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ECOLOGICAL RISK POTENTIAL ASSESSMENT OF METAL CONTAMINATED SOILS IN BAGHDAD CITY OF IRAQ

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ECOLOGICAL RISK POTENTIAL ASSESSMENT OF METAL CONTAMINATED SOILS IN BAGHDAD CITY OF IRAQ

By Hussain Ali Hussain ALZUABIDI

February 2023

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

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ABSTRACT

ECOLOGICAL RISK POTENTIAL ASSESSMENT OF METAL CONTAMINATED SOILS IN BAGHDAD CITY OF IRAQ

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Master of Science in Agriculture and Life Sciences
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February 2023

Metal pollution in the soil leads to deterioration of agricultural production by negatively affecting chemical, physical, and biological properties of the soils. In this research, levels of metal pollution in the soils of Baghdad city of Iraq was studied. Three different sites (farm, camp and park) were selected. Ten soil samples samples were taken randomly from 0-15 cm depht on each of three sites. Concentrations of metals (manganese (Mn), copper (Cu), zinc (Zn), cobalt (Co), chromium (Cr), lead (Pb), cadmium (Cd), nickel (Ni), iron (Fe), calcium (Ca), and magnesium (Mg)) of soil samples were measured using atomic absorption spectrophotometer (AAS). Texture components, electrical conductivity (EC), pH, $CaCO_3$ content, field capacity (FC) and wilting point (WP) content, organic matter (OM) content, and bulk density (D_b) of the soils' were measured on the disturbed samples. Metal concentrations increased as Cr<Ni<Fe<Co<Mg<Cd<Cu<Ca<Zn<Pb<Mn respectively. Metal concentrations were evaluated by I_{geo} indices to assess soil quality. No high ecological risk was found in farm, camp, and park sites except for Cd and Pb. High concentrations above the permissible limits of Cd and Pb were attributed to anthropogenic activities on the study sites.

2023, 62 pages

Keywords: Soil pollution, Baghdad soils, Metal, Cadmium, Anthropogenic pollution

ÖZET

IRAK'IN BAĞDAT ŞEHRİNDE TOPRAKLARDA METAL KİRLİLİĞİNİN EKOLOJİK RİSK POTANSİYELİNİN DEĞERLENDİRİLMESİ

Hussain Ali Hussain ALZUABIDI
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Topraktaki metal kirliliği, toprakların kimyasal, fiziksel ve biyolojik özelliklerini olumsuz etkileyerek tarımsal üretimin bozulmasına neden olmaktadır. Bu araştırmada, Bağdat kenti topraklarındaki metal kirliliği düzeyleri araştırıldı. Örnekleme noktaları için 3 farklı alan seçilmiş (çiftlik kamp ve park) ve her bir alandan 10'ar adet olmak üzere 0-15 cm derinliktenen toplam 30 adet toprak örneği alınmıştır. Toprak örneklerinin metal konsantrasyonları (mangan (Mn), bakır (Cu), çinko (Zn), kobalt (Co), krom (Cr), kurşun (Pb), kadmiyum (Cd), nikel (Ni), demir (Fe), kalsiyum (Ca) ve magnezyum (Mg)) atomik absorpsiyon spektrofotometresi (AAS) kullanılarak ölçülmüştür. Aynı toprak örneklerinde tekstür bileşenleri, elektriksel iletkenlik (EC), toprak reaksiyonu (pH), kalsiyum karbonat ($CaCO_3$), tarla kapasitesi (FC) ve solma noktası (WP), organik madde (OM) içeriği ve hacim ağırlığı (D_b) ölçülmüştür. Metal konsantrasyonları sırasıyla Cr<Ni<Fe<Co<Mg<Cd<Cu<Ca<Zn<Pb<Mn şeklinde artmıştır. Metal konsantrasyonları, toprak kalitesini değerlendirmek için I_{geo} indeksleri ile değerlendirilmiştir. Çiftlik, kamp ve park topraklarında Cd ve Pb dışında yüksek ekolojik risk bulunmamıştır. İzin verilen limitlerin üzerindeki Cd ve Pb konsantrasyonları, çalışma alanlarındaki antropojenik faaliyetlere bağlanmıştır.

2023, 62 sayfa

Anahtar Kelimeler: Toprak kirliliği, Bağdat toprakları, Metal, Kadmiyum, Antropojenik kirlilik

PREFACE AND ACKNOWLEDGEMENTS

This study named ‘Ecological risk potential assessment of metal contaminated soils in Baghdad city of Iraq’ was prepared as a master's thesis in Çankırı Karatekin University, Graduate School of Natural and Applied Sciences, Program of Agriculture and Life Sciences.

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Hussain Ali Hussain ALZUABIDI
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CONTENTS

LIST OF SYMBOLS

<	Greater
>	Smaller
≤	Smallerr or equal
℃	Degree centigrade
cm	Centimeter
gr	Gram
kg	Kilogram
m	Meter
mg	Miligram
mm	Milimeter
mL	Milliliter

LIST OF ABBREVIATIONS

AHT	Average high temperature
ALT	Average low temperature
AG	Agust
AP	April
AR	Average rainfall, mm
ARD	Average rainy days
ARH	Average relative humidity
ASI	Aggregate Stability Index
AAS	Atomic Absorption Spectrometry
AUI	Average ultraviolet index
Ca	Calcium
$CaCO_3$	Calcium carbonate
Cd	Cadmium
Co	Cobalt
Cr	Chrome
Cu	Copper
CV	Coefficient of Variation
Db	Bulk Density
DE	December
DM	Daily mean
EC	Electrical Conductivity
FC	Field Capacity
FE	February
Fe	Iron
GPS	Global Positioning System
Hg	Mercury
Igeo	Geo Accumulation Indexs
JA	January
JL	July
JU	June
Kurt	Kurtosis
Max	Maximum
MY	May
Mg	Magnesium
Min	Minimum
Mn	Manganese
MR	March
MSH	Mean monthly sunshine hours
N	Number of samples
Ni	Nickel
NO	November

OC	October
OM	Organic matter
Pb	Lead
pH	Soil reaction
r	Correlation Coefficient
SD	Standard Deviation
SE	September
Skew	Skewness
WP	Wilting Point
Zn	Zinc

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1. INTRODUCTION

The world has faced a very complex environmental pollution, which increased in severity in the second half of the twentieth century due to human activity as a result of scientific, technological, and industrial development (Perman 1996). Environmental pollution is defined as the accumulation of pollutants at levels greater than the ability of the ecosystem to get rid of them. The sources of environmental pollution may be both natural reasons such as volcanoes and may be from anthropogenic reasons such as industrial, factory, or home wastes (Hassan 2000). These pollutants of natural and anthropogenic origin affect the physical, chemical, and biological properties of air, water, and soil and cause them to be polluted (Peirce *et al.* 1998).

The soil that makes up our terrestrial ecosystem is a natural resource that can renew itself. However, most of the main sources of soil pollution are anthropogenic and can cause the accumulation of pollutants in large quantities beyond the regenerative capacity of the soil (Cachada *et al.* 2018). Protection of the soil sustainability is essential for the balance of ecosystems and biodiversity. Therefore, it is important that land use is planned in such a way that the cycles in nature are not disrupted and that it is sustainable. In this way, the soil can continue to be a natural resource on which living things survive. However, in addition to natural resources such as erosion and volcanoes, soils are polluted by many human-induced factors due to population growth and developing industry.

Soil pollution can be defined as the presence of pollutants in the soil at a level in excess of the soil's absorption capacity. When the plants growing in the soil, or the soil organisms that feed on these plants can be exposed to these toxic and harmful chemicals, soil quality degrades and the yield capacity of the soil decreases. In addition, the soil system is also a final storage point for the pollutants contained in the water and air systems with which it is associated. These pollutants originate from natural resources, wrong use of fertilizer and agricultural pesticides, and accumulation of chemical and biological household and factory wastes in soil that included toxic heavymetals. Therefore, heavy metals have become a problem that causes the deterioration of the ecosystem balance by polluting the environment. Before humans recognized this danger, it was thought that pollutants would not pose any risk to human health or the environment when they were buried in soil or even mixed with air and water, and would somehow disappear (Swartjes 2011). Whereas, soil pollution can involve complex environmental processes that can lead to direct pollution with accumulation in soil or indirect pollution through water or atmospheric deposition (Tarazona 2014).

Soil pollution is defines as the reduction of soil fertility due to the presence of soil pollutants such as fertilizers, radioactive waste, pesticides, wastewater, and chemicals. Some of these chemicals in soil that are called heavy metals such as iron, lead, copper, zinc, and cadmium reach the soil directly by water or indirectly by air and human activities (Mishra *et al*. 2016).

Heavy metals are those elements that have a density of more than 5 g cm^{-3} (Barakat 2011). Manganese (Mn), copper (Cu), zinc (Zn), cobalt (Co), chromium (Cr), lead (Pb), cadmium (Cd), nickel (Ni), iron (Fe), calcium (Ca), and magnesium (Mg) are the main examples of these heavy metals. These metals are of great importance in the growth of plants and the activity of reviving the microscopic soil. The origins of these metals in soil also are weathered parent materials, agricultural, chemical, and industrial activities, and mining or traffic emissions (Jin *et al*. 2019).

On the other hand, anthropogenic sources of toxic elements in urban environments include emissions from vehicles, industrial waste, atmospheric deposition of dust and aerosols, domestic emissions, and incinerators (Lee *et al*. 2006, Luo *et al.* 2012). Thus, anthropogenic activities are the main reason for HMs contamination of soil (El- Segany *et al.* 2011). In this context, urban soils are often contaminated with HMs owing to anthropogenic sources. Studies confirmed that potentially toxic elements pollution is principally derived from anthropogenic sources (Faiz *et al*. 2009, Wei and Yang 2010, Davis *et al*. 2009, Yu and Li 2011).

A decrease in input of heavy metals does not always result in a rapid decrease of their content in soils, because under certain environmental conditions metals are firmly fixed in soils. Therefore, heavy metal contaminated soils can be considered as a source of potential and real risk to the environment (Motuzova *et al.* 2014). Because, unlike other organic pollutants, heavy metals can't be degraded by microorganisms (Yan *et al*. 2020). In addition, heavy metals can seriously affect human health through food chain transfer after being absorbed by plants and accumulated in plants (Xue *et al*. 2017, Shen *et al*. 2019, Qin *et al*. 2021). Aransiola *et al.* (2019) stated that heavy metals that are essential or not, can become fatal if their contribution is excessive and even cause death for every organism.

Heavy metal pollution in soils causes the degradation of soil quality (Hu *et al*. 2020), threatens the living organism in the soil, and reduces productivity (Chodak *et al.* 2013, Yang *et al*. 2018a, Tseng *et al.* 2021). It was of course stated that the soil has a self-cleaning capacity up to a certain level (Lin *et al*. 2022), but if this level is exceeded, heavy metals will pose an important risk also for economic development besides affecting human health. Therefore, heavy metals have gained increasing attention around the world in recent decades due to their increasing pollution levels, harmful effects, and risks they pose (Li *et al*. 2015). Moreover, pollution of soils with toxic heavy metals has become a universal problem due to its adversarial impacts especially on plant growth and yield (Seleiman *et al.* 2013), ecosystem health and food safety (Antoniadis *et al.* 2017), and soil enzyme activities and microbial community structure (Pan and Yu 2011).

In this regard, soil pollution with heavy metals has started to cause great problems due to their toxic effects, non-biodegradations, and accumulations due to human and industrial activities in urban soils. Because, urban soils are accepted as sinks for heavy metals and other pollutants from various industrial activities, coal, and fuel combustion, vehicle emissions, and municipal waste (Wei and Yang 2010, Yu *et al*. 2012). According to Liu *et al.* (2016), urbanization processes not only changed the natural properties of affected soils such as pH, texture, and bulk density, but also unintentionally caused harmful substances such as heavy metals to accumulate in the soil (Vega *et al.* 2004, USS 2006, Obrador *et al.* 2007).

In addition, there is a continuous increase in the urban population of the world. This increase causes an increase in vehicle traffic, buildings, and waste production that causes soil pollution. (Silva *et al.* 2021).

Pollution from heavy metals in urban soil systems is mainly due to natural processes such as the decomposition of minerals, industry, agriculture, burning of fossil fuels, vehicle emissions, activities in mining, and waste disposal (Likuku *et al.* 2013). Accurately identifying the major sources of metal pollution in the soils of a region is the first key to effectively controlling this heavy metal pollution (Lou *et al.* 2023).

To remediation measures for heavy metal pollution in soils, it is thought that first of all, a comprehensive study of heavy metal pollution from possible sources and therefore their spatial distribution should be known. In addition, knowing the concentrations and the level of pollution of heavy metals and comparing them with global determinants add to knowing the impact of environmental factors and detection of the changes in the soil quality in polluted sites. According to Salman *et al.* (2019) pollution indices are a powerful tool for environmental quality assessment. The mostly used pollution indeks for heavy metals in soils have classified into single and integrated pollution index (Yuan *et al.* 2004, Qingjie *et al.* 2008, Hafizur Rahman *et al.* 2012). Generally, in studies three single indices, namely index of geoaccumulation (I_{geo}), contamination factor (CF) and ecological risk factor (Er), as well as three integrated indices; degree of contamination (DC), pollution load index (PLI), and potential ecological risk index (PRI) are used. However, as noted by Salman *et al.* (2019), it is well known that most of metal and metalloid contamination in the surface environment is associated with all contaminant metals rather than one metal (Chon *et al.* 1997, Swapnil *et al.* 2011, Elnazer *et al.* 2015).

