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Air Quality Index (AQI) for Kirkuk City

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ABSTRACT

Urban air pollution problem is a major concern in many large cities and becomes increasingly critical around the world. The effects of urban air pollution on public health are being felt worldwide. Pollutants can destroy sensitive tissues (in people, animals and plants). Kirkuk city is considered as the main petroleum city in Iraq. The recent year's rapid growth of this city has resulted in a significant increase in environmental pollution. The aim of this research was to measure some important pollutant concentrations such as (SO2, NO2, CO, O3, and $PM_{2.5}$, PM_{10}) in Kirkuk city. The studied area contains (18) sites which are taken for the period (January – May, 2014), the coordinate of each individual sample location was determined by Global Position System (GPS) (Garmin navigator). Geographic Information System (GIS) was utilized to map urban air pollution dispersion over Kirkuk city. Air Quality Index (AQI) for Kirkuk city is calculated using six main pollutants for five months of measurements. The average AQI of Kirkuk city was found to be polluted to unhealthy (AQI values = 101 – 200).

Keywords: *Urban Air Pollution, Particulates Matters, global positioning system (GPS), Geographic Information System (GIS).*

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مؤشر جودة الهواء لمدينة كركوك

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الملخص

تعتبر مشكلة تلوث هواء المدن من المشاكل الرئيسية التي تعاني منها المدن الكبيرة حيث أزدادت نسب التلوث فيها الى مستويات حرجة.وبدأ تأثير هذه الملوثات على الصحة العامة ولساكني تلك المدن .أن الملوثات ممكن أن تدمر الاغشية الحساسة ووظائف أجهزة التنفس وتؤثر على مواد البناء وأثار جانبية أخرى على البيئة.. هناك توسع كبير في مدينة كركوك كونها مدينة نفطية رئيسية في العراق خلال السنوات الاخيرة نتج عنه زيادة ملحوظة في تلوث هواء هذه المدينة. لقد تضمنت الدراسة قياس الملوثات ((PM, SO_2, NO_2, CO, and O_3,)) في (١٨) محطة في مدينة كركوك خلال فترة (كانون الثاني الى مايس 2014). وقد تم اختيار احداثيات المواقع بالاعتماد على نظام نظام المواقع العالمية GPS وباستخدام برنامج نظم المعلومات الجغرافية Arc GIS تم رسم خرائط توزيع أنتشار الملوثات في مدينة كركوك. تم حساب معامل جودة الهواء (AQI) لمدينة كركوك بأستخدام ستة (O_3, CO, SO_2, NO_2, $PM_{2.5}$, PM_{10}) ملوثات أساسية وللاشهر القياس الخمسة.حيث كان معدل قيم جودة الهواء لمدينة كركوك بين (ملوث و غير صحي) (AQI = 101 – 200) خلال فترة القياس.

الكلمات الدالة: تلوث هواء المدن, الدقائق العالقة, نظام المواقع العالمية, نظم المعلومات الجغرافية.

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1. Introduction

Air is essential for all life. All depends on its existence; without it nothing breathes or lives. For these reasons, the monitoring of air quality should be one of the top priorities. Recognizing that air quality has such a great impact on quality of life, the European Union has placed air quality at the top of its thirteen quality of life indicators list [1]. Over the years there has been a continuous increase in human population, road transportation, vehicular traffic and industries which has resulted in further increase in the concentration of gaseous and particulate pollutants released to the environment [2]. Urban air pollution is an environmental problem in many countries. The sources of urban air pollution emanate mostly from combustion activities originating mainly from automobiles and industrial activities. These combustion activities release numerous air pollutants that are toxic to both the environment and to humans [3]. As shown in other studies such as [4], the effects of Air Quality Index value for each day and the information for each of the 45 counties revealed a similarity of behaviors, such as variations in maxima and minima, as well as a dichotomy and divergence of values based on their positions.[5] explained that the people use the API to help them make decisions on outdoor activities; for example, schools and sports organizations may check the latest API (air pollutant index) figures to decide whether outdoor sporting events should be conducted on a certain day. In addition, air pollutants commonly used in AQI / API include nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), reparable suspended particulate matter (PM_{10}), and lead fine suspended particulate matter ($PM_{2.5}$). [6] The main objective of this study is to review the recent literature of Air Quality Index (AQI) and Air Quality Health Index (AQHI). Also, the study used the hourly concentrations of six air pollutants at 47 fixed-site stations in Ontario, measured from 2003 to 2010. The pollutants included in the Ontario AQI are $PM_{2.5}$, O_3, NO_2, SO_2, CO, and total reduced Sulphur compounds.

