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Assessment of the Heavy Metal Pollution in the Surface Sediments along Upstream at Wadi Al-Arab, Jordan

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Abstract
Twenty stream sediment samples collected from Wadi Al-Arab study area. These samples extracted and analyzed by Atomic Absorption Spectrometer (AAS) to determine their heavy metal for Cu, Zn, Cd, Mn, Fe and Pb concentrations. Calciometry method used to identify the CO_3^{-2} content and loss on ignition (L.O.I) at 550 °C used to determine the total organic matter (TOM). The results of the analyses of Wadi Al Arab sediments showed that concentrations of Mn, Cu, Pb, and Fe are safe and these elements are practically unchanged by anthropogenic influences, while the concentration of Zn and Cd exceeded the average shale value. The elevated concentration of Cd and Zn can be due to anthropogenic sources, including fertilizers and pesticides used in agricultural activities, effluent of the treatment plant, and natural weathering of surrounding geological formations. The Pollution Load Index (PLI) analysis indicated that Wadi Al Arab is facing probable environmental pollution especially with dangerous heavy metals (Zn and Cd) which result from increased rate of non-treated wastewater, which discharged to Wadi Al Arab stream. The results of Enrichment Factor (EF) showed high concentrations of Zn and Cd in the study area; these high concentrations in the study area derived from anthropogenic sources including; fertilizers and pesticides used in agricultural activities and the effluent of the close treatment plant. In addition, natural weathering of the surrounding rock formations considered as an additional source of heavy metals to the sediments.
Keywords: Heavy metal, Pollution, Assessment, Sediments, Wadi Al-Arab, Jordan

1. Introduction

Heavy metal accumulations in aquatic environments are of great importance on a worldwide scale due to their toxicity to both; ecosystem and humans. Metals such as Cu and Zn generally viewed as vital trace metals due to their valuable role in metabolic activities in organisms. Though, metals like Cd, Pb, Ni and Hg show life-threatening toxicity even at trace levels (**Merian, 1991**). The sediments known to be an important sink of heavy metals in aquatic systems, as well as, a possible source, which may directly affect overlying water. Heavy metals are not fixed permanently in sediment and may be recycled through biological and chemical agents **(Zoumis et al. 2001)**. Incidences of metals in stream sediment can be times adduced to geo-genic or anthropogenic activities of man in such an environment. Many industrial processes concentrate metals like copper, cadmium, lead and zinc (**Courchesne et al. 2005**). These metals may enter the aquatic environment through natural source; involving weathering of minerals and soil or from anthropogenic sources **(Merian, 1991; Komarek and Zeman, 2004)**. Anthropogenic contributions are mainly from domestic sewage, industrial effluent, traffic emissions or from mining and refining operations (**Kabala and Singh, 2001**).

Heavy metals settled in aquatic systems can be restrained within the stream sediments by main processes such as adsorption, flocculation and co-precipitation. Thus, sediments in aquatic environments act as a pool that can keep metals or release metals to the water column by numerous processes of remobilization **(Caccia et al., 2003; Pekey, 2006; March et al. 2006**).

Heavy metals may accumulate in the sediments by complex adsorption mechanisms whether physical or chemical depending on the nature of sediment matrix and properties of the adsorbed compounds (**Maher and Aislabie, 1992; Leivouri, 1998; Ankley et al. 1992**). Some processes lead to association of heavy metals with solid phases, such as; direct absorption by fine grained inorganic particles of clays; adsorption of hydrous ferric and manganese oxides which may sequentially be associated with clays; adsorption on or complication with natural organic substances, which may also be associated with inorganic particles, and direct precipitation as new solid phases (**Gibbs, 1973**).

Several studies have confirmed that the concentrations of metals in sediments can be sensitive indicators of contaminants in aquatic systems **(Bellucci et al. 2002; Bloundi et al. 2009; Suthar et al. 2009; Sekabira et al. 2010; Alaoui et al. 2010)**. In addition, many methods have been applied in order to evaluate the severity of sediment contamination and to comprehend the natural and anthropogenic inputs in the water system. The metal assessment indices specifically enrichment factor, geo accumulation index, and pollution load index guidelines were frequently used to screen the potential for contaminants within sediment (**Barakat et al. 2012**). The aims of this study focus on the heavy metals (Cu, Zn, Cd, Mn, Fe and Pb) concentrations and distribution in sediments from Wadi Al Arab area, and to assess heavy metal pollution to the sediment by using Geoaccumulation (Igeo), Pollution Load index (PLI) and Enrichment Factor (EF).

2. Study Area

Wadi Al-Arab situated on the East bank of the Jordan Rift Valley about 10 km south of the Lake Tiberies, while, (Figure 1) shows different views of the study area. Occupying an area of 265 km^2 Wadi Al-Arab originates in the vicinity of Irbid City and runs westward to pour into the Jordan River. The highest spot is 850 m south of Irbid, and lowest spotis200 m below the mean sea level near North Shuna. The deep V-shaped is formed in the mid and upstream parts, whereas the Wadi meanders in a wide-open valley in the downstream part, forming river terraces, 100–150 m wide. Wadi Zahar, a big tributary of the Wadi Al-Arab, forms rather a straight valley trending from south to north. The confluence to the Wadi Al-Arab is located about 2 km upstream from the dam site.

