Sriwijaya Journal of Environment
Article
ojs.pps.unsri.ac.id

Distribution of Ability *Eleocharis dulcis* to Adsorb Heavy Metals in Roots, Stems and Leaves

Mazidah[1*], Suheryanto[2], Sarno[3]

[1]*Environmental Management Department, Graduate School, Universitas Sriwijaya, Jl. Padang Selasa No. 524 Bukit Besar, Palembang, South Sumatera, Indonesia*
[2]*Chemistry Department, Faculty of Mathematics and Natural Sciences, Universitas Sriwijaya, Jl. Raya Palembang – Prabumulih KM. 32, Indralaya, Ogan Ilir Regency 30862, South Sumatra, Indonesia*
[3]*Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Sriwijaya, Jl. Raya Palembang – Prabumulih KM. 32, Indralaya, Ogan Ilir Regency 30862, South Sumatra, Indonesia*
[*]*Corresponding author: mazidahunsri@gmail.com*

Article history

Received	Received in revised form	Accepted	Available online
17 July 2025	25 July 2025	27 July 2025	29 July 2025

Abstract: Heavy metal pollution, including lead (Pb), zinc (Zn), and copper (Cu) in swamp environments, is increasing and poses a significant threat to ecosystem integrity and human health. This study aims to evaluate the phytoremediation potential of Eleocharis dulcis in accumulating heavy metals in root, stem, and leaf tissues. The experimental method involved growing Eleocharis dulcis for 20 days in media artificially contaminated with Pb, Zn, and Cu metals at concentrations of 5, 10, and 15 ppm. Observations were made on metal accumulation in plant tissues on days 5, 10, 15, and 20. The results showed that concentration and duration of exposure significantly influenced the pattern of metal accumulation. The highest accumulations were recorded in leaf tissue, specifically Pb at 87.527 mg/kg, Zn at 32.93 mg/kg, and Cu at 43.522 mg/kg. These findings indicate that Eleocharis dulcis has selective metal uptake and translocation mechanisms and high tolerance to heavy metal stress, and has the potential to be an effective phytoremediation agent for the rehabilitation of heavy metal-contaminated wetlands and support sustainable environmental management.
Keywords: Eleocharis dulcis, heavy metal, phytoremediation

1. Introduction

Over the past two decades, environmental degradation caused by heavy metal pollution has become a significant concern worldwide, particularly in areas with natural water systems, such as swamps, lakes, and tropical wetlands [1]. Heavy metals, including lead (Pb), zinc (Zn), and copper (Cu), are toxic inorganic elements that are naturally present in the environment in small amounts [2]. The accumulation of these metals in soil and water not only disrupts the balance of ecosystems but can also pose a risk to human health through the food chain. One area vulnerable to heavy metal contamination is the tidal swamp ecosystem, particularly in tropical regions with high anthropogenic pressures, such as domestic activities, agriculture, and industrial waste from households [3].

Swamp environments are unique, characterized by dynamic hydrological characteristics, pH fluctuations, and high organic matter content, which makes them natural traps for various pollutants, including heavy metals [4]. These ecosystems not only store large amounts of carbon but also play a vital role in local and global biodiversity. However, changes in land use and the lack of waste management systems have led to eutrophication and the accumulation of metal contaminants in many Indonesian swamps. In response to these challenges, various environmental rehabilitation approaches have been developed, one of which is phytoremediation. Phytoremediation is an environmentally friendly biotechnological technique that utilizes plants to absorb, accumulate, transform, or stabilize contaminants from soil and air [5]. The main advantages of this method over conventional engineering approaches are its low cost, minimal environmental impact, and its ability to repair ecosystems in situ [6]. Plants used in phytoremediation must meet specific criteria: high tolerance to heavy metals, the ability to absorb and accumulate metals in their tissues, and rapid growth and high biomass [7].

In the context of tropical swamp ecosystems, one species that has great potential as a phytoremediator is *Eleocharis dulcis*, locally known as purun tikus. This plant belongs to the *Cyperaceae* family and grows naturally in tropical swamps. It is known to have physiological and morphological adaptations that enable it to survive in anaerobic conditions, low pH levels, and high concentrations of heavy metals. Structurally, purun tikus has an extensive root system and an efficient vascular network for transporting metal ions. Its vegetative components, including tubers, roots, stems, and leaves, function synergistically in absorbing and accumulating contaminants, making it an ideal candidate for vegetation-based phytoremediation programs using local plants [8].

