



Research Article

Assessment of Heavy Metal Contamination of Soil in West of Karbala City by Using Geospatial Analysis

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Abstract | Contamination of soil with heavy metals is a global issue that has a significant impact on ecosystems and human health. Soil contaminated with heavy metals presents a serious risk to human health and ecosystems. This study quantified the level of heavy metal pollution in the soil. The study aimed to identify the origins of heavy metals, chart their locations, and evaluate potential impacts on the environment and public health. fifteen samples of soil have been collected from the Al_saqi farm, which is west of Karbala City. X-ray fluorescence (XRF) machine has been used and the normalized difference vegetation index (NDVI) to find out how much heavy metal was influencing the area. The samples vary in terms of contamination, ranging from completely uncontaminated to somewhat contaminated by Cd, Zn, Ni, and B, and substantially polluted by Fe. Furthermore, the B, Ni, Pb, Cu, and Zn contamination factors (CF) show minimal contamination, whereas the Cd and Fe contamination factors (CF) show moderate to high contamination. The findings suggest that heavy metals do not heavily contaminate the region, as the concentrations of the HM (heavy metals) elements are lower than their averages in the Earth's crust. Groundwater is responsible for the high levels of heavy metals in the research region. The chemicals used in fertilizers on agricultural lands may be the cause of the high levels of heavy metals in the research region. Phosphate One important factor contributing to diffuse cadmium pollution is ore fertilizers. Acidity is the main factor affecting cadmium solubility in water.

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Introduction

Human activity primarily releases heavy metals into the environment in the form of volatile dust from cement plants, as well as from a variety of sources such as mining waste, volatile compounds, home sewage, and industrial effluents. Lead and

cadmium are particularly concerning because they are hazardous to living things, even in very small amounts. On the other hand, despite being normal components of ecosystems and biologically necessary for other creatures, copper and zinc typically only show toxicity in very high quantities (Jadaa and Mohammed, 2023). Not only does heavy metal pollution have an

impact on crop yield and quality, but it also degrades the atmosphere and waterways, endangering the lives and health of both humans and animals. Numerous researchers have unequivocally determined that human activity is a primary factor contributing to the ecosystem's metal contamination (Kasassi *et al.*, 2008). Atmospheric pollution and particulate matter deposition contribute to the deterioration of soil quality (Barbulescu and Postolache, 2021). Heavy metal contamination leads to a change in some of the physical and chemical properties of the soil and thus leads to disruption of the vital balance of elements (Aydin-Alp and Marinova, 2003). Determine the geographical distribution of several heavy metals present in soil in this study, such as Pb, Cd, Ni, B, Fe, Cu, and Zn. these elements in the research area have been evaluated the contamination levels using the Geo-accumulation Index (Igeo) and Contamination Factor (CF) to identify potential sources of heavy metals causing soil pollution in the Al-Saqi farm west of Karbala city Geographic autocorrelation often skews the distribution of heavy metal content (Kishné *et al.*, 2003). It is important to consider the expenses associated with conducting frequent and comprehensive soil sampling and analysis. Usually, sampling is not possible. Charting the geographical distribution of soil contamination, spatial interpolation methods are required. Consequence As a result, we employ interpolation techniques such as inverse distance weighting. Soil science frequently utilizes kriging, spline, and IDW techniques. Imperato *et al.* (2003) conducted research and mapped contamination. Amini *et al.* (2005) and McGrath *et al.* (2004). Accurate interpolation relies on a precise definition of the contaminated region and its borders. This directly affects the precision of the pollutant estimate. Numerous studies have explored the effectiveness of the following spatial interpolation techniques. Currently, the results are inconclusive (Shi *et al.*, 2009). A few of them discovered that the Kriging technique outperformed IDW. Some studies (Saffari *et al.*, 2009; Panagopoulos *et al.*, 2006). The primary goal of studies on soil heavy metal contamination is to identify regions with a greater risk of contamination. The samples originate from regions that are highly susceptible to contamination. These are often isolated areas in space (Zhang *et al.*, 2009).

Materials and Methods

Field work begins in December 2023 and ends

in April 2024, with fifteen samples collected in different parts of the Al-Saqi farm that showed in Table 5. The sampling area has been selected randomly to encompass the entire study area. the GPS (Geographic Position System) device has been used to pinpoint the locations and measure the soil depth (20 cm) from various locations, logging the coordinates for each sample. Then we measured soil salinity using the portable TDS, EC, and PH meters. A professional instrument with several uses measures the temperature, conductivity (the ability of conduction current expressed in digits and measured in the unit us/cm), and TDS (the weight of total dissolved solids in water, measured in the unit mg/L or ppm). It has a pen-style design that is extremely accurate, producing rapid and accurate results.

The laboratory work involves preparing the samples for chemical analysis. The samples have been filtered using a 2 mm sieve. Next, then took the sample, mixed it thoroughly, placed it in a 32 mm press, compressed it to seven tones of pressure, and then placed it in an X-ray fluorescence (XRF) holder. An XRF aperture can analyses both liquid and solid materials. High-energy X-ray or gamma ray bombardment stimulates a material to emit characteristic secondary (or fluorescent) X-rays, known as X-ray fluorescence (XRF) Chen and Walter (2008).