Jordan is a country with very limited water resources as compared to its population. Some dams constructed in various places in Jordan including Wadi Al-Arab Dam. Wadi Al- Arab Dam is a vital source of water in the northern part of Jordan **(Jordan Valley Authority, 1995**). Wadi Al-Arab Dam type is Zoned Rock fill with center core. The volume of the reservoir is 31,000,000 m3 and the estimated sedimentation rate is 70,000 m^3/yr. The reservoir water used to irrigate about 12,500 donums from Al Shuna to Al Baqura. It also serves as drinking water source in periods of water shortage by draining to King Abdullah Canal (J**ordan Valley Authority, 1995).**

Figure 1: Photographs shows the Wadi Al-Arab within Study area.

3. Geological Setting

The study area characterized by moderate to low relief, developed on differentially eroded, northeastwards and northward dipping Upper Cretaceous and Lower Tertiary limestone, marls, shale and dolomites. In many places, Quaternary gravels overlie the cretaceous and Tertiary beds and the northward flowing tributaries of the Yarmouk River drain terrace deposits as the basin. The description of each geological units of the study area has given in Table 1 and Figure 2. Wadi Al-Arab area is situated adjacent to the Jordan River Valley. Under the great influence of this active structural line it shows complicated geological structure. According to feasibility report on Wadi El-Arab dam and irrigation project. The geology of the study area consists mainly of Mesozoic to Cenozoic marl and limestone as a base rock; a description of each geological units of the study is as given in Table 1.

The structural setting of the study area lies to the east of Jordan Valley, which is a segment of major rift structure recognizable from east Africa to south Turkey. Where a sinistral movement took place during last 27 Ma with a proven horizontal movement slightly exceeding 100 km. Regional dips are a few degree towards the north, northeast and northwest, high westerly dips accompanying the north -south step faulting associated with the rift formation are well expressed in the western parts of the study area especially the Miocene Waqqas conglomerate (**Moh'd, 2000**). The area can be structurally subdivided in three main zones, first: the narrow western N-S trending zone adjacent to the rift dominated by N NW to N-S fault, Flexure, and some folds (**Moh'd, 2000**).

Table 1: Geological Classification of Rock Units in the Study Area

	period	epoch	Stage	Group	Formation	Description
Cenozoic	Quaternary	Recent	Holocene	Plateau	Alluvium	Soil, sand and Gravel
Mesozoic	Cretaceous	Upper	Pleistocene	Belqa	Basalt	Basalt ,clay
			Maestrichtian		Muwaqqar(B3)	Chalk ,marl and chalky limestone
			Campanian		Amman(B2)	Chert, limestone with phosphates
			Santonian		Umm Ghudran(B1)	Chalk, marl and marl limestone
		Middle	Turonian	Ajlun	Wadi Es-SIR(A7)	Hard crystalline Limestone, Dolomite
			Cenomanian		Shueib	Light grey Limestone interbedded with marls and marly limestone
					Hummar	Hard dense limestone and dolomite limestone

4. Sampling and Analytical Techniques

Twenty composite stream sediment samples collected along the main valley of Wadi Al-Arab and tributary (**Figure 3**).the samples were taken at depths of 10–30 cm depending on sediments condition, through the period of (Feb. to Mar. 2015). The samples transported to the laboratory of Al-Al-Bayt University by polyethylene bags. The samples dried in the oven at 55°C for 2 hours, and sieve to chose particles <63 µm (0.05-mm) in size. This size is a proven to the best size for analysis for arid and semi-arid regions (**Saffarini and Lahwani, 1992; Singh et al. 1999**). The extraction method was used into pollution studies to determine the heavy metal contents and the best extraction results were obtained with Ammonium-Acetate-EDTA. Extraction solution was prepared by adding 0.5M NH4Ac 0.5M+ HAc + 0.02M EDTA (pH 4.65). Then, 38.5gm of NH4Ac dissolved in 500 ml H2O+ 25ml Acetic Acid and adding 5.8gm EDTA and then the volume was raised to one litter with distilled water. After that, 20 gm. air-dry soil samples (<63 µm) were placed in a 300 ml Erlenmeyer flask, with adding 100 ml extracting solution. Then, it has shaken mechanically for 30 minutes. After shaking, suspension materials filtered through 0.45-µm filters and the clear solution collected in a polyethylene bottles. The heavy metal Cu, Zn, Cd, Mn, Fe and Pb were determined by using Atomic Absorption Spectrophotometer (AAS) at Al al-Bayt University for Water Environment and Arid Regions Research Center.

The calciometry titration method for **Loring and Rantala, (1992**) used to determine the carbonate (CO3^{2-}) content of the sediments at Institute of Earth and Environmental Sciences lab, Al-al-Bayt University. The calciometry titration prepared by using three steps:

The first Step**:** prepared the sample study**:**

1) Weight 2.5 gm from the powdered sample (<63 µm in size). 2) Add 100 ml of 1.N. of HCl to the sample and keep the beaker undisturbed for about 20 minutes after that stirr the solution at the end with a glass rod.3) After 20 minutes, filter the solution and collect the clear solution in a new beaker. This is sample solution.

