Biological and Applied Environmental Research

Vol. 6(2): 162-177, 2022

https://doi.org/10.51304/baer.2022.6.2.162

ISSN: 2002-6153
Biol. Appl. Environ. Res.
www.baerj.com
editor@baerj.com

Long Term Monitoring of Heavy Metal Pollutants in Sediment of Southern Iraq

Inaam A. Qzar*, Israa A. Al-Gizzi & Fadya M. Saleem

Department of Ecology, College of Science, University of Basrah, Iraq

*Corresponding author: inaam.abdulhusein@uobasrah.edu.iq

Abstract: The levels of seven heavy metals (Cd, Co, Cu, Fe, Ni, Pb and Zn) were determined in the sediment samples from different water bodies southern Iraq. Distribution of these heavy metals in sediment showed variations in concentration with sampling site, it was undetectable for Cd and Pb for all sites, while the highest concentration was 2.207 µg/g for Ni in the upper and the middle part of Shatt Al-Arab River. Co, Cu, Fe, Ni and Zn ranged from 0.083, 0.402, 1.829, 0.214 and 0.307 µg/g, respectively in Al-Chibayish Marsh to 0.486, 0.863, 2.186, 2.207 and 1.343 µg/g, respectively in the middle part of Shatt Al-Arab River. The geoaccumulation Index (Igeo) was calculated for the metals in the sediment of this study and for all other findings since 2001, to evaluate the levels of sediment pollution with heavy metals. The values of Igeo indicated that the sediment of southern Iraq were mostly unpolluted with heavy metals, except for Cd which was the polluting element in almost all of the previous studies.

Keywords: Heavy metals, Igeo, Marsh, Sediment, Shatt Al-Arab River, Southern Iraq

Introduction

All environments, such as freshwater or marine ecosystem, have a low concentration of most of the heavy metals that naturally occurred in the Earth's crust or come from dust storms (Jassim et al., 2021) in addition to those come from different sources of pollution in the area (Issa et al., 2020). Sediment act as a sink for heavy metals that makes it a possible source for water pollution in case of any changes in environmental conditions (Al-Hejuje, 2014; Al-Edresy et al., 2019; Cui et al., 2019).

Heavy metals occur in the aquatic environment either in water, suspended load, or in deposited sediment. However, measuring their concentrations in water for a short period does not give accurate results on the extent of pollution due to heterogeneity in water discharges, as well as the irregularity of topical releases of these pollutants. So, there were a focus on the sediment as it act as a recipient of all kinds of pollutants and organic matter that fall from the water column above, because they reflect more stable indicators about the degree of heavy element pollution of water environment (Al-Sayegh & Taka, 2002). Sediment is also a good

Received Jan. 10, 2022, accepted Apr. 6, 2022

indicator for pollution due to its ability of archiving many types of pollutants in the aquatic ecosystem (Adam et al., 2007; Azeez & Mahdi, 2019).

Trace elements, especially the heavy ones, are not soluble for long periods of time in water as they appear in the form of suspended or stabilized particles by plankton. The heavy metals are easy to be attracted and captured by clay minerals, organic compounds, iron or manganese hydroxides and other metals or carbonates (Njinga et al., 2011). They accumulate on surface sediment or adsorb by aquatic organisms (Ali et al., 2019; Yousif et al., 2021). Therefore, their concentration in surface sediment or in plants is evidence of water pollution with these elements. So, the percentage of pollutants and concentrations of minerals rises in the sediment more than in water (Qzar, 2009). Thus, sediment act as a potential source of pollution in aquatic environment and used to record the history of pollution (Hassan et al., 2008).

In recent years, the rapid growth of population is associated with the expansion of industrial sector, which raises the heavy metals concentration in the environment. Many studies have been conducted to assess heavy element pollution in water bodies south of Iraq. Qazar et al. (2019) reviewed most of them in the water for both particulate and dissolved phase from 1985 till 2016. Many researchers have studied heavy metals concentration in sediment of Southern Iraq since 1985 such as Abaychi & DouAbul (1985), Al-Khafaji (2001) and Awad et al. (2004) who didn’t find any serious pollution in Shatt Al-Arab River sediment. On the other hand, Hassan (2007) and Al-Hechamai (2012) found that the sediment were strongly polluted with cadmium for the same river.

This study aims to determine the geochemical distribution of the trace elements in sediment south of Iraq and the levels of pollution with heavy metals from 1985 to 2019, providing a comprehensive view of the pollution with heavy metals.

Materials and Methods

Sixteen sediment samples were collected in early spring 2019 from four areas south of Iraq including upper and middle part of Shatt Al-Arab River, Al-Hammar and Al-Chibaysh marshes (Table 1, Fig. 1). Sediment samples were dried out, finely ground, sieved with a pore size of 63µm, digested according to R.O.P.M.E. (1987) and analyzed using flame atomic absorption spectrophotometer type Phoenix 986 (UK).

Most of researches in the field of heavy element pollution in sediment of the southern region of Iraq were reviewed, a sole value for each trace elements in each individual study was obtained by calculating the mean annual value for each element in the concerned study. These studies were classified in three groups according to their location; Shatt Al-Arab River group, which includes all the studies conducted about this river from its beginning until the estuary and the nearby region of the Arabian Gulf. Second group is the southern marshes group, which includes three major marshes; Al-Hammar, Al-Chibayish and Al-Hawizah. Third group includes many different water bodies in Basrah and Thi-Qar provinces.

Table 1: Locations of studied stations.

Station	North	East
Upper part of Shatt Al-Arab River	31˚00'02''	47˚27'22''
	30˚48'25''	47˚34'49''
Middle part of Shatt Al-Arab River	30˚33'31''	47˚47'58''
	30˚30'13''	47˚51'30''
Al-Hammar Marsh	30˚40'04''	47˚38'34''
	30˚36'39''	47˚40'13''
Al-Chibayish Marsh	30˚59'05''	47˚07'10''
	30˚58'59''	47˚02'08''

Figure 1: Map of Southern Iraq.

