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Phytoremediation of Heavy Metals(Cd, Cu, Fe, and Pb) by Using Aquatic Plants in Shatt Al-Arab River

Abstract- The study conducted to evaluate the ability of some aquatic *plants in absorption and accumulate some heavy metals (Cd, Cu, Fe, and Pb) in their tissues from contaminated water in two sites of Shatt Al-Arab River, Province of Basrah/Iraq. Water samples were collected from two sites one of them north of Basrah (Gurna) and the other from Sindbad island middle site of Shatt Al-Arab river. The chemical analysis had been performed to find out water quality. A laboratory experiment had been conducted by using three types of aquatic plants which were; Common Hornwort (Ceratophyllum demersum L., Common Reed (Phragmites australis L, and Nut Grass (Cyperus rotundus L.). Two types of water qualities (Gurna and Sindbad island) from Shatt Al-Arab river in addition to distilled water as a control treatment. Plants were planted in glass containers filling with water samples to know the ability of plants to absorb heavy metals. Results showed that water quality, according to American salinity laboratory classification was C_4S_1 for both sites. Concentration of cadmium, copper, iron, and lead in Shatt Al-Arab river in both sites was (0.021, 0.034), (15.40, 23.50), (248.1, 181.0), and (15.5, 54.0) ugL^{-1} respectively. The preliminary analysis of heavy metals concentration in aquatic plants of Cd, Cu, Fe and Pb were 0.18, 14.5, 650.5, and 26.2 mg kg^{-1} of dry weight respectively. While the results were 0.45, 36.2, 1173.0, and 50.5 mg kg^{-1} dry weight respectively in the Ceratophyllum, Finally, in the common reed, the concentration was 0.2, 30.5, 1095.2, and 45.2 $mgKg^{-1}$ dry weight for each heavy metals respectively. The removal efficiency of aquatic plants was varied with plant species and they took the following order common hornwort >common reed>nut grass.*

Key words- *Water pollution, Aquatic plants, Removal efficiency,*

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1. Introduction

Heavy metals are hazardous environmental pollutants, their dangerous in cumulative in living organisms and cause damage to a human when he eats contaminated food [1]. Shatt Al-Arab River and its tributaries are exposed a lot of pollutants resulting from domestic, agricultural and industrial waste, power plants, hospitals which affect the quality of water and its various uses [2,3]. Several studies had been conducted on Shatt Al-Arab river and its pollution with heavy metals [4,5] and they mentioned that water pollution depends on the quantity of water, soil sampling time, temperature, and source of pollution.

Akpour and Muchie [6] mentioned that there are three physiochemical methods for removal heavy metals from water: chemical precipitation, ion exchange, and reverse osmosis, as well as plant technology (phytoremediation) which is used plants for removal heavy metals from water. Thomas et al. [7] mentioned that more than one thousand species of aquatic plants are found in nature, but 1% of them are capable of treating polluted water including floating, emergent, and submerged plants. Abdel-Shafy et al. [8] used P. australis and Schoenplectus lacustris plants to study the accumulation of heavy metals in their tissues, it was found that reed plant is more capable of accumulation of heavy metals compared with schoenoplectus lactris plant, and heavy metals were accumulated in roots than in leaves and stems.

Emergent plants are more resistant to heavy metals than submerging plants [1]. They are more tolerant than floating plants, like lemna spps and phragmites, which can tolerate more than 250

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mg.gm-1 of copper and zinc, common hornwort plant is less tolerant than phragmites and papyrus [9]. Aziz et al. [10] mentioned that phragmites and papyrus plants are good biological indexes and environmental treatments for Shatt Al-Arab River and they have the ability to accumulate copper, lead, and zinc in their tissues. A study of Hanaf [11] found that the concentration of lead in leaves of Ceratophyllum demersum and phragmites sp in three stations of Shatt Al-Arab river (Sindbad island, Koreha, and Al-Zuhair) were 31,0,34.5, and 47.4 ug.gm-1 dry matter) and (30.3, 41.0, and 15.6 ug.gm-1 dry weight) respectively. Duo to deterioration of water quality in Shatt Al-Arab River because of water scarcity and pollution, the study was conducted to evaluate the ability of aquatic plants to accumulate and removal of heavy metals from the water of Shatt Al-Arab River one of them north of Basrah Province (Gurna) and other Sindbad island central of Basrah Province.

