Original Research

Enrichment Capacity of Lead in Water by Aquatic Plants

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Abstract

Phytoremediation is a promising, low-cost and environmentally friendly technology. By simulating different concentrations of Pb, Pb+Zn and Pb+EDTA in aqueous solutions, taking *Acorus calamus*, *Eichhornia crassipes* and *Iris tectorum* as experimental material, hydroponics was used to study the enrichment of aquatic plants to Pb in water under different conditions. The results show that *Eichhornia crassipes* has the best bioconcentration capacity, *Acorus calamus* has good bioconcentration and *Iris tectorum* has weak bioconcentration. The bioconcentration factors (BCFs) are more than 1 and the BCFs of the underground parts are greater than that of the aboveground parts. However, the translocation factors (TFs) are less than 1. The presence of Zn enhances the enrichment of the aquatic plants to Pb. The presence of EDTA reduces the enrichment, but promotes the transfer of Pb from underground parts to aboveground parts. All of the conclusions can provide reference for the application of aquatic plants for Phytoremediation of Pb.

Keywords: lead pollution; combined pollution; wastewater; phytoremediation

Introduction

With the rapid development in urbanization and industrialization, heavy metals have been widely used in industrial processes. Improper treatment of municipal sewage or industrial wastewater can easily lead to the increase of heavy metals in water. The heavy metal pollution of water resources is a key problem that has adverse effects on human beings, animals and plants [1]. Although heavy metals are natural components of the environment, excessive human activities have altered their geochemical cycles and biochemical balances [2]. Heavy metals are non-biodegradable and persistent environmental contaminants [3]. When heavy metals enter the bodies of animals and humans through the food chain, they eventually pose a risk to the environment and human health [4-6].

Lead is one of the most common heavy metal pollutants with a very high toxicity level. The toxicity levels of lead, mercury, arsenic and cadmium as listed by the Agency for Toxic Substances and Disease Registry (ATSDR), ranking first, second, third and sixth, respectively [7, 8]. When an excessive amount of lead is absorbed in the human body, it affects the nervous system through the blood and causes IQ reduction of the brain. In addition, lead can accumulate in the human body over time and eventually affects the kidneys, hematopoietic system, reproductive system and cardiovascular system [9].

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The three most common methods used to remediate heavy metal-contaminated water are physical remediation, chemical remediation and bioremediation [10]. However, the physical and chemical methods are costly, require trained staff and may produce secondary pollutants [11-14]. On the contrary, phytoremediation is a low-cost and environmentally friendly method [15]. It is a technology that uses plants and microorganisms to remediate partially or completely selected contaminants from soils, sludge, sediments, wastewater and groundwater [2, 16]. Phytoremediation techniques include plant extraction, plant filtration, plant stabilization, plant volatilization and plant degradation [17]. Wetland plants are biological filters that can absorb heavy metals from sediments and water [18]. High element absorption and high biomass make aquatic plants the best species for remediating a heavy metal-polluted environment [19].

At present, much research is underway on phytoremediation of heavy metals in contaminated soil, and the removal of heavy metals from wastewater is gradually becoming a research hotspot. Bingöl et al. [20] studied the phytoremediation and biosorption potential of *Lythrum salicaria* L. for nickel removal from aqueous solution. Lu et al. [21] studied the phytoremediation potential of eight aquatic plants for copper contamination. Li et al. [22] studied the interaction between *Alternaria helix philoxeroides* (Mart.) Griseb and cadmium movement in aquatic environment through hydroponic stress experiments, and found that *A. philoxeroides* could be used to remediate cadmium-contaminated water. Dogan et al. [23] bred *Ceratophyllum demersum* L. using tissue culture techniques, and studied the potential for *Ceratophyllum demersum* L. to bioaccumulate Pb and Cd. The result showed that *Ceratophyllum demersum* L. could be used to remediate Cd- and Pb-contaminated aquatic environments. In this study we conducted a simulation experiment to compare the growth of aquatic plants and their ability to uptake lead in different concentrations of lead-alone stress, Pb-Zn combined stress and Pb-EDTA combined stress (with EDTA as a chelating agent).