Data Processing

Concentration of Elements

Seven heavy metals were considered: Cd, Co, Cu, Fe, Ni, Pb and Zn. The average value of each trace element concentration in the reviewed studies was calculated individually, from 1985 till the recent study in 2019, to compare their spatial and temporal distribution, concentration and pollution levels. All the data were analyzed (one-way ANOVA) using Minitab 16.1 software to identify the existence of spatial and temporal significant differences with 5% as a significance degree.

Geoaccumulation Index (Igeo)

Igeo, which was first introduced by Müller (1969), was used to show the level of pollution of the sediment by Cd, Cu, Fe, Ni, Pb and Zn. This index identifies a single metal pollutant or the co-pollutant of multiple metals in urban areas by comparing the metal concentration in the sediment with its permissible limits. The geochemical background concentration of that metals was based on CBSQG (2003).

Igeo = log2 [Cn/ 1.5 Bn]
Where:
Cn: The measured concentration of the analyzed metal in the samples.
Bn: The geochemical background concentration of the metal.
1.5: The factor used because of possible variations in background values due to lithological variability.
The calculated value will be compared with Table 2 to identify the pollution level.

Table 2: Categories of Igeo classes.

Igeo value	Description
Igeo ≤ 0	Unpolluted (unP)
0 ≤ Igeo ≤ 1	Unpolluted- moderately polluted (unP-M)
1 ≤ Igeo ≤ 2	Moderately polluted (M)
2 ≤ Igeo ≤ 3	Moderate- strongly polluted (M-S-P)
3 ≤ Igeo ≤ 4	Strongly polluted (S-P)
4 ≤ Igeo ≤ 5	Strongly- extremely polluted (S-E-P)
5 ≤ Igeo	Extremely polluted (E-P)

Results and Discussion

Heavy metals Concentration

Concentrations of all studied heavy metals were low or not detected. They were also much lower than what was recorded during all the past years attributed to the heavy rains in winter and early spring 2019, which leads to a great dilution of pollutants in water. Pb and Cd were undetected, while Fe was significantly lower than its concentration in the previous studies, it was more than 2000 times lower as recorded in some studies (Table 3).

Table 3: Heavy metals concentration (µg/g dry weight) in sediment of some areas in south of Iraq 2019.

Location	Cd	Co	Cu	Fe	Ni	Pb	Zn
Upper part of Shatt Al-Arab River	ND	0.391	0.707	2.011	2.207	ND	1.017
Middle part of Shatt Al-Arab River	ND	0.486	0.863	2.186	2.207	ND	1.343
Al-Hammar Marsh	ND	0.385	0.724	1.877	1.931	ND	0.963
Al-Chibayish Marsh	ND	0.083	0.402	1.829	0.214	ND	0.307

ND= Not detected.

For the southern Iraqi region, heavy element concentration varied throughout the years (Tables 4, 5 & 6). This variability resulting from different probabilities, such as change in natural phenomena like weathering and erosion or washing to groundwater in addition to change in non-natural additives such as human factors (Hassan et al., 2008).

Temporally, there were significant changes in the studies dealing with metals concentration in Shatt Al-Arab River through the time except for Ni and Pb. Cd reached a high dangerous level according to Al-Shamary et al. (2015), while Co was significantly higher in 2008 according to Mahmood (2008). The current study shows the presence of a significant lower concentration of Co. Fe concentration was high in almost all studies, although it was significantly high in Al-Muddafar et al. (1992) and Al-Timari et al. (2001). Spatially, there were no significant differences for all the studied metals along Shatt Al-Arab River (Table 4).

Table 4: Spatiotemporal variations of some heavy metals concentration (µg/g dry weight) in sediment of Shatt Al-Arab River and Arabian Gulf from 1985-2019.

Location	Cd	Co	Cu	Fe	Ni	Pb	Zn	Reference
Shatt Al-Arab River	0.03	17.4	39.6	6205	57.2	19	25.8	Abaychi & Al-Saad (1988)
	-	-	6.51	-	12.23	1.58	-	Daigham (1989)
	0.05	-	30	31800	421	61.5	135	Al-Muddafar et al. (1992)
	-	64.988	-	15009.35	92.695	-	-	Al-Hejuje (1999)
	0.22	10.68	21.66	-	526.8	16.3	34.7	Al-Khafaji (2005)
	24.52	-	36.61	14443.29	-	263.47	149.28	Hassan (2007)
	-	-	26.69	1911.03	-	83.78	75.56	Alshmery (2013)
Upper part of Shatt Al-Arab River	7.46	255.97	24.4	7500.33	201.09	46.53	89.66	Mahmood (2008)
	15.5	-	-	-	-	42.83	-	Al-Hechamai (2012)
	79.6	-	-	-	-	-	111.3	Al-Shamary et al. (2015)
Middle part of Shatt Al-Arab River	0.175	17	33.9	6801	655	34.4	63	Abaychi & DouAbul (1985)
	0.03	-	39	-	-	19.3	24.8	Abaychi & Mustafa (1988)
	0.2	-	-	6731	-	16.1	62.8	Al-Khafaji (2001)
	0.57	-	53.21	-	352.25	70.35	68.86	Atte (2004)
	5.58	-	-	-	39.44	15.35	21.12	Awad et al. (2004)
	6.39	86.155	4.3	4119.55	-	16.6	235.4	Al-Saffie (2005)
	6.99	261.78	23.66	7225.4	150.22	178.77	198.87	Mahmood (2008)
	-	-	52.4	-	-	117.56	-	Haneff (2009)
	8.12	-	-	8317.19	-	69.3	74.1	Al-Milky (2011)
	20.62	-	-	-	-	53.4	-	Al-Hechamai (2012)
	13.08	-	44.11	20485.79	234.64	104.97	106.21	Al-Hejuje (2014)
	37.72	-	-	-	-	-	66.96	Al-Shamary et al. (2015)
Lower part of Shatt Al-Arab River	6.53	236.2	20.44	6441.55	141.74	48.53	138.11	Mahmood (2008)
	25.88	-	-	-	-	68.97	-	Al-Hechamai (2012)
Shatt Al-Arab Estuary	0.12	-	15.9	2494.95	252.9	9.05	10.1	Al-Saad & Al-Khafaji (1996)
	0.27	16.98	29.24	5210.5	104.2	17.74	31.99	Al-Khafaji (1996)

	33.75	-	-	723.25	158.9	20.42	42.1	Al-Khafaji (1997)
	8.67	277.09	19.18	4579.71	116.86	44.43	128.99	Mahmood (2008)
	9.58	10.72	18.16	2924.8	48.2	30	34.36	Al-Shamsi et al. (2016)
Arabian Gulf	5	-	31.73	88.15	344.33	21.73	79.67	Al-Imarah & Al-Timari (1996)
	0.6	-	-	32506.7	81.97	23.7	96.52	Al-Timari et al. (2001)
Upper part of Shatt Al-Arab River	ND	0.391	0.707	2.011	2.207	ND	1.017	The present study
Middle part of Shatt Al-Arab River	ND	0.486	0.863	2.186	2.207	ND	1.343	The present study

ND= Not detected, -= No data.

