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Analysis of lead (Pb) and iron (Fe) concentration in water spinach (*Ipomoea aquatica*) collected from Lake Siombak, Medan Marelan

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Abstract
Heavy metal contamination in aquatic ecosystems is an environmental concern due to the persistence and accumulation of metals in aquatic organisms. Water spinach (*Ipomoea aquatica*) has the ability to absorb and accumulate heavy metals from its growing environment, making it a potential bioindicator of aquatic pollution. This study aimed to analyze the concentrations of lead (Pb) and iron (Fe) in the leaves and stems of *Ipomoea aquatica* and determine differences in their concentrations among sampling stations in Lake Siombak, Medan Marelan. Samples were collected from three stations representing aquatic vegetation, residential, and fish-pond areas, with three replicates at each station. The samples were dried, digested using nitric acid, and analyzed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Data were analyzed descriptively and statistically using the Kruskal-Wallis test. The results showed that Pb concentrations in leaves ranged from 0.573–2.295 mg/kg, while concentrations in stems ranged from 0.385–15.136 mg/kg. The highest Pb concentration was found in stems at Station I. Fe concentrations were generally higher in leaves, with the highest concentration of 138.77 mg/kg recorded at Station I. Statistical analysis showed that Pb and Fe concentrations did not differ significantly among sampling stations ($p > 0.05$). Pb concentrations in both leaves and stems exceeded the maximum reference value of 0.20 mg/kg based on BPOM Regulation No. 23 of 2017, whereas Fe concentrations remained below the comparison value of 425 mg/kg dry weight. These findings indicate that I. aquatica has the ability to accumulate Pb and Fe and has potential as a bioindicator of heavy-metal contamination in Lake Siombak. However, the high Pb accumulation indicates that the consumption of I. aquatica from the study area requires caution.

Keywords: Bioindicator, heavy, iron, *Ipomoea aquatica*, lake siombak, lead, metals

Introduction

Water pollution is an environmental problem that continues to increase along with human activities. Anthropogenic activities such as industrialization, agriculture, transportation, domestic waste disposal, and urban development can introduce various pollutants, including heavy metals, into aquatic ecosystems. Heavy metals are persistent, difficult to degrade naturally, and can accumulate in sediments and aquatic organisms, potentially disrupting ecosystem balance and posing risks to human health through bioaccumulation and biomagnification (Sharma *et al*., 2025; Zhang *et al*., 2023) [15, 20]. Lake Siombak in Medan Marelan District is an artificial lake connected to the Deli and Belawan Rivers; it is situated amidst residential areas, fish ponds, transportation routes, and the Terjun Final Disposal Site (TPA). These conditions create a potential for increased pollutant input into the water. Pressures from human activities surrounding Lake Siombak have also been linked to the ecological condition of the waters and the presence of pollutants (Ramananda *et al*., 2023) [11].

Lead (Pb) and iron (Fe) are among the metals that can be found in aquatic environments. Pb is a non-essential and toxic metal that can originate from domestic waste, industrial activities, transportation emissions, and landfill leachate. In contrast, Fe is an essential micronutrient required by plants for physiological processes such as chlorophyll formation, respiration, and enzymatic activity. However, excessive Fe concentrations may also indicate environmental contamination and negatively affect aquatic ecosystems. Therefore, monitoring Pb and Fe accumulation in aquatic organisms is important for assessing environmental conditions and potential risks associated with contaminated aquatic resources (Rahman *et al*., 2024; Liang, 2022) [8, 13].

Water spinach (*Ipomoea aquatica*) is a semi-aquatic plant commonly found in rivers, wetlands, lakes, and irrigation channels. Its well-developed root system enables the uptake of nutrients and contaminants from the surrounding environment, including heavy metals, which can subsequently be distributed to stems and leaves. This ability has led to the use of I. aquatica as a bioindicator of aquatic pollution and as a potential phytoremediation plant. However, the accumulation of heavy metals in edible plant tissues may also pose a potential health concern when contaminated plants are consumed (Hisam *et al*., 2022) [6].