Studies on heavy metals at different scales have been conducted in the urban soils of Iraq (Sulaivany and Al-Mezori 2007, Salah *et al.* 2012, Al Obaidy and Al Mashhadi 2013, Fayad *et al.* 2013). However, studies conducted on mapping metals in urban soils and using pollution indices for evaluating metal pollution were rare. In addition, for understanding the reasons for pollution and deterioration of urban soils, it must be known the sources of metals in soils. The aims of this study were 1) to examine pollution levels of some metals in soil samples taken from 3 different regions in Baghdad city, 2) to investigate the environmental factors that caused pollution and their effects and the spatial distribution of metals, and 3) to calculate the Geo-Accumulation Index (I_{geo}) to assess soil quality in Baghdad urban soils.

2. LITERATURE REVIEW

Al-Bassam (1985) studied soil samples contaminated with Cr, Pb, and Ni elements from different regions of Iraq. Cr and Ni concentrations were found within the permissible range. He noted that the desert in southern and western Iraq lacked Cr and Ni elements, in more concentrations found in the area between the Tigris and Euphrates rivers. However, he reported that the concentration of Pb was within the normal and permissible levels, except for industrial and residential areas and transportation routes, in which Pb contamination was found above the permissible limits of 10 mg kg^{-1}.

Awwad (1986) referred during his study of the relationship between organic matter and cadmium that the amount of cadmium ions associated with organic matter was very high compared to the amount associated with other separations. He attributed to this result that soil contamination with high levels of used motor oil that led to an increase in organic matter. The high efficiency shown by the organic matter in the adsorption of cadmium ions may be due to the affinity and high preference of that material for metal ions, especially ions.

The study carried out by Al-Hamdani (1987) found that smoke, dust, and materials emitted from chimneys of factories and oil refineries in Mosul and Salah al-Din in north of Baghdad have negatively affected the soils of neighboring agricultural areas. The study recorded that soils were highly polluted by iron, nickel, cadmium, and lead. It was measured that these metals' pollutions were higher in the surface layer and a few cm depths of the soils close to the factories. On the other hand, it was determined that the percentage of pollution decreased in the soil samples taken far from the factory areas.

Ivask *et al.* (2004) referred during their studies to recombinant bacterial fluorescent sensors for measuring the bioavailability of cadmium and lead in soil contaminated by metal smelters in northern France in which bacterial sensors were used to analyze the bioavailability of cadmium and lead in soil-water suspensions (contact test) and extracts free of particles from natural soils sampled around smelters. They compared of their results from contact and aqueous assays and showed that approximately 90-fold more of cadmium and at least 21-fold more of lead proved to be bioavailable when sensor bacteria were incubated in soil and water suspensions. They also reported that contaminants in the soil and soil matrix may interfere with the assay.

Abdul Karim (2005) analyzed soil samples polluted with lead in Baghdad. She found the lead content in Baghdad as 102.9 mg kg^{-1}, and the lead content in the cities adjacent to Baghdad is 17.2 mg kg^{-1}. This study indicated that the concentration of lead was 10 times the permissible concentration. These results attributed the weak correlation of the natural factors affecting lead pollution such as pH, the natural gradient of soil, clay minerals, and others. In addition, high levels of lead were observed in industrial areas and old residential areas, therefore the pollution was also caused by human activity. The decrease in lead pollution was observed in modern residential areas because they contain public parks, gardens, and green spaces. It was also determined through the study that the surface layer of the soil is polluted with lead much more than the lower layers, and this is evidence that lead pollution is a result of human activity and the increase in population and industrial facilities.

Faiz *et al*. (2009) analyzed samples of road dust collected along the Islamabad Expressway for Cd, Cu, Ni, Pb, and Zn. The concentrations of these elements were generally on the lower level. When the pollution level of the elements for Islamabad Expressway was estimated, they found that the pollution level of this area is in the category of "lower to intermediate level ". They reported that inter-elemental relations showed that Cu and Pb contamination may have similar anthropogenic origins. They noted that the Expressway was said to be a pollution-controlled region up till a few years ago. However, it was noted that the number of vehicles on the Islamabad Expressway has grown tremendously in the past few years due to the availability of cars, wagons, and pickups. In addition, due to the rapidly increasing population of Islamabad, the pollution status along this Expressway is expected to increase in the coming years. They suggested some protective measures such as the use of public transport, conversion of liquid fossil fuel to gaseous fuel, and having more green areas since road dust, is an increasing problem for developed and developing countries and is a source of various diseases.

Muntean (2010) referred during the study of soil contamination with cadmium and lead in the city of Copsa Mica of Romania, that the results obtained in relation to the food chain that soil contamination with lead and cadmium in the surrounding area of CopsaMică was very high. According to their results, it was reported that the high content of heavy metals in plants grown near the industrial site, as well as in various products for food purposes represents a serious danger to public health.

Ismail (2010) examined soils polluted with lead, nickel, chromium, and cadmium for Maysan in Baghdad by the Jackson method. The results were lead rates 58 mg kg^{-1}, nickel 84.94 mg kg^{-1}, chromium 81 mg kg^{-1}, and cadmium 15.86 mg kg^{-1}. It was noted that the rates of lead, cadmium, and nickel are high, the chromium concentration is low. She attributed this result to a weak relationship between the hydrogen function, organic matter, and the volumetric gradient of soil and clay minerals.

Al-Awsi (2014) studied the soil contaminated with lead and cadmium in Baghdad and these metals' impact on the chemical and physical relations of the soil. He noted that cadmium pollution ranged from 10.6 to 56.9 mg kg^{-1}, which is higher than the limit allowed by the World Health Organization (WHO) (3 mg kg^{-1}) and lead ranged from 12.8 to 136 mg kg^{-1}, while the permissible limit by WHO is 50 mg kg^{-1}. He also reported that the ability of soil to adsorb lead and cadmium and a direct relationship between Pb and Cd contamination and motor oils pollution in soil. The adsorbed quantity of Pb and Cd by soil increased with the increase of the added concentration of each metal. However, it was noted that the difference in the ability of soils to adsorb and release was due to the variation in the soil's chemical and physical properties such as pH, ionic strength, calcium carbonate, organic matter, and colloid contents.

Luo *et al.* (2015) investigated the source contribution for typical heavy metals (Cd, Co, Cr, Cu, Mn, Ni, Pb, Zn) in urban park soils of Xiamen in China. They found that the average contributions for Pb were natural (49%), coal combustion (45%), traffic emissions (6%), respectively. They also noted that although the urban surface soils are usually more contaminated owing to recent and current human sources, leaching effects and historic vehicle emissions can also make deep soil layers contaminated by heavy metals.

Salman *et al.* (2019) determined the As, Cd, Cr, Cu, and Pb concentrations in alkaline sansy soils of Orabi farms, El Obour city, Egypt. They assessed eleven soil samples by contamination factors and indexs. They recorded that soil samples were uncontaminated with Cr, Cu, and Pb, considerably contaminated with Cd, and highly contaminated with As. They attributed the distribution of Cd in soil to the application of P-fertilizers.

Aminiyan *et al*. (2016) referred during their study to the heavy metal pollution affected by human activities in the city of Rafsanjan, Iran. Based on what was obtained, almost all few element concentrations determined in the urban soils of Rafsanjan are higher than their baseline values and the maximum concentrations of zinc, lead, copper and chromium in the soil samples were above the permissible limit. The lowest concentrations of heavy metals were found in green lands, parks and gardens within strict traffic rules for cars and trucks. This study found that the highest concentrations of heavy metals were found in highways, industrial areas, and the city center, which suffers from traffic jam. In addition that human and industrial activities and industrial mismanagement, have made the residents of this city expose to severe danger due to heavy metal pollution.

Stırbescu et al. (2019) collected a total of 700 samples from the surface of Targoviste soils. They analyzed important metals, Pb, Fe, Mn, Cd, As, Zn, and Ni in samples that were taken from 40 sampling points. Their results indicated that Cd, Cu, Pb, Fe, and Zn occurred from anthropogenic and industrial sources, but As occurred from both anthropogenic and natural sources.

Hanfi and Yarmoshenko (2020) investigated the reviews that previously studied metal's effect on human health. They reported that Cd (7200), Pb (662), Cu (42), Zn (23), and Ni (6) have a high environmental risk index in urban soils between 1980 and 1990.

Silva *et al.* (2021) determined the content of Pb, Cr, Ni, and Cd metals in Lisbon’s (Portugal) soils. They studied the 700 samples that were taken from six cities over a decade. These locations have different residential areas, traffic zones, mixed areas, and urban parks. However, they calculated that Ni and Cd metals exceeded the limit values and the reason for it was attributed to their anthropogenic origins.

Ali *et al*. (2021) said during their study of environmental pollution with heavy metals that this pollution is a source of public health concern and that heavy metals and metals were critical environmental pollutants for both marine and terrestrial environments and the ecosystem. Environmental pollutants are considered dangerous due to their ability to accumulate within living organisms and their stability and toxicity. They reported that the most dangerous heavy metals and metalloids of environmental importance include Cr, Cd, Pb, Ni, Cu and Zn.

Yuan *et al.* (2021) investigated a total of 713 research papers about field monitor experiments of heavy metals in farmland and urban soils in China, published from 2000 to 2019 and mainly focusing on eight heavy metals. They reported that the Cd content showed a twofold (0.19 mg/kg) rise in farmland soils and a threefold (0.29 mg/kg) rise in urban soils. The decreasing order of the mean I_{geo} was Cd (1.77) > Pb (0.62) > Zn (0.60) > Cu (0.58) > Hg (0.57) > Cr (0.54) > Ni (0.47) > As (0.28). Nearly 33.54% and 44.65% of sites in farmland and urban soils were polluted with Cd. They concluded that heavy metal pollution in urban soils was more serious than that in farmland where industrial activity dominates, the most polluted.

Ren *et al.* (2022) collected a total of 121 studies including heavy metals published during 1998–2019. They used the geoaccumulation index (I_{geo}) and the standard deviation ellipse (SDE) method in pollution studies over the past 20 years. Their result showed that most heavy metals in farmland soil from the study cases are similar to the world average. However, they noted that Cd and Hg were the most polluting metals in China, and agriculture and industry activities were the reason for this pollution.

He *et al.* (2022) evaluated heavy metal characteristics by using 34 cities' urban soil and dust data in China. They found Pb, Zn, Cu, and Cd were higher in dust than in soils. In addition, they also found that Igeo values for Cd (2.50-1.07), Zn (1.39-0.31), and Pb (1.17-0.25) were higher in urban dust than in urban soils. They attributed the results to polluting enterprises such as metal and smelting industries. They reported that anthropogenic factors are more affecting factors than soil properties on heavy metal pollution in soils.

Yang *et al*. (2022) studied heavy metal pollution and risk assessment of surface dust in Arid NW China. They reported that spatial distribution analysis revealed that the hotspots of Pb, Mn, and Cu were located in the city center and northeastern industrial areas while Cd was located in the electrical and mechanical industrial areas.

3. MATERIALS AND METHODS

3.1 Materials

3.1.1 Study area

The study was carried out on 3 different locations in Baghdad city, located in the centre of the Iraq (33° 15' 5165" N Latitude and 44° 28' 0976" E Longitute). Baghdad is the largest city in Iraq and the second largest capital in the Arabian Region (Fadhel and Abdulhussein 2022) (Figure 3.1).

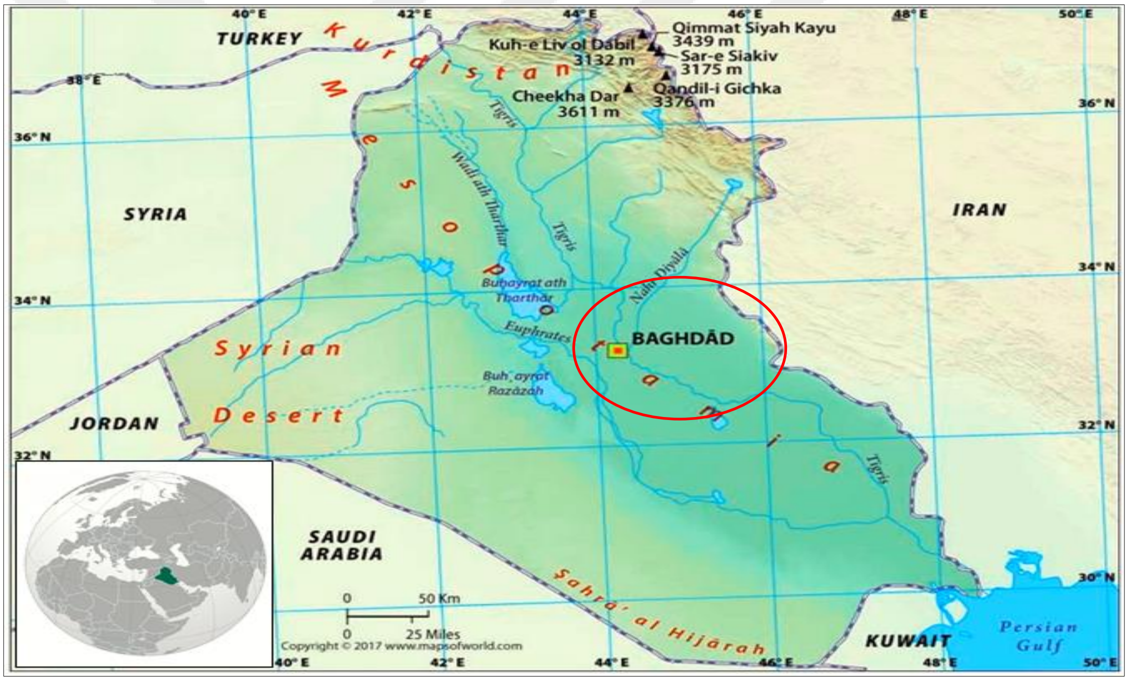

Figure 3.1 Location of Iraqu (Wikipedia 2022) and Baghdad city in Iraqu (Maps 2007)

Tigris River crosses Baghdad city, dividing it into two sides. The eastern side is called Al-Rasafa and the western side is called Al-Karkh. The city area is 869 km^2 (Al-Maliki 2005) and the slope in the south direction is 0.1 km and it rises 34 m above sea level. This city is characterized by the presence of industrial facilities, agricultural lands, and a population gathering of more than 8 million people (Al-Hiti 1985).

