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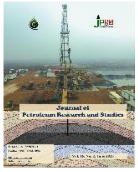

Application of A GIS and Geo-Statistical Analysis to Assess the Potential Environmental Risks in Stream Sediments Shwan Sub-Basin, Kirkuk, Northern Iraq (Case Study)

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Abstract

Recent stream sediment samples were taken from the Shwan sub-basin, Kirkuk governorate, northern Iraq. In forty-one sediment samples, the heavy metals represented by Cr, Co, Cd, As, and Pb were studied and utilized as an indicator for contamination by employing many parameters, such as the pollution ecological risk (Er), risk index (RI), contamination factor (CF), adverse effect index (AEI), and toxic units (TUs). The value of CF refers to the studied sediments being low contaminated with Pb, while the level of Co contamination was moderate and considerably contaminated with Cd, Cr, and As. Generally, the degree values of contaminations for all sites indicated that the sediment samples had medium levels of contamination. Depending on the values of Er and RI, all of the heavy elements in the sites under study indicate a moderate ecological risk. An increasing trend of RI values is closely linked to the growth of human activities, especially agricultural activities, and pollution from private oil and gas fields and refineries, which negatively impact the region's ecosystem. According to the Adverse Effect Index (AEI) and toxic units (∑TUs), values refer to probable impacts on biota due to the values of Cd and Cr content in most of the studied sediment samples, suggesting that the depositional and behavioural forms of the studied sediments were exposed to moderate toxicity, indicating moderate toxicity to an ecosystem.

Keywords: Heavy metal; Pollution; Ecological Risk; Stream sediment; Shwan sub-basin.

تطبيق نظام المعلومات الجغرافية والتحليل الإحصائي لتقييم المخاطر البيئية المحتملة في رواسب مجاري حوض شوان الثانوي، كركوك، شمال العراق (دراسة حالة)

الخلاصة:

تم أخذ عينات من الرواسب النهرية الحديثة ضمن حوض شوان الثانوي، محافظة كركوك، شمالي العراق. في واحد وأربعين عينة من الرواسب، تمت دراسة العناصر الثقيلة المتمثلة بالكروم، والكوبالت، والكادميوم، والزرنيخ، والرصاص وتم استخدامها كمؤشر للتلوث من خلال تطبيق العديد من المعايير، مثل مخاطر التلوث البيئي (**Er**)، ومؤشر المخاطر (**RI**)، وعامل التلوث (**CF**)، ومؤشر التأثير الضار (**AEI**)، والوحدات السمية (**Tus**). تشير قيمة **CF** إلى أن الرواسب المدروسة كانت منخفضة التلوث بالرصاص،

بينما كان مستوى التلوث بالكوبالت متوسطًا وملوثًا بشكل كبير بالكادميوم والكروم والزرنيخ. وبشكل عام، أشارت قيم درجات التلوث في جميع المواقع إلى أن عينات الرواسب كانت ذات مستويات تلوث متوسطة. بناءً على قيم **Er** و**RI**، تعكس جميع العناصر الثقيلة في المواقع المدروسة خطرًا بيئيًا معتدلًا. يرتبط الاتجاه المتزايد لقيم **RI** ارتباطًا وثيقًا بنمو الأنشطة البشرية، وخاصةً الأنشطة الزراعية، والتلوث الناجم عن حقول ومصافي النفط والغاز، مما يؤثر سلبًا على النظام البيئي للمنطقة. ووفقًا لمؤشر التأثير السلبي (**AEI**) ووحدات السمية (**∑ Tus**)، تشير القيم إلى التأثيرات المحتملة على الكائنات الحية نتيجةً لقيم محتوى الكادميوم والكروم في معظم عينات الرواسب المدروسة، مما يشير إلى أن الأشكال الترسيبية والسلوكية للرواسب المدروسة تعرضت لسمية معتدلة، مما يشير إلى سمية معتدلة للنظام البيئي.

1. Introduction

Heavy elements are among the most dangerous pollutants entering the freshwater environment [1], causing an imbalance in the ecological balance, which has direct or indirect effects on humans [2], [3]. Recent sediments from rivers and their feeding basins, including the recent sediments of the Shwan sub-basin, are rich in a wide range of pollutants, including several heavy elements such as zinc, copper, cadmium, and lead, resulting from the discharge of industrial waste into them, in addition to chemical fertilizers, which play a role in enhancing river pollution levels [4], [5], [6] [7].

Despite the biological importance of some heavy metals, they have a toxic effect due to their inability to be decomposed by natural processes such as microorganisms, in addition to their persistence in the environment and their spread over long distances from their sources of origin due to wind, storms, and rain [8], [9], [6], [10]. These metals as well as distinguished by their capability to bio-accumulate in the bodies of living organisms, as their values rise through the food chain and enter the bodies of living organisms through the air, water, and soil. Then, bioaccumulation occurs, which causes permanent toxicity to living organisms [11], [12]. Therefore, they are dangerous to humans because they are situated at the top of the food pyramid, and they are the final reservoir for the accumulation of these metals in the bodies of various organisms [13].

Many studies have indicated that rivers are exposed to heavy metal pollution from various sources, such as household waste, mining activities, and agricultural activities such as adding fertilizers and pesticides, which negatively affects the balance of the aquatic ecosystem [11], [12]. [13] and [12], indicated that the main cause of water pollution is the direct discharge of untreated wastewater into rivers and water reservoirs. Among these pollutants are heavy elements, pesticides, and others. In aquatic environments, heavy elements can be found in the water, suspended load, or bottom sediments. However, due to the irregularity in the local release of these pollutants, the suspended load, the lack of balance and stability of the pollution source, and the variability in water discharges, estimating their concentrations in the water for a brief period of time does not provide accurate indications of the extent of pollution. Since the bottom sediments are thought to be a trap for different elements, the emphasis is on them since they offer a more reliable indicator of these elements [16], [17].

Natural sediments consist of a mixture of sand, clay, and organic matter. The proportions of these components vary depending on the sediment type [14]. Interaction with heavy elements occurs depending on the nature of the sediment and the prevailing chemical and physical conditions. [15] and [13], indicated that increased concentrations of heavy elements in sediments are higher than in water because sediments act as traps for pollutants and originate from polluted water, as well as sediments containing various types of clay minerals, which made them adsorb these elements [16] and [17]. [15] also pointed out in his study that sediments reflect the degree of pollution in the aquatic environment. Many researchers have indicated that heavy elements not associated with silicate structures in sediments originate from polluted water [16], [17]. For these reasons, the concentrations of heavy elements in the sediments of the studied areas were studied.

