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# Heavy metals assessment in sediments bed of Habbaniyah Lake, Iraq

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**Abstract:** Heavy metals (HMs) concentrations (Zn, Cr, Cd, Ni, Cu, Co, Fe, Pb and Fe) were analyzed by Atomic absorption spectrometer (AAS) in sediment bed samples of Habbaniyah lake (HL), Anbar province, Iraq. Thirty-three locations were selected in the field of study during (2020 – 2021) to assess the contamination of (HMs) in sediments by using pollution load index (PLI), contamination factor (CF), contamination degree (CD), and geo-accumulation index (I-geo). The following are the average concentrations: 2152.97 mg/kg of Fe, 47.35 mg/kg of Pb, 25.18 mg/kg of Cr, 18.00 mg/kg of Ni, 10.60 mg/kg of Co, 9.57 mg/kg of Zn, 4.53 mg/kg of Cu and 3.53 mg/kg for Cd during the research time. The average concentration of Pb, Ni, Fe, and Cd surpassed the USEPA recommendation. Cadmium (Cd) is responsible for extremely high contamination; lead (Pb) is responsible for moderate pollution and severe contamination at some places based on the (CF). According to the (CD), the lake is classified as significant pollution degree and very pollution degree in some sites. Results indicated that HL was not polluted with (HMs) based on (I-geo) index and (PLI) index for all sample locations during study period. According to (CF), (I-geo) index, (PLI) index, and (CD) the Lake is unpolluted by Fe, Cr, Co, Ni, Zn, and Cu.

*Keywords:* Heavy Metals; Lake Sediment; Contamination indices; Habbaniyah Lake

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## 1. Introduction

### *1.1. Background*

The pollution of water and sediments with heavy metals increases due to the increase in pollution activities such as industrial, agricultural and surface runoff (Bhagat et al., 2020). The accumulation of heavy metals is one of the most important factors and reasons to study water quality (Elzwayie et al., 2017). Sediment is the highest pool of heavy metals (HMs) in water (Xu et al., 2018). HMs, due to toxicity, persistence and bioaccumulation problems in the natural environment, are major pollutants (Seshan et al., 2010). The level of HMs is calculated under three situations in the marine ecosystem: water, sediment, and organisms (Andreas et al., 2019). Water, the food chain, and sediment can collect large amounts of (HMS), which can have fatal consequences on aquatic species (Benson et al., 2017; Iqbal & Shah, 2014; Mehrgan et al., 2019). Trace elements in marine ecosystems can be affected by the column of water, sediments, and biota by chemical and biological processes (Mohiuddin et al., 2010; Nowrouzi & Pourkhabbaz, 2014). Sediments consist of clay, sand, and some organic materials at different rates; the concentrations of HMs in sediment are greater than in the water (Habeeb et al., 2015). Toxic elements accumulate in rivers, sediments, plants, and animals, due to agricultural, human, industrial activity, and sewage. All contribute to pollution (Ilie et al., 2014; Mohd et al., 2014; Shanbehzadeh et al., 2014; Yi et al., 2020). Urban, agriculture, industries, and commercial operations add to the input into the aquatic ecosystem of substantial quantities of substances of pollutant (in particular heavy elements) and damage the often deposited environmental systems (Jiang & Sun, 2014; Zourarah et al., 2009). Anthropogenic activities and natural processes, particularly rock weather and volcanic activity, play an important influence in the build-up of HMs in sediments (Devanesan et al., 2020; Maanan et al., 2015; Saeed & Shaker, 2008). discharge of wastewater contain hm without any treatment and its apply for agricultural purpose are possible ways of heavy metals accumulation in plants food chain (Basra et al., 2014).

Sediments due to its toxicity, persistence, and bioaccumulation of heavy metals is considered a critical issue for the aquatic ecosystem (Harikumar et al., 2010; Salah et al., 2012). Sediments as environmental markers have been widely used and they also reported their ability to track sources of pollution (Alaoui et al. 2010).

Several studies have shown that aquatic systems in various areas of the world are polluted with HMs (Habeeb et al., 2015). (Ghalib & Ramal, 2021) study some of (HMs) (Zn, Cr, Cd, Ni, Cu, Co, Fe, Pb and Fe) in water of Habbaniyah lake (HL), Results showed that (HL) was polluted with HMs, Based on international and national guides, (contamination degree), (heavy metal pollution index) and (heavy metal evaluation index) indices were calculated and compared with limitations, which show that water quality of (HL) was bad.

Total sediment concentrations of HMs are useful for detecting any net changes, but there is no indication of the chemical form of sediment metals (Yunus et al., 2020). Depending on sediment type and characteristics of adsorbed molecules, various physical and chemical absorption mechanisms of HMs accumulate in sediments (Rabee et al., 2011). The scientific community has become increasingly aware of lake sediment pollution, as it is an important cause of ecosystem-based health stress and various research showed that in sediments, HMs may have a direct effect on aquatic ecosystem quality (Devanesan et al., 2017). The correct evaluation and biological and ecological importance of sediment pollution in lake are therefore critical. Can rotate the sediment in the water because of the biological perturbation and change the pH and temperature, although the sediment is a sink of HMs analysis pollution of HMs in sediments helps to find these sources of pollutants in the water ecosystem (Maina et al. 2019; Balasim et al., 2013). Toxic pollutant discharges including wastewater treatment, fossil fuel burning, and air deposition, can penetrate marine environments from anthropogenic sources (Singovszka et al., 2017).

The environmental quality indexes and indices are a valuable instrument in which decision-makers, administrators, technicians or the public can process, analyze and provide raw environmental knowledge (Habeeb et al., 2015). HMs, that are both essential and inessential ions, are highly crucial in ecotoxicology so they are highly persistent and can seriously impact living organisms. (Öztürk et al., 2009). Although trace metals, like chromium (Cr), zinc (Zn), copper (Cu), arsenic (As), manganese (Mn) and vanadium (V) are important components of biological activities at low concentrations, but at high concentrations will becomes a global issue due to potential harm impacts on human health and aquatic ecosystems (Andreas et al., 2019). HMs such as copper, zinc and nickel play an integral role in biological processes and are important metals, while others, such as cadmium and lead, are not essential elements (Benzer et al., 2013). Pb and Cd are rare elements, do not have basic biological roles, and are extremely poisonous to plants and animals (Nowrouzi & Pourkhabbaz, 2014). In addition, sediment research can help to clarify pollutant origins in marine environments (Salah et al., 2012).

### *1.2. Research objectives*

Habbaniyah Lake (HL) has environmental, recreational, drinking and agricultural importance due to the fact that many activities were surrounded (HL). This research aims at (i) Examine the spatial and temporal of HMs in sediments (ii) assessing the metal toxicity in sediments using environmental pollution indexes (iii) Combining operations and technology of geographical information systems (GIS) to form a framework that provides the ability to capture and analyze spatial and non-spatial geographic data from different sources and merge in one form for analysis to evaluate contamination in sediments of HL.

## 2. Materials and methods

### 2.1. Study area

Figure 1. Shows the study area of Habbaniyah lake HL, HL is a crucial strategic location in Iraq where it is far from Baghdad 68km, far away from Fallujah 20km, and far away from the south of Ramadi 25km. A neighborhood of the HL is 426 square kilometer, 35km length, 25km width, and therefore the depth of the HL between 9-13m with a complete capacity of this size is attributed to 3.3billion m3 (Salah et al., 2014). HL is found between the latitudes (33°18'21" N and longitudes 43°26'14" E) at elevation (51m) above water level (AL-Fahdawi et al., 2015). HL is fed by the Euphrates through Warrar Canal and has two outlets: the Mijarrah Canal and Dhiban Canal (Salah et al., 2014).

### 2.2. Sampling

Thirty-three stations were selected within HL monthly during (October 2020 - April 2021), sediments samples taken from HL bed to measure HMs. Stations were located using (Garmin, GPS map pro 60 CSx).

Stations were selected regularly by interpolation method to cover the lake fully. Sediment samples were collected in clean polyethylene bags (1kg) by employing an Ekman bottom grab sampler at a depth of 10-13m. A sensitive balance was used to weigh one gram of sediment samples after they had been dried at 120°C for 3 hours. (37 percent of HCl acid) and (65% of HNO3 acid) were added to sediment samples in a flask of (100 ml), using Whatman paper (No. 42) to eliminate undesirable particulates (e.g., wood pieces, plants, and other particles), and storing the samples at (4 °C) further investigation. The samples were heated around 20 minutes to get (1ml) samples size, the one ml samples were mixed with (24 ml) of double water in (25 ml) flask size. Finally, the samples were ready for analysis.

### 2.3. Instruments

United States (US) Phoenix 986 atomic absorption spectrophotometers (AAS) (GBC- company) have been employed in the analysis of (HMS), sensitive balance (Mettler-Toledo- company), nitric and hydro-chloric acids (BDH - company) were used. Standard solutions of Ni, Cd, Cr, Fe, Co, Zn, Pb, and Cu solutions with the purity of (99.99%) (BDH - company), (ARC GIS.V 10.33) was applied to show maps.

### 2.4. Evaluation of heavy metal pollution

The lake sediments metals contamination is evaluated with (I-geo), (CF), (CD) and (PLI).

Geo-accumulation index (I-geo)

The next Müller equation computed the index of geo-accumulation (Rabee et al., 2011).

$$\mathrm{I-geo} = \log 2\left(\frac{\mathrm{C_n}}{1.5\times \mathrm{B_n}}\right) \tag{1}$$

Were,

Cn = the (HMs) level measured in the lake sediments.

Bn = Average shale geochemical value of element n world surface rock average given by Salah et al. (2012).

Factor 1.5 is applied to potentially modify the background values because of lithological variances in seven classes; I-geo was classified as shown in Table 1. by Kassim et al. (1991).

