

Quality Assessment for Shatt Al-Arab River Using Heavy Metal Pollution Index and Metal Index

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Abstract
The objectives of the present study were to prepare heavy metal pollution index (HPI) and metal index (MI) for the Shatt Al-Arab River (Iraq) and to evolve the sources of heavy metals. Nine locations were selected before and along of the river, five samples distributed on Euphrates and Tigris Rivers before confluence with each other forming Shatt Al-Arab River, and four samples distributed along the route of Shatt Al-Arab River. Six heavy metals viz. Iron (Fe), Zinc (Zn), Copper (Cu), Lead (Pb), Cadmium (Cd) and Nickle (Ni) were analysed using Inductively Coupled Plasma - Mass Spectrometry (ICP-MS). The mean HPI (8.33) was found to be below the critical pollution index value of 100. The result of the MI indicates that the river is pure with respect to heavy metal pollution.
Though the water was not found to be critically polluted with respect to heavy metals, the situation is still a matter of concern as Fe, Zn,Cu, Cd, Pb and Ni were found to have anthropogenic origin and mainly came from industrial activities, though municipal sewage, domestic wastes, traffic sources, atmospheric depositions and Chemical weathering of minerals.
Keywords: Shatt Al-Arab River, Heavy metal pollution index, metal index, Water contamination.

1. Introduction

Heavy metals are among the most common environmental pollutants, and their occurrence in waters and biota indicate the presence of natural or anthropogenic sources. The main natural sources of metals in waters are chemical weathering of minerals and soil leaching. The anthropogenic sources are associated mainly with industrial and domestic effluents, urban storm, water runoff, landfill leachate, mining of coal and ore, atmospheric sources and inputs rural areas (Zarazua et al., 2006). Monitoring and assessment of the water pollution has become a very critical area of study because of direct implications of water pollution on the aquatic life and the human beings. The contamination of surface water by heavy metals is a serious ecological problem as some of them like Hg and Pb are toxic even at low concentrations, are non-degradable and can bio-accumulate through food chain. Though some metals like Fe, Cu and Zn are essential micronutrients, they can be detrimental to the physiology of the living organisms at higher concentrations (Kar, et al.,2008, Nair et al., 2010). The spatial study of heavy metals by producing heavy metal pollution index can be helpful in identifying and quantifying trends in water quality (Prasad & Kumari, 2008; Reza & Singh, 2010) and can provide the accumulated information and assessments in a form that resource management and regulatory agencies can use to evaluate alternatives and make necessary decisions(Nair et al., 2010). In Basrah city the problem of environmental pollution has been worsen because of the large quantities of industrial wastes, waste water, fertilizers and pesticides, which find their way into the side branches and then to the Shatt Al - Arab then up to the different organisms (Abdullah *et al*., 2007).

The objectives of the present study are to prepare the most recent heavy metal pollution index and meal index for Shatt Al-Arab River and to evolve the sources of heavy metals, as well as an attempt to reveal possible environmental effects on Shatt Al-Arab river by Tigris and Euphrates Rivers.

2. Materials and Methods

2.1 Study area:

The study area is located between Latitude (29° 45´00" N- 31° 15´ 00" N) and Longitude (47° 10´ 20" E- 48° 45´ 00" E), as shown in Figure 1. It lies in Basra Governorate south east of Iraq, within unstable shelf in Zubair subzone (Buday and Jassim, 1987) along Mesopotamian plain which is mostly covered by sediments of Quaternary period which consist largely of silt and clay with little amount of sand (Buringh, 1960). Shatt Al-Arab is one of the largest fluvial systems in the world. It originates from the confluence of the two twin rivers Tigris and Euphrates, at Qurmat-Ali (about 70 Km north of Basra governorate) and it also constitutes delta before finally spills into the Arabian Gulf nearby Fao city (about 90 Km south of Basra city) (Hussein, 2011). It is about 204 km long and the width varies between 500-2000 m, and its drainage basin is about 882200 km^2 (Abdulla,1990).