Material and Methods

Experimental Design

The collected aquatic plants were first washed with tap water and left for 7 days. The plants were again washed with deionized water. Pb $(NO_3)_2$, Zn $(NO_3)_2$ and Edetate disodium were dissolved in deionized water to prepare the mother liquor of Pb^{2+}, Zn^{2+} and EDTA of 50 mg/L in 1000 mL volumetric flask. Lead alone, Pb-Zn and Pb-EDTA solutions with different initial concentrations were prepared in glass bottles of 1 L volume. After adding 5 mL nutrient solution to each bottle, the treated aquatic plants were placed in those bottles, with three plants in a group. The water level

line was marked after finishing the above steps. The research objects were left in an open air room, with adequate light and ventilation, and cultured at ambient temperature. For lead-alone stress, the concentration of lead in the solution was 5, 10, 50, 100 and 500 mg/L in turn. For Pb-Zn combined stress, the concentration of lead in solution was 50 mg/L, and the concentration of Zn was 5, 10, 50, 100 and 500 mg/L in turn. For Pb-EDTA combined stress, lead and EDTA in solution were formulated according to a 1:1 ratio, followed by 5, 10, 50, 100 and 500 mg/L in turn. Meanwhile, the concentration of *Acorus calamus* on three medium-low concentration lead-containing wastewater was studied. The same as the previous preparation method, the concentrations of Pb, Zn and EDTA changed to 5, 10, 20 and 50 mg/L.

Analysis of Heavy Metal Elements Content

The growth response of the plants needs to be observed and recorded. 50 mL water samples were taken after every 10 days. In the meantime, deionized water was added to the glass bottle until it reached the water level line marked earlier. After that, the water samples were filtered with 0.45 μm filter membrane. The content of Pb was measured by flame atomic absorption spectrometry.

After 60 days of cultivation, the aquatic plants were taken out, rinsed with tap water and rinsed three times with deionized water. The plants were divided into aboveground and underground parts, and their fresh weight was recorded. The aquatic plants were then put in the oven for drying and the dried samples were weighed with an electronic balance. A constant weight sample was ground into a powder with a mortar. The aboveground parts and the underground parts were accurately weighed 0.4000±0.0001 g by quartering method. First they were put into a 5 mL crucible and carbonized powder was obtained in a low-temperature electric furnace. Then it was transferred in a crucible in the muffle furnace ashing at 500ºC. Then nitric acid solution of 1:1 (10 mL) and 1 drop of hydrogen peroxide solution were added and passed through the 0.45 μm membrane. The content of Pb was measured by flame atomic absorption spectrometer thereafter.

Data Analysis

Double factor variance analysis was used to compare the effects of Pb concentration and culture time on the enrichment of Pb under Pb, Pb-Zn combined and Pb-EDTA combined solutions. Additionally, this analysis was used to compare the effects of different plant species on Pb enrichment ability under different Pb treatments. The data were analyzed by MINITAB 17.

The bioconcentration factors (BCFs) and translocation factors (TFs) were used to assess the potential of plants for removal of heavy metals [24]. BCFs can be used to assess the ability of plants to

accumulate heavy metals from water. TFs can be used to assess the ability of elements to transfer in plants, and it is the proportion of one element concentration in two parts of the plant [25]. They have been proved by many studies [26-31]. The K_{pb} value characterizes the effect of combined stress on plant Pb accumulation.

$$BCFs = (C_{underground} \text{ or } C_{aboveground}) / C_{water}$$

$$TFs = C_{aboveground} / C_{underground}$$

$$K_{pb} = C_{combined} / C_{single}$$

$C_{underground}$ and $C_{aboveground}$ indicate the concentration of heavy metals in the plants underground parts and aboveground parts, respectively (mg L^{-1}). C_{water} represents the concentration of heavy metals in the solution (mg L^{-1}). $C_{combined}$ and C_{single} represent the concentration of heavy metals in the plants under combined stress and single heavy metal stress, respectively (mg L^{-1}).