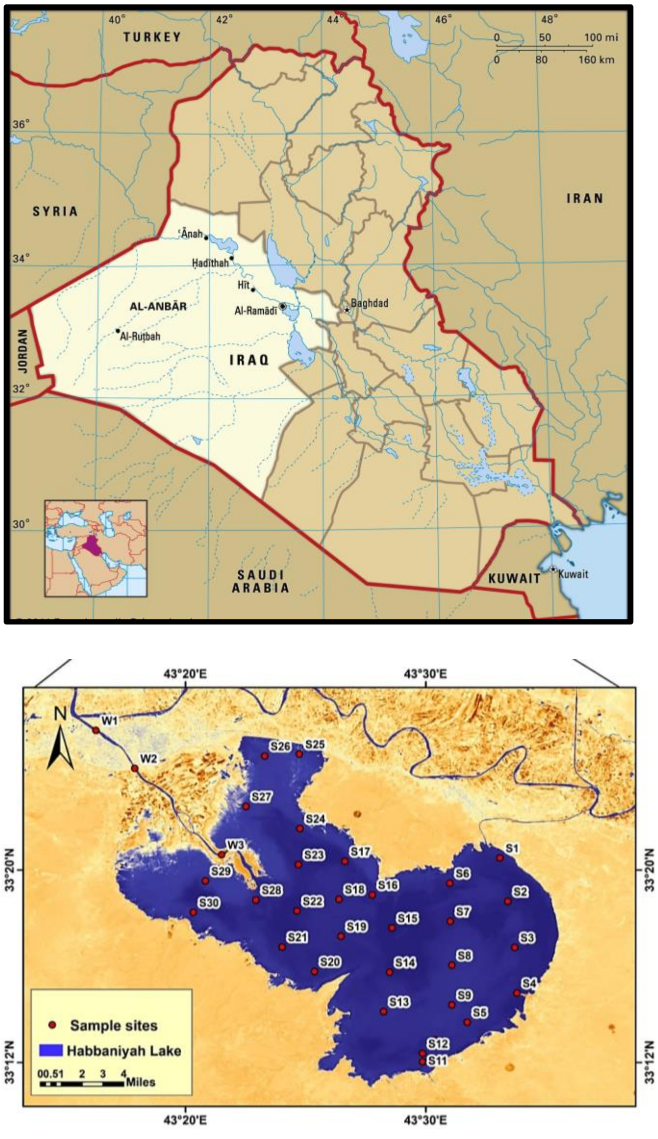

Figure 1. Study area.

Table 1. Geo accumulation index description.

| I-geo | classes |
|---|---|
| I-geo ≤ 0 (grade 0) | Unpolluted |
| 0< I-geo ≤1 (grade 1) | Slightly polluted |
| 1 < I-geo ≤ 2 (grade 2) | Moderately polluted |
| 2< I-geo ≤3 (grade 3) | Moderately severely polluted |
| 3< I-geo ≤4 (grade 4) | Severely polluted |
| 4< I-geo ≤5 (grade 5) | Severely extremely polluted |
| I-geo > 5 (grade 6) | Extremely polluted |

### 2.5. Contamination factor (CF)

The Contamination level by heavy metals of sediment is calculated by contamination factor (CF) (Salah et al., 2012):

$$\mathrm{CF} = \left(\frac{\mathrm{C\ (element\ )}}{\mathrm{C\ (background)}}\right) \tag{2}$$

$$\mathrm{CD} = \sum_{i=1}^{i=n} \mathrm{CF} \tag{3}$$

C (element) is polluted bed sediment element concentration

C (background) is background value of that element in bed sediments (world surface rock average given by Maina et al. (2019).

Table 2. shows CF values to describe the degree of pollution (Salah et al., 2012). Table 3. presents CD values to describe the degree of pollution.

Table 2. Factor of contamination (CF).

| Contamination Factor | Contamination Level |
|---|---|
| CF < 1 | Low pollution |
| 1 ≤ CF < 3 | Slightly pollution |
| 3 ≤ CF < 6 | Significant pollution |
| CF > 6 | Extremely big pollution |

Table 3. CD values to describe the degree of pollution description.

| CD | Degree |
|---|---|
| CD < 6 | Low contamination degree |
| 6 ≤ CD < 12 | Moderate polluted degree |
| 12 ≤ CD < 24 | Significant polluted degree |
| CD ≥ 24 | High polluted degree* |

*: (A high degree of contamination suggests anthropogenic pollution).

### 2.6. The Pollution load index (PLI)

The PLI of the location is determined from the n-root of CFs for all the toxic metals collected. The PLI from any location is obtained (Öztürk et al., 2009). General equation proposed by Salem et al. (2014) pollution load index follows: (PLI) as

$$\mathrm{PLI} = \sqrt[n]{(\mathrm{CF1} \times \mathrm{CF2} \times \mathrm{CF3} \times \ldots\ldots \mathrm{CFn})} \tag{4}$$

Were,

CF = factor of pollution, n = elements number The PLI of > 1 is contaminated, while <1 does not indicate any contamination.

## 3. Results

### 3.1. Concentration of heavy metal

Table 4. Shows the results of the (HMs) concentrations of sediments collected from the HL. (HMs) quantities found in the research area of (HL) are shown in Table 4. The mean concentrations of (HMs) were followed the order: Fe> Pb> Cr> Ni> Co> Zn> Cu> Cd. Figures (2, 3, 4, 5, 6, 7, 8 and 9) show the mean spatial concentration of (Pb), (Fe), (Cr), (Co), (Ni), (Zn), (Cu) and (Cd) respectively. Table 5. shows the results of heavy metals analytical value (mg/kg) compared with the guide.

### 3.2. Pollution loaf index (PLI)

Table 4. Presents the values of (PLI) and (I-geo) of (HMs) in sediments. (Fig 10) Shows the PLI values by heavy metals in all sities of HL sediments.

### 3.2. Pollution load index (PLI)

Table 4. Presents the values of (PLI) and (I-geo) of (HMs) in sediments. (Fig 10) Shows the PLI values by heavy metals in all sites of HL sediments.

### 3.3. Geo-accumulation index (I-geo)

The sediments contamination level was estimated by use the geo-accumulation index (I-geo). I-geo values presented (Fig 11) and in (Table 4).

### 3.4. Contamination factor (CF) and contamination degree (CD)

The predicted *contamination factors* ($\mathrm{CF_s}$) and CD for different heavy metals in HL sediments displayed in (Fig. 12 and 13) and listed Table 6.

Table 4. Concentration of (HMS) (mg/ kg), (I-geo) and (PLI) in the sediments of HL during period time.

| Station | Pb | Fe | Cr | Co | Ni | Zn | Cu | Cd | I-geo | PLI |
|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 54.816 | 2158.02 | 31.493 | 12.359 | 19.810 | 12.156 | 4.791 | 1.974 | -12.660 | 0.505 |
| S2 | 46.859 | 1552.57 | 17.618 | 14.443 | 16.809 | 9.688 | 3.870 | 1.376 | -15.155 | 0.404 |
| S3 | 39.090 | 1180.99 | 10.087 | 9.193 | 13.725 | 4.555 | 2.838 | 0.241 | -21.532 | 0.231 |
| S4 | 35.988 | 1901.73 | 33.214 | 11.686 | 19.184 | 8.721 | 4.254 | 0.600 | -15.613 | 0.388 |
| S5 | 59.116 | 2172.91 | 30.947 | 11.599 | 19.771 | 10.191 | 5.582 | 3.254 | -11.727 | 0.543 |
| S6 | 58.385 | 1828.57 | 27.060 | 11.645 | 18.406 | 9.030 | 4.368 | 2.157 | -13.370 | 0.471 |
| S7 | 53.592 | 2316.35 | 35.035 | 10.254 | 19.141 | 9.899 | 4.946 | 4.150 | -11.632 | 0.547 |
| S8 | 51.160 | 2234.76 | 25.912 | 9.545 | 18.666 | 13.258 | 5.013 | 3.772 | -12.120 | 0.525 |
| S9 | 45.731 | 2145.03 | 24.608 | 9.518 | 17.368 | 10.401 | 4.974 | 3.688 | -12.889 | 0.491 |
| S10 | 45.256 | 2089.34 | 25.091 | 11.100 | 18.411 | 10.435 | 4.914 | 3.637 | -12.632 | 0.501 |
| S11 | 51.952 | 2377.01 | 28.191 | 12.175 | 20.044 | 11.351 | 5.014 | 4.295 | -11.444 | 0.557 |
| S12 | 48.599 | 2331.71 | 26.499 | 12.418 | 19.246 | 10.830 | 5.188 | 4.115 | -11.793 | 0.540 |
| S13 | 44.348 | 2002.86 | 24.011 | 10.840 | 17.630 | 9.953 | 5.008 | 3.756 | -12.910 | 0.489 |
| S14 | 44.623 | 2040.88 | 23.906 | 11.470 | 17.032 | 8.914 | 4.404 | 3.721 | -13.187 | 0.478 |
| S15 | 45.445 | 2215.73 | 24.630 | 11.683 | 18.463 | 9.147 | 4.293 | 3.734 | -12.861 | 0.491 |
| S16 | 51.854 | 2463.46 | 28.160 | 11.815 | 19.217 | 10.522 | 4.732 | 4.305 | -11.706 | 0.544 |
| S17 | 47.869 | 2432.67 | 25.768 | 10.657 | 17.645 | 9.611 | 4.528 | 4.150 | -12.482 | 0.508 |
| S18 | 44.521 | 2162.44 | 23.581 | 10.042 | 15.988 | 8.949 | 3.312 | 3.880 | -13.795 | 0.454 |
| S19 | 55.659 | 2713.49 | 28.671 | 13.559 | 19.111 | 10.886 | 4.574 | 4.510 | -11.234 | 0.567 |
| S20 | 41.033 | 1785.40 | 21.451 | 10.361 | 14.198 | 8.723 | 3.293 | 3.293 | -14.706 | 0.420 |
| S21 | 51.985 | 2606.91 | 28.072 | 11.219 | 19.882 | 12.022 | 3.526 | 4.513 | -11.840 | 0.539 |
| S22 | 48.720 | 2280.45 | 26.242 | 10.235 | 17.409 | 10.745 | 4.330 | 4.254 | -12.478 | 0.509 |
| S23 | 44.535 | 2167.10 | 24.901 | 9.220 | 17.327 | 8.472 | 4.360 | 3.89 | -13.345 | 0.472 |
| S24 | 48.698 | 2275.86 | 25.914 | 10.242 | 19.069 | 9.255 | 4.311 | 4.158 | -12.592 | 0.504 |
| S25 | 44.941 | 2061.20 | 24.267 | 9.061 | 18.442 | 8.371 | 4.631 | 4.041 | -13.250 | 0.474 |
| S26 | 43.792 | 2121.99 | 23.349 | 8.679 | 17.773 | 8.191 | 4.657 | 3.884 | -13.545 | 0.463 |
| S27 | 40.309 | 1785.63 | 22.068 | 8.310 | 15.806 | 7.507 | 4.871 | 3.498 | -14.435 | 0.430 |
| S28 | 45.964 | 2247.24 | 21.979 | 9.227 | 18.521 | 8.415 | 5.049 | 3.997 | -13.161 | 0.480 |
| S29 | 46.368 | 1934.98 | 24.472 | 9.810 | 18.452 | 8.375 | 4.979 | 3.631 | -13.274 | 0.476 |
| S30 | 43.848 | 2163.44 | 22.456 | 10.518 | 17.515 | 7.737 | 4.577 | 3.230 | -13.699 | 0.457 |
| W1 | 48.150 | 2418.07 | 24.954 | 11.118 | 19.969 | 10.434 | 4.420 | 4.627 | -12.046 | 0.528 |
| W2 | 43.941 | 2384.18 | 22.735 | 7.470 | 16.677 | 9.409 | 4.929 | 4.121 | -13.325 | 0.473 |
| W3 | 45.535 | 2494.90 | 23.865 | 8.584 | 17.361 | 9.880 | 4.972 | 4.345 | -12.717 | 0.498 |
| Min. | 35.988 | 1180.99 | 10.087 | 7.470 | 13.725 | 4.555 | 2.838 | 0.241 | -21.532 | 0.231 |
| Max. | 59.116 | 2713.49 | 35.035 | 14.443 | 20.044 | 13.258 | 5.582 | 4.627 | -11.234 | 0.567 |
| Avg. | 47.354 | 2152.97 | 25.188 | 10.608 | 18.002 | 9.577 | 4.531 | 3.539 | -13.187 | 0.484 |
| SD | 5.262 | 302.891 | 4.422 | 1.527 | 1.537 | 1.590 | 0.598 | 1.075 | - | - |
| Background value | 16 | 35900 | 71 | 13 | 49 | 127 | 32 | 0.2 | | |

