Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.8, 2014

Mapping Dispersion of Urban Air Particulate Matter Over Kirkuk City Using Geographic Information System

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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), impair respiratory functions, degrade building materials and deteriorate the aesthetic aspects of environment. Mapping of urban air pollution dispersion is very complex as it depends upon various factors including weather conditions, urban structural features and their topographic.

In this research , the relationship between in-suite urban air pollutants (particulates matters - PM and total suspend particulate-TSP) and some metrological factors (Temperature, Humidity and wind speed) has been investigated. Geographic Information System (GIS) was utilized to map urban air pollution dispersion in Kirkuk city - Iraq. The rapid growth of Kirkuk city as the main petroleum city in Iraq last years has resulted in significant increase in environmental pollution.

A correlation analysis was performed to establish between air pollutants and metrological parameters. GIS technique was used to investigate the spatial distribution of the pollutants and identification of the city area of high concentration of pollutants.

The results shows that there is a weak linear correlation between metrological factors and most of air pollutants. PM10 only shows a significant correlation with temperature. Generally we can conclude that the impact of metrological factors can be almost ignored. From GIS distribution maps for PM and TSP pollutants, the highest concentration pollutants located around oil industrial area and in the center of the city.

Keywords Urban Air Pollution, Particulates Matters, Total Suspend Particulate, Geographic Information System (GIS) , Correlation Analysis.

Introduction

Urban Air pollution causes a number of health problems and it has been linked with illnesses and deaths from heart or lung diseases. Nowadays, air quality is a major problem in many countries and they having build up their own network for measuring the air quality levels. Air pollution has received considerable attention by local and global communities (Wald & Baleynaul, 1999). Air Pollutant, any substance emitted to or produced in the atmosphere as a result of human activity in sufficient quantity to cause harm to plants, animals or materials. Air pollution is caused by both natural and man-made sources. Major man-made sources include automobiles, power generation and the industrial activities, which represent the main source of air pollution (Byeong et al.,2005).

The aim of air pollution monitoring is to get an estimate of pollutant concentrations in time and space. Urban air Pollution mapping is strongly recommended and required for all large cites for many reasons such as (Wald & Baleynaul, 1999):

- Provides a complete air pollution survey of the city.
- Shows the main sources of pollution with their extension.
- Shows the areas that severely effect by pollution and indicates where efforts should be made to decreases the pollution level.
- Helps further analysis in showing relationship that might exist between city features and air pollution distribution.

Air quality is important to our health and environment, but sources of contamination are often difficult to monitor. GIS technology manages statistical and spatial data to provide a tool that shows the relationship between air quality and occurrences of deficient human and environmental health. In this way, a GIS aids in monitoring pollutant emissions. A Geographic Information System(GIS) can be used to track the Environmental Protection Agency (EPA) regulated pollutant emissions by delineating the effects of smog, dust, and other harmful airborne pollutants on plant and human life. By monitoring those relationships, a GIS becomes a tool conservationists can use to ensure that no further pollution occurs. GIS technology allows to locate where pollutants are coming from and monitor those areas for change to conserve the quality of air (Song 2008; Yerramilli et al., 2011).

The rise of technology and its use in a wide range of disciplines enables air quality researchers with a powerful tool for developing new analysis capability. Indeed, thematic air pollution maps can be developed. Moreover, the organization of data by location allows data from a variety of sources to be easily combined in a uniform framework (David et al,2010) .
GIS has the advantage of the high power of analyzing of spatial data and handling large spatial databases. Indeed, in air pollution there are a large amount of data that GIS can be used for their handling. Data that is used for air pollution studies is air pollutants, wind direction, wind speed, traffic flow, solar radiation , air temperature etc (Patil & Kaushal, 2003).
Kirkuk city- north of Iraq , is one of the most important city in Iraq oil field sources. There is a layer of aerosols and other particulate matter in its atmosphere due to oil fields and refiners, random urban expansion and population growth, the exhaust from huge number of vehicles and heavy traffic, private electric generators. Kirkuk oil refinery industry considered as an important source for air pollutants, where volumes of the released pollutants from these industries were estimated to be in millions of tons per year.
The objective of this study is to investigate the relationships between in suite ground measurements of Particulate matters and Total Suspended particulate pollutants with some metrological data. also using GIS techniques for mapping air pollutants spatial distribution dispersion for these pollutants over Kirkuk area. Air pollution maps can be serves as a basis for proper distribution of air pollution measurement stations.

