study also found that the dustfall in Mosul city was above the lowest grade of the standard of dustfall. Additionally, the peak dustfall moved between March and September and mostly in March where the storms increased. The results of this research indicate the need to vegetate most of the unplanted areas and to make a green belts around the cities to decrease the dustfall effectively.

Keywords: Dustfall, Storms, Vegetation

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توزيع الساقط الغباري في مدينة الموصل وماحولها / العراق

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□ ملخّص □

هدف البحث الحالي إلى تحديد مستويات الساقط الغباري (Dustfall) في مناطق مختلفة من مدينة الموصل شملت السكنية والتجارية والصناعية فضلا عن مناطق مختارة حولها تضمنت الحضر وتلكيف وسنجار والقيارة والحمدانية ومخمور . تم جمع نماذج الساقط الغباري من هذه المواقع لمدة شهر بواسطة جهاز أخذ النماذج المكون من إناء أسطواني مصنوع من مادة البولي اثيلين وضع على ارتفاع 4–6 متر للفترة من كانون الأول 2007 ولغاية تشرين الاول 2008. أظهرت التحليل الإحصائي للنتائج وجود فروقات معنوية في كمية الساقط الغباري بين مدينة الموصل والمناطق الأخرى حولها ، بينما كانت الفروقات قليلة ضمن مدينة الموصل بين المناطق ذات الأنشطة المختلفة . وقد سجلت أعلى كمية للساقط الغباري في مدينة الحضر وبمقدار 185 غم/م^2 . شهر ، كما سجل التردد الأعلى لأكبر كمية ساقط غباري في مدينة الحضر أيضاً وبمقدار 33.33% ، بينما سجل التردد الأعلى لأقل كمية ساقط غباري في كل من مدينة تلكيف وسنجار وبمقدار 44.44% . وبلغ معدل الساقط الغباري في المناطق التجارية لمدينة الموصل 16.23 غم/م^2 . شهر . كما وجدت الدراسة أن مستوى الساقط الغباري هو أعلى من أدنى مستوى في المحددات . كما تبادل شهرا آذار وأيلول حصول أعلى ساقط غباري وكانت نسبة حصولها في آذار أكثر منها في أيلول نتيجة لازدياد العواصف خلال هذا الشهر . وعلى ضوء هذه النتائج أوصت الدراسة بضرورة التشجير (Vegetation) وزيادة المساحات الخضراء وجعلها بشكل حزام حول المدن المدروسة لتقليل تأثير العواصف وبالتالي الساقط الغباري .

الكلمات المفتاحية: الساقط الغباري ، العواصف ، التشجير

Introduction

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Dustfall is particulate matter which is too heavy to remain suspended in the atmosphere indefinitely. Sources of dustfall include windblown soil, road dust, dust generated by agricultural activities, ash from forest fires and recreational fires, and fly ash from industrial sources. Dry climate, desert areas and windy conditions normally generate the larger particles found as dustfall. The dust blowing in Iraq is considered familiar in spring and autumn because of the decrease of vegetation in the last years and increase of wind storms [1].

Particulate air pollution can cause a wide range of damage to surfaces and materials. Merely by requiring more frequent cleaning, particulates can accelerate deterioration. If the particle is corrosive or has other pollutants, for example sulfur dioxide may react with or corrode the surface or material.

Under normal condition a human respiratory tract in good health is able to deal with inhaled particles without undue stress or long-term effect. In sensitive individuals, or when high levels of particles are present, particulate matter may contribute to increased rates of respiratory illness and symptoms.

Dustfall quantities recorded large values in different sites of the world. It reached 23 ton/km^2.month in London and 33 ton/km^2.month in Osaka [2], while it reached 50 ton/km^2.month in Al-Riyadh city and 270-300 ton/km^2.month in the entrances of the city. In Damascus, Othman and Sabra [3] estimated the dustfall from 69-117.7 ton/km^2/month. In Amman, dustfall reached a mean of 163.6 mg/m^2.day with a range from 80.4 to 212.4 mg/m^2.day [4]. Additionally, it ranged between 200 to 390 mg/day in Quetta using Petri dish method [5]

In Mosul city, Al-Sayegh and Al-Kattan [6] estimated the dustfall quantity near Hammam Al-Alel cement factory between 114.8-172.7 ton/km^2.month. Al-Hyalli [7] measured the dustfall in different sites within Mosul city, she found the dustfall ranged from 9.94 gm/m^2.month in Al-Methak site to 66.39 gm/m^2.month in Al-A'kedat site. Additionally, Al-Saffawi [8] found the maximum dustfall in Mosul city of 43.67 gm/m^2.month in Bab Al-Tob site. He attributed that to the dense human activities in this area in addition to high traffic volume and commercial activities.