Table 5. Comparison the guidelines with results of heavy metals analytical value (mg/kg) (Salah et al., 2012).

| HMs | Avg.± SD | WHO (SQG*) | USEPA (SQG**) | CCME (SQG***) |
|---|---|---|---|---|
| Co | 10.60± 1.52 | - | - | - |
| Fe | 2152.97 ± 302.89 | - | 30 | - |
| Pb | 47.35± 5.26 | - | 40 | 35 |
| Cr | 25.18± 4.42 | 25 | 25 | 37.3 |
| Ni | 18.00±1.53 | 20 | 16 | - |
| Zn | 9.57±1.59 | 123 | 110 | 123 |
| Cd | 3.53±1.07 | 6 | 0.6 | 0.6 |
| Cu | 4.53±0.59 | 25 | 16 | 35.7 |

*: World Health Organization (WHO) [2004]; **: United State Environmental Protection Agency (USEPA) [1999].
***: Canadian Council of Minister of the Environment (CCME) [1999]; SQG: sediments quality guidelines.

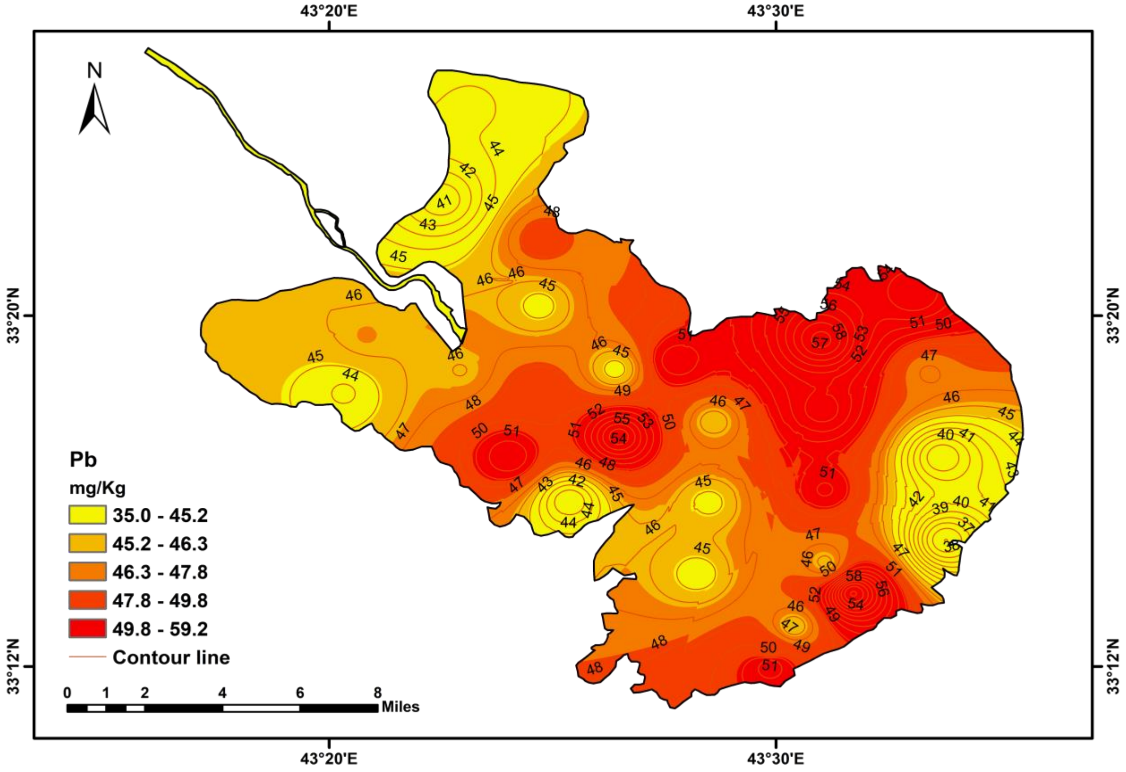

Figure 2. Average spatial concentration of (Pb).

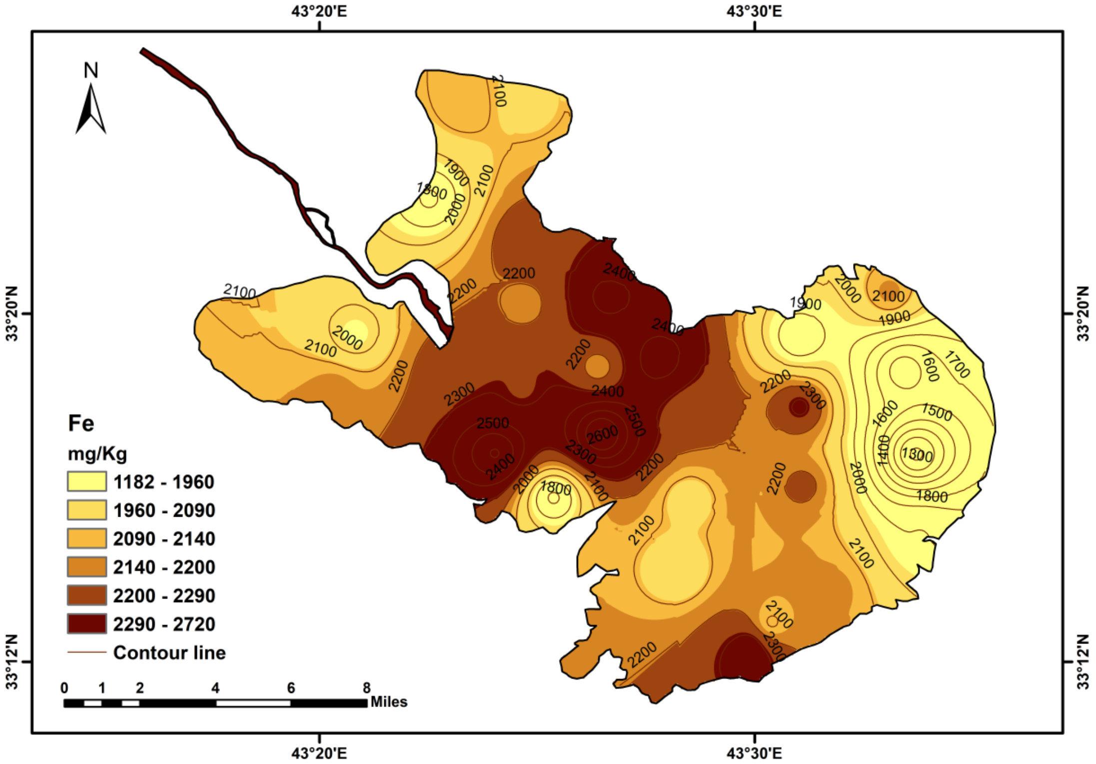

Figure 3. Average spatial concentration of (Fe).

