ASSESSMENT OF SEDIMENT QUALITY COLLECTED FROM SHATT AL-ARAB RIVER, BASRA, SOUTHERN IRAQ

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ABSTRACT

This work was carried out to monitoring of Shatt Al-Arab river pollution by assessing the degree of heavy metals pollution in the sediment samples. Sediment samples were taken from three stations (Al-Qurna, Al-Diar, and Abo AL-Khaseeb).Mean of concentrations of metals in the sediments ranged from 23.52 to 28.90 for Cd, 253.01 to 333.42 for Pb, 34.82 to 61.22 for Zn and 130.71 to 249.56 mg kg^{-1} for Cu . The order of the mean concentrations of examined heavy metals fallow was as: Pb>Cu>Zn >Cd. The concentrations of Pb and Cd were much higher than normal background values .The degree of contamination in the sediments had been evaluated by using Enrichment factor (EF), Geo accumulation index (I-geo), and Contamination factor (CF). Based on I-geo the sediment of Shatt Al-Arab river within the study area can be considered to be a strongly to extremely polluted with Cd and Pb, while the I-geo values of Zn show moderately polluted degree. Suggesting that the site located in the downstream is more seriously polluted by heavy metals than other sites, attributed to the feeding river input. Furthermore, Abo AL-Kaseeb station displayed the highest EF and I geo value and reflects the highest presence of all the examined heavy metals; indicating that this site is considerably affected by different anthropogenic activities.

KEYWORDS: Shatt Al-Arab river; heavy metal concentration; geoaccumulation index (I-geo);Contamination factor (CF) and Enrichment factor (EF)

INTRODUCTION

The chemical analysis of river sediment is a useful method of studying environmental pollution with heavy metals (Batley 1989 and Goorzadi et al.,2009). Sediments are important carriers of trace metals in the environment and reflect the current quality of the system, sediments usually provide a record of catchments inputs into aquatic ecosystems, natural sediment formed during weathering process might be modified markedly during transportation and deposition by chemical of anthropogenic origin (Chapmann 1992).

Heavy metals accumulate in the sediments through complex physical and chemical adsorption mechanisms depending on the nature of the sediment matrix and the properties of the adsorbed compounds (Ankly et al.,1992).

Trace metals are among the most common environmental pollutants and their occurrence in waters, sediments and biota indicate the presence of natural or anthropogenic sources. The remains of trace metals in aquatic environments has led to serious concerns about their influence on plants and animals life (Sheikh et al.,2007 and Zvinowanda et al.,2009).

The behavior of metals in natural waters is a function of the substrate sediment composition, the suspended sediment composition and the water chemistry (Shrestha et al.,2007 and Harikumar and Jisha 2010).

The assessment of sediment enrichment with elements can be carried out in many ways. The most common ones are the index of geo-accumulation index (I-geo) , pollution load index (PLI) Enrichment factor(EF)and Contamination factor(CF) . The I-geo has been widely used as a measure of pollution in freshwater sediment (Singh et al 1997), while the pollution load index (PLI) represents the number of times by which the heavy metal concentrations in the sediment exceeds the background concentration, and gives a combined indication of the overall level of heavy metal toxicity in a particular sample (Priju and Narayana 2006). Pollution Load Index (PLI) was used to evaluate the extent of pollution by heavy metals in the environment. The range and class are same as Igeo. PLI for a particular site has been calculated following the method planned by(Tomlinson et al.,1980).

To assess the environmental impact of contaminated sediments, information on total concentrations is not enough and particular interest is the fraction of the total trace metal content that may take part in further biological processes (Al-Haidarey 2009).

