Int. J. Aquat. Biol. (2024) 12(3): 296-301
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Predicting the extent of pollution of the Shatt al-Arab River with some heavy metals using the heavy metals index (HPI)

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Abstract: This study evaluated the extent of pollution of the Shatt al-Arab water with heavy metals, viz. manganese, iron, zinc, lead, and cadmium, using the Heavy Pollution Index (HPI). For this purpose, seven stations were selected along the river's course in southern Iraq, including Al-Qurna, Al-Hartha, Sinbad, Al-Ashar, Muhayla, Siba, and Al-Faw. From October 2021 until September 2022, water samples were collected from the stations every month and repeated three times at each station. The study months were divided into two seasons: The dry season, which included June, July, August, and September, and the wet season, which represented January, February, March, and April. HPI was calculated on an annual basis. The result of the HPI was within the range of 313.30-1146.28 during the wet season in all stations and 324.81-1748.63 in the dry season, with values ranging from 1083.18-299.64 as an annual average. HPI values were high in all stations during the two seasons, and the annual revealed that the water in the river has very high levels of pollution, and it was most severe when temperatures rose in summer.

Article history:
Received 7 March 2024
Accepted 6 June 2024
Available online 25 June 2024

Keywords:
Pollution
HPI
Heavy metal
Freshwater ecosystem

Introduction

Due to natural and human activity, heavy metals are widely present in the environment. Living organisms are exposed to these metals via many routes (Wilson and Pyatt, 2007). Heavy metals refer to metallic components weighting atoms larger than forty and more than 5 g/cm^3 of gravity by weight. However, this phrase excludes actinides, lanthanides, alkali metals, and metallic alkaline earth metals (Al-Hejuje et al., 2017). All heavy metals exist in surface waters in colloidal, particulate, and dissolved phases. The dissolved metals have a size below 0.45 µm and are found as free ions or unionized organometallic chelates or complexes or as colloids, excluding the alkaline earth metals, alkali metals, lanthanides, and actinides. They are among the most common environmental pollutants, and their occurrence in water, sediments, and biota is a result of inputs from natural or anthropogenic sources, which may include domestic effluents and sewage, atmospheric deposition through rainfall, gas faring, bush burning, fossil fuel combustion, paints (He et al., 2005). Urbanization and industrialization are among the main indices of national and global development. Still, despite enhancing the quality of life, they pose serious threats to the management of the natural ecosystem and public health (Umoren and Onianum, 2005).

Heavy Metal Pollution Index (HPI) is a rating technique and an effective tool for water quality assessment, especially for heavy metals (Reza and Singh, 2019). HPI is a rating that reflects the combined impact of various measured heavy metals on water quality (Balakrishnan and Ramu, 2016). Evaluation and understanding of the sources and impacts of heavy metals on water is important for effective water management and preservation of water sources. Determining water quality is one of the primary priorities that must be known when managing the water resources of any water body (Moyel et al., 2015). This study aimed to determine the extent of

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DOI: https://doi.org/10.22034/ijab.v12i3.2268

Table 1. the coordinates of the stations under study.

Stations	E	N
Qurna	47°27'5.76 "	31°00'24.48"
Hartha	47°45'40.32"	30°39'40.32"
Sindbad	47°48'15.84"	30°34'3.36"
Ashar	47°49'33.6"	30°33'11.52"
Mhela	47°53'52.8"	30°28'26.4"
Seba	48°16'7.68"	30°19'48.00"
Faw S_7	48°27'47.52"	30°00'21.6"