There were no significant changes along time for all the studied elements in marshlands except Co. Spatially, the changes between the three marshes were insignificant for all the metals (Table 5).

Table 5: Spatiotemporal variations of some heavy metals concentration (μg/g dry weight) in sediment of southern marshes 1995-2019.

Location	Cd	Co	Cu	Fe	Ni	Pb	Zn	Reference
Al-Hawizah Marsh	88	-	397	-	-	1244	330	Awad et al. (2008)
	11.01	350.7	31.53	12011	182.29	55.37	97.23	Mahmood (2008)
	58	62	-	-	-	-	120	Al-Baidany (2013)
Al-Chibayish Marsh	-	-	13.1	-	118.14	31.1	-	Talal (2013)
	2.32	-	2.25	-	81.25	5.1	109.47	Al-Khafaji (2015)
	3.5	-	2.75	-	-	6.75	127	Al-Khafaji et al. (2015)
Al-Hammar Marsh	-	50	35.5	316.5	184.5	-	93	Abaychi (1995)
	0.56	-	36.8	61960	40	21	106	Al-Imarah et al. (1997)
	6.92	228.09	19.73	7051.63	137.41	46.95	101.63	Mahmood (2008)
	125	-	527	-	-	2233	241	Awad et al. (2008)
	0.37	-	16.13	-	-	3.29	26.7	Qzar (2009)
	3.62	223.3	19.8	-	122.64	41.65	420.5	Al-Yaseri (2011)
	-	-	14.7	-	122.76	67.94	-	Talal (2013)
	-	18.66	34.81	36541	167	11.06	76	Al-Gburi et al. (2017)
Al-Hammar Marsh	ND	0.385	0.724	1.877	1.931	ND	0.963	The present study
Al-Chibayish Marsh	ND	0.083	0.402	1.829	0.214	ND	0.307	The present study

ND= Not detected, -= No data.

Temporally, Cu, Pb and Zn were significantly higher in Basrah canals during 1997 according to Al-Hejuje. Spatially, Al-Jubayla Creek had higher levels of Fe, while Basrah canals had higher levels of Zn and Pb (Table 6).

It is well known that the concentration of pollutants including heavy metals in the rivers increases downstream due to the increase in the civil activities and variability in sediment discharges as a result of heterogeneity in basin geology, and the variation in screening during sediment transport (Al-Sayegh & Taka, 2002).

Shatt Al-Arab River represents the downstream of Tigris and Euphrates with all its pollutants. So, it is expected to have a high concentration of metals.

Abaychi & DouAbul (1985) explained the increased concentration of heavy metals of downstream due to the deposition of heavier particles along the river, leaving the lighter particles to the end, represented by the phytoplankton that accumulate trace elements in their body six times more than the surrounding environment.

The Geoaccumulation Index (Igeo)

Igeo results of the recent study showed a healthy situation of the studied areas (Table 7) this might be due to the heavy rains during winter 2019 at this region.

While most of the former studies demonstrate a dangerous level of Cd and Ni pollution in Shatt Al-Arab River, marshlands, and different water bodies in Basrah and Nassiriyah cities (Tables 8, 9 & 10). It was unpolluted with Cu, Fe and Zn for Shatt Al-Arab River (Table 8). Meanwhile Al-Hammar Marsh, Al-Hawiza Marsh 2008 (Table 9) and Al-Garaf River 2001 (Table 10) recorded Cu pollution. One can say also that there was no Fe pollution southern Iraq in most studies despite its high levels and the presence of wrecked ships along Shatt Al-Arab River since the 1980's of the last century. In terms of the current study and most of the reviewed studies, sediment were unpolluted with Pb and Zn in almost all the reviewed studies (Tables 7, 8 & 9). This is in agreement with Issa et al. (2020), who indicated unpolluted to moderate polluted Tigris River sediment.

Table 6: Spatiotemporal variations of some heavy metals concentration (µg/g dry weight) in sediment of some locations in Basrah and Nassiriyah provinces 1991-2016.

Location	Cd	Co	Cu	Fe	Ni	Pb	Zn	Reference
Al-Garaf River, Nassiriyah City	1.7	-	15.94	-	56.72	-	89.06	Fahad (2006)
	0.87	-	26	-	67.5	24.4	-	Al-Khazali (2012)
Euphrates at Nassiriyah City	0.3	-	30.4	2034	-	11.17	24.05	Al-Khafaji et al. (2011)
	5.87	-	17.75	2237.58	46.26	24.4	23.65	Al-Awady et al. (2015)
	0.19	21.9	31.7	-	171.5	8.86	66.2	Isa & Qanbar (2016)
Shatt Al-Basrah Canal	24.807	-	13.11	-	84.682	21.58	-	Al-Saa'don (2002)
Upper part of Shatt Al-Basrah Canal	-	-	29.025	-	-	18.075	13.1	Aziz et al. (2006)
North Basrah	12.22	10.93	9.785	-	10.306	-	-	Raaheem (2009)
Khor Al-Zubair	0.26	-	28	72	90	29	72	Al-Edanee et al. (1991)
	43.38	-	41.21	-	139.871	47.76	-	Al-Saa'don (2002)
	1.07	-	12.8	806.3	-	26.82	31.27	Sultan et al. (2013)
Basrah Canals	5.92	-	67.86	-	-	132.59	290.44	Al-Hejuje (1997)
Al Jubayla Creek	1.26	-	20.36	8684.75	-	22.68	55.97	Al-Khafaji (2000)
Um-Khaser	40.78	-	31.52	-	150.036	33.52	-	Al-Saa'don (2002)
Al-Masab Alamm	3.76	-	25.9	-	-	24.73	-	Al-Khafaji et al. (2012)

-= No data.