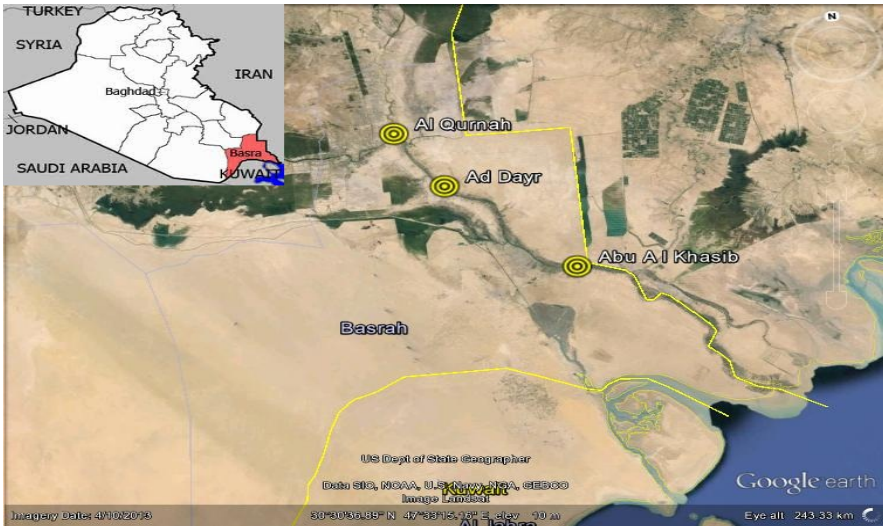
Concentrations of metals in sediment of the Shatt Al-Arab waters have been documented by (Al-Khafaje 1996 ; Hassan 2007;Al-Sabah 2007; Al-Hejuje 2015).

The aim of this study is measure the concentration of some heavy metals and their association with various geochemical substrates in sediments of Shatt AL-Arab river and to assess the influence of anthropogenic activities in sediment pollution.

Materials and Methods

Sediment sampling

The research method followed collecting sediment samples from three selected stations along the Shatt al-Arab river for the purpose of analysis and estimation the concentration of Cd , Cu , Pb and Zn during one year and for four seasons starting from December 2013 until November 2014 .The rate of values for three months were recorded according to the seasons of the year. The first station is Al-Qurna ,in North of Basra, the second is AL-Diar, and third station is Abo AL-Khaseeb.



Analysis of sediments

Preparation and analysis of sample

One gram of dried air sediment sample was transferred to 100 mL Teflon tube and wet-digested with concentrated HNO_3 and HCL (1:3 v/v) on a hot plate. The tubes were cooled and volumes prepared with double distilled water in volumetric flask. The digested samples were analyzed for Cd, Cu, Pb and Zn. according to (Sparks et al.,1996)using Atomic Absorption Spectrophotometers Technique .

Determination of geoaccumulation index

The geoaccumulation index I*geo*values were calculated for different metals as introduced by (Muller 1969) is as follows :

I-geo = log2 Cn / 1.5 Bn

Where, Cn is the measured concentration of element n in the sediment and Bn is the geoaccumulation background for the element n which is either directly measured in precivilization sediments of the area or taken from the literature (average shale value described by (Kabata 2011) . The factor 1.5 is introduced to include possible variation of the background values that are due to lithologic variations.(Al-Lami and Al-Jaberi 2002).

Igeo	Sediments pollution case
<0	practically unpolluted- Background sample
1-2	unpolluted to moderately polluted
2-3	moderately polluted to polluted
3-4	strongly polluted
4-5	strongly to extremely polluted
>5	extremely polluted

Determination of Contamination Factor (CF)

Contamination Factor was used to determine the contamination status of sediment in the current study. CF was calculated according to the equation described below:

CF=Mc/Bc

Where Mc Measured concentration of the metal and Bc is the background concentration of the same metal. Four contamination categories are documented on the basis of the contamination factor (Hakanson 1980).

CF	Contamination factor
CF<1	low contamination
1≤CF≤ 3	moderate contamination
3≤CF<6	considerable contamination
CF>6	very high contamination

while the degree of contamination (Cd) was defined as the sum of all contamination factors. The following terms is adopted to illustrate the degree of contamination:

CD	degree of contamination
Cd<6	low
6≤Cd<12	Moderate
12≤Cd<24	Considerable
Cd>24	very high

Determination of pollution load index

The pollution load index (PLI) proposed by (Tomlinson et al.,1980) has been used in this study to measure PLI in sediments of Shatt AL-Arab river. The PLI for a single site is *n*th root of n number multiplying the contamination factors (CF values) together . PLI was calculated according to the equation described below:

$$\text{PLI for site} = \sqrt[n]{CF1 \times CF2 \ldots \times CFn}$$

Determination of enrichment factor

To evaluate the magnitude of source material to that found in the Earth's crust (Huheey 1983) and following equation was used to calculate the EFC as contaminants in the environment, the enrichment factors (EF) were computed relative to the abundance of species in proposed by (Atgin et al.,2000).