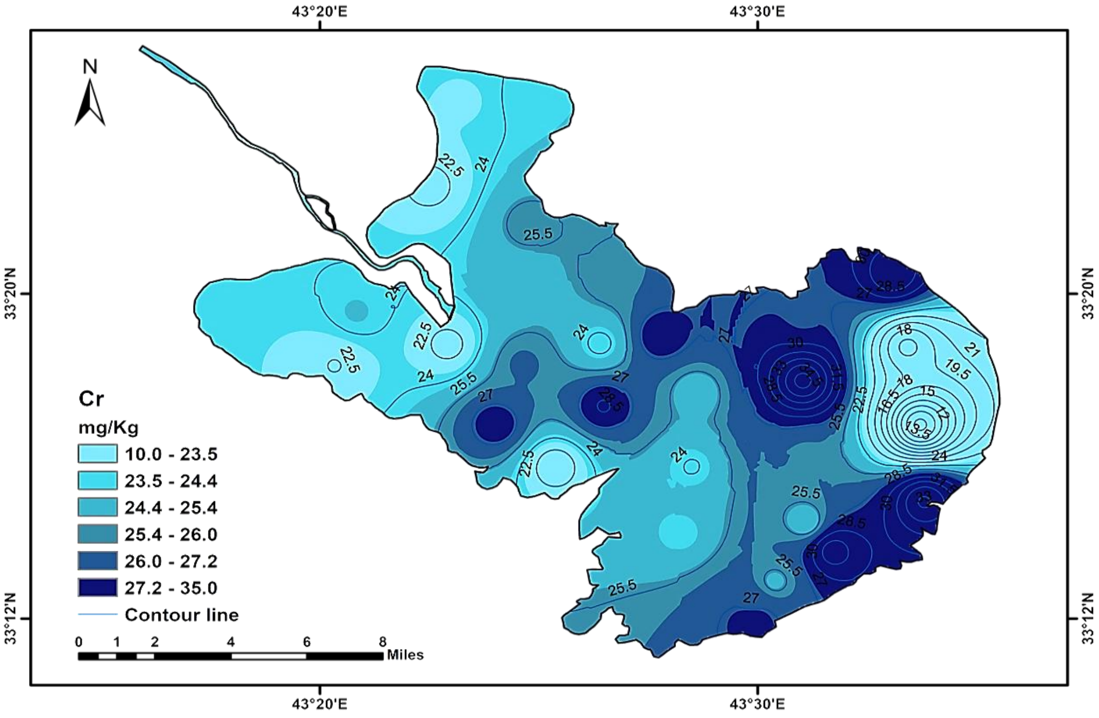

Figure 4. Average spatial concentration of (Cr).

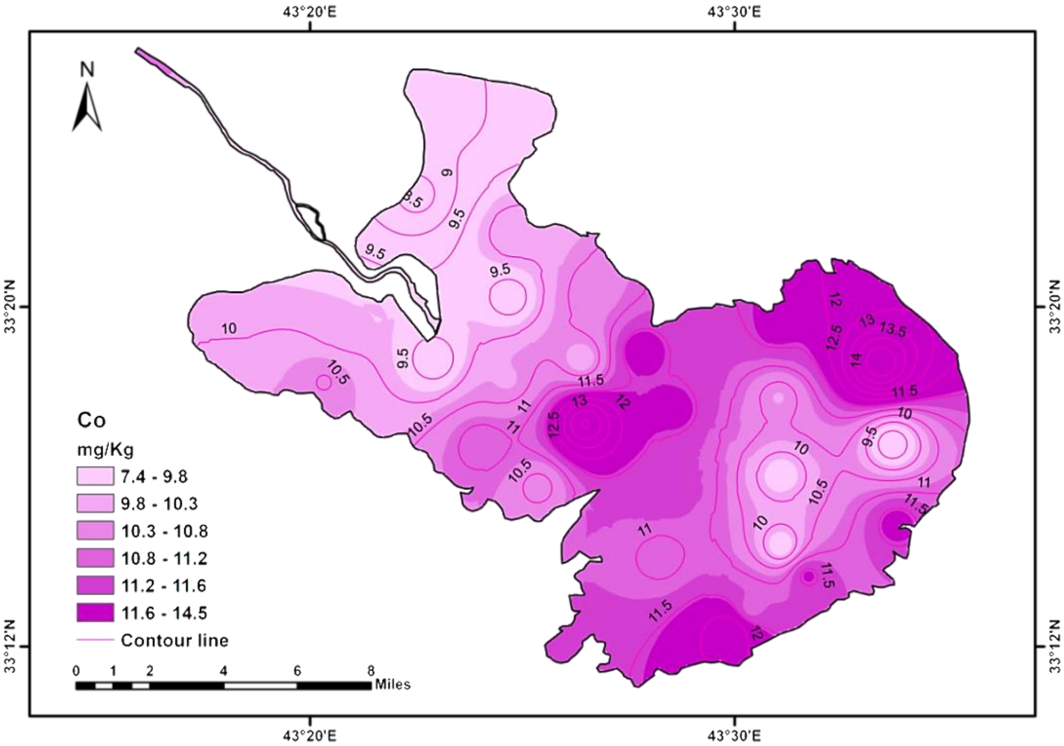

Figure 5. Average spatial concentration of (Co).

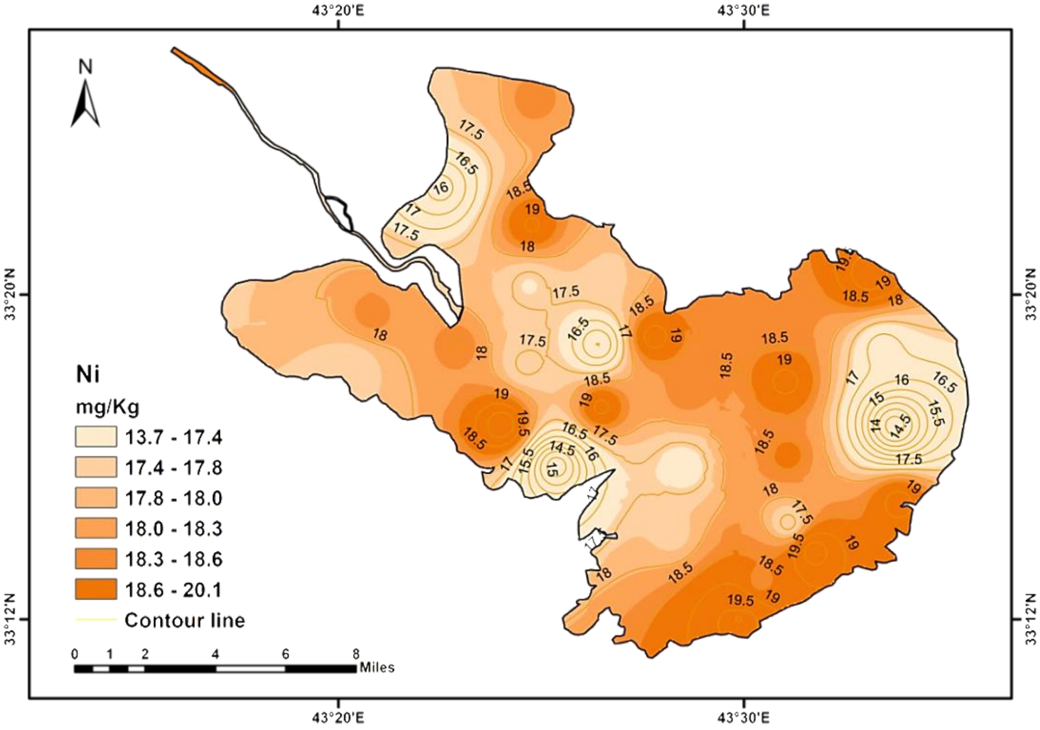

Figure 6. Average spatial concentration of (Ni).

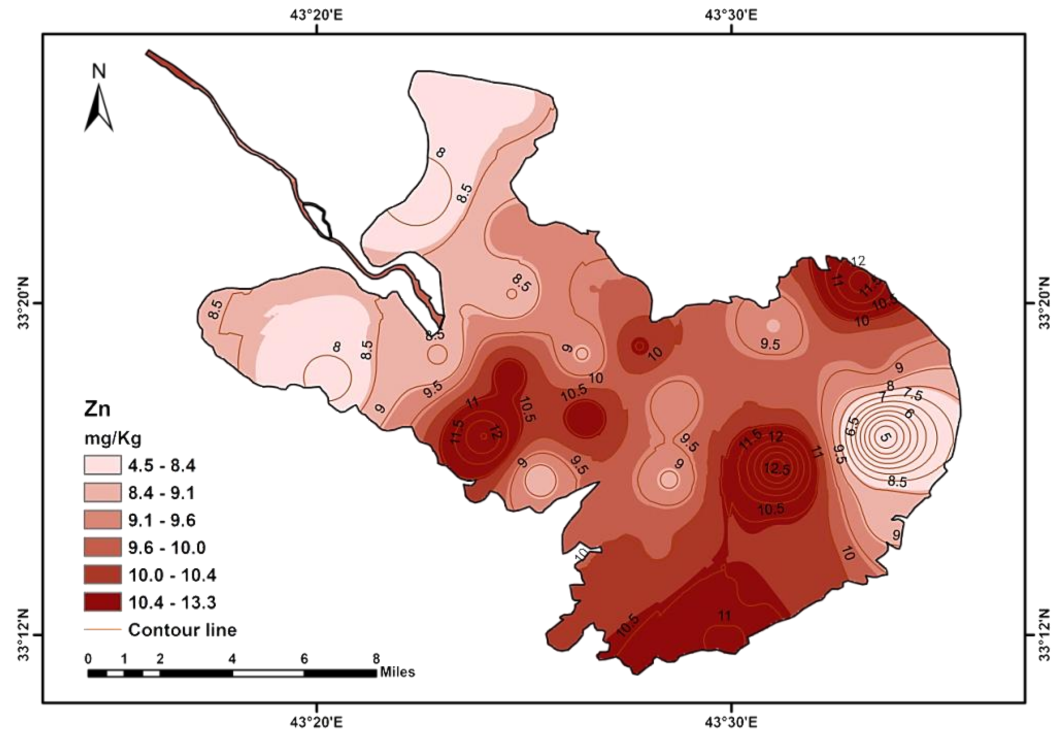

Figure 7. Average spatial concentration of (Zn).