In Lanzhou city (China), Xia et al. [10] identified the improvement in air quality depending on the decrease of the dustfall samples during the period 1997-2005. Additionally, Qu et al. [11] study the variation of the particulate matter over 86 Chinese cities. He found a decreasing trend in the Northern cities during 2000 to 2006, while the middle zone showed unobvious change with an increasing trend in the Southern zone.

Aims of the Research

Due to the climate change in the last years and rain shortage, dust increased. This research tries to investigate the quantities of dustfall in Mosul city and in selected sites around it in addition to the seasonal variation and comparison with the standard.

Materials And Methods

Sites were selected within Mosul city to represent the residential, commercial and industrial areas for dustfall measurements for the period from December 2007 to October 2008. Additionally, six sites were selected in the sub-boarder of Mosul city in Al-Hatra, Talkif, Sinjar, Al-Qayara, Al-Hamdania and Makhmor cities (Figure 1). Some of the data were missed due to circumstances out of the reach of the researchers.

Dustfall samples were collected from the sites at a height of 4-6 m using dry polyethylene cylindrical containers placed on the roofs of the buildings. The dimensions of

these containers were 31 cm in height and 15.5 cm in diameter. They were mounted on 1.5 m-high tripod to avoid the collection of dust picked up by wind eddies. There was a bird ring on each holder in order to avoid material from birds. Additionally, distilled water was added continuously in each container to avoid the blowing of the dust from them. The collectors were exposed to the atmosphere for a sampling period of 30 days. After that the containers were closed tightly and transported to the laboratory for measurements. The dry weight of the dustfall was weighted then divided by the area of the container to obtain the quantity of dustfall in gm/m^2.month.

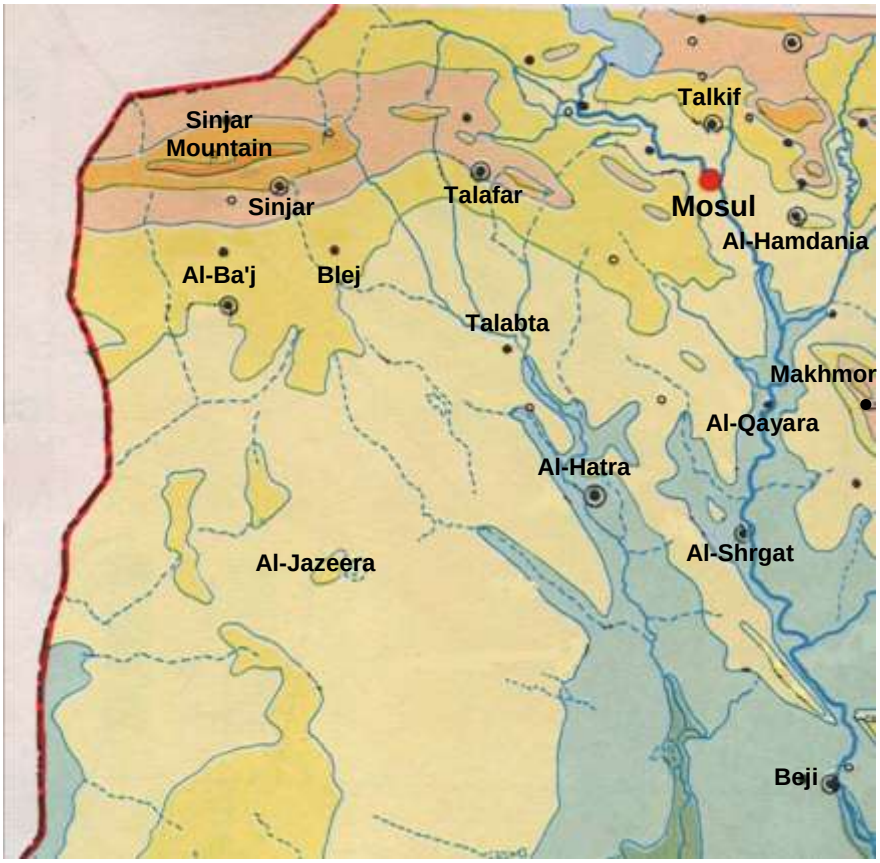

Figure (1) Location map including the sampling sites.

