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Bioremoval of heavy metals from polluted soil by *Schoenoplectus litoralis* (Schrad.) Palla and *Cyperus rotundus* L. (Cyperaceae)

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ABSTRACT

The present work aimed to assess the ability of plant species namely, *Schoenoplectus litoralis* and *Cyperus rotundus* belonging to family Cyperaceae in bioremoval of heavy metals from polluted soil by As, Pb, Cd, Zn. Soil planted with both plant species was regularly irrigated (twice a week) by water containing different concentrations of 10, 20, 30, 40, and 50 ppm of the metals in a laboratory experiment. The tested metals residues were determined in the shoot and root system of plants after 45 days and expressed as mg/g dry weight of the plant. *C. rotundus* had a high power for absorbing and accumulating heavy metals from the contaminated soil by higher rate by roots than by shoot system (root: As 183 mg/g, Pb 82 mg/g, Cd 122 mg/g, and Zn 137 mg/g, shoot: As 145 mg/g, Pb 512 mg/g, Cd102 mg/g, and Zn 110 mg/g). *S. litoralis* absorbed and accumulated heavy metals from soil in less amount (root: As 148 mg/g, Pb 46 mg/g, Cd 113 mg/g, and Zn 127 mg/g, shoot: As 132 mg/g, Pb 44 mg/g, Cd 100 mg/g, and Zn 105 mg/g). The bioaccumulation power increased with the increase of heavy metal concentrations in soil and with the time exposure in the both plant species.

INTRODUCTION

Most of human activities produce heavy metals as side effects into the nature **environment (Shreadah *et al*., 2006; Younis, *et al*., 2014; Amin, *et al*., 2018; Soliman *et al*., 2018; Younis, *et al*., 2018; Nafea, 2019a & b)**. Heavy metals are among ninety five chemicals that defined as toxic materials which are released into water, sediments and soil environment **(Asamudo *et al*., 2005; Said *et al*., 2006; Nayyef and Amal 2012; Younis and Nafea 2012; Younis *et al*., 2018; Soliman *et al*., 2019; El-Naggar *et al*., 2019).** Most of higher plants can dominated the metal enriched environments and some of them can accumulate very high concentrations of toxic metals in their tissues, which are essential for their growth and development (**Nafea , 2019a).** These metals include As, Mg, Cd, Mn, Pb, Zn, Cu, Mo, Ni, Cr, and Co. Airborne pollutants are precipitated on soils surrounding highways causing serious ecological hazards and the investigated soils are contaminated with Pb, Ni, and Cd. These contaminants were brought to the subsurface layers of the soil at relatively high concentrations. Contents of Pb and Ni in the top surface soil decreased with increasing the distance from the high way on both sides of the road. The concentrations of heavy metals in roots of plants cultivated on road sides are higher than other plant parts. Traffic activities are one of the major sources leading to heavy metal contamination in roadside soils due to their long-term accumulation. Therefore, the local contamination resulting from transportation activities is receiving increasing attention in the most countries **(Onder *et al*., 2007; Cui *et al*., 2009; Rajiv *et al*., 2009; Hashim *et al*., 2017).**

More accumulation of heavy metals can be harm from soil into some plants. **Fuksová *et al.* (2009) and Amin *et al*., (2014)** used the *Salix dasyclados* in phytoextraction of heavy metals from contaminated soil in separate and co-cropping experiments. They confirmed that the remediation efficiency of the individual species in the co-cropping system did not differ from those obtained in separate cropping mode. The phytoextraction of heavy metals from contaminated soil by plants was studied by **Kacálková *et al*. (2009),** where the ability of maize (*Zea mays*), willow-tree (*Salix* × *smithiana*), and poplar (*Populus nigra* × *maximowiczii*) to accumulate Cd, Cu, Hg, and Zn was differ according to species and organs inside the species. The impact of polluted air on the rick of heavy metals on plants were examined by **Kuklová *et al*. (2019),** whom indicate risk of exposure to risk elements in soils and plants of forest stands under conditions of polluted air. The effect of altitudinal zonation on the heavy metals was studied b**y Kuklová *et al*. (2017),** whom stated that the relation between energy and toxic elements in soils revealed that with an increasing amount of energy, contents of Zn and Cu significantly declined with altitude.

