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A Preliminary Study of Potential Aquatic Macrophytes in Phytoremediation of Lead in The Muar River

Nurul' Ain Jamion[1,2,3*], Faiz Idden Shah Ismail[1], Nur Salwani Ab Wahid[1] and Nur Sofiah Abu Kassim[1]
[1]School of Chemistry and Environment, Faculty of Applied Sciences, Universiti Teknologi MARA, Negeri Sembilan Branch, Kuala Pilah Campus, 72000 Kuala Pilah, Negeri Sembilan, Malaysia
[2]Research Centre for Sustainability Science & Governance (SGK), Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[3]Soil Assessment and Remediation Research Group, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia
*Corresponding author (e-mail: ain7059@uitm.edu.my)

It has been observed that phytoremediation of wastewater using the aquatic macrophytes system is a predominant method that is economical to construct, requires little maintenance, and can increase water quality. This research aims to quantify the potential of water hyacinth (WH) and water lettuce (WL) as phytoremediation agents to accumulate lead (Pb) and to determine the water quality of Muar River. Atomic Absorption Spectroscopy (AAS) was used to demonstrate Pb absorption from the water sample by plant tissue, which are the roots. WH and WL uptake rates of Pb were measured in a short-term experiment. The initial concentration of Pb in the Muar River was 0.514 mg/L. The maximum absorption efficiency of Pb was observed with WL compared to WH after ten days. Pb concentration in the Muar River remediated with WH and WL decreased to 0.104 mg/L and 0.063 mg/L, respectively. The bioconcentration factor (BCF) of WL and WH was greater than 1, indicating that both plants were good accumulators. The water was characterized by six parameters, which were Ammonia Nitrogen (AN), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), pH, and Total Suspended Solid (TSS). Our study demonstrated that water quality was significantly improved after phytoremediation by both plants. In conclusion, the study shows that water hyacinth and water lettuce can be used effectively as a phytoremediator agent to absorb Pb i.e. as a potential bio-accumulator.

Key words: Aquatic macrophytes; phytoremediation; water hyacinth; heavy metals; lead

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Rivers are essential for the ecosystem and vital freshwater resources. Nevertheless, an increase in population and developments have put forth terrifying and various pressures on the water quality and quantity [1]. Toxic substances such as heavy metals easily enter the rivers through point sources and non-point sources [2]. The primary sources come from non-point sources such as anthropogenic activities, dumping of untreated or partially treated waste from industrial processes and undiscriminating heavy metal-containing pesticides and fertilizers used in agriculture [3]. The contamination of heavy metal, especially lead (Pb), in the aquatic ecosystem, has garnered worldwide attention in the past decade due to its health effect. This is due to the increasing concentration of Pb in waters which is a significant concern since the element is indestructible. The heavy metal cannot be biologically degraded, and has a toxic effect on aquatic organisms, animals, and humans [4]. Even with a low concentration of Pb accumulated in fish gills, it may result in fish death due to suffocation. Humans highly exposed to Pb chain contamination and may suffer behavioral changes and IQ impairments [5].

There has been an increased interest in exploring methods to remove or reduce trace metal concentration in water in recent years. Research in this areas is usually carried out using conventional methods such as adsorption by activated carbon [6], ion-exchange by catalyst [7], electrodialysis [8], chemical precipitation [9] and reverse osmosis [10]. These methods are well-established, but most of them need sophisticated instruments, expertise, are energy-intensive and produce secondary wastes [11,12] Phytoremediation is envisaged to be inexpensive, clean, easy to conduct, and efficient in absorbing and trapping a wide range of organic and inorganic pollutants [13]. Furthermore, phytoremediation is also environmental friendly for water treatment, hence its increased demand in both practical and academic applications [14].