1.1. Study area

The area of the study is represented by the Shwan Sub-basin, located in the northeastern part of Iraq, northeast of Kirkuk Governorate. Its area is 829 square kilometers. The study area is bordered on the eastern and southeastern sides by the Khasa River Basin and on the western and northwestern sides by the Lower Zab River (Figure1). The basin is bounded in its northeastern part by the Chamchamal anticline and in the southwestern part by the X Dome formation [18], [19]. About 58% of the study area is made up of flat to semi-flat plains, which are represented by the central and western portions of the basin. The remaining 42% of the basin is made up of high areas, which range in elevation from 500 to 850 meters above sea level [20]. Geological formations are exposed in the basin, represented by the Al-Muqdadiya Formation, the Bai Hassan Formation, and Quaternary sediments, which range in age from the Upper Miocene to the Holocene (Figure 2), [21].

1.2. Aim of study

The significance of such a natural ecosystem necessitates ongoing environmental quality monitoring for conservation and protection. Accordingly, we use environmental evaluation indexes to analyze the possible ecological hazards of cobalt, chromium, cadmium, lead, and arsenic in recent stream sediment cores taken from the Shwan sub-basin. Furthermore, one of the main goals of this study is to determine how the metal concentration has changed over time and what ecological risks it may provide. Because stream sediments are an effective instrument for assessing pollution levels, the current study's findings would help to improve our understanding of this sub-basin's environmental quality.

2. Materials and Methods

During the fieldwork, field trips were made to different parts of the Shwan sub-basin area, northeast of Kirkuk city, to get to know the area in the field from a geological perspective and to see the rock outcrops in it and to determine the sampling sites within the study area, as well as to collect samples, amounting to (41) samples of recent stream sediments, the locations and numbers from sites that were previously identified on the site map, Figure (1), in a way that covers the drainage tributaries and the main channel of the drainage systems within the Shwan sub-basin.

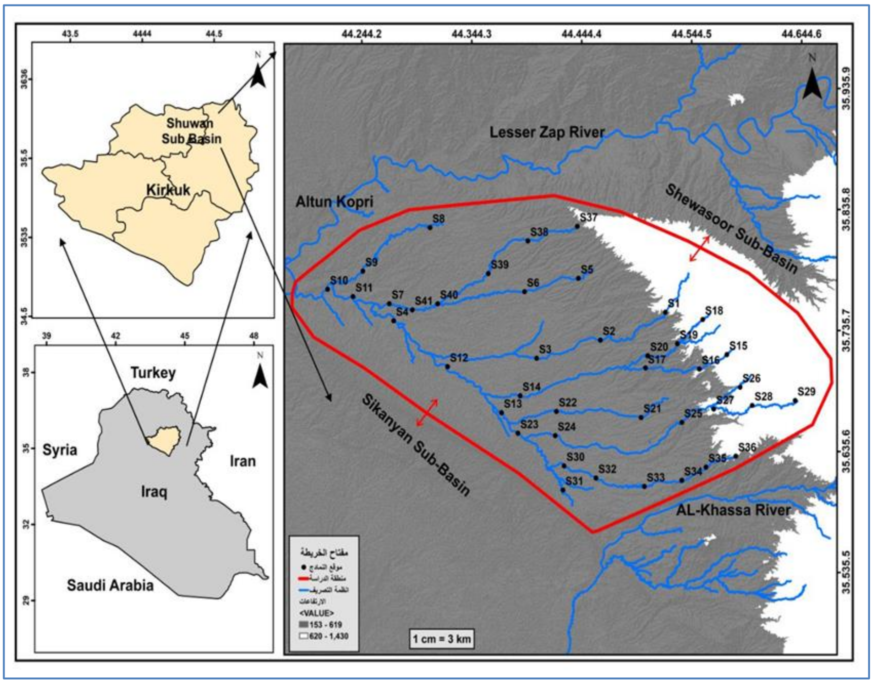

Fig. (1): A map of the Shwan sub-basin displaying sample locations

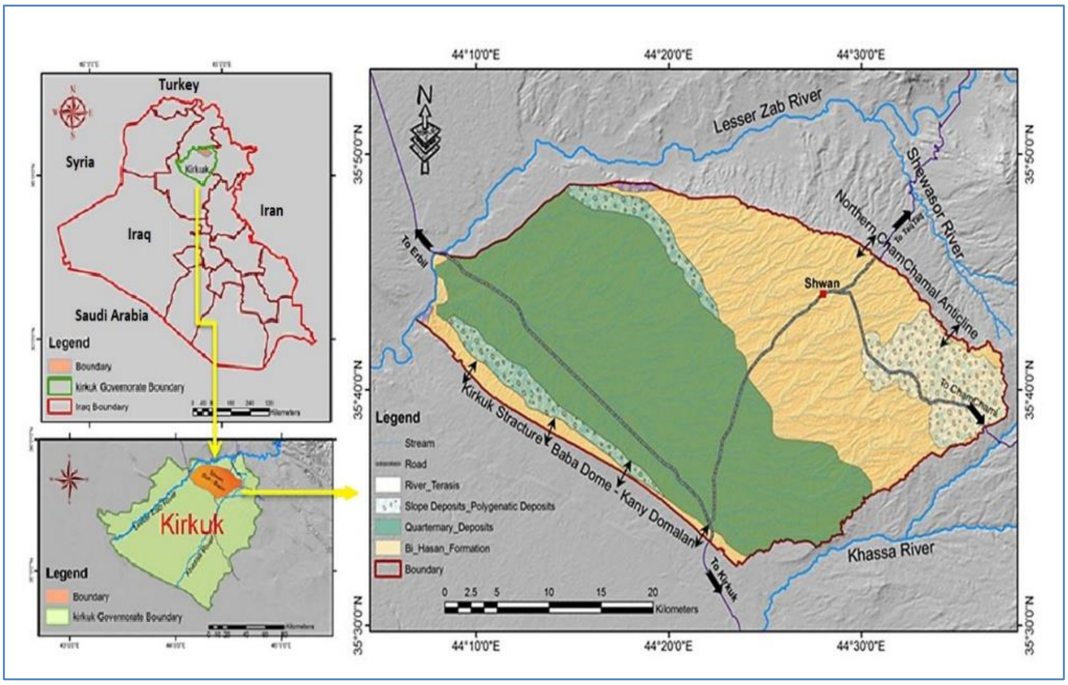

Fig. (2): Geological map of the study area based on [22]

After 48 hours of air drying, the sediment samples were ground in a ceramic mortar and sieved through a 63-mesh screen. Polarized energy dispersive XRF was used to analyze these materials in the Earth Science Research and Application Centre (YEBIM) laboratory in Ankara, Turkey, using the Spector XLAB 2000 PEDXRF spectrometer. Ten grams of samples were ground into powder to determine the content of the heavy elements Co, Cr, Cd, Pb, and As.