The second Step: Titration of the Blank:

1) Take 20 ml of 1.N. HCl by a pipette, put it in a conical volumetric flask and add 4 or 5 drops of bromophynol blue indicator. 2) Then the solution turns yellow color, titrate it with 1.N. NaOH reagent, take in a burette up to the zero level. 3) At the end point of the titration the color of the solution in the conical volumetric flask turns blue.4) At this step, note the reading on the burette and note the amount of NaOH used in the solution. 5) Repeat this procedure for blank titration three times and calculate the average blank value.

The third Step: Titration of the sample study

1)Take 20 ml of the sample solution from first step and put it in the conical volumetric flask. 2) Adding 4 or 5 drops of the indicator bromophynol blue and titrate this solution with 1.N NaOH in the burette,. 3) At the end point of the titration the color of the sample solution in the conical volumetric flask turns blue. 4) At this step, note the reading on the volumetric flask (burette) and note the amount of NaOH used in the sample solution. This is the test of titration value. 5) Repeat this procedure for sample solution titration three times and calculate the average test value. Calculations the carbonate percentage by using the equation [Carbonate percent = 10 X (Blank value – Test value)].The amount of carbon dioxide (CO_2) released from the reaction and dependent on the amount of calcium carbonate ($CaCO_3$) in the samples.

The total organic matter (TOM) in each sample was determined by using loss on ignition (LOI) at 550°C for two hours at Institute of Earth and Environmental Sciences lab, Al-al-Bayt University.

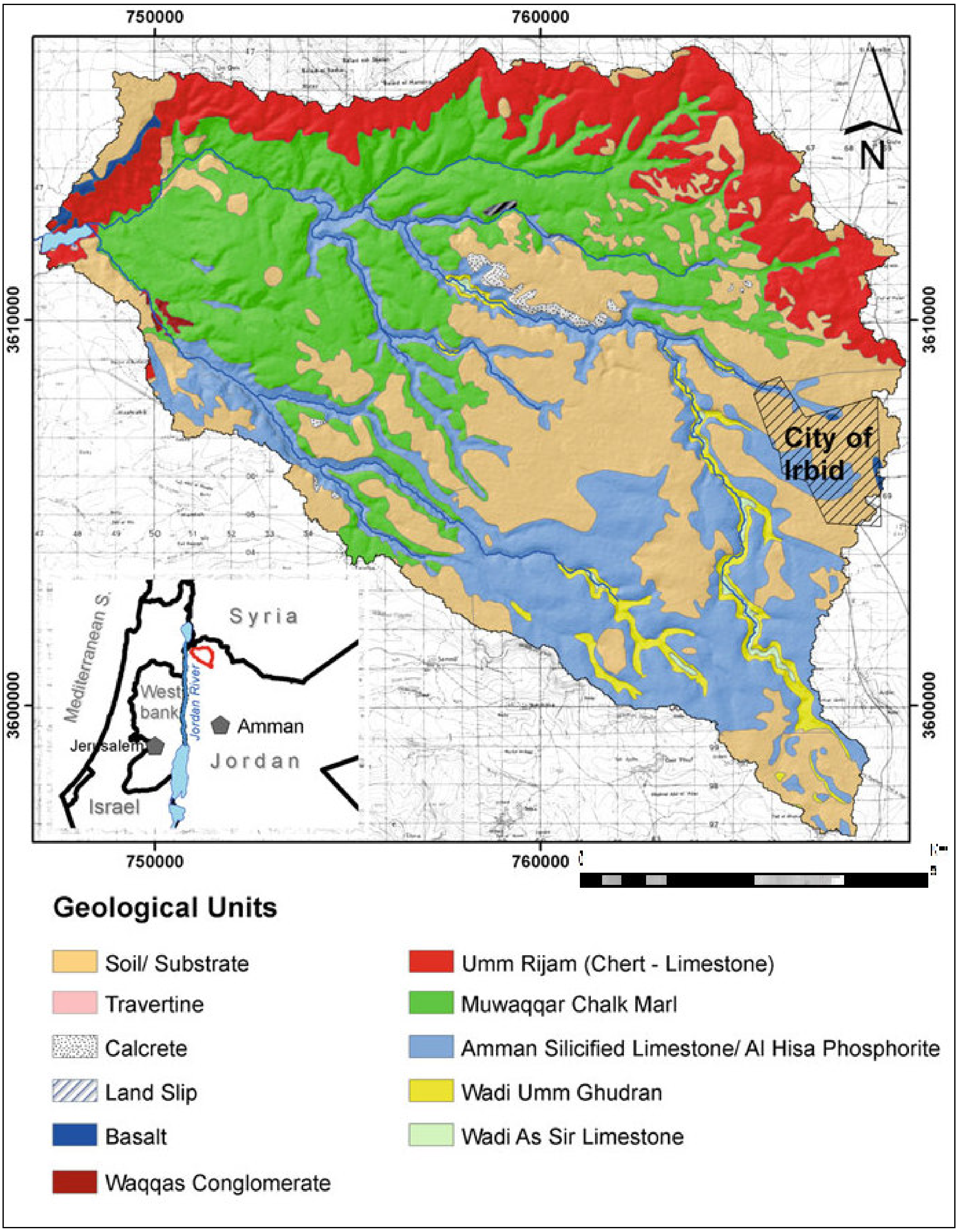

Figure 2: Geological Map of the study area.