2. Materials and Methods

Water samples were collected from two sites in Shatt Al-Arab River in Basrah province south of Iraq. One of them in Gurna, north of Basrah Province and other from Sindbad island middle of Basrah Province during the spring season, April 2001. Water samples were stored in plastic containers with a volume of 1000 ml in the refrigerator at 25°C for chemical analysis which consist, acidity (pH), electrical conductivity (EC), alkalinity, turbidity, soluble ions (Ca^{2+}, Mg^{2+}, Na^{+}, SO_4^{2-}, and Cl^{-}) according to methods APHA [12]. Water samples were digested by nitric acid with heating for determining the total concentration of heavy metals according to APHA methods [12]. Heavy metals (Cd, Cu, Fe, and Pb) were determined by atomic absorption spectrophotometry (Phoenix-986AA).

Plant samples were collected from three types of aquatic plants, submerge plant, common hornwort (Ceratophylum demersum L.), emergent plant, common reed (Phragmites australis L.) from Sindbad island, and mesophyte plant, nut grass(Cyperus rotundus L.) from the field of college of Agriculture, University of Basrah. Plants and water samples were collected at the same time. Plants were dried at 65°C for 48hrs and digested with nitric and perchloric acid (3:1) (Nitric: Perchloric acid) with heating according to Kalra [14] and heavy metals were determined by atomic absorption spectrophotometry. Laboratory experiment was conducted to study the efficiency of aquatic plants for removing of heavy metals(Cd, Cu, Fe, and Pb) from Shatt Al-Arab river from two sites by using glass basins (25x15 x 50 cm3) (length x width x height). Basins were filled with 18L of water besides distilled water as a control treatment and planted with three studied plants (25gm for each plant to 18 L of water sample). After one and two weeks, water and plants samples were analyzed for heavy metals concentration.

3. Results and Discussion

I. Properties and chemical composition of water

Results in Table 1 indicate pH values of water samples at Gurna and Sindbad island sites of Shatt Al-Arab River, which were 7.66 and 7.51, respectively. Water samples were classified according to slight alkaline. Many researchers [15,16] had pointed out that pH values are affecting by several factors such as water temperature, amount of organic wastes, salts, and others. The results of the preliminary analysis of water samples in two studied sites showed a high concentration of salts wherever south of Shatt Al-Arab River. The values of electrical conductivity in Gurna and Sindbad Island were 2.40 and 4.62 dS.m-1, respectively. The high value of water salinity in Sindbad island sites due to a multiplicity of sources of pollution from power plants, hospitals, agricultural and industrial wastes and shortage of water quota in recent year with high temperature and establishment of water barriers on Tigris and Euphrates rivers which contributed to increased salinity water of Shatt Al-Arab river. These results consisted of the results founded by [4,5,14].

Table1: Chemical characteristic of Shatt Al-Arab River in Gurna and Sindbad Island site

Property		Unit	Site	
			Gurna	Sindbad island
pH			7.66	7.51
E.C		$dS.m^{-1}$	2.40	4.62
Turbidity		NTU	1.07	6.83
Total alkalinity		$mg.l^{-1}$	177.2	148.3
Soluble ions	Ca^{2+}	$mg.l^{-1}$	27.64	41.74
	Mg^{2+}		13.22	19.96
	Na^{+}		24.34	36.75
	SO_4^{2-}		1368.00	1619.52
	Cl^{-}		21.90	42.20

The values of turbidity in Gurna and Sindbad island sites were 1.07 and 6.83 NTU, respectively. These results were a high value of turbidity because of a multiplicity of the source of pollution from mineral and organic pollutants. Water is turbid from living and non-living materials with different shape and size, which reach the water from the soil, plants, animal resides, phytoplankton and organic matter [15]. Antonie and Al-Saadi [16] found a high value of turbidity in Shatt Al-Arab river because pollution which affected water quality. Results in table 1 showed that values of total alkalinity in two studied sites, which were 177.2 and 148.3 mg CaCO3.L-1 respectively. According to [12]. Water quality classified as moderate to alkaline (200 mg CaCO3.L-1). It should be noted that the values of total alkalinity vary depending on the quantity and kind of organic pollutants, temperature, and aquatic plants founded in the rivers. These results agreed with the results of [4,5,17.[