The collected data were analyzed statistically to find the differences among the sites at each month using Duncan multiple range test at $p \leq 0.05$. In addition, the monthly variation at each site was analyzed using analysis of variance.

Results And Discussion

Table (1) shows significant variation in the dustfall quantity among the studied sites. No significant difference was recorded between residential and commercial locations in Mosul city in December, while it was significantly higher in the industrial locations than the previous sites as these sites were located near the boarder of the town.

The highest dustfall quantity was recorded in Talkeef then Al-Hatra and Sinjar cities in the sub-boarder of Mosul city. The high quantity of dustfall in sub-boarder towns is due to the very slight land vegetation around these cities and between Mosul cities and those in the sub-boarder especially in the dry seasons. Therefore, the wind

can easily transport the particulate materials to these towns. In addition, these small towns do not have multistory buildings of high elevation which work as a barrier obstruct the path of the particulate transported by wind and storms. Furthermore, these towns lie in open areas which ease the role of wind to blow the soil to these towns (Fig. 1).

In February, the quantity of dustfall increased since the rainfall decreased and it was low in this year also. The highest dustfall quantity was recorded in Sinjar city, then Al-Hatra with non-significant difference between them. On the other hand, the lowest dustfall quantity was recorded in Mosul residential and commercial area. Whilst, it was higher in the industrial area with significant difference from the latter, as they lie near the boarder of the town, in addition to the particulate matter generated from these activities.

Table (1) Comparison of dustfall quantity among the selected sites in winter.

Sites	Mean ± SE (gm/m^2.month)	
	Dec 2007	Feb 2008
Al-Hatra	50.0 ± 3.51 d	95.0 ± 5.51 f
Talkif	60.0 ± 3.25 e	45.0 ± 2.25 c
Sinjar	43.0 ± 1.26 c	102.0 ± 5.53 f
Mosul-Residential	13.0 ± 0.76 ab	15.0 ± 1.04 a
Mosul-Commercial	9.0 ± 0.31 a	14.2 ± 0.70 a
Mosul-Industrial	16.4 ± 0.63 b	29.4 ± 1.31 b
Al-Qayara	-	60.0 ± 2.75 d
Al-Hamdania	-	83.0 ± 3.75 e

Means with different letters vertically have significant difference at $p \leq 0.05$.

In spring season, the highest dustfall quantity was recorded in Al-Qayara south of Mosul city at March (table 2). Although the rain in March made a wet deposition of the particulates from the air and assist in the land vegetation, but dust storms increased in this season and bring the particulate matter from the Iraqi western desert. The quantity of dustfall in Al-Hatra site came in the second order after Al-Qayara. It is the nearest location to Al-Qayara site, where most of the areas were unplanted and the wind can blow the soil particulate, in addition to the shortage of rain in this year. Talkef and Sinjar areas were more vegetated that the previous sites, therefore, lesser quantity of dustfall was recorded. Additionally, Sinjar mountain work as a barrier from the North-West wind, while. The dustfall quantity in Mosul residential was the lowest with non-significant difference from commercial area. The source of dustfall in Mosul city was the wind also which blow the soil particles in the air, but there are a low number of un-vegetated or unoccupied areas in the city.

In April, the highest dustfall was recorded in Al-Qayara city also. Additionally, the dustfall increased in Sinjar city as it became after Al-Qayara due to the increase of wind storm in this month in the Western desert and it came across the Syrian boarder. Al-Hamdania city also recorded high quantity of dustfall reached 62.0 gm/m^2.month due to the lack of land vegetation in this area. On the other hand, the quantity of dustfall in Talkif reduced at this month with non-significant difference from Mosul city due to the growth of grasses which cover the ground.

In May, the highest dustfall quantity occurred in Al-Hatra city, then Al-Hamdani (table 2). These sites lied in open area in which the storms play a main role in transporting the particulate materials to the residential areas. Makhmor city also recorded a high level

of dustfall of 93.0 gm/m^2.month which is mostly affected by the storms from the west. The lowest level of dustfall was recorded in Mosul residential and commercial areas.

Table (2) Comparison of dustfall quantity among the selected sites in spring months.