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Table 1. Studies on removing heavy metals by aquatic macrophytes (water hyacinth and water lettuce) in various water types

Aquatic macrophytes	Types of water	Removal of heavy metal	References
Water hyacinth	Petroleum Refinery Effluents	Cd, Cu, Pb, Fe, Mn, Ni, Sn, Zn, As, Hg, Cr	[18]
	Composting wastewater	Fe, Mn, Zn, Cr, Cu, Ni, Pb, Cd,	[19]
	Hydroponic medium	Hg	[20]
	Sewage wastewater stabilization ponds under humid lowland tropical climatic conditions	Pb, Zn, Cu, Cd	[21]
	Abandoned mining lake	Fe	[12]
Water lettuce	Textile wastewater	Cd, Ni, Zn	[22]
	Abandoned mining lake	Fe	[12]
	Acid mine drainage	Cu	[23]
	Stormwater detention ponds	Al, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, and Zn	[24]
	Cr and Pb contaminated water	Cr and Pb	[25]

Phytoremediation is a combination of two Latin words, which are plant and remedy. Phytoremediation is defined as chemically and biologically plant activities' effectiveness to purify, debilitate, or remove environmental pollutants in water, sludge, and soil through biosorption [15]. This method combines the interactions of biotic and abiotic species as one system. The unique physiological process in the plants allows absorption capacity and metal tolerance. The phytoremediation principle is simple, i.e., a process to remove organic or inorganic pollutants in water by cultivation of aquatic plants which are able to absorb pollutants. In addition, based on a bioaccumulation factor (BAF) index, plants with high exceptional metal accumulating capacity are classified as accumulator plants and hyperaccumulator [16]. More than 400 plants have been discovered to be potential phytoremediators [17]. Hence, phytoremediation is considered as a green technology as it is a natural solution to absorb the various types of pollutants in water.

Previous studies showed that aquatic macrophytes such as water lettuce and water hyacinth have excellent tolerance and massive metal uptakes in various types of water, as shown in Table 1. Water hyacinth (*Eichhornia crassipes*) is a member of the *Pontederiaceae* family, a free-floating macrophytes mostly found in wetlands and lakes. This plant has high durability because it can be grown under a heavy metal stress. In addition, water hyacinth biomass is less toxic toward the aquatic environment [15]. Water lettuce (*Pistia stratiotes*) also grows as a simple free-floating thalli on or just beneath the water surface and can proliferate on new water bodies through vegetative reproduction. Water lettuce is able to absorb and remove suspended solids and nutrients besides enhancing microbial activity.

Furthermore, this plant has the potential to use sewage nutrients to produce a large phytomass and increase the nutrient supply imbalance. Therefore, it has become one of the most popular plants for use in the phytoremediation of wastewater in tropical areas [16]. Both aquatic macrophytes show significant activities in absorbing contaminants and heavy metals. Therefore, the present study assesses free-floating aquatic macrophytes to treat Pb in the Muar River water sample. Moreover, this preliminary study also provides the necessary knowledge of pollution removal for phytoremediation.

METHODOLOGY

Description of Study Area

Muar River is the Muar River Basin's main channel, the most extensive river system in Johor, Malaysia. The river flows through three states in southern Peninsular Malaysia; Negeri Sembilan, Pahang, and Johor. The Muar River Basin coordinate is from latitude 1° 52'00" North to 2° 54'00" North and longitude 102° 14'00" East to 103° 04'00" East with a total length of approximately 329 km. The basin covers a catchment area of 6149 km^2, of which more than half the area (58.7%) is located in Johor, while 39.2 % is in Negeri Sembilan, and a small percentage is located in Pahang and Melaka, 1.98% and 0.13%, respectively [26].