Previous studies have demonstrated the ability of I. aquatica to accumulate various metals. Hisam *et al*. (2022) [6] reported that I. aquatica was capable of absorbing Cd, Cu, and Zn during phytoremediation, while Hanafiah *et al*. (2020) found that water spinach accumulated Fe in industrial wastewater. Other studies have shown that metal uptake and translocation in aquatic plants are influenced by plant physiology, metal characteristics, and environmental conditions, resulting in differences in metal concentrations among plant organs (Widyawati & Kuntjoro, 2021; Mulyadi *et al*., 2022; Yan *et al*., 2022) [9, 18, 19].

Despite these findings, information regarding the accumulation of Pb and Fe in the leaves and stems of water spinach (*Ipomoea aquatica*) growing in Lake Siombak remains limited. In particular, studies comparing metal accumulation among sites with different environmental characteristics, such as aquatic vegetation, residential areas, and fish-pond areas, are still scarce. Therefore, this study aimed to analyze the concentrations of Pb and Fe in the leaves and stems of water spinach (*Ipomoea aquatica*) and determine their differences among sampling stations in Lake Siombak, Medan Marelan. The findings are expected to provide scientific information regarding heavy-metal accumulation in aquatic plants and support environmental monitoring and the management of aquatic resources in Lake Siombak.

Materials and Methods

This study employed a descriptive quantitative method to analyze the heavy metal content specifically lead (Pb) and iron (Fe) in water spinach (*Ipomoea aquatica*) at Lake Siombak, Medan Marelan District, Medan City. The research was conducted from March to May 2026. Sampling was carried out at three stations with distinct environmental characteristics: Station I (aquatic vegetation area), Station II (residential area), and Station III (fish farming area).

The research samples consisted of water spinach (*Ipomoea aquatica*) collected from the three stations, with three replicates per station. The plant parts analyzed included the leaves and stems. Collected samples were cleaned of adhering debris and separated by plant part. Subsequently, the samples were oven-dried to a constant dry weight, then ground and sieved to obtain homogeneous samples.

A 0.50 g portion of the dried and ground water spinach (*Ipomoea aquatica*) was weighed out. Sample digestion was performed at the Biology Laboratory of Medan State University using nitric acid (HNO_3). The resulting digest solution was then prepared for heavy metal analysis. Testing for lead (Pb) and iron (Fe) content was conducted at a partner laboratory (Medan Public Health Laboratory Center) using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). Analysis results were obtained in mg/L and subsequently converted to mg/kg dry weight based on the sample weight used.

The research data were analyzed quantitatively through the following stages

a. Data Conversion

Measurement results for Pb and Fe concentrations using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) were obtained in mg/L. These values were then converted to mg/kg (dry weight) by taking into account the ICP-OES reading, the final solution volume, and the dry sample weight. The conversion was performed using the formula:

$$Metal\ Content\ (mg/kg) = \frac{(C\ x\ V)}{\mathrm{W}}$$

Description

C = metal concentration from the ICP-OES reading (mg/L),
V = final solution volume after dilution (L),
W = dry sample weight (kg).

b. Descriptive analysis

Data on Pb and Fe concentrations in the leaves and stems of water spinach (*Ipomoea aquatica*) were analyzed descriptively by calculating the mean and standard deviation for each study station. The analysis results are presented in tabular form to illustrate trends and variations in heavy metal content across the different plant parts.

c. Statistical analysis

Differences in Pb and Fe content in the leaves and stems of water spinach (*Ipomoea aquatica*) across stations were analyzed using the Kruskal-Wallis test, a non-parametric statistical method. The test was conducted at a 5% significance level ($\alpha = 0.05$) using IBM SPSS Statistics. A p-value < 0.05 indicates a significant difference between stations, whereas a p-value ≥ 0.05 indicates no significant difference.