The use of plants to remediate contaminant in contaminated soil called phytoremediation and green remediation, where higher plants and microbes could be used in phytoremediation of contaminated soil by heavy metals. A wide range of contaminants enter the soil according to the human activities, like mining, smelting, fuel burning. However, heavy metals are the most toxic of all these pollutants. Among these, Pb, Cd, Cr, Hg, and As are the most toxic and can cause multiple organ damages even when present in small quantities **(Meagher, 2000; LeDuc and Terry 2005).** Phytoremediation is considered as a sustainable means for environmental clean-up when compared to physico-chemical methods **(Rahul , 2015)** and it could be considered as a highly promising method in degrade and accumulate contaminants from soil and water by using various plants and their associated microbes (Dietz and Schnoor 2001) and is relatively inexpensive to apply and simple to be managed **(Meagher, 2000, LeDuc and Terry 2005),** where the plant materials used in phytoremediation could be reprocessed into wood chips, pulp, or bioenergy resources. So phytoremediation is likely to attract public support and the plants can be easily monitored for effective performance. This technology is comparatively efficient, economical and environmentally safe process and should be encouraged for large scale cleanup of soil contaminated with heavy metals.

Cyperus rotundus L. is an aromatic species belonging to family Cyperaceae. It grows as a perennial herb near water bodies in moist or dry soils. It is widespread in Egyptian habitats in cultivated and non-cultivated lands and closely related to *C. esculentus* L., its height may reach 140 cm. It is used in folk medicine and in cosmetic industry or as a favouring for food. It can be reproduces by seeds and bulbs (**Boulos, 2005, 2009).** *Schoenoplectus litoralis* (Schrad.) Palla is a perennial emerged hydrophytes belonging to family Cyperaceae present in moist soil and dry soil around water bodies, its height may reach 160 cm. It reproduces by bulbs and seeds (**Boulos , 2005, 2009).**

The main concern of this study is to investigate the efficiency of *S. litoralis* and *C. rotundus* as a biomaterials for removing of heavy metals (As, Cd, Pb, and Zn) from polluted soil as a sustainable treatment strategy in the laboratory and as a trial to be used at a wide scale treatment strategy.

MATERIALS AND METHODS

Solutions of heavy metals were prepared for each metal by dissolving salts of the metal in distilled water, with concentration 10, 20, 30, 40 and 50 ppm then used for irrigation of the tested plants twice a week for 45 days.

The tested plants *Schoenoplectus litoralis* (Schard.) Palla and *Cyperus rotundus* L. were collected from the natural habitat at Baltim (Kafr El Sheikh Governorate, north coast of Egypt) around Burullus Lake. Soil of the collected plant species are characterized by medium sandy, with pH 6.2 and salinity 3.2 mg/l which have physico-chemical characteristics summarised in Table 1. Which are the ideal conditions for their growth and dominance. Plants of 25 individuals for each species were collected and washed with fresh and distilled water for removing particles and possible parasites, where plants with similar size and growth stage were selected for the experiment.

Soil collected from the natural habitat for cultivation, cleaned and analysed for soil type (mechanical analysis) by sieves, salinity and pH were according to **Allen *et al*. (1986)** of the original habitat were measured in the field to know the ideal conditions for cultivation of the tested plants. The plant cultivation was in plastic pots 60 cm height, 100 cm length and 50 cm width with the same size .The tested plants were planted as 10 individuals in each pot and irrigated twice per week for 45 days (see above).

The plants were collected and their roots were separated from shoots then dried and grinded in to powder and kept for analysis of metal residues where the final concentrations of As, Cd, Pb, and Zn in the plants samples were measured in 1 g powder (**APHA, 1998)** by the Atomic Absorption Spectroscopy in both root and shoot system for determination the concentration of these metals in different plant parts in both tested plants.

RESULTS

The results as presented in Tables 1, 2 and 3 showed that ; soil characteristics of the tested plants are medium laomy with mean PH 6.2 and salinity of 1.3 and 5.1 with mean value 3.1 mg/l. as in Table 1.

Table1. Soil characteristics of the tested plants .

