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Reeds and Reedmace Bioreactor Technique in Wastewater Heavy Metals Treatment, Rhizofiltration

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تقنية المفاعلات الحيوية لمعالجة مياه الصرف باستخدام الترشيح الجذري بنباتي القصبة والسمار

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Abstract

Direct usage of plants to decrease pollution in groundwater and surface water, has gained popularity in both academic and applied fields. Phytoremediation is a low-cost technique and environmentally beneficial technology; heavy metals are absorbed via aquatic plants also usage aqua plants as fertilizer since *Phragmites australis* have the capability to regrow when harvesting. This would allow heavy metals to be removed from waterways over multiple growing seasons; there was a significant difference in the concentration of copper between reeds bioreactors before and after treatment. The concentration of Cu decreased from 4.00 to 0.0087 mg/L. The lower concentration of Cu values at end of the experiment might be due absorption of heavy metals from the contaminated media. The concentration of Zn was also lower than before planting having the lower concentration (0.0868 mg/L) in the fifth hydroponic. Reed has a high ability to reduce zinc concentration. The concentrations of Co and Cd decreased from 0.400 to 0.043 mg/L. As shown in the results, the levels of concentration of Cd in the reeds bioreactor were decreased. Also, the concentration of Mn decreased from 20 to 0.0219 mg/L. Moreover, Reedmace has the capacity to clean up contaminated water. The values of Cu concentration decreased from 4.00 to 0.0477 mg/L during the entire growth period. Zn from 20 to 0.1685 mg/L. Also, the concentrations of Co and Cd decreased from 0.400 to 0.043 mg/L. The concentration of Mn decreased from 20 to 0.0133 mg/L. The efficiency of reeds bioreactor for heavy metals removal in the following sequence: Mn (99.89%) > Cu (99.78%) > Zn (99.65%) > Co (89.2%) > Cd (86.08%). On the other hand, the sequence of removal efficiency of the Reedmace bioreactor was in the following sequence: Mn (99.93%) > Zn (99.15%) > Cu (98.81%) > Mn (89.25%) > Cd (88.40%).

Keywords: *Bioreactor, Heavy Metal, Reed, Reedmace, Rhizofiltration, Wastewater*.

الملخص

اكتسب استخدام النباتات مباشرة للحد من تلوث المياه الجوفية والسطحية اهتمام واسع بين الأوساط الأكاديمية والتطبيقية. وتعتبر النباتات المائية مثل القصبة/الغاب *Phragmites australis* ذات قدرة عالية على امتصاص المعادن الثقيلة مما يرفع من كفاءتها في إزالتها من المياه الملوثة على مدى عدة

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مواسم زراعية. حيث اظهرت النتائج وجود فرق كبير في تركيز Cu قبل المعالجة وبعدها فقد انخفض التركيز من 4.00 إلى 0.0087 مجم/لتر. كما انخفض تركيز Zn إلى 0.0868 مجم/لتر. كما انخفضت تراكيز Co و Cd من 0.400 إلى 0.043 مجم/لتر و Mn من 20 إلى 0.0219 مجم/لتر. بالإضافة إلى ذلك اظهرت النتائج أن نبات السمار *Typha australis* لديه القدرة على معالجة المياه الملوثة. حيث انخفضت تراكيز Cu من 4.00 إلى 0.0477 مجم/لتر، Zn .من 20 إلى 0.1685 مجم/لتر. علاوة على ذلك، انخفضت تركيزات Co و Cd من 0.400 إلى 0.043 مجم/لتر و انخفض Mn من 20 إلى 0.0133 مجم/لتر. اجمالاً كانت كفاءة عامل الإزالة الحيوي للمعادن الثقيلة لنبات القصبة وفقاً للتسلسل التالي: Mn (99.89%) > Cu (99.78%) > Zn (99.65%) > Co (89.2%) > Cd (86.08%) ومن ناحية أخرى، كان تسلسل كفاءة الإزالة لنبات السمار وفقاً التالي: Mn (99.93%) > Zn (99.15%) > Cu (98.81%) > Mn (89.25%) > Cd (88.40%) .