2. Study Area

Kirkuk is an ancient city. It had been built, firstly, as a castle on a circular four cornered hill. It includes the areas among Zagros Mountain, the rivers of minor Zab and Tigris, and Himreen Mountain series. History of Kirkuk City goes back to 1.600 years B. C. Kirkuk is famous for the shrines, mosques and the ruins of some buildings and antiques it has which can be traced back to the beginnings of the third millennium B. C., i. e. the early beginnings of the

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historical eras, in addition to its geographical and commercial situation [7]. Astronomically, Kirkuk city it is located between the two great circles of (35° 31' 20" N) and (35° 20' 20" S), and two longitudinal circles of (44° 26' 10" E) and (44° 16' 30" W). It is the administration center of Al Tamem State before and currently Kirkuk [8].

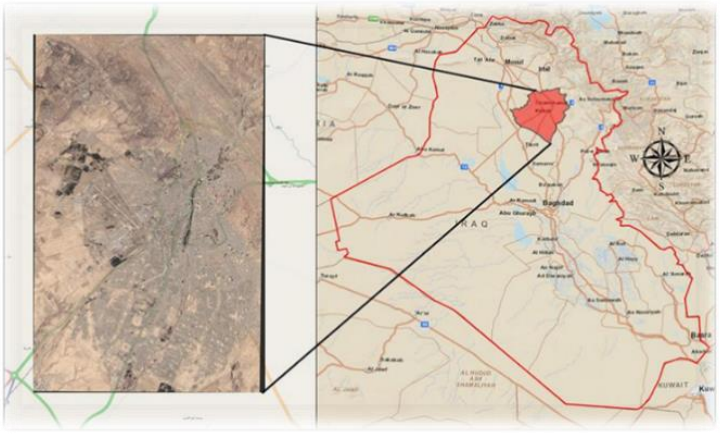

Fig. (1): The satellite image of Kirkuk city & the map of Iraq showing the location of Kirkuk governorate

3. Methodology

3.1. Ground-Base Measurements

Pollutant concentrations were collected at 18 locations around KIRKUK city using Particle Mass Profiler and Counter in a Single Handheld Unit (AEROCET 531 is a small, handheld to measure the PM2.5, PM10). The specialize portable devise which was used for testing and measurements in Selected sites of study included NOVA 600 Series Portable Devices designed to monitor different type of ambient air pollutants such as (CO, NO_2, SO_2) While The Eco Sensors model UV-100 ozone analyzer is used for general purpose measurement of ozone in air (This device is one of Kirkuk Directorate of Environment Equipment). Table (1) shows 18 deferent location of samples distributed in the study area and their names.

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Table (1): Coordinates of the sampling sites by GPS (Garmin navigator)

No.	X	Y	Area Name	NO.	X	Y	Area Name
1	443138	3929753	Chorao control	**10**	441948	3921311	Sahat ihtifalat
2	441111	3931665	Eternity fire	**11**	445386	393034	Shoraw compound
3	440030	3932208	Gas station AB3	**12**	443337	3925746	Baglar health center
4	438943	3933565	Baba residential	**13**	442724	3928192	Drilling company
5	443362	3926437	Arafa	**14**	444792	3926332	Almas
6	439376	3929069	Alamal alshaby	**15**	446694	3927582	Rzgary
7	443904	3931290	Shoraw hospital	**16**	445321	3926091	Imam qasim
8	441665	3935108	Sekanyan	**17**	444241	3923971	Khassa 2
9	445035	3928489	Rahimawa	**18**	444058	3920336	Hay mualmeen

