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Spatial Analysis of Heavy Metals in Soil at East and West Area of the Tigris River's In Baghdad Using GIS and Remote Sensing Techniques

Maryam Basim Musa[1a*], Sundus A. Abdullah Albakri[1b] and Maitham A. Sultan[2c]
[1]*Remote Sensing and GIS, College of Science, University of Baghdad, Baghdad, Iraq*
[2]*Scientific Research Commission, Research & Technology Center of Environment, Water and Renewable*
[a*]Corresponding author: mariam.Musa2209m@sc.uobaghdad.edu.iq

Abstract

Heavy metal pollution is one type of pollution that can affect soil and plants. The research uses spatial analysis techniques to evaluate soil pollution with heavy metals in the areas east and west of the Tigris River in Baghdad. Thirty five soil samples were collected from the study area and analyzed using atomic absorption spectoscopy. When comparing the concentrations of metals (cadmium, lead, nickel, iron, and copper) in the soil samples with the permissible limit, it was found that they were arranged as follows: Cd > Ni > Pb > Cu > Fe. Cd concentrations range was 3.55-5.4 ppm, Pb concentrations range 1.445-8.2 ppm, and Ni concentration 4.7-9.35 ppm. Fe was found in very small proportions compared to the permissible limit, as the concentration of Fe ranged from 43.1 ppm to 70.15 ppm. Cu concentrations in the soil of the study area ranged from 0.47 ppm to 4.86 ppm. Cd concentrations exceeded the permissible limit in the soil of the study area, and the results indicate that the area suffers from Cd pollution. The spatial analysis maps also indicated the accumulation of Cd throughout the study area, indicating the causes of pollution with this metal, such as using sewage water for irrigation and pesticides and fertilizers containing Cd. Cd is an inorganic metal, so if it accumulates in the soil, it can be absorbed by plants and accumulate in edible parts such as leaves and roots.

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1. Introduction

In general, pollution is the introduction of substances harmful to humans and other living organisms into the environment. Pollutants are harmful solids, liquids, or gases that exist higher than normal concentrations. Their existence reduces the quality of our environment [1]. Environmental pollution and its risks do not stop only at the borders of the country causing it, but its impact extends to the rest of the countries [2]. Human activities through urbanization, industrialization, mining, and exploration are at the forefront of reasons for global environmental pollution [3]. Rapid population growth is the cause of many pollution problems [4]. The population in Baghdad is distributed densely in the city center and decreases towards its border [5]. Amidst the various degradation processes around the world, soil degradation is undoubtly one of the world's most pressing environmental issues [6].

Soil is a complex and dynamic natural system and a medium that includes minerals, organic matter, countless organisms, liquids, and gases that support life on Earth through many services [7]. Man has contributed to the pollution of his surroundings and did not care about this problem, due to the small population size. The increase in population and the decrease in soil productivity due to pollution contributed to a decline in the standard of living [8]. Soil is a substantive component of the biosphere, which is exposed to many pollutants, including heavy metals [9]. In this day of industrialization, the effects of heavy metal pollution are gradually deteriorating the quality of the soil [10]. Soil contaminated by heavy metals is a serious environmental problem [11]. Heavy metal accumulation in soil and water is one of the major problems caused by inorganic contaminants [12]. There are many heavy metals in the environment, and while some come from geological processes like rock weathering and volcanic eruptions, most come from human activities, including household, agricultural, and industrial operations [13]. Over-enrichment of heavy metals in soil may endanger human health [14]. Heavy metals found at elevated levels of soil are easily absorbed by humans through inhalation of dust-contaminated air or skin contact [15]. The health of people is at risk when heavy metals are present in food. Due to the toxicity of contaminated plants, eating them might expose one to heavy metal [16].

"Save Soil Save Earth" is more than just a term; protect the soil ecology against unwelcome and uncontrolled xenobiotic pollution is essential [17]. Graphic Information system (GIS) integrated approaches aid in providing decision-makers with a clear image to address contaminated regions as needed [18]. Identifying the sources of heavy metals helps control pollution [19]. Using plants that can grow, adapt, and absorb metals is thought to be one way to clean up heavy metal-contaminated soils [20].