EF = (CM / CFe)sample / (CM / CFe)Earth's crust

Were, (CM / CFe)sample is the ratio of concentration of trace metal (CM) to that of Fe (CFe) in the sediment sample and (CM / CFe)Earth's crust is the same reference ratio in the Earth's crust. The average abundance of Cd ,Cu ,Pb and Zn (0.35,55,15,70 $mgKg^{-1}$, respectively) and the reference value of Fe is 5.2% was selected as the reference element, due to its crustal dominance and its high immobility (Huheey 1983).

EF <1 indicates no enrichment, EF <3 is minor enrichment , EF = 3-5 moderate enrichment , EF = 5-10 is moderate to severe enrichment, EF = 10-25is severe enrichment, EF 25-50 is very severe enrichment EF >50 extremely severe enrichment.

Results and Discussion

Total heavy metals concentration

In order to assess the metals concentration in Shatt AL-Arab sediments, it is important to establish the allowable levels of these metals, heavy metals may be merged in to the aquatic system from anthropogenic sources. However, knowledge of the distribution and concentrations of the heavy metals in the sediments will help to detect the source of pollution in the aquatic systems (Al-Hjaij , 2015) .

The total concentration of heavy metals in sediments for each station in this study were shown in Fig 1,2 and 3 . Metal concentration were ranging over following intervals: Cd: (24.3-30.9); Cu: (149.6-264.56) Fe: (8615.3–23348.7) ;Pb: (274.24-353.42) and Zn: (43.57-70.22) ;mg kg^{-1} respectively with the mean values Cd: (27.49); Cu: (179.05) ; Pb: (313.97) and Zn: (54.7) mg kg^{-1} respectively, the metals concentration with the order as follow : Pb>Cu>Zn> Cd.

The mean concentration of Cd, Cu and Pb in sediments of all the stations were more than the background values (Fig 1,2and 3).It is similar to the results findings by previous studies(Hassan,2007 ;Al-Sabah 2007;Al-Hejuje 2015).

