Spatial Distribution of Heavy Metals in Surface Soil Horizons Surrounding Erbil Steel Company (ESC) Areas

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ABSTRACT:
This study was carried out during September 2015 to investigate the impact of Erbil Steel Company (ESC) on soil pollution of the surrounding area. Soil samples were collected from 40 sites around Erbil Steel Company at different distances and eight directions (N, NE, E, ES, S, SW, W and NW) on five different circled belts named (50, 100, 500, 1000 and 2000 m) far from the source of the pollution in the study area and 1 sample as control sample. The samples were analyzed for some physico-chemical properties, as well as for the five heavy metals Iron (Fe), Chromium (Cr), Lead (Pb), Zinc (Zn) Copper (Cu) and Nickel (Ni) by using a portable x-ray fluorescence (XRF). As a results of the distance that effected on the heavy metals concentration are: Fe had the highest concentration value and ranged from 4752.00 to 15873.69 mg kg\(^{-1}\) while Cr had the lowest concentration value and ranged from 4.00 to 74.00 mg kg\(^{-1}\) and Pb, Zn, Cu and Ni concentrations ranged from (56.00 to 378.00, 1.27 to 220.40, 8.00 to 85.20 and 1.43 to 10.17 mg kg\(^{-1}\) ) respectively. An interpolation property was applied to prepare the special map of natural distribution of heavy metals of the soils in the studied area using Arc GIS 10.1 programs.

KEYWORDS: Soil pollution, Erbil steel company, Heavy metals, Interpolation map.
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INTRODUCTION:
Soil pollution is one of the most serious problems in the world with long term consequences on human life. In recent years, with the rapid development of industry, various dangerous pollutants such as heavy metals (Cu, Cr, Fe, Mn, Ni, Pb and Zn) have been released due to production, smelting and tailings and got deposited in soils around industrial areas causing serious pollution and soil quality degradation. Iron and steel manufacturing produces important quantities of solid wastes containing heavy metals. Heavy metals and some trace elements are biologically toxic and can affect and threaten the health of human being owing to their accumulation and persistence in the compartments of the food chain. Hence, it is very important to investigate and monitor soil contamination for economic sustainable development and people’s health (Ene and Bosneaga, 2010).

Several analytical techniques have been extensively employed for environmental pollution monitoring, such as: X-Ray Fluorescence Analysis (XRF), Atomic Absorption Spectrometry (AAS) and Inductively Coupled Plasma Spectrometry-Atomic Emission Spectroscopy (ICP-AES) (Popescuet al., 2009). XRF is one of the preferred methods for the assessment of the elemental composition of soils and sediments, because XRF has the advantage of being a rapid and inexpensive method with a simple sample preparation. Quantitative and qualitative analyses by XRF without chemical digestion and a great number of elements can be determined
simultaneously in a short time (Eneet al., 2009). The main aims of the present study was to produce the point interpolation theme maps of the heavy metals concentration of the selected area.

2. MATERIALS AND METHODS

2.1. Descriptions of the study area of (ESC)

The current study was the 1st investigation that carried out at different locations surrounding Erbil Steel Company (ESC) which is located at about 15 km west outskirts of Erbil city (Latitude.36° 08' 18"N, Longitude.43° 47' 43"E), in order to assess the effect of steel industry refuses on soil pollution Fig (1).

2.2. Erbil Steel Company (ESC)

Its establishment commencing in 2006 in Erbil Kurdistan region, ESC has started integrated steel production in December 2006, taking into account its production and employment capacity. Erbil steel company currently is the most prominent heavy industry investment in the region and produces as an average of about 700 ton/day collected scrap irons from different sources and locations in the main raw material of the steel bar manufacturing. All incoming raw materials are melted in induction furnace at 1700°C in the furnace most of the generated or melted matter are heavy metals, including cadmium, chromium, lead and nickel. ESC has also a fume extraction system and this causing pollution (Anonymous, 2010).