الكلمات الدالة: مفاعل حيوي، عنصر ثقيل، القصبة، السمار، مياه الصرف.

1. Introduction

Human health, living species, and other resources are all at risk when industrial waste is discharged into soil and water. Hazardous organics, pesticides, dyes, oils, cyanides, phenol, phosphorus, suspended particles, and heavy metals are all found in untreated industrial and domestic wastewater. Heavy metals are among the harmful compounds that can easily accumulate in the environment. Geothermal energy plants, metal processing, mining, automobile, paper and pesticide production, tanning, dying, and plating are all blamed for heavy metal contamination around the world. Heavy metals are difficult to remove from wastewater because they can be found in different chemical forms. Heavy metals are mostly non-biodegradable, and they can easily accumulate in the biota through numerous trophic levels. (Ali *et al.*, 2020). Water quality is being destroyed by numerous inorganic and organic pollutants on a daily. The phytoremediation technique using aquatic plants is the most preferable of the many strategies developed so far. Because of contaminating elements, aquatic ecosystems are under a lot of stress and depletion. Water pollution, along with a water scarcity, have created a significant challenge for the environment. Water scarcity affects about 40% of the world's population owing to climate change, rapid urbanization, the food demand, and uncontrolled usage of environmental resources. In recent years, fast urbanization, agricultural operations, industrialization, geothermal water discharge, and discharge of olive wastewater, mainly in olive-cultivating lands, have all increased the disposal of contaminated wastewater into the surrounding environmental. Wastewater with high contaminants levels is extremely harmful to the aquatic ecosystem as well as human health. Wastewater reclamation has been the only choice left to meet the increasing water demand in growing industrial and agricultural sectors (Ahmed *et al.*, 2017). Heavy metals, without exception, are known to create health problems in all living organisms. Heavy metals have a negative impact on the biota due to their toxicity and non-biodegradability, especially when they accumulate in sediment. Toxic metals have been removed from industrial effluents using a variety of processes, including reduction, precipitation, artificial membranes, and ion-exchange (Qdaisa and Moussa, 2004; Aishah and Elssaidi, 2019; and Aishah *et al.*, 2019). But these methods are expensive and may produce a huge quantity of waste, causing disposal issues. Furthermore,

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these techniques are insufficient to remove heavy metals in low concentrations. Therefore, there is an urgent need to develop an innovative process, which can remove heavy metals economically from aqueous solution even at low concentration. Phytoremediation has recently been promoted as a low-cost, environmentally beneficial approach (Volesky, 2000; Aishah *et al.*, 2018; and Aishah *et al.*, 2019). Generally, there are numerous major ways of remediation. Bioremediation for instance land farming, natural attenuation, bio piling, bioventing, bioaugmentation and bioreactor. Phytoremediation, defined as the usage of plant species (including trees and grasses) to remove, destroy or sequester hazardous pollutants from different media such as soil, water, and air (Aishah *et al.*, 2018; and Aishah *et al.*, 2019). Phytoremediation is a cost-effective, economically and environmentally benign method of removing potentially hazardous metals from the environment (Aishah *et al.*, 2019). Agro-remediation, green remediation, vegetative remediation, green technology, and botany remediation are all terms used to describe phytoremediation. There are some of plant species that have the capability to uptake considerably heavy metals concentrations in different their parts, such as a stems, leaves, and roots and devoid of presentation any toxicity symptoms. plant species must have the unique characteristics to create the phytoremediation and an eco-sustainable, such as quick growth rate and native, great biomass produce, uptake great amount of heavy metals, and trans-located heavy metals in plant parts, and tolerate heavy metals toxicity (Aishah *et al.*, 2016; and Ali *et al.*, 2020). Phytoremediation uses a variety of processes to remove heavy metals including phytoextraction, phytostabilization, phytovolatilization, and rhizofiltration. Where, rhizofiltration includes the usage of the plant to the pollutants ab/adsorb, causing in limited pollutants movement in underground water. The roots were the important part in rhizofiltration. The heavy metal precipitation on the roots surface is enhanced by factors such as changing pH in the rhizosphere and root exudates. Once the roots of plant have soaked up all the pollutants, they can simply be disposed after harvested. Plant species for rhizofiltration must have the capability to produce a widespread roots system, uptake high heavy metals concentrations, be simple to manage and having low-cost maintenance. Rhizofiltration can be achieved with aquatic and terrestrial plants that have long fibrous root systems. Agricultural runoff, discharge from industrial, radioactive contaminants, also heavy metals can all be controlled and treated by rhizofiltration. Heavy metals such as Cd, Cr, Zn, Pb, and Cu, which are mostly absorbed in the soil, can be successfully remediated using rhizofiltration (Reeves *et al.*, 2018). The adaptability of *P. australis* is seen in its competitive behavior. Studies demonstrate that heavy metals removal from the aquatic environment is one of the priorities of the environmentalist world-wide. *P. australis* is a heavy metal-removal aquatic plant that has been investigated widely. *P. australis* is a perennially emergent aquatic plant with the widest geographical distribution of any flowering reed grows in different pH of soils, salinity, fertility and textures. Aquatic macrophytes including reedmace plants are widespread in various habitats. These aquatic weeds take advantage of their incredible growth potential in a variety of freshwater habitats as well as contaminated or effluent sites. The capability of aquatic plant species to survive in high substances concentrations such as heavy metals, and successfully proliferate in the