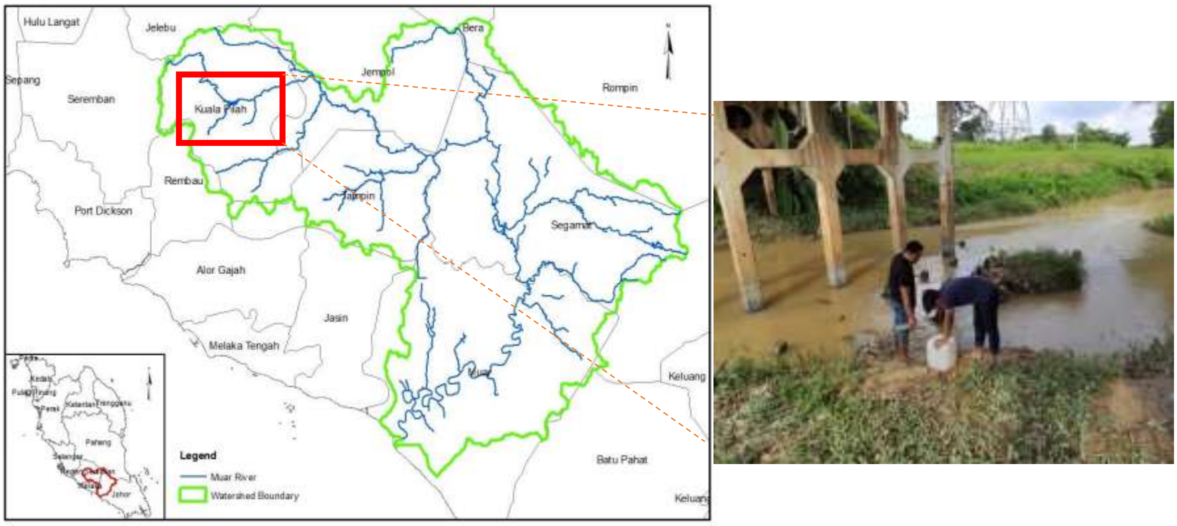

Figure 1. Sampling point of Muar River, at Kuala Pilah Negeri Sembilan. Source-[28]: Author picture taken on August 2019

The Muar River is one of the important rivers in Malaysia with a significant effect on the socio-economic status for surrounding communities. The Muar River water resources are used for aquaculture, agriculture, and recreational activities such as fishing. The origin of the river is from Jambu Lapan in Jempol, Negeri Sembilan, from which the upstream parts of the river Muar cover the central areas in Kuala Pilah, Negeri Sembilan. Kuala Pilah is one of the densely populated towns that cause a gradually deterioration to water quality in the Muar River due to the rapid increase in human population and the industry. According to Huang *et al.* [27], the estimated Bio oxygen demand (BOD) load in the Muar River Basin was 24 tons per day. Mulana *et al.* [3], suggested to monitor trace metal levels, especially that of Pb in the Muar River because previous result reported that this trace heavy metal was over the permissible limits allowed by the World Health Organization (WHO). However, in their study, the sampling locations were at Johor, Malaysia. Up to this date, to the best of our knowledge, there is no reported study on the concentration of Pb and water quality in the Muar River at Negeri Sembilan. In this present study, water samples were collected from the Muar River at Kuala Pilah, Negeri Sembilan, Malaysia as shown in Figure 1.

Water Sampling and Collection of Aquatic Macrophytes

Water samples from the Muar River were collected and placed into polyethylene grade containers. After collection the water samples were stored at room temperature.

Two aquatic macrophytes, water hyacinth (WH) and water lettuce (WL) were collected from a local constructed wetland in Kampung Parit Tinggi, Kuala Pilah, Negeri Sembilan. The plants were hand-picked, and old leaves cut off. The roots were carefully handled during the rinsing process to eliminate insect larvae and epiphytes on the plants. The acclimatization period was set at one week in order to stabilize the plants [15]. The plants were exposed to sunlight to enable them to survive under the experimental environment.

Sample Preparation for Phytoremediation Treatment and Analysis

The phytoremediation experiments for Pb removal were conducted in an open environment at an ambient temperature range of between 27 °C to 30 °C in separate 10 L rectangular plastic containers. The volume of the container was 0.07 m^3, with dimensions of 0.50 m (L) x 0.35 m (H) x 0.40 m (W). Each container was filled with 6 L of the river water sample together with 300 g of initial wet mass of the relevant fresh plant species. The experiment was carried out for ten days, alongside a controlled water sample with no plant. Deionized water was added daily to compensate water loss through plant evaporation, transpiration, and sampling [29]. The setup for the experiment is shown in Figure 2.

The study consists of two phases of analysis. The first, is the analysis of Pb analysis in the Muar River water samples after phytoremediation by the two selected aquatic macrophytes (WH and WL). The second analysis is the determination of water quality of the phytoremediated water sample each plant type.