Sites	Mean ± SE (gm/m^2.month)		
	March 2008	April 2008	May 2008
Al-Hatra	87.0 ± 4.04 e	72.0 ± 3.75 c	185.67 ± 6.17 g
Talkif	48.0 ± 2.52 c	22.0 ± 0.76 ab	40.0 ± 1.76 b
Sinjar	55.0 ± 2.52 c	146.0 ± 6.11 d	65.0 ± 3.51 c
Mosul-Residential	19.4 ± 1.51 a	16.0 ± 0.75 a	20.7 ± 0.85 a
Mosul-Commercial	25.8 ± 1.51 ab	23.2 ± 1.10 ab	25.2 ± 1.35 a
Mosul-Industrial	32.0 ± 1.55 b	30.4 ± 1.40 b	37.0 ± 1.76 b
Al-Qayara	102.0 ± 5.03 f	165.3 ± 7.51e	76.33 ± 1.45 d
Al-Hamdania	74.0 ± 3.36 d	62.0 ± 2.85 c	132.33 ± 6.07 f
Makhmor	-	-	93.0 ± 4.25 e

Means with different letters vertically have significant difference at $p \leq 0.05$.

In summer at June, there is a significant difference of dustfall among the studied sites (table 3). The quantity of dustfall graduated from Al-Hatra as the highest to Mosul city as the lowest, while Makhmor came in the second with 114 gm/m^2.month. No differences were recorded in dustfall among residential, commercial and industrial Mosul locations.

Table (3) Comparison of dustfall quantity among the selected sites in summer months.

Sites	Mean ± SE (gm/m^2.month)	
	June 2008	July 2008
Al-Hatra	180.0 ± 7.02 f	78.0 ± 3.51 d
Talkif	64.7 ± 2.89 c	63.0 ± 3.51 c
Sinjar	45.0 ± 2.25 b	40.0 ± 1.44 b
Mosul-Residential	15.0 ± 0.50 a	15.6 ± 0.31 a
Mosul-Commercial	13.0 ± 0.45 a	14.9 ± 0.50 a
Mosul-Industrial	22.0 ± 1.04 a	17.0 ± 0.76 a
Al-Qayara	52.3 ± 1.01 b	90.0 ± 5.03 e
Al-Hamdania	84.3 ± 4.34 d	79.0 ± 4.04 d
Makhmor	114.0 ± 5.51 e	94.67 ± 4.7 e

Means with different letters vertically have significant difference at $p \leq 0.05$.

In July, the number of dust storms decreased [10]. The dustfall in Makhmor and Al-Qayara was the highest among the sites included in the study, then Al-Hatra and Al-Hamdania with non-significant difference between the two formers. Mosul city stay with the lowest quantity of dustfall.

In September, the highest dustfall occurred in Al-Hatra city with significant difference from other sites (table 4). It reached about 170 gm/m^2.month as the dust storms increased in autumn. The dustfall in Makhmor and Talkif came next with about 80 gm/m^2.month with significant difference from Mosul city which recorded the lowest dustfall quantity around 20 gm/m^2.month.

In October, with the starting of rainy season, Al-Hamdania city recorded the highest dustfall with significant difference from other sites ($p \leq 0.05$), then came Makhmor, Al-Hatra and Al-Qayara with significant difference from Mosul-residential site which recorded the lowest dustfall. The rain in this month gives cohesion to the soil and reduces the particulate blown by wind.

Table (4) Comparison of dustfall quantity among the selected sites in autumn months.

Sites	Mean ± SE (gm/m^2.month)	
	Sep 2008	Oct 2008
Al-Hatra	171.0 ± 7.25 e	85.0 ± 3.77 e
Talkif	78.0 ± 3.85 cd	56.0 ± 2.75 c
Sinjar	61.0 ± 3.25 b	29.0 ± 1.76 b
Mosul-Residential	20.0 ± 1.26 a	11.4 ± 0.5 a
Mosul-Commercial	17.0 ± 0.72 a	21.6 ± 1.15 b
Mosul-Industrial	26.0 ± 1.55 a	26.8 ± 1.15 b
Al-Qayara	72.0 ± 3.25 c	75.0 ± 4.04 d
Al-Hamdania	57.0 ± 2.55 b	105.0 ± 4.75 g
Makhmor	84.73 ± 1.45 d	95.0 ± 4.1 f

Means with different letters vertically have significant difference at $p \leq 0.05$.

Table (5) shows the mean quantity of dustfall in the studied sites. The mean value of Mosul residential site was 16.23 gm/m^2.month which was higher than that recorded in Amman 4.91 gm/m^2.month and Cairo 14.25 gm/m^2.month. This is probably due to the weak land plantation in and around the city and the topography of site. Additionally, this result was more closer to the lower value of the range recorded by Al-Hyalli [7] from 9.96 to 66.39 gm/m^2.month.