Office work: The inverse distance weight (IDW) approach in GIS has been used to interpret soil elements and create distribution maps based on element concentration. The process of interpolation involves anticipating attribute values in unsampled points, and IDW utilizes a specific number of nearest points, weighted based on their distance from the interpolated point (Zuo *et al.*, 2018). Additionally, measure the vitality of plants using the NDVI from satellite image data. NDVI separates the natural green vegetation from other land cover types (such as soil, urban, water, etc.). Its use of the vegetation standard differences index is necessary to ascertain the various land cover categories within the research region. Therefore, we derive NDVI by dividing the difference between the red (RED) and the near-infrared (NIR) band spectral bands on a per-pixel basis. When selecting the NDVI value from -1 to +1, lower values may indicate land cover types like sparse grasslands (0.2 to 0.3), while higher values indicate dense vegetation (0.6 to 0.8). NDVI values from 0 represent soil types, while negative values indicate water bodies.

The following equation can calculate the vegetation index (NDVI) by measuring the difference:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where; The normalized difference vegetation index is known as NDVI. The term “red” refers to the red band, while “NIR” stands for the near-infrared band (Rouse *et al.*, 1973).

Site description

The study area is situated west of Karbala city, near al-Ukhaidar fortress. The study area spans approximately 25 km in the Khudaira area, situated between latitudes of 32° 26' to 32° 22'N and longitudes of 43° 34' to 43° 30' E, as showed in Figure 1. The topography spans from a high point of 95 to a low point of 61 meters above sea level. The General Commission for Groundwater initiated the project in 2016, with 50 wells ranging in depth from 86.5 to 137 m (Hashim, 2021). This project used to plant various types of trees, such as citrus palms, as well as wheat crops. Structurally, the study area is located to the west of the Mesopotamia zone within the stable shelf, which represents the northwest portion of the Euphrates subzone (Buday and Jassim, 1987). In a tectonic sense, the area is home to two distinct groups of faults: The first group, which includes the NE-SW trending Khanaquin-Baquba-Karbala Fault and the Rhaimawi-Hilla Fault. The same positioning applies to two additional faults that exclusively affect the basement. The second group, the Heet-Abu Jir Fault, follows the NW-SE trend of the Abu Jir fault zone and is located in the northern part of the research area. Earth Science: The Umm Er Radhuma Formation (Paleocene–Early Eocene) and the Euphrates Formation (Lower–Upper Eocene) comprise the study area’s geological backdrop. And the Dammam Formation (Lower–Upper Eocene). The former primarily consists of recrystallized nummulitic limestone, varying in thickness from 80 to 147 m and exhibiting grey, creamy, yellowish, and white hues (Al-Jawad and Ridha, 2008), and the Lower Miocene Euphrates Formation Limestone, marl, and basal breccia make up the formation, which is 10–20 m thick. These formations are made up of rocks with different carbonate compositions. Anwar *et al.* (1995), claim that recently deposited sediments, ranging in thickness from one to two meters, cover these formations. The region’s productive hydrogeological unit is the Dammam Aquifer. There

are several fissures in this limited aquifer. These cracks significantly influence the distribution of groundwater and the hydraulic characteristics of the aquifer (Al-Shamari, 2014).

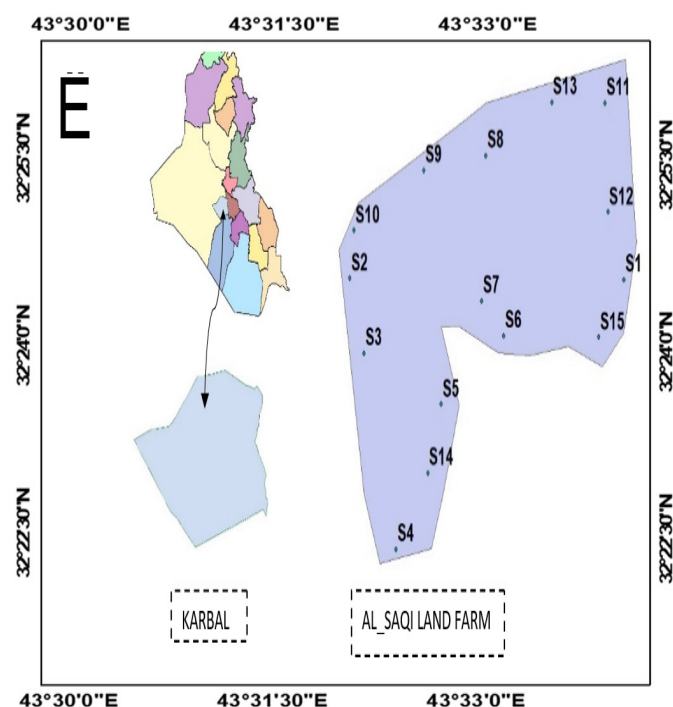


Figure 1: Location of the study area.