The study area is located within the range of the sedimentary plain in the unstable pavement area due to the tectonic division of Iraq (Buday and Halk 1980). The shallow reservoirs of groundwater throughout the sedimentary plain are of the sulfate type (Parson 1957) and whose water is characterized by very high salinity (Al-Sultani 2006). The sedimentary plain is characterized by a thick stratigraphic sequence of sediments of riverine origin consisting of gravel, sand, silt and clay. The layers containing water mainly date back to the Quaternary ages (Pleistocene and Holocene) and are characterized by sudden changes in the vertical and horizontal directions of these sediments (Shanchal 2004).

Therefore, the basin has a complex hydro geological system. The study area is located in the eastern part of the sedimentary plain of Mesopotamia. This sedimentary plain has a slight slope from Samarra in the north to the Arabian Gulf in the south north to south and characterized by flat topography (Jassim and Goff 2006). Our studied soils in Baghdad city were identified as Aridisol (Abed and Saliem 2017). The climate of Baghdad is semi-arid and this is the dominant feature of the climate of central Mesopotamia, where the extreme difference in temperature characterizes it. The temperature is very high during the day in the summer and at the night is very low during the winter (Al-Sultani 2006) in Table 3.1.

Table 3.1 Monthly climatic characteristics of Baghdad city (Wikivand 2013)

	JA	**FE**	**MR**	**AP**	**MY**	**JU**	**JL**	**AG**	**SE**	**OC**	**NO**	**DE**
DM	9.7	12.0	16.6	22.6	28.3	32.3	34.8	34.0	30.5	24.7	16.5	11.2
AHT	15.5	18.5	23.6	29.9	36.5	41.3	44.0	43.5	40.2	33.4	23.7	17.2
ALT	3.8	5.5	9.6	15.2	20.1	23.3	25.5	24.5	20.7	15.9	9.2	5.1
AR	26.0	28.0	28.0	17.0	7.0	0.0	0.0	0.0	0.0	3.0	21.0	26.0
ARD	5.0	5.0	6.0	4.0	2.0	0.0	0.0	0.0	0.0	1.0	5.0	6.0
ARH	71.0	61.0	53.0	43.0	30.0	21.0	22.0	22.0	26.0	34.0	54.0	71.0
AUI	3.0	4.0	6.0	8.0	10.0	11.0	11.0	10.0	9.0	6.0	4.0	3.0
MSH	192	203	249	255	300	34	347	353	315	272	213	195

DM: Daily mean, AHT: Average high temperature, ^0C, ALT: Average low temperature, ^0C, AR: Average rainfall, mm, ARD: Average rainy days, ARH: Average relative humidity, %, AUI: Average ultraviolet index, MSH: Mean monthly sunshine hours, JA: January, FE: February, MR: March, AP: April, MY: May, JU: June, JL: July, AG: Agust, SE: September, OC: October, NO: November, DE: December

The first sampling area is an abandoned farm. The second is an old camp turned into a random residential area that does not contain municipal services or service facilities. The third one is a public park in the main streets. These sampling sites were shown in Figures 3.2, 3.3, and 3.4.

Figure 3.2 Abandoned farm (Original 2022)

Farm has more than 3000 m^2 area. It was abandoned and not planted more than 15 years ago. That's why there are desert plants such as thorns and saplingsgrowing naturally on the farm soils.There is an apartment complex just a few meters away near the abandoned farm.

Figure 3.3 Residental area which used for army camp in the past (Original 2022)

After camp area abandonment, it changed into a random residential area that does not contain municipal services such as drinking water and sewage. Poor families inhabite in houses that built random and irregular somewhat similar to huts. The number of these housing ranges from 200 to 300 housing approximately 2.000 people.

Figure 3.4 Park in downtown Baghdad (Original 2022)

This park is located on one of the public streets in the city and is divided into several gardens. The park gardens include herbs, ornamental plants, weeds, flowers, and some ornamental trees. The plants grown in this park are irrigated with an irrigation system of plastic tubes.

3.2 Methods

3.2.1 Soil sampling and analyses

The coordinates from which soil samples were taken within the study areas were chosen randomly. For soil samples, a total of 30 sample points were determined by GPS (Global Positioning System), 10 samples from each different areas (Figure 3.5).

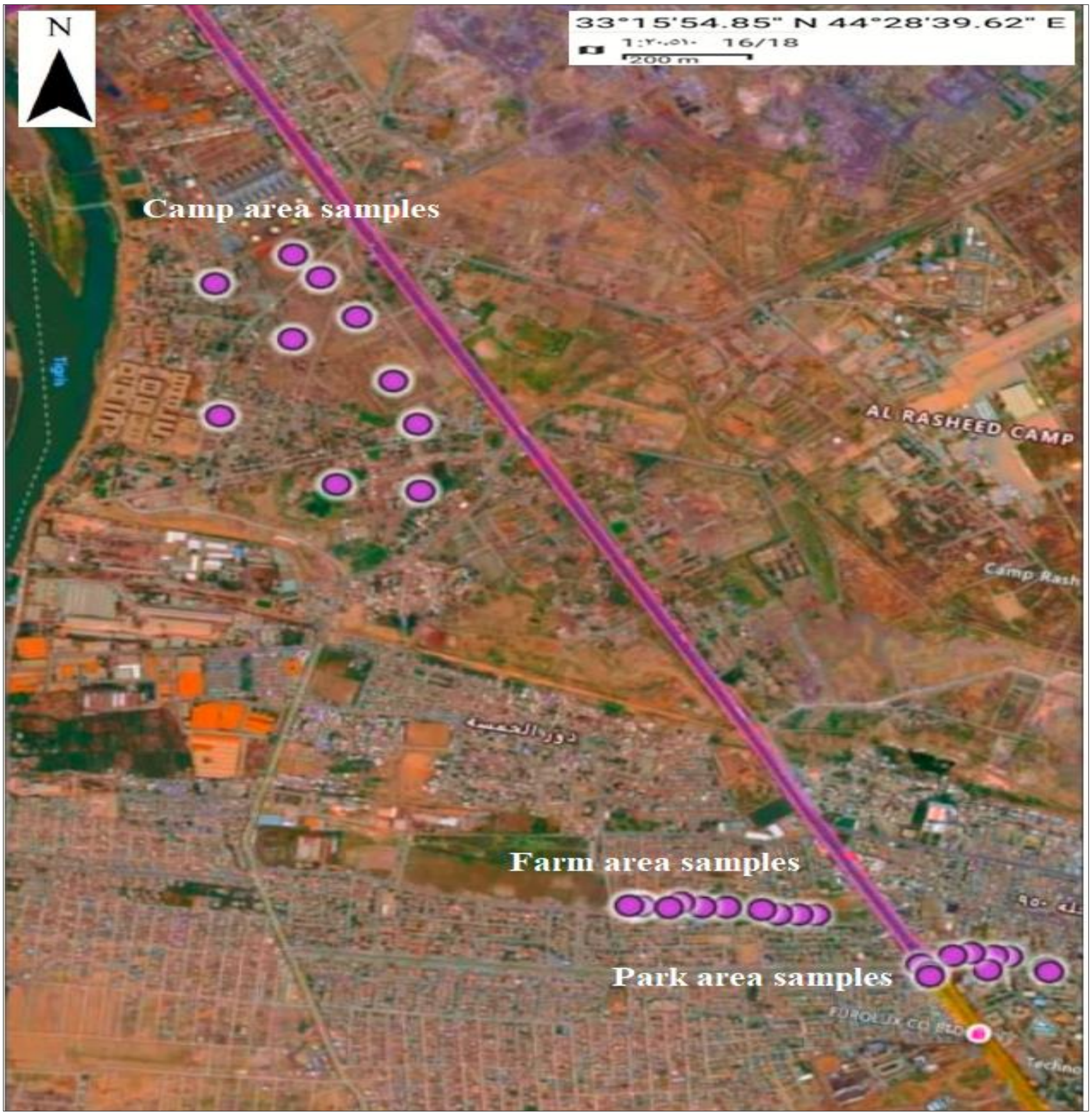

Figure 3.5 Sampling points for studied locations (The map was downloaded from Google earth, and sampling points marked according to their coordinates)

After cleaning the topsoil, undisturbed soil samples were taken with a sampling cylinder (100 cm^3). From the same points, disturbed soil samples were taken from 0-15 cm depth for basic soil analysis in November 2021. These samples were placed in plastic bags, numbered, and transferred to the soil laboratory at the College of Agriculture, University of Baghdad (Figure 3.6). Stone and plant particles in soil samples were removed and left to dry in the shade. The dried soils were beaten with hammers and passed through a 2 mm steel sieve and made ready for analysis.

Figure 3.6 Soil samples taken from farm, camp, and park sites in Baghdad city (Original 2022)

Bulk density: The bulk density of the soils were measured as suggested by Blake and Hartge (1986). Then bulk density was banchmarked according to soil texture are given in Table 3.2.

Table 3.2 The values of soil bulk density class (Schoeneberger 2002)

TEXTURE	BULK DENSITY (gr cm^{-3})	RANGE OF BULK DENSITY
Clayey	1.25	1.20-1.30
Silty clay	1.30	1.30-1.40
Clayey loam	1.35	1.30-1.40
Silt	1.40	1.35-1.5
Sandy loam	1.50	1.40-1.60
Sand	1.65	1.55-1.80

Soil texture: Soil texture was determined in the samples that dispersed using a 40 g soil sample with the help of a hydrometer, “Bouyoucos Hydrometer” method (Gee and Bauder 1986) and with the help of the texture triangle (Soil Survey Division Staff 1993) (Figure 3.7).

Figure 3.7 Soil texture analysis (Original 2022)

Field capacity and wilting point: The field capacity was determined by applying a pressure of 0.33 bar on the samples, which were filled with plastic rings placed on the ceramic plates, passed through a 2 mm sieve and saturated with distilled water given to the bottom of the ceramic plate for 24 hours. Similarly, permanent wilting point was determined by applying a pressure of 15 bar on the samples (Klute 1986). These analyses were shown in Figures 3.8.

Figure 3.8 Soil field capacity and permanent wilting point analyses (Original 2022)

Organic matter: Organic matter content in soil samples was determined by Jackson's modified version of the Wakley-Black method (Page *et al.* 1982) (Figure 3.9).

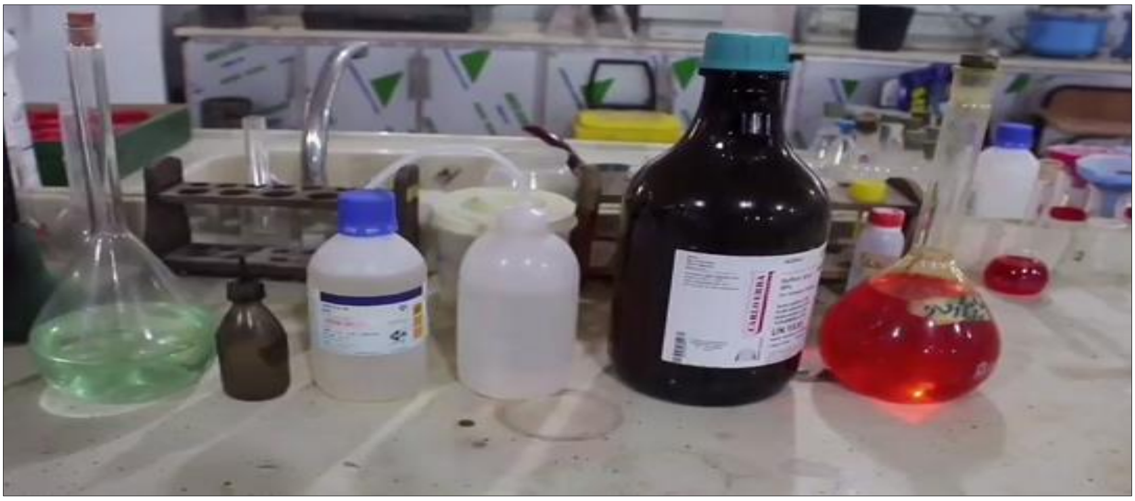

Figure 3.9 Soil organic matter analysis (Original 2022)

Calcium carbonate content: Scheibler calcimeter under standard temperature and pressure was used to determination of the content of lime ($CaCO_3$) in soil samples. The basis of the volume of carbon dioxide (CO_2) gas released as a result of the dissolution of calcium carbonate ($CaCO_3$) from the soil sample mixed with acid in a closed system was taken (Page *et al.* 1982).

Soil reaction and soil electrical conductivity: Soil reaction was measured in a 1/2.5 soil distilled water suspension with an Orion 420 A digital pH meter with glass electrodes (Page *et al.* 1982) (Figure 3.11a). The electrical conductivity of the soil samples was determined in the saturation sludge and its extract with a conductivity meter instrument (Model 3200 Conductivity Instrument) (Rhoades 1982) (Figure 3.10).