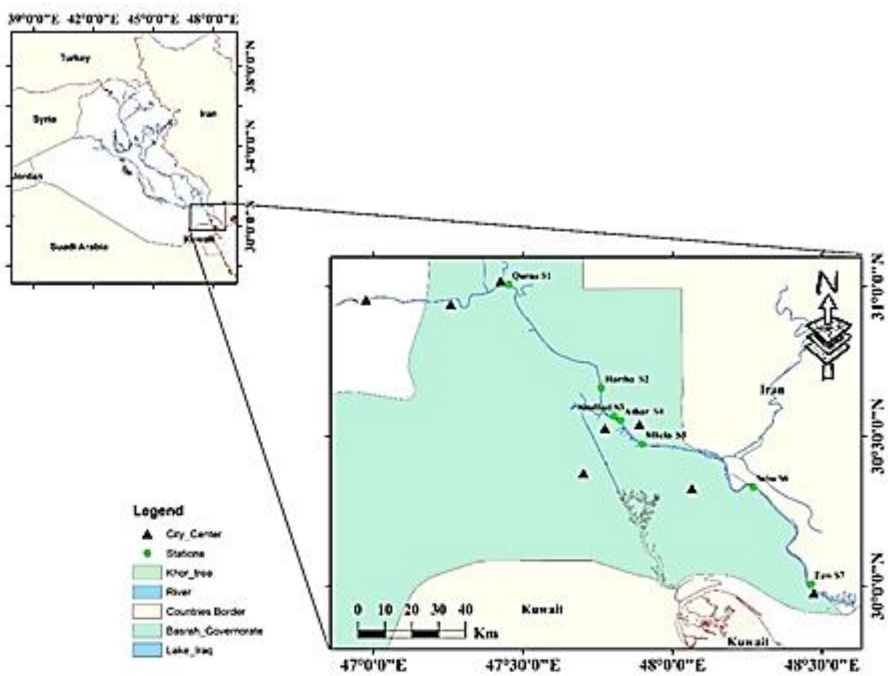

Figure 1. The sampling site and study area map.

pollution in the waters of the Shatt al-Arab for five important and influential heavy elements using the HPI pollution index.

Materials and Methods

Study area: The Shatt al-Arab is one of the main rivers in Iraq in general and in Basra Governorate in particular. It consists of the confluence of the Tigris and Euphrates rivers and is characterized by tidal phenomena. It continues to approximately 200 km in the southwestern direction of the Persian Gulf. The river is roughly 330 meters wide at its source, 400 meters wide in the middle, and 1250 meters wide in the estuary (Al-Asadi, 2016). The hydrological network of the Shatt al-Arab River is sophisticated, creating a distinct river environment that varies from other river environments in Iraq. Semi-diurnal tides, which are uneven in their range and timing, affect the Shatt al-Arab River (AL-Ramadan and Pastor, 1987). After 2008, the rivers and tributaries that feed the Shatt al-Arab River underwent significant hydrological changes that affected the freshwater that enters the river's mainstream. The drainage of the Shatt al-Arab River became completely dependent on the Tigris River after the Euphrates River was blocked and covered in 2010 in Medina, north of Basra Governorate. The Karkha River, which feeds the Shatt al-Suwaib River to the east, was closed, and the Karun River became the Bahmashar River, a canal within Iranian territory. The only way the Tigris River feeds the Shatt al-Arab River is through water flows from the Qal'at Saleh regulating dam (Al-Asadi, 2017). For the current study, seven water sampling stations along the Shatt al-Arab River were selected (Table 1, Fig. 1).

Table 2. The yearly average ($\mu g.L^{-1}$) and seasonal variations of the heavy metals in the Shatt al-Arab River water ways.

Stations	season	Cd	Pb	Zn	Fe	Mn
	Wet	28.2	69.0	3.67	8.4334	37.8
Qurna	Dry	17.5	161.1	241.2	2540.2	24.2
	annual	20.2	97.4	128.2	3286.4	36.8
	Wet	16.4	61.3	71.3	4779.3	34.0
Hartha	Dry	15.8	227.8	201.5	3385.4	28.4
	annual	15.3	119.4	109.9	3696.1	38.8
	Wet	57.3	51.2	57.8	5028.8	40.3
Sindbad	Dry	55.5	216.7	211.9	2344.4	27.4
	annual	45.1	110.1	106.4	3672.4	37.2
	Wet	49.5	69.6	63.5	3999.5	33.0
Ashar	Dry	69.2	237.3	214.2	2548.5	33.7
	annual	50.5	125.9	109.5	3217.7	38.4
	Wet	59.0	71.3	73.5	4055.0	34.3
Mhela	Dry	71.3	225.8	231.4	2409.1	42.9
	annual	53.7	119.4	124.2	3257.0	40.1
	Wet	65.5	69.8	158.3	4062.3	39.0
Seba	Dry	90.5	222.2	286.3	2477.9	46.6
	annual	61.5	120.6	190.7	3187.9	46.6
	Wet	41.8	92.2	102.8	5237.0	121.0
Faw	Dry	98.8	301.8	327.6	2440.2	139.7
	annual	57.1	155.3	195.7	4702.1	114.9
Standard concentrations ($\mu g.L^{-1}$)		5	50	500	300	100

Sampling and filed procedures: From October 2021 to September 2022, water samples were taken at seven stations along the Shatt al-Arab River: Qurna, Hartha, Sindbad, Ashar, Mhela, Seba, and Faw stations. Measurements were performed every month for an entire year. The heavy metals of manganese, iron, zinc, lead, and cadmium were estimated in water samples using standard methods (APHA, 2017). A 100 ml sample was digested using a hot plate with 5 ml of concentrated nitric acid (HNO_3) and 1 ml of concentrated hydrochloric acid (HCl). The instrument that measures atomic absorption was then used to measure the filtrate.