2.2 Field sampling and laboratory methods

Water samples were collected at July 2012 from nine locations. The locations were classified into three categories, Euphrates River (before confluence with Tigris) representing locations: E1,E2, E3; Tigris River (before confluence with Euphrates at Qurmat-Ali) representing locations: T1, T2 and Shatt Al-Arab River (from Qurmat-Ali to Al_AShar) representing locations: S1, S2, A, A2. Figure 1.

The samples were collected at 10-15 cm depth in separate pre-conditioned and acid rinsed clean polypropylene bottles The collected samples were filtered (Whatman no. 42) and acidified with concentrated nitric acid to a pH below 2.0 to minimize precipitation and adsorption on container walls. For the determination of total heavy metals in the samples extraction procedures as described in APHA, 2005 were followed. Heavy metals concentrations (Fe,Zn, Cu,Pb, Cd, Ni) were determined in acidified filtrates water samples by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) in ALS Laboratory Group, Spain.

2.3 Heavy metal Pollution index

Heavy metal pollution index (HPI) is a technique of rating that provides the composite influence of individual heavy metal on the overall quality of water. The rating is a value between zero and one, reflecting the relative importance of individual quality considerations and inversely proportional to the recommended standard (Si) for each parameter (Reza & Singh, 2010; Prasad and Mondal, 2008; Prasad & Kumari ,2008). The calculation of HPI involves the following steps:

First, the calculation of weightage of i^{th} parameter

Second, the calculation of the quality rating for each of the heavy metal

Third, the summation of these sub-indices in the overall index

The weightage of i^{th} parameter

$$W_i = k / S_i \quad (1)$$

Where W_i is the unit weightage and S_i the recommended standard for i^{th} parameter, while k is the constant of proportionality.

Individual quality rating is given by the expression

$$Q_i = 100 V_i / S_i \quad (2)$$

where Q_i is the sub index of i^{th} parameter, V_i is the monitored value of the ¡th parameter in µg/l and S_i the standard or permissible limit for the i^{th} parameter.

The Heavy Metal Index (HPI) is then calculated as follows

$$HPI = {}^{n}{}_{i=1}(Q_i W_i) / {}^{n}{}_{i=1} W_i \quad (3)$$

where Q_i is the sub index of i^{th} parameter. W_i is the unit weightage for i^{th} parameter,n is the number of parameters considered. The critical pollution index value is 100. For the present study the S_i value was taken from the Iraqi drinking water specifications standard, 2009, No.417.

2.4 Metal Index

Another index used is the general metal index (MI) for drinking water (Bakan et al., 2010) which takes into account possible additive effect of heavy metals on the human health that help to quickly evaluate the overall quality of drinking waters. Metal pollution Index is given by the expression proposed by (Caeiro et al., 2005).

$$MI = \sum [Ci/ (MAC)i]$$

Where MAC is maximum allowable concentration and Ci is mean concentration of each metal. The higher the concentration of a metal compared to its respective MAC value the worse the quality of water. MI value > 1 is a threshold of warning (Bakan et al., 2010). Water quality and its suitability for drinking purpose can be examined by determining its metal pollution index (Mohan et al., 1996; Prasad & Kumari, 2008).

3. Results and discussion:

Concentrations of the six studied heavy metals have been shown in Table 1. The metal concentrations were significantly different between sampling locations. However, the concentrations of Fe, Zn,Cu, Cd, Pb and Ni were found to be below the highest permissible value of Iraqi standards for drinking water , 2009, No.417.

Based on the concentration ranges and abundance heavy metals are ranked as Fe > Zn > Ni> Cu > Cd >Pb (Table 1).

Heavy metal pollution index is an effective tool to characterise the surface water pollution (Prasad& Kumari, 2008; Reza & Singh, 2010) as it combines several parameters to arrive at a particular value which can be compared with the critical value to assess the level of pollution load. In Table 2 the methodology of HPI calculation has been presented in detail. Mean concentrations of the six heavy metals were used for the HPI determination. Overall HPI for the Euphrates, Tigris and Shatt Al-Arab Rivers was found to be 8.332, which is below the critical value of 100. Though HPI value indicates that Shatt Al-Arab River is not critically polluted with respect to heavy metals.

