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Distribution modeling of hazardous airborne emissions from industrial campuses in Iraq via GIS techniques

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Abstract. The presence of considerable amounts of hazardous elements in air may represent prolonged lethal effects for the residential and/or commercial campuses and activities, especially those around the emission activities, hence it is so important to monitor and anticipate these concentrations and design an effective spatial forecasting models for that sake. Geographic information systems GIS were utilized to monitor, analyze and model the presence and concentrations for airborne Pb, Cr, and Zn elements in the atmosphere around certain industrial campuses at the northern part of Iraq. Diffusion patterns were determined for these elements via the adaptation of GIS extension; the geostatistical and spatial analysis that implement Kriging and inverse distance weighted (IDW) methods to interpolate a raster surface. The main determination factors like wind speed, ambient temperature and topographic distributions were considered in order to design a prediction model that serves as early alert of future possible accidents. Results of eight months observation program have proved that the concentrations of the three elements had significantly exceeded the Iraqi and WHO limits at most of the observed locations especially for summer times. Also, the predicted models were validated with the field measures and have proved close match especially for the geostatistical analysis map that had around 4% percentage error for the three tested elements.

1. Introduction

In spite of the fact that there is no evident meaning of what an overwhelming metal is, thickness is largely taken to be the characterizing variable. Substantial metals are regularly characterized as those having a particular thickness of more than 5 g/cm3. The primary dangers to human being from substantial metals are related with introduction to lead, cadmium, mercury and (arsenic is a metalloid, however is normally delegated a heavy metal). The sources of heavy metals in air might be characteristic (soils, and transported sediments dregs by winds), or counterfeit incorporate mechanical sources that supply the heavy metals to the air and cause pollution of the air. Although unfavorable health impacts of heavy metals have been known for quite a while, introduction to substantial metals proceeds and is notwithstanding expanding in a few regions. Emanations of heavy metals to the earth happen by means of an extensive variety of procedures and pathways, including to the air (e.g. amid ignition, extraction and handling), to surface waters (by means of overflow and discharges from capacity and transport) and to the soil (and thus into groundwater and harvests). Barometrical outflows have a tendency to be of most prominent worry as far as human wellbeing, both on account of the amounts included and the far reaching scattering and potential for presentation that regularly follows.
Individuals might be presented to possibly hurtful substance, physical and natural specialists in air, nourishment, water or soil. In any case, presentation does not come about just from the nearness of an

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unsafe specialist in the earth. The watchword in the meaning of introduction is contact, hence there must be contact between the heavy metals and the human body organs.

Air quality is important to our health and environment, but sources of contamination are often difficult to monitor. GIS innovation oversees statistical and spatial data to provide a tool that demonstrates the relationship between poor air quality and occurrences of deficient human and environmental health. Along these lines, a GIS aids in monitoring pollutant emissions (ESRI, 2007).
The former uses statistical or other methods to model the pollution surface, based upon measurements at monitoring sites. With the development of GIS and geostatistical techniques in recent years, a wide range of spatial interpolation methods has now become available (Briggs 1992). A number of interpolation methods have found applications in pollution mapping, albeit mainly at a relatively broad, regional scale. Linear interpolation, for instance, has been generally used to derive contour maps of pollution surfaces based on point measurements (e.g., Archibold and Crisp 1983, Muschett 1981). Kriging in its various forms has been used to map national patterns of NO2 concentrations (Campbell et al. 1994), acid precipitation (Venkatram 1988, Schaug et al. 1993) and ozone concentrations (Lefohn et al. 1988, Liu et al. 1995), and to help design continental-scale monitoring networks (Haas 1992). Wartenberg (1993) also reports the use of kriging to estimate and map exposures to groundwater pollution and microwave radiation.