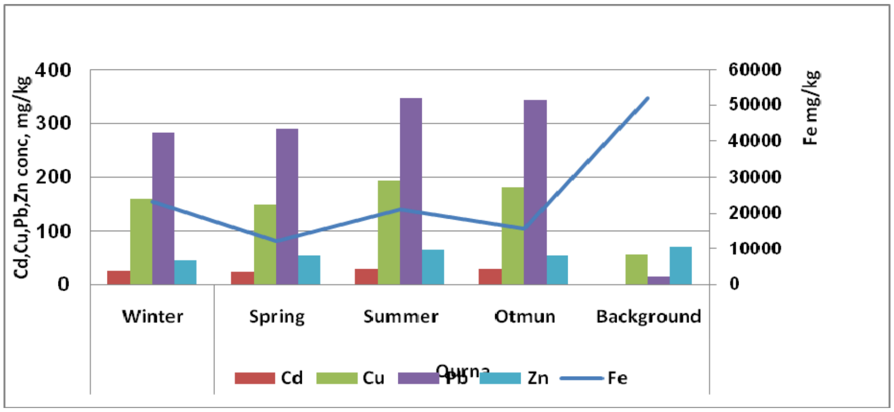


Fig 1: Concentration of heavy metals (mg/Kg) for sediments of Qurna station

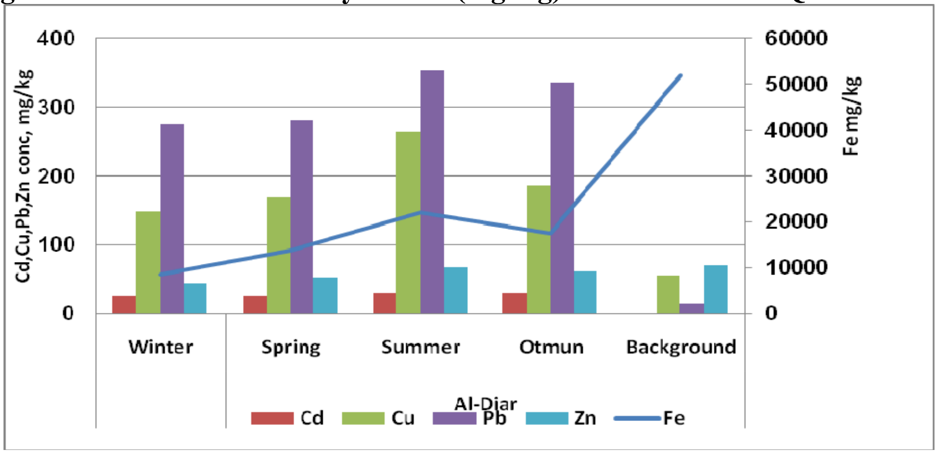


Fig 2: Concentration of heavy metals (mg/Kg) for sediments of Al-Diar station

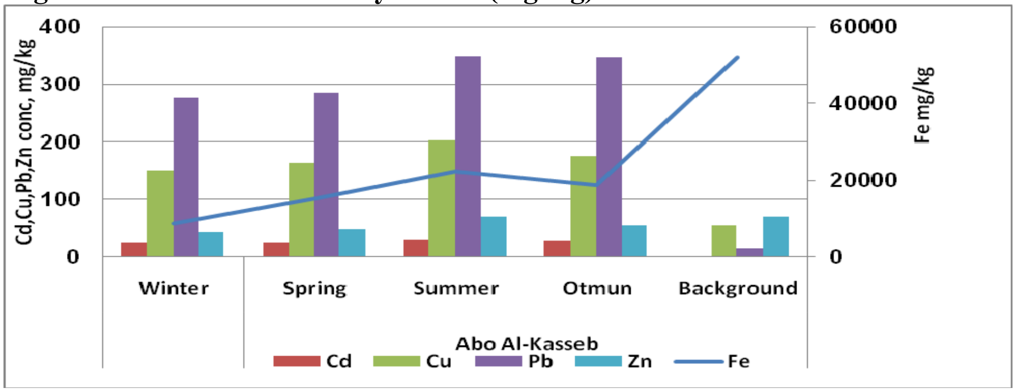


Fig 3: Concentration of heavy metals (mg/Kg) for sediments of Abo Al-Kasseb station

The ecological risk of the polluted sediments stemmed mainly from Cd, and from Pb, Cu and Zn to less degrees. The highest potential risks occurred near the aquaculture base, indicating that need to control heavy metal inputs from aqua farming activities.(Wenfeng et al.,2012) Tab. (1)shows that the mean contents of Cd, Cu, Pb and Zn in the surface sediments from the same station were significantly more than the background concentration in the curst

Table(1): Total Heavy metals concentrations in sediments ($mgKg^{-1}$ dry weight) in the present study as compared with the other previous studies.

Cd	Cu	Fe	Pb	Zn	Reference
0.27	29.24	5210.50	17.74	31.99	(Al-Khafaji 1996)
6.39	61.3	4119.55	116.6	235.4	(Al-Saffie 2005)
2.0-7.8	5.9-81.3	4700-23700	27.6-96.2	24.8-112.4	(Al-Sabah 2007)
24.52	36.61	14443.29	263.47	149.28	(Hassan 2007)
5.81	30.15	4170.33	40.13	-	(Al-Qarooni 2011)
-	26.69	1911.03	83.78	75.56	(Al-Shmery 2013)
13.08	44.11	20485.79	104.97	106.21	(Al-Hejuje 2015)
27.49	**179.05**	**16695**	**313.97**	**54.7**	Present Study

Pb> Cu > Zn > Cd.

The present study showed non-significant differences among stations in total metals concentration, this variation in the concentrations could be attributed to the interactions between multi factors that affect the concentrations of total metals, such as the unequal amounts of sewage discharged, the phytoplankton, fish cage and aquatic plants densities which absorbed or adsorbed the ionic metals, the sand storms occurring, and the fuel burn emissions specially during Summer as a result of electrical power generation machines that released large amounts of metals especially lead compounds .these results agree with many studies like (Hassan 2007) and (Al-Hejuje 2015).

The stations of study were generally exposed to pollutants, both which presents industrial facilities established on the river or sewage, which continuously and without treatment, or the impact of an activity or boating traffic, which has increased recently, especially in the (Abo Al-Kassseb station) and water transport activity. in addition to the moves with dust is a good ratio of trace elements that were added to the river and lead (Hassan 2007).

