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Ability of *Cyperus papyrus* in the bioaccumulation of some heavy elements in the Shatt Al-Basrah canal, Iraq

Majida Sabah AL-Enazi[1]*, Israa Ibrahim Lazim[2], Huda Hilo Ali[2]

1. Department of Biology, College of Education for pure science, University of Basrah, Basrah, Iraq
2. Department of Biology, College of Science, University of Misan, Maysan, Iraq

** Corresponding author's E-mail: Majida.abdalsaied@uobasrah.edu.iq*

ABSTRACT
The current study aimed to estimate the efficiency of *Cyperus papyrus* for the accumulation of some heavy elements in Shatt al-Basrah Canal - southern Iraq. Six elements (Co, Mn, Cu, Ni, Pb, Fe) were used during a seasonally period that extended from the autumn 2018 to the summer 2019. These elements were studied in the dissolved and particulate phase of water. In addition, the same elements were studied in the exchangeable and residual phase of the precipitate and in the tissues of *C. papyrus*. The current study also showed the mechanism of accumulation of heavy elements through water-sediments-aquatic plants. *C. papyrus*, which was well developed in the Shatt Al Basrah, was used. The system of abundance of elements in water in the dissolved phase was as follows: Ni < Pb < Cd < Cu < Mn < Fe. As for the exchangeable phase of the sediment, it was as follows: Ni < Pb < Cd < Mn < Cu < Fe. The abundance of elements in *C. papyrus* was as follows: Ni < Pb < Cd < Mn < Cu < Fe. The study concluded that the accumulation of the studied elements follows the ascending system (water - sediment - aquatic plant). The bioaccumulation factor of the studied elements in the tissues of *C. papyrus* was as follows: 3.62, 11.27, 8.47, 10.37, 12.58, 11.08 once as much as their concentrations in water, respectively.

Keywords: *Cyperus papyrus*, Heavy elements, Bioaccumulation, Shatt al-Basrah canal.
Article type: Research Article.

INTRODUCTION
Pollution of the aquatic environment with heavy elements has become an important problem all over the world because most of them have toxic effects on living organisms (Duruibe *et al.* 2007). Mineral elements are present in natural waters in low concentrations, and their concentrations increase due to human activities, which negatively affects living organisms (Scheid *et al.* 2017; Sattari *et al.* 2019a,b,c,d; Sattari *et al.* 2020a,b,c,d; Forouhar Vajargah *et al.* 2020a,b; Forouhar Vajargah *et al.* 2021; Khudhair *et al.* 2021). Some of them are harmful even in their low concentrations and represent dangerous environmental pollutants as they are not biodegradable. Therefore, they remain suspended or dissolved in the water column and enter the organisms through food, air or contaminated water and accumulate in these organisms over time, causing various damages to them (Blanco 2005). These elements are also characterized by their ability to bioaccumulation. As their concentrations increase through the food chain and enter the bodies of living organisms, then bioaccumulation occurs, which causes permanent toxicity to them (Ahmed *et al.* 2010). Heavy elements have the ability to move from sediments and water and thus enter the food chain and aquatic plants (Marseile *et al.* 2000; AL-Enazi *et al.* 2020). The growth of plants in water rich in heavy elements leads to an abundance and accumulation of these elements in plant tissues (Prasad 1998). Therefore, aquatic plants are considered as a good bio-indicators of water pollution with heavy elements, and they play a major role in removing these pollutants by accumulating them inside their bodies (Jackson *et al.* 1994). Thus, they represent important organisms for purifying water from heavy elements because of their physiological structure, which makes them able to accumulate and store heavy elements in the form of non-toxic materials in their vacuoles without affecting them (Memon *et al.* 2001). *Cyperus papyrus* is one of the