Results

The research results indicate the presence of the heavy metals lead (Pb) and iron (Fe) in the leaves and stems of water spinach (*Ipomoea aquatica*) collected from three sampling stations at Lake Siombak, Marelan. Heavy metal content analysis was conducted using the Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) method. Measurements were performed to determine the concentrations of Pb and Fe in each plant part and to observe variations in heavy metal content across the sampling stations. The results of the Pb and Fe content analysis for the leaves and stems of the water spinach are presented in Table 1.

Table 1: Laboratory analysis results for lead (Pb)

Station	Plant Organs	Test	Result ICP-OES (mg/L)	Final Volume (L)	Sample Weight (g)	Metal Content Pb (mg/kg)
I	Leaf	I	0,005374	0,03	0,50	0,32244
		II	0,039707	0,03	0,50	2,38242
		III	0,011769	0,03	0,50	0,70614
	Stem	I	0,013289	0,03	0,50	0,79734
		II	7,25922	0,03	0,50	435,5532
		III	0,01757	0,03	0,50	1,0542
II	Leaf	I	0,093842	0,03	0,50	5,63052
		II	0,004894	0,03	0,50	0,29364
		III	0,016006	0,03	0,50	0,96036
	Stem	I	0,058954	0,03	0,50	3,53724
		II	0,004993	0,03	0,50	0,29958
		III	0,004352	0,03	0,50	0,26112
III	Leaf	I	0,009024	0,03	0,50	0,54144
		II	0,0074	0,03	0,50	0,444
		III	0,012219	0,03	0,50	0,73314
	Stem	I	0,013472	0,03	0,50	0,80832
		II	0,005345	0,03	0,50	0,3207
		III	0,000443	0,03	0,50	0,02658

Based on Table 1, the highest Pb content was found in the stems at Station I, Replicate III (435.5532 mg/kg), while the lowest Pb content was found in the leaves at Station III, Replicate II (0.444 mg/kg). Subsequently, an analysis of the heavy metal iron (Fe) was conducted on water spinach leaf and stem samples. Sampling was performed in triplicate at each station. The analysis results indicate variations in Fe content both between stations and between replicates. The analysis data are presented in Table 2.

Tabel 2: Laboratory analysis results for iron (Fe)

Station	Plant Organs	Test	Result ICP-OES (mg/L)	Final Volume (L)	Sample Weight (g)	Metal Content Fe (mg/kg)
I	Leaf	I	1,76611	0,03	0,50	105,9666
		II	3,33491	0,03	0,50	200,0946
		III	1,63747	0,03	0,50	98,2482
	Stem	I	0,404531	0,03	0,50	24,27186
		II	0,472084	0,03	0,50	28,32504
		III	0,668039	0,03	0,50	40,08234
II	Leaf	I	0,870888	0,03	0,50	52,25328
		II	2,05882	0,03	0,50	123,5292
		III	0,774723	0,03	0,50	46,48338
	Stem	I	1,12627	0,03	0,50	67,5762
		II	0,852121	0,03	0,50	51,12726
		III	0,368732	0,03	0,50	22,12338
III	Leaf	I	2,85467	0,03	0,50	171,2802
		II	2,60809	0,03	0,50	156,4854
		III	1,2335	0,03	0,50	74,01
	Stem	I	0,327855	0,03	0,50	19,6713
		II	0,271941	0,03	0,50	16,31646
		III	0,660653	0,03	0,50	39,63918

Based on Table 2, the heavy metal content of iron (Fe) shows variations in values across stations and replicates. The highest Fe content was found in leaves from Station I, Replicate II (200.0946 mg/kg), while the lowest Fe content was found in leaves from Station III, Replicate III (74.01 mg/kg).