Results and Discussion

Growth Response

In the process of aquatic plant culture, plant biomass, plant root length and plant height have been changed. Taking *Acorus calamus* as an example, only the change rate of biomass and root length are listed, because the change of plant height mainly shows the increase of plant root length (Fig. 1). The roots of three

Fig. 1. The change rate of root length and fresh weight of *Acorus calamus.* after 60 days of culture.

experimental groups were elongated after 60 days of culture. In general, the rate of root length change of plants in the Pb-EDTA combined stress environment is much larger than the ones in Pb alone stress and Pb-Zn combined stress environment. In addition, for biomass growth rate, both plants growing in Pb-alone stress and Pb-EDTA combined stress environment had increased biomass, which indicates that the low concentration of lead can increase the metabolism of plants. However, in the experimental group contaminated by Pb-Zn, the biomass of plants was increased under low Zn concentration (≤5 mg/L) and the biomass of plants was decreased under medium-low Zn concentration (≥10 mg/L). It can be seen that when Zn concentration is high, the combined effect of lead and zinc can inhibit the growth and metabolism of plants.

Traits of Plant Injury

Aquatic plants can purify lead-contaminated wastewater by absorbing and enriching Pb. When Pb concentration exceeds a certain threshold, plant growth and metabolism may be affected and even plant death may occur [10, 32]. When exogenous heavy metal pollutants enter into the water, plants can absorb them through root metabolism. Some remain in the roots, while others move to the aboveground parts with the transpiration in plants and accumulate in the stems and leaves of the plants, thereby harming them [33].

Root decay phenomenon: On the 10th day of culture, the number and growth of new shoots of *Acorus calamus* was less and slower in the experimental group than the one in the control group (Fig. 2). In the late stage of cultivation (30 days), Pb-free wastewater had more shoots and longer roots and there was no decay found. In contrast, the plant roots in Pb-containing wastewater started to decay, and roots in Pb-Zn contaminated water were severely damaged. In the later stage of culture, the root of *Eichhornia crassipes* had a slight decay phenomenon, and the root decay of *Iris tectorum* was the worst.

Yellowing effect on Leaves: On the 3rd day of culture, there was a slight yellowing sign on the edge of leaves. On the 30th day, the leaves were partially yellowed. On the 60th day, some of *Acorus calamus* turned yellow in the experimental group of Pb-alone stress and Pb-EDTA combined stress, and all of the *Acorus calamus* leaves were yellowed in the experimental group under Pb-Zn combined stress. Moreover, with the increase of concentration of Pb and Zn in the solution, the yellowing effect of the plant was more obvious. *Eichhornia crassipes* in the latter part of the cultivation showed slight leaf yellowing effect, and *Iris tectorum* early in the culturing showed damage symptoms. There are two reasons explaining chlorosis phenomenon in plants. The toxicity of lead affects photosynthesis, and synthesis of chlorophyll degradation can reduce or increase, thus changing the plant carotenoid and chlorophyll ratio, which results in plant leaf chlorosis [34]. Another
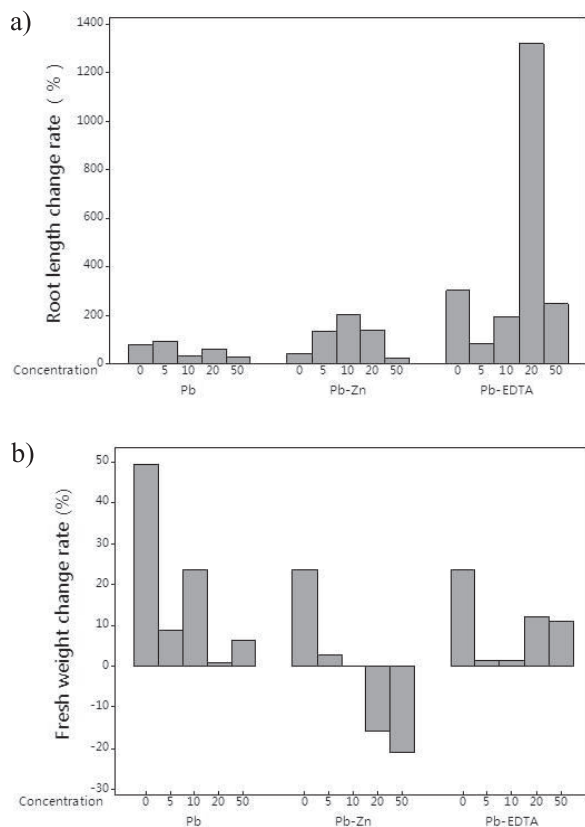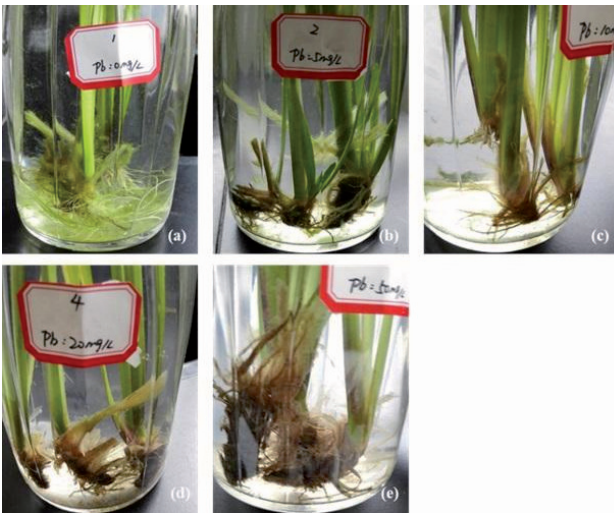
Fig. 2. Comparison of root elongation of *Acorus calamus* after 10 days of culture: a) control group b-e) experimental group, the concentration of lead was 5,10,20,50 (mg L⁻¹) in turn.

