Sustainable Resources Management Journal
2018, 3(2), 58-66
http://doi.org/10.5281/zenodo.1287926

Using GIS Techniques for Mapping the Pollution of Particulate Materials in Kirkuk

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ABSTRACT

Urban particulate pollution has been recognized as a major problem in emerging major cities in Iraq such as Kirkuk as a result of industrial and man-made pollutions in addition to natural factors such as dust storms. One way of monitoring the atmospheric pollution is to estimate the particulate matter emissions by using a sampling location with advanced measuring techniques.

This article studies the particulate matter (PM_{10}) emissions in Kirkuk city for the period of 2013-2017. The data was obtained form forty-four measuring stations distributed in the study area. The prediction map of the spatial distribution for PM_{10} emission levels was obtained using ArcGIS10.3/ Inverse Distance Weighting (IDW) interpolation method. The results show that the PM_{10} emissions are clearly increased in the city's main entrances spatially near the checkpoints due to the exhaust emission from the large trucks and small vehicles. Also, it is found that the higher pollution in the sampling location occurred near the North Oil Company (NOC), which was 460µg/m^3. The annual average PM_{10} pollution in Kirkuk obtained from all stations is about (120.8µg/m3).

Keyword: IDW interpolation; particulate matter (*PM10); GIS; Kirkuk; Air pollution*

1. INTRODUCTION

Air pollution is any atmospheric condition in which certain substances present in such concentrations and duration that they may produce harmful effects on man and his environment (Efe and Efe, 2008). The quality of air is a very important factor in projecting or representing the status of environment and health of any region. Globally, air pollution has become a major environmental problem in major cities where urban-based activities and residents generate high proportion of gas and particles emissions.

In general, particulate matter is the term given to the tiny particles of solid or semi-solid material found in the atmosphere as suspended mixtures (Elisaveta and Darby, 2013). The chemical complexity of airborne particles makes it imperative to consider the composition and sources of selected primary and secondary particulates deemed to be of health concern. Primary particulates are introduced into the atmosphere from a variety of natural and anthropogenic sources. Secondary particulates tend to form in the atmosphere as a result of chemical processes (Hassony and Zaid, 2010). The particles with a diameter varied by the range of (1-10 µm), can constitute a significant health risk because they are small enough to penetrate the lungs and cause acute respiratory diseases (Pedro, Monica and Luis, 2012). These particles are responsible for most of the adverse human health effects of particulate matter because of the particles' ability to reach the lower regions of the respiratory tract (Saleh et al., 2014).

Urban particulate pollution has been recognized as a major problem in major-cities in Iraq such as Kirkuk as a result of man-made pollutions, as well as the presence of NOC in Kirkuk city. Fuel burning causes disorder in the concentration of these problems.

The present study introduces the importance of the in-site measurements of the PM_{10} pollution to identify and delineate the locations of the high pollution levels. ArcGIS10.3/IDW interpolation technique was used for mapping the prediction levels of the PM_{10} emission measured by (44) stations distributed over the study area. Generally, air pollution maps can be serves as a basis for proper distribution of air pollution measurement stations.

2. STUDY AREA

2.1. Location

Kirkuk city is located in the north of Iraq, 236 Km north of Baghdad and 83 km south of Erbil (Figure 1). The area coordinates (E: 429082.1-455910.9; N: 3908331.3-3935107.2). It is covered an area of (7247km^2).

The study area was chosen to represent different areas within Kirkuk city. Measuring stations of the particulate matter of 10μg/m³ (PM_{10}) were used and distributed in the area. Kirkuk is characterized by being rich for its mineral resources. Oil is the main axis of its economic activities. It has the largest oil field in Iraq. In addition, it has natural gas and sulfur. Kirkuk city is bounded from the South with Himreen mountains chains, which represents the southern boundaries of sub-mountain district besides the chain of hills (Al-Abdraba, 2005).