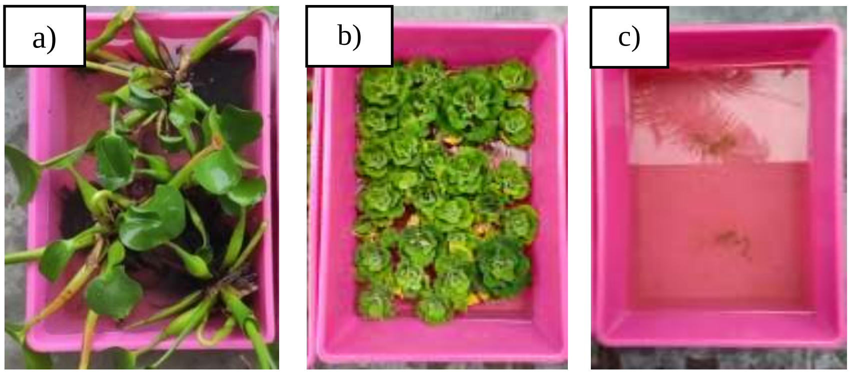

Figure 2. Experimental setup for phytoremediation removal of Pb. Image of a) WH b) WL, and c) control sample

Water samples from each container were collected on the initial day (day 0), day 3, 5, 7, and 10 for determinatione of Pb concentrations. Water sampling and analysis were based on the standard method APHA 3111 B [30] air acetylene flame analysis Atomic Absorption Spectroscopy (Perkin Elmer Analyst 600). The Pb standard stock solution was prepared at a concentration of 1000 mg/L in deionized water. All working solutions were prepared by serial dilution of the stock solution. The wavelength used for the detection of Pb by AAS was 283.3 nm.

The calibration curve was obtained using the standard samples. The percentage removal efficiency of Pb in each water sample was calculated, according to Equation (1) [31].

$$Removal\ efficiency = \frac{C_1 - C_2}{C_1} \times 100 \quad (1)$$

Where,

C_1 = initial concentrations of water sample

C_2 = final concentration of water sample

The plant's potential to accumulate heavy metal was determined by the bioaccumulation factor (BAF) index. BAF index was calculated according to Keeflee *et al.* [32], as shown in Equation (2):

$$BAF = \frac{C_{root}}{C_{water}} \quad (2)$$

Where,

C_{root} = concentrations of heavy metal in the roots

C_{water} = concentration of heavy metal in the water sample

BAF index was calculated based on a dry mass of plants, and the extraction of metalfrom plants was performed using the acid digestion method adapted from Zhao *et al.* [33], and Saha *et al.* [29]. A small number of roots from each plant type was allowed to air-dry for 24 hours, weighed, cut, and grounded into powder form. Then, 0.5 grams of the dried roots were weighed and placed in a conical flask. The root samples were digested using a 65 % nitric acid (HNO_3) and 69 % perchloric acid ($HClO_4$) mixture in a ratio of 1:3 together with added deionized water. The sample was heated until it became a clear solution (between 15 to 30 minutes). Pb concentration in root's tissues was also analyzed using the standard method based on APHA 3111 B [30]. BAF of Pb accumulated in both plant type was examined on day 3 and 10 of the experiment.

Water quality was determined based on Malaysia's Water Quality Index (WQI) [34]. The six parameters in the WQI are pH, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solid (TSS) and Ammonical Nitrogen (NH_3-N). All analyses were conducted ex-situ according to the standard method [30]. BOD was measured using the 5-day BOD test, and TSS was measured using the gravimetric method, while COD was measured using closed reflux and analyzed by a HACH VIS Spectrophotometer. Table 2 shows the standard analysis method for water quality for each of the parameter. The data were then used to calculate the WQI value using the WQI formula as per Equation (3).