reason is that iron is an activator of some enzymes of chlorophyll synthesis. Lead accumulation in plants affects the absorption of iron and prevents the synthesis of chlorophyll, leading to a yellowing of plant leaves [35].

Factors Affecting the Enrichment of Lead in Plants

Double-factor variance analysis showed that culture time and different concentrations of lead and combined stress treatment had significant effects on Pb accumulation in plant tissues (P<0.05) (Table 1). For the underground parts and the whole plant, the accumulation of Pb was significantly influenced by the initial concentration of Pb and the species of plants (P<0.05) (Table 2). However, for the aboveground parts, the initial concentration of Pb and the species of plants could not be considered to have significant effects on the accumulation of Pb (P>0.05) (Table 2).

Table 1. Double-factor variance analysis results of concentration and culture time.

Pollution	Variable	F	P
Single Pb pollution	Pb concentration	5.60	0.005
	Culture time	18.65	<0.001
Pb-Zn combined pollution	Zn concentration	4.95	0.009
	Culture time	126.33	<0.001
Pb-EDTA combined pollution	EDTA concentration	30.88	<0.001
	Culture time	6.33	0.003

Table 2. Double-factor variance analysis results of concentration and plant species.

Plant parts	Variable	F	P
Aboveground parts	Pb concentration	2.63	0.114
	Plant species	1.24	0.340
Underground parts	Pb concentration	5.27	0.022
	Plant species	5.74	0.028
Whole plant	Pb concentration	6.54	0.012
	Plant species	4.65	0.046

Plant Accumulation of Lead

The effect of different initial concentrations of lead alone on *Acorus calamus* was studied. When the initial concentration of Pb increased, the concentration of Pb in the wastewater also increased (Fig. 3). Fitting the curves in Fig. 3, it shows that the five fitting curves have a common mode that complies with the law of quadratic curve (Table 3). The lowest point of the curve is found between 27 days and 36 days. The lowest point is the lowest concentration of Pb in water sample and indicates that the plant has the maximum Pb absorption, which is the threshold of plant absorption. Because of the constant concentration of Pb in the environment, with the passage of time, the effect of Pb toxicity on plants increased. Therefore, the absorptive capacity of plants to Pb is weakened. P-value of the five curves are greater than 0.05, because each sample was taken from the same group, so there is no significant difference.