From measured sample points like levels of pollution which stored in a point feature layer or raster layer or by utilizing polygon centroids. With ArcGIS Geostatistical Analyst, you can easily create a continuous surface, or map. At the point when utilized as a part of conjunction with ArcMap ArcMap, Geostatistical Analyst gives a far reaching set of apparatuses for making surfaces that can be utilized to visualize, analyse, and understand spatial phenomena (ESRI, 2013).

Amongst the many interpolation tools, the comparison was limited between Inverse distance weighted (IDW), and Kriging. IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. While Kriging is an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with z-values. Unlike other interpolation methods in the Interpolation toolset, to use the Kriging tool effectively involves an interactive investigation of the spatial behavior of the phenomenon represented by the z-values before the selection of the best estimation method for generating the output surface. The IDW (inverse distance weighted) is referred to as deterministic interpolation methods because they are directly based on the surrounding measured values or on specified mathematical formulas that determine the smoothness of the resulting surface. A second family of interpolation methods consists of geostatistical methods, such as kriging, which are based on statistical models that include autocorrelation—that is, the statistical relationships among the measured points. Because of this, geostatistical techniques not only have the capability of producing a prediction surface but also provide some measure of the certainty or accuracy of the predictions (ESRI, 2015). Kriging assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. The Kriging tool fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. Kriging is a multistep process; it includes exploratory statistical analysis of the data, vario-gram modeling, creating the surface, and (optionally) exploring a variance surface.

2. Study area

The study area lies at the northern part of Iraq at Salah Al-Dien governorate between latitudes (34' 56" – 35' 34") and longitude (43' 30" – 43' 34"). The study area includes the industrial area of Biji oil refinery. Pollution effects of heavy minerals that are emitted from industrial area must be concerned in order to make a vision of their impacts on all population activities in the study area. Also, Fig.1, demonstrates the sampling locations in the study area. The formation outcrops have age of Miocene -Pleistocene and sequences of Fatha Formation; M.

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Miocene, Injana Formation ;L.Miocene, and Mukdadiyah Formation; Pliocene, in addition to Quaternary deposits (Jassim and Goff 2006).
The aim of this study is to prepare a distribution model of some hazardous and risky airborne heavy metal emissions of the industrial areas, utilizing GIS technique procedure in order to give a sign of the ecological effects on the residential and agricultural areas around the industrial area.

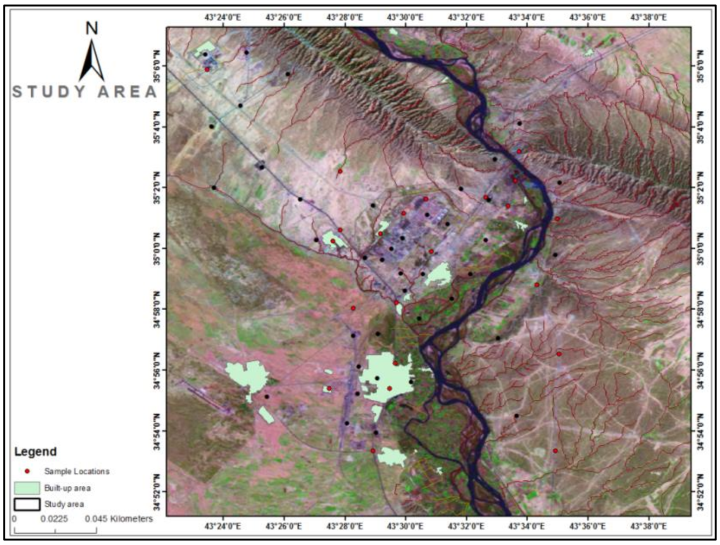


Figure 1. Samples Location in Study Area.

3. Materials and method

The heavy metals concentration in air at the industrial area and the zones around were measured for two periods; January and July 2013. The airborne contaminants were collected by utilizing low volume air sampler (Sniffer) device for twenty-two distinct locations inside and outside the industrial region, considering the predominant wind, due to its critical role in determining poisons appropriation. The air sample tests were arranged to measure the concentrations of Pb, Zn, and Cr in the laboratory via the atomic absorption spectrometry device. The Geographic Information Systems GIS; Arc GIS 10.4 was connected using Geostatistical Analyst in order to estimate noticeable contaminants all around for the inspection period.