The use of *Eleocharis dulcis* in environmental rehabilitation schemes not only provides ecological benefits but also supports community-based circular economy dimensions. Previous studies have shown that *Eleocharis dulcis* has a significant capacity to accumulate heavy metals, particularly Pb and Zn, in its leaf tissue, as well as high physiological tolerance to ionic stress. However, in-depth studies mapping the specific distribution of heavy metals in each plant organ under different media conditions and exposure times remain limited [9].

This research focuses on evaluating the phytoremediation potential of *Eleocharis dulcis* in accumulating heavy metals Pb, Zn, and Cu through an experimental approach. Plant specimens were cultivated in metal-enriched media with graded concentrations (5, 10, 15 ppm) for 20 days to assess the dynamics of metal accumulation in root, stem, and leaf tissues over time.

2. Material and Methods

2.1. Research Location

The *Eleocharis dulcis* plant samples in this study were collected from natural water bodies in the Jakabaring area, Banyuasin Regency, South Sumatra Province (Latitude: -3.037930; Longitude: 104.796302), which ecologically represent flooded swamp habitats with potential exposure to heavy metals. This research was carried out from May to June 2021 at the Postgraduate Integrated Research Laboratory, Sriwijaya University. Analysis of heavy metals Pb, Zn, and Cu in *Eleocharis dulcis* was carried out at the Chemistry Faculty of Mathematics and Natural Sciences Laboratory, Sriwijaya University, Inderalaya.

2.2. Materials and Procedure

This study utilised standard heavy metal solutions with a concentration of 1000 ppm, each consisting of $Pb(NO_3)_2$ for lead, $ZnCl_2$ for zinc, and $CuSO_4$ for copper, which were prepared according to analytical specifications. In addition, *Eleocharis dulcis* plants were used as biomass tests, demineralised air with a conductivity of 0.9 µS/cm as a reference solvent, and natural lake water from the plant's native habitat as an environmental simulation medium. The equipment used included a pH meter, DO meter, analytical balance, drying oven, furnace, volumetric flask, dropper pipette, Whatman filter paper, and an Atomic Absorption Spectroscopy (AAS) device.

The *Eleocharis dulcis* plants used in this study were selected based on morphological homogeneity and originated from a uniform growing habitat, with individual lengths ranging from 30 to 40 cm. Phytoremediation media were prepared in 72 units of 2-litre plastic jar-type containers, each filled with approximately 50 grams of fresh *Eleocharis dulcis* biomass. The heavy metal solution consisted of Pb, Zn, and Cu with varying concentrations of 5 ppm, 10 ppm, and 15 ppm, respectively, dissolved in river water to simulate natural environmental conditions. The solutions with adjusted concentrations were then added to each media unit as an experimental treatment.

Figure 1. Phytoremediation Research

2.3. Data Analysis

Data on heavy metal concentrations accumulated in plant tissues were analysed using a descriptive approach to identify spatial distribution patterns in roots, stems, and leaves. Measurement results were presented graphically to visualise the dynamics between treatments. All experimental procedures were performed in three independent replicates (n = 3) to ensure consistency of results and statistical validity of data reproducibility.

3. Results and Discussion

The Jakabaring area in Banyuasin Regency, South Sumatra, is a typical wetland ecosystem with an elevation of 0–5 meters above sea level and sandy loam alluvial soil rich in organic matter. The soil is acidic to neutral (pH 4.5–6.5) with a thin peat layer and indications of heavy metal accumulation (Pb, Zn, Cu) due to residential waste. The area experiences seasonal flooding of up to 2 meters for 6–8 months per year. The dominant vegetation includes *Eleocharis dulcis*, *Ipomoea aquatica*, and *Eichhornia crassipes*, which are adapted to anaerobic conditions and have the potential to accumulate heavy metals. Despite being threatened by anthropogenic activities, this ecosystem remains ecologically important as a habitat for waterbirds and a carbon sink.