3.2. Air Quality Index

This work mainly deals with the in suite measurements concentration of air pollutants namely (PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO and O_3) at 18 deferent locations in Kirkuk city. The locations are distributed in the whole study area caring of the most important pollutant sources which are eternity fire and flares. Various monitoring programmers have been undertaken to know the quality of air by generating vast amount of data on concentration of each air pollutant (e.g., PM, CO, NOx, SO_2, etc.) in different parts of the world. The large data often do not convey the air quality status to the scientific community, government officials, policy makers, and in particular to the general public in a simple and straightforward manner. This problem is addressed by determining the Air Quality Index (AQI) of a given area. AQI is also known as Air Pollution Index (API) [9]. AQI aims to measuring the status of air pollution with respect to its effect on human health. The mean objective of AQI is to measure the air quality with respect to its effects on human health. AQI is defined with respect to the six main common pollutants, CO, NO_2, O_3, SO_2, $PM_{2.5}$ and PM_{10}.The index for each pollutant is calculated using the following expression. (EPA 1999).

$$I_P = \frac{I_{HI} - I_{LO}}{BP_{HI} - BP_{LO}} (C_P - BP_{LO}) + I_{LO} \quad \text{..... (1)}$$

Where Ip = the index for pollutant p;

Cp = the rounded measured concentration of pollutant p

BPHi = the breakpoint that is greater than or equal to Cp

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BPLo = the breakpoint that is less than or equal to Cp

IHi = the AQI value corresponding to BPHi

ILo = the AQI value corresponding to BPLo

Pollutant concentration is converted in to a numerical index (AQI) which assumes value in the range of (0-500). The overall range is subdivided into six ranges to which six categories of air quality correspond and it is divided into six levels of health concern as shown in Table (2).

The conversion of the concentration of each pollutant to the corresponding numeric value of the AQI is not a simple linear operation. The breakpoint concentration, corresponding to each category, is not at linear scale. Break point concentration has been defined by Environmental Protection Agency (EPA). Different breakpoint concentration values and air quality standards are reported. In defining breakpoint concentrations it would be significant to consider local condition. As different areas of the world are characteristic by different pollution and weather condition influencing the effect of atmospheric pollutant, therefore it is not realistic to assume the same AQI as valid all over the world [10].

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Table (2): AQI and health effect (U.S EPA 2009)

Index	Level	General health effect
0 - 50	Good	None
51 - 100	Moderate	Few or non for general population
101 - 200	Unhealthy	A level that may have harmful impacts on patients and member of sensitive groups and also causes the general public un pleasant feeling
201 - 300	Very unhealthy	Have a serious impact on patients and members of sensitive group in case of acute exposure.
301 - 400	Hazardous	A level which may need to teak emergency measures for patients and members of sensitive groups and have harmful impacts on the general public.
401 - 500	Very hazardous	Healthy people will experience reduced endurance in activities older and the sick people should remain indoors and avoid exercise. Healthy individuals should avoid out activities

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4. Result and discussion

Air quality index (AQI) has developed and implemented for Kirkuk area. Data of six pollutants (O_3, CO, SO_2, NO_2, $PM_{2.5}$ and PM_{10}) are collected from (18) stations during January to May 2014 and the AQI has been calculated using Equation (1) which modifies the break point as shown in Table (3) [11].

Table (3): Modified AQI Break Point of Kirkuk City

O_3 ppm	CO Ppm	SO_2 ppm	NO_2 pm	$PM_{2.5}$ µg/m^3	PM_{10} µg/m^3	AQI	level	color
0.00	0-4.4	0-0.35	0-0.053	0-12	0-54	0-50	Good	Green
0.00	4.5-9.4	0.36-0.75	0.054-0.10	12.1-35.4	55-154	51-100	Moderate	Yellow
0.125-0.164	9.5-12.4	0.76-1.85	0.101-0.360	35.5-55.4	155-254	101-150	polluted	Orange
0.165-0.204	12.5-15.4	1.86-3.04	0.361-0.649	55.5-150.4	255-354	151-200	Unhealthy	Red

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0.205-0.404	15.5-30.4	0.305-0.604	0.650-1.244	150.5-250.4	355-424	201-300	Very Unhealthy	Purple
0.405-0.504	30.5-40	0.605-0.804	1.245-1.644	250.5-350.4	425-504	301-400	**Hazardous**	**Maroon**
0.505-0.604	**40.5-50**	**0.805-1.000**	**1.65-2.0**	**350.5-500**	**505-600**	**401-500**	**v-hazardous**	Maroon

Calculation of AQI

Suppose we have measured concentration of No_2 pollutants (Cp= 0.08 ppm).