The distribution of heavy metals in stream sediments was investigated by digitizing and analyzing heavy metal concentration measurements as input data for sediment contamination maps using ArcGIS 10.7. To estimate the level of pollution and the richness degree with metals of recent stream sediment, multiple indicators were selected to evaluate the contamination level of cobalt (Co), chromium (Cr), cadmium (Cd), lead (Pb), and arsenic (As) heavy metals. These are the contamination factor and degree of contamination (CF and Cdeg), adverse effect index (AEI), toxic units (TUs), the ecological risk of pollution (Er), and risk index (RI) that have been utilized for evaluating the sediment pollution level with these metals by applying the following equations:

$$CF = \frac{(Cs)\ sample}{(Cb)\ background} \qquad (1)$$

$$Er = Ti * CF \qquad (2)$$

$$RI = \int Er \qquad (3)$$

Where;

Cf: Contamination factor.

Cs: Concentration of the heavy metal in the sediment.

Cb: The natural value of the background of the same metal, which is the mean value in the upper crust of the earth.

Er: The ecological risk of heavy metal;

Ti: toxic response factor (Co = Pb = 5; Cr = 2; Cd = 30; As = 10).

RI: Ecological Risk Index.

The value of RI values can be defined according to the [23], A low ecological risk is indicated by RI values less than 150 [23]. A moderate ecological risk is indicated by RI values between 150 and 300, and a large ecological risk is indicated by RI values between 300 and 600. An extremely high ecological risk is indicated by a RI > 600.

To determine if these metals could have detrimental biological consequences on this sub-basin ecosystem, the current study employed the Adverse Effect Index (AEI). The AEI was thus estimated using the following equation:

$$AEI = \frac{C}{TEL} \qquad (4)$$

Where; C represent the heavy metal content in the studied samples, and TEL is the threshold effect level (Co= 30; Cr = 52.3; Cd = 0.68; Pb = 30.24; As = 7.24) [24]. According to Koukina and Lobus [24], if these metals' current values are less than 1, they are insufficient to cause a detrimental biological effect (or a moderate influence is suspected). Conversely, when the AEI values above 1, negative impacts on biota are likely to occur.

The units of toxic (TUs) for the metal concentration of sediment samples were determined according to the Equation (5):

$$TUs = \frac{C}{PEL} \qquad (5)$$

Where C; refers to the amount of heavy metals in the sediment under study, whereas PEL indicates the level of probable effect (Co=20; Cr = 160; Cd = 4.21; As = 41.6; Pb = 112). Based on Yan et al. [25], minimal toxicity to an environment is indicated if ΣTUs < 4. On the other hand, moderate toxicity to an environment is indicated if ΣTUs > 4.

3. Results and Discussion

3.1. Heavy metals distribution

The spatial distribution of heavy elements in sediments is a considerable topic for a variety of ecological, climatic, and general health reasons [21]. Where the dispersion and transport of elements are influenced by the organic combinations and content of iron, magnesium oxides and hydroxides and clay minerals in sediments [5], [6].

The coefficient of variation values for heavy metals in general diverge by 28 to 42% for recent sediment samples and are following arranged: Cd > Cr > Pb > As > Co. The coefficient of variation (C.V.) is significantly high (C.V. > 40%) for Cr and (30 < C.V. < 40%) for Pb, As, and Cr and is within 30% for Co (Table 1, Figures 3, 4, 5, 6, and 7). These findings refer to the values of the coefficient that could have been influenced by outward factors, such as anthropogenic activities [11], [12], [13], [15]. Whereas Statistical description values of analyzed heavy metals, including coefficient of variation (C.V.), standard deviation, arithmetic mean, and maximum and minimum values, are statistical techniques and processes used to understand the movement and distribution of heavy elements in various ecosystems.

The results also show that the average values of Cr, Co, Cd, Pb, and As are 367.63, 28.31, 0.77, 8.68, and 6.47 ppm, respectively (Table 1), throughout each of the sediment samples, which are higher than their mean values recorded for the earth's crust, with the exception of Pb (8.68 ppm), which is lower than the earth crust rate values (Table 1, and Figures 3, 4, 5, 6, and 7). Human activities like industrial effluents, phosphate fertilizers, pesticides, and atmospheric deposition can contribute significant amounts of heavy metals to the sediments, although most naturally occurring sediments have low levels of these metals [6], [15].

Table (1): The statistical data description of heavy metal concentration values in the sediments.

Elements	Concentrations (ppm)		Upper earth crust (ppm)	Standard deviation	Coefficient of variation
	Range	Average	Average		
Cr	167 – 764	367.63	100	142.61	38.79
Co	15.12 – 43.12	28.31	25	7.82	27.61
Cd	0.11 – 1.29	0.77	0.2	0.32	41.90
Pb	4.14 – 15.92	8.68	13	3.30	38.07
As	2.67 – 12.82	6.47	1.8	1.99	30.74