One of the characteristic species in this area, Eleocharis dulcis, is a wild plant that thrives well in acidic, sulfate-rich tidal swamp soils. In addition to its ecological and economic value, Eleocharis dulcis also plays a role in reducing environmental toxicity, including heavy metal contaminants. Its morphological structure, comprising tubers, roots, stems, leaves, and flowers, enables the plant to absorb and store heavy metals from its growth medium. This study aims to determine the distribution patterns of heavy metals, including lead (Pb), copper (Cu), and zinc (Zn), in the root, stem, and leaf tissues of Eleocharis dulcis as part of efforts to understand its potential for phytoremediation of contaminated wetlands.

3.1. Distribution of Lead (Pb) in Plant Tissue

Lead (Pb) is a toxic heavy metal that is non-essential and harmful to organisms, even at low concentrations, particularly due to anthropogenic activities such as industrial and domestic waste. Exposure can disrupt the physiological functions of plants. Based on the spatial-temporal distribution graph, Pb accumulation in *Eleocharis dulcis* exhibits a consistent pattern across plant organs, with the order of dominance in accumulation being roots, stems, and leaves, indicating that roots play a primary role in the entry of metals into the plant's biological system (Figure 2-4):

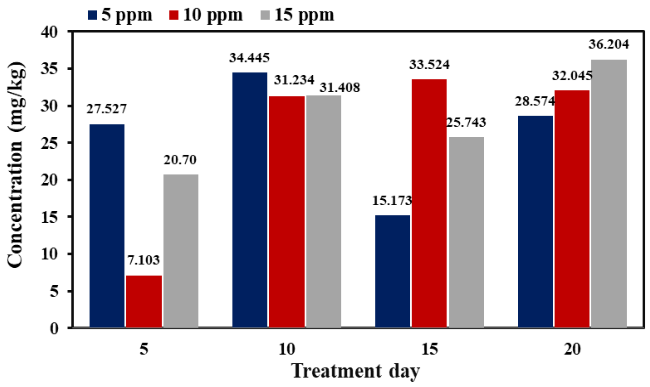

Figure 2. Distribution of Pb concentration in *Eleocharis dulcis* roots at various solution concentrations

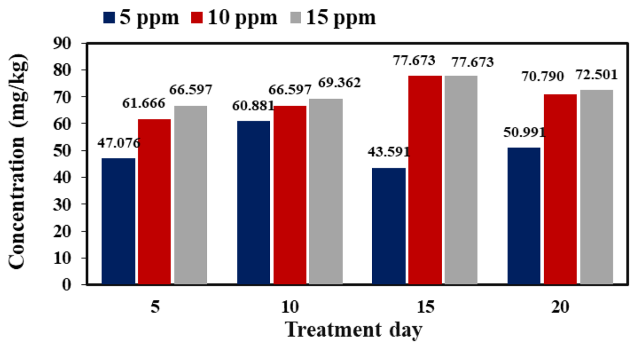

Figure 3. Distribution of Pb concentration in *Eleocharis dulcis* stem at various solution concentrations

Roots showed the highest accumulation, especially on day 20, with a concentration of 15 ppm (24,594 mg/kg). The high accumulation of Pb in roots reflects the physiological role of roots as the first barrier in the phytoextraction process, through metal ion adsorption by cell walls, precipitation in the apoplast, and complexation with phenolic compounds or phytochelatins [10]. The increasing accumulation pattern, in line with exposure time, supports the concept of metal sorption kinetics, indicating that a longer contact time allows for greater Pb accumulation [11].

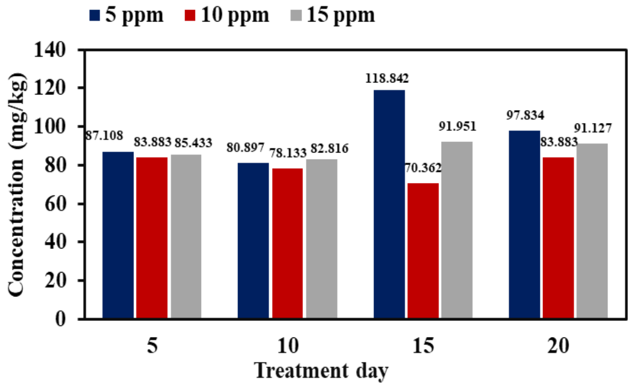

Figure 4. Distribution of Pb concentration in *Eleocharis dulcis* leaves at various solution concentrations

In the stem organ, Pb accumulation showed an increasing trend from day 5 to day 15, but decreased slightly on day 20. The highest accumulation was recorded at a concentration of 10 ppm on day 15 (77.679 mg/kg), decreasing to 72.501 mg/kg on day 20. These fluctuations are likely related to the mechanism of metal transport through the xylem system and the efficiency of tissue response to metal stress. Several studies have shown that plants have a maximum mechanism to inhibit translocation, thereby avoiding damage to upper tissues [12].Metal accumulation in stems is also influenced by lignification capacity and the presence of ion-binding tissues such as hemicellulose, which has an affinity for divalent metals [13].