The accumulation of lead in *Acorus calamus* and *Eichhornia crassipes* under two kinds of combined stress was studied. The coexistence of elements in water has a synergistic or antagonistic effect on plant absorption of heavy metals, and the concentration level of some
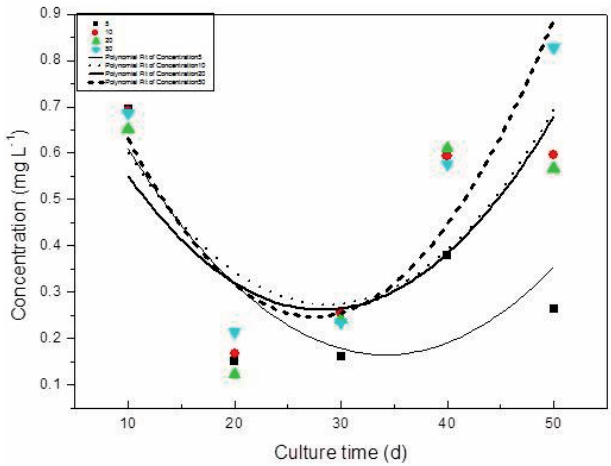

Fig. 3. When the initial concentration of lead is different, the concentration of lead in solution changes with the time of incubation.

Table 3. Equation of fitting curve and its correlation.

Concentration (mg L^{-1})	Regression equation	R^2	F	P
5	y = 0.0008x^2 - 0.0519x + 1.052	0.6027	1.52	0.397
10	y = 0.0009x^2 - 0.0535x + 1.042	0.5823	1.39	0.418
20	y = 0.0009x^2 - 0.0493x + 0.956	0.5077	1.03	0.492
50	y = 0.0013x^2 - 0.0693x + 1.198	0.8848	7.68	0.115

heavy metal ions may affect the selective absorption of plants to other metal ions [36]. When *Acorus calamus* and *Eichhornia crassipes* were cultured in the waste liquid containing Pb and Zn, part of the leaves started to turn yellow on the 3rd day, and partly yellowing occurred on the 30th day. The poisoning symptoms of *Acorus calamus* and *Eichhornia crassipes* were worse than those living under Pb alone contaminated solution. Therefore, there is a synergistic effect of the combined toxicity of Zn and Pb on plants. The changes of Pb concentration in the wastewater with different culture time are shown in Fig. 4. In the first 20 days, the *Acorus calamus* (Fig. 4a) showed higher initial Zn concentration and slower absorption rate of Pb, which is caused by toxic synergistic effects. The concentration of Pb in all Pb-Zn combined contaminated water samples

was almost 0 when grown to 40 days. For *Eichhornia crassipes* (Fig. 4b), the concentration of Pb in all Pb-Zn combined contaminated water samples was almost 0 on the 10th day of the culture. This experiment shows that the existence of Zn in the wastewater promotes the absorption of Pb, and *Eichhornia crassipes* has better absorption ability of Pb than *Acorus calamus*.