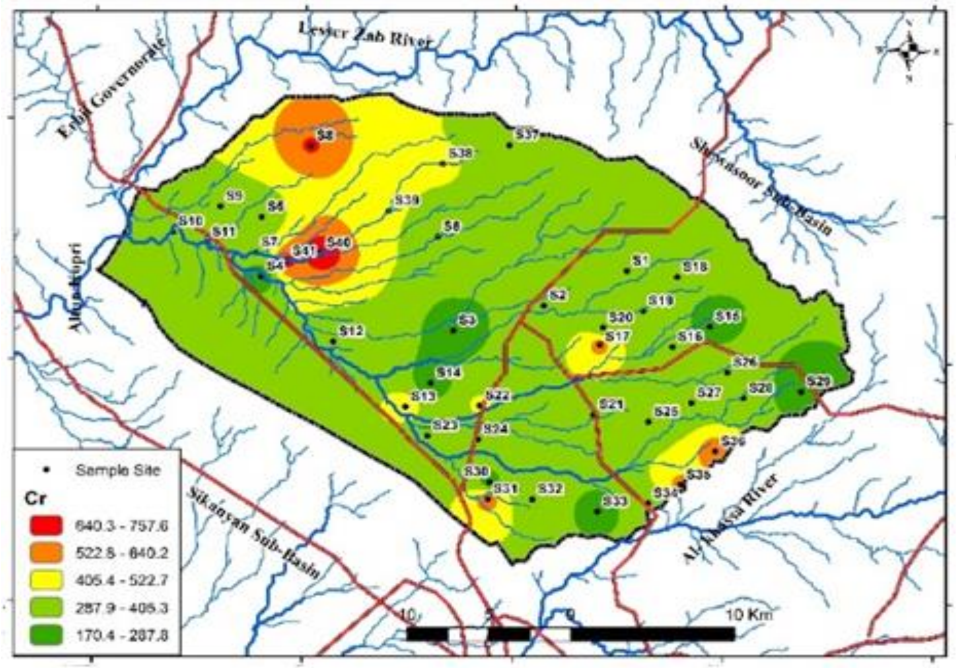

Fig. (3): The map of chromium (ppm) values distribution in stream recent sediment in the Shwan sub-basin, which the researcher created using ArcGIS.

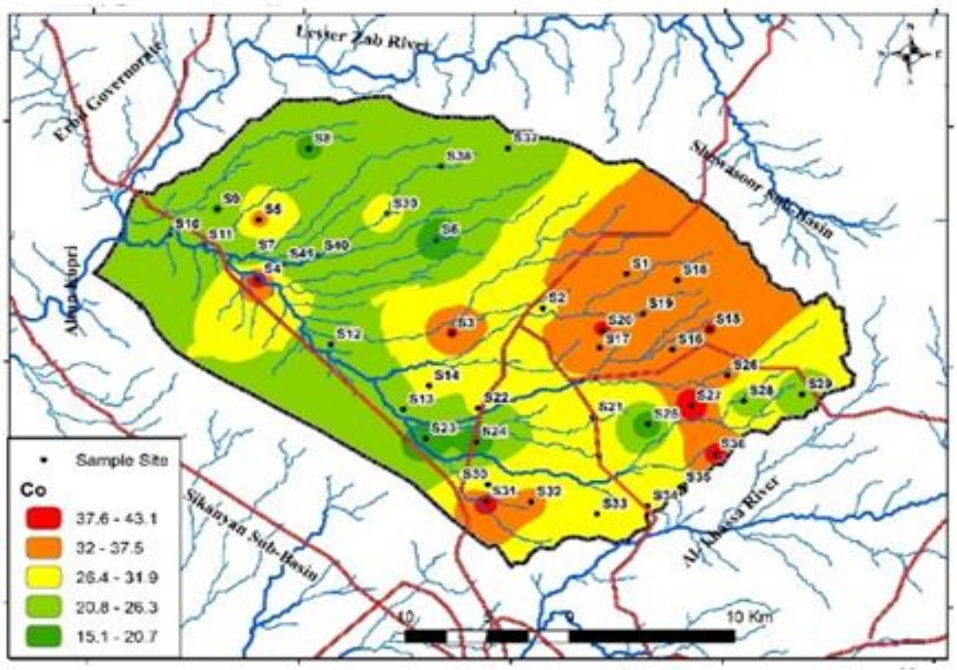

Fig. (4): The map of cobalt (ppm) values distribution in stream recent sediment in the Shwan sub-basin, which the researcher created using ArcGIS.

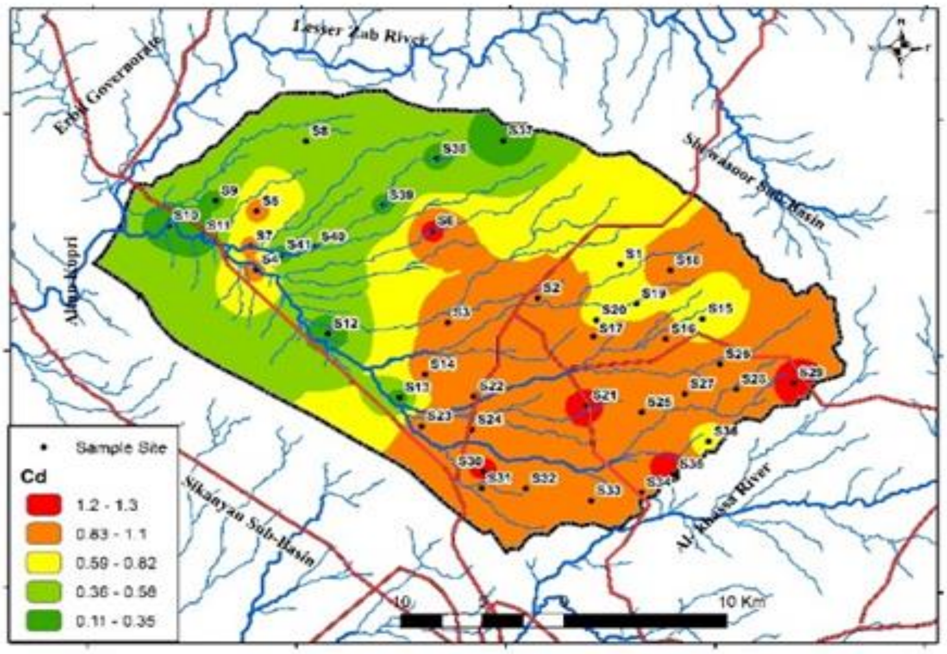

Fig. (5): The map of cadmium (ppm) values distribution in stream recent sediment in the Shwan sub-basin, which the researcher created using ArcGIS.