Table 7: Igeo results for heavy metals in sediment of some areas south of Iraq 2019.

Location	Cd	Desc.	Cu value	Desc.	Fe	Desc.	Ni	Desc.	Pb	Desc.	Zn	Desc.
Upper part of Shatt Al-Arab River	ND	unP	-6.08	unP	-13.87	unP	-3.96	unP	ND	unP	-7.46	unP
Middle part of Shatt Al-Arab River	ND	unP	-5.80	unP	-13.74	unP	-3.64	unP	ND	unP	-7.07	unP
Al-Hammar Marsh	ND	unP	-6.05	unP	-13.96	unP	-4.15	unP	ND	unP	-7.55	unP
Al-Chibaysh Marsh	ND	unP	-6.90	unP	-14.00	unP	-7.36	unP	ND	unP	-9.18	unP

ND= Not detected, Desc.= Description. See table 2 for other abbreviations.

Table 8: Igeo results for heavy metals in sediment of Shatt Al-Arab River and Arabian Gulf from 1985-2019.

Location	Reference	Cd	Desc.	Cu	Desc.	Fe	Desc.	Ni	Desc.	Pb	Desc.	Zn	Desc.
Shatt Al-Arab River	Abaychi & Al-Saad (1988)	-5.63	unP	-0.28	unP	-2.27	unP	0.73	unP-M	-1.51	unP	-2.80	unP
Shatt Al-Arab River	Daigham (1989)	-	-	-2.88	unP	-	-	-1.50	unP	-5.09	unP	-	-
Shatt Al-Arab River	Al-Muddafar et al. (1992)	-4.89	unP	-0.68	unP	0.08	unP-M	3.61	S-P	0.19	unP-M	-0.42	unP
Shatt Al-Arab River	Al-Hejuje (1999)	-	-	-	-	-1.00	unP	1.43	M-P	-	-	-	-
Shatt Al-Arab River	Al-Khafaji (2005)	-2.75	unP	-1.15	unP	-	-	3.93	S-P	-1.73	unP	-2.37	unP
Shatt Al-Arab River	Hassan (2007)	4.05	S-P	-0.39	unP	-1.05	unP	-	-	2.29	M-S-P	-0.27	unP
Shatt Al-Arab River	Alshmery (2013)	-	-	-0.85	unP	-3.97	unP	-	-	0.63	unP-M	-1.25	unP
Upper part of Shatt Al-Arab River	Mahmood (2008)	2.33	M-S-P	-0.98	unP	-2.00	unP	2.54	M-S-P	-0.21	unP	-1.01	unP
Upper part of Shatt Al-Arab River	Al-Hechamai (2012)	3.38	S-P	-	-	-	-	-	-	-0.33	unP	-	-
Upper part of Shatt Al-Arab River	Al-Shamary et al. (2015)	5.74	E-P	-	-	-	-	-	-	-	-	-0.69	unP
Middle part of Shatt Al-Arab River	Abaychi & DouAbul (1985)	-2.89	unP	-0.50	unP	-2.14	unP	4.25	S-E-P	-0.65	unP	-1.51	unP
Middle part of Shatt Al-Arab River	Abaychi & Mustafa (1988)	-5.63	unP	-0.30	unP	-	-	-	-	-1.48	unP	-2.86	unP
Middle part of Shatt Al-Arab River	Al-Khafaji (2001)	-2.89	unP	-	-	-2.16	unP	-	-	-1.75	unP	-1.52	unP
Middle part of Shatt Al-Arab River	Atte (2004)	-1.38	unP	0.15	unP-M	-	-	3.35	S-P	0.38	M-unP	-1.39	unP
Middle part of Shatt Al-Arab River	Awad et al. (2004)	1.91	M-P	-	-	-	-	0.19	unP-M	-1.81	unP	-3.09	unP
Middle part of Shatt Al-Arab River	Al-Saffie (2005)	2.11	M-S-P	-3.48	unP	-2.86	unP	-	-	-1.70	unP	0.39	unP-M
Middle part of Shatt Al-Arab River	Mahmood (2008)	2.23	M-S-P	-1.02	unP	-2.05	unP	2.12	M-S-P	1.73	M-P	0.14	unP-M
Middle part of Shatt Al-Arab River	Haneff (2009)	-	-	0.13	unP-M	-	-	-	-	1.12	M-P	-	-
Middle part of Shatt Al-Arab River	Al-Milki (2011)	2.45	M-S-P	-	-	-1.85	unP	-	-	0.36	unP-M	-1.28	unP
Middle part of Shatt Al-Arab River	Al-Hechamai (2012)	3.80	S-P	-	-	-	-	-	-	-0.02	unP	-	-
Middle part of Shatt Al-Arab River	Al-Hejuje (2014)	3.14	S-P	-0.12	unP	-0.55	unP	2.77	M-S-P	0.96	unP-M	-0.76	unP
Middle part of Shatt Al-Arab River	Al-Shamary et al. (2015)	-	-	-	-	-	-	-	-	-	-	-1.43	unP
Lower part of Shatt Al-Arab River	Mahmood (2008)	2.14	M-S-P	-1.23	unP	-2.22	unP	2.04	M-S-P	-0.15	unP	-0.38	unP
Lower part of Shatt Al-Arab River	Al-Hechamai (2012)	4.12	S-E-P	-	-	-	-	-	-	0.35	unP-M	-	-
Shatt Al-Arab Estuary	Al-Khafaji (1996)	-2.46	unP	-0.72	unP	-2.53	unP	1.59	M-P	-1.61	unP	-2.49	unP
Shatt Al-Arab Estuary	Al-Khafaji (1997)	4.51	S-E-P	-	-	-5.37	unP	2.20	M-S-P	-1.40	unP	-2.10	unP
Shatt Al-Arab Estuary	Al-Saad & Al-Khafaji (1996)	-3.63	unP	-1.59	unP	-3.59	unP	2.87	M-S-P	-2.58	unP	-4.16	unP
Shatt Al-Arab Estuary	Mahmood (2008)	2.55	M-S-P	-1.32	unP	-2.71	unP	1.76	M-P	-0.28	unP	-0.48	unP