Then refer to the No_2 in Table (3) for all the values fall above and below measured No_2 value (0.054-0.10 ppm), which represent Bp_{Lo} and Bp_{HI} in the Equation (1) respectively. Where Bp_{Lo} is the break point that is less than or equal Cp, and Bp_{HI} is the break point that is greater than or equal Cp. Also, from Table (3) our measured value of No_2 (0.08ppm) falls with index values of (51-100) which represents (I_{Lo}) and (I_{HI}) in Equation (1) respectively. Where I_{Lo} the AQI value corresponding to Bp_{Lo} and I_{HI} the AQI value corresponding to Bp_{HI} . Now, we can use Equation (1) to calculate the index of No_2 pollutant:-

$$\frac{100-51}{0.10-0.054}(0.08-0.054)+51=$$

$$\frac{49}{0.046}(0.026)+51=78.69=79 \quad moderate$$

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Table (4): AQI for Kirkuk city (Jan-May 2014)

	* O_3 ppm	*CO ppm	*SO_2 Ppm	*NO_2 ppm	*$PM_{2.5}$ µg/m^3	*PM_{10} µg/m^3	Result	Color
January	0.034	2.674	0.641	0.376	12.5	124.72	Unhealthy NO_2 is high	Red
	Good	Good	Moderate	Unhealthy	Moderate	Moderate		
February	0.037	4.268	0.863	0.509	10.77	121.38	Unhealthy NO_2 is high	Red
	Good	Good	Polluted	Unhealthy	Good	Moderate		
March	0.028	0.622	0.322	0.287	5.83	40.88	Polluted NO_2 is high	Orange
	Good	Good	Good	Polluted	Good	Good		
April	0.030	0.452	0.556	0.376	3.388	50	Unhealthy NO_2 is high	Red
	Good	Good	Moderate	Unhealthy	Good	Good		
May	0.016	0.424	0.554	0.470	3.388	49.166	Unhealthy NO_2 is high	Red
	Good	Good	Moderate	Unhealthy	Good	Good		

***average concentration of the pollutant**

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Table (4) shows that CO, O_3 and $PM_{2.5}$ is in good category of AQI (AQI value = 0-50), while SO_2, PM_{10} and NO_2 in moderate, polluted unhealthy categories of AQI respectively (AQI value=151-200) the overall AQI in January 2014 for Kirkuk area was unhealthy (AQI value =151-200) as shown in Figures (2) and (3) .