HPI was also calculated separately for each river and for each sampling location to compare the pollution load and assess the water quality of the selected locations Table 3, Figure 2. HPI for the Euphrates, Tigris and Shatt Al-Arab Rivers was found to be 7.949, 9.526, 8.140 respectively, The highest values of HPI were found in Tigris river, and location E2, that may be attributed to domestic sewage, rock-water interaction. Lower HPI values were found in Euphrates River and location E1 indicate the dilution affect due to seepage or percolation of rain water.

The result of the MI for the Euphrates, Tigris and Shatt Al-Arab Rivers was found to be 0.9486 table 4, suggests that the river is pure with respect to heavy metal pollution according to Lyulko et al., 2001; Caerio et al., 2005,Table 5.

In the present study the concentrations of Fe, Zn,Cu, Cd, Pb and Ni were found to be below the highest permissible value may be because of the dilution factor affected by Euphrates and Tigris Rivers as they confluence with each other forming Shatt al-Arab. In other Iraqi studies; Abaychi & DouAbal ,(1985) found that the northern part of the Shatt Al-Arab polluted by the metals Nickel and Vanadium, Al-Saad *et al*., (1996) illustrated that the Shatt Al-Arab water polluted by trace metals fall within the acceptable level, while Al-Kafaji *et al*.,(1997) showed that the trace metals, within the accepting of the limit with the exception of Iron. Al-Kafaji (2000) pointed rise of trace metals in the suspended parts of the water more than the dissolved, while Awad *et al*. (2004) noticed that trace metals within the accepting limit with the Nickel, Mohammed (2012) reported that trace elements concentrations from southern part of Iraq were higher than allowed levels by WHO and IRPR.

This difference with other Iraqi studies may be related to the difficulty of investigating heavy metals in toxic aquatic system, where heavy metal concentrations will be low. Moreover the many factors affect the concentrations, such as: the flow of the dredged materials from upper regions of the river, dilution and increase of water flow, direct drainage from farmlands, factories, sewage disposal plants, dissolution of sediments, increases in the numbers of phytoplankton in water, bioaccumulation, chemical adsorption on sediments and complexes with organic matter (AL-Saad et al., 1994; Kaiser et al., 2004).

No work has been done on HPI and MI related to Iraqi Rivers, Prasad and Jaiprakash (1999) studied the mining area filled with fly ash and reported 11.25 HPI value, while Prasad and Sangita (2008) reported 36.67 which is below critical index, Nalawade et al., 2012 reported 5.5 index value near fly ash dumping sites,Manoj et al., 2012 reported 49.12 HPI value of the Subarnarekha River (India), Reza and Singh, 2010 found The mean values of HPI were 36.19 in summer and 32.37 for winter seasons of river water Angul-Talcher region india. Amadi et al., 2012 found that the MI indicates that the River Chanchaga, Minna, North-central Nigeria is slightly affected with respect to heavy metal pollution. Ameh and Akpah, 2011 reported MI index the River PovPov in Itakpe Nigeria status was 403 and 87.12 respectively, clearly indicating low-quality water.

4. Conclusion

Heavy metal pollution index is an effective tool to characterize the surface water pollution. Overall HPI calculated based on the mean concentration of the heavy metals was found to be 8.33 which is below the critical pollution index value of 100, indicates that the selected water samples from the river are not critically contaminated with respect to heavy metals. The result of the MI was found to be 0.9486 suggests that the selected river is pure with respect to heavy metal pollution. Though the water was not found to be critically polluted with respect to heavy metals, the situation is still a matter of concern as Fe, Zn,Cu, Cd, Pb and Ni were found to have anthropogenic origin and mainly came from industrial activities, though municipal sewage, domestic wastes, traffic sources and atmospheric depositions, Chemical weathering of minerals, and industrial discharges increase their concentration in water.