Fig.1. Erbil Steel Company (ESC)
Soil sampling around the (ESC)
Soil samples were collected in September 2015 from 41 sites of the surface layer using an auger. The soil samples were taken from sites at eight directions (N, NE, E, ES, S, SW, W and NW) on five different circled belts named (50, 100, 500, 1000 and 2000 m) far from the source of the pollution (Ruffel et al., 2011). Soil sample were mixed thoroughly and then passed through a 2 mm sieve. Quantitative amount of soil samples were taken around the ESC in order to measure total heavy metal concentration in soil samples (mg kg$^{-1}$) after drying, sieving by 2 mm and powdering of the material. Soil samples were analyzed by XRF method and heavy metals were measuring by portable (X-MET7500) XRF analyzer (X-Ray Fluorescence) (Sitko et al., 2004). The selected sites for soil sampling around ESC are shown in Fig (2).

2.4. The point interpolation maps
Soil pollution by heavy metals is commonly assessed by interpolating concentrations of heavy metals (Fe, Cu, Cr, Ni, Zn and Pb) sampled at location points so that each heavy metal represented in a separate map Fig. (3), using Arc GIS 10.1 kriging methods. (Delava and Safari, 2016). Interpolation refers to the process of estimating the unknown data values for specific locations using the known data values for other points. In many instances we may wish to model a feature as a continuous field (i.e. a 'surface'), yet we only have data values for a finite number of points. It therefore becomes necessary to interpolate (i.e. estimate) the values for the intervening points. For example, we may have measurements of the depth of a particular geological stratum from a number of bore holes, but if we want to model the stratum in 3-dimensions then we need to estimate its depth for places where we do not have borehole information (Burrough and McDonnell, 1998). Interpolation is a process of using points with known values to estimate values at other points forming the surface. Also interpolation is used to convert the data from point observations to the continuous fields so that the spatial patterns sampled by these measurements can be compared with the spatial patterns of other spatial entities. Spatial interpolation is thus a means of converting point data into surface data.

3. RESULTS AND DISCUSSION

3.1. Soil map on the basis of interpolation heavy metals.
Mapping the spatial distribution of contaminants in soils is the basis of pollution evaluation and risk control. Interpolation methods are extensively applied in the mapping processes to estimate the heavy metal concentrations at sampled sites. Interpolation accuracy is related to the precise definition of the polluted area and its boundaries. Consequently, this directly affects the accuracy of pollution assessment (Xie et al., 2011). Figure 3 shows the spatial distribution patterns of Cr, Cu, Fe, Ni, Pb and Zn concentrations respectively. The results indicated that the point interpolation method helps to make soil chemical and physical properties and heavy metals concentration maps and their distribution patterns for selected study area. Table (1) declared the results in the present study of the heavy metals in the soil around of Erbil steel company were higher than the other studied sites or in comparing with control sample this agree with (Khudhuret al. 2016).
Table 1. Concentration of heavy metals of studied soils at different distance from ESC