Figure 3.10 The instrument used for soil reaction and soil electrical conductivity measurement (Original 2022)

3.2.2 Soil metal analyses

Atomic Absorption Spectrophotometry (AAS) (Figure 3.12) is working principally convert elements to gas phase at high temperature on the basis of absorbing electromagnetic rays by converting. Quantitative analyzes of samples are usually performed at concentrations of mg kg^{-1}, in addition, performed at concentrations of µg kg^{-1} even if it does not go down to low limits. First, the standards should be read to the device in certain calibrations and a calibration curve should be drawn. Then the samples are burned with different solvents and made ready for the device (Izol and Inik 2022).

Jackson's method (Jackson and Watson 1977) was used for analyzing heavy metals in soils. The steps of preparing the soil samples to read their heavy metal concentrations in AAS were applied as follows:

1. The soil samples in the beaker that were washed with distilled water were put in the oven for drying at a temperature of 100 °C for two hours.
2. After the sample came out of the oven, it was sieved with a 1 mm diameter sieve. 1 g of soil was weighed and put in a 250 mm beaker. 15 mL of hydraulic acid (HCl) with 5 mL of nitric acid ($HN0_3$) were added to each sample.
3. The samples were placed in a sand bath for an hour at a temperature of 200°C (Figure 3.11). After the baker cooled at laboratory temperature, 5 mL of hydraulic acid was added and heated in a sand bath until dry.

Figure 3.11 Preparation of soil samples for metal analysis (Original 2022)

4. The beaker was cooled again and 5 mL of hydraulic acid was added. 50 mL of distilled water was added to clean the beaker's sides from the traces of the dissolved samples.
5. The mixture was heated at boiling point for 3 minutes, then filter with filter paper No. 42 and put into a bottle of 100 mL.

6. The insoluble precipitate was washed with distilled water and the wash water was added to the filtrate to complete the volume to 100 mL.
7. The samples were placed in the atomic absorption device (AAS) to record the values of the heavy elements present in them.
8. The device was operated. The gas valve was opened and the cathode lamp was put in position. The elements that will decompose and the number of samples were chosen.
9. The devise tube was put in a beaker containing a solution in which the substance was dissolved.
10. The values of the items that appear on the reading screen of the device were read.

Figure 3.12 Atomic Absorption Spectrophotometry (AAS) used for metal analysis (Original 2022)

3.2.3 Statistical analyses of soil variables and metals

Descriptive statistics (minimum, maximum, arithmetic mean, standard deviation, skewness, kurtosis, coefficient of variation) were made to evaluate the data distribution of soil samples taken from 3 different regions. SPSS 23 package program was used for descriptive statistical values of soil parametric properties and soil heavy metal contents. The skewness coefficient is an indicator of how skewed the distribution of the datasets compared to the normal distribution. If the absolute value of skewness coefficient is between 0 and 0.5, the distribution is assumed to be slightly, between 0.5 and 1.0 moderately, and >1.0 strongly skewed. However, when the skewness coefficient value is between 0.5 and 1.0, square root transformation and when skewness coefficient value is higher than 1.0 a logarithmic transformation can be applied (Webster 2001). Lark (2000) stated that necessary transformations should be made in data sets that do not show normal distribution in order to make a successful geostatistical modeling. However, as stated in Webster (2001), although the necessary transformations were made, the skewness coefficients of some variables were greater than 1, so the transformations were not applied. In addition, Webster and Oliver (2008) stated that data transformation is not important and there may be little change after transformation. The coefficient of variation is an important indicator that determine the variability in soil properties. Soil variable was identified as having low variability if its coefficient of variation was less than 15%, if between 16 and 35% as having moderately variability, and if greater than 35% as having highly variability (Cambardella *et al.* 1994). Correlation analysis was performed to evaluate the relationships among soil properties and metals.

3.2.4 The geoaccumulation index (I_{geo})

The I_{geo} (Geo accumulation index) value is a widely used method for estimating the degree of heavy metal pollution risk in soils. In addition, the index of geoaccumulation is one of the most commonly used indicators in assessing the content of trace elements in the soil. This indicator is used to assess the intensity (Kowalska *et al.* 2018) and degree of anthropogenic pollution as a source of metal pollution (Xu *et al*. 2021) and is also a used to understand whether a metal comes from natural or anthropogenic sources (Xu *et al.* 2021). Land use type and land use intensity are the most important human-controlled factors that affect the heavy metals' geochemical characteristics in soils. Moreover, understanding the effects of human activities on heavy metals in soil requires the potential sources of the heavy metals in different land use levels to be identified (Yan *et al.* 2018). I_{geo} was calculated to assess the level of metal accumulation in urban soil (Muller 1969; Ma *et al.* 2016b; Wang *et al.* 2014) by Equation (3.1).

$$I_{geo} = \log_2\left(\frac{C_n}{1.5B_n}\right) \quad (3.1)$$

Where C_n is the measured concentration of element n and B_n is the background value of element n in study soil, the constant 1.5 compensates for natural fluctuations of given metal and for minor anthropogenic impacts (Taylor and Mclennan 1995). The geo-accumulation index consists of 7 classes and was given in Table 3.3 (Yaqin *et al*. 2008).

Table 3.3 Seven classes of the geo-accumulation index (Yaqin *et al.* 2008)

CLASS	VALUE	URBAN SOIL QUALITY
0	$I_{geo} \leq 0$	Practically uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated to moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately to heavily contaminated
4	$3 < I_{geo} < 4$	Heavily contaminated
5	$4 < I_{geo} < 5$	Heavily to extremely contaminated

3.2.5 Spatial analyses of metals

Horizontal distributions of metals in soils were mapped by GS^+ program (Robertson 2001). It has been stated that geostatistics is generally used for the evaluation of spatial models of environmental variables (Blanchet *et al*. 2017). Tajudin *et al.* (2022) also reported that GS^+ analysis was used as an applied statistic for spatial correlation of the dataset. Creating the spatial distribution of heavy metal concentrations is a beneficial method to obtain the possible and point sources of high metal concentrations (Kunamneni *et al*. 2008).

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics of Soil Properties

Descriptive statistics of soil variablesfor3 sites were given in Tables 4.1, 4.2, and 4.3.

Table 4.1 Descriptive statistics of soil variables in the farm soils (n:10)

Soil variables	Min	Max	Mean	SD	Skewness	Kurtosis	CV(%)
Sand (%)	37.20	79.20	51.69	15.36	1.28	0.51	29.00
Silt (%)	12.00	48.00	35.25	12.47	**-1.58**	**-0.22**	35.00
Clay (%)	8.80	22.80	13.06	5.65	1.12	-0.47	43.00
EC(dSm^{-1})	2.40	47.10	23.48	16.40	0.19	-1.35	**69.00**
pH (1:2.5)	7.11	7.44	7.28	0.12	-0.15	-1.68	**2.00**
$CaCO_3$ (%)	25.64	36.51	29.77	3.52	0.73	-0.44	12.00
FC(%)	0.16	0.27	0.21	0.03	0.15	-1.20	16.00
WP (%)	0.13	0.22	0.17	0.03	0.66	-1.20	19.00
D_b(gr cm^{-3})	1.32	1.55	1.44	0.10	**-0.05**	**-2.40**	7.00
OM (%)	3.20	5.90	4.79	0.95	-0.43	-1.33	19.00

n: Number of soil samples, Min: Minimum, Max: Maximum, SD: Standard deviation, CV: Coefficient of variation, EC: Electrical conductivity, pH: Soil reaction, $CaCO_3$: Calcium carbonate, FC: Field capacity, WP: Wilting point, D_b: Bulk density, OM: Organic Matter

Of the farm soils, 50% are loam, 20% are sand and 30% are sandy loam. In terms of EC, 20% of the farm soils are very slighly (EC<4 dSm^{-1}), 10% are moderately (8<EC<15 dSm^{-1}), and 70% are strongly saline (EC>15 dSm^{-1}) (Ghassemi *et al.* 1995). It has been reported that Baghdad soils are characterized as mostly saline soils due to dryness, lack of precipitation, and evaporation (NCCL 1986). The pH ranged from 7.11 to 7.44 and therefore was slighly alkaline (Eyüpoğlu 1999). The average $CaCO_3$ content was 29.77% and high in calcareous contents ($CaCO_3$>25%) (Kihschuk 2000). FC was measured 21% and WP was 17% in farm soils in Table 4.1. It has been reported by Zotarelli *et al.* (2009) that the maximum water holding capacity is low due to rapid drainage in sandy soils. According to Zekri and Parsons (1999), observed small differences in field capacity measurements in sandy soils can make a large difference in the available water content of soils. However, even if the field capacity was increased with irrigation, which isn't possible at this site, the water supplied would be removed by infiltration or drainage and would not be used by the plants. Although farm soils have lower sand content than the other 2 sites, due to the high evaporation from the climate conditions, the impossibility of irrigation facilities, and the effect of the political situation in the region, a sustainable activity couldn't be carried out on the farm soils. Therefore, it is thought that lower FC and higher WP were measured in farm soils than in other sites. As associated with the lowest sand content, mean D_b value was measured as the lowest in farm soils (1.44 g cm^{-3}). The decrease in D_b with low sand content and increasing silt content is consistent with the result of Hillel (1982).

According to the normal D_b values (1.2 to 1.8 mg m^{-3}) given for sandy soils (Aubertin and Kardos 1965), D_b values in farm soils are between these limits (1.32-1.55 mg m^{-3}) in Table 4.1. In addition, the higher mean clay content in farm soils compared to the park and camping area confirms the lower D_b values in this area. In Ülgen and Yurtsever (1995) classification, 30% of farm soils were adequate in organic matter content (3-4%) and 70% are high (>4.0%), and the average organic matter value is 4.79%. Organic matter content is high on all 3 sites, which are generally in the sandy class. However, the organic matter content of sandy soils is stated to lower (Rutkowska and Pikuła 2013; Šimanský and Bajčan 2014). Similarly, since there is rapid decomposition in hot climates, organic matter is not stored and decomposed (Coyne and Thompson 2006). Measured high organic matter in high sand content and hot climate conditions don’t match this result. Therefore, the high amount of organic matter in farm soils can be attributed to animal manure. Animal manure application increases soil organic matter and reduces bulk weight (Moral *et al.* 2005). Considering the climate and soil texture of the region, lower sand content than other regions may be the reason why it was used as a farm in terms of water necessary problems and soil fertility. In addition, the highest average clay and silt content also belong to farm soils. Carter *et al.* (1998) added clay to the sandy soil and measured that clay reduced water repellency and increased crop yield in sandy soil. The high ability of clay content for hold water and nutrients than sandy soil reported by Al-Omran *et al.* (2005) and they noted that adding clay to sandy soil increased the available water and nutrients at the top 20 cm soil. Contrary to the negatively highest skewed distribution of silt content, sand and clay had a highly positively skewed distribution. D_b has the lowest and silt content has the highest negatively skewed distribution (Webster 2001). It is seen that D_b, pH, and $CaCO_3$ content show low variability while texture compenents, FC, WP, and OM show moderate variability. EC has the highest and pH has the lowest variability (Cambardella *et al.* 1994) in Table 4.1.

Table 4.2 Descriptive statistics of soil variables in the camp soils (n:10)

Soil variables	Min	Max	Mean	SD	Skewness	Kurtosis	CV(%)
Sand (%)	36.00	69.20	55.40	9.37	-0.40	1.60	16.00
Silt (%)	12.00	53.20	33.08	12.44	-0.69	0.71	37.00
Clay (%)	8.80	19.00	11.52	3.97	1.58	1.01	34.00
EC(dSm^{-1})	3.20	133.80	48.38	47.72	0.86	-0.35	**98.00**
pH (1:2.5)	7.19	8.10	7.54	0.28	0.63	0.15	**3.00**
$CaCO_3$ (%)	24.11	37.49	30.41	4.71	**0.02**	-1.50	15.00
FC(%)	0.21	0.28	0.25	0.02	-0.54	-1.02	9.00
WP (%)	0.18	0.23	0.21	0.01	-0.06	-1.79	8.00
D_b(gr cm^{-3})	1.35	1.54	1.49	0.05	**-1.95**	4.06	4.00
OM (%)	4.90	7.10	5.82	0.77	0.41	-0.97	13.00

n: Number of soil samples, Min: Minimum, Max: Maximum, SD: Standard deviation, CV: Coefficient of variation, EC: Electrical conductivity, pH: Soil reaction, $CaCO_3$: Calcium carbonate, FC: Field capacity, WP: Wilting point, D_b: Bulk density, OM: Organic Matter

90% of the camp soils are in sandy loam, and 10% are silt loam. In terms of EC, 20% of the camp soils are very slighly (EC<4 dSm^{-1}), 20% are slightly (4<EC<8 dSm^{-1}), and 60% are strongly saline (EC>15 dSm^{-1}) (Ghassemi *et al.* 1995). It has been reported that Baghdad soils are characterized as mostly saline soils due to dryness, lack of precipitation, and evaporation (NCCL 1986). The pH values of camp soil samples were higher than 6.50 and 50% of them showed nötr (6.50-7.50) and 50% of slightly alkaline (7.50-8.50) soil properties (Eyüpoğlu 1999). The average $CaCO_3$ content of camp soils was 30.41% and 20% have strong (15<$CaCO_3$>25) and 80% have very strong ($CaCO_3$>25) calcareous (Kihschuk 2000). FC (25%) and WP (21%) were higher in the camp soils than in the farm and park soils as given in Table 4.1. Although there were no large differences in the average clay contents of the 3 regions, the FC value was low and the WP value was high also in the camp soils due to the high temperature, irrigation problems, and higher sand content. Texture component percentages of farm and camp soils are closer and D_b values were also measured more close each other. According to Ülgen and Yurtsever (1995) classification, camp soils have high organic matter content with an average value of 5.82%. EC is higher in camp (48.3%) than in farm (23.4%) and park (10.7%) sites. Contrary to silt and sand, clay content had a highly positively skewed distribution in camp soils. $CaCO_3$ content has the positively lowest and D_b has the negatively highest skewed distribution in camp soils (Webster 2001). It is seen that D_b, pH, FC, WP, OM, and $CaCO_3$ content show low variability, sand and clay content show moderate variability, and EC and silt content have the high variability in these samples (Cambardella *et al.* 1994) in Table 4.2.