Urban Air Pollution

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 (Azad et al.,1998; Manjola et al.,2010).
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 (Daly & Zannti, 2007).
Pollutants can be in the form of solid particles , liquid droplets or gases. In addition they may be natural or man-made. Pollutants can be classified as primary or secondary . Primary pollutants are usually produced from a process, such as carbon monoxide gas from motor vehicle. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. Ground level ozone is a prominent example of a secondary pollutant (Monn et al.1997).
There are many primary pollutants produced by human activity. Particulates is one type of these pollutants.

Total Suspended Particulates (TSP)

Total suspended particulate (TSP) refers to all particles in the atmosphere. TSP are tiny particles of solid material or liquid aerosols, defined collectively as particulates, are present in the air, and at high concentrations, may become an air pollution concern. TSP range in size from 0.001 to 500 micrometres and, depending on their size and other properties, may remain suspended in the air for a few seconds or indefinitely. Suspended particles may result from a variety of natural and human sources . These sources include vehicle exhaust emissions, industrial emission sources, soil, road dust, dust resulting from other human activities (i.e. agriculture), smoke from forest fires, smoke from recreational sources (i.e. campfires and fireplaces). TSP was the first indicator used to represent suspended particles in the ambient air In July 1987 (Akimoto, H., 2003).

The particles, with a diameter bounded 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. This fraction of TSP is 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. The impact of suspended particles is significant to human health because exposure to these particles for a long time increases the respiratory diseases, especially asthma, and may lead to lung tissue damage [Wang & Christopher, 2003] . Studying those particles is important because of their long survival periods in the atmosphere, unlike the other big particles which will settle down more rapidly. In addition to that smaller particles seem to interact with other air pollutants, leading to severe damages. The major sources of atmospheric particulates are fossil-fuel combustion (which produces ash and soot), industrial processes (involving metals, fibers, etc.), transportation, wind and soil erosion (producing fugitive dust), and photochemical reactions (complex chain reactions between sunlight and gaseous pollutants) (Yassen et al., 2007).

Particulate Matter (PM)

Also known as particle pollution , or aerosol, is the general term used for a mixture of solid particles and liquid droplets found in the atmosphere. Particulate matter smaller than 10 microns (PM10) is a major air pollutant in cities, particularly in the developing world where maximum levels recommended by the World Health Organization (WHO) are frequently exceeded. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals and dust particles (Masitah et al., 2007). Monitoring natural (dust and volcanic ash) and anthropogenic aerosols (biomass burning smoke, industrial pollution) has gained renewed attention because they influence cloud properties, alter the radiation budget of the earth-atmosphere system, affect atmospheric circulation patterns and cause changes in surface temperature and precipitation (Leili et al. 2008). Particulate matter (PM10) pollution consists of very small liquid and solid particles floating in the air. PM10 particles are less than 10 microns in diameter, this includes fine particulate matter known as PM2.5. PM10 is a major component of air pollution that threatens both our health and our environment (Masitah et al.,2007) .
United State Environmental Protection Agency (USEPA) began using a new indicator, PM10, which includes only those particles with aerodynamic diameter smaller than 10 mm. Recent data suggests that particles of 2.5 um or smaller may pose the greatest threat to human health because, for the same mass, they absorb more toxic and carcinogenic compounds than larger particles and penetrate more easily deep into the lungs. The size of particles is directly linked to their potential for causing health problems. EPA is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. These particles can affect the heart and lungs and cause serious health effects.

Materials and Methods:

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 historical eras, in addition to its geographical and commercial situation.
Kirkuk City is capital of Iraqi governorate of Kirkuk located at 35.47°N, 44.41°E, , 236 kilometers north of the capital, Baghdad. Kirkuk city lies 83 km south of Erbil, 149 km southeast of Mosul, 97 km west of Sulaymaniyah, and 116 km northeast (Fig.1). The population of Kirkuk city is about 600 000 people.
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.