Index of heavy metal contamination (HPI): The HPI is determined in three steps: (1) calculating the weight of parameter I, (2) determining the standard score for each heavy metal, and (3) combining these sub-indicators into the overall index. The HPI is produced using the arithmetic weighted average quality method. The system of ratings is a random number with a range of zero to one that shows the relative importance of every aspect of the assessment. In addition, values can be assessed by inversely relating them to the suggested norm for the relevant variable (Horton, 1965; Mohan et al., 1996). Wi represents the unit weightage, the proportionality constant is represented by k, and Si is a suitable standard for the ith parameter (i = 1–5). These equations, $Wi = k / Si$, show how much weight each ith parameter has. The following represents an individual's quality rating: For every ith parameter, vi is its monitored value in µg/L, Si is its standard or acceptable limit, and Qi is its sub-index. $Qi = 100\ Vi / Si$. The equation below calculates the HPI: $HPI=\Sigma WiQi/\Sigma Wi$, where Qi corresponds to the ith parameter's sub-index. For each parameter, wi is the unit weightage, and n is the entire number of parameters considered. For water consumed, the HPI value for severe pollution rating is typically 10 (Prasad and Bose, 2001). January, February, March, and April were considered the wet season, and June, July, August, and September were considered the dry season. Additionally, calculations were conducted on an annual basis.

Results and Discussions

Table 2 shows the yearly average ($\mu g.L^{-1}$) and seasonal variations of heavy metals in the Shatt al-

Table 3. The seasonal values of the Heavy Metal Pollution Index (HPI) for the waters of the Shatt al-Arab.

Stations	season	wi*Qi	wi*Qi	wi*Qi (Zn)	wi*Qi (Fe)	wi*Qi (Mn)	Sum (Wi*Qi)	HPI
Qurna	Wet	112.8	2.76	0.02692	4.816444	0.378	120.7814	513.24
	Dry	70	6.444	0.09648	2.822444	0.242	79.60492	338.26
	annual	80.8	3.896	0.05128	3.651556	0.368	88.76684	377.20
Hartha	Wet	65.6	2.452	0.02852	5.310333	0.34	73.73085	313.30
	Dry	63.2	9.112	0.0806	3.761556	0.284	76.43816	324.81
	annual	61.2	4.776	0.04396	4.106778	0.388	70.51474	299.64
Sindbad	Wet	229.2	2.048	0.02312	5.587556	0.403	237.2617	1008.19
	Dry	222	8.668	0.08476	2.604889	0.274	233.6316	992.77
	annual	180.4	4.404	0.04256	4.080444	0.372	189.299	804.39
Ashar	Wet	198	2.784	0.0254	4.443889	0.33	205.5833	873.58
	Dry	276.8	9.492	0.08568	2.831667	0.337	289.5463	1230.37
	annual	202	5.036	0.0438	3.575222	0.384	211.039	896.77
Mhela	Wet	236	2.852	0.0294	4.505556	0.343	243.73	1035.68
	Dry	285.2	9.032	0.09256	2.676778	0.429	297.4303	1263.87
	annual	214.8	4.776	0.04968	3.618889	0.401	223.6456	950.34
Seba	Wet	262	2.792	0.06332	4.513667	0.39	269.759	1146.28
	Dry	362	8.888	0.11452	2.753222	0.466	374.2217	1590.18
	annual	246	4.824	0.07628	3.542111	0.466	254.9084	1083.18
Faw	Wet	167.2	3.688	0.04112	5.818889	1.21	177.958	756.20
	Dry	395.2	12.072	0.13104	2.711333	1.397	411.5114	1748.63
	annual	228.4	6.212	0.07828	5.224556	1.149	241.0638	1024.35

Arab River, and Table 3 reveals the seasonal values of HPI in the studied stations. The lowest Mn value was recorded at 24.2 μg/L. According to the Iraqi River Maintenance System, its permissible range is 100 $\mu g.L^{-1}$, and all stations were under this value except the seventh station (Faw) (Table 2). The lowest value of Fe was recorded at 8.4334 $\mu g.L^{-1}$ during the rainy season at the site Qurna, and the highest at the site Al-Faw with 5237.0 $\mu g.L^{-1}$ during the rainy season. This indicates that, following the guidelines of the 1967 standard for protecting Iraqi rivers, levels of Fe were significant in all sites examined except the first station (Qurna).

