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Spatial distribution and source identification of major and trace elements in topsoil from Erbil region, Iraq

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ABSTRACT

This paper examined a total of 103 samples that were collected from various land usage in the Erbil area, Northern Iraq. These samples were sieved with 850 µm and analyzed by ICP-MS for the spread of 26 trace elements including some major elements such as Al, Ca, Mg and Fe. The research sought to determine the breadth of human pollution and anthropogenic input in the area, where a variety of industrial and economic operations, transit, and natural temperature variables may all add to pollution. Statistical tactics like mean, median, standard deviation, skewness, kurtosis, and multidimensional statistical approaches were utilized to analyze the analysis data. To determine trace element amounts at unmeasured sites, the inverse distance weighted (IDW) extrapolation technique was used. The levels of Ag, Be, Cu, Mo, Ni, Sb and Zn in the studied soil samples were found to be greater than the acceptable boundaries established by the Iraqi Ministry of Environment. For evaluating the scope of human pollution, the enrichment factor (EF) and geoaccumulation index (I_{geo}) were computed. The findings revealed that the enrichment factor (EF) values for trace elements in topsoil samples were mostly greater than 2, indicating moderate to exceptionally high enrichment, with Be, Ca, Cd, Cu, Mo and Zn having the greatest enrichment factor values in the study. According to the I_{geo} categorization, some trace elements, like Cu, Mo, Sb, and Zn, were mildly to highly polluted. The influence of different land uses on studied elements were investigated through the Kruskal–Wallis H test. This research emphasizes the importance of efficient industrial area manufacturing, transit administration and landfill management for reducing the negative impacts on the ecosystem and human health in the Erbil area. The study also aimed at the contamination stratus of the analyzed elements.

Keywords: Spatial distribution, trace elements, topsoil, Erbil, Iraq

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التوزيع المكاني وتحديد مصدر العناصر النزرة في التربة السطحية من منطقة أربيل، العراق

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الملخص

تناولت هذا البحث 103 عينة تم جمعها من مختلف استخدامات الأراضي في منطقة أربيل، شمالي العراق. وقد تم غربلة هذه العينات بـ 850 ميكرومتر وتحليلها بواسطة ICP-MS لمعرفة انتشار 26 عنصرًا أثريًا بما في ذلك بعض العناصر الرئيسية مثل Al و Ca و Mg و Fe. وقد تم خلال البحث تحديد مدى التلوث البشري والمدخلات البشرية في المنطقة، حيث قد تؤدي مجموعة متنوعة من العمليات الصناعية والاقتصادية والنقل ومتغيرات درجة الحرارة الطبيعية إلى زيادة التلوث. واجريت المعالجات الاحصائية مثل المتوسط والوسيط والانحراف المعياري والانحراف والتفرطح والأساليب الإحصائية متعددة الأبعاد لتحليل بيانات التحليل. لتحديد كميات العناصر النزرة في المواقع غير المقاسة، تم استخدام تقنية الاستقراء الموزونة بالمسافة العكسية (IDW). وقد وجد أن مستويات Ag و Be و Cu و Mo و Ni و Sb و Zn في الرواسب أكبر من الحدود المقبولة التي وضعتها وزارة البيئة العراقية. لتقييم نطاق التلوث البشري، تم حساب عامل الإثراء (EF) ومؤشر التراكم الجيولوجي (Igeo). كشفت النتائج أن قيم عامل الإثراء (EF) للعناصر النزرة في عينات التربة السطحية كانت في الغالب أكبر من 2، مما يشير إلى إثراء متوسط إلى مرتفع بشكل استثنائي، مع وجود Be و Ca و Cd و Cu و Mo و Zn ذات أعلى قيم لعامل الإثراء في الدراسة. وفقًا لتصنيف Igeo، كانت بعض العناصر النزرة، مثل Cu و Mo و Sb و Zn، ملوثة بشكل خفيف إلى شديد. تم التحقيق في تأثير استخدامات الأراضي المختلفة على العناصر المدروسة من خلال اختبار Kruskal-Wallis H. يؤكد هذا البحث على أهمية التصنيع الفعال للمناطق الصناعية وإدارة النقل وإدارة مكبات النفايات للحد من التأثيرات السلبية على النظام البيئي والصحة البشرية في منطقة أربيل. كما هدفت الدراسة إلى طبقة التلوث للعناصر المحللة.

INTRODUCTION

Rapid industrialization and urbanization in Erbil city led to economic development and created a chance to be a developed city in the near future; on the other hand, this development will have a negative impact on the environment dramatically. Environment can abate the adverse effect. However, it is alarming now to take steps to ensure that this pollution will not cross the line. Drastic increase of vehicles and its emission on one hand, and increased population on the other hand are the main reason to degrade the system [1, 2]. The situation of 120-meter ring road highway polluted by vehicle emission, industrial pollution and landfill leachate were all studied and received much concentration due to its toxicity [3].