Table 4.3 Descriptive statistics of soil variables in the park soils (n:10)

Soil variables	Min	Max	Mean	SD	Skewness	Kurtosis	CV(%)
Sand (%)	57.20	85.20	77.14	10.96	-1.45	0.65	14.00
Silt (%)	4.00	34.00	12.71	11.78	1.42	0.52	92.00
Clay (%)	8.80	12.80	10.15	1.34	0.57	-0.10	13.00
EC(dSm^{-1})	1.10	36.60	10.73	12.49	1.41	0.92	**116.00**
pH (1:2.5)	7.14	7.57	7.25	0.12	**2.16**	5.28	**1.00**
$CaCO_3$ (%)	18.74	33.17	25.40	4.92	**0.03**	-1.35	19.00
FC(%)	0.21	0.27	0.23	0.024	0.87	-0.57	10.00
WP (%)	0.11	0.23	0.18	0.04	-1.38	0.79	21.00
D_b(gr cm^{-3})	1.53	1.59	1.56	0.02	-0.67	-1.47	2.00
OM (%)	6.30	7.57	7.04	0.41	-0.70	-0.48	5.00

n: Number of soil samples, Min: Minimum, Max: Maximum, SD: Standard deviation, CV: Coefficient of variation, EC: Electrical conductivity, pH: Soil reaction, $CaCO_3$: Calcium carbonate, FC: Field capacity, WP: Wilting point, D_b: Bulk density, OM: Organic Matter

60% of the park soils are in loamy sand and 40% are sandy loam. In terms of EC, 50% of the park soils were very slighly (EC<4 dSm^{-1}), 30% were moderately (8<EC<15 dSm^{-1}), and 20% were strongly saline (EC>15 dSm^{-1}) (Ghassemi *et al.* 1995; NCCL 1986). The 10% pH values of park soils were neutral (6.50-7.50) and 90% were slightly alkaline (7.50-8.50) (Eyüpoğlu 1999). The mean $CaCO_3$ content was 25.40% and 30% were strong (15<$CaCO_3$>25) and 70% were very strong ($CaCO_3$>25) (Kihschuk 2000). The park is located in the city center and little maintenance and irrigation works are done. Therefore, although the maximum (85.2%) and average (77.14%) sand contents of the park soils were higher than on the other areas, FC and WP values of these soils were measured between farm and camp values. According to Ülgen and Yurtsever (1995) classification, park soils had high organic matter content with an average value of 7.04%. Contrary to the low positively skewed distribution of clay, silt and sand content had a high positively and negatively skewed distribution, respectively. $CaCO_3$ content has low and pH has high positively skewed distribution in park soils (Webster 2001). D_b, pH, FC, OM, sand and clay content had low variability, $CaCO_3$ and WP had moderate variability, and EC and silt content had high variability in park soil samples (Cambardella *et al.* 1994) in Table 4.3.

In general, farm, camp, and park soils were sandy in texture, very strongly calcareous, and high in organic matter content in Table 4.1-4.3. However, the highest average sand content was found in park soils (77%) and the lowest was measured in farm soils (51%). Similarly to sand content, average OM and D_b were measured as the highest in park (7.05% and 1.57) and the lowest in farm soils (4.8% and 1.44) in Table 4.1-4.3. The bulk density values of study soils (1.32-1.59 gr cm^{-3}) are in agreement with the given limit values (1.10-1.78 gr cm^{-3}) given for sandy soils (Bruand *et al.* 2005). It was noted that sandy soils often have low field capacity and permanent wilting point (Huang and Hartemink 2020). FC values ranged from 0.05 to 0.22 (m^3 m^{-3}) and WP values ranged from 0.01 to 0.07 (m^3 m^{-3}) for sandy soils (Yost and Hartemik 2019a). In the studied soils, the range found for FC was between 0.162% and 0.283%, and for WP, it ranged from 0.112% to 0.234 %. However, compared with the FC and WP limit values given for sandy soils, FC was slightly high although WP was quite high in farm and camp soils. Due to their proximity to the Tigris river, the groundwater level is high in some sampling sites. In addition, these soils comprise a high organic matter, especially on the first site (the abandoned farm) and have high values of field capacity. Al-Adari (2020) indicated that the rise in groundwater leads to an increase in its moisture by filling soils' pores with water, and thus the increase in the field capacity of the soil. It was also reported that higher temperatures in areas with semi-arid climates cause a rise in the water in their soils, due to the high rates of evaporation, which increases the value of water losses. This increases the ability of soil to absorb water. In our study, the soil pH ranged from 7.11 to 8.10 and had the lowest variability (1, 2, 3 %). The low variability of pH was reported in other studies (Erşahin 1999, Mulla and McBratney 2001). In addition, EC has the highest variability (69, 98, 116 %) in farm, camp, and park soil samples. The high variability in EC can be explained by the rather high EC values (120.6 and 133.8 dSm^{-1}), especially in soil samples taken from a few points on the camp soils.

4.2 Descriptive Statistics of Metals

Descriptive statistics of metal contents in 3 sites soils were given in Table 4.4.

Table 4.4 Descriptive statistics of metal values in the farm, camp, and park soils

Metals ($mg\ kg^{-1}$)		Min	Max	Mean	SD	Skew	Kurt	CV (%)
Farm (n:10)	**Mn**	58.54	99.18	**79.10**	14.76	-0.20	-1.57	18.66
	Cu	14.62	31.52	23.02	6.22	0.05	-1.63	27.03
	Zn	18.45	54.29	34.90	12.12	0.15	-0.83	34.73
	Co	2.11	5.01	3.59	0.96	0.04	-0.64	26.92
	Cr	0.98	1.51	**1.31**	0.16	-1.01	0.52	12.54
	Pb	13.47	77.25	**35.36**	25.46	0.88	-0.92	71.98
	Cd	2.27	7.12	**4.74**	1.80	-0.23	-1.72	37.98
	Ni	1.00	3.46	1.84	0.69	1.44	2.78	37.35
	Fe	0.90	9.20	3.22	2.51	1.64	2.99	**77.81**
	Ca	23.4	29.7	27.37	1.67	-1.37	3.53	**6.12**
	Mg	1.1	9.00	4.28	2.87	0.89	-0.67	67.10
Metals		**Min**	**Max**	**Mean**	**SD**	**Skew**	**Kurt**	**CV (%)**
Camp (n:10)	**Mn**	61.58	125.44	**97.72**	19.61	-0.16	-0.07	20.07
	Cu	11.25	33.87	23.92	8.461	-0.26	-1.28	35.36
	Zn	27.99	58.14	39.08	10.69	0.60	-1.12	27.36
	Co	1.54	9.32	5.00	2.43	0.41	-0.53	48.63
	Cr	0.88	1.69	**1.19**	0.31	0.65	-0.78	26.23
	Pb	2.74	83.96	**40.71**	26.56	0.59	-0.78	65.24
	Cd	3.12	7.41	**5.29**	1.56	-0.01	-1.57	29.61
	Ni	1.99	4.33	3.41	0.88	-0.58	-1.59	26.03
	Fe	3.00	15.10	8.32	3.57	0.55	0.14	42.87
	Ca	21.12	30.00	26.06	3.26	-0.140	-1.44	**12.51**
	Mg	1.00	8.49	2.39	2.17	2.99	9.24	**90.76**
Metals		**Min**	**Max**	**Mean**	**SD**	**Skew**	**Kurt**	**CV (%)**
Park (n:10)	**Mn**	61.55	129.32	**100.85**	22.10	-0.06	-0.47	**21.91**
	Cu	13.56	29.54	18.00	4.82	1.58	3.24	26.81
	Zn	20.29	55.87	36.12	10.68	0.64	0.01	29.56
	Co	3.11	7.32	5.03	1.53	0.48	-1.03	30.47
	Cr	0.55	1.98	**1.15**	0.54	0.61	-1.38	47.22
	Pb	36.99	89.32	**64.97**	15.83	-0.24	-0.46	24.36
	Cd	1.24	6.39	**3.37**	1.92	0.32	-1.58	57.15
	Ni	1.10	5.00	2.83	1.36	0.42	-0.66	48.13
	Fe	0.10	8.82	4.38	3.01	-0.07	-1.19	**68.66**
	Ca	15.00	29.12	24.30	5.43	-0.96	-0.97	22.37
	Mg	1.21	5.00	2.58	1.26	0.74	-0.30	48.94

n: Number of soil samples, Min: Minimum, Max: Maximum, SD: Standard deviation, Skew: Skewness, Kurt: Kurtosis, CV: Coefficient of variation, Mn: Manganese, Cu: Copper, Zn: Zinc, Co: Cobalt, Cr: Crom, Pb: Lead, Cd: Cadmium, Ni: Nickel, Fe: Iron, Ca: Calcium, Mg: Magnesium

Mean concentrations of metals in the farm, camp, and park soil samples are given in Figure 4.1 and limit values of metals in soils in Table 4.5.

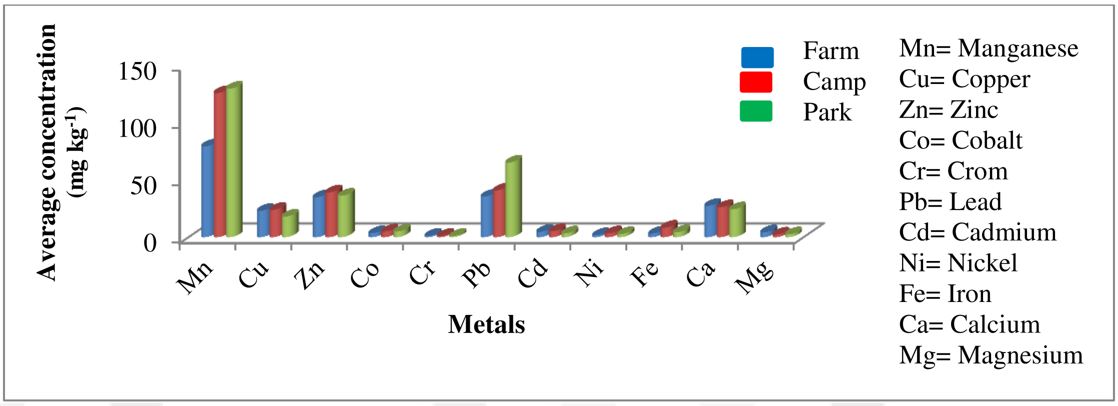

Figure 4.1 Average concentration of metals in the farm, camp, and park soils

Table 4.5 Upper limit values of metals in soil

Metals	Limit in dry weight (mg kg^{-1})	Data source(s)
Manganese	850	Rose *et al.* 1981
Copper	300	Kabata Pendias 2001
	20	Rose *et al.* 1981
Zinc	50	Rose *et al.* 1981
Cobalt	8	Rose *et al.* 1981
Cromium	1.5	Kabata Pendias 2001
	16	Rose *et al.* 1981
Lead	10	Lindsay 1979
	30	Kabata Pendias 2001
Cadmium	1.1	Lindsay 1979; Kabata Pendias 2001
	0.06	Rose *et al.* 1981
Nickel	60	Kabata Pendias 2001
	40	Rose *et al.* 1981
Iron	550	Rose *et al.* 1981
Calcium	3500	Rose *et al.* 1981
Magnesium	480	Rose *et al.* 1981

According to Table 4.4 and Figure 4.1, the highest metal concentrations in soil samples taken from farm, camp, and park areas were Mn, Pb, and Zn, respectively. It was thought that dry conditions and high-temperature factors as in sampling sites can affect the availability of plants, thus increasing their concentration in the soil. Karahan (2009) measured the heavy metal concentrations in the samples taken from the surface soils around Erciyes Mountain in Turkey. They reported that the highest mean value was found in manganese and the lowest average value in Cr, and stated that the high heavy metal content in the soil was due to the high amounts of heavy metals in the bedrock and parent materials. In addition, high vehicle traffic in the parking area in the city center, where the highest average Mn value was measured, may be the reason for the Mn concentration. Similarly, Al-Khatib (2019) reported that the reason for the increase in Mn concentration is the entry of manganese into the automobile fuel industry. Mn's octane number is increased through the compound pentadenyl tricarbonyl manganese and then is emitted from car exhaust, causing pollution to the environment and soil.

In farm soil samples, the highest mean metal concentration was measured at Mn (79.10 mg kg^{-1}) and the lowest at Cr (1.31 mg kg^{-1}). The greatest variation belonged to Fe (77.81 %) while the lowest variation was found in Ca (6.12 %) in farm samples. The high variation of iron could be due to geological, chemical, and human reasons. The geological reason is the parent rocks that form these soils. The chemical reasons are the high degree of soil interaction and the presence of calcium carbonate in the soil. Calcium carbonate's presence leads to ironis deposited in the soil. Human reasons for the high variation of Fe, include solid household waste, car exhausts, and others (Al-Khatib 2019). These results are somewhat consistent with Erşahin *et al.* (2019). They found an increase in iron pollution in urban soils of Cankiri city for geological and human reasons. The low calcium amount in the soil of the abandoned farm is due to the lack of agricultural exploitation (Al-Dulaimi 2010). This is consistent with Al-Rawi (1988) finding an increase in calcium in the cultivated orchard soils and a decrease in the uncultivated ones in the middle of the sedimentary plain.