II. Heavy Metals Concentration

Results in Table 2 are shown the concentration of cadmium, copper, iron, and lead in Shatt Al-Arab river at Gurna and Sindbad sites, which reached for cadmium 0.021 and 0.034 ug .L-1, copper 15.4 and 23.5 ug.L-1,iron 248.1 and 181.0 Ug.L-1 ,and for lead 15.5 and 54.0 ug.L-1 respectively. The concentration of heavy metals for both sites were arranged as follows: Fe>Cu>Pb>Cd. It is clear from the results that the concentration of heavy metals increased with the south of Shatt Al-Arab river accept iron element because the iron element is necessary for all living organisms. These results agree with the result of [5].
In general, the concentration of heavy metals in studied sites was high because of domestic, industrial wastewater, fertilizers, detergents and pesticides, which affect the concentration of heavy metals in Shatt Al-Arab River.

Table 2: Heavy metals concentration in Shatt Al-Arab River in Gurna and Sindbad Island

Heavy metals	Unit	Site	
		Gurna	Sindbad island
Cd	$mg.L^{-1}$	0.021	0.034
Cu		15.40	23.50
Fe		248.00	181.00
Pb		15.50	54.00

III. Evaluation of Shatt Al-Arab Pollution with Heavy Metals

Many scientific institutions and international organizations had set limits for heavy metals concentration in water for drinking, irrigation, industry, or swimming; these limits varied according to countries and surrounding environmental conditions. FAO [18] classification is a global classification that has set limits of heavy metals in irrigation, which was adopted by many countries of the world for agriculture. According to FAO [18] classification ,water pollution with heavy metals in Gurna and Sindbad sites (Table 3) showed that cadmium concentration in two sites had exceeded the limit concentration (0.01 mg .L^{-1}) with 2.1 and 3.4 times respectively. This confirms that Shatt Al-Arab river pollution from many sources may be from power plants, hospitals, sewage waste, domestic as mentioned by many researchers [4,5,19].
Copper concentration exceeded limits (0.2 mg L-1) in Gurna and Sindbad Island also with 77.0 and 117.5 times respectively. Copper concentration in studied sites was higher that cadmium concentration and more pollution, these results agreed with the results of [20].

Table 3: Evaluation of Shatt Al-Arab water pollution with heavy metals In Gurna and Sindbad island site

Heavy metals	Critical limit ($mg.L^{-1}$)	Site			
		Gurna		Sindbad Island	
		Initial Concentration	Pollution evaluation	Initial Concentration	Pollution evaluation
Cd	0.01	0.021	polluted	0.034	polluted
Cu	0.20	15.4	polluted	23.5	polluted
Fe	5.0	284.1	polluted	181.0	polluted
Pb	5.0	15.5	polluted	54.0	polluted

Although the iron element is a nutrient element for all living organisms, the present study showed a very high concentration of iron in Shatt Al-Arab River of both studied sites. The limit concentration of iron in water for irrigation is 5 mg.L-1, but its concentration exceeded the limits concentration with 49.61 and 36.2 times, respectively. The results showed that iron element differed than other studied heavy metals, it was decreased at the south of Shatt Al-Arab river because of changes with ionic composition, salinity, turbidity, and total alkalinity.
The results of the current study showed that Shatt Al-Arab river was contaminated with lead in Sindbad island (3.1 mg.L-1) while it was exceeded the limit (5mg .L-1) in Guran its concentration was 10.8 mg.L-1. Al-Khafaji [21]; Aziz and et al. [10] found Shatt Al-Arab river was polluted with lead.

We can conclude from the current study that water was polluted with heavy metals in two studied sites of Shatt Al-Arab river and they took the following order: Cd>Pb>Fe>Cu .

IV: Evaluation of Aquatic Plants Efficiency in Accumulation of Heavy Metals from Shatt Al-Arab

Table 4 shows the initial concentration of heavy metals (Cd, Cu, Fe, and Pb) in aquatic plants samples of common reed, common hornwort and nut grass. The concentration of cadmium for three aquatic plants was 0.18, 0.44, and 09.20 mg.kg-1 dry weight, copper 14.5, 36.2, and 30.5 mg.Kg-1 dry weight, iron 650.5, 1173.0, and 1095.2 mg .Kg-1 dry weight, and for lead 26.2,50.5, and 45.2 mg.Kg-1 dry weight, respectively. The studied aquatic plants took the following order in absorption and accumulation of heavy metals in their tissues: common hornwort> common reed > nut grass. These results with the results of Hanaf [11]. These results indicate the importance of using Ceratophyllum demersum and Phragmites australis as biological indexes for heavy metals pollution in water; these results agreed with the results of [11].