Assessment of heavy metal contamination

Mason (1966) used the Geoaccumulation Index (Igeo) and the Contamination Factor (CF) to determine the extent of heavy element contamination in soil.

Igeo accumulation index (Igeo)

Muller (1969) states that the (I geo) index is used to assess the level of heavy metal pollution in soil by using the following equation to determine the extent of heavy metal enrichment in the soil.

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

According to Mason's (1958) research, while Bn indicates the concentration, Cn denotes the concentration of heavy metals in the research samples relative to the average concentration of heavy metals in the earth's crust. We use a constant value of 1.5 to minimize fluctuations and potential shifts in the concentration of heavy metals impacted by both natural and human factors (Muller, 1969). We then compared the results with Table 1.

Contamination factor (CF)

CF is one of the metrics used to illustrate the

relationship between soil contamination and human activity (Ahmed *et al.*, 2016). You can compute the contamination factor, a crucial instrument for assessing the level of heavy metal contamination in soil, using the equation below (Hakanson, 1980):

$$CF = \frac{Cn}{Bn}$$

Mason (1958) defined Bn as the concentration of heavy elements in the earth's crust's typical rocks, and Cn represents the number of heavy metals present in the soil. Hakanson (1980) divided the contamination factor (CF) into four categories. We determined the level of soil pollution in the study area by comparing it to Table 2.

Table 1: Geoaccumulation (*I_{geo}*) classes (Muller, 1969; Kowalska *et al.*, 2018).

Value	Igeo category
$I_{geo} \leq 0$	Uncontaminated
$0 > I_{geo} > 1$	Uncontaminated to moderately contaminated
$1 > I_{geo} > 2$	Moderately contaminated
$2 > I_{geo} > 3$	Moderately to heavily contaminated
$3 > I_{geo} > 4$	Heavily contaminated
$4 > I_{geo} > 5$	Heavily to Extremely contaminated
$I_{geo} \geq 5$	Extremely contaminated

Table 2: Contamination factor (CF) category (Hakanson, 1980).

Value	CF Category
$CF > 1$	Low contamination
$1 > CF > 3$	Moderate contamination
$3 > CF > 6$	Considerable contamination
$CF < 6$	Very high contamination

Results and Discussion

The pH values of the surface soils at Al-Saqi Farm ranged from 7.24 to 7.79, indicating a pH range that falls between natural and weak. The electrical conductivity values of the soil at Al-Saqi farm range from 2.92 to 10.18 s/cm showed in Table 4. According to the Soil Quality Index (SQI), Al-Rifae and Al-Rubay (2017) indicated that 2.92 represents low soil salinity and 10.18 represents high soil salinity, as illustrated in Figure 2. Salinity has a direct relationship with soil electrical conductivity (Pathak and Rao, 1998). When we talk about salinity, we typically

mean that the soil contains soluble salts. The pH of the soil might have an impact on the solubility of salts and soil moisture levels. Less soluble salt will be present in more alkaline soil (Provin *et al.*, 2001). This indicates that a high soluble salt concentration and, hence, high electrical conductivity should be present in low-pH soil, as seen in all locations. Lower soil pH, according to Bruckner (2012), is associated with a higher concentration of hydrogen ions in the soil. The presence or absence of hydrogen ions in the soil environment might impact the electrical conductivity level. An increased rate of electrical conductivity in the soil is indicative of a larger concentration of hydrogen ions. Thus, the abundance of hydrogen ions in the soil influences low soil pH, potentially promoting soil electrical conductivity. Because a number of other factors, including soil temperature, moisture content, texture, porosity, and mineral content, also affect soil electrical conductivity, the relationship between soil pH and electrical conductivity in the soil is negative rather than linear (USDA, 2011).

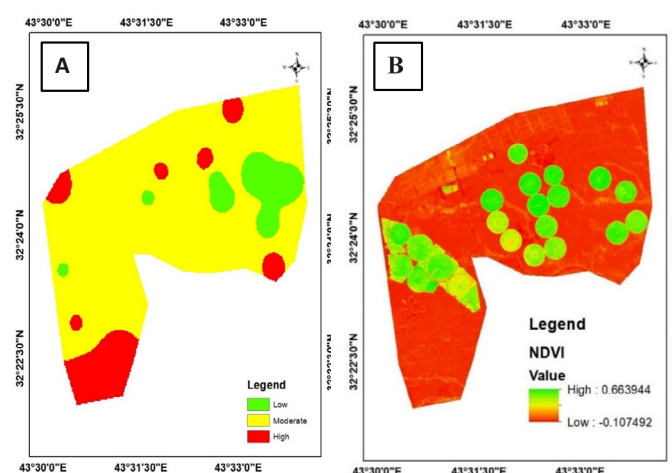


Figure 2: (A) IDW map of electric conductivity (EC), (B) distribution of normalized difference vegetation index.