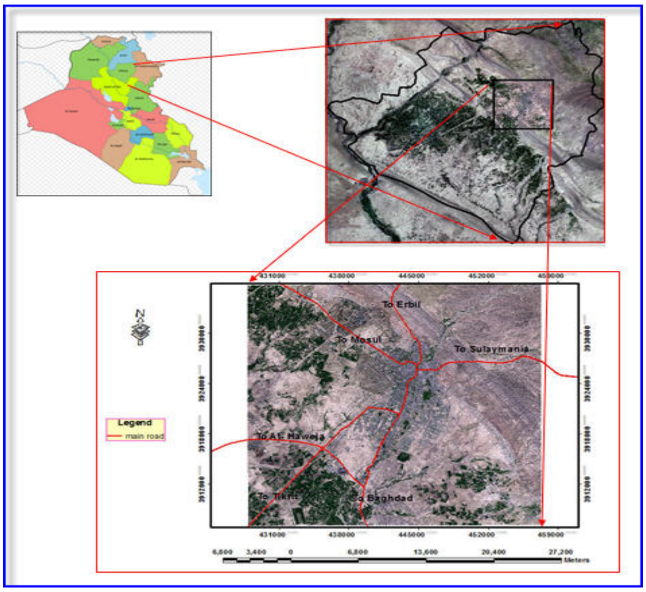

Figure 1: The map of the study area

2.2.Climate

The prevailing climate in Kirkuk is known as a local steppe climate with slight rainfall (Kottek et al., 2006). The average temperature in Kirkuk is 21.6 °C. The average annual rainfall is 365 mm. Most precipitation falls in

March; the precipitation varies 73 mm between the driest and the wettest month. The average temperatures vary during the season by 25.9 °C (Figure 2).

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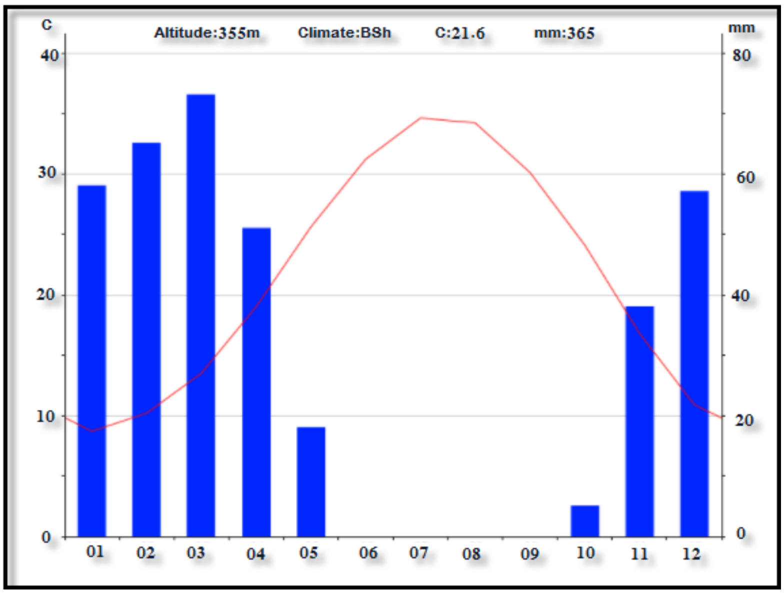

Figure 2: The average rainfall and temperature for Kirkuk area.

3. MATERIALS AND METHODS

3.1. Data used

This study examined the spatial distribution of the PM_{10} pollution in Kirkuk city. To achieve this, the PM_{10} concentration data were collected from 44 stations distributed inside the study area (Figure 3). Table 1 lists the sites and their PM_{10} emissions of the used stations in the study area.