In contrast, leaves showed the lowest accumulation of Pb. Although there was an increase (87.527 mg/kg) on day 15 for the 15 ppm treatment, the overall Pb concentration in the leaves remained below that of the stems and roots. This phenomenon can be explained by the limited transport of metal ions to the photosynthetic tissues, as well as the active metal exclusion system on the leaf surface, which serves as a form of physiological adaptation. According to Dwivedi et al. [13], the limited translocation of heavy metals to leaves is a physiological adaptive response of plants that prevents adverse effects on physiological processes, such as photosynthesis and primary metabolism.

3.2. Distribution of Zinc (Zn) in Plant Tissue

Zinc (Zn) is an essential micronutrient that plays a vital role in plant metabolism, but can be toxic at excessive concentrations. Zn accumulation in plant tissues serves as an indicator of physiological responses to metal exposure, identifying the adaptive potential of species in the context of phytoremediation. Based on observations, *Eleocharis dulcis* exhibits distinct Zn distribution patterns across different plant organs, with the highest accumulation consistently occurring in leaves, followed by stems, and the lowest in roots. This pattern indicates high zinc mobility within the plant's vascular system, supporting its role as an essential element in photosynthetic tissues.

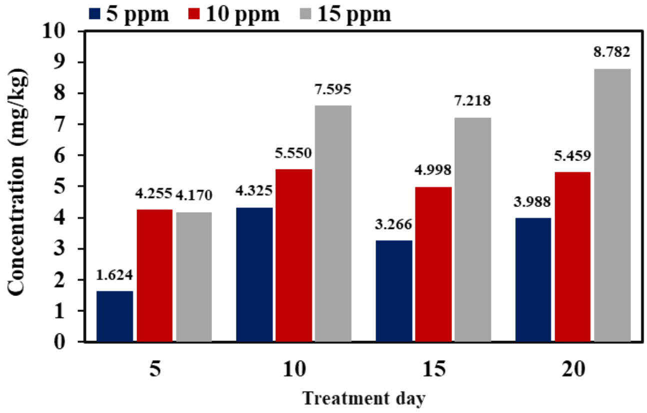

Figure 5. Distribution of Zn concentration in *Eleocharis dulcis* roots at various solution concentrations

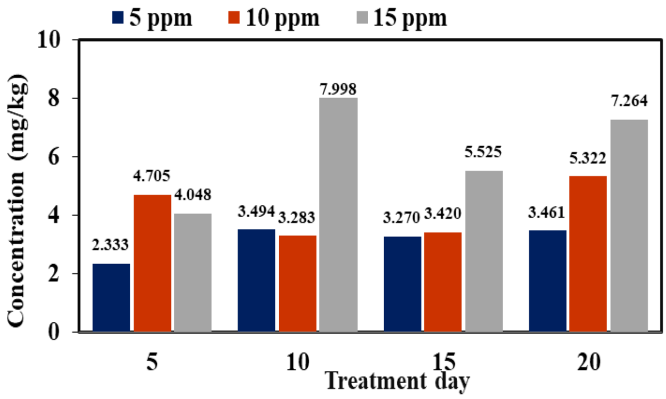

Figure 6. Distribution of Zn concentration in *Eleocharis dulcis* stem at various solution concentrations