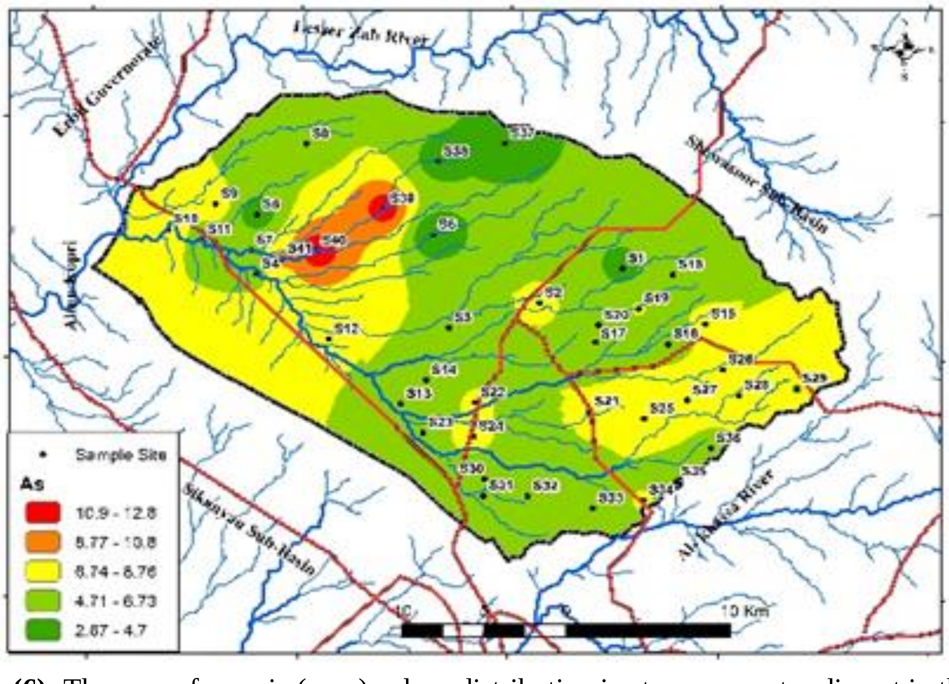

Fig. (6): The map of arsenic (ppm) values distribution in stream recent sediment in the Shwan sub-basin, which the researcher created using ArcGIS.

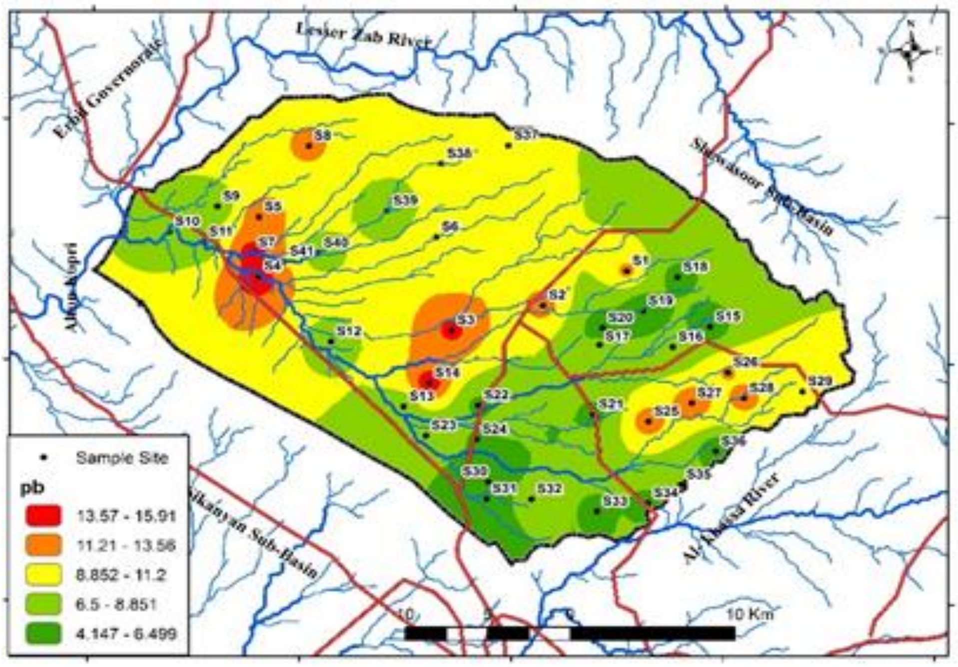

Fig. (7): The map of lead (ppm) values distribution in stream recent sediment in the Shwan sub-basin, which the researcher created using ArcGIS.

3.2. Contamination Factor and Potential Ecological Risks

The measurements of the heavy metal contamination factor for the recent stream sediments in the study region, which is situated in the Shwan sub-basin in the Kirkuk governorate in northeastern Iraq, are shown in Table (2) and Figure 8. The findings show that the detected heavy metal contamination factor (CF) falls in the following order: Cd > Cr > As > Co > Pb. There was a moderate level of Co contamination and a low level of Pb contamination. The findings also show the fact that the studied samples were considerably contaminated with Cd, Cr, and As. The degree values of contaminations were between 7.63 and 18.59, with a rate of 12.91. Generally, this indicated that the sediment samples had medium levels of contamination, as shown in Tables (2) and (3), Figure (8).

Table (2): The contamination factor (CF) and ecological risk values (Er) in the studied sediments

Elements	**Contamination Factor (CF)**		**Elements**	**Ecological Risk (Er)**	
	Range	Average		Range	Average
Cr	1.67 - 7.64	3.68	**Cr**	3.34 -15.28	7.35
Co	0.60 -1.72	1.13	**Co**	3.02 - 8.62	5.66
Cd	0.55 - 6.45	3.83	**Cd**	16.5-193.50	114.88
Pb	0.32 - 1.22	0.67	**Pb**	1.59 - 6.12	3.34
As	1.48 - 7.12	3.59	**As**	14.83 - 71.22	35.92
Contamination Degree (Cdeg)	7.63 - 18.59	12.91	**Ecological Risk Index (RI)**	64.78 - 241.33	167.15

The ecological risks of (Co, Cr, Cd, Pb, and As) in recent stream sediments taken from the Shwan sub-basin are assessed in this study. In most sediment samples, the potential ecological risk (RI) values of the metals under investigation indicate a moderate ecological risk (Tables 2 and 3). The RI rising trend values is closely linked to the growth of human activities, especially agricultural activities, in the sedimentary basin. The area is known for the cultivation of seasonal seeds of wheat and barley, which has contributed to metal pollution resulting from overuse of fertilizers and pesticides [26], [27]. In addition to the area being close to X fields and private oil and gas refineries, which negatively impact the region's ecosystem.

Refineries and oil facilities release wastes rich in polycyclic aromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPHs), which can settle in rivers or valleys, such as the Shawan Basin. These compounds are toxic and relatively inert, allowing them to accumulate in sediments for long periods and pose a risk to aquatic organisms and even humans through the food chain [7].

Industrial oil activities (refining, flaring, and spills) can release heavy elements such as lead (Pb), cadmium (Cd), nickel (Ni), zinc (Zn), and chromium (Cr). These elements settle to the bottom of waterways, increasing environmental toxicity and affecting soil and groundwater quality. They also affect local ecological balance [28].