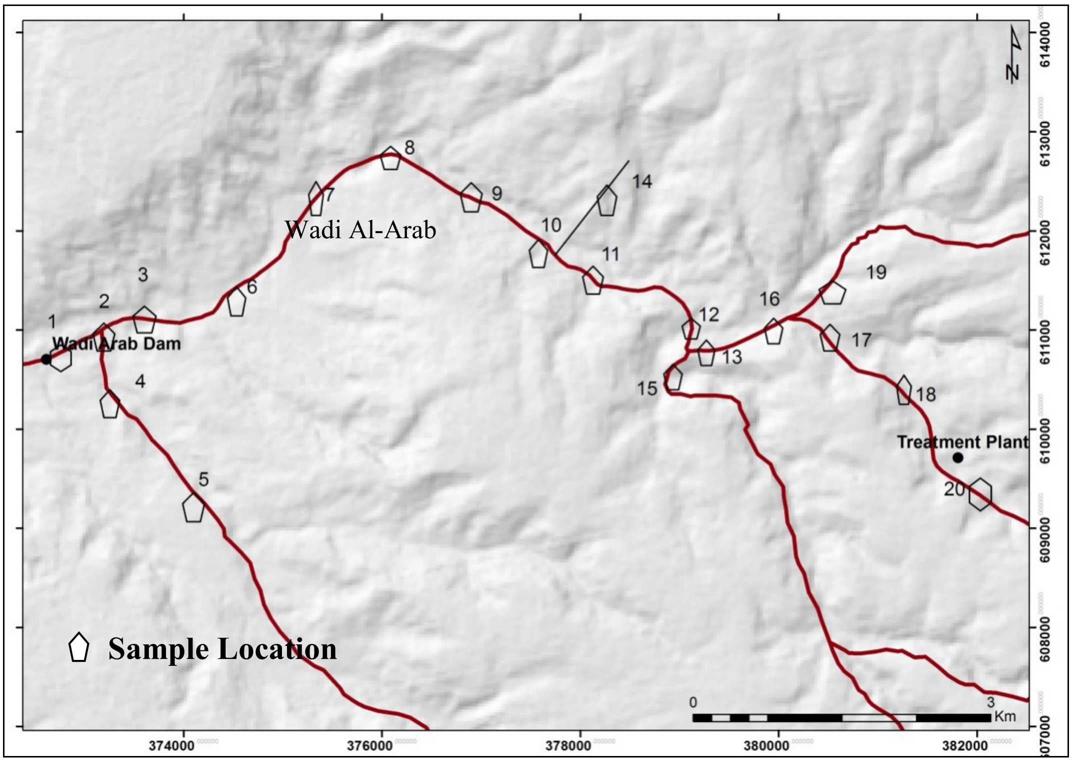

Figure 3: Sample Location Map

5. Results and Discussion

5.1. Heavy Metal Distribution

The chemical concentrations of the heavy metals for the sample study listed in Table 2. The variable concentration distributions along Wadi Al-Arab area shown in Figure (2). The concentration of Zn and Cu, increasing concentration for the upper stream but Fe and Mn are valuable concentration along the wadi (Figure 2a and b). The chemical analysis of the samples shows relatively high concentration of Fe, Mn, Zn and Pb in downstream (sample 1 and 2) to the upstream (samples 12, 13, 17 and 18) near the outlet of the wastewater treatment plant of the Irbid City. The average concentrations of Fe, Mn, Cu and Zn in Wadi Al Arab sediment has (8.19, 5.05, 3.99, 1.36 and 0.36 ppm) respectively. The average concentration of Cd has (0.29 ppm), where compared to uncontaminated sediment and soils for **Bowen, (1979**) are 0.0003 mg/g dry wt. The elevated concentrations of Fe, Mn, Zn, Pb and Cd in the surface sediments of Wadi Al-Arab probably due to the anthropogenic sources, within agricultural activities by using industrial contamination (**Ennouri et al. 2010**) such as fertilizers and pesticides, and effluent of the Irbed wastewater treatment plant flood along the wadi Al-Arab area, but Cu element demonstrated with a geogenic sources. This finding could mean that these metals have a common anthropogenic source and have similar properties (**Calace et al. 2005**). The elevated values identified for Pb and Cd might be related to human activities such as wastewater discharges (**Zarei et al. 2014**) for Irbed wastewater treatment plant.

The total organic matter (TOM) in the surface sediments of Wadi Al-Arab range betwen 0.23– 1.42%, with an average of 0.47% (Table 2). The content of TOM in Wadi Al-Arab sediments related to the organic content of the plant remains adjacent to the Wadi site at various stages of decomposition; cells and tissues of plant organisms and substances from plant roots and soil microbes considered as additional sources.

The content of CO_3^{2-} surface sediments of Wadi Al-Arab has been range between 73.8 to 91.3%, with an average of 73.8% (Table 2). The high CO_3^{2-}content in the sediments derived from the carbonate rocks exposed at the long Wadi site and in the catchment area. These rocks mainly include limestone, chalky marl and caliches (Table 1). The carbonate mineral is important for co-precipitation of heavy metals such as Cd and Zn (Alloway et al. 1997; Bany Yaseen and Al-Hawari, 2014).