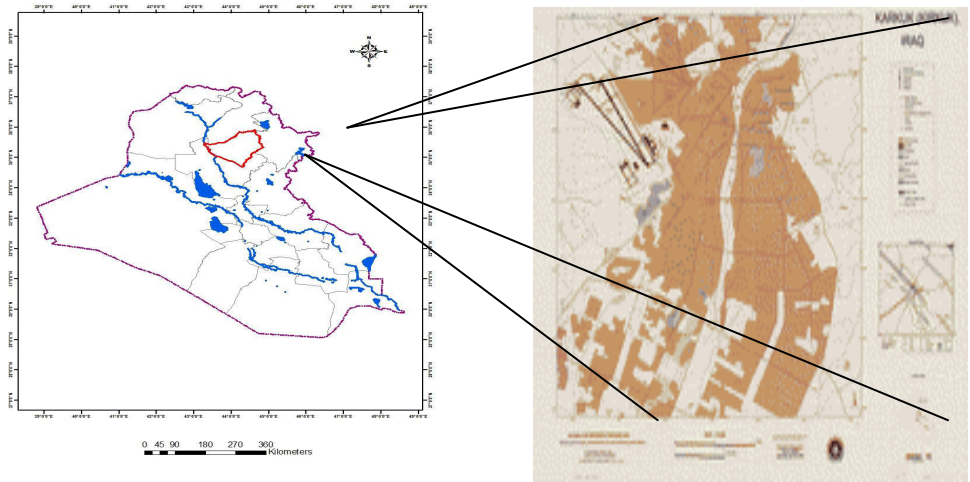

Fig 1. Study area map

Ground-Base Measurements

Pollutant concentrations were collected at 41 locations around KIRKUK city (Figure 2) using Particle Mass Profiler and Counter in a Single Handheld Unit (Aerocet 531) . It is a small, handheld, battery operated and completely portable unit. This unit provides both particle counts and mass PM measurements as stored data logged values, real-time networked data, or printed results. Five Mass Ranges and Two Particle Sizes . All five important mass size ranges (PM1, PM2.5, PM7, PM10, and TSP) are displayed in mass mode as well as two popular cumulative particle sizes (> 0.5 and > 5.0 microns) in particle mode. Temperature and Relative Humidity Option a plug-and-play option that immediately adds ambient temperature and relative humidity capabilities to the displayed and logged data. Pollutant concentrations measured in micrograms per meter cube unit (ug/m3). Wind speed obtained from metrological station (AWS) in the city.

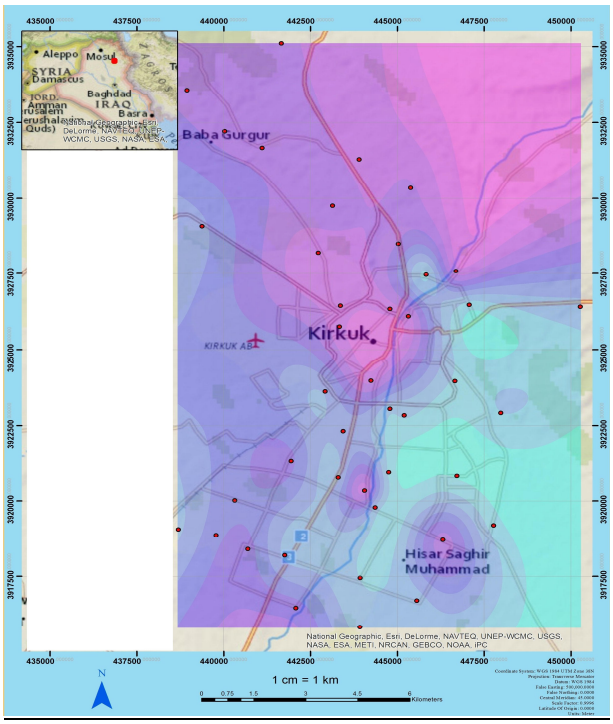

Fig 2- Air pollution stations used in current study

Results and Discussion

Correlation Analysis of Air Pollutants and metrological Factors

Table (1) show the result of linear correlation analysis of air pollutants(PM1, PM2.5, PM7, PM10 and TSP) with meteorological factors(Temperature, humidity and wind speed) for 41 ground stations around Kirkuk city.