Cadmium (Cd), a toxic element, poses high threats to soil quality, food safety, and human health [21]. Irrigation water, commercial fertilizer, and atmospheric deposition are among the main Cd sources [22]. Copper (Cu) is a substance with many uses and little toxicity to humans due to its physical properties. Nickel (Ni) is frequently used in electroplating and battery manufacturing; although it is not very hazardous to humans, it can lead to respiratory disorders [23]. Lead (Pb) is a widely occurring heavy metal employed in industrial products and hence released into the environment, causing several environmental health risks [24]. pb is highly toxic to humans; fetuses and young children are particularly sensitive to the neurobehavioral effects of Pb [25]. Although iron may be present in large amounts in the soil, it should be within normal limits [26]. Fe deficiency is a major limiting factor affecting crop yields, food quality and human nutrition [27]. Human and industrial activity may cause an increase in the concentrations of natural minerals, but it may also be due to natural factors, such as climate and rock type. Concentrations of these heavy minerals decrease in the winter because the soil is washed by rain, and their amounts fluctuate from year to year and from season to season [28].

Khalid et al. studied iron (Fe) and copper (Cu) concentrations in some agricultural soils in the city of Baghdad and evaluated the effect of agricultural practices and sources that led to an increase in their concentrations in the soil. The minimum concentration of copper was (<1 mg/kg), while the maximum concentration was (34.54 mg/kg). As for iron, it reached a maximum concentration of (18607.27 mg/kg), and the minimum value was (6579.03 mg/kg) [29]. Mohammed and Abdullah studied heavy metal contamination of soil at the northern site of the East Baghdad oil field. Cd concentrations ranged from (0.14ppm) to (4.31ppm). The concentrations of Cu ranged from (23ppm) to (82ppm). The values of pb concentrations ranged from (6.8ppm) to (31ppm). Those of Ni ranged from (51ppm) to (196.5pppm) [30].

Pollution is a modern problem, especially heavy metal pollution. It has adverse effects on human health. The research aims to evaluate soil pollution with heavy metals in areas adjacent to the Tigris River in Baghdad.

2. Study Area

The study area was in Baghdad Governorate in Iraq, including areas east and west of the Tigris River, which are located between the two circles of longitude (33°42'51''.18) north and (33°17'37''.64) south and the two circles of latitude (44°52''97''. 71) east and (44°29'88''. 97) west. The total area of the study area was

247.2 km^2, as shown in Fig. 1. The study area included residential, industrial, commercial and agricultural sites.

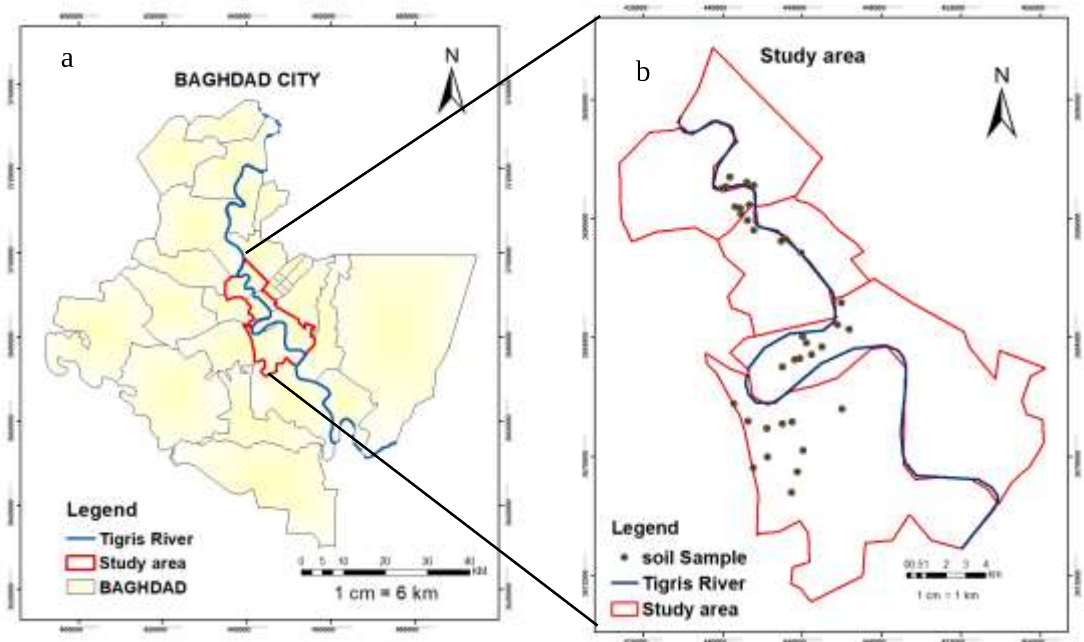

Figure 1: (a) A map of Baghdad city, (b) A map of the study area.