Shatt Al-Arab Estuary	Al-Shamsi et al. (2016)	2.69	M-S-P	-1.40	unP	-3.36	unP	0.48	unP-M	-0.85	unP	-2.39	unP
Arabian Gulf	Al-Imarah & Al-Timari (1996)	1.75	M-P	-0.60	unP	-8.40	unP	3.32	S-P	-1.31	unP	-1.18	unP
Arabian Gulf	Al-Timari et al. (2001)	-1.31	unP	-	-	0.12	unP-M	1.25	M-P	-1.19	unP	-0.90	unP
Upper part of Shatt Al-Arab River	The present study	ND	unP	-6.08	unP	-13.87	unP	-3.96	unP	ND	unP	-7.46	unP
Middle part of Shatt Al-Arab River	The present study	ND	unP	-5.80	unP	-13.74	unP	-3.64	unP	ND	unP	-7.07	unP

ND= Not detected, Desc.= Description, -= No data. See table 2 for other abbreviations.

Table 9: Igeo results for heavy metals in sediment of southern marshes from 1995-2019.

Location	Reference	Cd	Desc.	Cu	Desc.	Fe	Desc.	Ni	Desc.	Pb	Desc.	Zn	Desc.
Al-Hammar Marsh	Abaychi (1995)	-	-	-0.44	unP	-6.57	unP	2.42	M-S-P	-	-	-0.95	unP
Al-Hammar Marsh	Al-Imarah et al. (1997)	-1.41	unP	-0.41	unP	1.05	M-P	0.21	unP-M	-1.36	unP	-0.76	unP
Al-Hammar Marsh	Mahmood (2008)	2.22	M-S-P	-1.28	unP	-2.09	unP	1.99	M-P	-0.20	unP	-0.82	unP
Al-Hammar Marsh	Awad et al. (2008)	6.40	E-P	3.46	S-P	-	-	-	-	5.37	E-P	0.42	unP-M
Al-Hammar Marsh	Qzar (2009)	-2.00	unP	-1.57	unP	-	-	-	-	-4.04	unP	-2.75	unP
Al-Hammar Marsh	Al-Yaseri (2011)	1.29	M-P	-1.28	unP	-	-	1.83	M-P	-0.37	unP	1.22	M-P
Al-Hammar Marsh	Talal (2013)	-	-	-1.71	unP	-	-	1.83	M-P	0.33	unP-M	-	-
Al-Hammar Marsh	Al-Gburi et al. (2017)	-	-	-0.46	unP	0.28	unP-M	2.28	M-S-P	-2.29	unP	-1.24	unP
Al-Chibayish marsh	Mashkhool (2012)	0.64	unP-M	-4.42	unP	-	-	1.24	M-P	-3.40	unP	-0.72	unP
Al-Chibayish Marsh	Talal (2013)	-	-	-1.87	unP	-	-	1.78	M-P	-0.80	unP	-	-
Al-Chibayish Marsh	Al-Khafaji (2015)	0.64	unP-M	-4.42	unP	-	-	1.91	M-P	8.11	E-P	-0.72	unP
Al-Chibayish Marsh	Al-Khafaji et al. (2015)	1.24	M-P	-4.13	unP	-	-	-	-	-3.00	unP	-0.50	unP
Al-Hawizah Marsh	Awad et al. (2008)	5.89	E-P	3.05	S-P	-	-	-	-	4.53	S-E-P	0.87	unP-M
Al-Hawizah Marsh	Mahmood (2008)	2.89	M-S-P	-0.61	unP	-1.32	unP	2.40	M-S-P	0.04	unP-M	-0.89	unP
Al-Hawizah Marsh	Al-Baidany (2013)	5.29	E-P	-	-	-	-	-	-	-	-	-0.58	unP
Southern marshes	Al-Imarah et al. (2007)	3.22	S-P	-1.95	unP	-7.41	unP	0.43	unP-M	-0.73	unP	0.12	unP-M
Al-Hammar Marsh	The present study	ND	unP	-6.05	unP	-13.96	unP	-4.15	unP	ND	unP	-7.55	unP
Al-Chibaysh Marsh	The present study	ND	unP	-6.90	unP	-14.00	unP	-7.36	unP	ND	unP	-9.18	unP

ND= Not detected, Desc.= Description, -= No data. See table 2 for other abbreviations.

Table 10: Igeo results for some locations in Basrah and Nassiriyah provinces from 1991-2016.