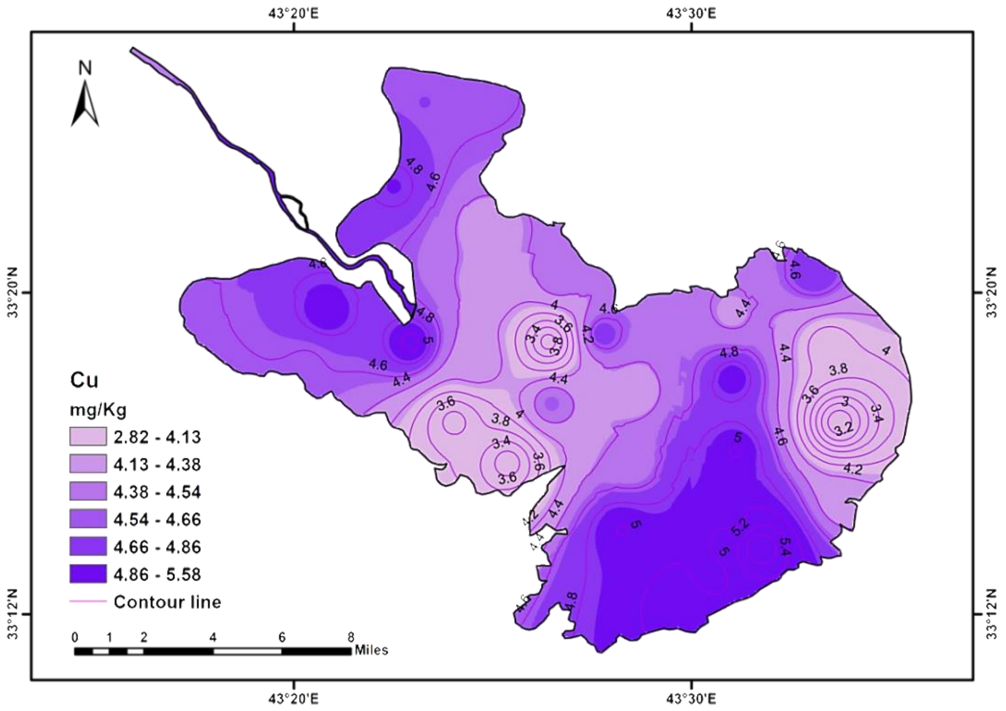

Figure 8. Average spatial concentration of (Cu).

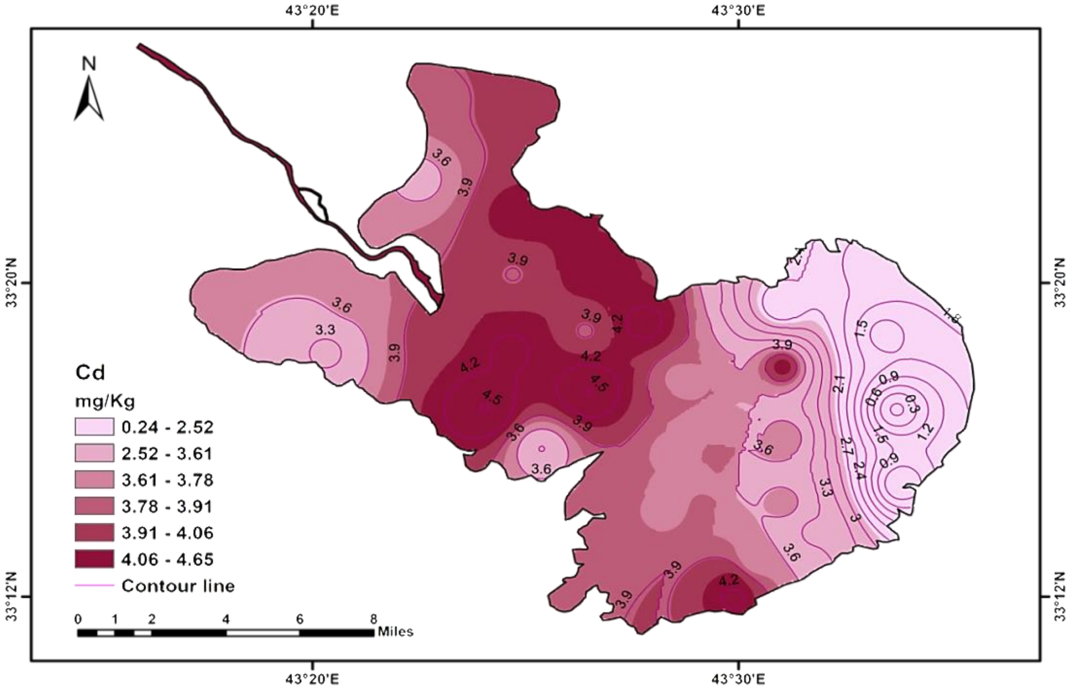

Figure 9. Average spatial concentration of (Cd).

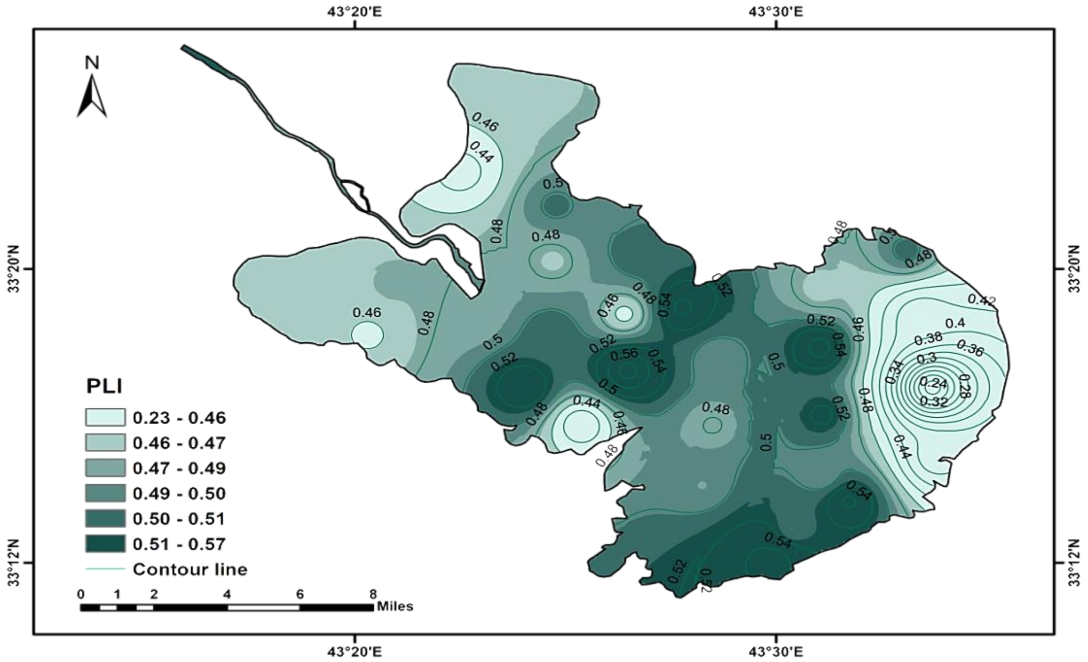

Figure 10. (PLI) of the sediments.

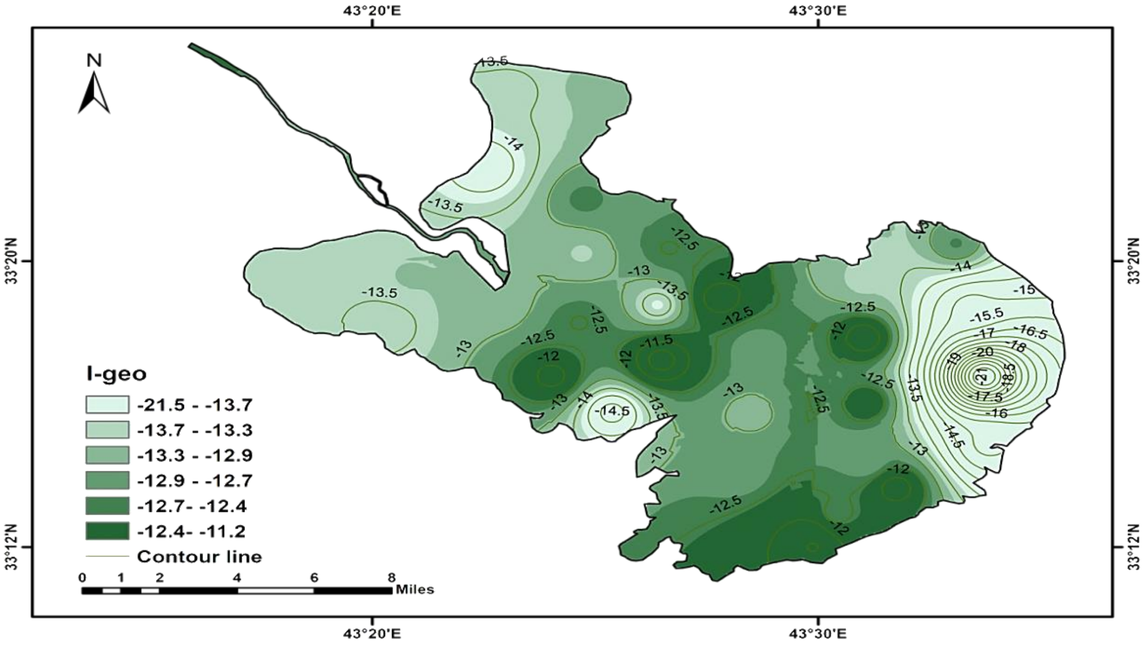

Figure 11. (I-geo) of the sediments.

