Al-Qadisiyah Journal of Pure Science
ISSN(Printed): 1997-2490 ISSN(Online): 2411-3514
DOI: 10.29350/jops
Al-Qadisiyah Journal of Pure Science

Efficiency of Water Hyacinth (*Eichhornia crassipes*) in the Phytoremediation of Lead Contaminated Water under Field Conditions

Riyam Taleb Nabai [1], Mohammed K. Al-kasser [2]

1: Department of Ecology, College of Science, University of Al-Qadisiyah.

Email: kgdfhjbf@gmail.com

2: Department of Ecology, College of Science, University of Al-Qadisiyah.

Email: mohammed.al-kasser@qu.edu.iq

Received: 12/05/2026; Accepted: 17/05/2026.

Abstract

This study aimed to evaluate the efficiency of water hyacinth (*Eichhornia crassipes*) in removing lead (Pb) from aqueous solutions under field conditions in Samawah, southern Iraq, from January 16 to February 17, 2026. The experiment was conducted using a completely randomized design with three replicates, and three lead concentrations (5, 10, and 25 mg/L), in addition to a control treatment.

The results showed that water hyacinth achieved high lead removal efficiency, ranging from 63.62% to 71.05%, with a significant increase in removal efficiency as the initial lead concentration increased. The pH values remained relatively stable within the range of 7.19–7.27, providing suitable conditions for lead precipitation and adsorption. The electrical conductivity (EC) showed only minor changes, reflecting variations in dissolved ion concentrations, without affecting the system's stability.

The results also showed that lead accumulated in both plant tissues and bottom sediments, with accumulation being greater in the sediments. This suggests that both phytoextraction and phytostabilization mechanisms contribute to the removal process. Algal growth was also observed during the experiment, which may have enhanced removal efficiency due to synergistic interactions within the ecosystem.

Overall, the study confirms that water hyacinth is an effective, low-cost, and environmentally friendly method for treating lead-contaminated water under local environmental conditions.

Keywords: water treatment, Phytoremediation, water hyacinth, Eichhornia crassipes, heavy metals.

1. Introduction

Water is considered the most vulnerable natural resource to pollution due to increasing human and industrial activities. Lead (Pb) stands out as one of the most dangerous heavy metal pollutants. It is a non-essential element for growth and has a chronic, cumulative effect that threatens the food chain, ultimately reaching humans, where it causes disturbances in kidney and nervous system function[1]. Given the limitations and high cost of traditional chemical and physical solutions, recent environmental research has turned to phytoremediation strategies as a sustainable and environmentally friendly alternative.

The water hyacinth (*Eichhornia crassipes*) is one of the most efficient aquatic plants for extracting heavy metals due to its rapid growth rate and high tolerance for stressful environments, This plant is characterized by a dense, fibrous root system that provides a large surface area for ion exchange between the aquatic medium and the plant tissues [2]. Its removal mechanism relies on a complex interplay between cellular absorption and biochemical precipitation stimulated by root exudates [3] .

Hence the importance of this study in evaluating the efficiency of this plant under local Iraqi environmental conditions, focusing on the role of physicochemical variables such as pH in stabilizing the treatment process and the distribution of the pollutant between water, living tissues, and bottom sediments. This contributes to a deeper understanding of the dynamics of Phytoremediation in open environments.

2. Materials and Methods

2.1 Study Description

This study was conducted in Samawah, southern Iraq, from January 16 to February 17, 2026. This period was chosen to represent winter conditions, with the aim of evaluating the efficiency of aquatic plants in removing lead under relatively low temperatures.

The experiment was carried out under field conditions, where tanks were exposed to natural light and ambient temperature variations, thus realistically simulating environmental conditions.

2.2 Experimental Design

The study employed a completely randomized design (CRD) using a triplicate to ensure the accuracy of the results and minimize experimental error.

The experiment included three lead concentrations (5, 10, and 25 mg/L) in addition to a lead-free control treatment. Three replicates were performed for each treatment (R1, R2, and R3).

Samples included water, plant tissue, and sediment were collected and analyzed in two phases: Before treatment and After treatment. The mean for each treatment was calculated based on the three readings to minimize experimental variability [4]

2.3 Preparation of the Water and Plant Medium

10-liter plastic tanks were used, thoroughly cleaned and sterilized before the start of the experiment.

Water hyacinth (*Eichhornia crassipes*) was collected from a local source, manually cleaned to remove impurities, and then rinsed with distilled water.

Plants of uniform size and physiological condition were selected, and the biomass was fixed at 100 g (Fresh weight fw) per tank to ensure homogeneity of experimental conditions [5,6].