Spatial distribution of soil heavy metals

Lead (Pb): There are several human-caused factors that contribute to the presence of lead in both terrestrial and aquatic ecosystems (Selvi *et al.*, 2019). Lead is thought to be responsible for 10% of all heavy metal contamination. It has a wide range of applications, including lead batteries, buildings, cable coating, paints, petrochemical refineries, the addition of alkyl to gasoline, and more (Tchounwou *et al.*, 2012). One of the most prevalent heavy metal pollutants in soils is lead (Pb). Lead (Pb) significantly impacts plants (Zeng *et al.*, 2007). Exposure to lead can cause problems with the shape, function, and biochemistry of some plants. We measured the amount of lead in

Table 3: *Physicochemical properties (PH, EC) and NDVI values in the study area.*

Sample	X	Y	PH	EC $\mu\text{s}/\text{cm}$	NDVI
S1	43.564054	32.402476	7.76	9.87	0.57333300000
S2	43.501642	32.402697	7.47	4.40	0.18587700000
S3	43.504776	32.392925	7.64	7.09	0.43740300000
S4	43.512104	32.367434	7.60	5.48	0.58681900000
S5	43.522439	32.386285	7.44	3.58	0.12867300000
S6	43.536611	32.395233	7.67	8.29	0.06352090000
S7	43.531595	32.399787	7.79	10.18	0.42121200000
S8	43.532534	32.418639	7.60	5.85	0.40345400000
S9	43.518455	32.416741	7.61	5.96	0.33786100000
S10	43.502579	32.408908	7.62	7.00	0.10902700000
S11	43.559740	32.425457	7.70	8.95	0.63068900000
S12	43.560448	32.411305	7.24	2.92	0.56818200000
S13	43.547600	32.425590	7.53	4.54	0.16800000000
S14	43.519425	32.377377	7.64	7.23	0.10215100000
S15	43.558341	32.395032	7.76	9.71	0.07974330000
			Min= 7.24 Max= 7.79 Mean= 7.6047	Min= 2.92 Max= 10.18 Mean= 6.737	Min= 0.0635209 Max= 0.630689 Mean= 0.31972968

Table 4: *Soil quality index (SQI) Al-Rifae and Al-Rubay (2017).*

Soil salinity (ECe) dS.m^{-1}	Low	<4 dS.m^{-1}
	Moderate	4-8 dS.m^{-1}
	High	8-16 dS.m^{-1}
	Very high	> 16 dS.m^{-1}

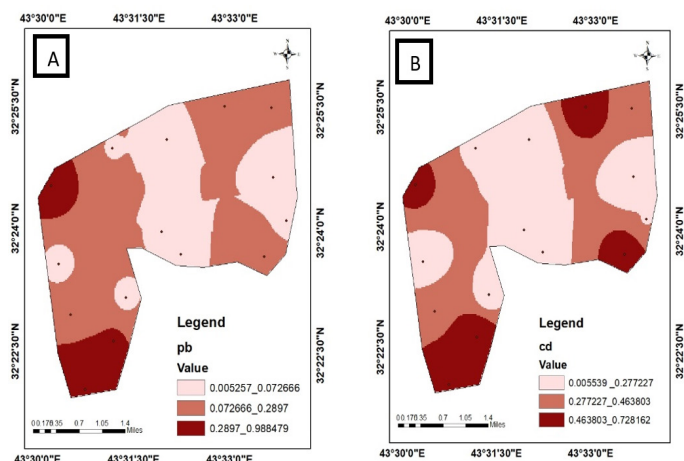


Figure 3: (A) IDW (inverse distance weight) of pb (B) IDW (inverse distance weight) of Cd.

soil samples from the Al-Saqi farmland and found that the pb levels ranged from 0.0021 to 0.9889% ppm. The geoaccumulation index (Igeo) showed that the samples ranged from -5.77 to 3.099 with an average of 2.180, and the contamination factor (CF) showed that the samples ranged from 0.00016 to

0.07606. According to Muller (1969) and Hakanson (1980), the study area ranges from completely uncontaminated to slightly contaminated. Figure 3 shows that the western and southern regions of the area contain the highest concentration of lead, while the medium concentrations occupy the largest part of the region. Hashim (2021) posits that the slightly increasing concentrations of lead in the groundwater of these wells cause the high concentrations of lead in the northwestern and southern regions.

Cadmium (Cd): The earth's crust contains the majority of cadmium. It is usually combined with zinc. Cadmium is released into natural streams through the weathering of Cd minerals like cadmoselite, greenockite, and olarite, as well as rocks from the earth's crust, such as clay, which contains 19 ppm of adsorbed Cd. According to Boyd (2000), the concentrations of cadmium in soil samples from the Al-Saqi farm land range from 0.0026_0.8415) ppm. Additionally, the geoaccumulation index (Igeo) shows that the samples range from -11.49_-3.15) with an average of 1.352. The contamination factor (CF) ranges from 0.013_4.207 with an average of 1.873, indicating that the study area is classified as either uncontaminated or moderately contaminated, according to Muller (1969) and Hakanson (1980). Figure 3 reveals the distribution of high percentages of cadmium in the northern, western, and southern

parts of the region, while the distribution of medium and small percentages varies across the region.