5.2. Correlation Analysis

The Pearson's correlation coefficients among the contents of TOM, CO_3^{2-}, Cu, Zn, Cd, Mn, Fe and Pb in the surface sediments of Wadi Al-Arab listed in Table 2. Strong positive correlation of Pb with Zn (r = 0.85), Pb with Fe (r =0.53), Fe with Mn (r = 0.74) and Fe with Zn (r = 0.50), these relation revealed to the industrial contamination (**Ennouri et al. 2010**). The negative correlations were observed for TOM with Cu, and Cd; CO_3^{2-}

with Pb, Cd, Zn, Fe and Cu; Cd with Mn, Fe and Cu (Table 3). These results indicate that the analyzed heavy metals are not associated with each other and no relationship exists between the variables. Furthermore, these metals have different anthropogenic and natural sources in the sediments of Wadi Al-Arab area (**Habes and Nigem, 2006).**

5.3. Sediment Contamination Assessment

5.3.1. Enrichment Factor (EF)

The EF analysis is a method proposed by Simex and Helz, (1981) to assess trace element concentrations. EF was calculated as follows: EF = (M/Fe)sample/(M/Fe) background, where (M/Fe) samples the ratio of metal and Fe concentration of the sample, (M/Fe) background is the ratio of metal and Fe concentration of a background (**Ergin et al. 1991; Loska and Wiechula, 2003; Chakravarty and Patgiri, 2009; Seshan et al. 2010; Bentum et al. 2011**). The considered geochemical background values of the investigated metals (Cu = 25, Zn = 0.095, Cd = 0.098, Mn = 8.2, Fe = 46.7 and Pb = 20) taken from **Turekian and Wedepohl, (1961).**

The accepted pollution ranking system or categorization of degree of pollution based on the enrichment ratio methodology so **Sutherland, (2000**), propos a preliminary five-category system. If the EF <2 indicate low or no pollution; EF = 2–5 moderate pollution; EF = 5–20 indicating significant pollution; EF = 20–40 indicating very high pollution; EF >40 extremely high pollution. The result of EF (Table 3) shows that high concentrations of Zn and Cd are present in the study area (Figure 3a). These high concentrations indicate extreme pollution is present with regard to Zn and Cd as the reference value for extreme pollution according to EF is >40. Cd and Zn in the study area well be derived from anthropogenic sources including; fertilizers and pesticides used in agricultural activities and the effluent of the close treatment plant. The difference in EF values well be attributed to the difference in the degree of input for each metal in the sediments or due to the difference in the removal rate of each metal from the sediments (Figure 3).

Table 1. Concentrations of Pb, Cd, Zn, Mn, Fe and Cu (ppm, dry wt.), TOM and CO_3^{2-} % in surface Sediments samples collected from Wadi Al-Arab area.

	%		**PPm**					
Sample No	**CO_3%**	**TOM %**	**Pb**	**Cd**	**Zn**	**Mn**	**Fe**	**Cu**
1	66.3	0.647	0.266	0.357	3.542	3.09	5.316	0.715
2	84.3	0.36	0.356	0.091	5.257	12.63	14.701	1.477
3	81.3	0.319	0.187	0.294	3.404	5.305	6.229	1.274
4	64.3	0.604	0.228	0.198	2.251	6.525	4.401	1.239
5	74.3	0.302	0.122	0.52	3.181	1.644	1.502	1.409
6	69.3	0.342	0.301	0.24	5.027	5.796	9.884	0.959
7	91.3	0.591	0.175	0.229	3.103	4.787	7.815	0.946
8	62.3	0.257	0.482	0.211	5.135	6.926	8.751	2.27
9	69.3	0.369	0.21	0.207	3.534	4.998	4.934	1.354
10	79.3	0.396	0.24	0.321	3.897	3.759	5.725	1.224
11	74.3	0.328	0.125	0.084	3.03	4.698	2.158	1.28
12	77.3	0.366	0.327	0.272	3.284	7.503	16.228	1.36
13	67.3	0.437	0.314	0.267	3.277	7.635	16.712	1.402
14	75.3	0.238	0.197	0.123	2.877	5.008	11.871	2.236
15	84.3	0.265	0.127	0.471	2.785	3.293	2.011	0.905
16	67.3	0.371	0.207	0.475	3.705	2.653	3.018	1.417
17	70.3	0.227	0.31	0.28	4.324	5.925	12.73	1.402
18	64.3	0.259	1.382	0.356	7.811	6.961	16.576	1.919
19	70.3	0.373	0.412	0.342	4.906	3.463	5.237	1.33
20	77.3	1.419	0.454	0.397	3.433	4.24	6.177	0.863
Maximum	91.3	1.419	1.382	0.52	7.811	12.63	16.712	2.27
Minimum	62.3	0.227	0.122	0.084	2.251	1.644	1.502	0.715
Average	73.8	0.471	0.36	0.288	3.992	5.505	8.19	1.362

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Table 2. Correlation matrix of the heavy metals in the surface sediments of the Wadi Al-Arab area.