As seen from the linear correlation coefficient table, there is a weak positive correlation between PM2.5, PM7 and PM10 with temperature . TSP show a weak negative correlation with temperature, while PM1 have a clear negative linear correlation with temperature. So the effect of temperature on air pollutants can be almost ignored and it seems that temperature effects only on PM1.

In humidity and pollutants correlation, PM1, PM2.5, PM10, TSP shows a weak positive linear correlations, only PM7 have a weak negative linear correlations with humidity. The effect of humidity on all pollutants can be ignored.
PM2.5, PM7 and TSP show a weak positive while PM1 and PM10 show a weak negative linear correlation with wind speed. The effect of wind speed on air pollutants can be almost ignored .

Table.1 Result of Correlation Analysis

	Temp. C°	Humidity %	wind speed m/sec
pm1 µg/m^3	-0.518	0.820	-0.251
pm2.5 µg/m^3	0.105	0.137	0.056
pm7 µg/m^3	0.110	-0.025	0.071
pm10 µg/m^3	0.043	0.036	-0.014
TSP µg/m^3	-0.031	0.151	0.011

Air Pollution Dispersion Maps

Particulates Matter and Total suspended Particulate data from 41 locations were imported in geographical information system environment to drive maps of air pollution dispersion for Kirkuk area. Arc GIS Spatial analysis extension used to produce air pollution dispersion maps by conducting an IDW interpolation on the air pollutant measurement.

Surface maps of Particulates Matter and Total suspended Particulate air pollution dispersion at Kirkuk area were where shows in figures 3-7. Figures shows that the highest concentration of Particulates Matter and Total suspended Particulate pollutants are mostly near and around oil field and refinery. Mostly oil industry activities using a huge amount of consumable fuel like oil refineries , due the high rate emission of fume , solid particulates and toxic gases more than other parts of the study area. Also, figures 6 and 7 shows that some locations of high TSP and PM10 concentration located at the center of city due to structure and distribution of buildings, heavy traffic and high population in the downtown of the city.