Table (3): The contamination factor (CF) and contamination degree index (Cdeg) classification, [23]

Contamination Factor level	The Value of Contamination	Contamination index value	Contamination level
Low contamination	$CF < 1$	$C_{deg} < 8$	Low pollution factor
Moderate contamination	$1 \leq CF < 3$	$16 \leq C_{deg} < 8$	Medium pollution factor
Considerable contamination	$3 \leq CF \leq 6$	$16 \leq C_{deg} < 32$	High pollution factor
Very high contamination	$CF > 6$	$C_{deg} \geq 32$	Very high pollution factor

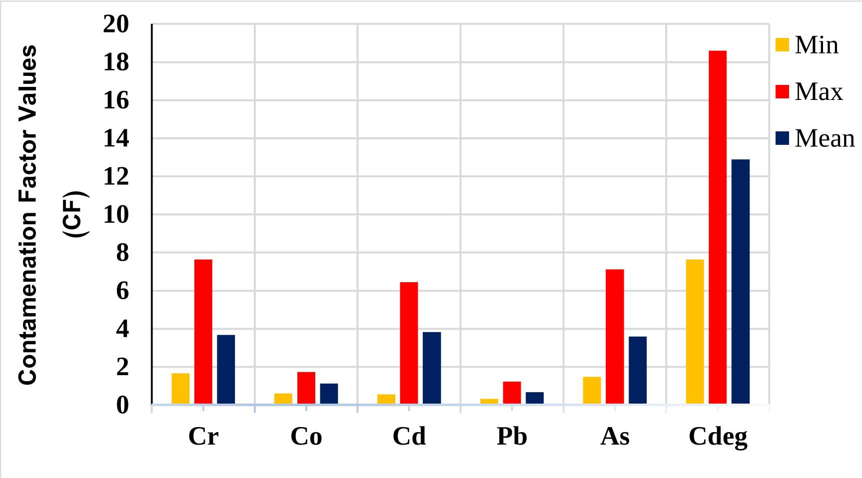

Fig. (8): The estimation of contamination factor (CF) and contamination degree for heavy elements at study area.

3.3. Adverse Effect Index (AEI) and Toxic Units

According to the Adverse Effect Index (AEI), values refer to probable impacts on biota due to the values of Cd and Cr content in most of the studied sediment samples (Table 4, and Figure 9). It is to be noted that, even if the other heavy metal concentrations are not sufficient to induce a negative biological effect, the ongoing monitoring of the levels of heavy metal in the Shwan sub-basin is necessary, as AEI values are close to 1, in most of the studied sediment samples.

The toxic unit analysis is described, followed by the applicable findings. The evaluation of toxic units (TUs) for the heavy metals in the Shwan sub-basin sediment based on the findings of the present study showed a decreasing trend in the order Cr > Co > Cd As > Pb in the present study (Table, and Figure 10). Generally, the calculated toxicity units for each heavy element have individual values below 4 (Table 4). In contrast, the total value of toxic units (∑TUs) for majority sites was greater than four (∑TUs > 4), suggesting that the depositional and behavioural forms of the studied sediments were exposed to moderate toxicity, indicating moderate toxicity to an ecosystem (Table 4, and Figure 10) [29].

Table (4): The values of adverse effect index (AEI) and toxic units (TUs) in the studied sediments

Elements	Adverse Effect Index (AEI)		Elements	Toxic units (TUs)	
	Range	Average		Range	Average
Cr	3.16 - 14.47	6.96	**Cr**	1.04 - 4.78	2.3
Co	0.50 - 1.44	0.94	**Co**	0.76 - 2.16	1.42
Cd	0.16 - 1.90	1.13	**Cd**	0.03 - 0.31	0.18
Pb	0.14 - 0.53	0.29	**Pb**	0.04 - 0.14	0.08
As	0.37 - 1.77	0.89	**As**	0.06 - 0.31	0.16
			Total Toxic units (ΣTUs)	2.91 - 6.44	4.13

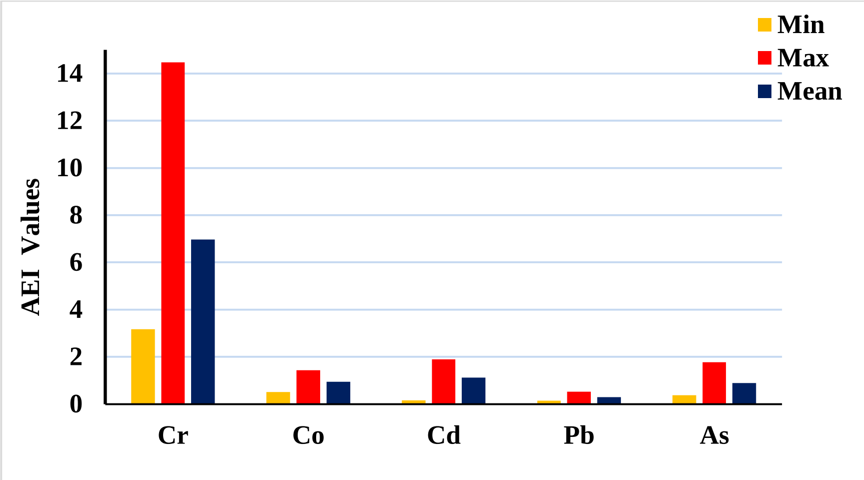

Fig. (9): The estimation of Adverse Effect Index (AEI) for heavy elements at study area.

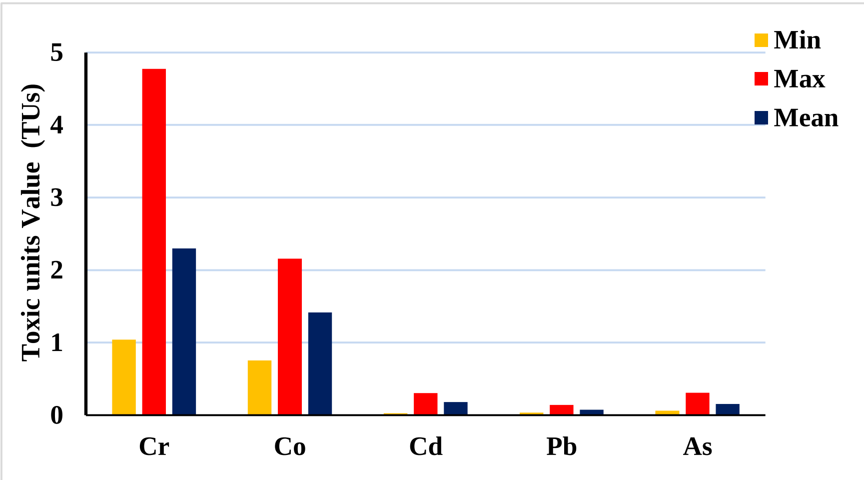

Fig. (10): The estimation of Toxic units (TUs)for heavy elements at study area.