Table 2. Analysis method for water quality analysis [30]

No	Parameter	Analysis Method
1	pH	APHA 4500-H^+ B (2005)
2	Dissolved Oxygen (DO)	APHA 4500 - O G
3	Ammonical Nitrogen (NH_3-N)	APHA 4500 NH_3 B (2005)
4	Biochemical Oxygen Demand (BOD)	APHA 5210 B
5	Chemical Oxygen Demand (COD)	APHA 5220 C
6	Total Suspended Solid (TSS)	APHA 2540 D (2005)

$$WQI = 0.22(SI_{DO}) + 0.19(SI_{BOD}) + 0.16(SI_{COD}) + 0.15(SI_{AN}) + 0.16(SI_{SS}) + 0.12(SI_{pH}) \quad (3)$$

Where,

SI_{DO} = Subindex DO (% saturation)
SI_{BOD} = Subindex BOD
SI_{COD} = Subindex COD
SI_{AN} = Subindex NH_3-N
SI_{SS} = Subindex SS
SI_{pH} = Subindex pH

Table 3 shows the WQI subindex equation for each parameter. The obtained WQI of each water sample was then compared with the DOE WQI Classification in Malaysia [34]. Tables 4a and 4b showed the pollution classification and limits for water.

Table 3. WQI subindex equation for each parameter [34]

Subindex Parameters	Ranges	Subindex (SI) equation
SI_{COD}	for x = < 20	SI_{COD} = -1.33x + 99.1
	for x > 20	SI_{COD} = 103* exp(-0.0157x) - 0.04x
SI_{BOD}	for x ≤ 5	SI_{BOD} = 100.4 - 4.23x
	for x > 5	SI_{BOD} = 108*exp(-0.055x) - 0.1x
SI_{AN} (NH_3-N)	for x ≤ 0.3	SI_{AN} = 100.5 - 105x
	for 0.3 < x < 4	SI_{AN} = 94* exp(-0.573x) - 5* Ix - 2I
	for x ≥ 4	SI_{AN} = 0
SI_{SS}	for x ≤ 100	SI_{SS} = 97.5* exp(-0.00676x) + 0.05x
	for 100 < x < 1000	SI_{SS} = 71* exp(-0.0061x) + 0.015x
	for x ≥ 1000	SI_{SS} = 0
SI_{pH}	for x < 5.5	$Sl_{pH} = 17.02 - 17.2x + 5.02x^2$
	for 5.5 ≤ x < 7	$Sl_{pH} = -242 + 95.5x - 6.67x^2$
	for 7 ≤ x < 8.75	$Sl_{pH} = -181 + 82.4x - 6.05x^2$
	for x ≥ 8.75	$Sl_{pH} = 536 - 77.0x + 2.76x^2$
SI_{DO} (% saturation)	for x ≤8	SI_{DO} = 0
	for x ≤92	SI_{DO} = 100
	for 8 < x < 92	$SI_{DO} = -0.395 + 0.030x^2 - 0.00020x^3$

Table 4a. Malaysia Interim of National Water Quality Standard (NWQS) with limit classes [34]

Parameters	Unit	Class I	Class II	Class III	Class IV	Class V
COD	mg L^{-1}	< 10	10 -25	25 – 50	50 – 100	> 100
BOD	mg L^{-1}	< 1	1 – 3	3 – 6	6 – 12	> 12
AN	mg L^{-1}	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
DO	mg L^{-1}	> 7	5 – 7	3 – 5	1 – 3	< 1
TSS	mg L^{-1}	< 25	25 – 50	50 – 150	150 -300	> 300
pH	-	> 7	6 – 7	5 – 6	< 5	< 5
WQI	-	**< 92.7**	**76.5 – 92.7**	**51.9 – 76.5**	**31.0 – 51.9**	**> 31.0**
Pollution level	-	**Clean(81 - 100)**		**Slightly Polluted (60 - 80)**	**Polluted (0 - 59)**	

Table 4b. WQI classification and it uses [34]

WQI	Uses	Class
>92.7	Natural environment conservation. Water supply I – No water treatment needed.	I
76.5 – 92.7	Fishery Type I – Susceptible aquatic species Water supply II – Need conventional water treatment	Class IIA
	Fishery Type II – sensitive aquatic species Suitable for recreational use – body contact such as swimming.	Class IIB
51.9 – 76.5	Water supply III – need extensive water treatment Fishery III – standard for economic value, livestock drinking, and for tolerance species.	Class III
31.0 – 51.9	Irrigation only	Class IV
<31.0	None of the above (not meet any uses)	Class V

Data Analysis

All analyses were conducted in triplicates, and the average values were presented in the results section. Microsoft Excel 2019 was used as a graphical tool to analyze all the study results. A paired two-tail samples *t*-test was used to determine the significance of WH and WL results at a significant level of $p <$ 0.05.