The total concentrations of heavy metals in the current studied compared with the previous studies (Table1) found that these concentrations were within the ranges in the Shatt Al-Arab river. (Martin and Meybeck 1979). This may be attributed to the removing of these metals by many ways such as adsorption by particulate matter, precipitation deposition and removal by organism (Mohiuddin et al.,2010).

Lead (Pb) was found in winter higher than in summer , it may be due to the less soluble of Pb containing minerals in natural water , this was in agreement with (Hassan 2007 ; Reza and Singh 2010) .

Geo-accumulation index

The calculated results of I-geo (Table 2), indicate that Cd can be considered to be a strongly to extremely polluted, while the Igeo values of Cu showed unpolluted to moderately polluted, PbI-geo values showed strongly polluted degree and Zn displayed practically unpolluted degree. On the basis of the mean values of I-geo, sediments in Shatt Al-Arab river at three stations were enriched with metals in the following order: Cd>Pb>Cu>Zn, and the pollution levels for the sites in the following order: St3>St2>St1.

Table 2: I-geo values for sediments samples of the Shatt Al-Arab river in three stations for Cd, Cu, Pb and Zn

Station	Season	Cd	Cu	Pb	Zn
Qurna	Winter	4.70	0.96	3.65	-1.27
	Spring	4.60	0.86	3.69	-0.97
	Summer	4.86	1.14	3.93	-0.96
	Autumn	4.88	1.24	3.95	-0.71
Al-Diar	Winter	4.65	0.85	3.61	-1.26
	Spring	4.68	1.03	3.64	-1.01
	Summer	4.85	1.17	3.90	-0.80
	Autumn	4.86	1.68	3.97	-0.64
Abo Al-Kasseb	Winter	4.70	0.87	3.63	-1.26
	Spring	4.72	0.99	3.66	-1.12
	Summer	4.88	1.10	3.95	-0.92
	Autumn	4.95	1.30	3.96	-0.58

Contamination factor and degree of contamination

Generally sediments had been used as environmental indicators, and this ability to identify heavy metal contamination sources and monitor contaminants is also well documented. Thus, the accumulation of metals in the sediments was strongly controlled by the nature of the substrate as well as the physicochemical conditions controlling dissolution and precipitation [Venkatramanan et al.,2012]. The level of metal contamination was expressed by the contamination factor [Pekey et al.,2004].

The average CF values (Table 3) for different heavy metals in the sediments of Shatt Al-Arab river were as follow: Cd>Pb>Cu>Zn (Table 3). For all sites along the Shatt Al-Arab river, the CF value for Cd and Pbare>6, indicating that this environment were very high contamination with Cd and Pb, while Cu displayed moderate to considerable contamination.CF value for Zn was less than 1 indicating that this environment was low contamination with Zn.

Table 3: Contamination factor (CF) , Contamination degree (CD) and Pollution Load Index (PLI) for sediments samples of the Shatt Al-Arab river in three station.

Station	Season	Contamination factor (CF)				C D	PLI
		Cd	Cu	Pb	Zn		
Qurna	Winter	74.20	2.91	18.83	0.62	96.56	7.09
	Spring	69.43	2.72	19.34	0.77	92.26	7.27
	Summer	83.17	3.31	22.83	0.77	110.08	8.34
	Autumn	84.11	3.53	23.11	0.92	111.68	8.91
Al-Diar	Winter	71.49	2.70	18.28	0.62	93.09	6.85
	Spring	73.46	3.07	18.72	0.74	96.00	7.49
	Summer	82.17	3.37	22.40	0.86	108.81	8.56
	Autumn	82.91	4.81	23.56	0.96	112.25	9.75
Abo Al-Kasseb	Winter	74.11	2.74	18.53	0.63	96.01	6.97
	Spring	75.17	2.98	19.03	0.69	97.87	7.36
	Summer	84.06	3.22	23.19	0.79	111.26	8.40
	Autumn	88.29	3.70	23.35	1.00	116.33	9.35

In contrast, the rest heavy metals exhibit moderate contamination in general. Furthermore, very high degrees of contamination (Cd>24) were observed indicating serious anthropogenic pollution. However, on the basis of the mean values of Cd, the pollution levels for the sites in the following order: St3>St1>St2, suggesting that the site located in the downstream was more seriously polluted by heavy metals than other sites, attributed to the feeding river input, very high degree of contamination indicating serious anthropogenic pollution. The average CF values for different heavy metals in the sediments of Shatt Al-Arab river in three stations were Cd>Pb>Cu> Zn (Table 3). For all sites along the Shatt Al-Arab river, the CF value for Cd was>24, indicating that this environment was contaminated with all study metals which indicating serious anthropogenic pollution.