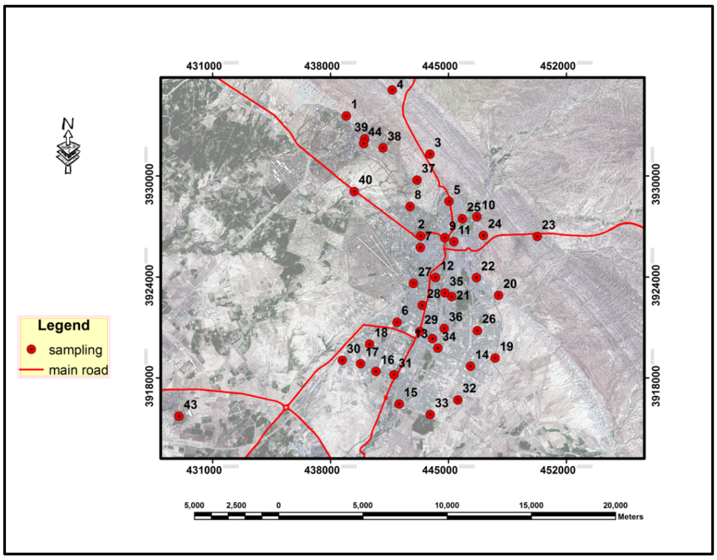

Figure 3: The spatially distribution of the stations in the study area

Table 1: The sites and the recorded average PM_{10} emission of the used stations

Station No.	**Station Sites**	**Average PM_{10}**	**Station No.**	**Station Sites**	**Average PM_{10}**
1	Baba residental area	22	24	Barood Khana	296
2	Arafa	153	25	Sarchanar	121
3	Shoraw hospital	113.5	26	Qadisyaa	87
4	Seekanyan village	25	27	Baghdad station	78
5	Rahimawa	77.5	28	Quides street	119
6	Ihtifallt squer	88	29	Baghdad road	115
7	Baglar health center	138.5	30	Wahed huzairan	139
8	Iraqi drilling company	121.5	31	Domeez	160
9	Almas residental	93.5	32	Tareq company	72
10	Rezgary	59	33	Domeez intersect	75
11	Imam Qasim	163	34	4th bridge	98
12	Kaassa	89	35	Al-Noor residental	91
13	Mualmeen residental	144	36	Al-Arubaa	77
14	Laylan road	50	37	Shoraoo controll	57.5
15	1st Aathar residental	24	38	Eternity fire	46
16	Sayada compartments	84	39	Gas station	52.5
17	Huzairan	238	40	Amal alshaby health	318
18	Gas compartments	100	41	Laylan health center	70
19	Panja Ali	102	42	Taza town	290
20	Panja Ali drinkind st.	92	43	Gas Company	460
21	Al-ullamaa	97	44	Kirkuk Refinary	85
22	Shorija	110			
23	Sulaymanya boundry	224			

3.2 Equipment used

Hi-volume air sampler from (Tish Environmental, Inc.) (Figure 4) and AEROCET 531 Handheld particles mass profiler & counter from (Environmental Remediation Equipment Inc.) have been used to measure PM_{10} concentration levels in the same sampling time. AEROCET 531 provides both particle counts and mass PM measurements as stored data logged values, real-time networked data, or printed results.

The following equations were used to calculate PM_{10} from the measured data obtained by the Hi-volume air sampler:

$$PM_{10} = \frac{\Delta W}{V} \qquad \text{............ (1)}$$

Where: $\Delta w = w_2 - w_1$

W_1=clean filter weight in µg

W_2=filter weight after sampling in µg

V= volumetric flow rate * sampling time .... (2)

Volumetric flow rate =1.13 m^3 /min , Sampling time=60 min.

Figure 4: Hi-volume air sampler

3.3 Analysis for generation of maps

GIS is a powerful tool that facilitates linking spatial data to non-spatial information (Julie, 2007). This study involved incorporating PM_{10} related air pollution data from field measurements into digital map layers for illustrating the application of spatial analysis to Kirkuk city. Easting (x-coordinate) and Northing (y-coordinate) of the sampling sites were determined using Garmin Global Positioning System (GPS) (model: GPSMAP76CSx). PM_{10} concentration measurements and coordinates of locations were stored in excel format while the image satellite of the study area is imported into the GIS environment using ArcGIS 10.3 software. Attribute data were then assigned to spatial objects to be ready for spatial analysis and generation of the air pollution map by using one of the interpolation methods. The georeferencing process of the obtained spatial data in this research was achieved according to the WGS84_UTM_Zone38N system. Georeferencing process is fundamental in data sharing and in integration of spatial data from various sources into a single consistent data set. This is often achieved using a single common geodetic reference ellipsoid, or datum (Heywood et al, 1998).