Location	Reference	Cd	Desc.	Cu	Desc.	Fe	Desc.	Ni	Desc.	Pb	Desc.	Zn	Desc.
Khor Al-Zubair	Al-Edanee et al. (1991)	-2.51	unP	-0.78	unP	-8.70	unP	1.38	M-P	-0.90	unP	-1.32	unP
Khor Al-Zubair	Al-Saa'don (2002)	4.87	S-E-P	-0.22	unP	-	-	2.02	M-S-P	-0.18	unP	-	-
Khor Al-Zubair	Sultan et al. (2013)	-0.47	unP	-1.91	unP	-5.22	unP	-	-	-1.01	unP	-2.53	unP
Al-Garaf River	Fahad (2006)	0.20	unP-M	9.58	E-P	-	-	0.72	unP-M	-	-	-1.02	unP
Al-Garaf River	Al-Khazali (2012)	-0.77	unP	-0.88	unP	-	-	0.97	unP-M	-1.15	unP	-	-
Euphrates at Nassiriyah City	Al-Khafaji et al. (2011)	-2.31	unP	-0.66	unP	-3.88	unP	-	-	-2.27	unP	-2.90	unP
Euphrates at Nassiriyah City	Al-Awady et al. (2015)	1.98	M-P	-1.44	unP	-3.74	unP	0.42	unP-M	-1.15	unP	-2.93	unP
Euphrates at Nassiriyah City	Isa & Qanbar (2016)	-2.97	unP	-0.60	unP	-	-	2.31	M-S-P	-2.61	unP	-1.44	unP
Shatt Al-Basrah Canal	Al-Saa'don (2002)	4.06	S-E-P	-1.87	unP	-	-	1.30	M-P	-1.32	unP	-	-
Shatt Al-Basrah Canal	Aziz et al. (2006)	-	-	-0.73	unP	-	-	-	-	-1.58	unP	-3.78	unP
Basrah canals	Al-Hejuje (1997)	2.00	M-P	0.50	unP-M	-	-	-	-	1.30	M-P	0.69	unP-M
Al Jubayla Creek	Al-Khafaji (2000)	-0.24	unP	-1.24	unP	-1.79	unP	-	-	-1.25	unP	-1.69	unP
Um-Khaser	Al-Saa'don (2002)	4.78	S-E-P	-0.61	unP	-	-	2.12	M-S-P	-0.69	unP	-	-
Main Drainage System	Atte (2004)	-1.93	unP	-1.09	unP	-	-	1.40	M-P	-1.15	unP	-2.95	unP
North Basrah	Raaheem (2009)	3.04	S-P	-2.29	unP	-	-	-1.74	unP	-	-	-	-
Al-Masab Alamm	Al-Khafaji et al. (2012)	1.34	M-P	-0.89	unP	-	-	-	-	-1.13	unP	-	-

ND= Not detected, Desc.= Description, -= No data. See table 2 for other abbreviations.

In conclusion, the sediment of the southern region of Iraq were polluted with Cd and Ni in most of the reviewed studies since 1985, while there is no significant pollution with other metals such as Cu, Fe and Zn. Rain season in late winter and early spring 2019 has led to a great dilution of heavy metals in sediment.

Acknowledgments

The authors of this paper would like to express a great appreciation to Prof. Najah A. Hussein for his valuable suggestions during the planning of this work and to Prof. Makia M. Al-Hejuje for her help in data analysis, their willingness to give their time and support that had been very much appreciated.

References

Abaychi, J.K. (1995). Trace elements distribution and sedimentation rate in Al-Hammar Lake, Southern Iraq. Mar. Mesop., 10(2): 379-392.

Abaychi, J. & Al-Saad, H.T. (1988). Trace elements in fish from the Arabian Gulf and the Shatt al-Arab River, Iraq. Bull Environ. Contam. Toxicol., 40(2): 226-323. DOI:10.1007/BF01881043.

Abaychi, J.K. & DouAbul, A.A.Z. (1985). Heavy metals in Shatt Al-Arab River, Iraq, Water Res., 19(4): 457-462. DOI:10.1016/0043-1354(85)90037-5.

Abaychi, J.K. & Mustafa, Y.Z. (1988). The Asiatic clam *Corbicula fluminea*: An indicator of trace metal pollution in the Shatt Al-Arab River, Iraq. Environ. Pollut., 54(2): 109-122. DOI:10.1016/0269-7491(88)90141-8.

Adam, R.S.; Al-Shawi, I.J.M. & Al-Imarah, F.J.M. (2007). Distribution of some chemical elements in marsh lands of Southern Iraq after rehabilitation. Marsh Bull., 2(1): 11-17.

Al-Awady, A.A.M.; Al-Khafaji, B.Y. & Abid, N.M. (2015). Concentration of some heavy metals in water, sediment and two species of aquatic plants collected from the Euphrates River, near the center of Al-Nassiriyia City, Iraq. Marsh Bull., 10(2): 161-172.

Al-Baidany, A.H. (2013). Geochemical assessment of trace element in core sediments from Hor Al-Ezaim, Southern Iraq. Marsh Bull., 8(2): 193-202.

Al-Edanee, T.E.; Al-Kareem, A.A. & Kadum, S.H.A. (1991). An assessment of heavy metals pollution in the Khor Al-Zubair environment. Mar. Mesop., 6(2): 143-154.

Al-Edresy, M.A.M.; Wasel, S.O. & Al-Hagibi, H.A. (2019). Ecological risk assessment of heavy metals in coastal sediments between Al-Haymah and Al-Mokha, south Red Sea, Yemen. Ecol. Conserv. Sci., 1(1): 14-28. DOI: 10.19080/ECOA.2019.01.555554.

Al-Gburi, H.F.A.; Al-Tawash, B.S. & Al-Lafta, H.S. (2017). Environmental assessment of Al-Hammar Marsh, Southern Iraq. Heliyon, 3(2) e00256. DOI:10.1016/j.heliyon.2017.e00256.

Al-Hechamai, A.M. (2012). Using LaGrange interpolation model for assessment of cadmium and lead in water and tissues from two Shatt Al-Arab's River fish. M. Sc. Thesis. Coll. Agric., Univ. Basrah: 127 pp. (In Arabic).

Al-Hejuje, M.M. (1997). Distribution of heavy elements in water and sediments from Al-Ashar and Al-Khandak canals connected with Shatt Al-Arab River and their effects on Algae. M. Sc. Thesis, Coll. Sci., Univ. Basrah: 104 pp. (In Arabic).

Al-Hejuje, M.M. (1999). Distribution of cobalt, nickel, manganese and iron in the sediment from Al-Ashar and Al-Khandak canals connected with Shatt Al-Arab River, Basrah. Mar. Mesop., 14(2): 365-379.

Al-Hejuje, M.M.K. (2014). Application of water quality and pollution indices to evaluate the water and the sediments status in the middle part of Shatt Al-Arab River. Ph. D. Thesis, Coll. Sci., Univ. Basrah: 240 pp.

Ali, H.; Khan, E. & Ilahi, I. (2019). Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. Hindawi J. Chem., Vol. 2019, Article ID 6730305: 14 pp. DOI:10.1155/2019/6730305.

Al-Imarah, F.J.M. & Al-Timari, A.A. (1996). Heavy metals in core sediments from North West Arabian Gulf. Mar. Mesop., 11(1): 1-15.