Table 3: Average Pb Content in Water Spinach Leaves and Stems (mg/kg)

Station	Leaf (Mean ± SD)	Stem (Mean ± SD)
I	1,14 ± 1,10	15,14 ± 24,61
II	2,29 ± 2,91	1,34 ± 1,90
III	0,57 ± 0,15	0,39 ± 0,39

Based on Table 3, the highest Pb concentration in water spinach leaves was found at Station II (2.29 ± 2.91 mg/kg), while the lowest was found at Station III (0.57 ± 0.15 mg/kg). Regarding the stems, the highest Pb concentration was found at Station I (15.14 ± 24.61 mg/kg) and the lowest at Station III (0.39 ± 0.39 mg/kg).

Table 4: Average Fe Content in Water Spinach Leaves and Stems (mg/kg)

Station	Leaf (Mean ± SD)	Stem (Mean ± SD)
I	138,77 ± 53,15	30,89 ± 8,21
II	74,08 ± 42,92	46,94 ± 23,01
III	133,93 ± 52,41	25,21 ± 12,61

Based on Table 4, the highest Fe content in water spinach leaves was found at Station I (138.77 ± 53.15 mg/kg), while the lowest was found at Station II (74.08 ± 42.92 mg/kg). Regarding the stems, the highest Fe content was found at Station II (46.94 ± 23.01 mg/kg), and the lowest was found at Station III (25.21 ± 12.61 mg/kg).

Prior to analyzing differences in heavy metal concentrations across stations, the data were evaluated using normality and homogeneity tests to determine the appropriate statistical analysis method. The test results indicated that the data did not fully satisfy the assumptions for parametric analysis. Consequently, the analysis of differences in Pb and Fe concentrations between stations was conducted using the non-parametric Kruskal-Wallis test.

Kruskal-Wallis Test Results for Pb and Fe Across Station

Table 5: Results of Inter-station Difference Analysis

Parameter	Plant Organs	Sig.	Explanation
Pb	Leaf	0,837	Not significantly different
Pb	Stem	0,288	Not significantly different
Fe	Leaf	0,301	Not significantly different
Fe	Stem	0,252	Not significantly different

Based on the Kruskal-Wallis test results in Table 5, the significance values for Pb levels in leaves and stems, and Fe levels in leaves and stems, were 0.837, 0.288, 0.301, and 0.252, respectively. All these significance values exceeded 0.05 ($p > 0.05$), indicating no significant differences in Pb and Fe heavy metal content in the leaves or stems of water spinach across the sampling stations.

Discussion

The results showed that water spinach (*Ipomoea aquatica*) growing in Lake Siombak accumulated lead (Pb) and iron (Fe) in both leaves and stems, with varying concentrations among sampling stations. This variation may be related to differences in environmental conditions, pollution sources, and the physiological ability of plants to absorb and translocate metals. Heavy metals entering aquatic ecosystems can be distributed through the water column, sediment, and aquatic organisms, where they may undergo bioaccumulation (Sharma *et al*., 2025; Ahmed *et al*., 2019) [1, 15]. Lake Siombak is connected to the Deli and Belawan Rivers and is influenced by anthropogenic activities, including settlements, fish ponds, transportation, and the

Terjun Final Disposal Site. These activities may contribute pollutants to the lake through surface runoff, domestic waste, and leachate. Previous studies have also reported anthropogenic pressure on the ecological condition of Lake Siombak (Muhtadi *et al*., 2017; Ramananda *et al*., 2023) [10, 11].

The Pb concentration varied between plant organs and sampling stations. The highest Pb concentration in leaves was found at Station II (2.295 mg/kg), while the highest concentration in stems occurred at Station I (15.136 mg/kg). The higher Pb concentration in stems suggests that stems may function as temporary storage tissues before further translocation to the upper organs. Pb is a non-essential metal with relatively low mobility within plants because it can bind to cell walls, pectin, and vacuoles, thereby limiting its translocation to leaves (Rahman *et al*., 2024; Collin *et al*., 2022) [5, 13]. The accumulation pattern observed in this study is consistent with previous findings that water spinach (*Ipomoea aquatica*) can accumulate Pb from aquatic environments and therefore has potential as a bioindicator of heavy-metal contamination (Katipana, 2015) [7]. Differences among stations may also be influenced by metal availability in sediments, exposure duration, plant age, and environmental conditions (Widyawati & Kuntjoro, 2021) [18].