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contaminated water, attracts attention from researchers (Dordio *et al.*, 2009; Chandra & Yadav, 2011; Dordio *et al.*, 2011; Eid *et al.*, 2012, and Grisey *et al.*, 2012). Briefly, research on the effects of heavy metals in mixtures is rare. Therefore, the present investigation was aimed at assessing the phytoremediation potentials of some heavy metals contained in industrial effluent by reeds and reedmace.

2. Materials and Methods

Reed (*P. australis*) and reedmace (*Typha australis*.) were used in this study, industrial waste water: The following heavy metals: Zn, Mn, Cu, Cd, and Co were chosen for our research. The heavy metals solutions were prepared using metals solutions, their solutions are prepared in different concentrations 20, 20, 4.0, 0.4, & 0.4 mg/L for Zn, Mn, Cu, Cd, & Co, respectively to simulate heavy metals concentration in wastewater according to Standard Methods (Federation W.E., & APH Association, 2005). Selection and propagation of Reeds and Reedmace rhizomes were taken from mature plants. Rhizomes of approximately 20 cm were placed in plastic trays (40×50 cm), in a glasshouse and watered with tap water every 48 hrs for 15 days, until roots and shoots had developed; then each plant was separated by cutting the old rhizomes. Plants were transferred to hydroponic culture in plastic containers (4 liters; 7 plants/container) with 1.5 mL of Hoagland nutrient solution (Hoagland and Arnon, 1941) to avoid a micronutrients deficiency hydroponic experiments plant of a uniform size (50 cm tall), then, plants were transferred to the different treatments to assessment the common reed bioreactors water heavy metals. Two hydroponic systems were used in this study in order to evaluate its phytoremediation potentials of heavy metals contained in industrial effluent. The first set used *P. australis* plants and the second for *T. australis*. Seven plants were placed in each hydroponic bath contains 5 litters of industrial wastewater and tap water as control. Plants were kept for 5 days (as show in Figure 1).