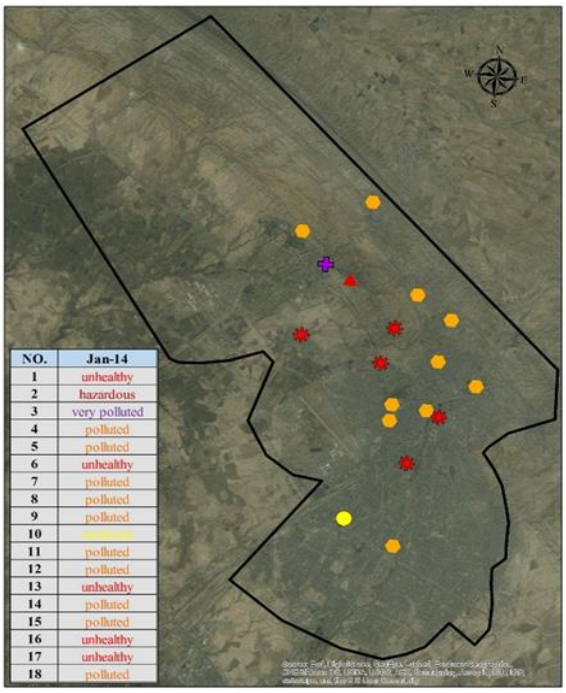

Fig. (2): January 2014 AQI at each sample locations

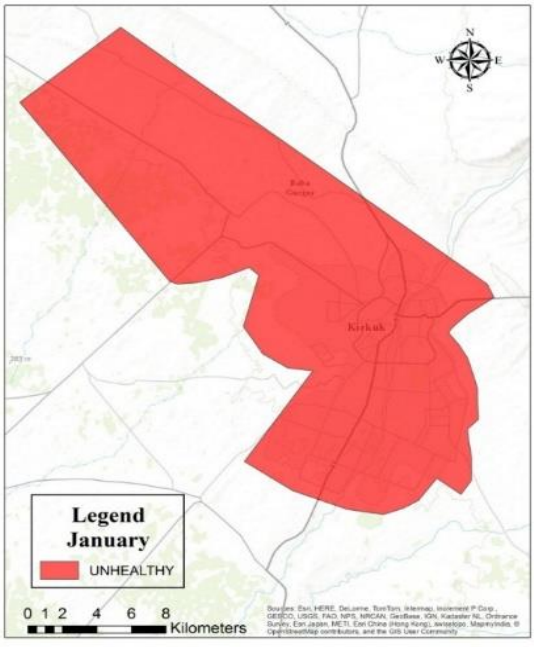

Fig. (3): Overall AQI in January 2014 for Kirkuk area

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In February 2014, CO, O_3, $PM_{2.5}$ in good category (AQI value= 0-50) and SO_2, PM_{10} in polluted Category (AQI value = 101-150) while NO_2 in unhealthy category for Kirkuk city. Figures (4) and (5) shows that the overall AQI was unhealthy (AQI value=151-200)

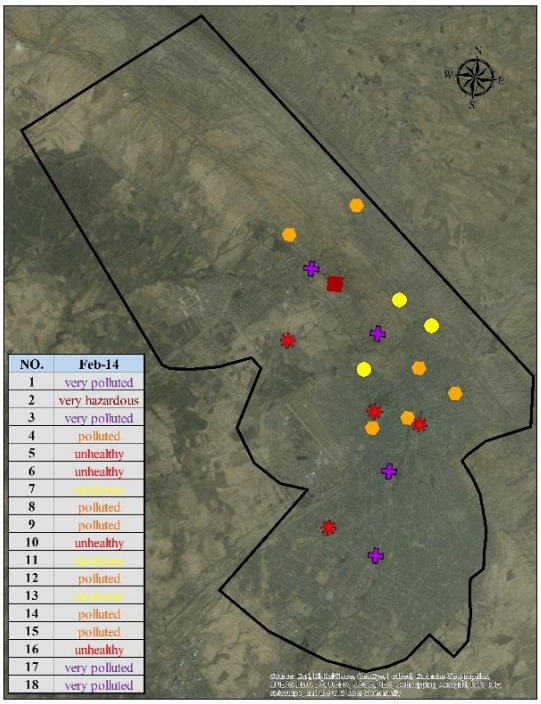

Fig. (4): February 2014 AQI at each sample locations

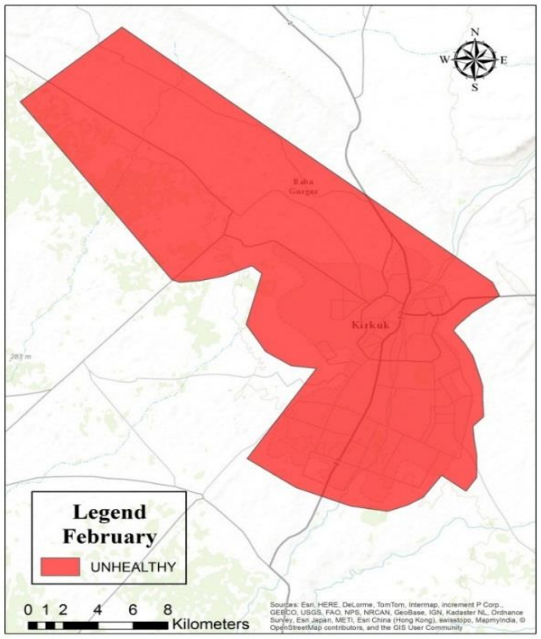

Fig. (5): Overall AQI in February 2014 for Kirkuk area

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In March 2014 only NO_2 in polluted categories (AQI value=101-150) while all other pollutants in good categories (AQI value =0-50). The overall AQI for the city in this month was polluted (AQI value =101-150) and presented in Figures (6) and (7).