3. Materials and Methods

3.1. Data Acquisition

The concentrations of the heavy metals (Cadmium, Lead, Nickel, Iron, Copper) in soil, were estimated by analyzing soil samples of the study area in the laboratories of the Ministry of Science and Technology / Environment, Water and Renewable Energy Directorate.

3.2. Soil Sampling

Thirty-five samples were collected in the areas of Baghdad adjacent to the Tigris River, located east and west of the Tigris River, namely (Al- Kadhmiyah, Al-Adhamiyah, Al- Karkh, Al- Resafah, Part of Al- Rashid district, and Al- Karada), for the time from October to December 2023. The locations of the samples were determined using a Global Positioning System (GPS) device (GPS 73 GARMIN).

3.3. The Process of Digesting the Sample and Turning the Soil into a Liquid

One gram of each sample was dried, ground and placed in the digestion chamber, to which 5ml of nitric acid was added. The sample was heated until it approached dryness and the color of the mixture became yellowish; then (3ml) of perchloric acid was added, and reheated until it was almost dry and the color became yellow. (2 ml) of hydrofluoric acid was added, and the sample was returned to the heater until it approached dryness to break all the soil bonds. The solution was then filtered and transferred into a 100 ml volumetric flask, and distilled water was added to the 100 ml mark. The sample was thus ready for heavy metals measurement by Atomic Absorption Spectroscopy (AAS).

3.4. Software Used

- Arc GIS Map 10.8 was used to Spatial analysis.
- Use Microsoft Excel to perform mathematical calculations.

The steps for processing and analyzing data as shown in Fig. 2.

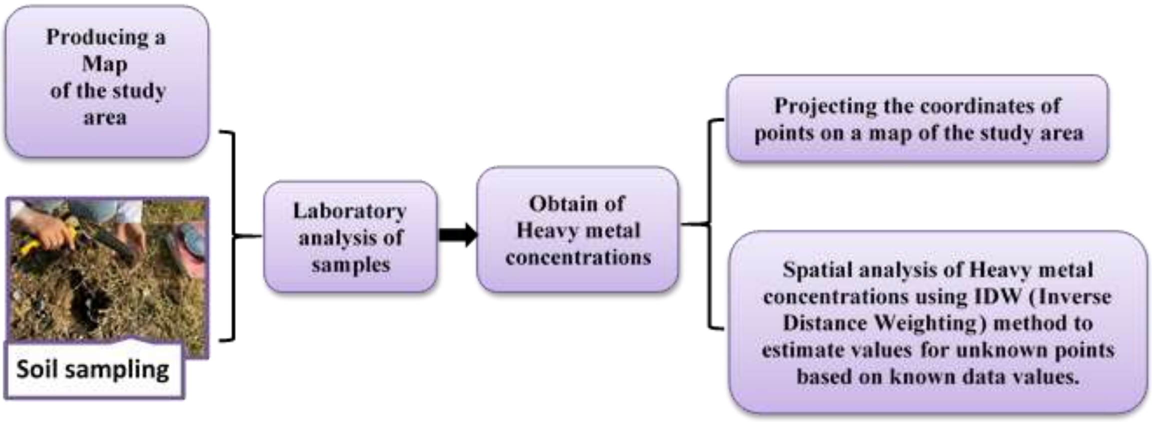

Figure 2: A flowchart showing the steps for processing and analyzing data.

3. 5. Spatial Analysis of Heavy Metal Concentrations

3. 5. 1. Inverse Distance Weighting (IDW) Method

Inverse distance weighting (IDW) method was used to the purpose of interpolating values at unknown locations based on known sample points [31]. It is a widely used spatial analysis technique in spatial analysis and geostatistics; it is believed that points closer to the location of interest have a greater influence than points further away. The IDW method was used in this study to evaluate heavy metal concentrations of unknown points using heavy metal concentrations of known points.

4. Results and Discussion

Heavy metal (Cd, Pb, Ni, Fe, Cu) concentrations were estimated in 35 soil samples collected from the areas adjacent to the Tigris River in Baghdad, located east and west of the River, namely (Al-Kadhimiya, Al-Adhamiya, Al-Karkh, Al-Rusafa, Part of Al- Rashid district, and Al-Karada). The concentrations of Cd were in the range of (3.55 - 5.4) ppm; Pb concentrations ranged (1.445-8.2) ppm; Ni concentration ranged (4.7-9.35) ppm. Fe was found in very small concentrations, as the ranged concentration of Fe was (43.1 - 70.15) ppm. Concentrations of Cu in the soil of the study area ranged (0.47 - 4.86ppm). The concentration values of the heavy metals with the latitude and longitude of the samples locations as measured with AAs are tabulated in Table 1.