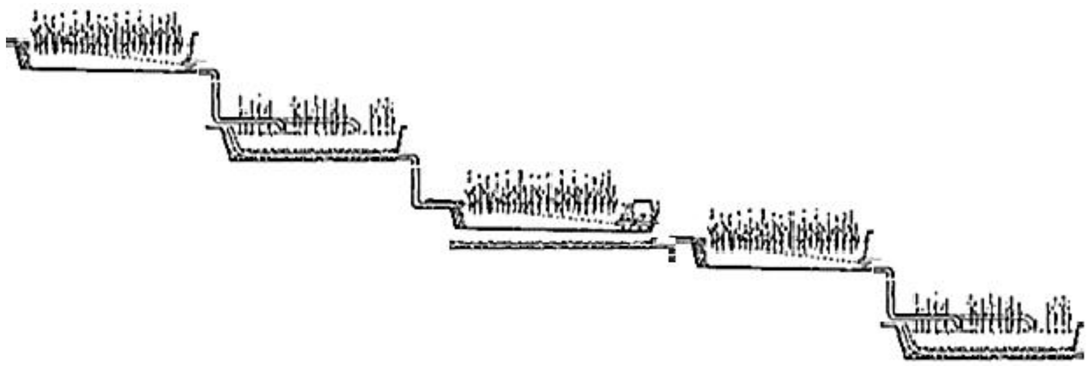

Figure 1. Hydroponic experiment design

Samples were taken to measure the change in concentration, then after wastewater passed to the second bath and another 7 plants were placed in a hydroponic bath separately, after 5 days, a sample from each hydroponic baths were taken to measure the change in

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concentration. Finally, was passed to the third bath prepared with other seven plants for another 5 days. Change in concentration was estimated and the same steps were repeated in the fourth and fifth basins. This process is designed to simulate the processing flow in bioreactors to treat polluted wastewater using plants with hyper-accumulation capacity (Bioreactors). Heavy element concentrations were measured using the atomic absorption Spectrophotometer. The percentage of metal removal was calculated as (Mustafa *et al.*, 2013):

$$Meta\ Remoal\ (\%) = \frac{ion\ conc.\ befor\ treatmemt - ion\ conc.\ after\ treatment}{ion\ conc.\ befor\ treatment} \times 100 \qquad \ldots\ldots \quad (1)$$

3. Results and Discussion

3.1. Changes in heavy metals concentration

The results (Table 1) showed that there was significant heavy metals absorption in the Reeds bioreactor and Reedmace bioreactor. These plants have been considered for the heavy metals remediation such as Cu, Zn, Co, Cd, and Mn, its ability to restore environmental quality could be proved. The roots of these plants have a higher ratio of surface area to volume, allowing heavy metals to accumulate.

3.2. Changes in Reeds Bioreactor

Reeds produce vertical and horizontal rhizomes; the rhizomes afford an effective remediation system for the heavy metals removal from the polluted industrial wastewater due to a higher ratio of surface area to volume and high absorption capacity (bioreactors). A lot of studies have demonstrated that the common reed causes a significant decrease in metal concentrations in water. One of the most significant effects of heavy metal exposure on plants is an increase in the concentration of oxygen free radicals as well as peroxidation of lipid. Plants, in general, have a tendency to release excessive metal ions by transpiration, lowering the toxic concentration in common Reed tissues (Bouchama *et al.*, 2016). The common reed is a tall, perennial grass that grows on level ground in tidal and non-tidal marshes, lakes, swales, and the backwaters of rivers as well as streams. Direct usage of green plants to stabilize or decrease pollution in soils, surface water, or ground water has gained increasing acceptance in both academic and practical fields. Phytoremediation is a low cost, environmentally beneficial technology (Bouchama *et al.*, 2016). Plants' capability to remove metals and accumulate them is depend largely on their growth phase and physiological characteristics. (Windham *et al.*, 2001). *Reeds* can survive in higher Cu concentration (Ali *et al.*, 2002). As a result, it is classified as a Cu-tolerant plant. Also, higher Zn and Mn accumulation in the roots of *Reeds* (Peltier *et al.*, 2003). As findings show (Table 1 and Figure 2), there was a significant difference in the concentration of copper between *Reeds* bioreactor before and after treatment. The concentration of Cu decreased from 4.00 to 0.0087 mg/L. The lower concentration of Cu values at end of experiment might be due absorption of heavy metals from the contaminated media. The concentration of Zn was also lower than before planting having the lower concentration (0.0868 mg/L) in the fifth hydroponic. *Reeds* have a high ability to reduce zinc

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concentration. The concentrations of Co and Cd decreased from 0.400 to 0.043 mg/L. As shown in the results, the level of concentration of Cd in the Reeds bioreactor was decreased. Also, the concentration of Mn decreased from 20-0.0219 mg/L (Srivastava *et al*., 2005). Bioreactor provides the advantage of using Reeds to clean up contaminated water.