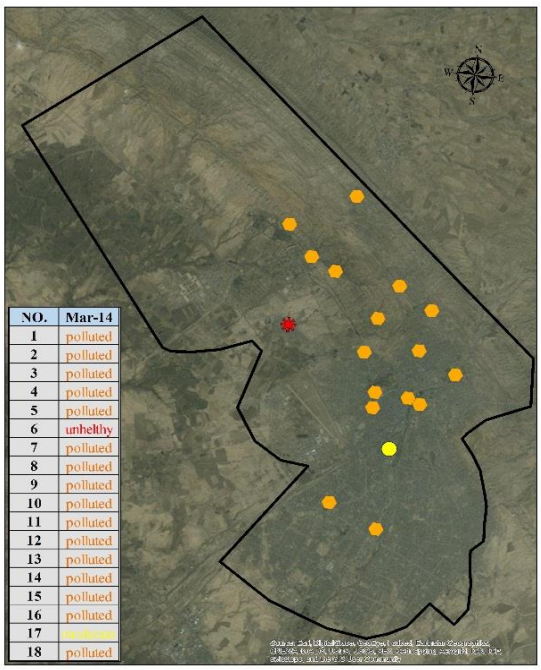

Fig. (6): March 2014 AQI at each sample locations

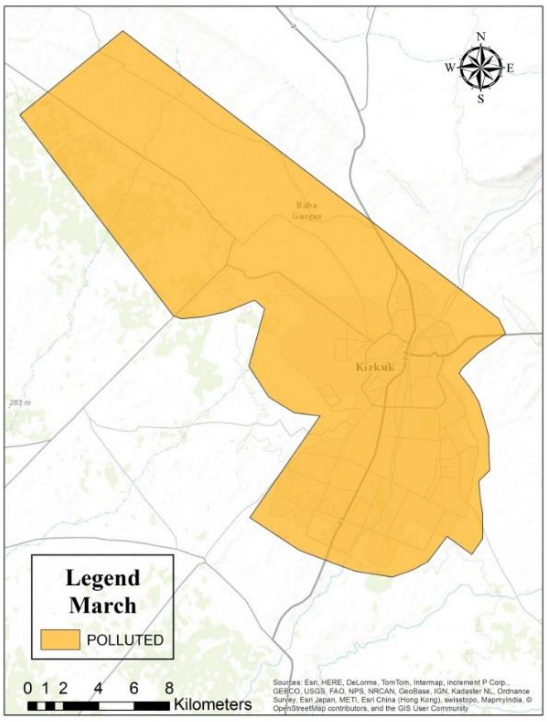

Fig. (7): Overall AQI in March 2014 for Kirkuk area

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The pollutants CO, O_3, $PM_{2.5}$and PM_{10} in good categories (AQI value=0-50). SO_2, in moderate categories (AQI value=51-100) and NO_2 in unhealthy category (AQI value=151-200). The overall AQI in April 2014 for the city was unhealthy category (AQI value=151-200) as shown in Figures (8) and (9).