In camp soil samples, the highest mean metal concentration was measured for Mn (97.72 mg kg^{-1}) and the lowest at Cr (1.19 mg kg^{-1}). The greatest variation belonged to Mg (90.76 %) while the lowest variation was found in Ca (12.51 %) in camp samples. The high amount of magnesium is believed to be due to the presence of dolomite minerals in the study area, in addition to the presence of soil loam (Khalil 2013). This opinion was supported by Daham (2009) during his study of the soils of the city of Faw, in the south of Iraq, where he found that the high magnesium in the study area is due to the presence of the Dolomite and sandy loam soils. The low amount of calcium is due to the lack of agricultural exploitation of these soils (Al-Dulaimi 2010). This is consistent with the study conducted by Al-Rawi (1988), who found high calcium content in the cultivated soils and a decrease in the uncultivated soils. In addition, Cu, Zn, Cd, Ni and Fe metals were found more in camp soils than in farm and park soils.

Likewise in park soil samples, the highest mean metal concentration was measured in Mn (100.85 mg kg^{-1}) and the lowest at Cr (1.15 mg kg^{-1}). As in farm soils, the highest variability in park soils belongs to Fe (68.66 %), however the lowest variation was found in Mn (21.91 %) in camp samples. The high variation of iron can be due to geological, chemical, and human reasons and the lowest variation of manganese is due to a soil reaction degree higher than 6.5. These results are consistent with a study by Al-Shami (2017) who found that the activity and concentration of manganese increase with a decrease in the soil pH in Iraqi soils. The amount of manganese in the soil is affected by soil pH, organic matter content, moisture, and soil aeration. Manganese increases when pH values decrease in soil. Manganese can be toxic in acid soils that have a pH of 5.5. However, Schulte and Kelling (2004) reported that manganese was generally low in soils with a pH above 6.5. In addition, Co, Mn, and Pb metals were found more in park soils than in farm and camp soils. It was noted that soils with a high organic matter content will immobilize heavy metals (Fayiga and Saha 2016, Hernandez *et al.* 2003), and with high organic matter resulting in less leaching of metal contaminants (Williams and Rintoul-Hynes 2022).

Fe has the highest CV in the farm (77.81%) and park (68.66%) soils, Mg (90.76%) has the highest CV in camp soils. Both metals were in the highly variable (>35%) according to Cambardella *et al*. (1994). Ca had the lowest CV% in the camp (12.51%) soils. For the camp soils, Mn had the lowest CV% (21.91%) while it was moderately variable (16-35%) (Cambardella *et al.* 1994) in Table 4.4.

Except for Cd and Pb, regarding measured metals in the farm, camp, and park soils, it was concluded that the soils were not polluted with these elements. According to the samples taken from 3 sites, Cd and Pb were the only metals that showed toxic pollution by exceeding the limit values that have been given by Lindsay (1979) and Rose *et al*.

(1981) as 0.06 mg kg^{-1} in Table 4.5. The highest concentration of Cd (5.29 mg kg^{-1}) was in the slum residential area that was formerly an army camp. In addition, lead pollution is very high compared to the permissible rate. The highest concentration of Pb (64.97 mg kg^{-1}) was measured in farm soils. However, the minimum mean concentration of Pb in the studied soils is 35.36 mg kg^{-1} in farm soils, the permissible level as given by Lindsay (1979) and Rose *et al.* (1981) is 10 mg kg^{-1}.

High concentrations of lead and cadmium are due to the exposure of this city to aerial bombardment and the dropping of large quantities of missiles during the wars between 1991 and 2003 years. There are studies reporting similar reasons. Williams and Rintoul-Hynes (2022) evaluated the effects of war on metal contamination and reported that the enrichment of copper and lead is due to warfare rather than natural or other anthropogenic causes. They also reported that the cause of pollution with high Pb and Cu concentrations was war-related activity. It was reported that Lead (Pb) and mercury (Hg) were the major metals detected along with uranium in Baghdad soils after the Gulf war (Al-Sabbak *et al.* 2012). In our studied sites, although such attacks are not completely over, we can say as another reason for high concentrations of these metals is the emission of large quantities of vehicle exhaust, traffic jams, population congestion, and the presence of an electricity station and a cement factory near the city. These findings are compatible with several studies that evaluate heavy metal concentrations in the urban soils in Baghdad City (Al-Anbari *et al*. 2015; Al Obaidy and Al Mashhadi 2013; Habib *et al*. 2012; Rahi *et al*. 2014; Tawfiq *et al*. 2015; Al-Khatib 2019). The results of these studies showed that Pb and other metals (Cd < Cr < Cu < Ni < Pb< Zn) were increasingly accumulated in urban soils, especially Cd. Based on enrichment factor (EF) in Salah Al-Heety *et al*. (2017), they found that the garden soils in Baghdad City were extremely highly enriched with Cd. They attributed their results to that Cd would be released from traffic and industrial emissions.

Similarly, Abu Ras *et al.* (2017) studied heavy metal pollution of sandy soils at 3 different sites different depths in the city of Al-Khums, Libya. They found that the average concentrations of lead at the three study sites exceeded the permissible limits of 100 mg kg^{-1}. They attributed the high percentage of lead to the automobile gasoline industry and household e, hospitals, sewage, and factory waste. Kananke *et al*. (2014) studied some metals from urban and sub-urban market sites in and around Piliyandala area of Colombo District, Sri Lanka. They found that Pb was stemming from nearby traffic activities. Imperato *et al*. (2003), reported that the heavy metal content increased with the effect of urbanization in the soil sample in 173 samples taken from the Naples region of Italy. They determined that 76% of the samples contained Pb above the determined limit value (>100 mg kg^{-1}) and that the pollution increased especially around the highway. Sarıyer (2017) explained the accumulation of Pb as a result of the study was due to the widespread use of lead in industrial and agricultural activities.

In our study, the measured concentrations of Cr, Cu, Ni, and Zn were found lower than those concentrations previously reported in the urban soil of Baghdad city. The reason why these metals are much less in our soil samples can be attributed to the absence of agricultural or irrigation activities, as well as also the lack of human activity, as the farm was abandoned a long time ago.

4.3 Correlations Between Metals and Soil Variables

Linear correlations between soil properties and total metal contents were carried out to assess which soil properties affected metal distribution in Tables 4.6, 4.7, and 4.8 for the farm, camp, and park soils, respectively.

Table 4.6 Corelations between soil variables and metals in farm soils (n:10)

	D_b	Sand	Silt	Clay	EC	pH	$CaCO_3$	FC	WP	OM	Mn	Cu	Zn	Co	Cr	Pb	Cd	Ni	Fe	Ca	Mg
Db(g cm^3)	1																				
Sand (%)	**0.77****	1																			
Silt (%)	0.49	0.03	1																		
Clay (%)	**-0.83****	-0.47	**-0.75***	1																	
EC	-0.11	-0.50	0.11	-0.19	1																
pH	-0.30	0.01	**-0.66***	0.49	0.02	1															
$CaCO_3$	0.55	0.28	0.01	-0.50	0.49	0.22	1														
FC (%)	0.54	0.32	0.28	-0.45	0.19	-0.20	0.34	1													
WP (%)	0.17	0.55	-0.34	-0.11	-0.02	0.33	0.14	0.37	1												
OM (%)	-0.37	-0.02	-0.18	0.39	-0.57	-0.23	**-0.93****	-0.36	0.04	1											
Manganese	-0.36	-0.59	0.01	0.35	0.02	-0.19	-0.42	-0.52	**-0.86****	0.30	1										
Copper	0.42	0.46	0.04	-0.32	-0.07	0.48	0.49	0.55	0.51	-0.49	**-0.70***	1									
Zinc	-0.11	0.01	-0.22	0.12	0.10	-0.15	-0.33	0.59	0.53	0.34	-0.31	0.05	1								
Cobalt	0.01	0.42	-0.48	0.02	0.05	0.52	0.17	0.22	**0.95****	0.02	**-0.76***	0.51	0.45	1							
Crom	0.19	0.21	0.35	-0.24	-0.04	-0.27	-0.19	-0.31	-0.01	0.31	0.25	-0.43	-0.22	-0.11	1						
Lead	0.56	**0.68***	0.28	-0.49	-0.44	0.15	0.04	0.10	0.37	0.12	-0.33	0.57	-0.14	0.33	0.28	1					
Cadmium	0.54	0.57	0.07	-0.43	-0.03	-0.45	0.29	0.58	0.48	-0.13	-0.61	0.09	0.41	0.248	-0.02	-0.06	1				
Nickel	0.20	-0.14	**0.78****	-0.42	0.01	-0.31	0.11	0.29	-0.34	-0.35	-0.05	0.34	-0.28	-0.43	-0.12	0.15	-0.16	1			
Iron	0.20	0.06	0.49	-0.38	0.29	**-0.65***	0.03	0.23	0.11	0.01	-0.11	-0.38	0.19	-0.08	0.59	-0.22	0.52	0.13	1		
Calcium	0.14	0.06	0.58	-0.25	0.00	-0.33	-0.01	0.24	-0.01	-0.04	-0.12	0.02	-0.02	-0.08	0.33	0.04	0.09	0.53	**0.64***	1	
Magnesium	-0.31	-0.19	0.07	0.19	0.22	-0.06	-0.18	0.12	0.23	0.15	-0.10	-0.18	0.33	0.25	0.28	-0.27	0.02	0.04	0.60	**0.78****	1

** Significant at P<0.01 *Significant at P<0.05. n: Number of samples, D_b: Bulk density, pH: Soil reaction, EC: Electrical Conductivity, $CaCO_3$: Calcium carbonate content, OM: Organic Matter, FC: Field capacity, WP: Wilting point

Table 4.7 Corelations between soil variables and metals in camp soils (n:10)

	D_b	Sand	Silt	Clay	EC	pH	$CaCO_3$	FC	WP	OM	Mn	Cu	Zn	Co	Cr	Pb	Cd	Ni	Fe	Ca	Mg
D_b ($g\ cm^{-3}$)	1																				
Sand (%)	0.43	1																			
Silt (%)	-0.52	-0.34	1																		
Clay (%)	-0.24	0.24	-0.06	1																	
EC	-0.09	0.63	-0.43	0.28	1																
pH	0.15	0.01	0.45	0.12	-0.54	1															
$CaCO_3$	-0.27	0.13	0.32	-0.02	0.17	-0.45	1														
FC (%)	0.32	0.27	**-0.71***	-0.16	0.42	-0.39	-0.07	1													
WP (%)	0.03	0.51	-0.19	0.01	**0.65***	-0.38	0.18	0.42	1												
OM (%)	0.43	-0.03	-0.01	0.14	-0.59	0.57	-0.41	-0.47	-0.44	1											
Manganese	0.14	-0.10	0.10	-0.58	-0.15	-0.48	0.53	-0.13	-0.02	-0.16	1										
Copper	-0.22	0.05	0.52	-0.21	-0.29	0.35	0.15	**-0.68***	-0.36	0.33	0.27	1									
Zinc	-0.63	-0.16	0.10	0.47	-0.01	0.12	-0.09	-0.11	-0.36	-0.08	-0.36	0.25	1								
Cobalt	0.02	-0.10	-0.26	-0.16	-0.12	-0.52	0.43	-0.08	-0.32	0.15	0.62	0.31	0.13	1							
Crom	0.36	0.29	-0.15	-0.12	-0.15	0.46	-0.22	0.20	-0.48	0.16	-0.12	0.30	0.30	0.04	1						
Lead	0.28	0.21	-0.23	-0.21	-0.11	0.23	-0.35	-0.15	-0.49	0.37	0.15	0.60	0.28	0.37	**0.71***	1					
Cadmium	-0.41	0.15	0.03	0.43	0.50	-0.39	0.08	-0.29	0.51	-0.16	0.03	-0.01	0.11	-0.01	**-0.68***	-0.22	1				
Nickel	0.14	0.38	-0.23	0.03	0.53	-0.51	0.23	0.30	0.54	-0.54	0.44	-0.33	-0.18	-0.01	-0.19	-0.12	0.47	1			
Iron	0.47	-0.28	-0.21	-0.42	-0.22	-0.29	-0.06	0.04	-0.23	-0.02	**0.63***	-0.26	-0.48	0.23	-0.03	0.11	-0.14	0.43	1		
Calcium	-0.03	-0.29	0.26	-0.26	-0.11	-0.16	0.01	-0.51	-0.25	-0.06	0.59	0.23	-0.21	0.14	-0.19	0.22	0.28	0.38	**0.71***	1	
Magnesium	0.38	0.12	0.18	-0.08	-0.24	0.08	0.01	-0.38	0.20	0.35	0.49	0.12	-0.45	0.03	-0.30	-0.01	0.36	0.46	0.46	0.50	1

*Significant at $P<0.05$. n: Number of samples, D_b: Bulk density, pH: Soil reaction, EC: Electrical Conductivity, $CaCO_3$: Calcium carbonate content, OM: Organic Matter, FC: Field capacity, WP: Wilting point

Table 4.8 Corelations between soil variables and metals in the park soils (n:10)