Nickel (Ni): The minerals carniorite, millerite, nicolite, and pentlandite contain nickel, according to Rankama and Sahama (1950). According to Drever (1997), nickel oxidises in an acidic environment. It finds its way into groundwater and surface waterways through biological cycles, industrial operations, waste disposal, and the erosion and disintegration of rocks and soils. The concentrations of Ni in the samples range from 0.0442_0.2907 ppm, while the geoaccumulation index (Igeo) varies from 1.144_4.572 ppm with an average of 0.739. The contamination factor varies from 0.00589_0.063 with an average of 0.0028, indicating that the study area, according to Muller (1969), is either uncontaminated or slightly contaminated (Hakanson, 1980). The Figure 5 shows that high percentages of nickel are distributed in different parts of the region, specifically the northern, western, and southern regions, while medium and small percentages are distributed differently throughout the region.

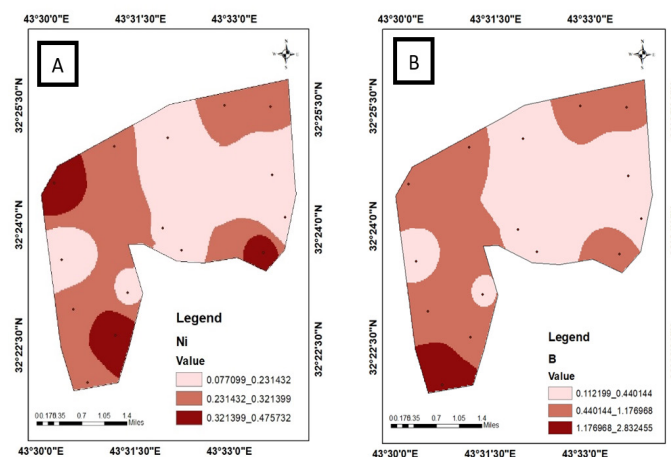


Figure 4: (A) IDW (inverse distance weight) of Ni (B) (inverse distance weight) of B.

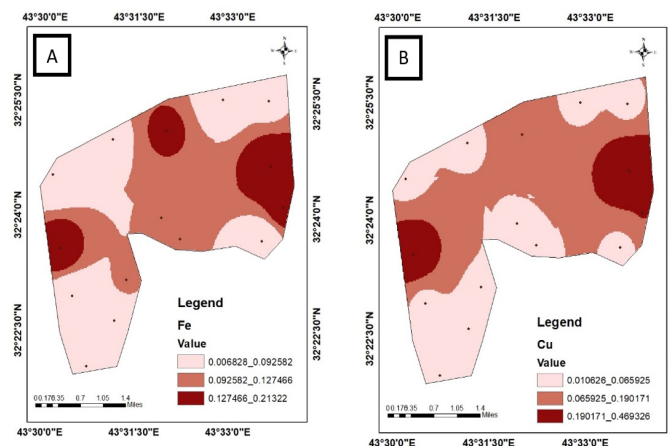


Figure 5: (A) IDW (inverse distance weight) of Fe (B) IDW (inverse distance weight) of Cu.

Boron (B): By producing glass, burning coal, melting copper, and adding fertilizer to crops, humans contribute boron to the environment. Unsealed home landfills often release boron into the groundwater and soil. Despite its excessive concentration (greater than 2 ppm) in irrigation water, which may damage certain plants, the element boron is crucial for plant sprouting. Boron concentrations as low as 1 ppm can impact certain plants (Chester and Voutsonou, 1981). The B concentrations of the samples range from 0.056_2.8366 ppm, the geoaccumulation index (Igeo) of the samples ranges from -1.421_4.239 ppm with an average of 1.38, and the contamination factor (CF) of the samples ranges from 0.005_0.28336 with an average of 0.0658. This indicates that Muller (1969) and Hakanson (1980) classify the study area as either uncontaminated or moderately contaminated. Boron is distributed in different parts of the region; specifically southern regions show the heights values as showed in Figure 4.

Iron (Fe): Hydrolyzed sediments, well casings, piping, storage tanks, and other cast iron and steel objects that may come into contact with water are all sources of iron, along with high-iron-content igneous rocks such as olivine, biotite, amphiboles, and pyroxenes (Rankama and Sahama, 1950). We found that the concentrations of lead (Pb) in soil samples from the Al_Saqi farmland range from (0.0068_0.3266) ppm. Additionally, the geoaccumulation index (Igeo) shows that the samples range from (7.99_13.58) with an average of 11.27, and the contamination factor (CF) shows that the samples range from (1.207_5.9325) with an average of 2.859. These findings indicate that the study area is extremely contaminated, according to Muller (1969). The increase in iron concentration can be attributed to the amount of organic matter present in the soil also affects the total Fe concentration (Schulte, 2004). Because soil microbes break down organic materials, they contribute iron, sulphur, phosphorus, and nitrogen to the soil. Aciego-Pietri and Brokes (2008) state that a pH of 7.00 is optimal for microbial activity. Raising the pH of the soil to a neutral level tends to increase the biomass of soil microorganisms and stimulate microbial activity, which in turn increases the soil's Fe content. There is a strong relationship between the pH of the soil and its Fe content (Jelic et al., 2010). Juzefaciuk et al. (1995) found that the pH of the soil in its natural state contains the highest amount of total Fe content.