In comparison with the permissible limits, according to the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), shown in Table 1, the concentrations of the metals (Pb, Ni, Fe and Cu) did not exceed the permissible limits. This means that the area is not contaminated with these metals, rather it was found that the soil of the study area suffers from a deficiency in the metal Fe, which plants need in large quantities but within the permissible limit of (5000ppm). The concentrations of Cd exceeded the permissible limit of (3ppm) in the soil of the study area, indicating Cd pollution. The reason is the use of wastewater for irrigation, pesticides, and fertilizers containing Cd, and it may be from atmospheric deposits, as well as other causes of human activity and wrong agricultural policies. Plants absorbing Cd from the soil become contaminated with this metal and thus have harmful effects on human health if humans consume these plants. Therefore, the concerned authorities must follow policies to address this situation and limit the spread of pollution.

The spatial distribution in the prediction maps (Fig. 3) shows the extent of the spread of heavy metals in the study area and the polluted areas.

Table 1: Concentrations of heavy metals (Cd, Pb, Ni, Fe, Cu) in the soil of the study area (PPM=µg/g=mg/kg).

Area Name	No.	**Lat.**	**Long.**	**Cd**	**Pb**	**Ni**	**Fe**	**Cu**
Al-Karada	1	N 33°17'39.57530	E 44°23'55.67220	4.65	4.8	5.48	52.25	2.98
	2	N 33°17'59.28340	E 44°25.05794	4.05	4.45	5.14	51.6	1.33
	3	N 33°18'34.77930	E 44°25'11.47770	4.85	3.665	5.9	51.9	0.625
	4	N 33°17'0.69810	E 44°23'40.39720	5.3	3.9	5.63	70.15	1.02
	5	N 33°17'9.88650	E 44°24'13.77620	5.2	8.2	6.75	68.6	1.095
	6	N 33°17'22.38550	E 44°24'33.68020	4.85	6.3	6	63	0.71
	7	N 33°17'51.49880	E 44°25'26.18700	3.6	4.875	8.35	64.5	0.47
	8	N 33°16'49.67060	E 44°23'16.46600	4.25	5.15	7.155	65.65	2.19
	9	N 33°17'3.57650	E 44°23'51.39580	4.4	4.75	6.995	57.6	1.49
	10	N 33°17'28.89660	E 44°24'3.28500	4.55	7.05	9.35	55.4	0.86
Al-Adhamiyah	11	N 33°21'45.48500	E 44°22'18.79160	5.4	2.41	7.75	55.7	4.86
	12	N 33°21'43.58590	E 44°21'24.98010	5.05	4.195	7.45	59.6	2.35
	13	N 33°21'40.29380	E 44°21'16.29800	5.25	4.06	8.87	61.5	3.14
	14	N 33°21'51.48690	E 44°22'4.97260	4.35	3.865	5.85	60.25	2.19
	15	N 33°21'58.98240	E 44°21'32.29670	4.6	4.89	9.01	59.4	1.96
Al-Karkh	16	N 33°20'32.68800	E 44°22'19.27570	4.95	4.74	6.11	48	2.75
	17	N 33°20'48.08270	E 44°22'7.17180	3.55	2.41	4.88	43.1	4.6
	18	N 33°20'14.38310	E 44°23'12.98490	4.96	2.16	5.8	56.65	2.6
Al- Kadhmiyah	19	N 33°20'58.99470	E 44°21'54.78960	4.1	4.12	8.3	46	3.05
	20	N 33°21'13.39680	E 44°22'10.97430	3.9	1.685	7.15	45.75	4.03
	21	N 33°21'8.69260	E 44°21'52.66860	4.11	1.445	5.65	47.4	4.7
	22	N 33°21'10.97880	E 44°21'42.59230	4.07	4.92	5.6	47.55	4.11
Al- Rashid	23	N 33°15'41.48840	E 44°25'13.16510	4.08	6.25	5.25	47.95	4.21
	24	N 33°15'20.46820	E 44°22'10.69040	4.025	6.65	5.45	46.8	3.98
	25	N 33°15'19.27330	E 44°23'36.88440	4.16	8.1	6	45.4	3.65
	26	N 33°15'15.96810	E 44°23'18.39490	4.205	4.225	6.25	56.5	4.3
	27	N 33°14'22.27630	E 44°22'48.78330	4.135	4.655	6.15	58	4.22
	28	N 33°14'3.89210	E 44°22'21.78840	4.75	3.62	6.35	58.5	3.8
	29	N 33°14'32.77890	E 44°23'57.87930	4.535	4.465	4.82	53	4.05
	30	N 33°13'57.98210	E 44°23'47.06660	4.565	4.78	4.7	51.5	4.38
	31	N 33°13'24.09290	E 44°23'35.97960	4.61	4.655	5.15	54	4.66
	32	N 33°15'8.99700	E 44°22'47.68050	4.07	3.6	5.35	57.35	4.62
	33	N 33°15'48.89850	E 44°21'42.38640	3.76	4.06	6	55.4	2.15
Al- Resafah	34	N 33°20'19.09190	E 44°23'19.68310	4.06	3.9	5.65	57.1	2.7
	35	N 33°19'55.67840	E 44°23'52.49430	3.86	7.2	6.05	57.3	2.2
Range				3.55- 5.4	1.445 - 8.2	4.7 - 9.35	43.1 - 70.15	0.47 - 4.86
Average				4.41	4.6	6.43	55.45	3.03
* Global permissible limits of heavy metals in soil according to WHO AND FAO				3	100	50	5000	100