Al-Imarah, F.; Al-Timari, A. & Al-Edanee, T. (1997). Determination and comparison of heavy metals in shrimps and sediments from Iraq and Kuwait. Mar. Mesop., 12(1): 25-38.

Al-Imarah, F.J.M.; Mahmood, A.A. & Al-Mayah, A.R.A. (2007). Levels and distribution of heavy metals in the southern wetlands of Iraq. Marsh Bull., 2(2): 155-170.

Al-Khafaji, B.Y. (1996). Heavy metals in water, sediments and fishes from Shatt Al-Arab Estuary north-west Arabian Gulf. Ph. D. Thesis, Coll. Educ., Univ. Basrah: 131 pp.

Al-Khafaji, B.Y. (1997). Some heavy metals in *Cyprinus carpio* L. and *Tenualosa ilisha* from Shatt Al-Arab Estuary. Mar. Mesop., 12(1): 47-62.

Al-Khafaji, B.Y. (2000). Preliminary survey of selected heavy metals in Al-Jubayla Creek connected with Shatt Al-Arab River. Mar. Mesop., 15(1): 69-80.

Al-Khafaji, B. (2001). The initial assessment of some heavy metals in Qarmatt-Ali River connected with Shatt Al-Arab. Iraqi J. Biol., 1(1): 175-186.

Al-Khafaji, B.Y. (2005). Metal content in sediment, water, and fishes from the vicinity of oil processing regions in Shatt Al-Arab. J. Univ. Thi-Qar, 1(2): 2-11.

Al-Khafaji, B.Y. (2015). A comparison in accumulations of heavy metals in two species of aquatic plants in Al-Chibayish Marsh south of Iraq. Marsh Bull., 10(2): 112-122.

Al-Khafaji, B.Y.; Al-Awady, A.A. & Farhood, A.T. (2015). Distribution of some heavy metals in Al-Chibayish Marsh of part ecosystem in Thi-Qar Province in Southern Iraq. World J. Pharm. Res. 4(8): 1443-1456.

Al-Khafaji, B.Y.; Dawood, Y.T. & Maktoof, A.A. (2012). Bioaccumulation of some heavy metals (Pb, Cd and Cu) in common carp *Cyprinus carpio* relevant to their concentration in water and sediment of Al-Masab Alamm for Al-Nassiriyia City. Marsh Bull., 7(1): 17-26.

Al-Khafaji, B.; Mohammed, A. & Maqtoof, A. (2011). Distribution of some heavy metals in water, sediment and fish *Cyprinus carpio* in Euphrates River near Al-Nassiriya City center south Iraq. Baghdad J. Sci., 8(1): 552-560.

Al-Khazali, A.M.G. (2012). Ecological study of Mollusca and determination of heavy elements concentration in water, sediment and snail species in Al-Garaf River-Thi Qar/south of Iraq. M. Sc. Thesis, Coll. Educ., Univ. Basrah: 114 pp. (In Arabic).

Al-Milky, H.A.A. (2011). Seasonal variations in concentration of some heavy metals in the components of Shatt Al-Arab River ecosystem at Basrah. M. Sc. Thesis, Coll. Sc., Univ. Basrah: 122 pp. (In Arabic).

Al-Muddafar, N.A.; Jassim, T.E. & Omer, I.N. (1992). Distributional of heavy metals in sediments and biota from Shatt Al-Arab, Iraq. Mar. Mesop., 7(1): 49-61.

Al-Saad, H.T. & Al-Khafaji, B.Y. (1996). Distribution of heavy metals in water, sediments and biota samples from Shatt Al-Arab Estuary. Mar. Mesop., 11(1): 63-77.

Al-Saa'don, W.J.F. (2002). Determination and distribution of total petroleum hydrocarbons and heavy metals in waters and sediments from Shatt Al-Basrah and Khor Al-Zubair, Southern Iraq. Ph. D. Thesis, Coll. Educ., Univ. Basrah: 150 pp.

Al-Saffie, A.G.A. (2005). Study of some of heavy elements in water, sediments and phytoplankton in Shatt Al-Arab River. M. Sc. Thesis, Coll. Sc., Univ. Basrah: 85 pp. (In Arabic).

Al-Sayegh, A.Y. & Taka, A.S. (2002). Environmental pollution. Univ. Mosul Press: 247 pp. (In Arabic).

Al-Shamary, A.C.; Al-Ali, M.F. & Al-Najar, G.A. (2015). Valuation the concentration of the two elements (Zinc and Cadmium) in water and sediments and in Asian catfish *Silurus triostegus* of Shatt Al-Arab River in Southern Iraq. Basrah J. Agric. Sci., 28(2): 1-13. (In Arabic).

Al-Shamsi, Z.S.R.; Mohammed, A.A. & Al-Saad, H.T. (2016). Heavy metals in residual sediments core along Shatt Al-Arab Estuary. J. Pharm. Chem. Biol. Sci., 4(3): 440-449.

Alshmery, A.Y.H. (2013). Estimation of some heavy metals in clams, sediments and water from Shatt Al-Arab and treatment rocks porcellanite. M. Sc. Thesis, Coll. Educ., Univ. Basrah: 100 pp. (In Arabic).

Al-Timari, A.A.K.; Nasir, A.M. & Al-Imara, E.A. (2001). Seasonal variations of trace elements in the shrimp *Penaeus semisulcatus* from the Arabian Gulf. Basrah J. Sci., C, 19(2): 55-62.

Al-Yaseri, S.T. (2011). Concentrations of heavy metals in sediment of the southern part of Al-Hammar Marsh, Iraq. Marsh Bull., 6(1): 9-22.

Atte, R.S. (2004). Water quality criteria in the Shatt Al-Arab River and the Main Drainage System with levels of some heavy metals pollutants. Ph. D. Thesis, Coll. Agric., Univ. Basrah: 124 pp. (In Arabic).

Awad, N.A.N.; Abdulsahib, H.T. & Jaleel, A.A. (2008). Concentrations of heavy metals in aquatic plants and sediments of the southern marshes of Iraq (Al-Hawizah and Al-Hammar). Marsh Bull., 3(1): 57-66.