Soil is composed of organic matter, mineral particles, water, and air (gas) [4]. The soil matrix plays a crucial role in perpetuating life on Earth by providing the foundation for food production and supporting a vast array of ecosystem services [5]. Soil is also a receptacle for pollutants, such as trace elements that can accumulate and pose a hazard to the environment and human health [5]. Trace elements are elements that are typically present in soil at concentrations of less than 100 ppm but can still have significant environmental and physiological effects [6, 7].

The accumulation of trace elements in soil can occur naturally through geological processes but can also result from human activities like industrial activities, mining, and agriculture [7, 8]. In addition to the source of trace elements, other factors such as soil properties, climate, and land use can affect their distribution and bioavailability [9].

Increased level of studied elements in the environment may uptake by human through food chain because of its transfer by aquatic media [10]. One area that has been particularly affected by trace element contamination is Erbil region. Erbil is the capital of the Kurdistan Region of Iraq and is a rapidly growing urban center with a population of over one million people. The region is also home to a large number of agricultural and industrial activities, which can contribute to the contamination of soil with trace elements [3, 11].

The study of trace element distribution and sources in soil is therefore crucial for assessing the risk of exposure to trace elements, and for designing effective strategies for soil remediation and management. Numerous research has examined the level and distribution of trace elements in soil in various regions of the world, including Iraq [3, 11, 12]. The concentrations of heavy metals and trace elements in Iraqi urban soils were studied by [3, 13]. According to the results, the levels of trace elements in the soils were much greater than what is considered safe by WHO. Soils near industrial sites and those irrigated with wastewater contain the highest concentrations of these components. In addition,[14] studied the trace elements' distribution in Basra. The investigation revealed that (As, Zn, Cu, Ni, Co, and Pb) soil concentrations exceeded international standards. The increasing concentration of these heavy metals was a result of petroleum industries and the byproducts of fuel combustion in power plants. In addition, the investigation revealed that the mean concentrations of (B, V, Cr and Fe,) in the soil were lower than the international standards, which may be due to the character of the soil in the investigated region.

[15] presented a comprehensive evaluation of soil contamination resulting from a steel factory in Erbil city. The study reveals that the highest metal concentrations except for Al, were found in the vicinity of the Erbil Steel Company (E.S.C.). The dominant heavy metals in the soil followed the trend of Fe, Al, Zn, Mn, Ti, Pb, Cu, Ni, Cr, V, Co, As, Mo, and Cd. Notably, the concentration of Ni exceeded the limits set by the World Health Organization (WHO) in all sampled sites. Various contamination indices, such as index of Geoaccumulation (Igeo), enrichment factor (EF), contamination factor (CF), degree of contamination (Cdeg), pollution load index (PLI), element contamination index (ECI), and the overall metal contamination index (MCI), were employed to assess soil pollution. Comparisons with local soil backgrounds from Erbil city indicated moderate contamination in Sahdawa, Shamamal, and Sardasht areas, primarily with As, Co, Cr, Mn, Mo, Ni, Ti, V, and Zn. However, Sahdawa exhibited significant contamination by Pb. Sites 2-8 displayed a substantial degree of contamination ($16 \leq$ Cdeg $<$ 32). The PLI values, except for Sardasht, indicated a decline in site quality (PLI $>$ 1), highlighting the impact of the steel factory. Factor analysis identified three factors: metals originating from E.S.C. activities, a lithogenic factor, and the sampling date[16] Investigated and thoroughly researched the environmental impact of major and trace elements in selected Erbil city soils using ICP-MS analysis technique. The study found that Fe, K, Ce, Al, Na, P, Cr, Se, Rb, Li, Be, B, Sc, V, Sr, Y, Zr, Mo, Sn, Ga, As, Ba, Cd, Cs, La, Th, and U are in higher levels compared to the local background, however, are below international pollution levels. Despite exceeding pollutant levels, Ni, Cu, and Zn are not toxic or hazardous due to their immobility in current environmental conditions. Industrial sites and Citadel soils have critical Co, Mn, and Pb levels. All analyzed regions have higher Ca concentrations than international soil limits, Mg is lower, and Erbil Citadel soil samples have significant P values,

which are hazardous. This study provides crucial soil environmental data for Erbil.

Other studies in Bangladesh, Tunisia and Nigeria on source identification and spatial distribution on highways and roadsides conducted using the same methods used in this study also shows the increased amounts of heavy metals due to human activities and industrial input[2, 10, 17, 18] evaluated the level of soil pollution in Al-Qadisiyah Governorate, Iraq by employing GIS and Contamination Index. The investigation employs soil sampling and characterization techniques to evaluate the contamination levels of Cd, Ni, Pb and Zn using the I-geo contamination index and GIS methodologies. The findings indicate diverse levels of pollution, wherein the element Cd has significantly contaminated the soil in various strata. The research highlights the existence of elevated concentrations of Cd, Ni, Pb, and Zn in the soil, which may be associated with the burning of fossil fuels and diverse anthropogenic waste materials. The results underscore the importance of utilizing contamination indices and Geographic Information System (GIS) techniques to assess and control soil contamination in a proficient manner.