2.4 Preparation of Lead Solutions

A 1000 mg/L lead nitrate ($Pb(NO_3)_2$) stock solution was prepared, with the medium acidified using hydrochloric acid to ensure complete dissolution and prevent premature precipitation [7]. Concentrations of 5, 10, and 25 mg/L were prepared using the dilution equation:

($C_1V_1 = C_2V_2$)

This was done by adding calculated volumes of the stock solution to tanks containing 10 liters of water to achieve the desired concentrations. [1]

2.5 Monitoring and Physicochemical Measurements

The pH was monitored periodically using a calibrated pH meter [8]. The experiment lasted for 30 days, with daily monitoring of the plants' overall condition, including growth, color changes, and any signs of stress. After approximately 20 days, sediment began to form at the bottom of the tanks, believed to be the result of biogenic lead precipitation. Surface algal growth was also observed in some ponds, likely due to nutrient availability and lighting. [9]

2.6 Sample Collection and Laboratory Analysis

2.6.1 Water Samples

Water samples were collected from each pond at the begining of the experiment and again one month after its termination. These samples were then preserved and prepared for analysis according to standard procedures [7].

2.6.2 Plant Digestion

To estimate the concentration of lead accumulated in the tissues of the water hyacinth (*Eichhornia crassipes*), the plants were collected at the end of the experiment and thoroughly washed with distilled water to remove any surface contaminants. The samples were then oven-dried at 70°C for 48 hours until weight stabilized. The dried samples were then ground using a laboratory grinder, and 1 gram of the powder was accurately weighed using a sensitive balance.

Acid digestion was performed using a 3:1 mixture of nitric acid (HNO_3) and perchloric acid ($HClO_4$). The mixture was gradually heated until a clear, colorless solution was obtained.

After digestion, the samples were cooled and then diluted to 50 mL with distilled water, ready for analysis using Flame atomic absorption spectrophotometry (FAAS) according to standard methods [10]

2.6.3 Sediment Digestion

To determine the lead concentration in the sediments, samples were collected from the bottom of the tanks at the end of the experiment and then allowed to air-dry at room temperature. The samples were then crushed and ground, and subsequently sieved to obtain a homogeneous particle size.

One gram of the dry sediment was accurately weighed using a sensitive balance, and acid digestion was performed using a 3:1 mixture of nitric acid (HNO_3) and perchloric acid ($HClO_4$), with gradual heating until a clear solution was obtained.

After digestion, the samples were allowed to cool, and then the volume was diluted to 50 mL with distilled water, ready for analysis using Flame atomic absorption spectrophotometry (FAAS), according to standard methods [10].

3.Results and Discussion

3.1 Lead Removal Efficiency from Aqueous Medium

The laboratory measurements shown in Table 1 demonstrated the high efficiency of water hyacinth in reducing lead concentrations across all treatments. The removal efficiency increased with increasing initial lead concentration; at 5 mg/L, the removal rate was 63.62%, while it rose to 71.05% at 25 mg/L.

This variation indicates an active physiological response of the plant to high pollution levels, reflecting the efficiency of the root system in absorbing and sequestering metal ions. These results are consistent with those reported by [2,5], regarding the increased plant uptake efficiency with rising heavy metal concentrations.

Table (1): Lead concentration in water before and after treatment and removal percentage (Mean ± SD)

Concentration (mg/L)	Before	After	Removal %	Final pH
Control	0.0017 ± 0.00	0.0002 ± 0.00	88.23	7.20
5	4.81 ± 0.03	1.75 ± 0.03	63.62	7.22
10	9.82 ± 0.04	3.39 ± 0.04	65.48	7.27
25	24.32 ± 0.06	7.04 ± 0.03	71.05	7.20