Table 1. Changes in heavy metals concentration (mg/L) in Bioreactors (days)

Ions	Time (day)	Reeds Bioreactor		Reedmace bioreactor	
		Control	Wastewater	Control	Wastewater
Cu	0	0	4	0	4
	5	N.D.	0.0692	N.D.	0.0739
	10	N.D.	0.0612	N.D.	0.0652
	15	N.D.	0.0569	N.D.	0.0652
	20	N.D.	0.035	N.D.	0.0564
	30	N.D.	0.0087	N.D.	0.0477
Zn	0	0	20	0	20
	5	N.D.	0.3482	N.D.	0.3482
	10	N.D.	0.2175	N.D.	0.2992
	15	N.D.	0.1848	N.D.	0.2502
	20	N.D.	0.1194	N.D.	0.1848
	30	N.D.	0.0868	N.D.	0.1685
Co	0	0	0.4	0	0.4
	5	N.D.	0.2671	N.D.	0.3792
	10	N.D.	0.2223	N.D.	0.2391
	15	N.D.	0.1663	N.D.	0.1775
	20	N.D.	0.0934	N.D.	0.094
	30	N.D.	0.043	N.D.	0.043
Cd	0	0	0.4	0	0.4
	5	N.D.	0.3792	N.D.	0.2671
	10	N.D.	0.2391	N.D.	0.2223
	15	N.D.	0.1775	N.D.	0.1663
	20	N.D.	0.094	N.D.	0.0934
	30	N.D.	0.043	N.D.	0.043
Mn	0	0	20	0	20
	5	N.D.	0.289	N.D.	0.3753
	10	N.D.	0.2449	N.D.	0.287
	15	N.D.	0.2228	N.D.	0.1987
	20	N.D.	0.1566	N.D.	0.1325
	30	N.D.	0.0219	N.D.	0.0133