RESULTS AND DISCUSSION

Phytoremediation of Lead (Pb)

The initial concentration of Pb detected in the Muar River water sample was 0.514 mg/L, which is ten times greater than the Ministry of Health Department's permissible limit for standard raw water quality [35]. However, Pb concentrations in the water samples were significantly decreased in days by both plants. The mean Pb concentrations (mg/L) and removal efficiencies (%) in the Muar River water samples by WH and WL for the present study are given in Table 5. The percentage of Pb removal is also illustrated in Figure 3. In this study, all R^2 values are more than 0.99, demonstrating good linearities for Pb concentrations.

In the first three days of treatment, the Pb removal efficiency of WH and WL are 67.90 % and 49.03 % respectively. Although the results showed that WH absorbed Pb more rapid than WL during the first 3 days of treatment, absorption of WH became relatively slower from day 5, to 10. The result showed that WH's removal efficiency from day 5 to 10 only increases between 6 – 18 % (71 % to 79 %) while WL continues the excellent work of absorbing more Pb from day 5 to 10 where the removal efficiency is 52 % to 87 %. This shows that the WL absorption increased between 6 – 78 %, which is more significant than WH.

The result obtained result was also related to the pH values of the water samples. The absorption rate of WH was higher at a lower pH, as compared to that of WL for the early days of the experimental period. This indicates that an acidic environment enhances the mobilization of heavy metal towards the plants' root system. Furthermore, based on physical observation, both plants were in good condition on day 0 when they were still fresh. However, on day 5, WH started to wither, with some leaves turning brownish-yellow in color, and then dying on day 10 On the other hand, WL appeared to be a more hardy plant, turning yellowish only on day 10, with no dead leaves.

Although, the result showed that both plants could reduce Pb concentration in the river water, WL had a greater absorption efficiency and tolerance to Pb compared to WH. According to Dae et al., the mechanism of metal uptakes by the plant involves metal movement across the plasma membrane of the root cells, stacking in xylem tissue and translocation, and resulting in detoxification sequestration of metals at the whole plant [36]. Extracts of the plants or roots which contain compounds from several functional groups such as for example, the carboxyl group for instance, would enhance the absorption mechanism and help to withstand the the Pb effect [15]. The water pH value plays an important role in absorption of the metal pollutants. However, according to Abed *et al.* [37], the actual mechanism of reaction could not be determined easily.

Table 5. Mean Pb concentration (mg/L) and removal efficiency (%) in the Muar River by WH and WL

Days	R^2	Concentration of Pb (mg/L) Mean ± SD (Removal efficiency, %)					
		Control	Removal efficiency, (%)	WH	Removal efficiency, (%)	WL	Removal efficiency, (%)
0	0.995	0.514 ± 0.07	0	0.514 ± 0.07	0	0.514 ± 0.07	0
3	0.996	0.370 ± 0.07	28.01	0.165 ± 0.04	67.90	0.262 ± 0.05	49.03
5	0.991	0.263 ± 0.03	48.83	0.144 ± 0.37	71.98	0.243 ± 0.03	52.72
7	0.997	0.208 ± 0.06	59.53	0.119 ± 0.01	76.85	0.166 ± 0.01	67.70
10	0.997	0.201 ± 0.06	60.89	0.104 ± 0.04	79.77	0.063 ± 0.01	87.70