As the study aims to determine the contamination grade of the analyzed elements in different areas in question, the potential anthropogenic and geogenic soil input composition is studied. Mine versus non-mine geochemistry of the topsoil studied as per [17, 19]. Monitoring of anthropogenic input of heavy metals is commonly performed to establish the distribution of pollutant and source identification [20]. Amongst the statistical techniques, each of IBM SPSS, mean, median, kurtosis and skewness studied. Enrichment factor (EF) and geoaccumulation index (Igeo) techniques used to determine the grade of pollution [21]. Finally, ARC GIS 10 used to generate IDW maps to investigate the spatial distribution of several heavy metals [3]. Despite these previous studies, there is still a lack of comprehensive evidence on the distribution and sources of trace elements in soil in Erbil region. The aim of this research is also to provide a detailed insight of the contamination level and to fill this knowledge gap by investigating the concentration and distribution of trace elements in topsoil from heavily populated Erbil city. Moreover, identifying potential sources and caused of trace element contamination and its enrichment. However, not all analyzed and investigated elements discussed thoroughly due to their normal range appearance and their relation in discussion with other elements.

METHODOLOGY

Study area and sampling sites.

Erbil is one of the main and fast-growing communities in the Kurdistan region of Iraq, situated roughly 350 kilometers north of Baghdad, see figure 1 for more detail. It is home to a variety of industrial activities, such as oil and gas refineries, cement factories, and metal processing facilities. These industries are regarded as major pollutant contributors in the region. Moreover, the city is a transport center, with heavy road and rail traffic. Erbil's climate is characterized by chilly winters and scorching summers, with approximately 500 millimeters of annual precipitation. Although there are no ship-breaking yards or terminals in the city, its location in northern Iraq makes it a strategic hub for international trade. Erbil's population is estimated to be around one million, with a number of minor villages and agricultural zones in the adjacent area. The intricate relationship between Erbil's industrial activities, transportation, and natural climate indicates that environmental pollution is a major concern for the city's residents.

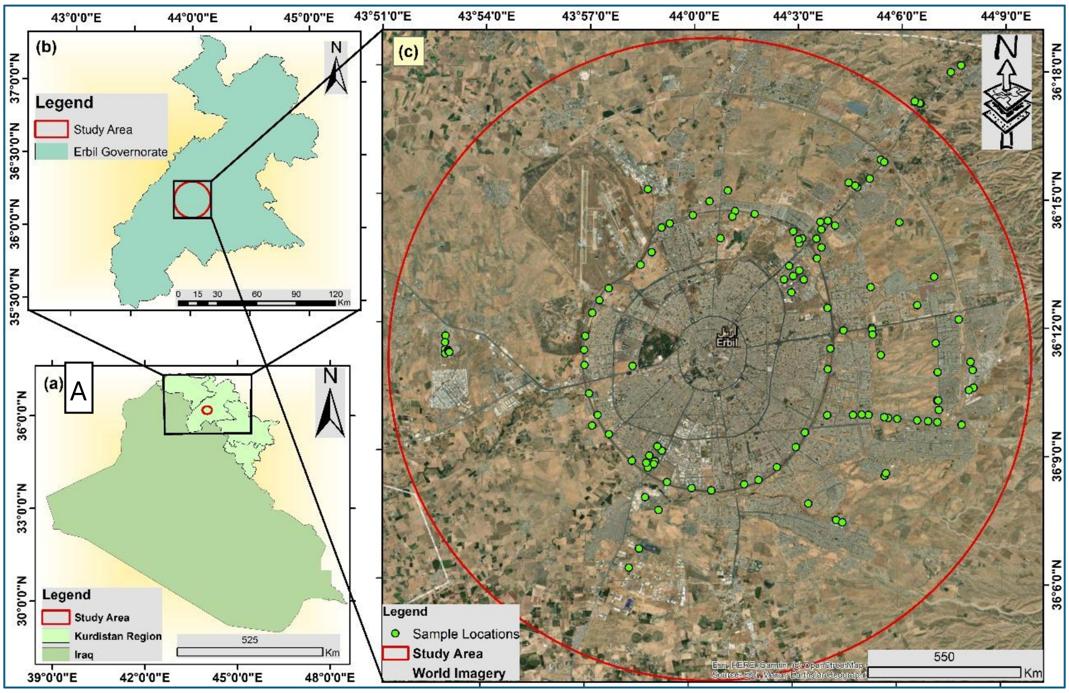

Fig. 1: Map showing the studied area: (a) Iraq and Iraqi Kurdistan region; (b) Erbil governorate; (c) Satellite image of the study area with sample locations.

Sample Collection and Preparation:

A total of 103 topsoil samples were gathered from Erbil region. see the figure 1 above. The sampling locations were selected based on land utilization and land cover information obtained from satellite imagery and field observations. The sites were categorized into four land use types: agricultural, industrial, residential, and natural (undeveloped and undisturbed nearby land).