Table 5: Heavy metals concertation in Al-Saqi farm.

Samples	Pb	Cd	Ni	B	Fe	Cu	Zn
S1	0.6864	0.7577	0.1562	1.6632	0.0112	0.0120	0.0145
S2	0.0056	0.3357	0.0857	0.1632	0.1706	0.1917	0.3004
S3	0.0537	0.2999	0.2637	0.2032	0.0970	0.0351	0.0607
S4	0.0168	0.1710	0.1560	0.3360	0.1278	0.0434	0.1060
S5	0.0056	0.1062	0.0807	0.1400	0.2066	0.4308	0.3121
S6	0.1364	0.5248	0.2907	0.8846	0.0334	0.0215	0.0349
S7	0.9889	0.8179	0.2709	2.8336	0.0068	0.0106	0.0138
S8	0.0187	0.1981	0.1989	0.3427	0.1094	0.0428	0.1037
S9	0.0266	0.1995	0.2124	0.3528	0.1011	0.0395	0.1024
S10	0.0387	0.2723	0.2304	0.3998	0.0985	0.0352	0.0956
S11	0.1612	0.8415	0.3805	0.6339	0.0276	0.0142	0.0321
S12	0.0021	0.0026	0.0442	0.0560	0.3266	1.7040	0.5006
S13	0.0078	0.0625	0.1040	0.2189	0.1533	0.1598	0.2142
S14	0.0666	0.3213	0.2767	0.5107	0.0713	0.0330	0.0388
S15	0.5042	0.7107	0.4758	0.6496	0.0163	0.0127	0.0145
	Min=0.0021	Min=0.0026	Min=0.0442	Min=0.056	Min=0.0068	Min= 0.0106	Min=0.0138
	Max=0.9889	Max=0.8415	Max=0.4758	Max=2.8336	Max=0.3266	Max= 1.704	Max=0.5006
	Mean=0.1812	Mean=0.3747	Mean=0.21512	Mean=0.62588	Mean=0.10384	Mean=0.18574	Mean=0.12962

Table 6: Values of (Igeo) factor of soil heavy metals in Al-Saqi farm.

Samples	pb	Cd	Ni	B	Fe	Cu	Zn
S1	2.572	-3.307	2.965	3.470	8.715	-1.05	-0.563
S2	-4.364	-4.481	2.099	0.121	12.644	2.93	3.809
S3	-1.103	-4.644	3.720	0.437	11.830	0.489	1.502
S4	-2.779	-5.454	2.963	1.163	12.227	0.795	2.306
S5	-4.364	-6.142	2.012	-0.099	12.920	4.107	3.864
S6	0.2413	-3.837	3.861	2.560	10.291	-0.2175	0.703
S7	3.099	-3.196	3.759	4.239	7.995	-1.237	-0.634
S8	-2.625	-5.242	3.313	1.191	12.003	0.775	2.274
S9	-2.116	-5.232	3.408	1.233	11.889	0.659	2.256
S10	-1.576	-4.783	3.526	1.414	11.852	0.493	2.157
S11	0.482	-3.155	4.249	2.079	10.01	-0.816	0.583
S12	-5.779	-11.494	1.144	-1.421	13.58	6.09	4.546
S13	-3.886	-6.906	2.378	0.545	12.49	2.676	3.321
S14	-0.792	-4.544	3.790	1.767	11.385	0.400	0.856
S15	2.127	-3.399	4.572	2.114	9.25	-0.977	-0.563
	Max= 3.09	Max=-3.15	Max=4.57	Max=4.23	Max= 13.5	Max=6.09	Max=4.54
	Min= -5.77	Min=-11.49	Min=1.144	Min=-1.421	Min= 7.99	Min=-1.237	Min=-0.634
	Mean= 2.180	Mean=1.352	Mean=0.739	Mean=1.38	Mean=11.27	Mean=1.008ss	Mean=1.761

Copper (Cu): Natural events disperse copper, a relatively common substance, in the environment. Chalcopyrite, azurite, chalcosite, and boronite minerals all contain copper (Rankama and Sahama, 1950). People use copper in many different ways. The agricultural and manufacturing industries use copper. These samples have Cu concentrations that range from 0.0106 to 1.704 ppm, an Igeo value that is

between -1.237 and 6.090 ppm on average, and a CF value that is between 0.000176 and 0.0284 on average as showed in Table 7 and distributed in Figure 5. This means that the study area is quite contaminated. Moderately contaminated, according Muller (1969) and Hakanson (1980) have classified the study area as moderately contaminated), According to Aciego Pietri and Brokes (2008), a pH of 7.00 is optimal for

Table 7: Values of (CF) factor of soil heavy metals in Al-Saqi farm.