| Samples Direction | Locations No. | Distance from the factory (m) | Cr | Cu | Fe | Ni | Pb | Zn |
|-------------------|---------------|-------------------------------|----|----|----|----|----|----|
|                   |               |                               |    |    |    |    |    |    |
| E                 | 1             | 50                            | ND | ND | 5732 | 8.60 | 56 | 22.80 |
|                   | 2             | 100                           | ND | ND | 5032 | 6.45 | ND | 3.80 |
|                   | 3             | 500                           | ND | ND | 5510 | 4.30 | ND | 4.43 |
|                   | 4             | 1000                          | ND | ND | 5540 | 7.17 | ND | 3.17 |
|                   | 5             | 2000                          | ND | ND | 5366 | 8.93 | ND | 2.53 |
|                   | LSD .05       |                               |    |    | 789.1 | 6.72 |    | 15.07 |
| SE                | 6             | 50                            | ND | 6 | 14.0 | 6325 | 4.30 | 103 | 37.75 |
|                   | 7             | 100                           | ND | 17 | ND | 5840 | 8.60 | ND | 5.90 |
|                   | 8             | 500                           | ND | ND | 5766 | 5.73 | ND | ND  |
|                   | 9             | 1000                          | ND | ND | 5256 | 5.73 | ND | 1.27 |
|                   | 10            | 2000                          | ND | ND | 5842 | 5.73 | ND | 0.63 |
|                   | LSD .05       |                               |    |    | 348.0 | 8.80 |    | 13.12 |
| S                 | 11            | 50                            | ND | 5 | 16.0 | 6700 | 1.43 | 90  | 37.60 |
|                   | 12            | 100                           | ND | ND | 4952 | 5.73 | ND | 12.63 |
|                   | 13            | 500                           | ND | 4 | ND | 5910 | 7.17 | ND | 3.80 |
|                   | 14            | 1000                          | ND | ND | 6008 | 5.73 | ND | 3.80 |
|                   | 15            | 2000                          | ND | ND | 5068 | 7.87 | ND | 3.17 |
|                   | LSD .05       |                               |    |    | 1322.2 | 6.50 |    | 13.73 |
| SW                | 16            | 50                            | ND | 6 | 44.8 | 1075 | ND | 288.0 | 115.90 |
|                   | 17            | 100                           | ND | 6 | 13.0 | 6435 | 2.87 | 56.0 | 39.90 |
|                   | 18            | 500                           | ND | ND | 5596 | 5.73 | ND | 3.80 |
|                   | 19            | 1000                          | ND | 4 | ND | 5386 | 5.73 | ND | 1.90 |
|                   | 20            | 2000                          | ND | ND | 5298 | 7.17 | ND | 1.90 |
|                   | LSD .05       |                               |    |    | 1676. | 9.47 |    | 63.77 |
| W                 | 21            | 50                            | ND | 14| 24.0 | 1194 | ND | 252.0 | 155.8 |
|                   | 22            | 100                           | ND | 54 | ND | 1134 | 9.00 | 378.0 | 180.5 |
|                   | 23            | 500                           | ND | ND | 5728 | 9.80 | ND | 7.60 |
|                   | 24            | 1000                          | ND | 8 | ND | 5262 | 10.2 | ND | 3.80 |
|                   | 25            | 2000                          | ND | ND | 5500 | 5.73 | ND | 2.85 |
|                   | LSD .05       |                               |    |    | 5535. | 4.33 |    | 102.96 |
| NW                | 26            | 50                            | ND | 58 | ND | 1122 | 0.00 | 207 | 153.90 |
|                   | 27            | 100                           | ND | 85 | ND | 1587 | 2.87 | 234 | 220.40 |
|                   | 28            | 500                           | ND | ND | 5692 | 5.73 | ND | 4.75 |
|                   | 29            | 1000                          | ND | ND | 6299 | 5.73 | ND | 1.90 |
|                   | 30            | 2000                          | ND | ND | 5184 | 0.00 | ND | ND  |
|                   | LSD .05       |                               |    |    | 1013.98 | 7.00 |    | 126.77 |
| N                 | 31            | 50                            | ND | 74 | ND | 6084 | 9.90 | ND | 3.17 |
|                   | 32            | 100                           | ND | ND | 5276 | 8.67 | ND | 3.80 |
|                   | 33            | 500                           | ND | 4 | ND | 4752 | 5.73 | ND | 5.07 |
|                   | 34            | 1000                          | ND | 8 | ND | 5178 | 1.50 | ND | 1.27 |
|                   | 35            | 2000                          | ND | ND | 5432 | 4.30 | ND | 1.27 |
|                   | LSD .05       |                               |    |    | 710.9 | 5.92 |    | 4.28  |
| NE                | 36            | 50                            | ND | 9 | ND | 5672 | 2.87 | ND | 5.70 |
|                   | 37            | 100                           | ND | 5 | ND | 5244 | 8.60 | ND | 1.90 |
|                   | 38            | 500                           | ND | 4 | ND | 5960 | 5.73 | ND | 1.90 |
|                   | 39            | 1000                          | ND | ND | 5676 | 5.73 | ND | 1.27 |
|                   | 40            | 2000                          | ND | 4 | ND | 6121 | 5.73 | ND | 1.27 |
|                   | LSD .05       |                               |    |    | 827.7 | 7.28 |    | 3.79  |