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plants spread along the banks of the Shatt al-Basrah canal. The plant is characterized by hollow stems that are in the form of rounded bundles up to 40 mm thick and 5 mm long under ideal conditions. It ends at the top with a group of sub-stalks, forming light green and shiny what looks like an inverted umbrella (Boulos 2005). In addition, the stems bear a group of flowers and in the last a number of small fruits of black-brown colour (Serag 2003). Also, *C. papyrus* has the ability to accumulate heavy elements in its tissues (Deng *et al.* 2004; Sekomo 2012). Depending on the ability of plant tissues to accumulate, they are able to get rid the environment of heavy metal pollutants using several mechanisms, including phytoextraction, rhizofiltration, phytostabilization, phytovolotalization and phytodegradation (Newete & Byrne 2016). The current study aimed to determine the concentrations of some heavy elements in water (dissolved and particulate phases) and in sediments (exchangeable and residual phases), and to study the accumulation of heavy elements in *C. papyrus* spread on the banks of the Shatt al-Basrah canal in southern Iraq.

MATERIALS AND METHODS

Study areas

Shatt al-Basrah canal is one of the important canals in Basrah Province, Southern Iraq. This canal passes on different areas located at its right and left sides. The canal starts from the Hammar marsh and ends in Khor al-Zubair. A distance of 15 km was selected from the Shatt al- Basrah canal from the general estuary within the southern sector in Basrah governorate, as shown in Fig. 1.

Fig. 1. The study site in the Shatt al-Basrah canal (Retreived from Google Earth).

Sample's collection and heavy element measurements

Water, sediments and aquatic plants were collected on a seasonally basis from autumn 2018 through summer 2019. Water samples were collected by polyethylene containers (5 L) and in 3 replicates and filtered using 0.45 μm Millipore filter paper. Then, identifying the elements in the dissolved part was performed based on the method of Riley & Taylor (1968). As for the filter papers, they were digested for the purpose of measuring heavy elements in the suspended part of the water, according to the method of Sturgeon *et al.* (1982). The sediments were collected from the study site by Grab Sampler and a 5-cm layer was taken from the surface of the sediment for the purpose of examining the exchangeable and residual phases, depending on the method of Yi *et al.* (2007). The aquatic plant, *Cyperus papyrus* was collected and the samples were digested as 0.5 g dry weight according to the method of Orson *et al.* (1992). Blank solutions were prepared for each type of samples (water, sediment, and aquatic plants) and were treated in the same way as the samples were analysed for the purpose of estimating the pollution that might occur as a result of using different chemicals or laboratory conditions. The value of these concentrations was subtracted from the concentrations of the original samples. The heavy element ions were measured in the examined samples using the Flame Atomic Absorption Spectrophotometer. Pyeunicam SP9 air acetylene device and special lamps were used for each element (Hollow cathode lamp). Stock solution was prepared according to APHA (2003). The bioaccumulation factor (B.A.F) was calculated according to the following equation (Demina *et al.* 2009):

$$B.A.F = \frac{Conc. of\ metal in\ plant \mu g/kg}{Conc. of\ metal in\ water\ \mu g/L}$$

Statistical analyses

The results were statistically analysed by extracting the value of the standard deviation of the rates and the correlation coefficient (r) to find out the correlation between the concentrations of different elements in the plant, water and sediment. Analysis of variance was also used to show the significant differences at $p < 0.05$ (Zar 1984).

RESULTS

Table 1 shows the concentrations of heavy elements in the dissolved and suspended phases, the exchangeable and residual phases in the sediments and in *C. papyrus*.

Table 1. The heavy element concentrations in the water, sediments and *C. papyrus* during the study period.