The *Acorus calamus* and *Eichhornia crassipes* were cultivated in wastewater containing Pb and EDTA. On the 3rd day, the leaves of the plants started to turn yellow, and partly yellowing occurred on the 30th day. Compared with the Pb alone stress, the poisoning symptoms of *Acorus calamus* and *Eichhornia crassipes* were alleviated in Pb-EDTA combined stress. Therefore, the combined toxicity of EDTA and Pb showed antagonistic effects on plants. Fig. 4 shows the concentration of Pb
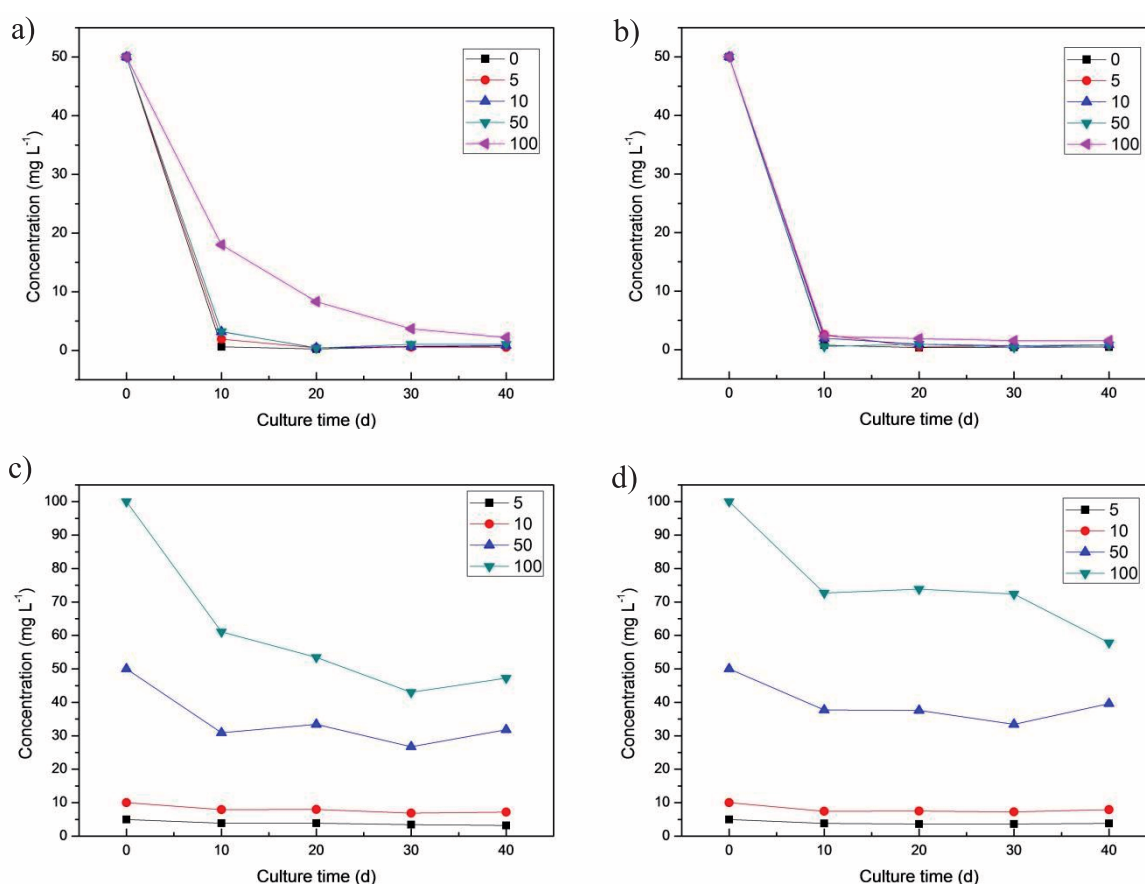

Fig. 4. The concentration of lead in combined stress changed with the culture time: a) *Acorus calamus* in Pb-Zn, b) *Eichhornia crassipes* in Pb-Zn, c) *Acorus calamus* in Pb-EDTA and d) *Eichhornia crassipes* in Pb-EDTA.

changing in the wastewater at different culture times. Both *Acorus calamus* (Fig. 4c) and *Eichhornia crassipes* (Fig. 4d) showed that the concentration of EDTA and Pb has a positive relationship. When the initial concentrations of EDTA and Pb were both 50 mg/L, after 40 days cultivation, Pb concentration in *Acorus calamus* and *Eichhornia crassipes* culture solution was still close to 50 mg/L. Compared with the experimental groups of Pb alone stress and Pb-Zn combined stress, the experimental group of Pb-EDTA combined stress absorbed more slowly, and other experimental groups of Pb-EDTA with different initial concentrations showed the same trend. Therefore, the presence of EDTA inhibits the uptake of Pb by plants. Adding exogenous EDTA does not always promote plant uptake [37]. Tian et al. [38] reported that although Pb-EDTA complex was detected in *Sedum alfredii* plants after adding EDTA, it significantly reduced the accumulation of lead in plant roots, stems and leaves. Anning et al. [39] studied the effects of soil amendments EDTA and $Al_2(SO_4)_3$ on plant uptake of heavy metals. The results showed that EDTA inhibited plants roots absorption ability of Pb. The results of this study are consistent with these studies.