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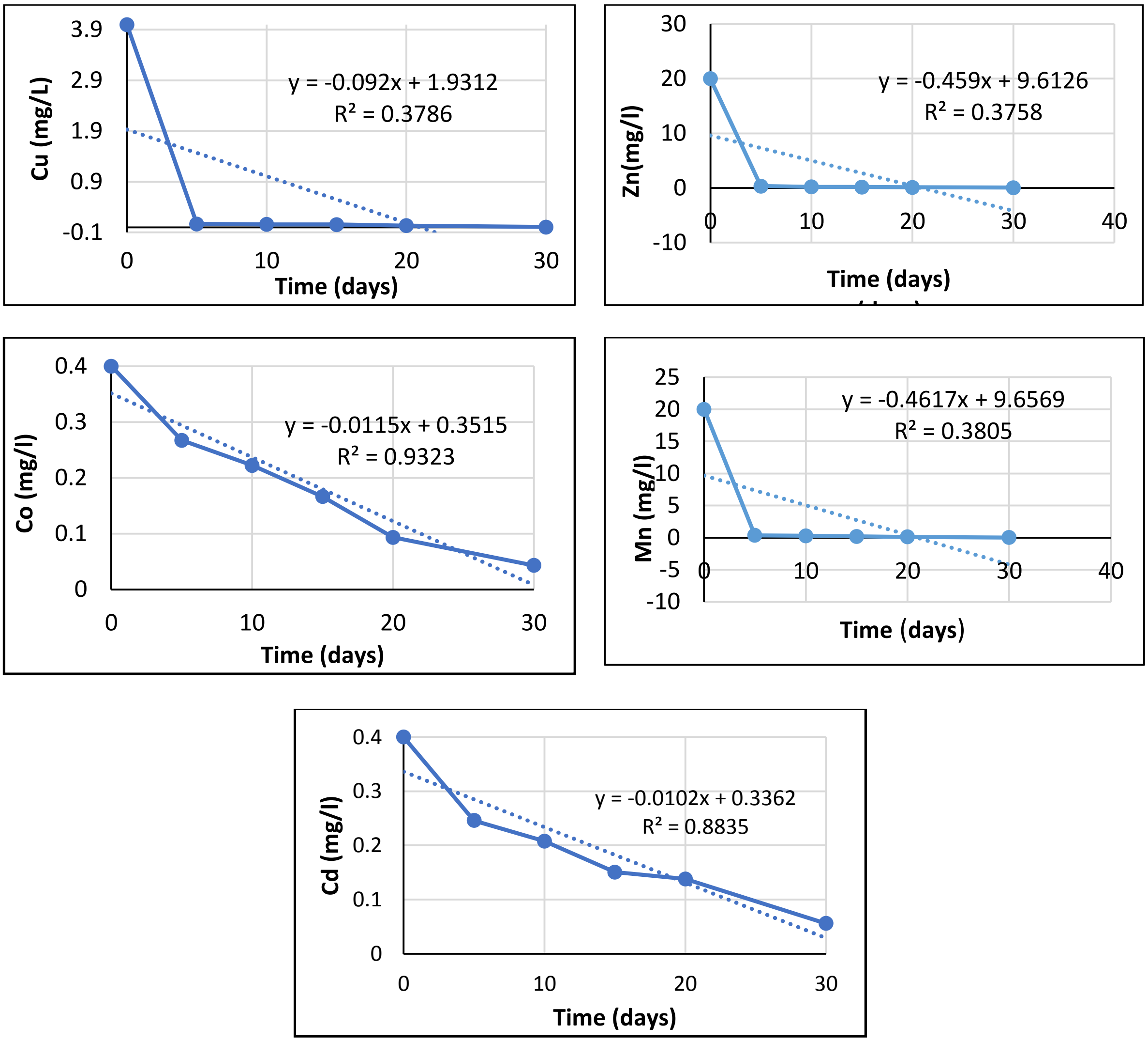

Figure 2. Changes in heavy metals concentration (mg/L) in Reeds bioreactor

3.3. Changes in Reedmace Bioreactor

The intensity of metal uptake also varies with plant species. As a result of their fast grow and produce large amounts of biomass. Reedmace have a significant potential heavy metals remediation. Some plants have the ability to tolerate and eve metals accumulate has opened new possibilities for phytoremediation research in soil and water treatment. Industrial procedures usually include hazardous and pollution prone actions such as effluent from metal or uranium mines that carry sulphide, pyrite and pyrhotite which are converted into sulphate in ground water streams. As the results show (Table 1 and Figure 3), Reedmace employ their remarkable growth capacity to clean up contaminated water. The values of Cu concentration decreased from 4.0 to 0.048 mg/L during the entire growth period. Zn from 20 to 0.169 mg/L. Also, the concentrations of Co and Cd decreased from 0.400 to 0.043 mg/L. The concentration of Mn decreased from 20 to 0.013 mg/L. This plant species has ability to uptake high quantities of pollutants like heavy metals, and efficaciously proliferate in the

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polluted water, attracts attention from researchers. Reedmace is environmentally very sound. Heavy metals such as Cd, Pb, Cr, Zn, and Cu, which are mostly retained in soil, can be adequately remediated using rhizofiltration (Reeves *et al*., 2018).