Based on the maximum limit for Pb in food stated in BPOM Regulation No. 23 of 2017 (0.20 mg/kg), Pb concentrations detected in both leaves and stems exceeded the reference value. Leaf concentrations ranged from 0.573–2.295 mg/kg, while stem concentrations ranged from 0.385–15.136 mg/kg. The highest value was found in stems at Station I. This finding indicates that Pb accumulation in water spinach (*Ipomoea aquatica*) at Lake Siombak requires attention, particularly because the plant has the potential to be consumed as food.

In contrast to Pb, Fe is an essential micronutrient required for chlorophyll formation, respiration, electron transport, and enzymatic activity. In this study, Fe concentrations were generally higher in leaves than in stems, with the highest concentration recorded in leaves at Station I (138.77 mg/kg). This pattern may be related to the physiological requirement for Fe in metabolically active tissues, particularly leaves involved in photosynthesis. Plants regulate Fe uptake, transport, and storage through homeostatic mechanisms to maintain adequate Fe availability (Zhang *et al*., 2019) [21]. The variation in Fe concentration among stations may be associated with both natural sources from soil and sediment and anthropogenic inputs such as domestic waste, runoff, and leachate from disposal areas (Rachmawati *et al*., 2024; Syukriah *et al*., 2024) [12, 17].

The ability of water spinach (*Ipomoea aquatica*) to accumulate Pb and Fe is also related to its well-developed root system and its potential as a phytoremediator. Metal uptake and translocation in wetland plants are influenced by metal characteristics, environmental conditions, and plant physiological mechanisms (Yan *et al*., 2022) [19]. Hisam *et al*. (2022) [6] reported that water spinach (*Ipomoea aquatica*) is capable of absorbing metals from aquatic environments, supporting its potential use as a phytoremediation plant.

Statistical analysis using the Kruskal-Wallis test showed that Pb and Fe concentrations did not differ significantly among sampling stations ($p > 0.05$), despite the descriptive differences in mean concentrations. This may be related to the interconnected water system of Lake Siombak, which allows pollutants to be distributed through water circulation and sedimentation. Thus, metal accumulation in water spinach (*Ipomoea aquatica*) may reflect not only local conditions but also the overall dynamics of the lake ecosystem.

Although Fe is an essential nutrient, excessive accumulation may cause oxidative stress and interfere with nutrient uptake and photosynthetic processes (Sanad *et al*., 2026) [14]. However, the Fe concentrations observed in this study remained below the comparison value of 425 mg/kg dry weight reported based on the FAO/WHO reference in Alkhatib *et al*. (2022). Therefore, the Fe concentration in I. aquatica from Lake Siombak was still below the comparison value, whereas the Pb concentration exceeded the applicable food safety reference.

Conclusion

The study concluded that water spinach (*Ipomoea aquatica*) growing in Lake Siombak was able to accumulate Pb and Fe in both leaves and stems, with differences in concentration among sampling stations and plant organs. Pb accumulation was higher in stems, particularly at Station I, with a concentration of 15.136 mg/kg, while Fe accumulation was generally higher in leaves, with the highest concentration of 138.77 mg/kg at Station I. These differences descriptively indicate variation in metal accumulation related to environmental conditions and the physiological characteristics of the plant. Statistical analysis using the Kruskal-Wallis test showed that the concentrations of Pb and Fe did not differ significantly among sampling stations ($p > 0.05$). Pb concentrations in both leaves and stems exceeded the maximum reference value of 0.20 mg/kg based on BPOM Regulation No. 23 of 2017, while Fe concentrations remained below the comparison value of 425 mg/kg dry weight. Therefore, I. aquatica in Lake Siombak has potential as a bioindicator of heavy-metal contamination, particularly Pb, although its elevated Pb accumulation indicates that its use as a food source should be approached with caution.

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