4. RESULTS AND DISCUSSIONS

The mapping of air pollution with PM_{10} concentration within the study area was carried out using IDW type of interpolation method in ArcGIS 10.3 environment. It's found that IDW interpolation method is the best method for representing the surface map of our PM_{10} spatial data because the applied data is dense enough to capture the extent of local variation needed for the analysis. IDW considered that, the sample points closer to the cell have a greater influence on the cell's estimated value than sample points that are further away. This consideration was clearly appeared in our results.

The interpolated surface map of PM_{10} air pollution dispersion at the study area was shown in Figure 5. The figure indicates that, the PM_{10} emissions are clearly increased in the city's main entrances near the checkpoints (stations no.: 23, 24, 40) due to the exhaust emissions from large trucks and small vehicles. Station no. 17 and 42, the missions can be attributed to exhaust emissions because the station is located on a public street in addition to the existence of industrial zones. Also, it is found that the higher pollution in the sampling location was occurred near the NOC (station no. 43) due to the high emission of fume and solid particulates (Ali, 2013). Table 2 lists the areas of the high emission of the PM_{10} pollution.

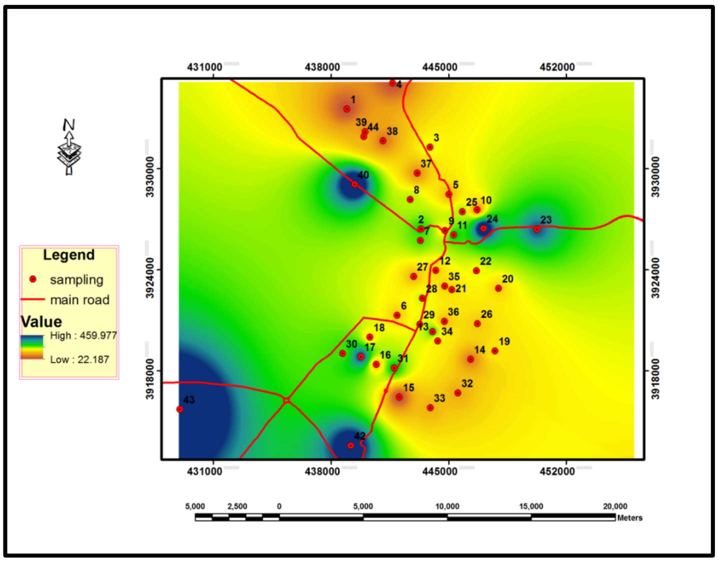

Figure 5: The interpolation surface map of the PM_{10} pollution

Table 2: The areas of the high PM_{10} emissions as comparing with the WHO and Iraqi Standard

Station no.	**Easting (m)**	**Northing (m)**	**Station sites**	**Annual Average PM10 emission** $\mu m3$	**WHO Annual standards** $\mu m3$	**WHO 24 hour standards** $\mu m3$	**Iraq 24 hour standards** $\mu m3$
17	439785	3918854	Huzairan	238	20	50	150
23	450273	3926404	Sulaymanya boundary	224			
24	447075	3926465	Barood Khana	296			
40	439401	3929076	Amal alshaby health	318			
42	427308	3892354	Taza town	290			
43	429004	3915732	Gas company	460			

The PM_{10} emission rate from the stations listed in table (2) is about (34.35%) of total emissions in the study area. The other areas of the low emission concentrations were distributed in the center of the study area, these low emissions could be due to the heavy traffic and high population in the downtown of the city.

The annual average PM_{10} pollution in Kirkuk obtained from all stations depended in this study (table 1) is ($120.8\mu g/m^3$). According to the suggested national ambient air quality standards in Iraq (Obaid, 2012). This value is acceptable and within the prescribed limits of ($150\mu g/m^3$) as can concluded from Fig. 6. However, this result is higher than the limit defined by the World Health Organization (WHO), which equal to ($20\mu g/m^3$) (Strategic Environment Assessment Report, 2013).