4. Conclusions

The findings of the contamination parameters applied to the chemical analysis data for heavy metals to measure contamination levels in recent sediment samples in the study region, which is situated in the Shwan sub-basin in the Kirkuk governorate in northeastern Iraq, showed that the detected heavy metal contamination factor (CF) falls in the following order: Cd > Cr > As > Co > Pb. The results also demonstrate that the stream sediments were considerably contaminated with cadmium, chromium, and arsenic. Generally, the degree values of contaminations indicated that the sediment samples had medium levels of contamination. This is also indicated by the potential ecological risk (RI) values in most sediment samples, which indicate moderate environmental risks. The impact of human activities, such as agricultural practices brought on by the overuse of fertilizers and pesticides, is directly related to the rising trend in RI values. Which negatively impact the region's ecosystem. According to the total value of toxic units (∑TUs) and AEI for majority sites, the depositional and behavioural forms of the studied sediments were exposed to moderate toxicity, indicating moderate toxicity to an ecosystem, so the potential effects on biota due to the AEI values of cadmium and chromium contents in most of the sediment samples studied. Activities like agriculture and oil and gas production may be potential resources of cadmium and chromium.

Author Contributions Statement: Fadia A. Majeed contributed to the Conception of the study; Methodology; Experimental work; Data analysis and interpretation; Modeling and simulation, Original draft preparation; Review and editing of the manuscript. Abbas R. Ali contributed to the conception of the study; Data curation; Data analysis and interpretation; review and editing of the manuscript. Both authors have read and approved the final version of the manuscript.

References

[1] M. Canli, O. Ay, and M. Kalay,, "Levels of heavy metals (Cd,Pb,Cu,Cr and Ni) in tissue of Cyprinus carpio, Barbus capito and Chondrostoma regium from the Seyhan river", *Turkish Journal of Zoology,* vol. 22, no. 2, pp. 149-158, 1998.

[2] A. Kaviraj and S. Konar,, "Acute toxicity of mercury, chromium and cadmium to fish, plankton and worm", *Giobios,* vol. 9, no. 3, pp. 97-100, 1982.

[3] A. R. Ali, T. M. Al-Mufti and C. M. Taqi,, "Evaluation of Elements Composition of Maize (Zea Mays) Cultivated in Kirkuk, and Their Environmental Impacts, Northern Iraq", in *MIDDLE EAST INTERNATIONAL CONFERENCE ON CONTEMPORARY SCIENTIFIC*, Ankara, Turkey, 2021.

[4] A. Farag, , O. Nimick,, B. Kimball, , S. Church, , D. Harper, and W. Brumbaugh, , "Concentration of metals in water, sediment, biofilm, benthic micro invertebrates and fish in the Boulder river watershed, Montana and role of colloids in the metal uptake", *Archives of Environmental Contamination and Toxicology*, vol. 72, pp. 397–409, 2007. https://doi.org/10.1007/s00244-005-0021-z.

[5] A. Ali,, T. Al-Mufti, and C. Taqi, "Geochemical Distribution of Some Heavy Metals in Agricultural Soil and Their Environmental Impacts in Kirkuk, Northern Iraq", *Iraqi geological Journal*, vol. 54, no. 2A, pp. 75-92, 2021. https://doi.org/10.46717/igj.54.2A.6Ms-2021-07-27.

[6] H. Rifat, A. Ali and M. Ahmed, "Distributions of Some Heavy Metals in Agricultural Soil and Their", *Iraqi geological journal*, vol. 57, no. 2A, pp. 80-94, 2024. https://doi.org/10.46717/igj.57.2A.6ms-2024-7-16.

[7] I. M. Zaidan and S. K. Al-khateeb, "The Use of FMEA to Assess Environmental Risks A Case Study at Middle Refineries Company / Dora Refinery", *Journal of Petroleum Research and Studies,* vol. 11, no. 3, pp. 1-19, 2021. https://doi.org/10.52716/jprs.v11i3.535.

[8] L. Feng, Y. Wen and P. Zhu, "Bioavailability and toxicity of heavy metals in a heavily polluted river, in PRD, china", *Bulletin of environmental contamination and toxicology,* vol. 81, pp. 90-94, 2008. DOI: 10.1007/s00128-008-9386-9.

[9] M. Gulfraz, T. Ahmad and H. Afzal, "Concentration level of heavy and trace metals in the fish and relevant water from Rawal and Mangla lakes", *Journal of Biological Sciences*, vol. 1, no. 5, pp. 414-416, 2001. https://doi.org/10.3923/jbs.2001.414.416.

[10] R. Y. Jasim, A. R. Ali and M. M. Hassan, "Ecological Risk Evaluation of Certain Heavy Metals in Dust at Industrial Sites in Kirkuk Governorate, Northern Iraq", *Iraqi geological journal,* vol. 58, no. 1D, pp. 202-219, 2025. https://doi.org/10.46717/igj.2025.58.1D.13.

[11] J. Karak, O. Anaser and S. Thanaa, "Accumulation of some heavy metals in Himr (Barbu sluteus) and common Carp (Cyprinus carpio) fish in Euphraters river - Syria", *J. Animal and Poultry prod., Mansoura Univ.,* vol. 1, no. 12, pp. 669-675, 2010. https://doi.org/10.21608/jappmu.2010.86282.

[12] A. H. Yaseen, A. Abdullah, M. Ziyadi and F. Mutlak, "Assessing Integrity of Aquatic Ecosystem in the Southern Part of the Euphrates River Using Fish as Bio-Indicators," *Egyptian Journal of Aquatic Biology & Fisheries,* vol. 28, no. 3, pp. 753-768, 2024. https://doi.org/10.21608/ejabf.2024.360916.