4. Results and discussions

4.1. Heavy Metals Analyses

The heavy metal results analyses in the study area are demonstrated in Table.1 for the two periods.

Table 1. The statistical analyses and results of heavy metals.

Characteristics μg/m^3		Pb	Zn	Cr
Concentration of January 2013 period	Min.	0.01	0.01	0.01
	Max.	0.42	0.07	2.13
	Median	0.09	0.03	0.14
	Sd.	0.10	0.02	0.74

Concentration of July 2013 period	Min.	0.48	0.01	0.02
	Max.	5.19	0.08	0.95
	Median	1.62	0.03	0.34
	Sd.	1.45	0.02	0.29
Iraqi National standards (MOE,2008)		3 μg/m^3		
World allowable limits (WHO, 1996)		0.05	6	0.04

The median and standard deviation reflect positively skewed distribution and a high degree of variation. The statistical results of Pb, Zn, and Cr, have medians of 0.09 (min. 0.01, max. 0.42), 0.03 (min. 0.01, max. 0.07) and 0.14 (min. 0.01, max. 2.13) respectively for January 2013. Also, Cd, Co, and Ni have medians of 1.62 (min. 0.48, max. 5.19), 0.03 (min. 0.01, max. 0.08) and 0.34 (min. 0.02, max. 0.95) respectively for July 2013.

The heavy metals data analysis demonstrate that median of the Cr surpasses the world allowable standards (WHO, 1996), and the Iraqi national standards (Ministry of Environment, 2008) breaking points for the two periods. In addition, that median of Pb surpasses (WHO, 1996) standards for July. However, the medians of Pb and Zn for January and two periods respectively are under the two standards. Generally, the heavy metals concentration increase mostly during July as compared to January. The expand of fixation in July can be alluded to the expand of fuel ignition operations at the area, for example, the operations of the power plant which works progressively amid July and in addition the impact of meteorological components reporting the nature effects during this period.

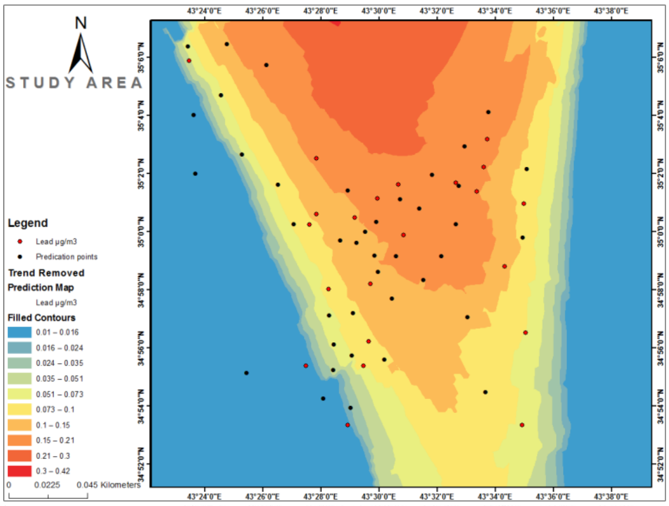
4.2. GIS modelling for hazardous air pollution

The samples were collected from 22 sites all over the study area, yet the contamination values for other (unmonitored) locations in study area are also of interest. Nevertheless, because of cost and reasonableness, the samples cannot be attached from all around. Geostatistical Analyst gives instruments that make ideal predictions possible by inspecting the connections between all the sampling points and producing a continuous surface of contamination concentration, standard errors of predictions, and probabilities that critical values are exceeded (ESRI, 2013).