Pollution Load Index

Pollution Load Index (PLI) was used to evaluate the extent of pollution by heavy metals in the environment. The range and class were same as Igeo. The value of PLI ranges from 8.16 in the downstream site to 7.9 in midstream site (Table 2), indicated moderately to strongly polluted. However, Abo Al-Kasseb station displayed the highest PLI value and reflects the highest presence of all the examined heavy metals; indicating that this site is considerably affected by different anthropogenic activities, while Al- Diar station exhibit the lowest contamination factors of all the studied heavy metals, except for Pb and Zn. Therefore, this site has the lowest PLI.

Enrichment factor

In this study iron was used as a conservative tracer to differentiate natural from anthropogenic components, following the hypothesis that its content in the earth crust has not been troubled by anthropogenic activity and it has been chosen as the element of normalization because natural sources (98%) greatly dominate its contribution (Sekabira et al.,2010). As shown in Table 3, average EF values for heavy metals have an order Cd>Pb>Cu> Zn, suggesting that sediment samples were extremely high enrichment with Cd and Pb, while Cu moderate to severe enrichment. In contrast, the rest of the metals show moderate or minimal enrichment in the study area. With respect to specific sites, high EF values (e.g., 440.04 for Cd, 132.05 for Pb, 16.27 for Cu and 3.72 for Zn) were found at Site 3, which was located at the downstream and continuously receives a vast amount of wastewater and other wastes of the city.

Table 4: Enrichment factor (EF) for sediments samples of Shatt Al-Arab river in three stations

Station	Season	Cd	Cu	Pb	Zn
Qurna	Winter	165.25	6.49	50.32	1.39
	Spring	292.33	11.45	97.73	3.22
	Summer	271.81	10.81	89.54	2.51
	Autumn	205.83	8.64	67.87	2.24
Al-Diar	Winter	431.47	16.27	132.42	3.77
	Spring	275.29	11.51	84.20	2.79
	Summer	243.53	10.00	79.65	2.56
	Autumn	194.20	11.27	66.22	2.25
Abo Al-Kasseb	Winter	440.04	16.27	132.05	3.72
	Spring	254.75	10.11	77.37	2.33
	Summer	231.57	8.87	76.67	2.19
	Autumn	206.16	8.63	65.42	2.34

Elements which are naturally derived hadan EF value of nearly unity while elements of anthropogenic origin have EF values of several orders of magnitude (Al-Saffar 2006). According to (Harikumar and Jisha 2010)EF values greater than 1.5 have such heavy metals derived from other sources suggesting environmental contamination by those particular heavy metals. It is presumed that high EF values indicates an anthropogenic source of trace metals mainly from activities such as accumulation of organic materials , decompositions, and export of particulate organic matter (Kwon et al.,2001). Science the bioavailability and toxicity of any heavy metal in sediment depend on chemical from and concentration of the metal, it can be inferred that trace metals in sediments samples with high EF values, along with higher labile fractions in sediments are potential sources for mobility and bioavailability in the aquatic ecosystems (Ameh et al.,2011). The high concentrations of EF values in some locations above may be attributed to the land base activities, sewage wastes and also from the erosion of soil (Al-Haidarey 2009).

Conclusion

This study revealed that the enhanced concentration of some heavy metals in sediment of Shatt Al-Arab river like Qurna, Al-Diar and Abo Al-Kasseb is due to anthropogenic influences. Distribution pattern of heavy metals in the sediments according to Indexes use to assessment in this research

	Geoaccumulation index (Igeo)	**Contamination factor (CF)**	**Enrichment factor (EF)**
Cd	strongly to extremely polluted	very high contamination	extremely severe enrichment.
Cu	unpolluted to moderately polluted	moderate to considerable contamination	moderate to severe enrichment
Pb	strongly polluted	very high contamination	extremely severe enrichment.
Zn	practically unpolluted	low contamination	minor to moderate enrichment