	D_b	Sand	Silt	Clay	EC	pH	$CaCO_3$	FC	WP	OM	Mn	Cu	Zn	Co	Cr	Pb	Cd	Ni	Fe	Ca	Mg
D_b(g cm^3)	1																				
Sand (%)	**0.68***	1																			
Silt (%)	-0.11	-0.38	1																		
Clay (%)	-0.06	0.57	**-0.73***	1																	
EC	-0.18	0.37	-0.18	**0.66***	1																
pH	**-0.66***	**-0.67***	0.24	-0.27	-0.13	1															
$CaCO_3$	0.08	0.53	-0.13	**0.67***	**0.69***	-0.35	1														
FC (%)	-0.16	0.19	0.00	0.48	0.37	0.01	0.62	1													
WP (%)	0.14	0.22	0.09	0.33	0.26	-0.22	**0.80****	**0.72***	1												
OM (%)	0.01	-0.14	-0.12	-0.01	-0.47	0.41	-0.11	0.10	0.23	1											
Manganese	-0.18	0.17	-0.21	0.22	0.02	-0.08	0.13	-0.16	-0.19	-0.29	1										
Copper	**-0.68***	-0.09	-0.22	0.59	**0.80****	0.30	0.42	0.37	0.07	-0.34	0.22	1									
Zinc	0.04	-0.03	0.26	-0.43	-0.08	-0.05	-0.51	-0.56	**-0.75***	**-0.65***	0.40	-0.06	1								
Cobalt	**-0.64***	-0.36	-0.22	0.43	0.50	0.54	0.33	0.36	0.30	0.24	-0.21	**0.74***	-0.56	1							
Crom	-0.19	0.28	-0.40	0.58	0.19	-0.00	0.58	0.52	0.41	0.08	0.54	0.34	-0.39	0.24	1						
Lead	-0.17	0.046	-0.32	0.26	0.17	-0.18	-0.06	0.13	-0.22	-0.54	0.54	0.39	0.44	-0.10	0.18	1					
Cadmium	-0.10	0.088	-0.27	0.50	**0.65***	0.24	0.47	0.43	0.42	0.06	-0.23	0.62	-0.40	**0.73***	0.12	0.11	1				
Nickel	0.24	0.31	0.11	0.01	0.29	-0.15	0.06	0.17	-0.08	-0.25	-0.4	-0.03	0.03	-0.11	-0.12	-0.34	-0.06	1			
Iron	0.25	0.28	0.35	-0.20	0.21	-0.06	-0.11	0.12	-0.24	-0.40	-0.34	-0.05	0.41	-0.33	-0.25	-0.09	-0.10	**0.86****	1		
Calcium	0.14	0.06	0.25	-0.18	0.03	-0.24	0.01	0.14	0.03	-0.23	-0.54	-0.21	-0.07	-0.18	-0.10	-0.40	-0.34	**0.87****	**0.65***	1	
Magnesium	0.26	0.21	0.13	-0.08	0.25	-0.20	-0.01	0.15	-0.08	-0.34	-0.60	-0.05	0.07	-0.12	-0.22	-0.24	-0.02	**0.97****	**0.85****	**0.88****	1

** Significant at $P<0.01$, *Significant at $P<0.05$. n: Number of samples, D_b: Bulk density, pH: Soil reaction, EC: Electrical Conductivity, $CaCO_3$: Calcium carbonate content, OM: Organic Matter, FC: Field capacity, WP: Wilting point

In farm soils, the highest correlation coefficients between soil variables were found between D_b andclay content (-0.83) and D_b andsand content (0.77). In addition, in park soils, D_b-sand content (0.68) and D_b-pH (-0.66). It was mentioned that there is strong relation between soil bulk density and soil texture components (Chaudhari *et al* 2013).

As related to soil moisture properties and metals, we found correlations between WP and Co(0.95), and WP and Mn (-0.86) in farm soils. In camp soils, there were correlations between FC and Cu (-0.68), FC and silt content (-0.71), and WP and EC (0.65). In addition, it was found that there were significant correlations between WP and $CaCO_3$ (0.80), WP and FC (0.72), and WP and Zn (-0.75) in park soils. Zheng and Zhang (2011) reported that soil moisture dynamics such as field capacity and wilting point directly affect many physicochemical properties of soils, including organic matter content, pH, and electrical conductivity, and are indirectly involved with metals in soils. Therefore they have drawn attention to the current soil water status such as field capacity and wilting point as well as the dynamics of soil moisture content should be taken into account in order to assess the status of metals in soils.

There was a positive correlation between Cu and EC (0.80) in the park soils. A similar result was found by Peris *et al.* (2008). They investigated the heavy metal content and sources of agricultural soils in Castellón province (Spain), a representative area of the European Mediterranean region, and found that Cu and Pb concentrations were found to be positively correlated with EC ($r=0.200$; $p \leq 0.05$). Correlations between sand content and Pb (0.68) and silt content and Ni (0.78) were significiant in thefarm soils. The effect of texture on metal accumulation in the soil has been reported, for example, Brummer *et al.* (1986), Ma and Rao (1997), Selim and Sparks (2001) noted that the severity of pollution depends not only on the total heavy metal content of the soil but also on the proportion of their mobile and bioavailable forms, which are generally controlled by the texture and other physicochemical properties of soils. In the farm soils, we found a negative correlation between WP and Mn (-0.86) while there was a positive correlation between WP and Co (0.95). In a similar study that investigated the effects of soil water status on metals in serpentine soil (Gunarathne *et al.* 2019), it was noted that there was a positive relation between WP and Mn and Co contents in soils which they attributed to the microbial reduction that occurs by water deficiency below the wilting point.

According to our results, the microbial reduction caused by the wilting point did not adversely affect, on the contrary, a positive effect was observed on the amount of Co.

However, no studied metals were correlated with soil pH except Fe metal in the farm soils. The pH values of all soil samples taken from all three regions are between 7.11 and 8.10, and the studied soils are characterized by alkaline. pH has a moderate level significant correlation (-0.65) with Fe at 0.05 level negatively in the farm soils in Table 4.6. Alloway (2013) reported that the movement and content of heavy metals in the soil can be controlled by pedogenic processes, soil management, and various anthropogenic and soil factors such as soil pH, organic matter, clay, carbonates, and salt content. In addition, there are studies reporting the accumulation of Cd and Pb in alkaline soils. It was stated by Metin (2010) that lead can dissolve at a very low level in acidic and alkaline conditions. Ismael (2010) studied heavy metal concentration in alkaline soils (pH=7.35) of A-Tala village in Maysan Governorate and reported the lead concentration to be approximately the same (35 mg kg^{-1}) as our study and exceeding the limit of Cd (8 mg kg^{-1}). However, she concluded that besides alkaline properties, the main factor in the development of high cadmium concentrations was pollution resulting from human activities. In our farm soil samples, the mean Cd concentration exceeding the limit value (1.5 mg kg^{-1} for pH>7 soils) was found to be 4.74 mg kg^{-1} although there was no human activity. However, there is an apartment complex just a few meters away near the abandoned farm. According to the results of such research, we can say that the higher Cd and Pb concentration in the park soils is of anthropogenic origin.

Weaver and Polard (2011) reported that the higher the percentage of organic matter in the soil, the higher the cadmium concentration with it is adsorbed on the particles of the organic matter, and when organic matter decomposes, cadmium is released into the soil. Since there were not adequate plants in the sampling areas, soil organic matter would be highly stabilized.

4.4 The Geoaccumulation Index (I_{geo}) of Metals

The Geoaccumulation index were calculated according to Muller's (1969) equation and classified using the Table that was given by Yaqin *et al.* (2008) and He *et al.* (2022) in Table 4.8.

Table 4.9 I_{geo} index classes of metals in the farm, camp, and park soils

FARM SOILS				
Metals	**Igeo**	**Class**	**Urban soil quality**	**Data sources**
Mn	-4.01	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Cu	-0.38	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Zn	-1.1	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Co	-1.73	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Cr	-4.18	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Pb	**1.23**	**2**	Moderately contaminated	Yaqin *et al.* 2008; He *et al.* 2022
Cd	**5.71**	**>5**	Extremely contaminated	Yaqin *et al.* 2008; He *et al.* 2022
Ni	-5.01	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Fe	-7.96	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Ca	-7.64	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Mg	-7.38	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
CAMP SOILS				
Metals	**Igeo**	**Class**	**Urban soil quality**	**Data sources**
Mn	-7.38	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Cu	-0.33	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Zn	-0.09	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Co	-1.26	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Cr	-4.32	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Pb	**1.44**	**2**	Moderately contaminated	Yaqin *et al.* 2008; He *et al.* 2022
Cd	**5.87**	**>5**	Extremely contaminated	Yaqin *et al.* 2008; He *et al.* 2022
Ni	-4.13	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Fe	-6.64	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Ca	-7.64	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Mg	-8.38	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
PARK SOILS				
Metals	**Igeo**	**Class**	**Urban soil quality**	**Data sources**
Mn	-3.66	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Cu	-0.74	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Zn	-1.05	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Co	-1.25	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Cr	-4.38	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Pb	**2.11**	**3**	Moderately to heavily contaminated	Yaqin *et al.* 2008; He *et al.* 2022
Cd	**5.22**	**>5**	Extremely contaminated	Yaqin *et al.* 2008; He *et al.* 2022
Ni	-4.41	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Fe	-7.64	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Ca	-7.64	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022
Mg	-7.96	0	Practically uncontaminated	Yaqin *et al.* 2008; He *et al.* 2022

I_{geo}: The Geoaccumulation index, Mn: Manganese, Cu: Copper, Zn: Zinc, Co: Cobalt, Cr: Crom, Pb: Lead, Cd: Cadmium, Ni: Nickel, Fe: Iron, Ca: Calcium, Mg: Magnesium

The I_{geo} values for the metals Cd > Pb > Cu > Zn > Co > Mn > Cr > Ni > Mg > Ca > Fe in the farm soils;, Cd > Pb > Zn > Cu > Co > Ni > Cr > Fe > Mn > Ca > Mg in the camp soils; and Cd > Pb > Cu > Zn > Co > Mn > Cr > Ni > Fe = Ca > Mg in the park soils in Table 4.8. All of the I_{geo} values of metals except Cd and Pb were lower than 0. Therefore, it was concluded that the soils of Baghdad were not contaminated with these metals. I_{geo} values of Cd in the farm, camp, and park soils were larger than 5, and they were calculated to exceed the extremely contaminated class. I_{geo} values of Pb in the farm and camp soils were larger than 1, taking place in the moderately contaminated class. However, in park soils, it was larger than 2, and in the moderately to heavily contaminated class. Farm and camping areas are quite uncrowded places. The higher Pb content in the park soils than in the farms and camp was attributed to the low density of people and therefore traffic since the park is located in the center of the city. There are studies that associate metal accumulations in city park soils with anthropogenic factors due to high population and traffic. He *et al*. (2022) stated that Cd and Pb, along with Zn and Cu, were the most studied metals in urban soils, as their concentrations are generally high. Chen *et al* (2005) reported that the high metal accumulation index values in China's cities were higher in old park soils than in new parks. They noted that it was related to the exposure time. Likewise, Peng *et al*. (2013) reported that the concentrations of metals in residential soil was increasing with the age of the residential buildings. These reports confirm that metal concentrations were related to the increasing population in urban soils. These results agree to that there was more contamination with Pb and Cd metals in the park soils of Baghdad city.

On the other hand, extremely high I_{geo} values of Cd in the farm, camp, and park soils (larger than 5) show that Cd pollution was at a very significant level in this city. Anthropogenic sources such as traffic emissions can be suspected as the main reason for the high I_{geo} values for Cd in Baghdad urban soils in Table 4.8.

4.5 Spatial Distribution of Metals

The kriging maps were built for depicting spatial distribution pattern of studied soil metals in the farm, camp, and park soils and were given in Figures 4.3, 4.4, and 4.5.

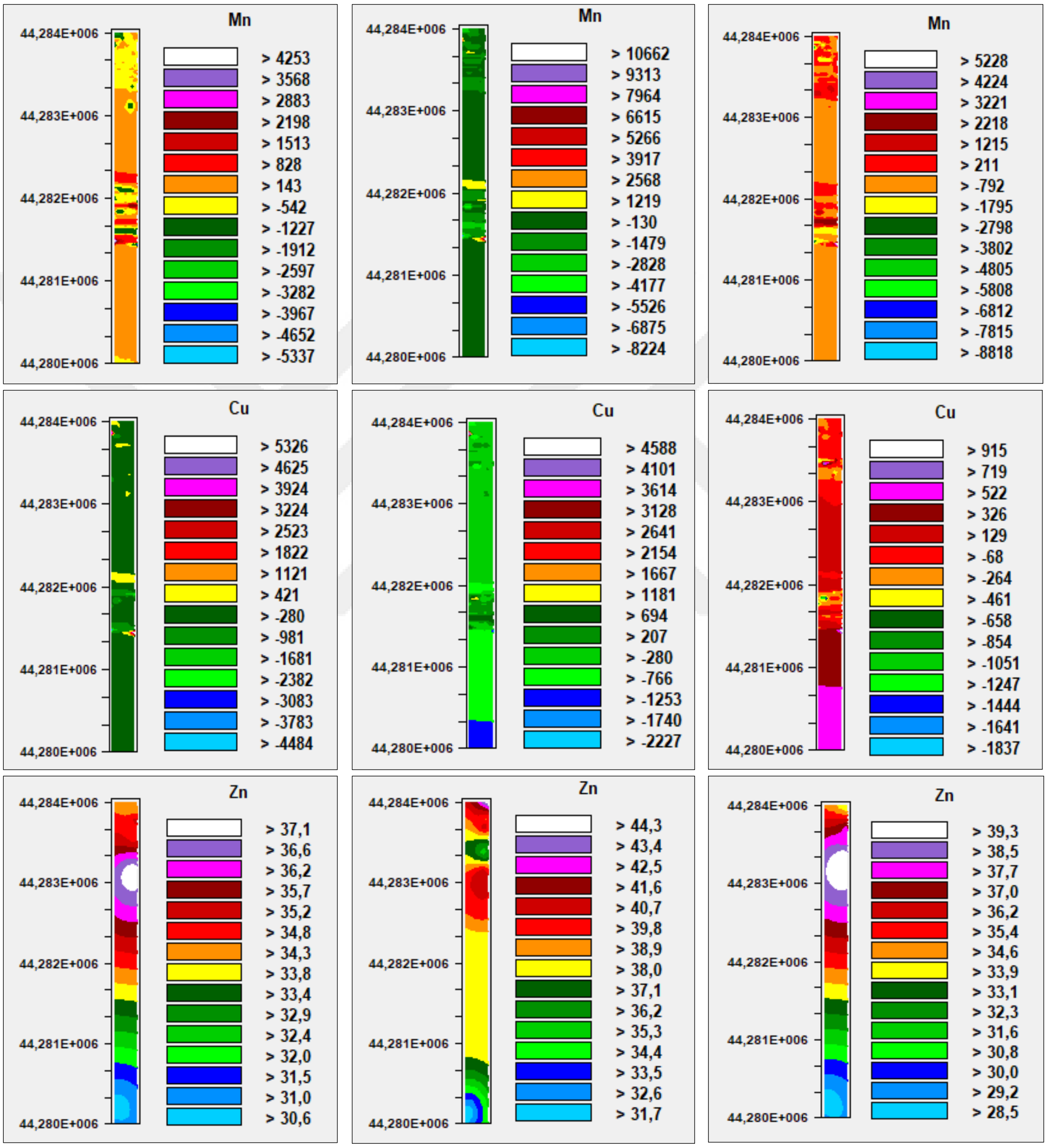

Figure 4.2 The spatial distributions of the Mn, Cu, and Zn metals in the farm (left), camp (middle), and park(right) soils