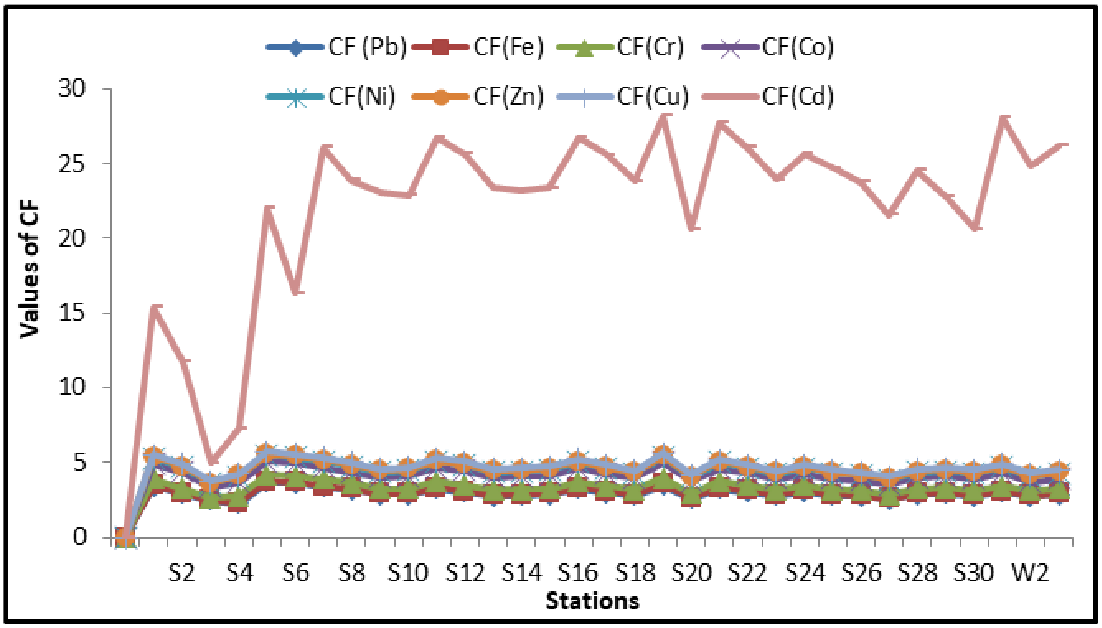

Figure 12. Contamination factor (CF).

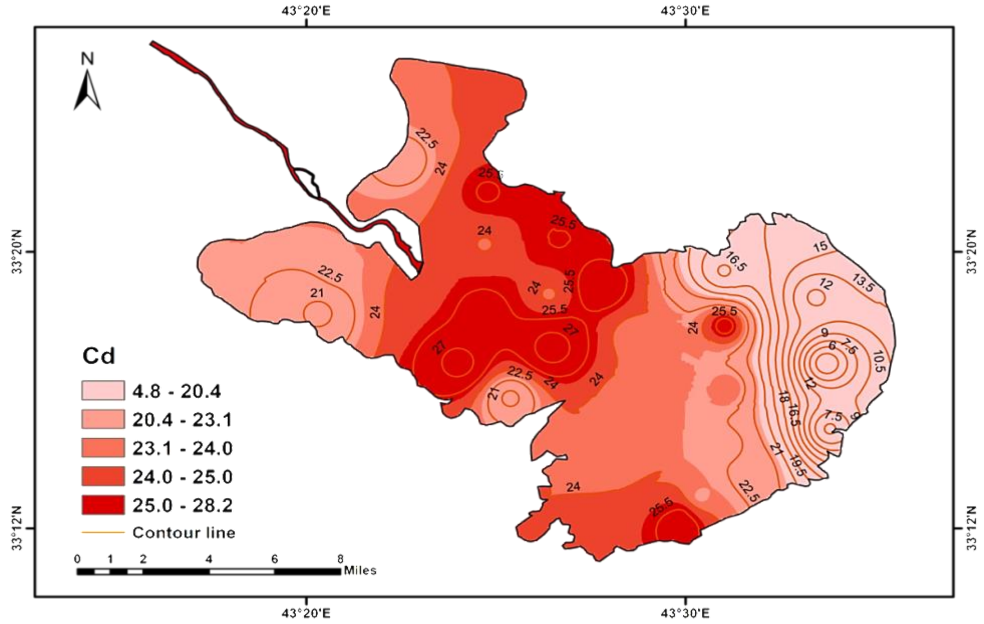

Figure 13. Contamination degree (CD).

Table 6. (CF) and (CD) in the sediment of HL.

| Station | CF (Pb) | CF(Fe) | CF(Cr) | CF(Co) | CF(Ni) | CF(Zn) | CF(Cu) | CF(Cd) | CD |
|---|---|---|---|---|---|---|---|---|---|
| S1 | 3.426 | 0.060 | 0.443 | 0.950 | 0.404 | 0.095 | 0.149 | 9.870 | 15.4 |
| S2 | 2.928 | 0.043 | 0.248 | 1.111 | 0.343 | 0.076 | 0.120 | 6.882 | 11.75 |
| S3 | 2.443 | 0.032 | 0.142 | 0.707 | 0.280 | 0.035 | 0.088 | 1.208 | 4.93 |
| S4 | 2.249 | 0.052 | 0.467 | 0.898 | 0.391 | 0.068 | 0.132 | 3.002 | 7.26 |
| S5 | 3.694 | 0.060 | 0.435 | 0.892 | 0.403 | 0.080 | 0.174 | 16.271 | 22.01 |
| S6 | 3.649 | 0.050 | 0.381 | 0.895 | 0.375 | 0.071 | 0.136 | 10.788 | 16.34 |
| S7 | 3.349 | 0.064 | 0.493 | 0.788 | 0.390 | 0.077 | 0.154 | 20.751 | 26.07 |
| S8 | 3.197 | 0.062 | 0.364 | 0.734 | 0.380 | 0.104 | 0.156 | 18.863 | 23.86 |
| S9 | 2.858 | 0.059 | 0.346 | 0.732 | 0.354 | 0.081 | 0.155 | 18.442 | 23.03 |
| S10 | 2.828 | 0.058 | 0.353 | 0.853 | 0.375 | 0.082 | 0.153 | 18.185 | 22.89 |
| S11 | 3.247 | 0.066 | 0.397 | 0.936 | 0.409 | 0.089 | 0.156 | 21.475 | 26.77 |
| S12 | 3.037 | 0.064 | 0.373 | 0.955 | 0.392 | 0.085 | 0.162 | 20.576 | 25.64 |
| S13 | 2.771 | 0.055 | 0.338 | 0.833 | 0.359 | 0.078 | 0.156 | 18.781 | 23.37 |
| S14 | 2.788 | 0.056 | 0.336 | 0.882 | 0.347 | 0.070 | 0.137 | 18.608 | 23.22 |
| S15 | 2.840 | 0.061 | 0.346 | 0.898 | 0.376 | 0.0720 | 0.134 | 18.671 | 23.40 |
| S16 | 3.240 | 0.068 | 0.396 | 0.908 | 0.392 | 0.082 | 0.147 | 21.527 | 26.76 |
| S17 | 2.991 | 0.067 | 0.362 | 0.819 | 0.360 | 0.075 | 0.141 | 20.752 | 25.57 |
| S18 | 2.782 | 0.060 | 0.332 | 0.772 | 0.326 | 0.070 | 0.103 | 19.403 | 23.85 |
| S19 | 3.478 | 0.075 | 0.403 | 1.043 | 0.390 | 0.085 | 0.142 | 22.553 | 28.17 |
| S20 | 2.564 | 0.049 | 0.302 | 0.797 | 0.289 | 0.068 | 0.102 | 16.469 | 20.64 |
| S21 | 3.249 | 0.072 | 0.395 | 0.863 | 0.405 | 0.094 | 0.110 | 22.568 | 27.75 |
| S22 | 3.045 | 0.063 | 0.369 | 0.787 | 0.355 | 0.084 | 0.135 | 21.272 | 26.11 |
| S23 | 2.783 | 0.060 | 0.350 | 0.709 | 0.353 | 0.066 | 0.136 | 19.45 | 23.91 |
| S24 | 3.043 | 0.063 | 0.364 | 0.787 | 0.389 | 0.072 | 0.134 | 20.793 | 25.65 |
| S25 | 2.808 | 0.057 | 0.341 | 0.697 | 0.376 | 0.065 | 0.144 | 20.206 | 24.69 |
| S26 | 2.737 | 0.059 | 0.328 | 0.667 | 0.362 | 0.064 | 0.145 | 19.423 | 23.78 |
| S27 | 2.519 | 0.049 | 0.310 | 0.639 | 0.322 | 0.059 | 0.152 | 17.491 | 21.54 |
| S28 | 2.872 | 0.062 | 0.309 | 0.709 | 0.377 | 0.066 | 0.157 | 19.985 | 24.54 |
| S29 | 2.898 | 0.053 | 0.344 | 0.754 | 0.376 | 0.065 | 0.155 | 18.156 | 22.80 |
| S30 | 2.740 | 0.060 | 0.316 | 0.809 | 0.357 | 0.060 | 0.143 | 16.151 | 20.63 |
| W1 | 3.009 | 0.067 | 0.351 | 0.855 | 0.407 | 0.082 | 0.138 | 23.137 | 28.04 |
| W2 | 2.746 | 0.066 | 0.320 | 0.574 | 0.340 | 0.074 | 0.154 | 20.606 | 24.88 |
| W3 | 2.845 | 0.069 | 0.336 | 0.660 | 0.354 | 0.077 | 0.155 | 21.727 | 26.22 |
| Min. | 2.249 | 0.032 | 0.142 | 0.574 | 0.280 | 0.035 | 0.088 | 1.208 | 4.93 |
| Max. | 3.694 | 0.075 | 0.493 | 1.111 | 0.409 | 0.104 | 0.174 | 23.137 | 28.17 |
| Avg. | 2.959 | 0.059 | 0.354 | 0.816 | 0.367 | 0.075 | 0.141 | 17.698 | 22.47 |

## 4. Assessment and discussion

### 4.1. Heavy metals concentration

Table 4. shows the results of (HMs) concentration in bed sediments of the HL. The mean concentrations of the (HMs) measured in the sediment were followed the order: Fe> Pb> Cr> Ni> Co> Zn> Cu> Cd. Figures (2, 3, 4, 5, 6, 7, 8 and 9) show the average Spatial concentration of (Pb), (Fe), (Cr), (Co), (Ni), (Zn), (Cu) and (Cd) respectively.

Table 5. shows the results of heavy metals analytical value (mg/kg) Compared with the guidelines.