Lead Enrichment Capacity of Different Plant Species

According to the Pb level measured from aboveground, underground parts and culture solution after 60 days cultivation, the enriched and transferred proportion of Pb was calculated (Table 4). For lead-alone stress, the TFs of the three plants were all less than 1, which showed that all three plant species were non-hyperaccumulator species. These plants stored heavy metals in their underground tissues, which were not suitable for plant extraction. They can be recommended for plant stabilization in lead-polluted water [40, 41]. The TFs show *Acorus calamus* > *Iris tectorum* > *Eichhornia crassipes*. For *Eichhornia crassipes*, the overall transfer coefficient is very small, which indicates that it cannot transfer the heavy metals in the underground parts to the aboveground parts effectively. The BCFs of the underground parts is greater than the aboveground parts. The BCFs of the underground parts show *Eichhornia crassipes* > *Acorus calamus* > *Iris tectorum*. The BCFs of the aboveground parts show *Acorus calamus* > *Eichhornia crassipes* > *Iris tectorum*. For *Acorus calamus* and *Eichhornia crassipes*, the BCFs of the underground parts increased gradually with the increase of Pb concentration in solution at the medium-low concentration (≤50 mg/L), which indicated that lead mainly enters into plant roots after entering the plants. This may be a result of self-protection mechanism of plants. It tries to prevent the transfer of Pb from roots to stems and leaves, and to avoid its influence on photosynthesis and metabolism [42].

Table 5 shows the BCFs and TFs of *Acorus calamus* and *Eichhornia crassipes* under different concentration gradients under the effects of two combined stresses. The BCFs of the underground parts were greater than aboveground parts for both plants. For plants living in Pb-Zn-contaminated solution, the Pb absorption capacity of

Table 4. Enrichment and transfer of lead by different plants.

Aquatic plants	Concentration (mg L⁻¹)	BCFs		TFs
		Aboveground parts	Underground parts	
Acorus calamus	5	9.22	30.82	0.30
	10	9.04	65.66	0.14
	50	6.27	87.28	0.07
	100	14.79	21.47	0.69
	500	0.78	1.94	0.40
	mean	8.02	41.43	0.32
Eichhornia crassipes	5	1.49	154.75	0.01
	10	1.75	555.56	<0.01
	50	1.80	602.18	<0.01
	100	1.55	198.43	0.01
	500	0.42	4.31	0.10
	mean	1.40	303.05	0.02
Iris tectorum	5	1.71	2.57	0.67
	10	1.24	46.35	0.03
	50	0.44	18.09	0.02
	100	1.48	69.05	0.02
	500	0.04	8.52	<0.01
	mean	0.98	28.92	0.15

Table 5. Enrichment and transfer of *Acorus calamus* and *Eichhornia crassipes* under combined pollution.

Combined pollution	Aquatic plants	Concentration (mg L^{-1})	BCFs		TFs
			Aboveground parts	Underground parts	
Pb-Zn combined pollution	*Acorus calamus*	0	8.96	11.79	0.76
		5	6.23	8.61	0.72
		10	6.56	94.47	0.07
		50	11.00	79.60	0.14
		100	6.78	2.22	3.06
		mean	7.90	39.33	0.95
	Eichhornia crassipes	0	1.80	602.18	<0.01
		5	10.46	180.34	0.06
		10	1.47	66.36	0.02
		50	2.57	176.87	0.01
		100	18.80	193.94	0.10
		mean	7.02	243.94	0.04
Pb-EDTA combined pollution	*Acorus calamus*	0	5.77	92.80	0.06
		5	4.98	5.05	0.99
		10	2.87	2.19	1.31
		50	0.31	1.45	0.21
		100	0.23	1.20	0.19
		mean	2.83	20.54	0.55
	Eichhornia crassipes	0	6.72	4.97	1.35
		5	0.40	6.78	0.06
		10	0.10	1.89	0.05
		50	0.02	2.61	0.01
		100	0.32	1.96	0.16
		mean	1.51	3.64	0.33

In the case of combined pollution, when the concentration of Pb, Zn and EDTA in the solution is 500 mg/L, the phenomenon of decay and death of aquatic plants cannot be measured and not listed in the table.

the *Eichhornia crassipes* underground parts was greater than that of the *Acorus calamus*. For those living in Pb-EDTA-contaminated solution, the absorption capacity of Pb of *Acorus calamus* aboveground and underground parts was greater than *Eichhornia crassipes*. Overall, the average BCFs of aboveground and underground parts of both plants showed Pb-Zn combined stress> Pb-EDTA combined stress. The TFs of *Acorus calamus* were higher than *Eichhornia crassipes* under the two combined stress states. The analysis shows that *Acorus calamus* has better ability in transferring heavy metals than *Eichhornia crassipes*.