Samples	Pb	Cd	Ni	B	Fe	Cu	Zn
S1	0.0528	3.7885	0.002082	0.16632	1.98934	0.0002	0.000207
S2	0.000430	1.6785	0.001142	0.01632	3.030	0.003195	0.00429
S3	0.004130	1.4995	0.003516	0.02032	1.722	0.000585	0.00086
S4	0.001292	0.855	0.00208	0.0336	2.269	0.000723	0.00151
S5	0.000430	0.531	0.001076	0.014	3.669	0.00718	0.00445
S6	0.01049	2.624	0.003876	0.08846	5.9325	0.000358	0.000498
S7	0.07606	4.0895	0.003612	0.28336	1.207	0.000176	0.000197
S8	0.00143	0.9905	0.002652	0.03427	1.943	0.000713	0.00148
S9	0.002046	0.9975	0.002832	0.03528	1.795	0.000658	0.00146
S10	0.002976	1.3615	0.003072	0.03998	1.749	0.000586	0.00136
S11	0.0124	4.2075	0.005073	0.06339	4.902	0.000236	0.000458
S12	0.000161	0.013	0.000589	0.0056	5.801	0.0284	0.00715
S13	0.0006	0.3125	0.001386	0.02189	2.722	0.00266	0.00306
S14	0.00512	1.606	0.003689	0.05107	1.266	0.00055	0.000554
S15	0.0528	3.553	0.006344	0.06496	2.89	0.00021	0.000207
	Max=0.07606	Max= 4.207	Max=0.063	Max=0.28336	Max=5.9325	Max= 0.0284	Max= 0.00715
	Min= 0.00016	Min= 0.013	Min=0.00589	Min=0.005	Min= 1.207	Min= 0.000176	Min= 0.000197
	Mean=0.01217	Mean=1.873	Mean=0.0028	Mean=0.0658	Mean=2.859	Mean= 0.00309	Mean= 0.00184

soil microbial biomass. Raising the soil pH to a neutral level increases the amount of soil microbial biomass, thereby increasing the organic matter content. After that, a higher overall concentration of Cu in the soil is often associated with a larger quantity of organic matter.

Zinc (Zn): The minerals magnetite, muscovite, biotite, amphibole, and ilmenite are the main providers of zinc, and olivine is the primary supplier (Emsley, 1998). Additional sources include organic animal remains and industrial processes such as metallurgy (Hem, 1991). Soil, sediments, natural resources, and waste water treatment facilities, including municipal and industrial ones, widely distribute the metallic element (CGWB and CPCB, 2000). The Zn concentrations in the samples range from (0.0138_0.5006) ppm, and the geoaccumulation index (Igeo) ranges from (0.634_4.546) ppm with an average of 1.761 as showed in the Table 6. The contamination factor (CF) ranges from (0.000197_0.00715) ppm with an average of 0.00184 as showed in the Table 7, indicating that the research area is classified as either moderately contaminated or uncontaminated Muller (1969). Zinc is distributed in different parts of the region; specifically eastern and western regions show the heights values as showed in Figure 6. Suggests that the chemicals used in fertilizers from agricultural lands may be the cause of this contamination.

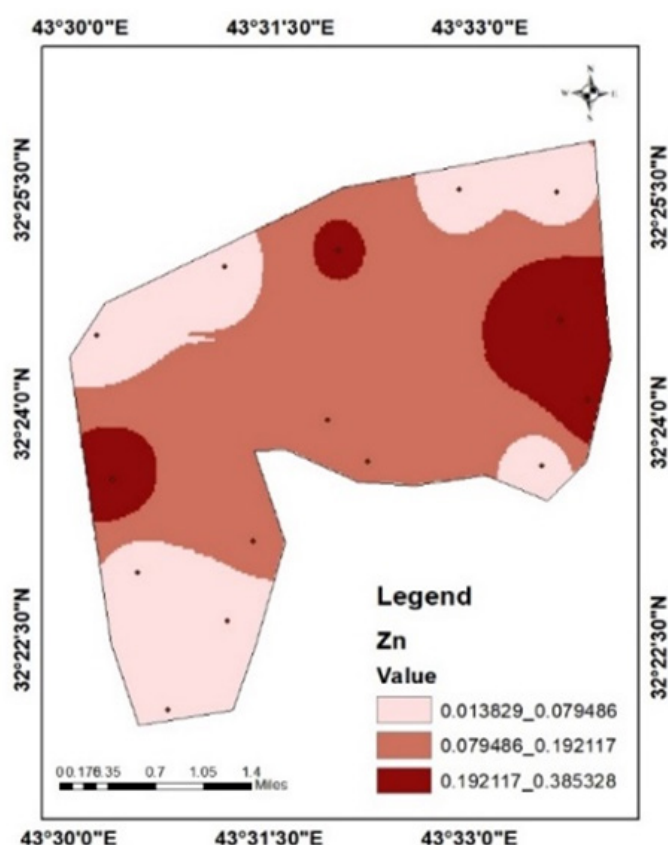


Figure 6: IDW (inverse distance weight) of Zn.