Elements	Seasons	Element concentrations in water		Element concentrations in sediments		Element concentrations in *C. papyrus*
		Dissolved phase (□g L^{-1})	Particulate phase (□g g^{-1})	Exchangeable phase (□g g^{-1})	Residual phase (□g g^{-1})	
Co	Autumn 2018	0/86	7/4	4.6	5.2	3.08
	Winter 2019	1.36	6.7	3.55	3.91	8.4
	Spring 2019	2.36	13.6	7.81	7.59	10.4
	Summer 2019	4.92	12.8	10.7	9.98	12.5
Mn	Autumn 2018	5.42	22.63	16.31	17.04	61.15
	Winter 2019	4.50	27.93	16.66	16.91	65.09
	Spring 2019	7.74	30.18	17.03	17.01	67.65
	Summer 2019	5.39	32.63	17.41	17.52	65.98
Cu	Autumn 2018	3.33	16.51	8.11	8.37	29.46
	Winter 2019	3.01	14.54	8.22	7.93	30.05
	Spring 2019	4.21	15.17	7.89	7.85	29.16
	Summer 2019	3.35	15.84	7.04	7.06	28.93
Ni	Autumn 2019	0.043	0.202	0.016	0.086	0.52
	Winter 2019	0.039	0.191	0.088	0.203	0.54
	Spring 2019	0.061	0.190	0.190	0.190	0.36
	Summer 2019	0.044	0.194	0.120	0.161	0.49
Pb	Autumn 2018	0.07	0.71	0.28	0.24	2.14
	Winter 2019	0.20	0.74	0.27	0.27	1.82
	Spring 2019	0.14	0.61	0.25	0.25	1.13
	Summer 2019	0.08	0.62	0.23	0.33	1.05
Fe	Autumn 2018	101.73	555.41	312.55	336.62	1202.33
	Winter 2019	95.31	587.31	317.36	349.19	1172.34

	Spring 2019	129.27	681.42	325.19	364.33	1165.37
	Summer 2019	97.63	636.63	299.93	360.76	1159.25

Table 2 depicts the annual heavy element concentrations in the dissolved and suspended phases, the exchangeable and residual phases of sediments and *C. papyrus* and the bioaccumulation factor of the plant.

Table 2. The annual heavy element concentrations in the water, sediments and *C. papyrus*, and the bioaccumulation factor of the plant.

Elements	**Element concentrations in water**		**Element concentrations in sediments**		**Element concentrations in *C. papyrus***	**Bioaccumulation factor of *C. papyrus* (BAF)**
	Dissolved phase (□g L^{-1})	**Particulate phase (□g g^{-1})**	**Exchangeable phase (□g g^{-1})**	**Residual phase (□g g^{-1})**		
Co	2.37	10.125	6.66	6.67	8.59	3.62
Mn	5.76	28.34	16.85	17.12	64.96	11.27
Cu	3.47	50.18	25.98	7.80	29.4	8.47
Ni	0.046	0.194	0.103	0.16	0.477	10.37
Pb	0.122	0.67	0.255	0.272	1.535	12.58
Fe	105.98	615.19	313.75	352.72	1174.82	11.08

Tables 1 and 2 show that there were apparently seasonal alterations in the examined elements concentration of the dissolved and particulate phases of water, the exchangeable and residual phases of sediment, and in the tissues of *C. papyrus*, where the ranges of the soluble elements including Co, Mn, Cu, Ni, Pb, Fe in water were as follows respectively: 0.86-4.92, 4.50-7.74, 3.01-4.21, 0.039-0.061, 0.07-0.20 and 95.31-29.27 □g L^{-1}. In the cases of their concentrations in the particulate phase, the ranges were: 6.7-13.6, 22.63-32.63, 14.54-16.51, 0.190-0.202, 0.61-0.74, (555.41-681.42 □g g^{-1} dry weight respectively. The examined element levels in the exchangeable phase of the sediment were 3.55-10.7, 16.31-17.41, 7.04-8.22, 0.016-0.190, 0.23-0.28 and 299.93-325.19 □g g^{-1} dry weight respectively. In the residual phase, the values ranged between 3.91-9.98, 16.91-17.52, 7.06-8.37, 0.086-0.203, 0.24-0.33 and 336.62-364.33 □g g^{-1} dry weight respectively and in *C. papyrus*, ranged between 3.08-12.5, 61.15-67.65, 28.93-30.05, 0.36-0.54, 1.05-2.14 and 1159.25-1202.33 □g g^{-1} dry weight respectively. The current study also showed that the mechanism of accumulation of heavy elements through water - sediments - aquatic plants, as the order of abundance of elements in water in the dissolved phase were as follows: Ni < Pb < Cd < Cu < Mn < Fe. In the case of the exchangeable phase of the sediment, the order was as follows: Ni < Pb < Cd < Mn < Cu < Fe. The abundance of elements in the aquatic plant *C. papyrus* was as follows: Ni < Pb < Cd < Mn < Cu < Fe. The results also show that Co, Mn, Cu, Ni, Pb, Fe bio-accumulate in the tissues of the *C. papyrus* and the bioaccumulation factors were 3.62, 11.27, 8.47, 10.37, 12.58, 11.08 once as much as their concentrations in water, respectively.