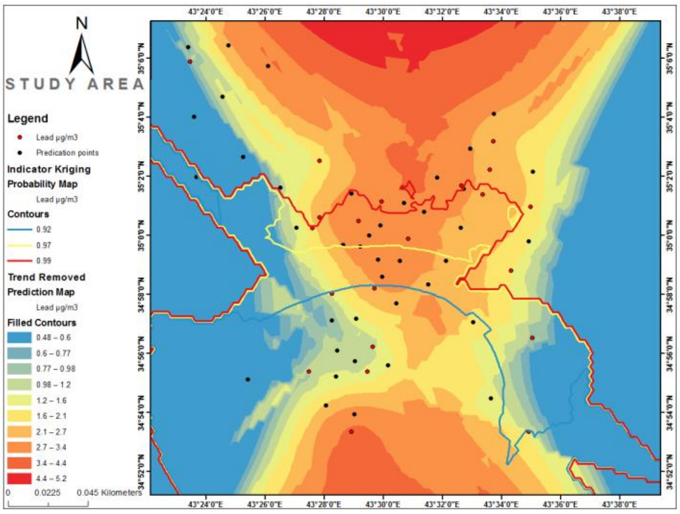
For the present study, examination of different geostatistical analysis interpolation tools have been done in order to create best GIS predictions maps for hazardous air pollutants.

As Kriging is most appropriate when it is confirmed that there is a spatially correlated distance or directional bias in the data. It is often used in soil science and geology (ESRI, 2015), therefore, Kriging interpolation tool with Ordinary kriging type was chosen finally to create a more accurate prediction surface (prediction map) for present study. Ordinary kriging assumes an unknown constant mean. The data points need to be sampled from a phenomenon that is continuous in space. Important parameters include an appropriate transformation, a possible de-trending surface, covariance/semi-variogram models, and search neighborhoods. The statistical analyses of data discovered a global trend. After refinement with the Trend Analysis tool, the results have demonstrated that a second-order polynomial seemed reasonable.

The GIS prediction maps exhibit in Figure (2: a-f) for heavy metals in study area for the two periods. The GIS maps represent the prediction values as filled zones. It can be noted that contaminants have global trend of north and northwest to south and southeast. Also, the their concentrations most rapidly change in the southwest–northeast direction and a more gradually change in the northwest–southeast direction. This is attributed to the prevailing wind direction in the study area. It can be noticed that contaminants have general pattern of north and northwest to south and southeast. Additionally, they most fast alter in concentrations in the southwest–northeast course and a more steadily alter in the northwest–southeast course