Awad, N.A.N.; Faisal, W.J. & Abdul-Nabi, A.S. (2004). Determination of total petroleum hydrocarbons and heavy metals in water and sediments from Shatt Al-Arab River. Mar. Mesop., 19(1): 19-35.

Azeez, N.M. & Madhi, A.K. (2019). Concentrations of some heavy elements in water, sediments and some aquatic plants in the Euphrates River in Al-Muthanna Province- Iraq. Mash Bull., 14(2): 111-120.

Aziz, N.M.; Al-Adhub, A.H.Y. & Al-Imarah, F.J.M. (2006). *Phragmites australis* and *Typha domengensis* as bioaccumulators and biomonitors of three heavy metals along Shatt Al-Basra Canal, south of Hammar Marsh. Marsh Bull., 1(2): 173-183.

CBSQG (Consensus-Based Sediment Quality Guidelines) of Wisconsin. (2003). Consensus-based sediment quality guidelines: Recommendations for use & application. Interim Guidance RR-088. Department of Natural Resources, Wisconsin: 35 pp.

Cui, S.; Zhang, F.; Hu, P.; Hough, R.; Fu, Q.; Zhang, Z.; An, L.; Li, Y.-F.; Li, K.; Liu, D. & Chen, P. (2019). Heavy metals in sediment from the urban and rural rivers in Harbin City, Northeast China. Int. J. Environ. Res. Public Health 16(22), 4313. DOI:10.3390/ijerph16224313.

Daigham, A.L. (1989). Effect of some heavy metals and environmental factors on the survival of *Sesarma bouleugeri* Calman in Shatt Al-Arab. M. Sc. Thesis, Coll. Educ., Univ. Basrah: 111 pp. (In Arabic).

Fahad, K. (2006). Ecological survey for southern sector of Al-Garaf River, Southern Iraq. Ph. D. Thesis, Coll. Agric., Univ. Basrah: 103 pp. (In Arabic).

Haneff, R.A.K. (2009). Bio-accumulation of copper and lead in three species of aquatic plants from Shatt Al-Arab. M. Sc. Thesis, Coll. Agric., Univ. Basrah: 105 pp. (In Arabic)

Hassan, W.F. (2007). Geochemical and hydrochemical study at Shatt Al-Arab Chanal sediments and overlying water. Ph. D. Thesis, Coll. Agric., Univ. Basrah: 206 pp. (In Arabic).

Hassan, W.F.; Albadran, B.N. & Faraj, M.A. (2008). The geochemical distribution of heavy metals in Shatt Al-Arab River sediments. Mar. Mesop., 23(2): 419-436. (In Arabic).

Isa, M.J. & Qanbar, A.S. (2016). Assessment of heavy metal contamination in Euphrates River sediments from Al-Hindiya Barrage to Al-Nasiria City, South Iraq. Iraqi J. Sci., 57(1A): 184-193.

Issa, M.J.; Al-Obaidi, B.S. & Muslim, R.I. (2020). Evaluation of some trace elements pollution in sediments of the Tigris River in Wasit Governorate, Iraq. Baghdad Sci. J., 2020, 17(1): 9-22. DOI:10.21123/bsj.2020.17.1.0009.

Jassim, H.H.; Salman, I.M. & Al-Khafaji, R.M.N. (2021). Sedimentological and heavy metals characteristics of streets dust in some areas east of Baghdad for 2020. Iraqi Geol. J., 54 (2C): 117-125. DOI:10.46717/igj.54.2C.11Ms-2021-09-30.

Mahmood, A.A. (2008). Concentrations of pollutants in water, sediments and aquatic plants in some wetlands in south of Iraq. Ph. D. Thesis, Coll. Sci., Univ. Basrah: 244 pp (In Arabic).

Mashkhool, M.A. (2012). Concentrations of some heavy metals in water, sediments and two types of plants in Al-Chibayish Marsh in Thi-Qar Province in Southern Iraq. M. Sc. Thesis, Univ. Queensland, Australia: 79 pp.

Müller, G. (1969). Index of geoaccumulation in sediments of the Rhine River. Geol. J., 2(3): 108-118. Cited by: Farkas A.; Erratico, C. & Viganò, L. (2007). Assessment of the environmental significance of heavy metal pollution in surficial sediments of the River Po. Chemosphere, 68: 761-768.

Njinga, R.L.; Alfa, B.; Sunday, O. & Muhammad, T.A. (2011). Evaluation of trace elements in clay sediments products of tatiko locality using x-ray fluorescence technique. Adv. Appl. Sci. Res., 2(6): 370-378.

Qazar, I.A.; Salem, F.M. & Aied, I.A. (2019). Spatiotemporal variations in the heavy metal pollution index (HPI) values southern Iraq. 8th National Conference on Environment and Natural Resources, 14-15/11/1028: 94-108.

Qzar, E.A.A. (2009). Concentration of heavy metals in environment and some Gastropoda (Mollusca) in East Hammar Marsh. M. Sc. Thesis, Coll. Sci., Univ. Basrah: 121 pp. (In Arabic).

R.O.P.M.E. (The Regional Organization for the Protection of the Marine Environment, Kuwait) (1987). State of the marine environment in the ROPME Sea Area. UNEP Regional Seas Reports and Studies No. 112: iii + 34 pp.

Raaheem, A.Z. (2009). Distribution of heavy metals in sediments of north zone of Basrah Governorate. Marsh Bull., 4(1): 75-84.

Sultan, A.W.A.; Al-Hello, A.A.; Aribi, M.A. & Al-Saad, H.T. (2013). Assessment of hydrocarbons and trace metal pollution in water and sediments of Fertilizer Plant wastes in Khor Al-Zubair, Iraq, Mesop. J. Mar. Sci., 28(1): 17-28.

Talal, A.A. (2013). Assessment of water quality and heavy metals in sediment of southern marshes. Marsh Bull., 8(2): 165-181.

Yousif, R.A.; Choudhary, M.I.; Ahmed, S. & Ahmed, Q. (2021). Review: Bioaccumulation of heavy metals in fish and other aquatic organisms from Karachi Coast, Pakistan. Nusantara Biosci. 13(1): 73-84. DOI:10.13057/nusbiosci/n130111.