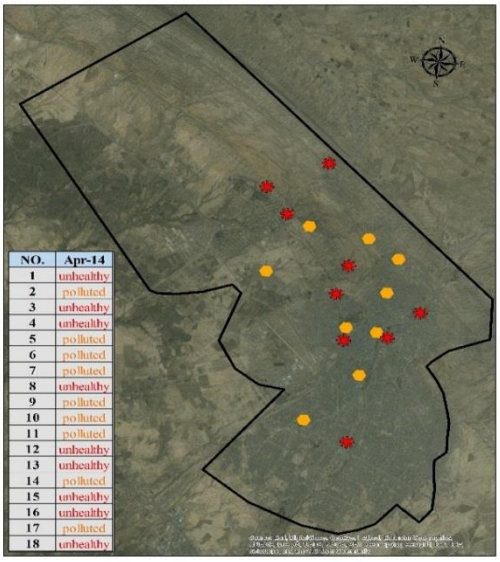

Fig. (8): April 2014 AQI at each sample locations

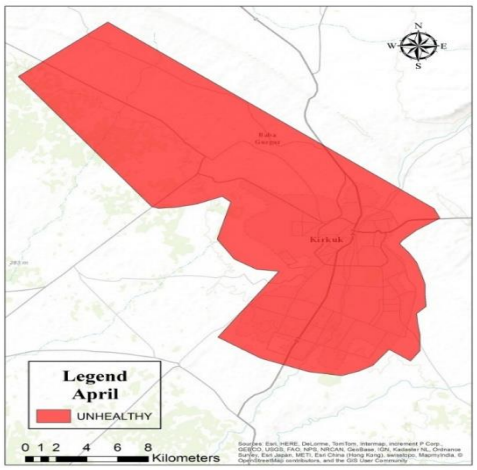

Fig. (9): Overall AQI in April 2014 for Kirkuk area

The pollutants CO, O_3, $PM_{2.5}$ and PM_{10} in good category (AQI value=0-50), while SO_2 in moderate (AQI value=51-100) and NO_2, in unhealthy categories (AQI value=201-300).The overall AQI for the city shown in Figures (10) and (11) was unhealthy category (AQI value= 201-300) .

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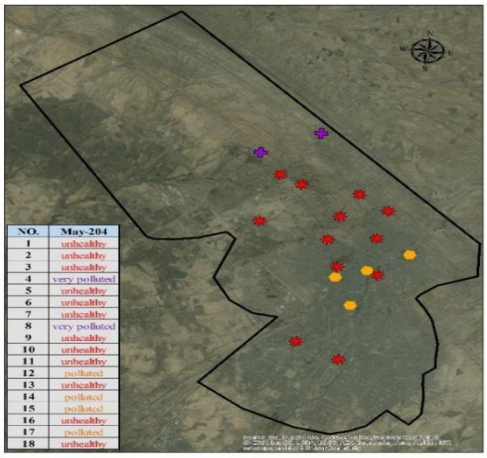

Fig. (10): May 2014 AQI at each sample locations

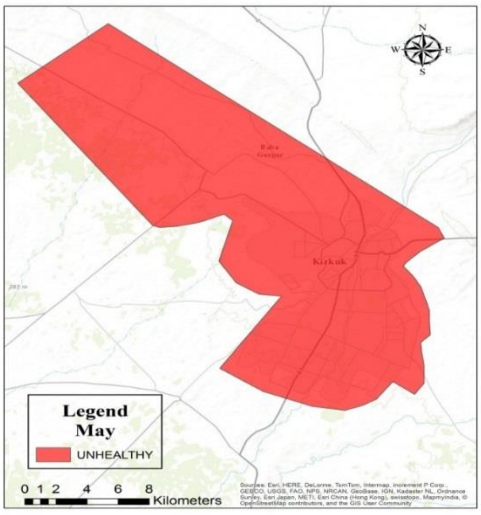

Fig. (11): Overall AQI in May 2014 for Kirkuk area

Generally it can be concluded that the air quality of Kirkuk city was polluted to unhealthy (AQI value=101-200) at the period January to May 2014.

5. Conclusions

The aim of this research was to measure important pollutant concentrations such as (SO_2, NO_2, CO, O_3, $PM_{2.5}$ and PM_{10}) in Kirkuk city. The field works had been done in order to compare the results with international and Iraqi standards. Furthermore, the research went deeper in air quality analysis in which the Air Quality Index of the city had been found showing the environments status of Kirkuk. The main results of this research can be summarized as in The monthly average AQI values over Kirkuk city for period January- May 2014 was found to be polluted to unhealthy (AQI values=101 – 200) according to AQI and

health effect table. Air pollution in Kirkuk city may have harmful impacts on patients and sensitive groups with unpleasant feeling for general public**.**

6. Recommendations

1. There is a need for continuously measuring air pollution parameters in order to determine the concentration of pollutants which results from the refinery and other sources.

2. Local consideration cannot be ignored in applying air quality index. So that EPA AQI is not appropriate for Iraqi urban areas. Therefore, it is important to develop air quality index for the main Iraqi cities. Using local AQI, one could evaluate and compare the air quality status of different locations in relative terms.

3. Around Kirkuk city, data of the existing and new stations could be used for hourly and daily AQI to evaluate air quality of the city.

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