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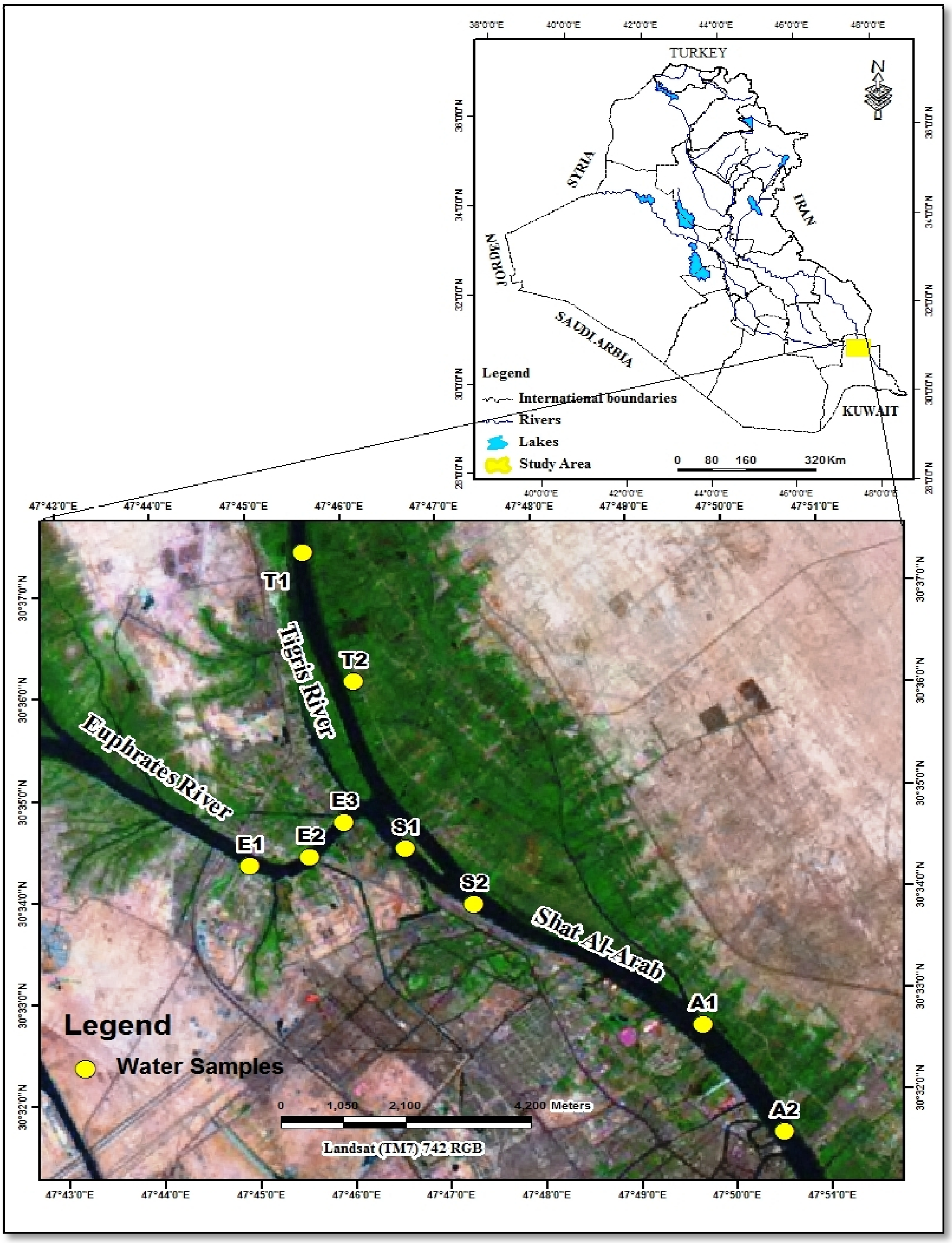

Figure 1: Map of Study area along with sampling locations.