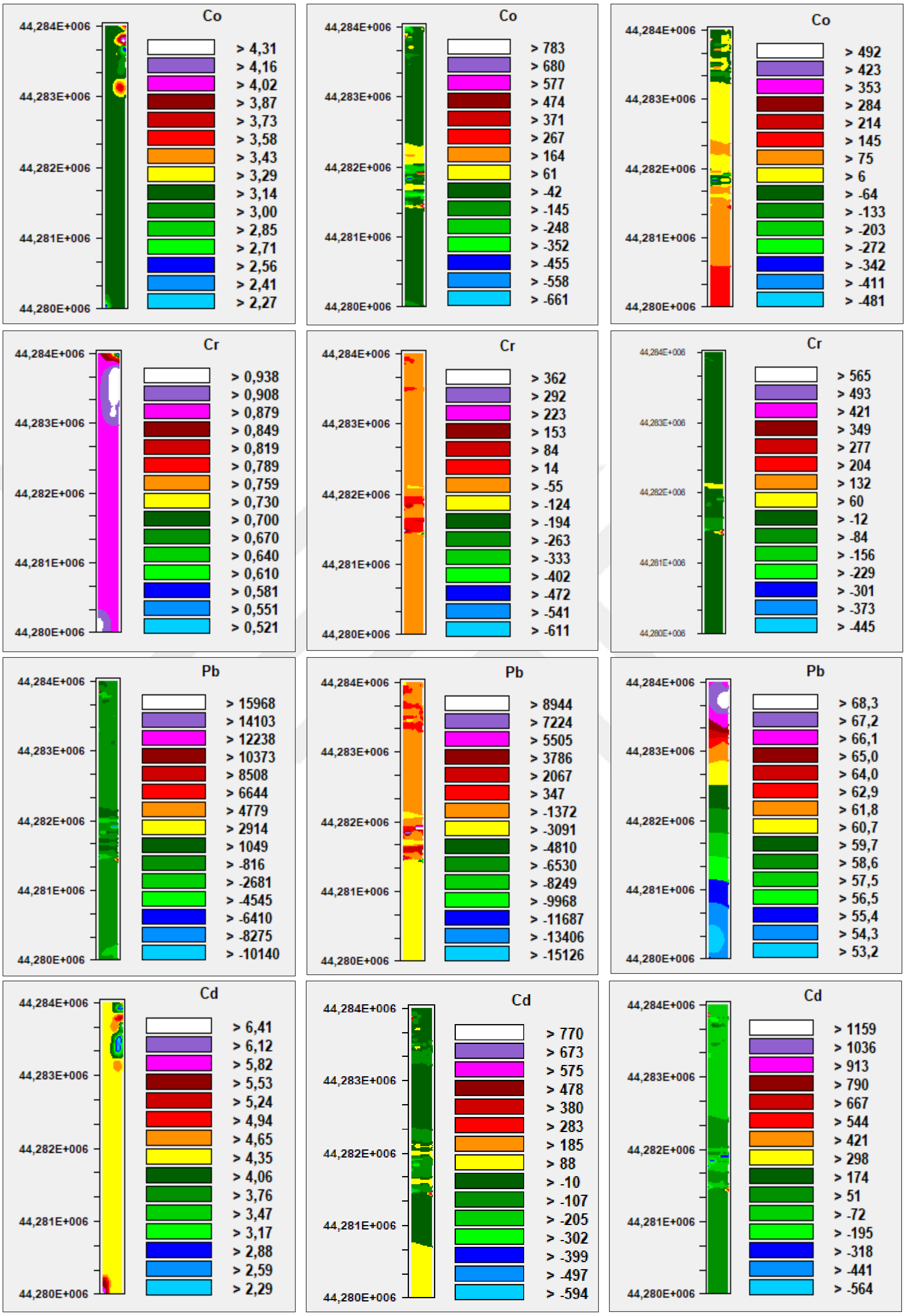

Figure 4.3 The spatial distributions of the Co, Cr, Pb, and Cd metals in the farm (left), camp (middle), and park (right) soils

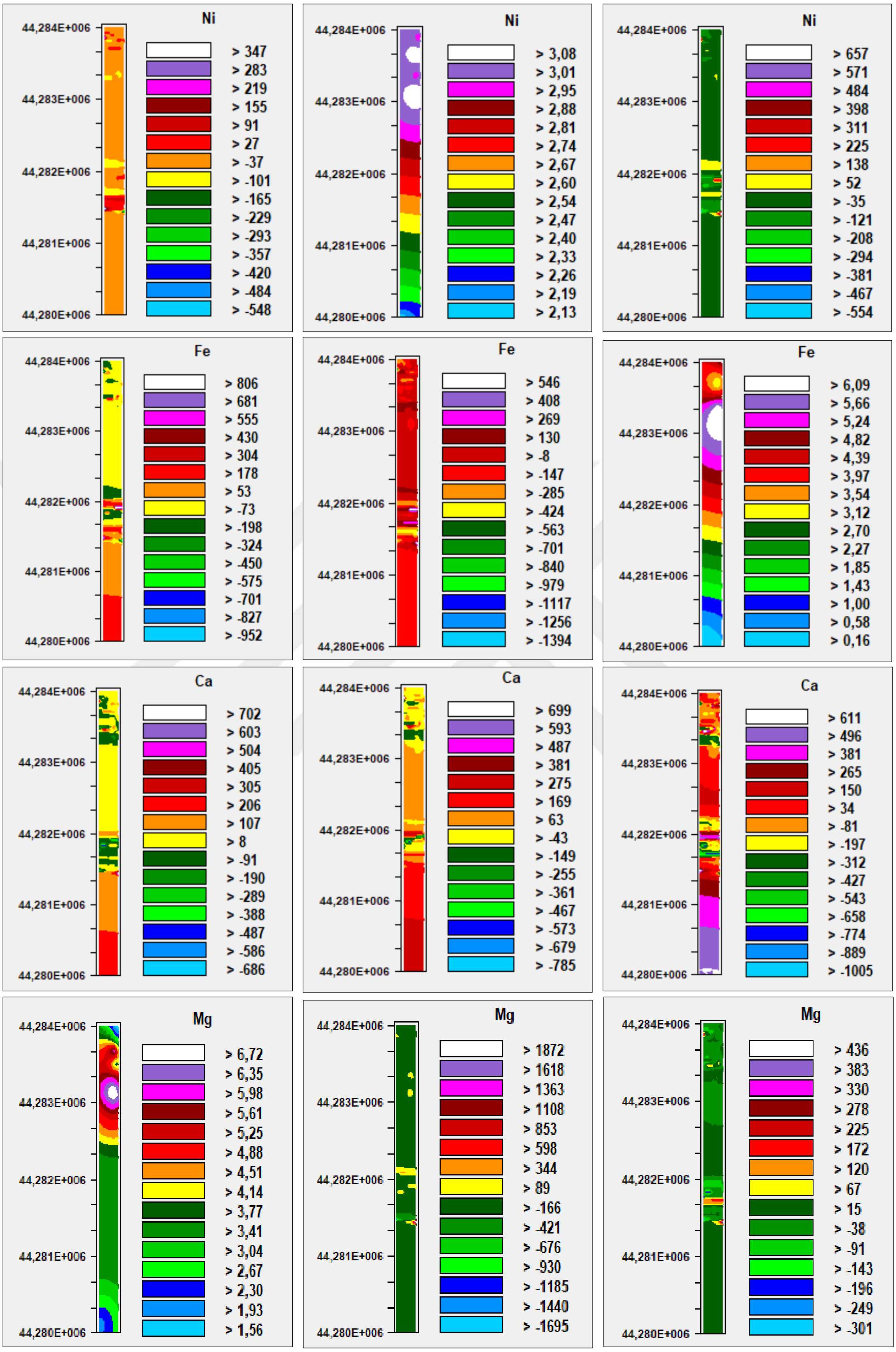

Figure 4.4 The spatial distributions of the Ni, Fe, Ca, and Mg metals in the farm (left), camp (middle), and park (right) soils

He (2022) reported that heavy metal contents in soils have strong spatial variability, and their statistical distributions are useful indicators of the long-term characteristics of urban pollution. Concentrations of Mn, Fe, and Ca have a increasing trends in the same direction while concentration of Mg has trended in the opposite direction on the farm site. These trends in farm soils can be attributed to the distribution of household and farm wastes since the site was used as a farm before. In addition, concentrations of Zn and Mg showed a patchy distribution in farm soils.

Similarly, concentration of Cd showed an increasing trend in opposite direction with concentrations of Cu, Pb, and Ca trends in the camp soils, and concentrations of Zn and Ni showed patchy distribution. Fe concentration is high in the camp soils compared to farm and park soils and mostly evenly distributed. The high concentration of Fe may be due to the long-term use of the camp site as a military area. As related to the park soils, concentration of Cu, Co, Cd, and Ca had a trend in opposite direction with concentration of Mn and Pb. Zn, Co, Pb and Ca concentrations showed patchy distribution in the park soils. Ca Co, Zn, Cu, Pb, and Mn concentrations were greater in park soils than in the farm and camp soils, which may beattributed the fact that the mostly higher concentartion of metals are in the park soils that the park is in the center of the city, and that human-related factors such as traffic are effective.

In regard with the soil pollution of Baghdad city, besides human-induced pollution, factors such as dry climatic conditions, low rainfall and vegetation can be important. Similar results have beenreported in previous studies. Imperato *et al.* (2003) reported that urban soil pollution would be resulted from the accumulation of nonsoil originated pollutants as well as where was little vegetation cover or dry conditions subsist.

5. CONCLUSIONS AND RECOMMENDATION

In this study, metal pollution levels in soils of Baghdad city was evaluated under three different land uses (a farm site, a camping site, and a city park site). The metals evaluated were Mn, Cu, Zn, Co, Cr, Pb, Cd, Ni, Fe, Ca, and Mg. The mean concentrations of the metals except Cd and Pb showed no significant pollution level. The results revealed that urban soils in Baghdad city were polluted by two metals. Cd was the most seriously polluting metal with 3.37%, 4.74%, and 5.29% of the pollution in the park, farm, and camp soil. In addition, Pb was significiant with 35.36%, 40.71%, and 64.97% of the pollution in the farm, camp and park soils. The high rates of soil pollution with Cd and Pb resulted from accumulation of household waste, sewage water, and gases emitted from cars all triggered by increased population. In addition, the accumulation of industrial waste from factories, blacksmithing workshops, and car repairs in soil and its failure to decompose are the reasons. Therefore, human activity played important role in the high levels of pollution of Cd and Pb besides natural factors such as soil texture compenents and soil dust in Baghdad.

Soil is generally considered as a sink for metals, especially in the urban environments. This result also led us to assess the health risk caused by exposure to metals in the urban soils, especially park soils in Baghdad City since children and adults spend a subtantial time on those sites.. metals are an increasingly serious problem for soil quality. Metals' presence in soil is strongly influenced by anthropic activities, thus soils contaminated with metals pose an increasing risk to human health.

In addition, metals are seen as important factors for many diseases. Especially metals, which are chemical warfare agents such as lead, have toxic properties on the nervous system and organs. Therefore, the recommendation is to impose environmental and health control over factories, power stations, blacksmiths, and car repair workshops and provide to dispose of industrial waste correctly. Furthermore, finding solutions traffic jams and preventing the use of car fuels that contain tetraethyl lead, raising environmental awareness and environmental culture in society and alerting the danger of pollution in general and soil contamination with toxic elements in particular through television and radio programs, seminars, conferences, printed publications and publications on social media are recommended. Public awareness should be raised that paying attention to vegetation cover, developing and caring for it, especially those plants that reduce pollution with heavy elements such as willow, not cutting trees, not removing forests, and not destroying agricultural lands. In addition, scientific research related to combating pollution of all kinds must be encouraged. Disposal of solid and factory waste should be implemented using the proper technology and pesticides and chemical fertilizers must be reduced. Along with these practices, more attention should be paid to metal pollution in soils in cities with dense populations and traffic.

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