Table 6 lists the BCFs, TFs and K_{pb} of two combined stress states when the concentrations of Zn and EDTA were changed under the initial concentration of Pb of 10 mg/L. The average BCFs of aboveground and underground parts showed Pb-Zn combined stress > Pb alone stress> Pb-EDTA combined stress, which proved that the combined toxicity of Zn and Pb on a plant has a synergistic effect; and combined toxicity of EDTA and Pb showed an antagonistic effect on plants.

For K_{pb}, the K_{pb} of the underground parts under Pb-Zn combined stress is greater than the aboveground parts; the aboveground parts under Pb-EDTA combined stress is larger than the underground parts. The K_{pb} of the aboveground parts is greater than 1. These results show that EDTA can increase the transfer ability of Pb from underground parts to aboveground parts. Wu et al. [43] research also showed that EDTA had a significant impact on increasing the concentrations of Cu and Pb in aboveground parts. The results of this study are similar to those reported.

Conclusions

Remediation of heavy metal pollution in water has become an urgent problem to be solved. The study shows that the existence of a certain concentration of Pb inhibits the growth of the roots and causes a yellowing effect on plant leaves. Double factor variance analysis showed that culture time, Pb concentration, and plant

Table 6. Enrichment and transfer of lead by *Acorus calamus* under different pollution conditions.

Pollution	Concentration (mg L⁻¹)	BCFs		TFs	K_pb	
		Aboveground parts	Underground parts		Aboveground parts	Underground parts
Single Pb pollution	5	9.22	30.82	0.30	-	-
	10	9.04	65.66	0.14	-	-
	20	6.31	78.45	0.08	-	-
	50	6.27	87.28	0.07	-	-
	mean	7.71	65.55	0.15	-	-
Pb-Zn combined pollution	0	13.27	65.66	0.20	-	-
	5	5.76	110.06	0.05	0.04	1.29
	10	38.08	68.27	0.56	0.25	0.70
	20	7.79	111.93	0.07	0.03	0.71
	50	4.89	287.27	0.02	0.03	2.55
	mean	13.96	128.64	0.18	0.09	1.31
Pb-EDTA combined pollution	0	13.27	65.66	0.02	-	-
	5	3.45	13.31	0.26	4.00	0.37
	10	1.52	6.42	0.24	4.89	0.50
	20	1.30	2.07	0.63	1.30	0.20
	50	0.68	2.22	0.31	2.34	0.18
	mean	4.04	17.94	0.29	3.13	0.31

species have significant effects on the enrichment of lead by aquatic plants. The study on the enrichment ability of lead of aquatic plants under single stress and combined stress shows that the absorption of lead by *Acorus calamus* and *Eichhornia crassipes* in three aquatic plants is better. According to the growth of aquatic plants and the absorption of lead, *Acorus calamus* is suitable for the treatment of lead-containing wastewater at medium-low concentrations, and *Eichhornia crassipes* has a better effect on treating wastewater that has a high concentration of lead compared to *Acorus calamus* and *Iris tectorum*. There is a threshold for the absorption of lead by aquatic plants. When the lead content in plants exceeds a certain threshold, it affects plant growth and metabolism. The combined toxicity of Zn and Pb on plants is synergistic. Although the combined toxicity of EDTA and Pb had an antagonistic effect on plants, EDTA can promote plants to transfer lead from underground to aboveground parts. The BCFs of the underground parts of the aquatic plant were much larger than the BCFs in the aboveground parts, and almost all TFs were less than 1, which indicated that the lead in the wastewater was mainly absorbed by the roots after it enters the plant. The *Eichhornia crassipes* had the best ability in enrichment of lead with lightest symptoms existing. *Acorus calamus* had the best ability of transferring the lead. Therefore, the high biomass of *Eichhornia crassipes* and *Acorus calamus*, as well as the high tolerance to lead, make it possible to effectively repair lead-contaminated wastewater, which can be used as a selection species for phytoremediation.

Conflict of Interest

The authors declare no conflict of interest.

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