(a): Pb January concentration



(b): Pb July concentration

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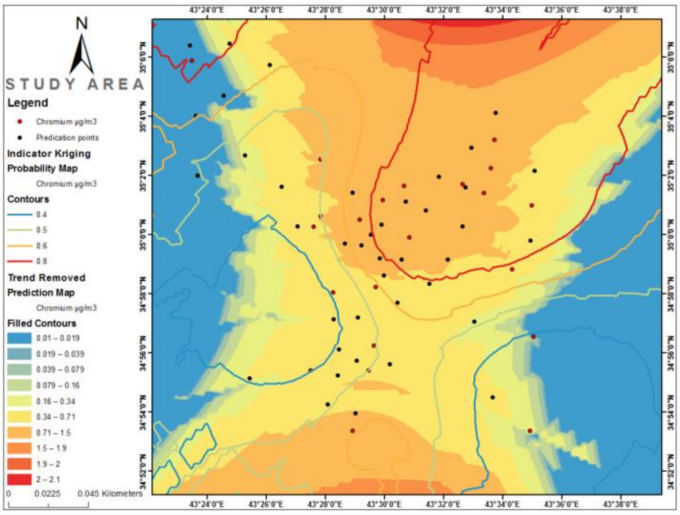
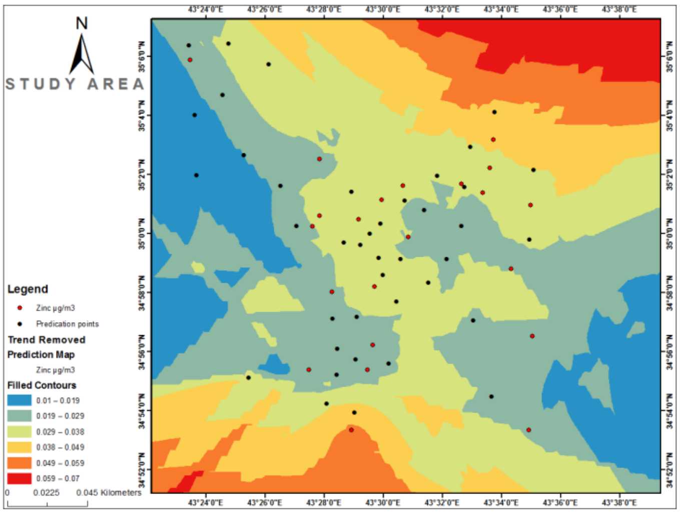
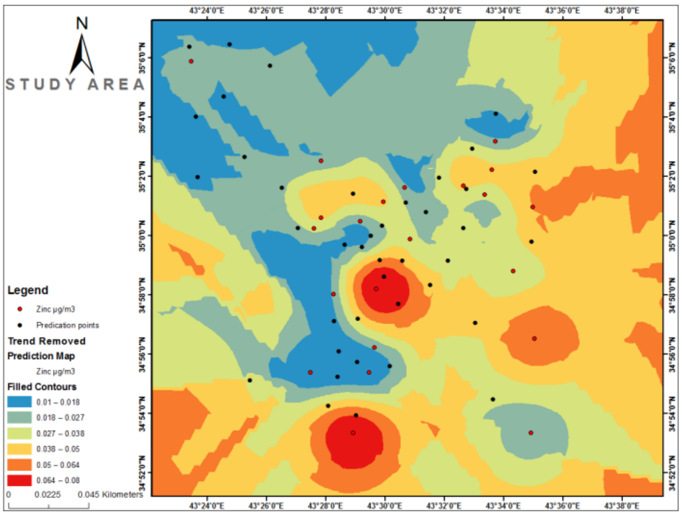


(c): Cr January concentration



(d): Cr July concentration



(e): Zn July concentration

Figure 2. Prediction and Probability GIS maps for heavy metals in study area.

The Geostatistical Analysis with indicator kriging model was used to map the probability that contamination values exceed the WHO guide limits in the study area. The indicator kriging has transformed the contamination values to a series of 0s and 1s according to whether

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the values of the data are below or above a threshold (ESRI, 2015). The GIS maps results from this step are shown in Figures 2, a-e. There is no compelling reason to make the probability map for each of Pb in January, in two periods due to the absence of surpassing to the WHO standard. The maps show the marker expectation values, translated as the probability of surpass to the threshold value. The GIS maps demonstrate the probability values as contour for all contaminants. These contours represent the region of surpassing threshold (standard) values with various probability values. That implies each contour value represents the level of concentration value for particular contaminant. The GIS maps now indicate ranges of high and low prediction of contaminant qualities and areas of high probability that the contaminant concentrations surpassed the WHO Standard.

5. Conclusions

The oil refinery activity in the study area causes heavy metals pollution and negatively affect the environment of population, agriculture and animals.

Heavy metals concentration increase mostly during July than January.

Amongst the various geostatistical analyst interpolation tools, Kriging interpolation tool with Ordinary kriging type is more suitable for the production of accurate prediction maps.

ArcGIS geostatistical analyst economize the cost and reasonableness that are incorporated with collecting samples from all over the study area.

The GIS Predictions (trend removal) map has proved significant performance in foreseeing the values for all contaminants for entire study area. Likewise, the GIS probability maps indicate the probability of some contaminants surpassing guide standards in the study area..

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