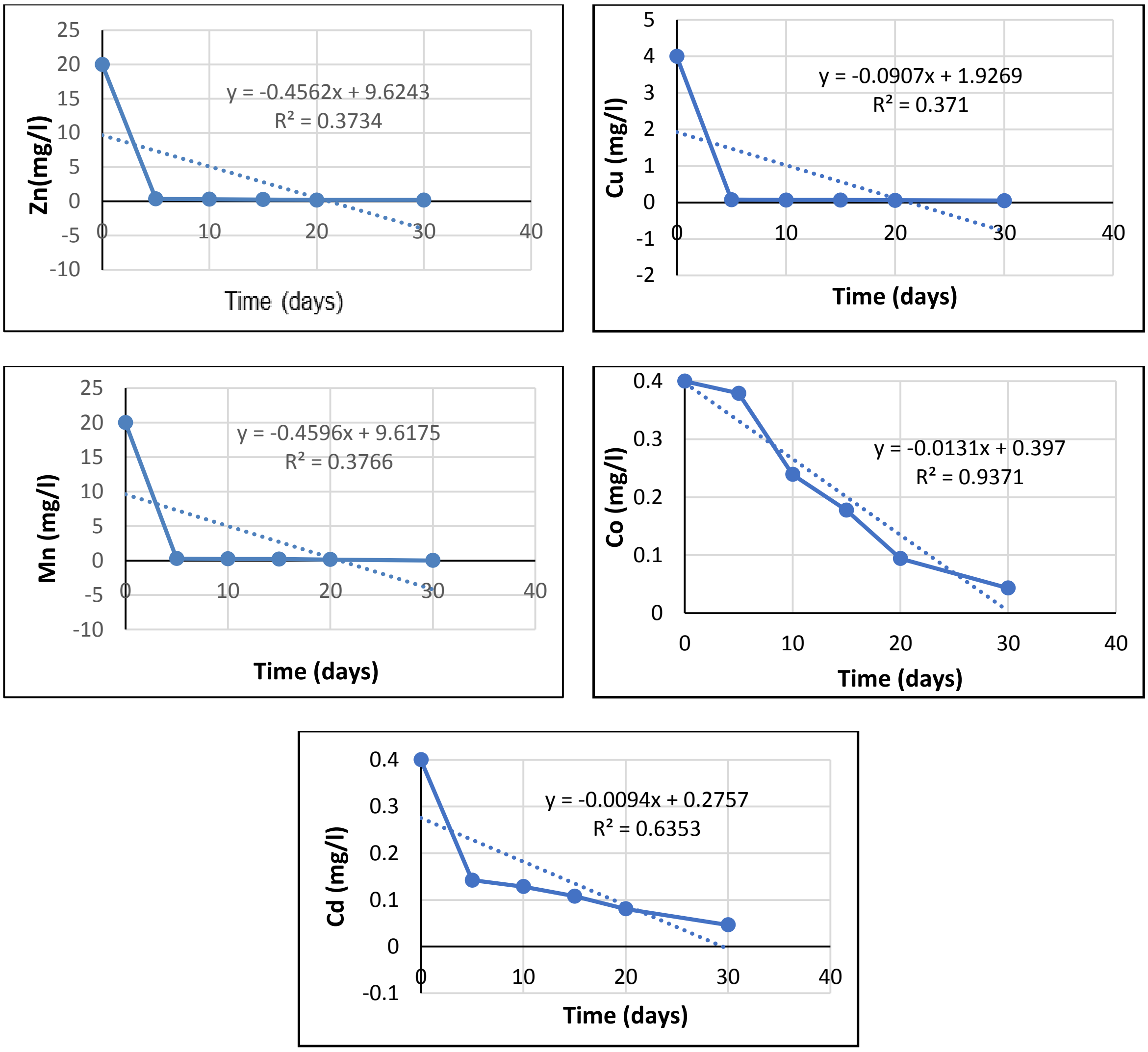

Figure 3. Changes in heavy metals concentration (mg/L) in Reedmace bioreactor

3.4. Bioreactor Efficiency in Industrial Wastewater Treatment

Generally, the results revealed that both tested pants were efficient in heavy metals uptake from polluted water. The Plants uptake was in the following sequence: Mn > Zn > Cu> Co > Cd, (Figure 4a). However, Reeds showed slightly high ability to remove the heavy metals compered to Reedmace, (Figure 4b).