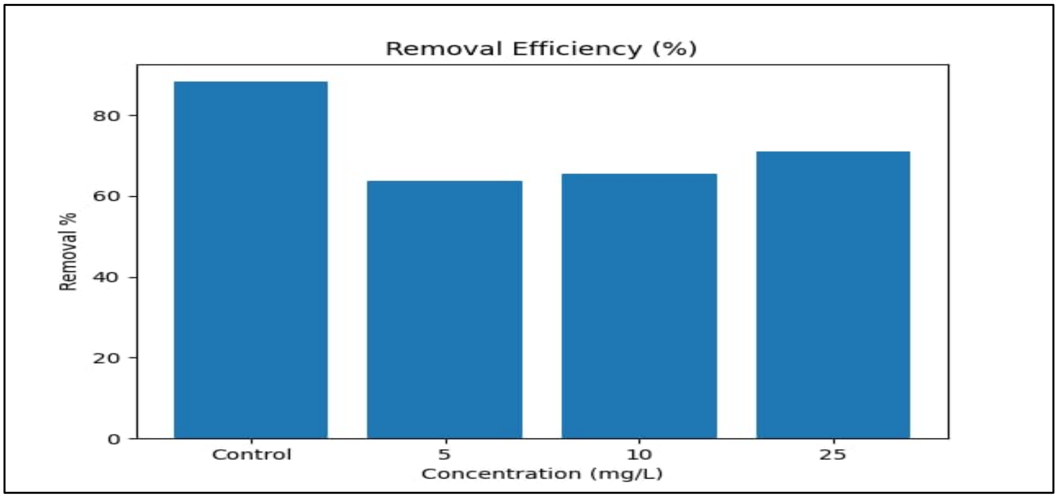

Figure (1): Lead Removal Efficiency at different concentrations

Figure (1) shows the increase in lead removal efficiency with increasing initial concentration, indicating that the water hyacinth plant has a high adaptive capacity towards high levels of pollution, as absorption efficiency increases with the increased availability of metal ions in the aquatic medium.

3.2 pH Changes

The results showed stable pH values throughout the experiment, with a slight tendency towards weak alkalinity, ranging from 7.20 to 7.27 compared to the initial values.

This indicates that the presence of the plant and the nutrient solution helped to balance the aqueous environment and prevent acid fluctuations that could lead to the re-dissolution of lead. This is consistent with the findings of [2,5]regarding the role of near-neutral conditions in the stabilization of heavy metals.

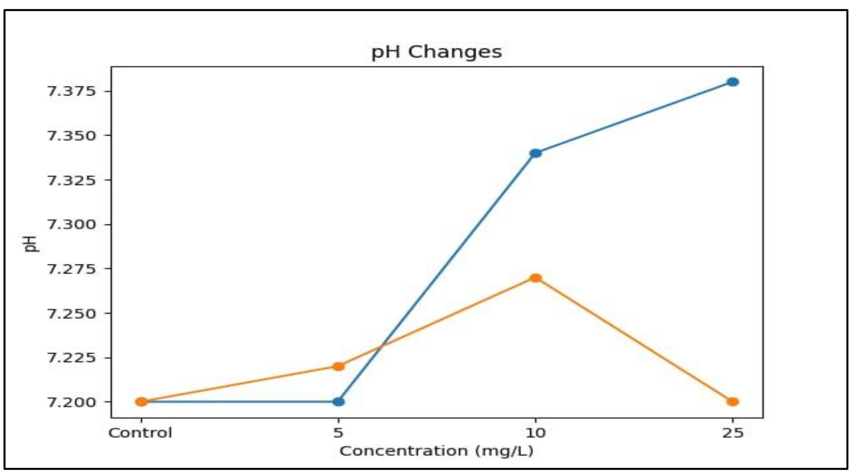

Figure (2): Change in pH before and after treatment

Figure (2) shows the stability of the pH values during the experiment period, as they remained within the quasi-neutral range, indicating that the experimental system maintained its chemical equilibrium, which is an important factor in enhancing the efficiency of lead removal.

3.3 Quantitative Distribution of Lead in Plants and Sediments

The comparative analysis in Table 2 revealed that lead was not only fully absorbed within plant tissues but also accumulated significantly in the bottom sediments. The sediments recorded a concentration of 9.63 mg/kg under the highest treatment, exceeding the accumulation in plant tissues (7.63 mg/kg).

This distribution indicates that phytostabilization was an effective mechanism alongside phytostabilization, supporting the multiplicity of pollutant removal mechanisms in the studied system [8]

Table (2): Lead accumulation in plants and sediments (Mean ± SD)

Concentration (mg/L)	Plant	Sediments
5	1.34 ± 0.06	1.73 ± 0.08
10	2.84 ± 0.06	3.08 ± 0.08
25	7.63 ± 0.11	9.63 ± 0.09

3.4 Interpretation of Field Observations

Field observations revealed the formation of a green algal layer on the water surface 20 days after the start of the experiment. This growth is attributed to the availability of nutrients in the aquatic medium, leading to the formation of a microalgal community.

This algal presence contributed to enhanced lead removal efficiency by increasing the absorbing surface area and creating a synergistic effect between the plant and algae, as noted by [8].

Sediment formation was also observed in all basins. This is interpreted as chemical precipitation of lead ions under near-neutral pH conditions, leading to reduced solubility and increased bottom stability [3].