Table (5) Average quantities of dustfall in mg/m^2.day for the studied sites along the study period.

Sites	Mean (gm/m^2.month)	SD
Al-Hatra	91.45	47.19
Talkif	52.96	16.35
Sinjar	65.11	36.83
Mosul-Residential	16.23	3.19
Mosul-Commercial	18.21	5.95
Mosul-Industrial	26.33	8.66
Al-Qayara	86.62	35.42
Al-Hamdania	84.58	24.24
Makhmor	96.28	10.75

All the values recorded for dustfall quantity exceeded the grade I of the standard of 4.5 gm/m^2.month in Mosul city and in the sites around according to the Statutory Authority Environmental Law [9], while only one value (11.1% of the reading) was within grade IV of dustfall standards of 9.0 gm/m^2.month in Mosul commercial areas. When using South African National Standards (SANS) [13], the level of dustfall for Mosul city (residential, commercial and industrial) was considered as "heavy" which indicates a fine layer of dust

on a surface. On the other hand, the other sites around Mosul city was considered "very heavy" with dustfall easily visible like a surface not cleaned for a few days.

Seasonal Variation

Figure (2) shows significant variation in the dustfall along the study period in Al-Hatra city. It is surrounded by open area mostly unplanted. Therefore, the quantity of dustfall was affected by the weather condition of wind and rain. The peak dustfall occurred in spring to summer due to the increase of storms in spring and the decrease of land vegetation in summer (Fig. 2). Additionally, the number of storms increased in Iraq in the last years [1 & 10].

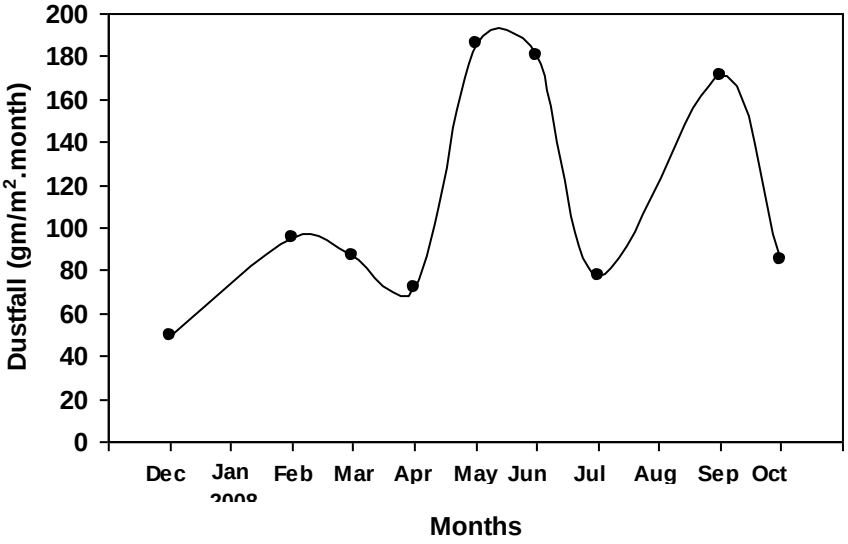

Figure (2) Variation of dustfall in Al-Hatra site along the study period ($p \leq 0.001$).

Figure (3) shows significant variation in the dustfall along the study period in Talkif city. The peak value was recorded in September since in spring the area in Talkif and around it was covered with the grass and green plants.

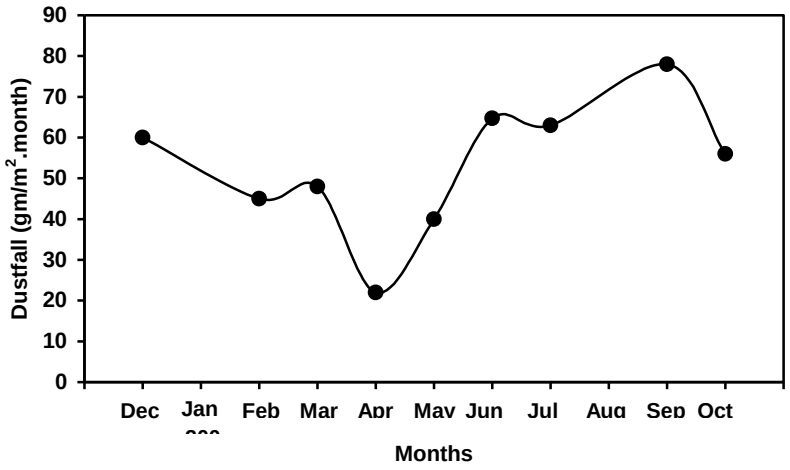

Figure (3) Variation of dustfall in Talkif site along the study period ($p \leq 0.001$).