| Control          | 4750          | ND | ND | 5263 | ND | ND | ND |

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Fig. 3. Patterns of (Cu, Ni, Zn, Fe, Cr and Pb) contents for the selected area derived by point interpolation
In general, the high accumulation of (Cr, Cu, Fe, Ni, Pb and Zn) in the center of the regions and decreasing these metals concentrations by moving away from the center of study area. Obviously the results of metal occurrence indicated that while Fe was the most dominant metal and highest concentration this result agree with (Khudhuret et al., 2018). This may be due to the locations were used as a storage of scraps most of wastes were scrap cars which manufactured from steels or iron this result agree with (Lak, 2007) observed that the iron has earlier been reported to the most abundant mineral in Erbil plain soils, while the lowest value of iron may be due to this location was away from the source of pollution (steel scrap site) and this agree with (Simon and Fadoju, 2016) obtained that the concentration of iron decreased with increasing horizontal distances from the scrap metal dump. There was a negative correlation between iron and nickel so the results of interpolation showed that the distribution of Ni was unlike iron which was lower in the center and being higher by faring away from the center of study area. While the leachate passes into soil, polluted materials are adsorbed on the soil. The high amount of chromium in location (31) may be due to this location lies near from the ESC and chromium originates in the environment mainly from anthropogenic sources industry emissions and combustion processes. The dumping of industrial waste materials significantly increase chromium concentration in soil Further, Cr found in particles of the atmosphere which released from the smoke of factories, while the low amount of Cr in locations (33 and 38) may be due to these locations lies away from factory and Cr in the soil were higher within the factory than outside of the factory (Salami et al., 2014). This high value may be due to this location is located inside the ESC, this company smelting scraps of steel and these scraps melting containing amount of copper. This is agree with (Jankeet et al., 2000) detected that Cu is introduced into steel melts by the smelting of scrap which originates from steel grades containing an increased amount of copper. For example, structural steels can contain up to 0.5% Cu. As well as this high value of copper may be due to the dust released from steel factory which contained amount of heavy metals like Cu, Pb and others and this agree with (Skorbiłowicz and Samborska, 2014) studied that the emissions of dust from factories containing heavy metals, especially Cu and Pb, into the atmosphere from steel works, while the lowest mean value of copper (8 mg. kg\(^{-1}\)) was obtained from location (34) in the N direction which lies (1000 m) away from the source of pollution and this low value may be due to this location far away from the source of pollution. The lowest and highest value of Pb both lies 100 m away from source of pollution but the highest value located at W direction while the lowest value located at SE direction and this means that this metal is deposited into soil at various distances depending on wind velocity, metal concentration in soil can vary greatly according to the strength and direction of wind, type of soil, composition and soil pH (Michael et al., 2015). The high value of Zn may be due to result from dust or fume of steel company, this location is inside of ESC and this site exposed to dust of company more than another site and this is agree with (Xuet et al., 2003) obtained that high amount of zinc is a result of inhaling large amounts of zinc as dust or as fumes associated with metal fume fever. As well as the causes of increasing Zn is a result of steel industry and this is agree with (Elekes, 2014).

4. CONCLUSIONS

According to the results obtained from this study the ESC refuses effects on soil properties such as increasing the heavy metals concentration at surrounding area of the factory. The velocity and direction of wind affected upon the concentration and transferring of heavy metals that present at the direction of the wind. The distance and depth effects on the distribution of heavy metals in the study area of ESC and some of the heavy metals were increased with depth and distance while some of them were decreased.

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