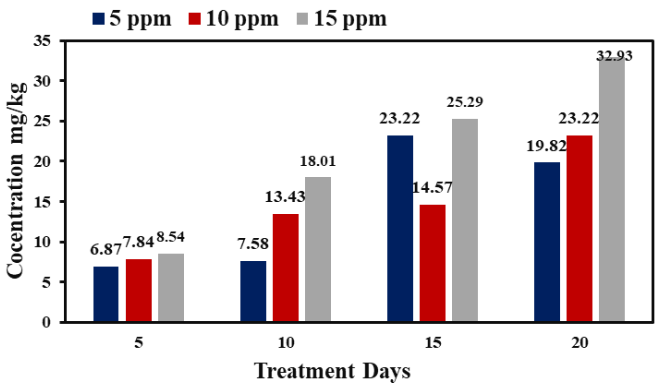

Figure 7. Distribution of Zn concentration in *Eleocharis dulcis* leaves at various solution concentrations

In root tissue, Zn accumulation increased gradually over treatment time. The highest accumulation was recorded at a concentration of 15 ppm on day 20 with a value of 8.782 mg/kg. This phenomenon supports the finding that roots are the primary site of initial nutrient and metal absorption, facilitated through both passive and active absorption processes within the root system (Broadley et al., 2007). Despite this increase in accumulation, Zn concentrations in the roots were relatively lower than in the aboveground tissue, indicating that Zn is not retained for long in the roots and tends to be quickly translocated to other parts of the plant, in line with the study by Yoon et. al [14] which stated that zinc (Zn) is a micro element that has mobility in plant tissue and can undergo systemic translocation through the xylem and phloem transport pathways, enabling efficient movement from the roots to photosynthetic organs such as leaves.

Zn distribution in the stems showed a moderate accumulation pattern. The highest value was observed in the 15 ppm treatment on day 10 (7.998 mg/kg), with a stable trend on days 15 and 20. This result suggests that the stem system serves as a major Zn transport pathway, but also has a limited capacity to store the metal. This stability of values suggests that after a certain accumulation threshold, plants regulate Zn distribution to avoid ionic imbalances that can disrupt physiological activities [15]. The stem, as a transport medium, is involved in regulating metal distribution through the xylem and phloem, but does not act as a central storage compartment.

In contrast, leaf tissue showed the highest Zn accumulation capacity, which increased significantly with treatment time and concentration. The highest accumulation was recorded on day 20 at a concentration of 15 ppm (32.93 mg/kg). This trend suggests that Zn is actively distributed to photosynthetic tissues to support enzymatic functions, protein synthesis, and the stabilisation of membrane structure. Efficient Zn translocation to the leaves also indicates that Eleocharis dulcis possesses an adaptive physiological system for meeting its micronutrient needs, facilitating Zn accumulation at locations where it is most metabolically required [16].

3.3. Distribution of Copper (Cu) in Plant Tissue

Copper is an essential element for plants at low concentrations, but it can be toxic if accumulated in excessive amounts. Based on observations, *Eleocharis dulcis* showed a tendency for heavy metal accumulation to be more pronounced in the root tissue than in the stems and leaves throughout the treatment period. This spatial distribution suggests the presence of physiological mechanisms, such as copper exclusion and retention in the roots, which serve as adaptive strategies to prevent toxicity in photosynthetic organs. This pattern highlights the crucial role of roots as the primary zone of copper

(Cu) immobilisation in aquatic plant-based phytoremediation systems. (Figure 8-10).

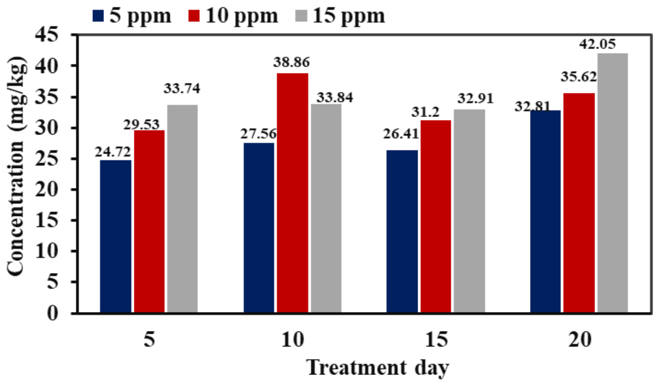

Figure 8. Distribution of Cu concentration in *Eleocharis dulcis* roots at various solution concentrations