The peak value of dustfall in Sinjar reached 140 gm/m^2.month in April due to the increase of dust storm in this month from the Iraqi desert south the city (Fig. 4).

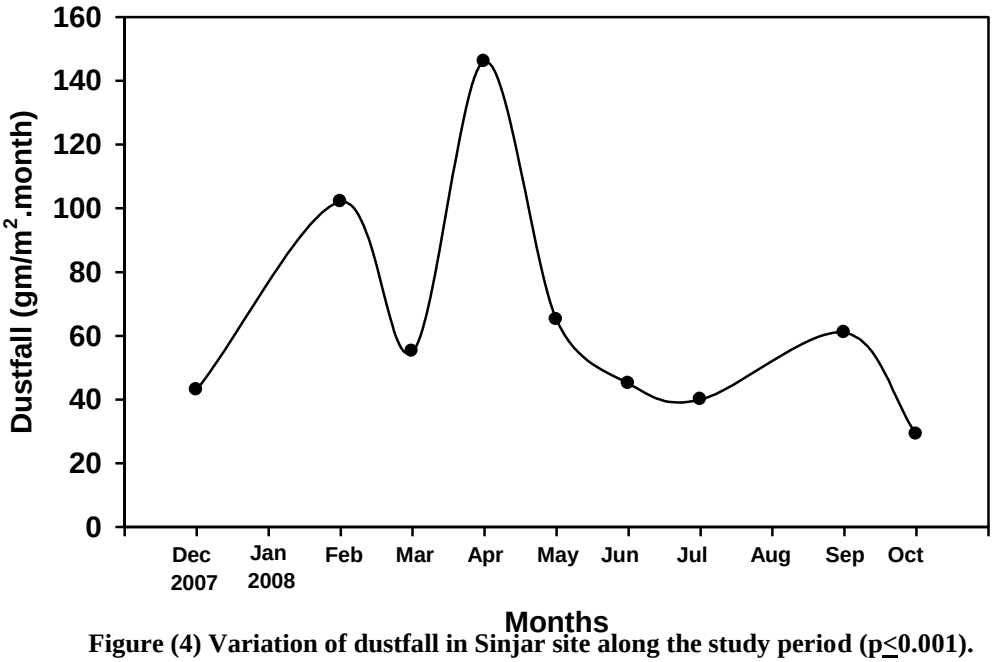

Figure (4) Variation of dustfall in Sinjar site along the study period ($p \leq 0.001$).

For Mosul city, the peak values of dustfall for residential, commercial and industrial were recorded in spring months due to the increase of storms in this season (Figs 5, 6 and 7), in addition to human activities especially car movement which contributes in the generation of dustfall.

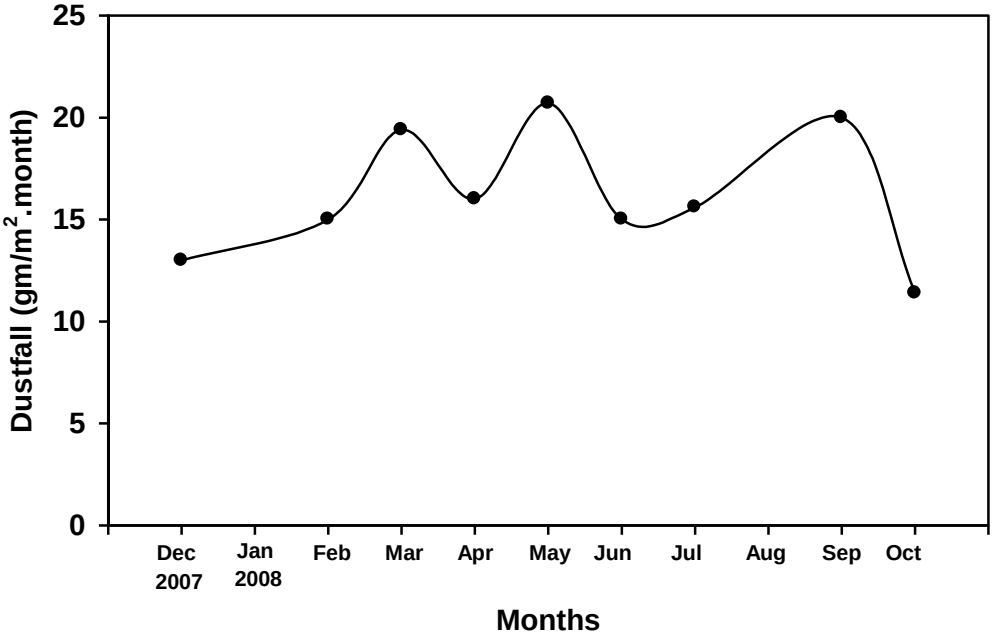

Figure (5) Variation of dustfall in Mosul-residential site along the study period ($p \leq 0.001$).