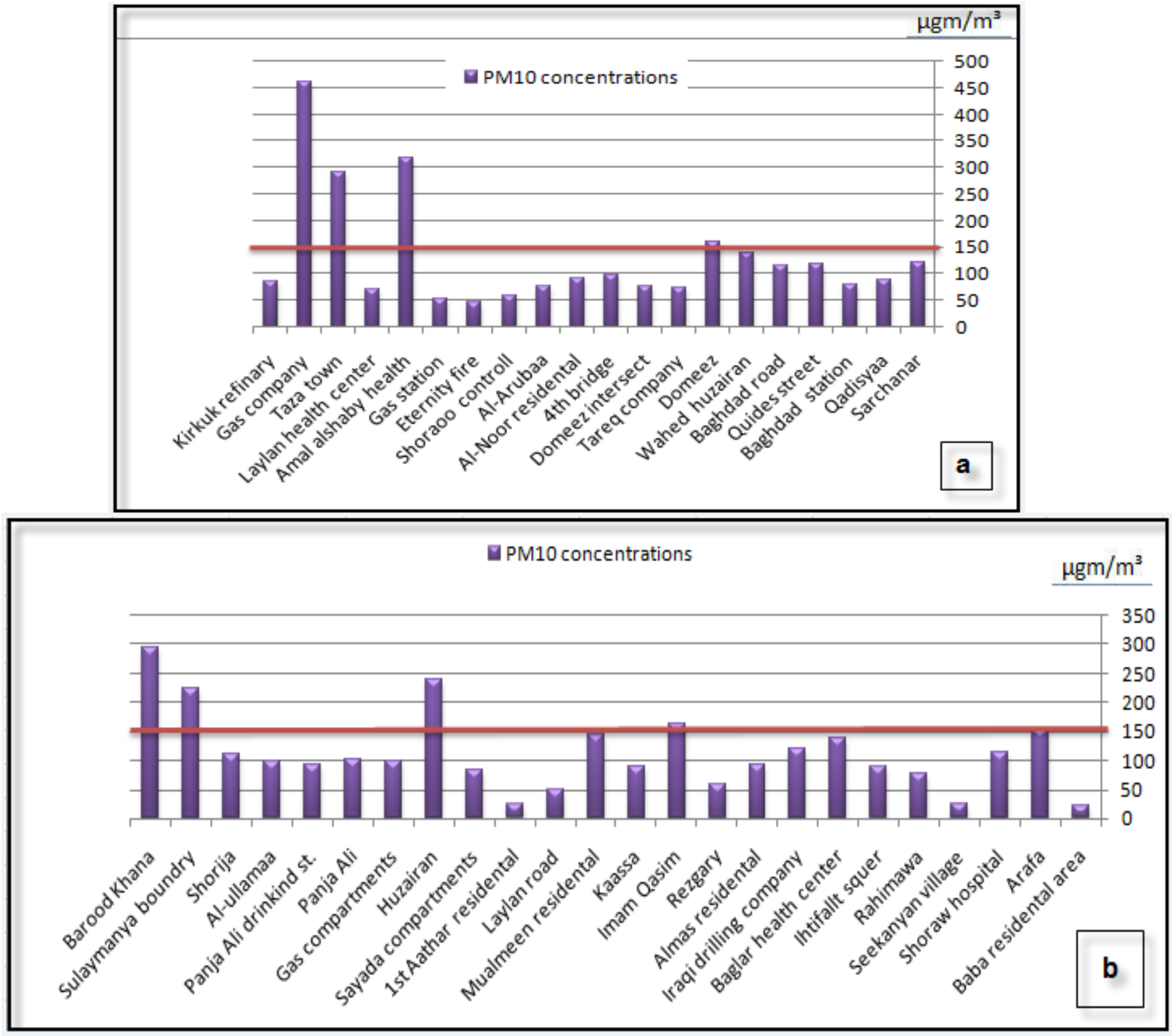

Figure 6: Comparing the levels of the PM_{10} pollution emission with the Iraqi standard limits

5. CONCLUSIONS

It is concluded that, the most emission levels of the PM_{10} pollution have been occurred due to the high emission of fume, solid particulates and the exhaust emissions from large trucks and small vehicles especially in the busy main streets and external checkpoints (special case in Iraq). IDW Interpolation method shows a perfect representation of the PM_{10} predicted map. The PM_{10} emission level was acceptable for the suggested National Ambient Air Quality Standards in Iraq, but not acceptable for the WHO.

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