DISCUSSION

The results of the study showed the elevated element concentrations in warm seasons of the year which may be attributed to the increased evaporation rates, the organic matter destroyed after the death of living organisms, reduced productivity and increased reduction in dissolved heavy elements (Park *et al.* 2008). We also found that the highest value was recorded for Fe, while the lowest for Ni in the water, sediments and *C. papyrus* (Tables 1 and 2). The results also showed an elevation in Co, Mn and Cu concentrations during the study period which may be due to untreated wastewater, domestic and commercial wastewater, the proximity of the oil facility and the gaseous and liquid pollutants left behind by them and their discharge into Shatt al-Basrah canal (Aziz *et al.* 2006). The particulate part of the water also recorded a higher value than the dissolved part, due to the increase in total suspended solid in the study area, such as the presence of mud, silt, the remains of living organisms, and the presence of phytoplankton and zooplankton, which have the ability to absorb and accumulate heavy elements in their bodies to higher levels of water (Nakanishi *et al.* 2004). Through the results of the current study, we note low heavy elements in the exchangeable and residual phases from the sediments due to the tendency of these elements to accumulation within the bodies of phytoplankton and zooplankton (Sasaki *et al.* 2003). Also it may be due to the continuous movement of water that do not allow enough time to precipitate plankton, and therefore less concentration in the sediment, in line with Al-Saadi *et al.* (1998). The results of the current study exhibited the higher heavy element levels within the tissues of the aquatic plant compared to water and sediments, which is consistent with other studies (Al-Taee 1999; Alkam 2002; Salman 2006, 2007; Enazi 2014). The higher heavy element concentrations in the plant tissue is the result of their elevated absorption from the water or sediments depending on the physical and chemical properties of these environments, and also due to upraised industrial and agricultural waste discharges to the environment. This confirmed by the positive correlations between the heavy elements in aquatic plant with the elements of water in the dissolved and particulate phases, and in sediments in the exchangeable and residual phases (Mohamad & Abdul Latif 2010; Naaz & Pandy 2010). It was found that most of the examined elements took the same positions in the dissolved phase of water, in the exchangeable phase of sediments, and in the aquatic plant *C. papyrus*. There are some evidences of an overlap between the water-sediment-aquatic plant system (Bai *et al.* 2018). Aquatic plants are capable of absorbing and recycling heavy elements in food chains (Singh *et al.* 2017) and a wide use in field of bio-filter to remove toxic heavy elements from water and accumulating in their tissues (Abdullah *et al.* 2011).

CONCLUSION AND RECOMMENDATIONS

We conclude from the current study that the aquatic plant *Cyperus papyrus* has a great ability to bioaccumulate the heavy elements examined. Thus, it can be used as a bio-indicators for heavy element pollutions. The study also recommends the use of other aquatic plants to learn how to transfer and accumulate heavy elements in environmental monitoring programs.

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