At each site, three composite soil samples were gathered from a depth of 5 cm utilizing a stainless-steel hand auger. The composite samples were combined thoroughly and homogenized for obtaining a representative sample. The samples were placed into polyethylene bags and conveyed to the laboratory. Then, they were air-dried in the laboratory, crushed and passed through a 1 mm sieve for removing large particles and other debris.

Major and trace Element Analysis:

The concentrations of 26 trace elements (Ag, Al, Be, Ca, Cd, Co, Cu, Cr, As, B, Ba, K, Mg, Mn, Pb, Sb, Se, Mo, Na, Ni, Th, Ti, V, Zn) in the soil samples were identified utilizing inductively coupled plasma- Mass Spectrometry (ICP-MS) SHIMADZU ICPE-9820 at Atmosphere company labs in Erbil. The samples collected from each site were manually homogenized and weighed to 0.5 g utilizing a microbalance capable of weighing 100 g. To prepare the samples for analysis, they were digested with a mineral acids' digestion reagent HNO_3 65% HCl 36% and HF 40% because ICP-MS requires aqueous and homogeneous solution. It is a recent development in analytical chemistry using microwave techniques in extracting heavy metals from contaminated soil [22]. The resulting digested samples were then with the operation method of appropriately adding 6 milliliters of HNO_3, 2 mL of HCl, and 2 mL of HF. Through high pressure microwave digesters (BIOBASE) and microwave oven. Which will significantly reduce time, effort, and solvent wastage.

For determining the levels of trace elements in the soil and fugitive dust samples, inductively coupled plasma-mass spectrometry (ICP-MS) was used. The analysis was conducted utilizing an Agilent 7700x ICP-MS system equipped with a high matrix introduction (HMI) kit. The elements analyzed included Ag, Al, Co, Be, Cu, Cr, B, Ba, Ca, K, Mg, As, Cd, Mn, Ni, Pb, Mo, Na, Th, Ti, Sb, Se, V, and Zn. For ensuring the precision and accuracy of the results, the procedures of the quality control and assurance were employed throughout the process preparing and analyzing the samples. Sandy loam soil (CRM030-50) from RT Corp. was digested and analyzed alongside the samples to measure the extraction procedure's recovery efficiency. Elements were recovered at levels between 80–110 percent of their certified concentrations. The validity of the calibration curve throughout analysis was checked utilizing a continuing check verification standard solution.

Statistical Analysis:

Statistical methods were used to the analytical data in order to reveal patterns and associations. The contents of the elements in the soil samples were analyzed utilizing IBM SPSS Statistics version 22. Basic statistical metrics including the mean, median, standard deviation, skewness, and kurtosis were used. The same program was also used to conduct Kruskal-Wallis H test. Trace element concentrations in unmeasured areas were estimated applying Geographic Information System (GIS) mapping software (ArcGIS 10) and the inverse distance weighted (IDW) interpolation approach.

Assessment of Contamination Methods:

The enrichment factor (EF) is a widely used index for determining the origins of trace elements in soil (either crustal or anthropogenic) and for assessing the extent of human influence. It is calculated using Equation 1 as derived from [23]:

$$EF = \frac{\left(\frac{CTE}{CR}\right)sample}{\left(\frac{CTE}{CR}\right)Backgroung} \text{ ....Equation 1.}$$

Here, (CTE/CR) sample is the ratio of the concentration of trace elements (TE) to that of the reference element (R) in the soil sample, and (CTE/CR) background is the corresponding value for the soil in the control area. Here, we calculated EF values for surface soil samples against a regional geochemical background soil which is crustal average by mason is used in this study as a background value [24]. Due to its abundance in the area's soil, aluminum (Al) was selected as the standard. However, previous studies have relied on other crustal elements as references, including titanium (Ti), strontium (Sr), iron (Fe), manganese (Mn), and sodium (Na) [25]. Human impact on soil has been measured using a number of EF categories. This research divided enrichment levels into five categories according to [26, 27]: low (EF2), moderate (EF5), high (EF20), very high (EF40) [1-3].

The trace element's pollution levels in rural, urban and industrial soils are assessed utilizing the geoaccumulation index (Igeo) (4). Igeo is employed by [4] to determine soil pollution by trace elements by comparing their present concentrations to pre-industrial levels. The concentrations earth's crust is utilized for Igeo calculations since obtaining pre-industrial concentrations is often difficult. The index is computed using Equation 2:

$$Igeo = log2\frac{CTE}{1.5*BTE} \text{ ....Equation 2.}$$

Here, CTE represents the level of trace elements in the analyzed soil, while BTE indicates the element concentrations in the earth's crust, as stated by [28]. The constant 1.5 accounts for lithogenic variations in a given substance's environmental content and enables the detection of minor anthropogenic influences (4). The Igeo classifications as per[29] are as follows: uncontaminated (Igeo≤0), uncontaminated to moderately contaminated (0<Igeo≤1), moderately contaminated (1<Igeo≤2), moderately to strongly contaminated (2<Igeo≤3), strongly contaminated (3<Igeo≤4), strongly to extremely contaminated (4<Igeo≤5), and extremely contaminated (5<Igeo).