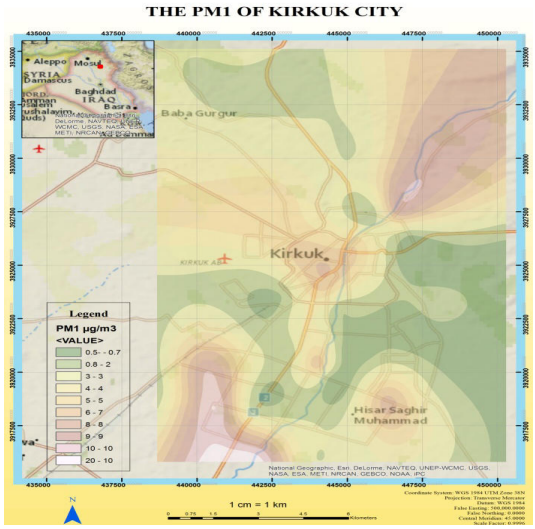

Fig 3. PM1 Spatial Distribution Map

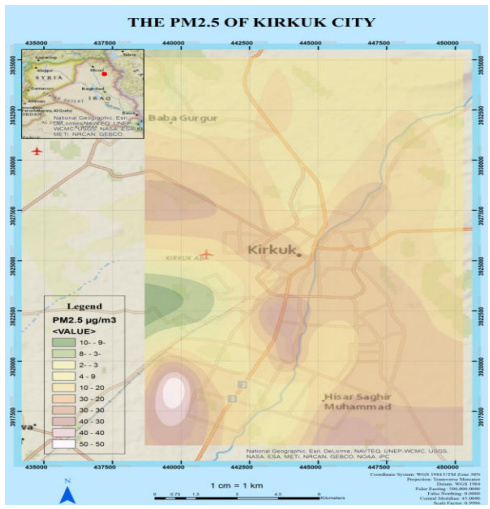

Fig 4. PM1 Spatial Distribution Map

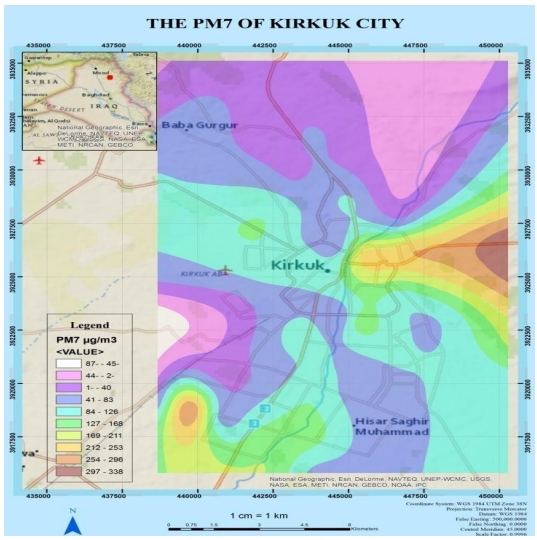

Fig 5. PM7 Spatial Distribution Map

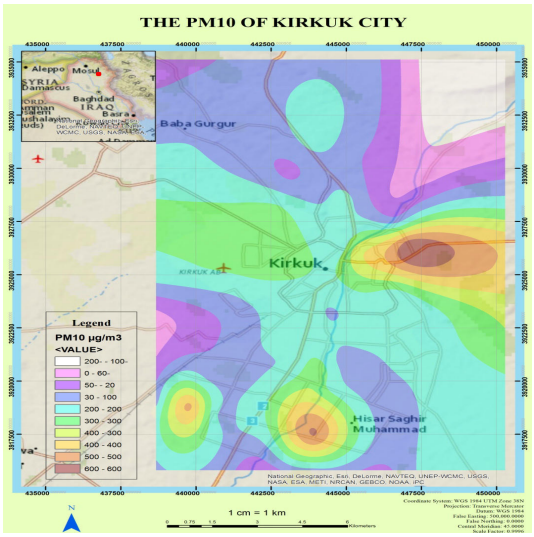

Fig 6. **PM10 Spatial Distribution Map**

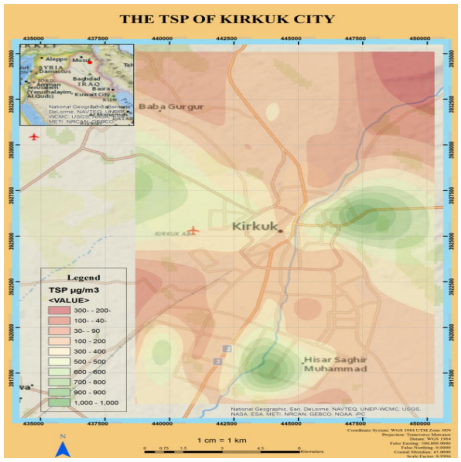

Fig 7. TSP Spatial Distribution Map

Conclusions

This research analyzed and visualized the linear correlation between air pollutants and meteorological factors in the Kirkuk area. There is almost a weak linear correlation between air Particulate matter and Total suspend matter pollutants (PM1, PM2.5, PM7 , PM10 and TSP) and metrological factors (Temperature, Humidity and Wind speed) and due un-significant weak relation we can conclude that the effect of temperature, humidity and wind speed on PM2.5, PM7, PM10 and TSP can be ignored. Only PM1 show significant linear relations with temperature and humidity and the effect of temperature and humidity on PM1 would not be ignored.

ArcGis Analysis distribution air pollution maps show that highest concentration pollutants were near and around oil field, oil refinery and in center of the city. Generally ,Arc GIS air pollution maps can be used as a basis for proper distribution of appropriate locations of air pollution measurement stations.

Acknowledgements

The authors are indebted to Environmental research center - University of Technology - Baghdad for kind permission of using particle mass profiler and count unit (Aerocet 531) in this research.

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