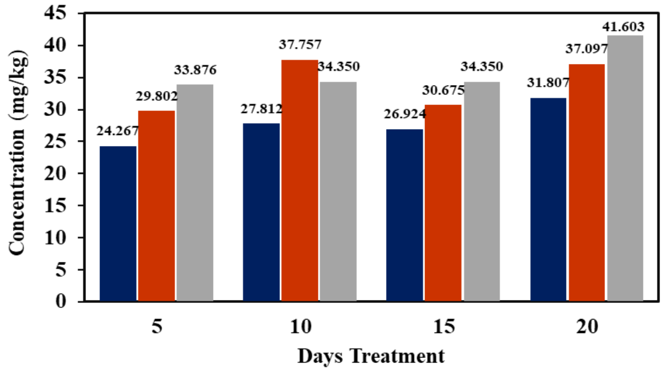

Figure 9. Distribution of Cu concentration in *Eleocharis dulcis* stem at various solution concentrations

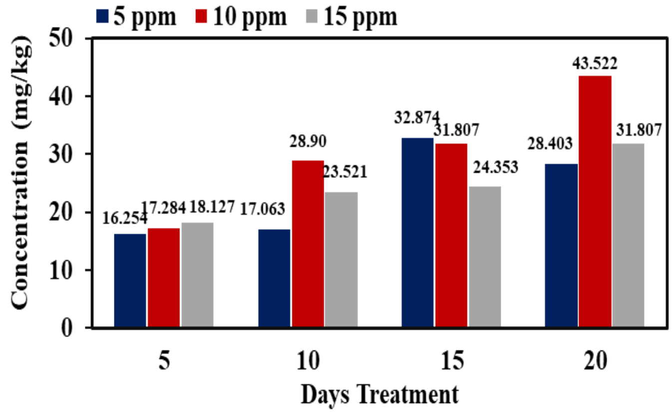

Figure 10. Distribution of Cu concentration in *Eleocharis dulcis* leaves at various solution concentrations

The increase in copper (Cu) levels in root tissue, along with the increasing treatment concentration, which reached 42.05 mg/kg at a dose of 15 ppm on day 20, indicates that the roots function as the primary site of initial metal accumulation. This finding aligns with the results of a study by Lasat et al. [16], which stated that hyperaccumulator plants generally retain heavy metals in their root tissue as a form of systemic protection mechanism against metal toxicity in more sensitive plant parts.

In the stem tissue, Cu accumulation exhibited a pattern similar to that in the roots, with the highest concentration recorded on day 20, at 41.603 mg/kg, corresponding to a dose of 15 ppm. . This phenomenon indicates the presence of active Cu translocation from the roots to the upper tissues through the xylem system. This vertical translocation is an integral part of phytoremediation dynamics, where plants distribute metals to different tissues according to their tolerance capacity and metabolic activity [14].

Interestingly, the leaves exhibited fluctuating accumulation patterns but still showed a general increase, with the highest accumulation occurring at the 10 ppm treatment on day 20, reaching 43.522 mg/kg. This result reflects the efficiency of transpiration and the potential for Cu accumulation in photosynthetic tissues. However, heavy metal exposure in leaves is generally associated with increased oxidative stress. The differences in peak accumulation between leaves, stems, and roots indicate the presence of organ-specific internal transport regulation in response to heavy metal stress.

4. Conclusion

This study demonstrates that *Eleocharis dulcis* exhibits distinct capacities for accumulating heavy metals, including Pb, Zn, and Cu, with distribution patterns that suggest a physiological role for plants in responding to metal toxicity.

1. Lead (Pb) showed the highest accumulation in root tissue, with a maximum value of 24,594 mg/kg. Lower accumulations were found in stems (72,501 ppm) at a treatment level of 10 ppm and leaves (87,527 mg/kg).
2. For zinc (Zn), the accumulation pattern showed an opposite trend, with the highest concentration detected in leaves (32.93 mg/kg), followed by stems (7.998 mg/kg) and roots (8.782 mg/kg).
3. Copper accumulation showed a relatively even distribution, with the highest value detected in the roots at 42.05 mg/kg, followed by the stems and leaves at 41.603 mg/kg and 43.522 mg/kg, respectively.

Aknowledgement

Thank you to the Postgraduate Environmental Management Study Program, Sriwijaya University for their assistance in the smooth running of this research activity.

References

[1] S. Ashraf, Q. Ali, Z. A. Zahir, S. Ashraf, and H. N. Asghar, “Phytoremediation: environmentally

sustainable way for reclamation of heavy metal polluted soils," *Ecotox. Environ. Safe*, vol. 174, pp. 714–727, 2019, doi: doi: 10.1016/j.ecoenv.2019.02.068.