Groundwater is the source of these high concentrations of these elements in the study area, according to a researcher's (Hashim, 2021) study of groundwater in Al-Saqi farm. The trace element analysis results in groundwater confirm that groundwater is polluted

with some elements; some concentrations in water samples are higher than the acceptable limits, and the reason for that may be the chemicals used in the fertilisers on agricultural lands. Phosphate One important factor contributing to diffuse cadmium pollution is ore fertilizers. Acidity is the main factor affecting cadmium solubility in water; as acidity increases, suspended or sediment-bound cadmium may dissolve (Ros and Slooff, 1987). The high concentration of lead in water samples may be due to the geological composition of the aquifers that recharged the study area, which are composed of carbonate rocks like limestone (Boyd, 2000). During our field visit, it became evident to us, based on our humble perspective, that the Karbala sewage drain, which flows into Lake Al-Razzaza, is the primary source of these elements' pollution. This water permeates through geological formations, allowing the elements to seep through the layers of rocks and soil into the groundwater. Consequently, these formations serve as sources or collectors of these elements. Due to the contamination of water loaded with heavy elements of different concentrations and by moving from place to place, the concentrations of these elements in the water fluctuate, and thus this groundwater is used to irrigate agricultural lands, irrigate animals, and for other purposes.

Conclusions and Recommendations

To determine the influence of physicochemical properties on pH, EC, and heavy metal distribution in soil, the pH readings show that the soil is generally alkaline and tends to be slightly alkaline, with an average pH of 7.937.24 to 7.79 as showed in Table 3. Because the narrow range of pH mostly determines the mobility of heavy metals, it has little effect on their distribution due to the neutral semi-alkaline environment of the research samples. The average values of electrical conductivity (EC) range from 2.92 to 10.18 μ s/cm. The results of the chemical analysis show that the average amounts are as follows: max 0.9889 for Pb, max 0.8415 for Cd, max 0.2907 for Ni, max 0.8846 for B, max 0.3266 for Fe, max 1.704 for Cu, max 0.5006 for Zn as showed in Table 5. The Igeo values show that the samples range from being uncontaminated to moderately contaminated by Cd, Zn, Ni, and B, and from being heavily contaminated by Fe. Additionally, the contamination factor (CF) for B, Ni, Pb, Cu and Zn indicates low contamination, whereas (Cd, Fe) indicates moderate

to heavily contaminated. According to Table 1 and also as distributor in Figures 7 and 8, the elements (Cu, Cd, B, Ni, Pb, Zn, and Fe) have concentrations that are lower than their averages in the Earth's crust, suggesting that the area is not highly polluted by heavy metals. (2) Groundwater is responsible for the high concentrations of heavy metals in the research area.

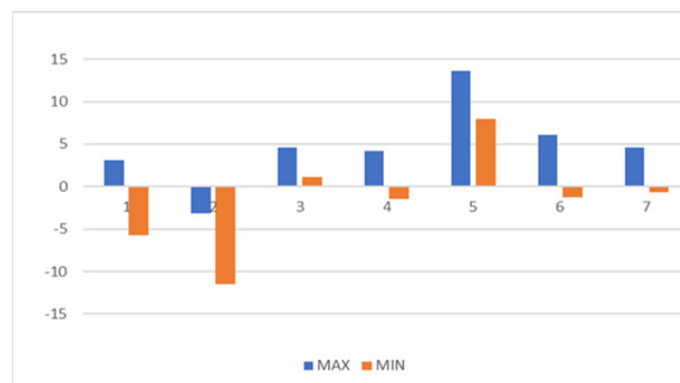


Figure 7: Igeo accumulation to the study area.

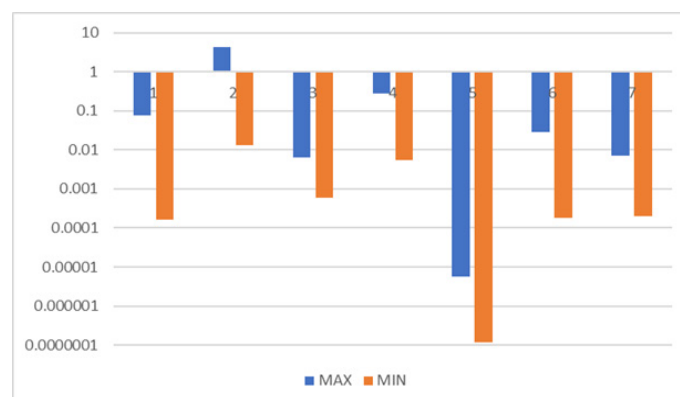


Figure 8: CF (Contamination factor) to the study area.

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Novelty Statement

The results of this study aim to identify the source of soil pollution and its impact on the consumer (animal and human) and to determine the extent of pollution in order to find modern methods and strategies to find solutions by the competent authorities.

Author's Contribution

Huda A. Mohsen: Writing, analyzing and discussing

the results and studying the geology of the area.

Kamal M. Abood: Supervision, data analysis and map analysis

Linaz A. Fadhil: Supervision, writing and reviewing

Conflict of interest

The authors have declared no conflict of interest.

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