2- Results and discussion:

Table 1 provides information on the average concentration of trace elements found in the topsoil, as well as their distribution across Erbil area sites. The statistics for overall median, kurtosis, and skewness are also included.

The findings of the major heavy metals analysis indicates that the heavy metal loads of the soil samples were higher than the control reference values which are crustal average indicated in [9]. This could be resulted to the serious anthropogenic influence from industrial, commercial and domestic wastes earlier discarded at the sites [5].

The metals Ag, Ba, Ca, Cd, Cu, Ni, and Pb had respective mean concentrations of (0.868 ppm), (50.93 ppm), (70417 ppm), (0.78 ppm), (90.83 ppm), (29.86 ppm), and (1.667 ppm) respectively. These disparities may be attributable to differences in Erbil's industrial and agricultural activities and pollution sources in comparison to the locations studied[6,7]. In addition to the increased anthropogenic inputs in Erbil, the variations in the geological composition of the soil and the presence of specific minerals in Erbil, as well as the influence of localized anthropogenic input, also have an impact on the city's water quality.

Comparing the findings of this research with [9], it was found that the mean concentration of Ag in this study (0.868 ppm) was higher than their reported value (0.06mg/kg). Similarly, the mean concentrations of Mo, Cu, Cd and V were less in the study of [9].

The elemental concentration of Arsenic (As) also showed exceeding limit set by [9] especially in soil samples at both north and south industrial areas. This high concentration of the element is likely due to the presence of liquid industrial waste as well as the combustion of fuel derivatives containing some heavy elements including arsenic [10, 11]. Zinc also showed increased concentration at landfill sites. This increased value is due to the metal's increased leaching behavior in semi-aerobic landfills [12, 13]. Beryllium (Be) also showed some spikes especially at landfill sites, which is due to its solubility as salts such as $BeSO_4$ and $BeCl_2$. The enrichment is mainly due to the combustion of fossil fuel, coal and municipal solid waste incineration [14, 17].

The mean concentration of Cobalt in particular shows some increase in industrial areas Perhaps, the exceeding high concentration is due to the generators, machineries and equipment. as the waste that generate from combustion of fossil fuel used in operating them contain high concentration of diverse heavy metals including Cobalt [19].

High concentration of copper found in agricultural land which might be due to the high usage of pesticides and fertilizers [20]. Cu concentration also found high in roadside samples. These results are from extensive road usage and anthropogenic input including tire residuals, emissions from heavy traffic usage, combustion of lubricating oil and fuel[21].

According to table 1, Antimony (Sb) shows relatively low concentration, The reason of having low concentration in the studied samples might be due to that property of antimony which absorbed easily and forms hydrous oxides. In soils it is also mildly mobile as it attaches to Al, Mn, and Fe [9]. In addition, as per [18] which has been conducted in Aliaga, Turkey, observed several differences. The mean concentrations of Ca, Fe, Al and Mg were significantly lower in the Erbil area compared to the Aliaga region. Conversely, the mean concentrations of Zn, K, Mn and Pb were higher in the Aliaga compared to Erbil area. Moreover, this study observed significantly different concentrations of Fe, Ca, K, AI , Mg, Na , P, Li, Be and Ba than findings observed by[16]. Furthermore, [22] who conducted an investigation in Wasit Governorate, Iraq, reported different mean concentrations for Fe, Mo, Cu, Pb, Mn, As, Cd, and Sr compared to the findings of this study. Various environmental circumstances and possible sources of contamination should be taken into account, since these investigations were done in various parts of the world. Depending on local geology and human activity, we may explain the observed differences in elemental concentrations [3, 22].

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Table1: Elemental concentrations in Erbil area and distributional statistics (concentration in ppm)

Element	Mean	Median	Skewness	Kurtosis
Ag	0.868	0.876	-0.359	-0.198
Al	8444	8430	-0.05	-1.188
As	4.171	4.13	0.058	-0.985
B	8.95	8.883	0.135	-0.691
Ba	50.93	38.703	2.215	6.26
Be	58.231	49.131	0.296	-0.952
Ca	70417	67633	0.474	-0.435
Cd	0.778	0.488	2.385	8.246
Co	7.145	6.429	1.957	5.577
Cr	4.117	3.078	1.908	2.971
Cu	90.83	76.6	2.954	12.342
Fe	4810	4197	3.271	12.11
K	1336	1426	-0.771	-0.333
Mg	2254	2233	0.789	3.324
Mn	296	288	0.368	-0.626
Mo	2.609	2.63	0.051	-0.637
Na	149	145	0.362	-0.63
Ni	29.867	18.931	8.016	64.494
Pb	1.667	1.62	2.813	14.331
Sb	0.244	0.243	0.364	0.315
Se	0.733	0.628	3.29	15.679
Th	2.289	2.247	1.386	4.747
Ti	180	61.8	1.168	-0.217
U	0.345	0.34	0.357	0.841
V	124	117	0.576	-0.624
Zn	74.625	37.312	0.743	-0.584