Variable	CO_3^{2-}	TOM	Pb	Cd	Zn	Mn	Fe	Cu
CO_3^{2-} %	1							
TOM	0.40	1.00						
Pb	-0.38	0.10	1.00					
Cd	-0.05	-0.28	0.08	1.00				
Zn	-0.31	0.06	0.85	0.00	1.00			
Mn	0.05	0.29	0.31	-0.65	0.36	1.00		
Fe	-0.08	0.21	0.53	-0.36	0.50	0.74	1.00	
Cu	-0.35	-0.06	0.38	-0.31	0.38	0.32	0.40	1.00

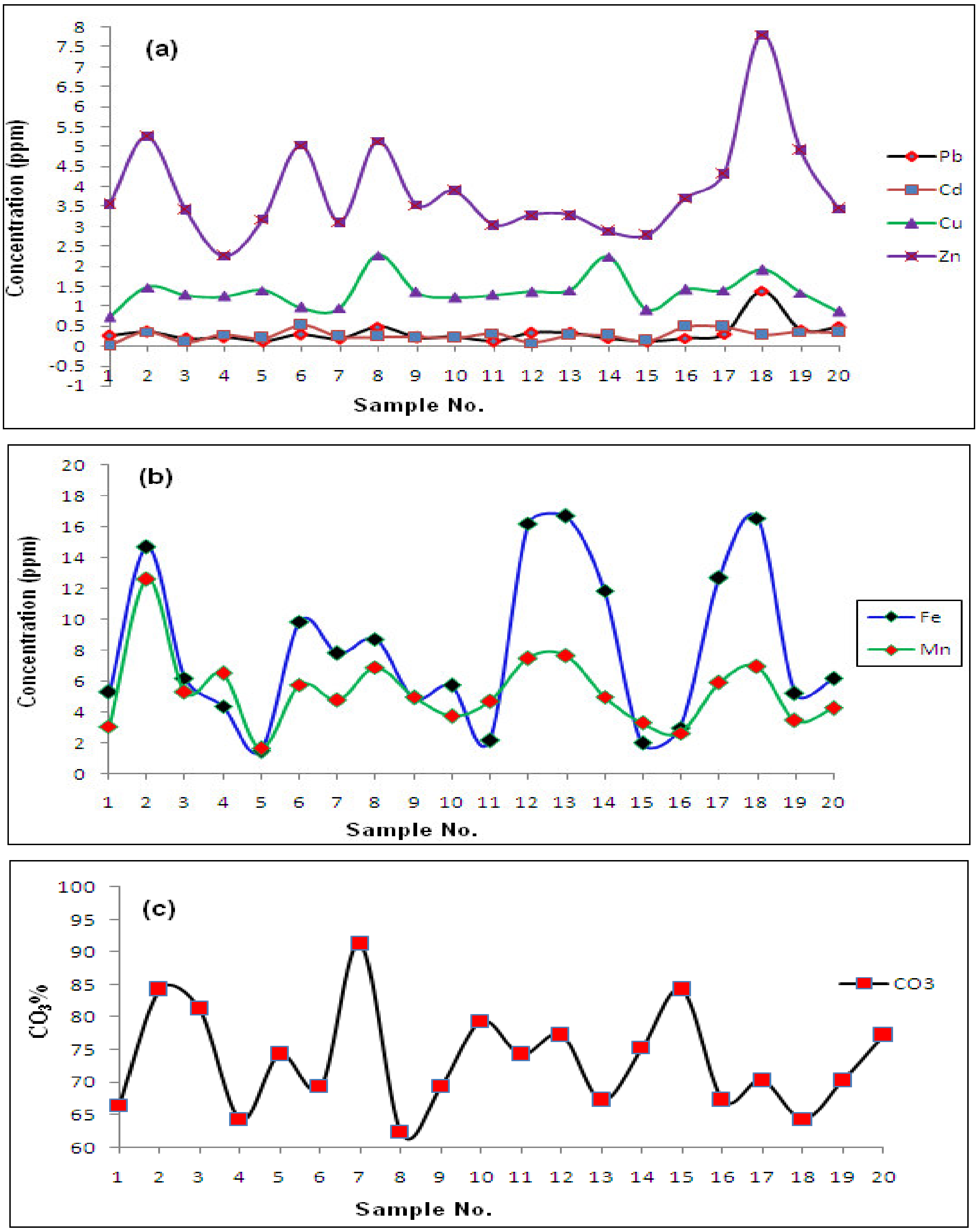

Figure (2): Distribution of heavy metal concentration (ppm) in upper sediment for Wadi Al-Arab area (a) Pb, Cd, Cu, Zn (b) Mn and Fe (c) CO_3^{2-} %

5.3.2. Geoaccumulation Index (Igeo)

The Geoaccumulation index (Igeo), introduced by Muller, (1981 for determining the extent of heavy metal pollution in Wadi Al-Arab sediments. The calculated as follows:

Igeo = $\log^2$(Cn/1.5Bn), Where; Cn is the concentration of element 'n' and Bn is the geochemical background value in average shale (**Turekian and Wedepohl, 1961**) of element n and 1.5 is the background matrix correction factor due to lithogenic effects. The geo-accumulation index (Igeo) scale consists of seven grades from 0 to 6, ranging from unpolluted to highly polluted as listed in Table 4.