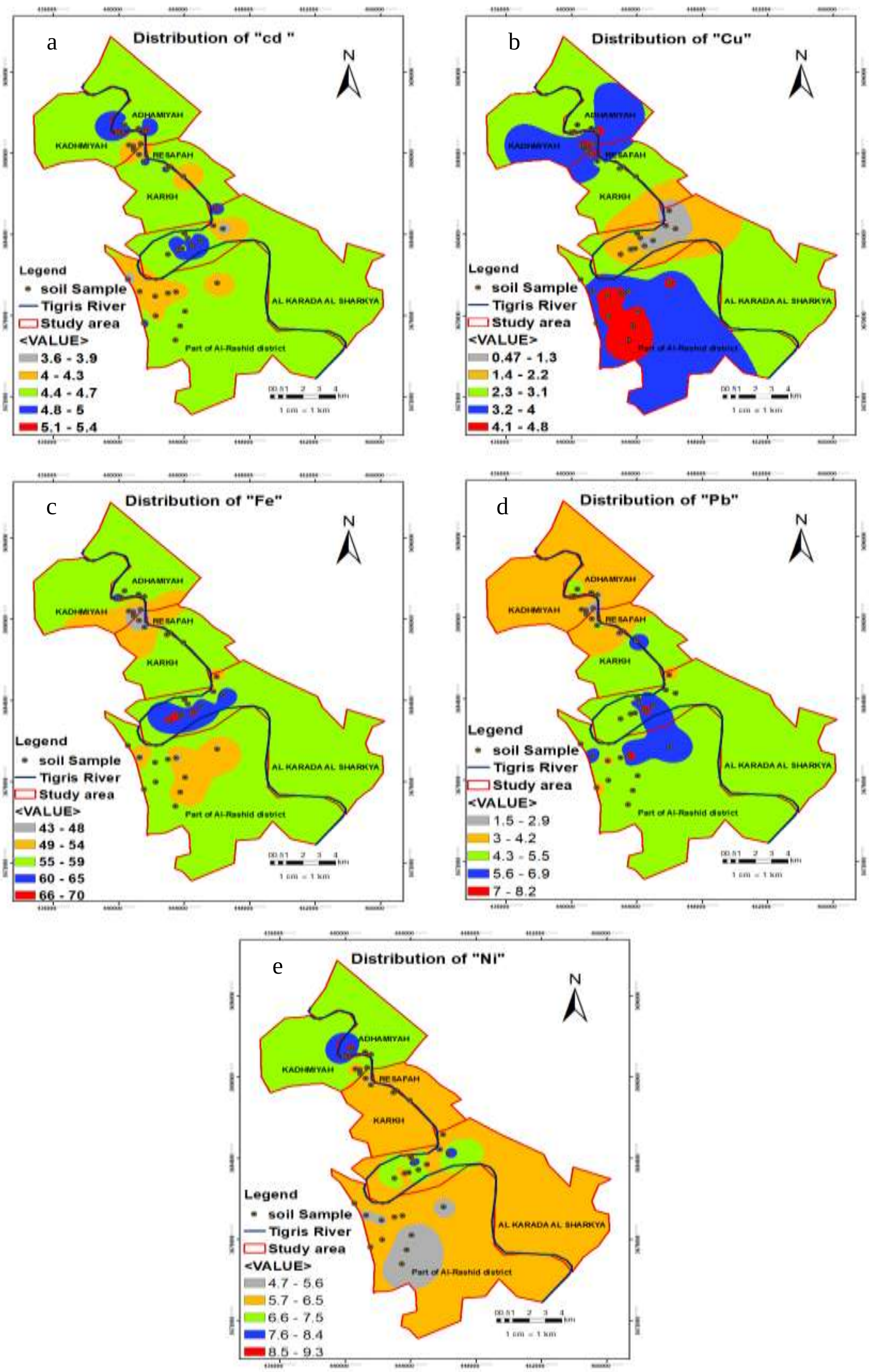

Figure 3: Spatial analysis maps of heavy metals in study area of: (a) Cd, (b) Cu, (c) Fe, (d) Pb, and (e) Ni.

5. Conclusions

When comparing the concentrations of heavy elements in the soil of the study area with the permissible limits according to (WHO) and (FAO), it was found that the Cd concentration exceeded the permissible limit in the soil of the study area, while the other elements did not. The study area suffers from Cd soil contamination due to the use of wastewater in irrigation, pesticides and fertilizers containing Cd, atmospheric sediments, the impact of industrial activities, and the accumulation of solid waste for an extended period, such as plastic waste and batteries. Due to the impact of this pollution on the environment, measures must be taken, such as preventing the use of pesticides and fertilizers that contain Cd, reducing water pollution, and monitoring institutions and companies that dispose of this metal incorrectly. Since Cd is an inorganic mineral, if it accumulates in the soil, it can be absorbed by plants and accumulated in edible parts such as leaves and roots.

Conflict of Interest

Authors declare that they have no conflict of interest.

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التحليل المكاني للمعادن الثقيلة في تربة المناطق الشرقية والغربية لنهر دجلة في بغداد باستخدام تقنيات نظم المعلومات الجغرافية والاستشعار عن بعد