Table 1: Heavy metal concentrations at different locations of Shatt Al-Arab River

Sampling locations	Fe µg/l	Zn µg/l	Cu µg/l	Pb µg/l	Cd µg/l	Ni µg/l
E1	190	8	9.9	0.2	0.2	3.4
E2	200	6	2.5	0.2	0.3	3.8
E3	180	6	2.5	0.2	0.2	3.4
T1	180	7	2.4	0.2	0.3	3.7
T2	200	7	2.4	0.2	0.3	3.5
S1	190	6	2	0.2	0.3	3.6
S2	220	7	2.1	0.2	0.2	4.4
A1	200	7	2.5	0.2	0.2	4.4
A2	210	8	2.4	0.2	0.2	4.3

Table 2: Mean HPI of the Shatt Al-Arab River.

Heavy metals	Range	Mean Concentrations µg/l (Vi)	Highest permitted value µg/l (Si)*	Unit weightage (Wi)	SubindexQ i	Wi x Qi
Fe	180-220	196.66	300	0.003	65.553	0.19665
Zn	6-8	6.88	3000	0.00033	0.2293	0.0000756
Cu	2-9.9	3.18	1000	0.001	0.318	0.000318
Pb	0.2	0.2	10	0.1	2	0.2
Cd	0.2-0.3	0.244	3	0.333	8.133	2.70828
Ni	3.4-4.4	3.83	20	0.05	19.15	0.9575
				∑ Wi=0.4876		∑ Wi x Qi= 4.06282
HPI = 8.3322						

*** Iraqi drinking water specifications standard, 2009, No.417.**

Table 3: HPI recorded at different sampling locations.

Sampling locations	E1	E2	E3	T1	T2	S1	S2	A1	A2
HPI	7.082	9.651	7.115	9.555	9.497	9.526	7.719	7.673	7.645
∑ HPI = 8.384									
Euphrates			Tigris			Shatt Al-Arab			
7.949			9.526			8.140			

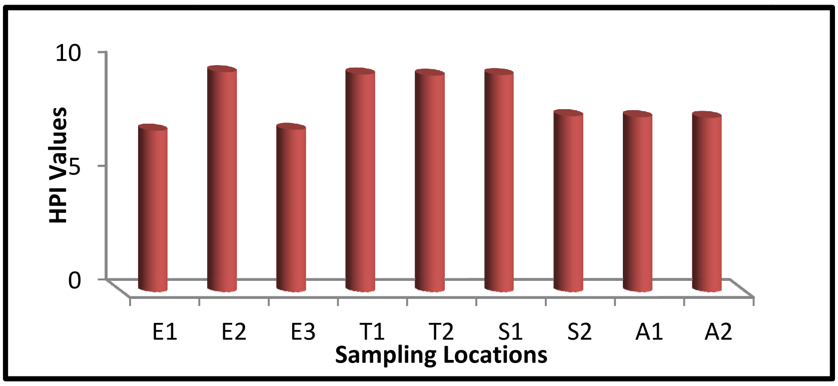

Figure 2 : HPI values at various sampling points.

Table 4: Mean MI of the Shatt Al-Arab River

Heavy metals	Mean Concentrations µg/l (Ci)	Highest permitted value µg/l (MAC)i	MI
Fe	196	300	0.6533
Zn	6.8	3000	0.002266
Cu	3.1	1000	0.0031
Pb	0.2	10	0.02
Cd	0.24	3	0.08
Ni	3.8	20	0.19
$\sum$ MI = 0.9486			

Table 5: Water Quality Classification using MI (Lyulko et al., 2001; Caerio et al., 2005)

MI	Characteristics	Class
<0.3	Very pure	I
0.3-1.0	Pure	II
1.0-2.0	Slightly affected	III
2.0-4.0	Moderately affected	IV
4.0-6.0	Strongly affected	V
>6.0	Seriously affected	VI