The Igeo values (Table 3) indicated that the sediments of Wadi Al-Arab are unpolluted with Iron, lead, Manganese and Copper remain in grade zero in all stations (Figure 3b), suggesting that the study area sediments are in background value with respect to this metal. Cd attain grade 0 in some samples (unpolluted), while, attain in grade 1 in other samples, which indicates that Zn and Cd, polluted sediments of these samples. All heavy metals are in grade 0 to 1. This suggests that the sediments of Wadi Al-Arab are having background concentrations for Mn, Cu, Pb, and Fe, and these elements are practically unchanged by anthropogenic influences, while the concentration of Zn and Cd exceeded the average shale value. These dangerous metals derived from industrial waste and gasoline additives used in the factories and cars. These elements also derived through corrosion of the numerous abandoned launches along the Wadi and agricultural activities.

5.3.3. Pollution Load Index (PLI)

Pollution load index (PLI) was used to assess the heavy metal pollution in the surface sediments of Wadi Al-Arab area. PLI was evaluated method proposed by **Tomilson et al. *(*1980)** and calculated as follows: PLI = (CF1*CF2*.....*CFn)1/n, where n is the number of metals (six in the present study) and CF is the contamination factor. CF is calculated as follows: CF = [C heavy metal]/[C background], where C is the measured concentration of a heavy metal in sediments, background value in average shale (**Turekian and Wedepohl, 1961**). PLI value of >1 indicates pollution, whereas PLI value <1 indicates no pollution ((**Harikumar et al. 2009; Chakravarty and Patgiri, 2009;; Seshan et al. 2010)**. The PLI value of Wadi Al-Arab sediments was <1 (Table 3). The CF analysis indicated that Wadi Al-Arab is facing probable environmental pollution especially with dangerous heavy metals Zn and Cd, which result from increased rate of non-treated wastewater, which discharged to Wadi Al Arab stream. The high concentrations in the study area have been deriving from anthropogenic sources including; fertilizers and pesticides used in agricultural activities and the effluent of the close treatment plant. In addition, natural weathering of the surrounding rock formations well be considered as an additional source of heavy metals to the sediments

Table 3. Enrichment Factor (EF), Geoaccumulation index (Igeo) and PLI of heavy metal in the upper sediments of Wadi Al-Arab area.

	Enrichment Factor (EF)						
	Cu	Mn	Zn	Cd	Pb		
Maximum	1.75	12.40	1041.09	164.98	0.20		
Minimum	0.16	2.39	96.39	2.95	0.04		
Average	0.52	5.02	365.64	36.53	0.11		
	Geoaccumulation Index (Igeo)						
	Cu	Mn	Zn	Cd	Pb	Fe	
Maximum	-4.05	0.04	5.78	1.82	-4.44	-4.05	
Minimum	-5.71	-2.90	3.98	-0.81	-7.94	-5.71	
Average	-4.86	-1.34	4.73	0.78	-6.76	-4.86	
	Contamination Factor (CF)						
	Cu	Mn	Zn	Cd	Pb	Fe	**PLI**
Maximum	0.09	1.54	82.22	5.31	0.07	0.36	< 1
Minimum	0.03	0.20	23.70	0.86	0.01	0.03	< 1
Average	0.05	0.67	42.00	2.94	0.08	0.17	< 1

Table 4: Igeo degree of metal pollution in terms of seven enrichment classes.

Igeo Value	Igeo Class	designation of sediment quality
>5	6	extremely polluted
4-5	5	strongly to extremely polluted
3-4	4	strongly polluted
2-3	3	moderately to strongly polluted
1-2	2	moderately polluted
0-1	1	un polluted to moderately polluted
< 0	0	Un polluted