[2] J. Pichtel, "Oil and gas production wastewater: soil contamination and pollution prevention," *Appl. Environ. Soil Sci.*, vol. 2016, pp. 1–24, 2016, doi: http://dx.doi.org/10.1155/2016/2707989.

[3] E. L. Arthur *et al.*, "Phytoremediation—An Overview," *Crit. Rev. Plant Sci.*, vol. 24, pp. 109–122, 2005, doi: 10.1080/07352680590952496.

[4] T. Hua and R. . Haynes, "Constructed wetlands: fundamental processes and mechanisms for heavy metal removal from wastewater streams," *Int. J. Environ. Eng.*, vol. 9, no. 2, pp. 148–178, 2017, doi: DOI: 10.1504/IJEE.2016.082306.

[5] M. M. Hasan, M. N. Uddin, I. A. Sharmeen, and H. Alharby, "Assisting Phytoremediation of Heavy Metals Using Chemical Amendments," *Plant J.*, vol. 8, no. 295, pp. 2–14, 2019, doi: DOI:10.3390/plants8090295.

[6] A. Yan, Y. Wang, S. N. Tan, M. L. M. Yusof, S. Ghosh, and Z. Chen, "Phytoremediation: A Promising Approach for Revegetation of Heavy Metal-Polluted Land," *Front. Plant Sci.*, vol. 11, no. 39, 2020, doi: DOI: 10.3389/fpls.2020.00359.

[7] A. Yan, Y. Wang, S. N. Tan, M. L. Mohd Yusof, S. Ghosh, and Z. Chen, "Phytoremediation: A Promising Approach for Revegetation of Heavy Metal-Polluted Land," *Front. Plant Sci.*, vol. 11, no. April, pp. 1–15, 2020, doi: 10.3389/fpls.2020.00359.

[8] I. Khairullah and Koesrini, "Purun Tikus (Eleocharis Dulcis)," *Tumbuh. Indik.*, vol. Vol 3, no. 3, p. 109, 2012.

[9] N. H. Haryanti, "Characterisation of Water Chestnut (Eleocharis Dulcis) Microfiber and E Glass / Polyester Hybrid," vol. 7, no. 1, pp. 9–19, 2023.

[10] A. Sêkara, M. Poniedzia, J. Ciura, and E. Jêdrszczyk, "Cadmium and Lead Accumulation and Distribution in the Organs of Nine Crops: Implications for Phytoremediation," *Polish J. Environ. Stud.*, vol. 14, no. 4, pp. 509–516, 2005.

[11] K. Chojnacka and H. Górecka, "Time-dependent Sorption and Accumulation of Heavy Metals in Aquatic Plants," *Chemosphere*, vol. 128, pp. 34–39, 2015.

[12] D. Urifah, H. B. Dwicahyono, and R. Yulliastuti, "Adsorpsi Logam Timbal (Pb) oleh Tanaman Hydrilla (Hydrilla Verticillata)," *J. Ris. Teknol. Ind.*, vol. 11, no. 2, pp. 100–108, 2017, doi: DOI: 10.26578/jrti.v11i2.3043.

[13] R. K. Dwivedi, P. Juyal, M. Sharma, V. Tyagi, A. Chandola, and N. S. Head, *Plant Physiology and Biochemistry*, vol. 267, no. 5614. Haldwani: Uttarakhand Open University, Haldwani, Nainital-263139, 1977.

[14] J. Yoon, X. Cao, Q. Zhou, and L. Q. Ma, "Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site," *Sci. Total Environ.*, vol. 368, no. 2–3, pp. 456–464, 2006, doi: https://doi.org/10.1016/j.scitotenv.2006.01.016.

[15] I. Cakmak, "Possible roles of zinc in protecting plant cells from damage by reactive oxygen species," *New Phytol.*, vol. 146, no. 2, pp. 185–205, 2000, doi: 10.1046/j.1469-8137.2000.00630.x.

[16] L. MM, B. AJM, and K. LV, "Physiological characterization of root Zn2+ absorption and translocation to shoot in Zn hyperaccumulator and nonaccumulator species of Thlaspi," in *Plant Physiol*, 1996, pp. 1715–1722.