Results showed that Pb ranged from 35.988 mg/kg to 59.116 mg/kg with a mean of 47.354 mg/kg above (USEPA) and (CCME) recommendation on sediments quality for marine life (Table 4). The high level of Pb was recorded at S5 (59.116 mg/kg), S1 (54.816 mg/kg), and S19 (55.659 mg/kg) might be due to agriculture waste and mud, high levels of fuel combustion lead in vehicles, also caused by the spillover of leaded petrol from fishing vessels and this may be related to increasing human activity. Higher amounts of Pb are typically seen in water bodies near highways and major towns due to significant gasoline consumption (Saeed & Shaker, 2008). Cd was varied from (0.241 mg/kg) at S3 to (4.627 mg/kg) at W1 with a mean of (3,539 mg/kg) above (USEPA) and (CCME) recommendation and with the limit of WHO (Table 4). Human activities like urban development, industrialization, and agricultural rushing can be ascribed to these elevated levels. Zn levels varied from 4.555 mg/kg to 13.258 mg/kg with mean (9.577 mg/kg) under the WHO, USEPA, and CCME standards. Cu levels ranged from (2.838 mg/kg) at S3 to (5.582 mg/kg) at S5 with mean (4.531 mg/kg) did not exceed the criteria of WHO, CCME, and USEPA. Cu concentrations were found to be high at locations in and around population centers. The result in Ni was 13.725 mg/kg to 20.044 mg/kg with the mean levels 18.002 mg/kg above the USEPA limit, attributable to agricultural and human activity. Co levels vary from (7.470 mg/kg) in W2 to (14.443 mg/kg) at S2 with an average of 10.608 mg/kg. The level of Cr was varied from (10.087 mg/kg) at S3 to (35.035 mg/kg) at S7 with mean value of 25.188 mg/kg with the limits of USEPA, WHO, and CCME guidelines of (USEPA), drinking and aquatic life limitations respectively (Table 4).

The highest value of Co can be due to the quantities of sewage, farm, and municipal wastewater pumped into the HL. The level of Fe varied from (1180.993 mg/kg) at S3 to (2713.491 mg/kg) at S19 with mean value (2152.971 mg/kg) above the limit of guidelines.

The average concentration of (Pb and Cd) was greater than the geochemical background level (Table 4). Based on USEPA guidelines, sediments from HL have been contaminated with (Cd, Ni, Pb and Fe) (Table 5).

Concentrations of (HMs) were varied spatially, The major significant spatial factors affecting the HMs distribution include, population, lake bank densities, beds hydrological conditions, landfilling by factories, and wastewater discharge. (Balasim et al., 2013).

### 4.2. Pollution indices

#### 4.2.1. Pollution load index (PLI)

Table 4. presents the values of (PLI) and (I-geo) of (HMs) in sediments. PLI values varied from (0.231) at S3 to (0.567) at S19, with (0.484) being the average. The values of PLI < 1 do not indicate any contamination by heavy metals in all sites of HL sediments (Fig 10).

#### 4.2.2. Geo-accumulation index (I-geo)

The sediment contamination level was assessed using the geo-accumulation index (I-geo). I-geo values ranged from (-21.532) at S3 to (-11.234) at S19 with a mean value of (-13.187), Based on (Kassim et al., , 1991) that classified (grade 0), HL is uncontaminated by (HMs) at all sites as shown in (Fig 11). This indicates that most (HMs) have an average concentration lower than the world average surface rock (Table 4).

#### 4.2.3. Contamination factor (CF) and contamination degree (CD)

Table 6. shows the predicted CF and CD for different heavy metals in HL sediments. CF magnitudes of Pb in sediments of HL varied from 2.249 to 3.694 with average value of 2.95 as shown in (Fig 12).

All sampling sites were classified moderate pollution by Pb except (S1, S5, S6, S7, S8, S11, S12, S16, S19, S21, S22, S24 and W1) were classified significant contamination by Pb. Generally, the sampling sites were moderate to significant pollution by Pb.

The (CF) magnitudes of Cd varied from 1.208 at S3 to 23.137 at W1, with an average of 17.698. All sampling stations have magnitudes of larger than 6 except S3 and S4 were less than 6. According to (Salah et al., 2012), all sampling stations were very high polluted by Cd except S3 and S4 have moderate pollution by Cd. The CF values of Co in HL vary from 0.574 at W2 to 1.111 at S2 with an average of 0.816. CF values of Co were less than 1 than classified low pollution by Co at all sample locations except S2 was more than 1 than that classified moderate pollution by Co.

The (CF) value of Fe was 0.032 at the S3 to 0.075 at S19 with an average value of 0.059. CF values for Cr ranged between 0.142 at S3 and 0.493 at S7 with an average value of 0.354. CF values for Zn ranged between 0.035 at S3 and 0.104at S8 with an average value of 0.141. CF values of Ni averaged between 0.280 at S3 and 0.409 at S11 with an average value of 0.075.

CF values for Cu ranged between 0.088 at S3 and 0.174 at S5 with an average value of 0.141. According to the (CF) the sediment of HL is low contaminated by (Fe, Ni, Zn, Cu, and Cr) as shown in (Fig 12). The Contamination Degree (CD) indicated that (S11, S12.S16, S17, S19, S21, S22, S24, W1, W2 and W3) sites recorded the highest value of pollution degree that classified very high contamination degree as shown in (Fig 13). The maximum value of (CD) was recorded in S19 (28.17) and the minimum value recorded in S3 (4.93) with a mean value (22.47). The Pollution degree indicated that the HL is significant pollution degree to high pollution of heavy metal contamination.

## 5. Conclusion

In this study, the Habbaniyah Lake's sediments were measured and some (HMS) such as (Cd, Pb, Cu, Zn, Cr, Fe, Ni and Co) were assessed spatiotemporally. In the period order, the average (HMs) concentration in sediment is following the order: Fe > Pb > Cr > Ni > Co > Zn > Cu > Cd. The HL contamination was assessed by measuring the (HMs) concentration in sediments based on (WHO, USEPA and CCME) guides. The (CF), (CD), (I-geo), and (PLI) Indices were calculated and compared with guidelines. The concentrations of Pb, Ni, Fe, and Cd exceeded the USEPA guideline. Cd is accountable for very high contamination, Pb is responsible for moderate pollution to significant contamination and (Fe, Ni, Zn, Co, Cu, and Cr) responsible for low pollution according to the contamination factor (CF). According to PLI, all sites indicate that the site quality is ideal or that there is no overall pollution. In this study, the geo-accumulation index was used to assess the accumulation of (HMS) environmental sediment quality.

Generally, for most heavy metals, I-geo indices were negative, meaning the (HMs) concentration in sediments of HL was lower than the average global surface rock and there was no heavy metals pollution on the HL. The Pollution degree indicated that the HL is significant pollution degree to high pollution of (HMs) contamination. (HMs) like Pb and Cd are found to be very high contamination and significantly contaminated in the sediments of the research region, which might be attributed to human and tourist activities, and sewage without treatment influencing the Lake's sediment quality.

High concentrations of heavy metals in sediments effect on the aquatic environment like microorganisms, plants and fishes, Plants are absorbing (HMs), Then aquatic species such as fishes beings feed on these plants thus leads to increase and accumulate the (HMs) concentrations in aquatic species. Accumulation of (HMs) in aquatic species through the chain food will increase the health and environmental risks on aquatic environment as well as human, This will lead to an increase in the number of fatal chronic diseases such as carcinogenic diseases, as well as other diseases such as hypertension, kidney failure, hemorrhagic gastritis and colitis. (World Health Organization [WHO], 2017).

The research faces some limitation because of Covid-19 pandemic curfew.

The researchers suggest the following:

1- Monitor the HMs and toxic chemicals concentration on fishes and plants of the HL to estimate their effects.

2- Preventing the wastewater discharge into the lake except after treating it and making sure that it complies with the guides.

3- High concentrations of heavy metals in sediments impose monitoring and surveying programs.

Monitor and assess the quality of supplied drinking water

## Conflict of interest

The authors declare that there is no conflict of interest to declare.

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## References

Mohd, S. E., Mohd, S. H., Shamsiah, A. R., Nazaratul, A. A. S., Wee, B. S., & Ezwiza, S. (2014). Ecological risk assessment of heavy metal in surface sediment collected from Tuanku Abdul Rahman National Park, Sabah.

Al-Fahdawi, A. A., Rabee, A. M., & Al-Hirmizy, S. M. (2015). Water quality monitoring of Al-Habbaniyah Lake using remote sensing and in situ measurements. *Environmental monitoring and assessment*, *187*, 1-11. https://doi.org/10.1007/s10661-015-4607-2

Alaoui, A. M., Choura, M., Maanan, M., Zourarah, B., Robin, M., Conceição, M. F., ... & Carruesco, C. (2010). Metal fluxes to the sediments of the Moulay Bousselham lagoon, Morocco. *Environmental Earth Sciences*, *61*, 275-286. https://doi.org/10.1007/s12665-009-0341-9

Andreas, V., Irvine, K., Jindal, R., Thongdara, R., Chatterji, N. N., & Sheng, W. B. (2019). Spatial patterns of heavy metals in the sediments of a municipal wastewater treatment pond system and receiving waterbody, Cha am, Thailand. *Journal of Water Management Modeling*, *27*(C465), C465.

Balasim, H. M., Al-Azzawi, M. N., & Rabee, A. M. (2013). Assessment of pollution with some heavy metals in water, sediments and Barbus xanthopterus fish of the Tigris River–Iraq. *Iraqi Journal of Science*, *54*(4), 813-822.