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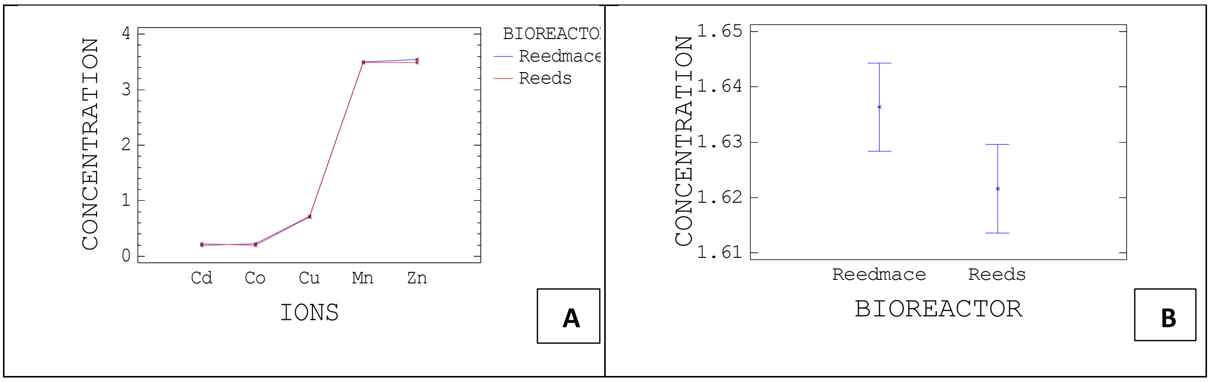

Figure 4. Uptake of heavy metals by; A) The *Reeds* and B) *Reedmace* bioreactor

Reeds is a type of aquatic plant that have been extensively studied for removing heavy metals owing to its high potential for metal removal and fast growth, as well as its metals accumulation in aboveground and belowground biomass. Rzymski *et al.* (2014) found the accumulation of Cr, Cd, Cu, Co, Mn, and Zn in the roots of *reeds.* The data in Table (2) indicate that *Reeds* and *Reedmace* are effective species for use in heavy metal removal.

Table 2 Removal efficiency (%) of the *Reeds* and *Reedmace* hydroponic system to industrial wastewater treatment

Metal	Reeds bioreactor	Reedmace bioreactor
Cu	99.78	98.81
Zn	99.65	99.15
Cd	86.08	88.40
Co	89.25	89.25
Mn	99.89	99.93
T-Test	***P =0.569127***	

There were no significant differences (P= 0.56912) between both Reeds and Reedmace efficiency**.** Both tested plants were characterized by very high absorption of heavy metals over a very short period of time**.** In both hydroponic systems, data regarding metal removal rates are extremely similar. The effectiveness of plant sequence as heavy metals biosorbents for reduction their concentrations in hydroponic systems. In general, the efficiency of Reeds bioreactor for heavy metals removal in the following sequence: Mn (99.89%) > Cu (99.78%) > Zn (99.65%) > Co (89.2%) > Cd (86.08%).

On the other hand, the sequence of removal efficiency of Reedmace hydroponic system was in the following sequence: Mn (99.93 %) > Zn (99.15%) > Cu (98.81%) > Co (89.25%) > Cd (88.40%). Heavy metals are removed from municipal or industrial effluent by aquatic plants, biosorption system can actually remove this heavy metals can be inferred the ability of both plants in question to act as a bioreactor. This is used to avoid the long time needs for most bio processors of treatments. Scientists have demonstrated its capability to restore the environmental matrices quality. Aqua plants are utilized as a good supply of roughage for cattle and as a source of fiber for paper production (Mal and Narine, 2004).

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4. Conclusion

Reeds and Reedmace are naturally strong and powerful main species found in many wetland habitats around the world. These plants can absorb, translocate, and accumulate a wide range of contaminants in both shoots and roots and can grow in a variety of environmental conditions. The plants capability to develop and grow in the industrial wastewater allowed the used of them in phytoremediation techniques owing to their efficiency in pollution remediation of aquatic ecosystem. It can advance heavy metals efficiency removing. Several additional field investigations are required to prove the potential of Reeds and Reedmace to mitigate pollutants from environmental matrices, especially under altered climatic conditions.

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