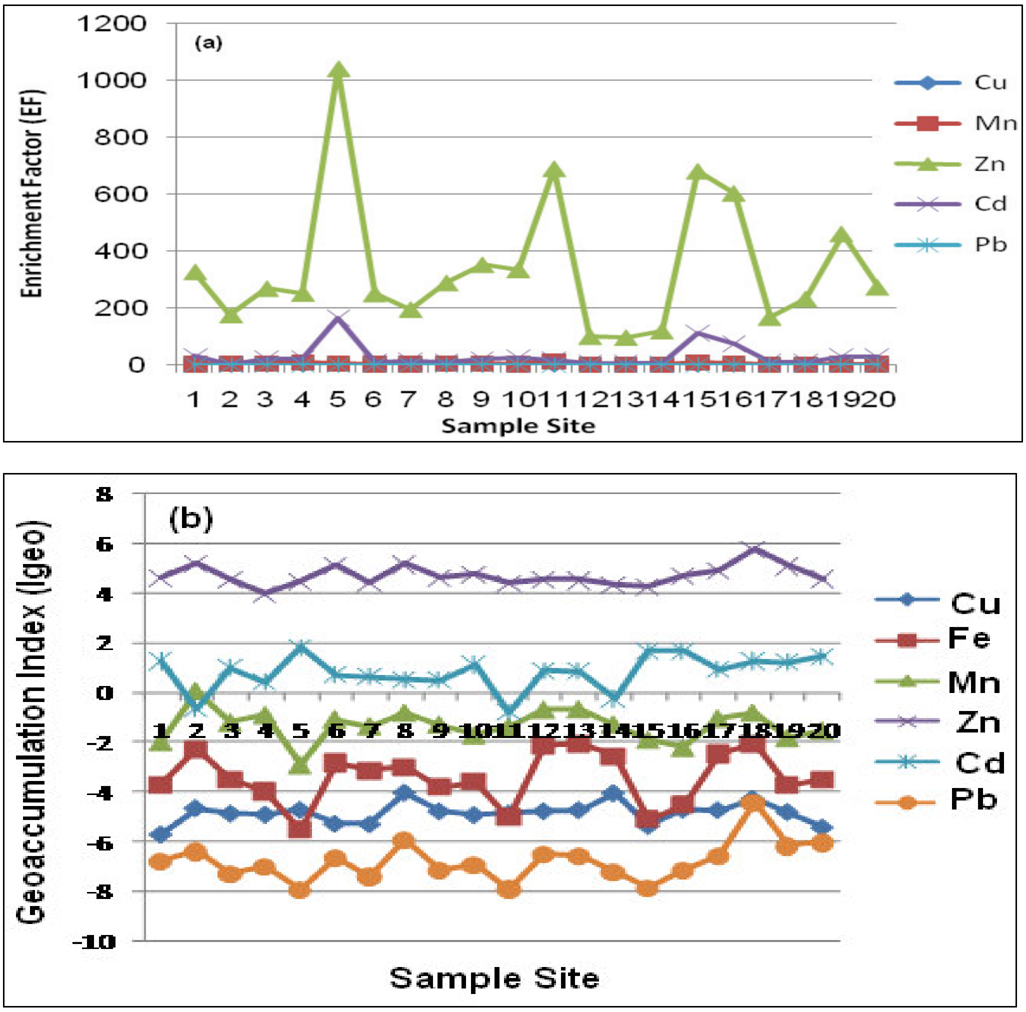

Figure 3: (a) Enrichment Factor (EF) and (b) Geoaccumulation index (Igeo) for the surface sediments from the Wadi Al-Arab area

6. Conclusions

Various verification methods has been applied in this study in order to provide an important tool for better understanding of the complex dynamics of heavy metal pollution in Wadi Al-Arab area. The following is the conclusions of these methods present the study:

1- Pearson's correlation coefficients analysis of concentrations among TOM, CO_3, Cu, Zn, Cd, Mn, Fe, and Pb. shows varying correlations among them, which indicates that these metals have complex geochemical behaviors.
2- The heavy minerals concentration in the sample distributions along Wadi Al-Arab area shows the concentration of Zn and Cu, increasing for the upper stream but Fe and Mn are valuable concentration along the wadi. Relatively high concentration of Fe, Mn, Zn and Pb in downstream (sample 1 and 2) than to the upstream (samples 12, 13, 17 and 18) near the outlet of the wastewater treatment plant of the Irbid City.
3- The elevated concentrations of Fe, Mn, Zn, Pb and Cd in the surface sediments of Wadi Al-Arab probably due to the anthropogenic sources, within agricultural activities by using industrial contamination (**Ennouri et al. 2010**) such as fertilizers and pesticides, and effluent of the Irbed wastewater treatment plant flood along the wadi Al-Arab area, but Cu element demonstrated with a geogenic sources. This finding could mean that these metals have a common anthropogenic source and have similar properties (**Calace et al. 2005**). The elevated values identified for Pb and Cd related to the human activities such as wastewater discharges for Irbed wastewater treatment plant.
4- The average content of TOM in Wadi Al-Arab sediments (0.47%) it related to the organic content of the plant remains adjacent to the Wadi site at various stages of decomposition; cells and tissues of plant organisms and substances from plant roots and soil microbes considered as additional sources.
5- The average contents of CO_3^{2-} the surface sediments of Wadi Al-Arab (73.8%). The high CO_3^{2-}content in the sediments derived from the carbonate rocks exposed at the long Wadi site and in the catchment area.

These rocks mainly include limestone, chalky marl and caliches. The carbonate mineral is important for co-precipitation of heavy metals such as Cd and Zn.

6- The sediments pollution in the present study has assessed by using the Igeo, PLI, and EF methods. The results Igeo analyses of Wadi Al-Arab surface sediments showed that concentrations of Mn, Cu, Pb, and Fe are safe and these elements are practically unchanged by anthropogenic influences, while the concentration of Zn and Cd with high average value. The elevated concentration of Zn and Cd can be due to anthropogenic sources, including fertilizers and pesticides used in agricultural activities, effluent of the treatment plant, and natural weathering of surrounding geological formations.

7- The PLI analysis indicated that Wadi Al-Arab is facing probable environmental pollution especially with dangerous heavy metals (Zn and Cd) which result from increased rate of non-treated wastewater, which discharged to Wadi Al-Arab stream. The high concentrations in the study area well be derived from anthropogenic sources including; fertilizers and pesticides used in agricultural activities and the effluent of the close treatment plant. In addition, natural weathering of the surrounding rock formations has considered as an additional source of heavy metals to the sediments.

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