Benson, N. U., Anake, W. U., Essien, J. P., Enyong, P., & Olajire, A. A. (2017). Distribution and risk assessment of trace metals in Leptodius exarata, surface water and sediments from Douglas Creek in the Qua Iboe Estuary. *Journal of Taibah University for Science*, *11*(3), 434-449. https://doi.org/10.1016/j.jtusci.2016.08.004

Benzer, S., Gül, A., Gül, A., Arslan, H., Uzel, N., Gül, A., & Yılmaz, M. (2013). Concentrations of metals in water, sediment and tissues of Cyprinus carpio L., 1758 from Mogan Lake (Turkey). *Iranian Journal of Fisheries Sciences*, *12*(1), 44-55. https://doi.org/10.22092/ijfs.2018.114260

Basra, S., Iqbal, Z., ur-Rehman, K., Ur-Rehman, H., & Ejaz, M. (2014). Time Course Changes in pH, Electrical Conductivity and Heavy Metals (Pb, Cr) of Wastewater Using Moringa oleifera Lam. Seed and Alum, a Comparative Evaluation. *Journal of Applied Research and Technology*, *12*(3). https://doi.org/10.1016/S1665-6423(14)71635-9

Bhagat, S. K., Tung, T. M., & Yaseen, Z. M. (2020). Development of artificial intelligence for modeling wastewater heavy metal removal: State of the art, application assessment and possible future research. *Journal of Cleaner Production*, *250*, 119473. https://doi.org/10.1016/j.jclepro.2019.119473

Devanesan, E., Chandrasekaran, A., Sivakumar, S., Freny Joy, K. M., Najam, L. A., & Ravisankar, R. (2020). Magnetic susceptibility as proxy for heavy metal pollution detection in sediment. *Iranian Journal of Science and Technology, Transactions A: Science*, *44*(3), 875-888. https://doi.org/10.1007/s40995-020-00865-9

Devanesan, E., Gandhi, M. S., Selvapandiyan, M., Senthilkumar, G., & Ravisankar, R. (2017). Heavy metal and potential ecological risk assessment in sedimentscollected from Poombuhar to Karaikal Coast of Tamilnadu using Energy dispersive X-ray fluorescence (EDXRF) technique. *Beni-Suef University journal of basic and applied sciences*, *6*(3), 285-292. https://doi.org/10.1016/j.bjbas.2017.04.011

Elzwayie, A., El-Shafie, A., Yaseen, Z. M., Afan, H. A., & Allawi, M. F. (2017). RBFNN-based model for heavy metal prediction for different climatic and pollution conditions. *Neural Computing and Applications*, *28*, 1991-2003. https://doi.org/10.1007/s00521-015-2174-7

Ghalib, H. S., & Ramal, M. M. (2021). Spatial and temporal water quality evaluation of heavy metals of Habbaniyah Lake, Iraq. *International Journal of Design & Nature and Ecodynamics*, *16*(4), 467-475. https://doi.org/10.18280/ijdne.160414

Habeeb, M. A., Al-Bermani, A. K., & Salman, J. M. (2015). Environmental study of water quality and some heavy metals in water, sediment and aquatic macrophytas in lotic ecosystem, Iraq. *Mesopotamia Environmental Journal*, *1*(2), 66-84.

Harikumar, A. P. S., Prajitha, B. K., & Silpa, C. S. (2010). Laboratory Research in Biology Assessment of Heavy Metal Contamination in the Sediments of a River Draining Into a Ramsar Site in the Indian Sub. *Analysis I*, 157-169.

Ilie, M., Marinescu, F., Ghita, G., Deak, G. Y., Tanase, G. S., & Raischi, M. (2014). Assessment of heavy metal in water and sediments of the Danube River. *Journal of environmental protection and ecology*, *15*(3), 825-833.

Iqbal, J., & Shah, M. H. (2014). Occurrence, risk assessment, and source apportionment of heavy metals in surface sediments from Khanpur Lake, Pakistan. *Journal of Analytical Science and Technology*, *5*, 1-12. https://doi.org/10.1186/s40543-014-0028-z

Jiang, B. F., & Sun, W. L. (2014). Assessment of heavy metal pollution in sediments from Xiangjiang River (China) using sequential extraction and lead isotope analysis. *Journal of Central South University*, *21*(6), 2349-2358. https://doi.org/10.1007/s11771-014-2187-x

Kassim, T. I., Al-Saadi, H. A., Al-Lami, A. A., & Al-Jaberi, H. H. (1997). Heavy metals in water, suspended particles, sediments and aquatic plants of the upper region of Euphrates river, Iraq. *Journal of Environmental Science and Health*. Part A: *Environmental Science and Engineering and Toxicology*, *32*(9-10), 2497–2506. D https://doi.org/10.1080/10934529709376698

Maanan, M., Saddik, M., Maanan, M., Chaibi, M., Assobhei, O., & Zourarah, B. (2015). Environmental and ecological risk assessment of heavy metals in sediments of Nador lagoon, Morocco. *Ecological Indicators*, *48*, 616-626. https://doi.org/10.1016/j.ecolind.2014.09.034

Maina, C. W., Sang, J. K., Raude, J. M., & Mutua, B. M. (2019). Geochronological and spatial distribution of heavy metal contamination in sediment from Lake Naivasha, Kenya. *Journal of Radiation Research and Applied Sciences*, *12*(1), 37-54. https://doi.org/10.1080/16878507.2019.1593718

Mehrgan, M. S., Shekarabi, S. P. H., Hassanzadeh, B., & Alhosseini, S. H. S. (2019). Seasonal Variations of Cadmium and Lead Concentrations in Water, Sediments, and Tissues of Fish in Mellat Artificial Lake, Iran. *Journal of Human, Environment, and Health Promotion*, *5*(4),177-182. https://doi.org/10.29252/jhehp.5.4.6

Mohiuddin, K. M., Zakir, H. M., Otomo, K., Sharmin, S., & Shikazono, N. (2010). Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. *International Journal of Environmental Science & Technology*, *7*, 17-28. https://doi.org/10.1007/BF03326113

Nowrouzi, M., & Pourkhabbaz, A. (2014). Application of geoaccumulation index and enrichment factor for assessing metal contamination in the sediments of Hara Biosphere Reserve, Iran. *Chemical Speciation & Bioavailability*, *26*(2), 99-105. https://doi.org/10.3184/095422914X13951584546986

Öztürk, M., Özözen, G., Minareci, O., & Minareci, E. (2009). Determination of heavy metals in fish, water and sediments of Avsar Dam Lake in Turkey. *Journal of Environmental Health Science & Engineering*, *6*(2), 73-80. https://ijehse.tums.ac.ir/index.php/jehse/article/view/196

Rabee, A. M., Al-fatlawy, Y. F., & Abd, A. N. (2011). Using Pollution Load Index ( PLI ) and Geoaccumulation Index (I-Geo) for the Assessment of Heavy Metals Pollution in Tigris River Sediment in Baghdad Region. *Journal of Al-Nahrain University, 14*(4), 108–114.

Saeed, S. M., & Shaker, I. M. (2008). Assessment of heavy metals pollution in water and sediments and their effect on Oreochromis niloticus in the northern delta lakes, Egypt. In *8th international symposium on Tilapia in Aquaculture* (Vol. 2008, pp. 475-490). Central Laboratory for Aquaculture Research, Agricultural Research Center. Limnology Department.

Salah, E. A., AbdulGhafoor, K. F., & Abdalwahab, E. M. (2014). Assessment of pollution level of Habbaniya Lake, Iraq, using organic pollution indicators. *International Journal of Lakes and Rivers*, *7*(1), 25-36. https://www.researchgate.net/publication/339003683

Salah, E. A. M., Zaidan, T. A., & Al-Rawi, A. S. (2012). Assessment of heavy metals pollution in the sediments of Euphrates River, Iraq. *Journal of Water Resource and Protection*, *4*(12), 1009. http://dx.doi.org/10.4236/jwarp.2012.412117

Salem, D. M. A., Khaled, A., El Nemr, A., & El-Sikaily, A. (2014). Comprehensive risk assessment of heavy metals in surface sediments along the Egyptian Red Sea coast. *The Egyptian Journal of Aquatic Research*, *40*(4), 349-362. https://doi.org/10.1016/j.ejar.2014.11.004

Seshan, B. R. R., Natesan, U., & Deepthi, K. (2010). Geochemical and statistical approach for evaluation of heavy metal pollution in core sediments in southeast coast of India. *International journal of environmental science & technology*, *7*, 291-306. https://doi.org/10.1007/BF03326139

Shanbehzadeh, S., Vahid Dastjerdi, M., Hassanzadeh, A., & Kiyanizadeh, T. (2014). Heavy metals in water and sediment: a case study of Tembi River. *Journal of environmental and public health*, *2014*. https://doi.org/10.1155/2014/858720

Singovszka, E., Balintova, M., Demcak, S., & Pavlikova, P. (2017). Metal pollution indices of bottom sediment and surface water affected by acid mine drainage. *Metals*, *7*(8), 284. https://doi.org/10.3390/met7080284

World Health Organization. (2017). WHO Library Cataloguing-in-Publication Data Geneva. Guidelines for Drinking- Water Quality: Fourth Edition Incorporating First Addendum. WHO Library Cataloguing-in-Publication Data. Available from: https://apps.who.int/iris/bitstream/handle/10665/254637/9789241549950-eng.pdf?sequence=1

Xu, J., Chen, Y., Zheng, L., Liu, B., Liu, J., & Wang, X. (2018). Assessment of heavy metal pollution in the sediment of the main tributaries of Dongting Lake, China. *Water*, *10*(8), 1060. https://doi.org/10.3390/w10081060

Yi, L., Gao, B., Liu, H., Zhang, Y., Du, C., & Li, Y. (2020). Characteristics and assessment of toxic metal contamination in surface water and sediments near a uranium mining area. *International Journal of Environmental Research and Public Health*, *17*(2), 548. https://doi.org/10.3390/ijerph17020548

Yunus, K., Zuraidah, M. A., & John, A. (2020). A review on the accumulation of heavy metals in coastal sediment of Peninsular Malaysia. *Ecofeminism and Climate Change*, *1*(1), 21-35. https://doi.org/10.1108/EFCC-03-2020-0003

Zourarah, B., Maanan, M., Robin, M., & Carruesco, C. (2009). Sedimentary records of anthropogenic contribution to heavy metal content in Oum Er Bia estuary (Morocco). *Environmental Chemistry Letters*, *7*, 67-78. https://doi.org/10.1007/s10311-008-0138-1