Soil characters	Minimum	Maximum	Mean
Soil type	light sandy	heavy clay	medium loamy
pH	5.2	7.3	6.2
Salinity (mg/l)	1.3	5.1	3.2

Table 2 shows that the *Schoenoplectus litoralis* plant could be absorbe and accumulate high rate of tested metals in its root and shoot systems. where , As was accumulated by high rate reached 149 mg/g dry weight in root and 132 mg/g dry weigh in shoot and the minimum were 114 mg/g dry weigh in root and 82 mg/g dry weigh in shoot system when compared with the control concentration, while the higher accumulation value was in root system and the lower was in shoot system.

Table 2. The concentration of heavy metals in shoot and root system mg/g dry weight of Schoenoplectus litoralis with different concentrations of irrigated water (%).

Metals	Plant organ	Control	10%	20%	30%	40%	50%
As	Root	102.0	114.0	122.0	132.0	137.0	149.0
	Shoot	72.0	82.0	96.0	117.0	125.0	132.0
Cd	Root	8.0	12.0	13.9	29.0	40.0	46.3
	Shoot	4.1	9.2	12.0	26.1	32.5	34.7
Pb	Root	45.0	47.0	56.0	87.0	95.0	113.0
	Shoot	21.0	37.0	52.0	83.0	93.0	99.0
Zn	Root	77.0	96.0	98.0	106.0	117.0	127.0
	Shoot	62.0	77.9	84.7	90.2	102.0	105.0

It was found that Pb concentration in S. litoralis ranged between 13 mg/g dry weight and 99 mg/g dry weight in root and 47 mg/g dry weight and 37 mg/g dry weight in shoot system, where the rate of accumulation increased by the increasing of the concentrations of metals in the irrigation water.Also There were no clear variations at Zn accumulation in different parts of S. litoralis and between the different concentrations of metals in irrigated water.

Table 3 shows that the *Cyperus rotundus* has a greate power for absorbing and accumulation of heavy metals from soil.

Table 3. The concentration of heavy metals in shoot and root system mg/g dry weight of Cyperus rotundus with different concentrations of irrigated water (%).

Metals	Plant organ	Control	10%	20%	30%	40%	50%
As	Root	109.0	118.3	127.0	142.4	159.7	182.3
	Shoot	75.0	89.0	101.0	120.0	129.0	145.0
Cd	Root	9.0	13.7	19.2	28.2	45.2	62.3
	Shoot	5.3	10.2	14.5	22.1	35.6	51.4
Pb	Root	49.0	52.0	67.0	90.0	111.0	122.0
	Shoot	23.0	49.0	57.0	84.0	90.0	102.0
Zn	Root	79.0	97.5	102.2	114.3	122.1	137.5
	Shoot	67.0	79.2	85.4	91.3	102.4	109.0

The As residues in *C. rotundus* showed a little variation between the control and the samples with different concentrations and also between root and shoot system as shown in Table 3. The Cd residues in *C. rotundus* appears to be more varied from control to the samples where the control was 9 mg/g dry weight in root and 5,3 mg/g dry weight in shoot. The tested samples reached 62.3 mg/g dry weight in root and 51.4 mg/g dry weight in shoot with the high concentration at the irrigation water 50 ppm of Cd (Table 3). There is no significant variation in both Pb and Zn at root and shoot system in the accumulation of these metals as in Table 3.

DISCUSSION

The obtained results revealed that the more suitable soil for the cultivation of the tested plants *Schoenoplectus litoralis* and *Cyperus. rotundus* are medium laomy with PH ranged between 5.2 and 7.3 with medium salinity reached 5.1 mg/l . Also after 45 days from irrigation with water containing different concentrations of heavy metals they have a good and high power for absorbing and accumulating heavy metals from polluted soil by high rate and could be used in treatment of polluted soils by heavy metals and bioremediation of them from polluted habitat. It was found that there are a clear differences in heavy metals concentrations between the control and the tested samples in all metals and between the tested plants where the *C. rotundus* has a high power for absorbing and accumulating heavy metals from the contaminated soil by high rate in their roots than shoot system (183 As, 82 Cd, 122 Pb, and 137.2 Zn) mg/g dry weight in root and (145 As, 51.4 Cd, 102 Pb, and 109.5 Zn) mg/g dry weight in shoot for while *S. litoralis* absorbing and accumulating heavy metals from soil less than *C. rotundus* (148 As, 46.3 Cd, 113 Pb, and 127 Zn) mg/g dry weight in root and (132 As, 43.7 Cd, 99 Pb, and 105 Zn) mg/g dry weight in its shoot system (Tables 2 and 3). **Shaheen *et al*. (2006)** found that *C. rotundus* accumulated high concentration of As and Cd in their shoot system when irrigated by water contain different concentration of these metals and the rate of accumulation increased with the increases of metal concentration in the water and the time of exposure to metals in soil.