The (figures 2) below show IDW-generated maps of the geographic distributions of various elemental concentrations. The similarity in patterns of distribution between Zn, Cd, and V, despite the differences in their amounts, suggests that these elements were released from the same or nearby sources. Cu was distributed spatially in a somewhat different pattern than Zn, Cd, and Cr. Scraps from ship breaking are used for copper recycling, which involves stripping the plastic insulation off of copper wire and technological debris. This process involves setting fire to the plastic covering in an open place. Figures 2 demonstrate that V hotspots, a marker for fuel-oil combustion, were most prevalent in the refinery section of the peninsula.

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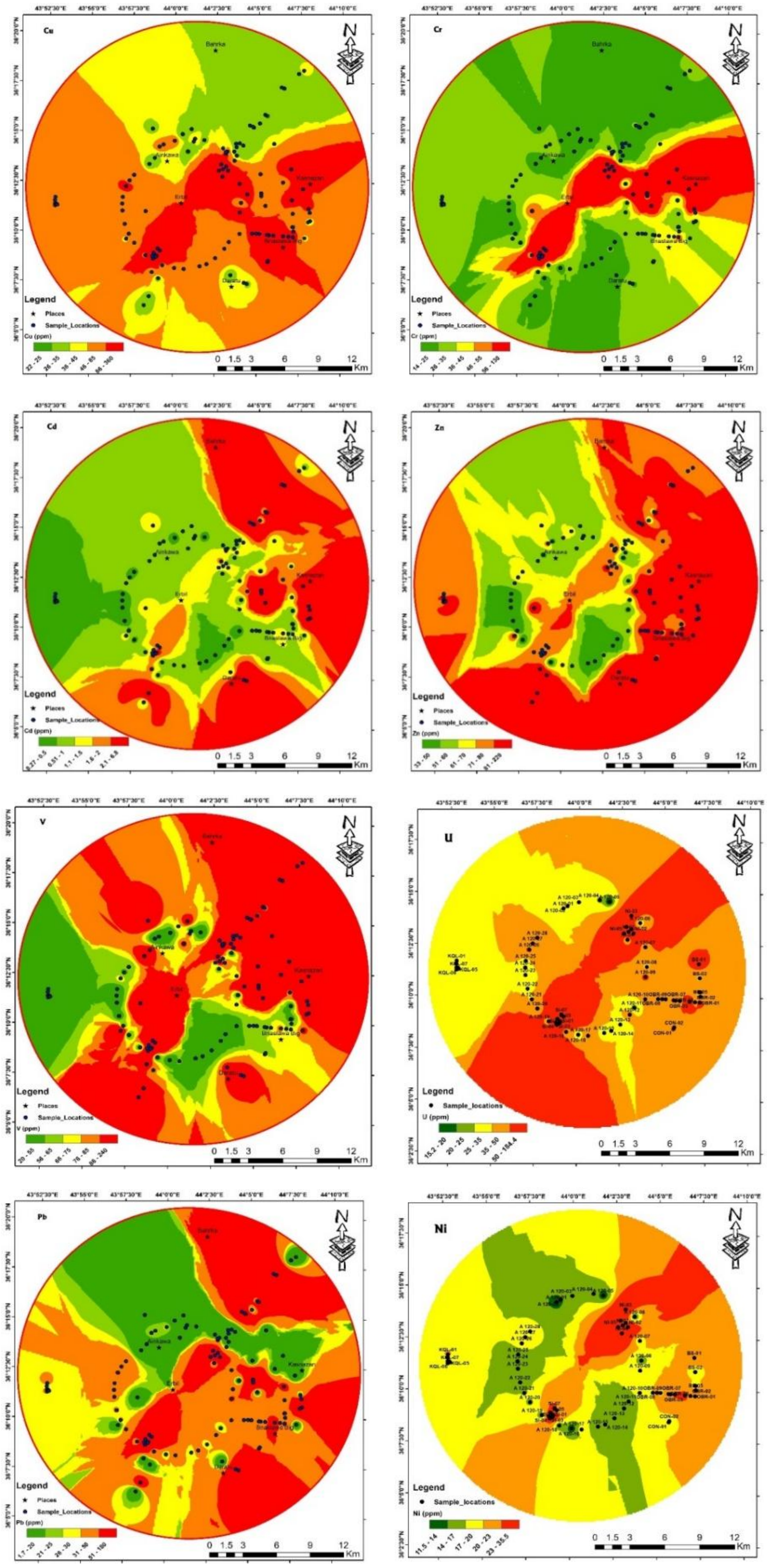

Fig. 2: Spatial distribution of trace elements Cu, Cr, Cd, Zn, V, U, Pb, and Ni, respectively.