The lowest Zn was recorded in the first station at 3.67 $\mu g.L^{-1}$ in the wet season. The standard limit for river water pollution was 500 $\mu g.L^{-1}$, and our findings are consistent with the results of Al-Khuzaie et al. (2020), as the zinc values in their study ranged from 0.314 to 0.197 $mg.L^{-1}$. The lowest Pb concentration was at 51.2 $\mu g.L^{-1}$ in the third station (Sinbad) during the wet season, while the highest concentration was recorded in the Al-Faw station at 301.8 $\mu g.L^{-1}$ during the dry season. The levels of Hg surpassed the 50 $\mu g.L^{-1}$ threshold of the 1967 standard for safeguarding rivers against contamination in all studied stations. The values in this study agree with those of Hassan et al. (2008), as Pb concentrations were within the range of 0.109-0.200 $mg.L^{-1}$. This is also consistent with Al-Khuzaie et al. (2020), as Pb concentrations were 0.217-0.137 $mg.\ L^{-1}$. This originated from industry, farms, and runoff waters. In addition, surfactants transfer the pollutants with rain from the air to the ground, which increases the concentration of Pb in the water, too.

As for Cd, its lowest concentration was recorded at 15.3 $\mu g.L^{-1}$ at the second station (Haritha) on an annual average. The highest concentration of Cd was 98.8 $\mu g.L^{-1}$, recorded in the FAO station during the dry season. The levels of Cd were higher than the standard of a clean river, which set the acceptable concentration at 5 $\mu g.L^{-1}$. These results indicate that Mn and Zn did not exceed the permissible limits. In contrast, Fe, Pb, and Cd exceeded the limits, indicating the presence of sources of pollution for these elements.

The results showed that HPI was high at all stations during the wet and dry seasons and on the annual average (Table 3), i.e., the water of the Shatt al-Arab River has significant pollution, particularly in the summer. During the wet season, Al-Siba, the sixth station, had the highest index value of 1146.28, while

Harita, the second station, recorded the lowest value of 313.30. Al-Faw, the final station, reported the greatest value (1748.63) during the dry season, while Haritha, the second place, reported the lowest value (324.81). Comparing the annual average of the six stations, Al-Siba and Al-Hartha had the highest pollution rate (1083.18) and the lowest (299.64), respectively.

Based on the results, the Shatt al-Arab water contains high concentrations of Cd, Pb, and Fe, and this is consistent with the findings of Al-Hejuje et al. (2017), who indicated that the river water is polluted with these three elements. The high concentrations of these elements result from a group of factors, including anthropological activities, such as waste resulting from the agricultural process, such as fertilizer and pesticide residues, industrial and sewage waste, garbage decomposition, air pollution, and natural sources. The concentrations of pollution in rivers and soils near industrial areas of this river are high when compared to other sites in Basra (Akesh, 2016), and these values are consistent with the results of Al-Khuzaie et al. (2020) study on the quality of Shatt al-Arab water based on heavy metals e.g., Cd concentrations were 0.025-0.011 $mg.L^{-1}$. Based on the findings of Moyel et al. (2015), the river water Cd concentrations had the range of 0.019-0.076 $mg.L^{-1}$, in addition to other elements present in the river sediments.

Al-Asadi et al. (2020) showed that the sediments of the Shatt al-Arab contain high concentrations of heavy metals, especially in the Al-Faw. The main sources of this pollution reported the effect of the tidal phenomenon, characteristic of the Shatt al-Arab, and the presence of phytoplankton, representing the main suspended materials in this river. They play an important role in the seasonal changes of heavy elements in the water, which are effectively linked to many environmental factors. These plankton can accumulate heavy elements in higher concentrations than in the environment (Al-Sabah, 2007). In addition to the atmospheric deposition that accompanies the production processes of oil and electrical generators, runoff from agricultural areas after rainfall is involved in the pollution of this river.

Conclusions

In the current study, the concentrations of the heavy metals in this research had an order as follows: Pb > Cd > Fe, while the concentrations of Mn and Zn were high but did not exceed the limits of the Iraqi river maintenance system from river pollution, except for the Al-Faw station. HPI showed a gradual increase toward the south, i.e., downstream. At the final station, Al-Faw, they reached the highest value because of the station's exposure to tidal waters from the Persian Gulf. In the summer, it increased and had more value from the upper stream toward the downstream of the Shatt al-Arab River.

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