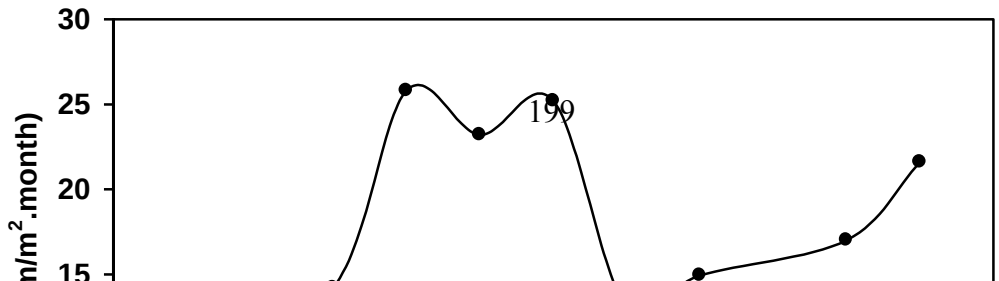

Figure (6) Variation of dustfall in Mosul-commercial site along the study period ($p \leq 0.001$).

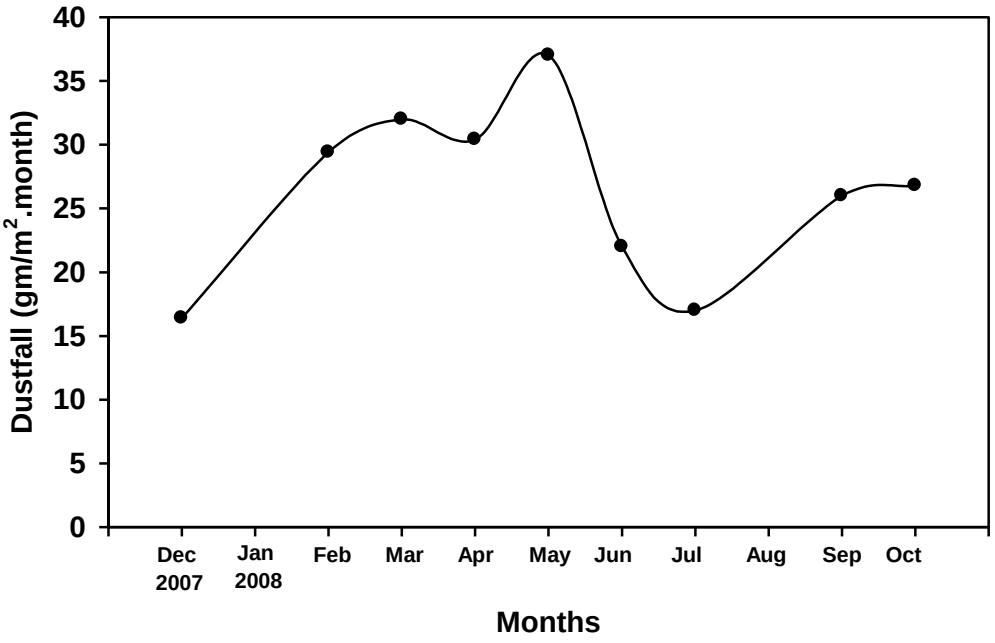

Figure (7) Variation of dustfall in Mosul-industrial site along the study period ($p \leq 0.001$).

For Al-Qayara site, the peak value of dustfall was 165.4 gm/m^2.month, which was recorded in April due to the increase of dust storms in this month. This site lies in an open area from the North and West where the wind mostly come.