مريم باسم موسى[1]، سندس عبد العباس عبدالله[1] وميثم عبدالله السلطان[2]

[1]التحسس النائي ونظم المعلومات الجغرافية، العلوم، جامعة بغداد، بغداد، العراق

[2]هيئة البحث العلمي، مديرية البيئة والمياه والطاقة المتجددة، بغداد، العراق

الخلاصة

التلوث بالمعادن الثقيلة هو أحد أنواع التلوث الذي يمكن أن يؤثر على التربة والنباتات، ويهدف البحث إلى تقييم تلوث التربة بالمعادن الثقيلة في المناطق الواقعة شرق وغرب نهر دجلة في بغداد باستخدام تقنيات التحليل المكاني، حيث تم جمع 35 عينة تربة من منطقة الدراسة وتحليلها باستخدام مطيافية الامتصاص الذري، وعند مقارنة تراكيز المعادن (Cd, Pb, Ni, Fe, Cu) في عينات التربة مع الحد المسموح به، وجد أنها مرتبة على النحو التالي: Cd > Ni > Pb > Cu>Fe، وتراوحت تراكيز الكادميوم (5.4-3.55) ، وتركيزات الرصاص (8.2-1.445)، وتركيزات النيكل (9.35-4.7)، ووجد الحديد بنسب صغيرة جداً مقارنة بالحد المسموح، حيث تراوح تركيز الحديد (70.15-43.1). وتراوحت تراكيز النحاس في تربة منطقة الدراسة (4.86-0.47) وتجاوزت تراكيز الكادميوم الحد المسموح به في تربة منطقة الدراسة وتشير النتائج إلى أن المنطقة تعاني من تلوث الكادميوم كما أشارت خرائط التحليل المكاني إلى تراكم الكادميوم في كافة أنحاء منطقة الدراسة مما يدل على وجود أسباب للتلوث بهذا المعدن مثل استخدام مياه الصرف الصحي للري والمبيدات والأسمدة المحتوية على الكادميوم. والكادميوم معدن غير عضوي فإذا تراكم في التربة يمكن أن تمتصه النباتات ويتراكم في الأجزاء الصالحة للأكل مثل الأوراق والجذور.

الكلمات المفتاحية: تلوث التربة، المعادن الثقيلة، الكادميوم، IDW، نظم المعلومات الجغرافية.