3.5 Relationship between pH, electrical conductivity (EC), and lead removal efficiency

The physicochemical measurements showed clear stability in pH values, ranging between 7.19 and 7.27 in all treatments, a range close to neutral. This range is suitable for reducing the solubility of lead ions in aqueous water, as these ions tend to form insoluble compounds at these values that settle to the bottom, thus contributing to a reduction in their concentration in the water [3]

On the other hand, the electrical conductivity (EC) values showed slight variation between treatments, registering a relative increase at higher lead concentrations, reaching 3.63 mS/cm at 25 mg/L compared to 3.32 mS/cm at 5 mg/L. This increase reflects a rise in the total ions dissolved in the medium due to the presence of lead and nutrients, without disrupting the system's stability.

This balance between pH stability and the limited increase in EC indicates that the experimental system maintained its chemical stability throughout the treatment period, allowing the water hyacinth to efficiently perform its role in absorbing and fixing lead. These conditions also promote the occurrence of two simultaneous mechanisms for removing the metal, namely phytoextraction and phytostabilization, which is consistent with what [1,8] indicated regarding the role of physicochemical factors in improving the efficiency of plant processing of heavy metals.

Table (3): pH and EC values before and after treatment

Concentration (mg/L)	pH Before	pH After	EC Before	EC After
Control	7.20	7.20	3.41	3.41
5	7.20	7.22	3.45	3.33
10	7.34	7.27	3.66	3.45
25	7.38	7.20	4.12	3.63

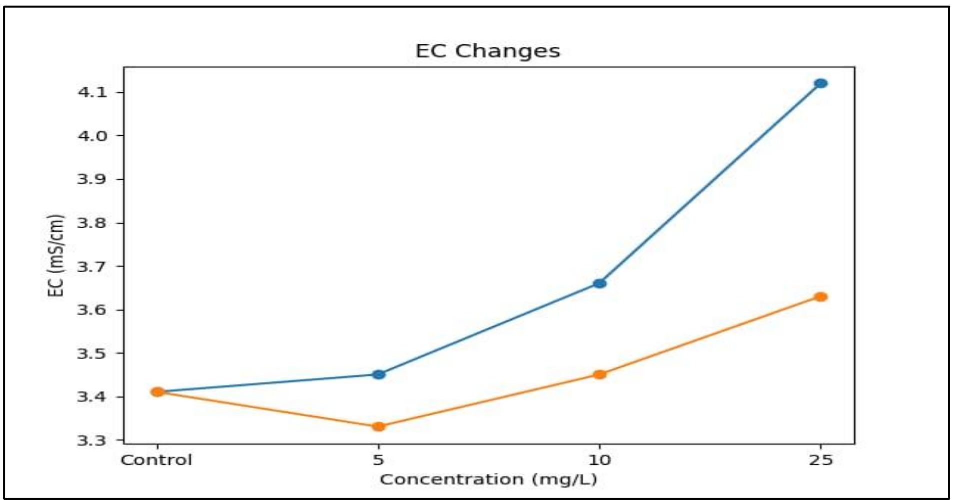

Figure (3): Change in Electrical Conductivity (EC)

Figure (3) shows slight changes in electrical conductivity, where the values increased with increasing lead concentration as a result of increased dissolved ions, then decreased after treatment, reflecting the role of the plant in reducing the ion load in the aqueous medium.

4. Conclusion

The results of this study showed that water hyacinth (*Eichhornia crassipes*) is highly efficient at removing lead from aqueous environments under field conditions. Removal rates were high, ranging from 63.62% to 71.05%, with a significant increase in removal efficiency at higher initial lead concentrations.

The results also indicated that the pH remained within a range close to neutral (7.19–7.27), which helped stabilize the aqueous system and reduce lead solubility, thus promoting precipitation and fixation processes.

In contrast, the electrical conductivity (EC) values showed only slight changes, reflecting the stability of the chemical medium throughout the experiment.

Furthermore, the results showed that lead distribution was not limited to plant tissues; a relatively higher accumulation was recorded in bottom sediments, indicating the contribution of both phytoextraction and phytostabilization to the removal of the pollutant. In general, the study confirms that the studied plant system represents an effective and low-cost technology for treating water contaminated with heavy metals, with the potential for application in polluted aquatic environments.

5. Recommendations

In light of the study results, the following recommendations can be made:

- The water hyacinth plant can be used as a natural system for treating water contaminated with heavy metals, especially in stagnant aquatic environments.
- Future studies should be conducted to evaluate the plant's efficiency under higher concentrations and for longer periods to determine its tolerance and removal limits.
- The integration of water hyacinth with other aquatic plant species should be studied to increase removal efficiency and improve the system's environmental stability.
- The impact of other environmental factors, such as light and temperature, on plant uptake efficiency should be assessed.
- Attention should be paid to managing the biomass produced by the plant after uptake to prevent the re-release of metals into the environment.

6.References

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