References

1. Batley,G.E.(1989). “Trace Metal Speciation: Analytical Methods and Problems”, CRC Press, Boca Raton, Florida.
2. Goorzadi , A., G. Vahabzadeh and A. R. Carbassi,(2009) “Assessment of heavy metals pollution in Tilehbon River sediments”, Iran Journal of Applied Science, Vol. 9, No. 6, pp.1190-1193.
3. Chapmann, D. 1992. Water Quality Assessment. A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. 1st Edn., Chapman and Hall, London, pp: 585.
4. Ankley ,G.T., K. Lodge, D.J. Call, M.D. Balcer, and B. J. Smith,(1992).“Heavy metal concentrations in surface sediments in a near shore environment, Jurujuba Sound, Southeast Brazil”, Environmental Pollution, Vol. 109.
5. Sheikh, M. A.; N. M. Noah ; K. Tsuha and T. Oomori. (2007). Occurrence of tributyltin compounds and characteristics of heavy metals. Int. J. Environ. Sci. Tech., 4(1), 49-60.
6. Zvinowanda, C.M.; J.O. Okonkwo; P.N. Shabalala; N.M. Agyei. (2009). A novelAdsorbent for heavy metal remediation in aqueous environments. Int. J. Environ. Sci. Tech., 6 (3), 425-434.
7. Shrestha, R.; R. Fischer and M. Sillanpaa. (2007). Investigations on different positions of electrodes and their effects on the distribution of Cr at the water sediment interface. Int. J. Tech., 4(4), 413-420.
8. Harikumar, P. S. and T. S. Jisha . (2010). Distribution pattern of trace metal Pollutants in the sediments of an urban wetland in the southwest coast of India Int. J. Eng. Sci. Tech., 2(5): 840- 850.
9. Singh ,M., A.A. Ansari, G. Muller, and I.B. Singh(1997).“Heavy metals in freshly deposited sediments of the Gomati river a tributary of the Ganga River: Effects of human activities”, Environmental Geology, Vol. 29, 1997, pp. 246-252.
10. Priju , C.P. and A.C. Narayana (2006), “Spatial and Temporal Variability of Trace Element Concentrations in a Tropical Lagoon, Southwest Coast of India: Environmental Implications”, Journal of Coastal Research, Vol.39, 2006, pp.1053 – 1057.
11. Tomlinson, D.L.; J.G. Wilson; C.R. Harris and D.W. Jeffery. (1980). Problems in the assessment of heavy metals levels in estuaries and the formation of a pollution index. HelgolWiss. Meeresunters, 33 (1-4), 566-575.
12. Al-Haidarey, M.J.S.(2009). Distribution of Some Heavy Metals in Mesopotamian Marshes. Ph.D. Thesis. College of Pharmacy. University of Kufa, Iraq.