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Assessment of pollution state and sources:

Table 2: Elemental mean concentrations in Erbil area, EF and I_geo

Element	Range (Minimum-Maximum) concentration	Mean Concentration (ppm)	EF	Igeo
Ag	0.52 – 1.15	0.868	8.68	0.62
Al	5660 – 10900	8444	0.42	-0.41
As	2.47 – 5.87	4.17	0.42	0.38
B	3.87 – 14.84	8.95	0.45	-0.47
Ba	11.08 – 230	50.93	0.13	-1.24
Be	1.45 – 132	58.231	1.45	3.11
Ca	14233 - 124917	70417	2.35	0.25
Cd	0.25 - 1.93	0.778	2.59	1.22
Co	3.014 - 19.15	7.145	0.29	-1.06
Cr	17.4 - 132	4.117	0.04	-2.12
Cu	30.066 - 381	90.83	2.27	1.6
Fe	2863 - 7089	4810	0.16	-1.45
K	101 - 2116	1336	0.07	-2.63
Mg	958 - 4447	2254	0.23	-2.21
Mn	177 - 434	296	0.3	-0.72
Mo	1.234 - 4.49	2.61	2.61	1.71
Na	724 - 3166	149	0.01	-2.95
Ni	11.38 - 35.56	29.867	0.6	-0.56
Pb	0.93 - 4.14	1.667	0.08	-0.79
Sb	0.148 - 0.39	0.244	1.22	1.77
Se	0.175 - 3.814	0.733	0.73	0.62
Th	1 - 5.27	2.289	0.38	-0.72
Ti	26.07 – 668	180	0.02	-2.96
U	0.173 – 0.487	0.345	0.12	-0.54
V	67.97 – 218	124	1.03	-0.26
Zn	32.33 – 85.41	74.625	2.54	1.09

The metals Ag, Be, Ca, Cd, Mo, Sb, Se, V and Zn are all examples of elements with high EF values (>1) and high I_{geo} values (>0) except for vanadium, indicating that they may be harmful to the environment and human health because of anthropogenic activities like agriculture, industry, transportation, and other human-induced sources [9, 30-32]. Be in particular, is heavily contaminated according to I geo classification which is 3-4. This increase can be related to the anthropogenic input [33, 34] into the environment such as glass and mirror industries, x-ray machines, electronic parts and electrical industries, vehicles structures, instruments, mining, burning fuel and coal [9, 35]. The increasing Cu and Mo levels in the soil of Erbil city may be related to their use in petroleum exploration and production [21, 34].

On the other hand, the elements with low EF values (<1) and I_geo values (<0) such as Al, B, Ba, Cr, Pb, Fe, Th, and Ti are considered to be of natural origin and are primarily derived from the soil's parent material [36], Moreover, the level of these elements should not be monitored as their accumulation in the soil can affect soil quality and plant growth [5].

It is also important to note that the level of some elements like As, Cu, Pb, and Zn, although not exceeding the permissible limits, is bigger compared to the average concentration in the soils of Iraq [22, 37, 38]. This could be due to the deposition of atmospheric pollutants from neighboring countries or the usage of pesticides and fertilizers in agricultural practices [3, 36, 39]. The data in this table agrees with those found in previous studies of the greater Erbil region. The average level of Al, Ca, Cu, Fe, and Mn in the Erbil region were found to be much greater than their crustal abundance in research conducted by [8]. Al, Ca, Fe, and Mn were all found to have much higher mean concentrations in the Erbil region than their crustal abundances in the research by[40].

The influence of the land use has a significant role in elevating some heavy metal [41, 42]. Cd as an example, from the spatial distribution figure, it is clear that the activities among north and south industrial areas have a vital role in increasing Cd contamination and making the area moderately contaminated according to geo-accumulation index classification. This may be attributed to the role of industrial activities in which they use petroleum derivatives such as Kerosene, gasoline and diesel contain cadmium in which it is emitted as they burnt. Moreover, from welding material solder [3, 5]. Cu is also recording alerting results and according to the geo-accumulation index the city is moderately polluted [4]. Other indications also reveled in the studied multivariate statistics as it is positively skewed along with other heavy metals in siderophile group such as Fe and Co [43]. These high concentration may due to the emissions from vehicles, lubricating oil and combustion of fuel. As well as tires and bitumen from tarmac [21]. The enriched spikes in residential and agricultural areas might be due to the use of fertilizers and porcicides [44]. Samples from landfill areas also have high concentration due to the burning of waste including plastic materials. Ash resulting from burning waste contains a wide variety of heavy metals including Cu [44]). Cr mainly enriched in north and south industrial samples which indicates the excessive use of fuel, combustion, solder and powders [45-47]. From the spatial distribution map of Ni, it shows that it is concentrated in industrial areas and land fill which is main due to the anthropogenic input via industrial incinerators and electric generators [48, 49]. Pb like Ni polluting industrial areas and landfill. Especially car repair shop and welding workshops [50].The traffic density on the southern part of the ring road is also affected by lead pollution (51) which is probably due to the fumes from vehicle exhausts, using extensive fertilizers and pesticides, and finally construction and building operation adding lead to the studied area [5, 49, 52]. Zinc in particular which recorded moderately enriched, and it is not polluted along roadside samples. Landfill and both north and south industrial zones show high concentration of Zn as per the spatial distribution pattern. Lots of vehicle repair shops, large number of spare parts, old car batteries, dyes, paints and metals. It is also included in tires which when burned release it to the atmosphere then subsequently into the soil [47, 53, 54].