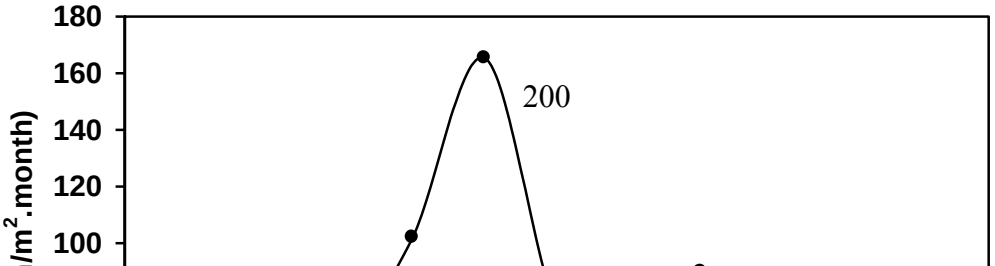

Figure (8) Variation of dustfall in Al-Qayara site along the study period (p≤0.001).

The peak value of dustfall in Al-Hamdania was 132.33 gm/m^2.month in May. This area was mostly affected by the dust storms generated from unplanted areas by the wind coming from North-West direction.

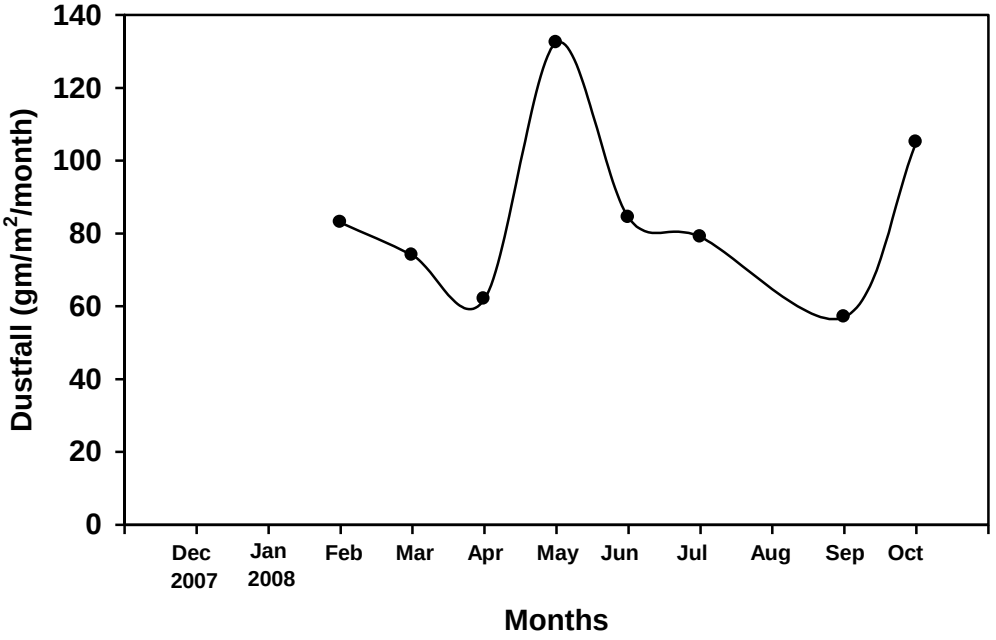

Figure (9) Variation of dustfall in Al-Hamdania site along the study period (p≤0.001).

The data included in this study for Makhmor site was for summer and autumn only. The peak value of 114 gm/m^2.month was recorded in June. This city was affected the dust storms formed by the wind as it lies in an open area from West and North.

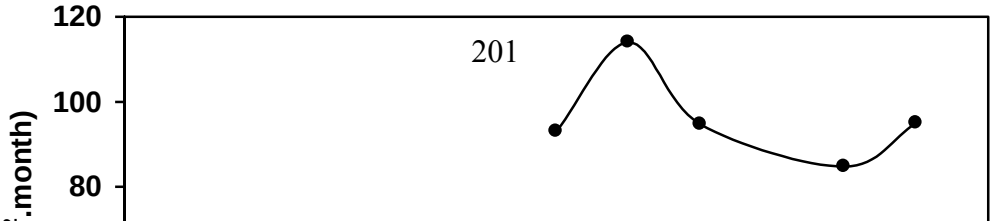

Figure (10) Variation of dustfall in Makhmor site along the study period ($p \leq 0.001$).

Conclusions:

1. Dustfall quantity in Mosul city recorded high levels above the lowest grade of the standard.
2. The slight land vegetation within most of the study area leads to high quantities of dustfall in the sub-boarder cities.
3. The peak dustfall moved between March to September and mostly in May where the storm increased.
4. The results of this research indicate the need to vegetate most of the unplanted areas or to make a green belt of trees around the cities to work as a barrier for dust to decrease the dustfall effectively.

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