Table 2 showed that As was accumulated by high rate in *S. litoralis* reached 149 mg/g dry weight in root and 132 mg/g dry weigh in shoot and the minimum were 114 mg/g dry weigh in root and 82 mg/g dry weigh in shoot system when compared with the control concentration, while the higher accumulation value was in root system and the lower was in shoot system. **Sao *et al.* (2007)** also observed that the rate of accumulation of As in the plant increased with the increases of the concentration of metal in the irrigated water.

The concentration of Cd in the *S. litoralis* show a clear variation between different concentration and different plant organs like root and shoot system, where the high accumulation of cadmium was in root 46.3 mg/g dry weight and in shoot was 34.7 mg/g dry weight and the lower values were 12 mg/g dry weight and 9.2 mg/g dry weigh in root and shoot, respectively (Table 2).

in shoot system, where the rate of accumulation increased by the increasing of the concentrations of metals in the irrigation water. **Ali *et al.* (2008)** assured this findings, too.

There were no clear variations at Zn accumulation in different parts of *S. litoralis* and between the different concentrations of metals in irrigated water (Table 2). **Nafea (2016)** and **Nafea and Zyada (2015)** observed the element absorbed and accumulated by low quantities in most all concentration used in treatment and irrigation.

Cyperus rotundus showed a great accumulation power toward bioremoval of heavy metals from polluted soils with different concentrations of heavy metals (Table 3).

Shaheen *et al.* (2006) found that *C. rotundus* could be absorb and accumulate As in its root and shoot system by higher rate and could be used in treatment of polluted soil with As. While **Aydin and Fulya (2009)** found that *C. rotundus* accumulate high concentration of heavy metals from soil irrigated with polluted water by heavy metals in the root system more than shoot system.

Molla (2002) found that root system of *Cynodon dactylon* L. plants accumulated heavy metal in their roots and rhizomes more than shoots and could be used as bioremoval agent for metal pollution from soil**. Elifantz and Tel-Or (2002)** assured that phytoremediation is a good and safe tools for pollution control. Also, **Ololade and Ologundudu (2007)** and **Das and Maiti (2007)** stated that the most tested plants accumulated high concentrations of heavy metals in their roots than their shoots and could be used in biotreatment of polluted soils by heavy metals and in the strategy for pollution control.

The As residues in *C. rotundus* showed a little variation between the control and the samples with different concentrations and also between root and shoot system as shown in Table 3. The Cd residues in *C. rotundus* appears to be more varied from control to the samples where the control was 9 mg/g dry weight in root and 5,3 mg/g dry weight in shoot. The tested samples reached 62.3 mg/g dry weight in root and 51.4 mg/g dry weight in shoot with the high concentration at the irrigation water 50 ppm of Cd (Table 3). There is no significant variation in both Pb and Zn at root and shoot system in the accumulation of these metals as in Table 3.

The concentration of heavy metals in roots of plants cultivated on road sides are higher than other plant parts so, they could be used in phytoremediation of polluted soil with heavy metals on roadside and decrease the rate of soil pollution and contamination on roadsides **(Onder *et al*., 2007; Cui *et al*., 2009; Rajiv *et al*., 2009; Hashim *et al*., 2017).** The tested plants could be used in phytoremediation of pollute soils with heavy metals at roadsides as an application of green technology.

CONCLUSION

In conclusions of the conducted study, it should be stated that *C. rutundus* and *S. litoralis* could be grow in soil polluted with high load of heavy metals and could absorb and accumulated As, Cd, Pb, and Zn in their roots and shoot systems by high values and could be used in bioremediation and natural treatment of degraded polluted soils and in the restoration and rehabilitation programs as a safe tools and low cost bioremediation agents. Also these plants could be used in phytoremediation and treatment of polluted and contaminated soils on roadside in safe and less economic manner.

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