[13] S. H. Yaseen, A. R. Ali and T. M. Al-Mufti, "Geomatics Study of Suspended Sediments in Selected Samples of Tigris River Between Sarafiya Bridge and Alshuhadaa Bridge, Baghda-IRAQ", *Kirkuk University Journal of Scientific Studies (KUJSS),* vol. 13, no. 3, pp. 174-187, 2018. https://doi.org/10.32894/kujss.2018.13.3.13.

[14] Z. J. Mohsen, A. R. Ali and T. M. Al-Mufti, "Geostatistical Analysis Application to Evaluate Heavy Mineral Distribution in Stream Sediments of Shwan Sub-Basin, Kirkuk, Northern Iraq", *Iraqi geological journal,* vol. 58, no. 1B, pp. 165-179, 2025. https://doi.org/10.46717/igj.58.1B.14ms-2025-2-22.

[15] A. R. Ali, "Major and trace elements distribution in stream. Sediments of the lesser zab river at. Northeastern iraq: implications to weathering. And transportation", *Iraqi Bulletin of geology and mining,* vol. 8, no. 3, pp. 25-44, 2012.

[16] R. Chester and F. G. Voutsinou, "The initial assessment of trace metal pollution in coastal sediments", *Marine Pollution Bulletin,* vol. 12, no. 3, pp. 84-91, 1981. https://doi.org/10.1016/0025-326X(81)90198-3.

[17] A. R. Ali and M. J. A. Talabani, "Heavy Metals Distribution and Their Correlation with Clay Size Fraction in Stream Sediments of the Lesser Zab River at Northeastern Iraq", *Journal of Geoscience and Environment Protection,* vol. 6, pp. 89-106, 2018. https://doi.org/10.4236/gep.2018.64006.

[18] S. Z. Jassim and J. C. Goff, *Geology of Iraq*, Prague, Czech Republic: Dolin Publishing House and Moravian Museum, 2006.

[19] H. D. Al-Hayali, O. S. Al-Tamimi and D. F. Hamamin, "Hydrogeological Assessment of the Aquifers in Shwan Sub-Basin, Kirkuk,Iraq", *Iraqi geological journal,* vol. 57, no. IC, pp. 276-292, 2024. https://doi.org/10.46717/igj.57.1C.18ms-2024-3-30.

[20] H. D. Al-Hayali, *Groundwater Vulnerability and Risk Intensity Mapping in Shwan Sub-basin, Kirkuk, NE Iraq*, M.Sc. thesis submitted to the College of Science, University of Kirkuk 85, 2020.

[21] Z. Stevanovic and M. Markovic, *Hydrogeology of Northern Iraq: Climate, Hydrology, Geomorphology and Geology*, vol. 1. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO), 2004, p. 190.

[22] V. K. Sissakian, *The Geology of Kirkuk Quadrangle Sheet NI-38-2, Scale 1: 250,000*. Baghdad, Iraq: State Organization of Minerals, General Directorate for Geological Survey and Mineral Investigation (GEOSURV), 1993.

[23] L. Hakanson, "An ecological risk index for aquatic pollution control. A sedimentological approach", *Water Research*, vol. 14, no. 8, pp. 975-1001, 1980. https://doi.org/10.1016/0043-1354(80)90143-8.

[24] S. E. Koukina and N. V. Lobus, "Relationship between enrichment, toxicity, and chemical bioavailability of heavy metals in sediments of the Cai River estuary", *Environmental Monitoring and Assessment*, vol. 192, p. 305, 2020. https://doi.org/10.1007/s10661-020-08282-6.

[25] C. Yan, T. Zhuang, J. Bai, X. Wen, Q. Lu and L. Zhang, "Assessment of As, Cd, Zn, Cu and Pb pollution and toxicity in river wetland sediments and artificial wetland soils affected by urbanization in a Chinese delta", *Wetlands*, vol. 40, p. 2799–2809, 2020. https://doi.org/10.1007/s13157-020-01330-4.

[26] M. Maanan, A. Ruiz-Fernandez, M. Maanan, P. Fattal, B. Zourarah and M. Sahabi, "A long-term record of land use change impacts on sediments in Oualidia lagoon, Morocco", *International Journal of Sediment Research*, vol. 29, no. 1, pp. 1-10, 2014. https://doi.org/10.1016/S1001-6279(14)60017-2.

[27] N. Mejjad, A. Laissaoui, O. El-Hammoumi, A. Fekri, H. Amsil, A. El-Yahyaoui and A. Benkdad, "Geochemical, radiometric, and environmental approaches for the assessment of the intensity and chronology of metal contamination in the sediment cores from Oualidia lagoon (Morocco)", *Environmental Science and Pollution Research,* vol. 25, p. 22872–22888, 2018. https://doi.org/10.1007/s11356-018-2370-y.

[28] T. A. Ahmed, S. S. Ayob, M. A. Shahatha, S. R. Khorsheed, and M. J. Mohammed, “Treatment of Contaminated Collected Wastwater at Petroleum Fuel Filling Stations for Using as Make Up Water for Cooling Tower in Petroleum Refineries”, *Journal of Petroleum Research and Studies*, vol. 13, no. 4, pp. 131-146, Dec. 2023. https://doi.org/10.52716/jprs.v13i4.723.

[29] R. Xiao, J. Bai, H. Gao, J. Wang, L. Huang and P. Liu, "Distribution and contamination assessment of heavy metals in water and soils from the college town in the Pearl River Delta, China", *CLEAN - Soil, Air, Water*, vol. 40, no. 10, pp. 1167-1173, 2012. https://doi.org/10.1002/clen.201200016.

[30] M. K. Ahmed, S. Islam, S. Rahman, M. R. Haque and M. M. Islam, "Heavy metals in water,sediment and some fishes of Buriganga River, Bangladesh", *Int. J. Environ. Res.*, vol. 4, no. 2, pp. 321-332, 2010. https://doi.org/10.22059/ijer.2010.24.

[31] I. Aoyoma, I. Yoshinob and I. Yoriteru, "Experimental study on the concentration process of trace element through a food chain from the view point of nutrition ecology", *Water Research,* vol. 12, pp. 831-836, 1978. https://doi.org/10.1016/0043-1354(78)90034-9.

[32] E. Al-Sarraj, M. Jankeer and S. Al-Rawi, "Estimation of the Concentrations of some Heavy Metals in Water and Sediments of Tigris River in Mosul City," *Alrafedain Science Journal,* vol. 28, no. 1, pp. 1-10, 2019. https://doi.org/10.33899/rjs.2019.159401.