The elevated concentrations of these elements in Erbil area are likely due to anthropogenic activities. Erbil area is located in a region that is rich in mineral deposits, including aluminum, copper, and iron. These mineral deposits are likely the source of the elevated concentrations of these elements in the soils in Erbil zone [34, 38].

The elevated concentrations of these elements in Erbil area could pose a potential health risk to humans [11, 55]. The principal pathway of human exposure to heavy metals are through food chain [56]. For example, high levels of Al have been linked to Alzheimer's disease [57], while high levels of Cu have been linked to liver damage [58, 59]. Cd is greatly neurotoxic and can cause morphological and functional changes in tissues and organs [60]. Most of the other heavy metals have carcinogenic risk and significant effect on humans [11, 61]. However, more research is needed to determine the specific health risks associated with the elevated concentrations of these elements in Erbil area.

After running the normality test. Given that most geochemical data were not normally distributed, the Kruskal–Wallis H test was run to determine in more detail the impact of various land uses on heavy metal concentrations in the study area's soils, see the table 3 below. This non-parametric test is an extension of the Mann-Whitney U test and is comparable to the one-way ANOVA. It enables the comparison of more than two independent groups [62-64], in our case, four distinct land uses. The probability level ρ values (Asymp. Sig. (2-tailed)) of Al, B, Cd, Co, Cu, Mg, Mo, Th, and Ti elements were lower than 0.05 this means that different land uses had a significant direct effects on the mentioned metals distribution [42, 65]. Nonetheless, other studied elements such as Ag, As, Ba, Be, Ca, Cr, K, Mn, Mo, Na, Ni, Sb, Se, U, V, and Zn presented ρ value greater than 0.05 meaning no significant differences in concentration among different land uses [66].

Table 3: The Results of the Kruskal-Wallis H Test for the studied elements

	Ag	Al	As	B	Ba	Be	Ca	Cd	Co	Cu	Cr	K
Observed J-T Statistic	2	6	3	6	4	4	5	6	6	6	5	3
df	3	3	3	3	3	3	3	3	3	3	3	3
Asymp. Sig. (2-tailed)	0.497	0.042	1	0.042	0.497	0.497	0.174	0.042	0.042	0.042	0.174	1

	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Th	Ti	U	V	Zn
Observed J-T Statistic	6	4	4	4	2	6	5	5	6	6	5	5	3
df	3	3	3	3	3	3	3	3	3	3	3	3	3
Asymp. Sig. (2-tailed)	0.042	0.497	0.497	0.497	0.497	0.042	0.174	0.174	0.042	0.042	0.174	0.174	1

CONCLUSION

This research evaluated the level of contamination through analyzed 26 trace elements in different environmental media (highways, residentials, landfill and industrial areas) of topsoil samples from the Erbil area of Iraq to determine the spatial distribution, effect of different land uses, and probable sources of trace elements. Topsoil samples indicated a wide range of variance in the content of individual trace elements. The skewness study showed that the distribution of several elements, such as Ag, As, B, Cd, Cr, Mg, Mn, Pb, V, and Zn, was more right skewed and had more outliers. This high concentration supports that this predominance is due to the high carbonate ratio. Subsequently, metal-rich elements persuade high human health and ecological risks. The Enrichment Factor (EF) study showed that the topsoil samples were highly enriched in elements including Be, Sb, and Se, most likely because of industrial activities and landfill leachate. Meanwhile, Ba, Fe, and Th all came from naturally occurring sources that were mostly impacted by geological processes. According to the Geoaccumulation Index (Igeo) study, most of the topsoil samples were either very clean or somewhat contaminated in terms of the components that were studied. Cd and Cu, for example, revealed low to moderate levels of contamination and ecological risks mediated by Cd mainly. Kruskal-Wallis test revealed that Al, B, Cd, Co, Cu, Mg, Mo, Th, and Ti were affected by different land use conditions.

The existing results suggest that an environmental risk assessment and management of the studied elements on the city scale is essential. The investigation evidently specifies that the soil is contaminated with some toxic elements. Subsequently, there is great need to regulate and manage the anthropogenic input in the study area. This study's results might aid in the creation of efficient soil management plans for the Erbil area by providing essential background data on the distribution and probable sources of trace elements in the region's topsoil. The study provides a pathway for a future study on the catchment areas and its influence on the concentration ratio.

Overall, the obtained results lead to the need of geochemical, epidemiological, and environmental studies to sketch the magnitude of the occurrence of pollution related to anthropogenic activities in the city.

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