Table 4: Initial concentration of heavy metal in aquatic plants

Aquatic plants	Heavy metal concentration ($mg.Kg^{-1}$) dry weight			
	Cd	Cu	Fe	Pb
Nut grass	0.18	14.5	650.5	26
Common hornwort	0.45	36.2	1173	50
Common reed	0.20	30.5	1095.2	45

Results in Table 5 shows the concentration of cadmium, copper, iron, and lead in aquatic plants growing in water from different sources(distilled water, Shatt Al-Arab river in Sindbad island site, and Shat Al-Arab water in Gurna site) with a removal efficiency of aquatic plants in accumulation of these elements in their tissues .In general, the concentration of heavy metals in aquatic plants was reduced in distilled water treatment as compared with initial concentration(table4),accompanied by a decrease in removal efficiency percentage. This may be explained by the absence of heavy metals in distilled water. Moreover, there was an increase in weight of aquatic plants caused a dilution effect of heavy metals in plants tissues.

Aquatic plants growing in Shatt Al-Arab river water in both studied sites differed in their ability in accumulation of heavy metals in their tissues, indicating the differences in pollution with heavy metals in studied sites. The amount of heavy metals absorbed by aquatic plants in Sindbad island site was more than Gurna site, indicating that Sindbad Island had more pollution sources than Gurna site such as ports, power plants.

The removal efficiency of aquatic plants was differed according to plant species; common hornwort was surprised over common reed and nut grass s plants in its ability in absorption and accumulation of heavy metals in tits tissues for all treatments.

The percentage of cadmium concentration in nut grass , common hornwort ,common reed plants growing in Sindbad island water was 14.28,18.18,1nd 16.6% respectively and for the same plants in Gurna site was 10.00, 13.46, and 9.59% respectively, and for copper element for the same plants sites was (10.49, 14.82, and 12.10 % respectively), (8.30, 11.05,and 8.45% respectively). While the removal efficiency for iron was decreased to reached (2.69, 3.29, 2.64% respectively), (1.43, 2.25, and 1.84% respectively) for lead element was (14.64, 22.54, and 22.46% respectively) and (78.39, 13.30, and 12.74% respectively).

The high concentration of heavy metals (Cd, Cu, Fe, and Pb) in studied aquatic plants indicated their ability in absorption and accumulation of these heavy metals in their tissues and transformed these elements in an active forms in gaps [22,23].

We can conclude from the present study that aquatic plants could be used as biotic indexes of water pollution and its ability to reduce levels of water pollution with heavy metals.

4. Conclusion

Shatt Al-Arab River was polluted with heavy metals and its pollution had been increased as we head south. The variation in susceptibility of aquatic plants in absorption of heavy metals according to their different chemical composition and water characteristics.

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Table 5: Removal efficiency of heavy metals in aquatic plants in Shatt Al-Arab River

Plant	Heavy metals	Source of water					
		Distilled water		Shatt Al-Arab river			
				Sindbad island		Gurna	
		Conc. after planting	Removal efficiency (%)	Conc. after planting	Removal efficiency (%)	Conc. after planting	Removal efficiency (%)
Nut Grass	Cd	0.16	-11.11	0.21	14.28	0.20	10.00
Common Hornwort		0.38	-15.55	0.55	18.18	0.52	13.46
Common Reed		0.18	-10.00	0.24	16.60	0.22	9.59
Nut Grass	Cu	12.00	-17.24	16.20	10.49	15.80	8.30
Common Hornwort		30.10	-16.85	42.50	14.82	40.70	11.05
Common Reed		25.30	-17.05	34.70	19.10	33.50	8.95
Nut Grass	Fe	600.00	-7.76	668.00	2.69	660.80	1.43
Common Hornwort		1150.00	-1.96	1213.00	3.29	1200.00	2.25
Common Reed		1080.00	-1.39	1125.00	2.64	1115.80	1.84
Nut Grass	Pb	24.00	-8.40	30.70	14.65	28.60	8.39
Common Hornwort		45.80	-9.31	65.20	22.54	58.30	13.37
Common Reed		40.70	-9.96		22.46	51.80	12.74