13. Al-Hejuje ,M.M.(2015)." Application of Water Quality and Pollution Indices to Evaluate the Water and Sediments Status in the Middle Part of Shatt Al-Arab River" . Ph.D Thesis . University of Basrah, college of science , biology department , 104 pp.
14. Al-Khafaji ,B.Y. (1996)." Trace metals in water , sediments and fishes from Shatt Al-Arab Estuary North-West Arabian Gulf ". Ph.D. Thesis , Biology Dep. , College of Education , Univ. Basrah . 131
15. Hassan, W.F.(2007)."Geochemical and hydro chemicalStady at Shatt Al-Arab Chanel Sediments and Overlying Water ". Ph.D. Thesis ,College of Agriculture, University of Basrah .205 pp(In Arabic).
16. Al-Sabah, B.J.J. (2007) ."Study of Physiochemical Behavior of Polluted Mineral Elements for Water and Sediments of Shatt AL-Arab .Ph.D.Thesis , College of Agriculture ,University of Basrah , 223 pp. (In Arabic) .
17. [Sparks, D. L.; A. I. Page; D. A. Helmke; R. H. Loeppert; P. N. Soltanpour; M.A. Tabatabai; C. T. Johnston and M. E. Sumuer (1996). Method of soil analysis Part. 3. Chemical methods. Inc. Madison Wisconsin, U.S.A.
18. Muller, G. 1969. Index of Geoaccumulation in sediments of the Rhine River.Geol. J. 2, 109-118.
19. Kabata-Pendias, A. (2011). Trace elements in soils and plants. 4th Edition, CRC Press.
20. Al-Lami, A.A. and H.H. Al-Jaberi, “Heavy metals in water, suspended particles and sediment of the upper-mid region of Tigris River, Iraq”, Proceeding of international Symposium on Environmental Pollution Control and Waste management,7-10 January, 2002, Tunis.
21. Hakanson, L. (1980). An Ecological Risk Index for Aquatic Pollution Control a Sedimentological Approaches, *Water Research*, 14(8), 975-1001.
22. Huheey, J. E. 1983. Inorganic chemistry : Principles of structure and reactivity. Harper and Row Publishers, New York, 912.
23. Atgin, R. S.; O. El-Agha; A. Zararsiz ; A. Kocatas ; H. Parlak and G. Tuncel.2000. Investigation of the sediment pollution in Izmir Bay : trace elements. Spectrochim. Acta B., 55 (7), 1151-1164.
24. Wenfeng Zhang, Xueping Liu, Hefa Cheng, Eddy Y. Zeng, Yuanan Hu (2012).Heavy metal pollution in sediments of a typical mariculture zone in South China Marine Pollution Bulletin 64 pp 712–720.
25. Al-Saffie , Abeer G.A.(2005)." Study of some of heavy elements in Water , Sediments and Phytoplankton in Shatt Al-Arab river ". M.Sc. Thesis . University of Basrah, college of science , biology department , 85pp(In Arabic).
26. [AlQarooni , I. H. M. (2011)." Estimation of some heavy metals concentrations in water , sediment and bioaccumulation in some invertebrates of Shatt Al-Arab River and Shatt Al-Basrah canal , southern Iraq ". Ph.D. Thesis , Biology Dep. , College of Education , Univ. Basrah . 243 pp. . (In Arabic).
27. Al-Shmery , A.Y.H.(2013)." Estimation of some heavy metals in clams , sediments and water from Shatt Al-Arab and treatment by porcellanite rocks". M.Sc. Thesis , Chemistry depart. , College Of Education For Pure Science , Unive. Basrah , 100 pp. . (In Arabic).
28. Martin, J. M. and M. Meybeck . 1979. Elemental mass balance of materials carried by major world rivers. Mar. Chem. 7: 173-206.
29. Mohiuddin, K. M.; H. M. Zakir and K. Otomo. (2010). Geochemical distributionof trace metal pollutants in water and sediments of downstream of an urban river. Int. J. Environ. Sci. Tech., 7(1), 17-28.
30. Reza ,R. ;and Singh ,G.(2010)." Heavy metals contamination and its indexing approach for river water". Intern.J. Envi.Sci. Technol. ,7(4):785-792.
31. Venkatramanan, S., Ramkumar, T., Anithamary, I. and Vasudevan, S. (2012). Heavy Metal Distribution in Surface Sediments of the Tirumalairajan River Estuary and the Surrounding Coastal Area, East Coast of India, *Arabian Journal of Geosciences*, 7(1), 123-130.
32. Pekey, H., Karakas, D., Ayberk, S., Tolun, L. and Bakoglu, M. (2004). Ecological Risk Assessment using Trace Elements from Surface Sediments of Izmit Bay (Northeastern Marmara Sea) Turkey, *Marine Pollution Bulletin*, 48(9-10), 946-953.
33. Sekabira, K.; H. OryemOriga ; T.A. Basamba; G. Mutumba and E. Kakudidi. 2010. Assessment of heavy metal pollution in the urban stream sediments and its tributaries. Int. J. Environ. Sci. Tech., 7 (3), 435-4465.
34. Al-Saffar, M. T. (2006). Interaction between the Environmental Variables and Benthic Macro invertebrates Community Structure in Abu Zirig Marsh, Southern Iraq, M.Sc Thesis, Biology Department, Science Collage, Baghdad University.
35. Kwon, Y. T ; C. W. Lee and B. Y. Ahn. 2001. Sedimentation pattern and sediments bioavailability in a wastewater discharging area by sequential Metal analysis. Microchem. J., 68(2-3), 135-141.
36. Ameh, E. G.; M. S. Kolawole and E. G. Imeokparia. 2011. Using Factor Cluster Analysis and Enrichment methods to evaluate impact of cement production on stream sediments around Obajana cement factory in Kogi state, North Central Nigeria. Pelagia Research Library., 2 (1): 76-89.