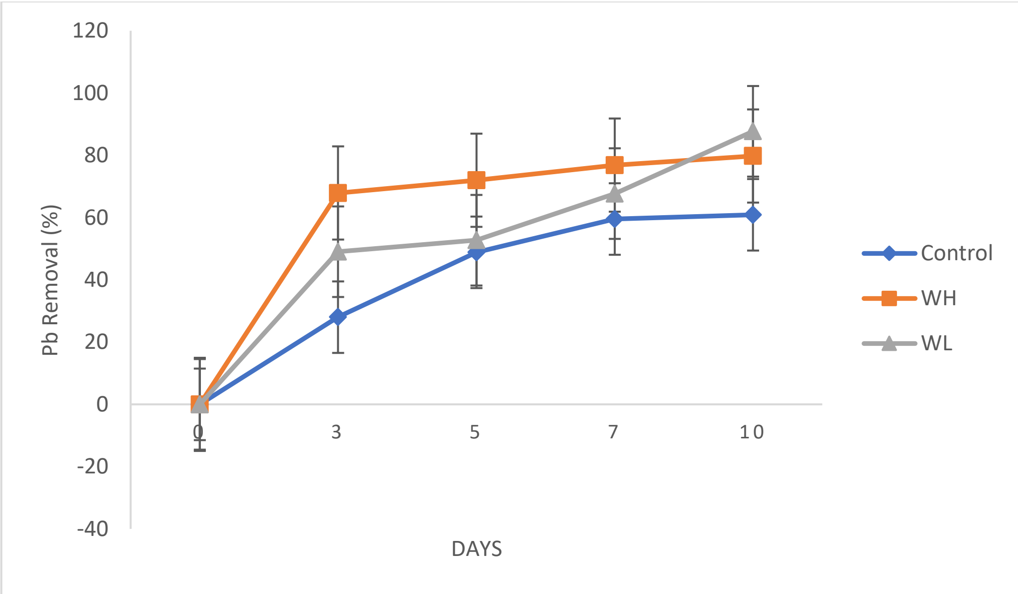

Figure 3. Percentage of Pb removal efficiency

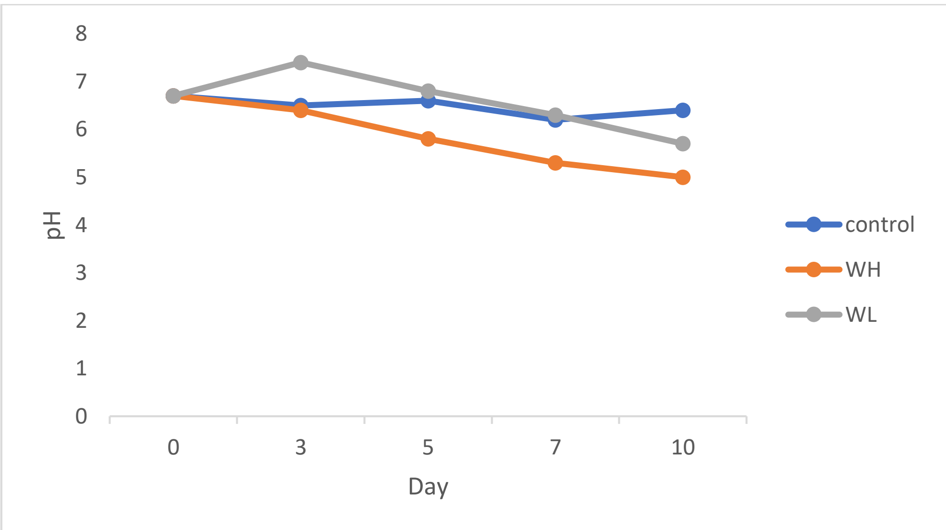

Figure 4. pH values of control water sample and water samples treated with WH and WL

Variation of pH

Figure 4 shows the pH values of water in the control water sample and the water samples treated with aquatic macrophytes from day 0 to day 10. The pH values recorded varied from 5.0 to 6.7 during the experimental period. The pH values decreased over the days in the treated water sample with WH and WL compared to that of the control. The pH values recorded on day 10 for WH and WL water samples were 5.0 and 6.1, respectively. After ten days of the experiment, the recorded pH values were in the range of 6.0 to 8.5, indicating that it is suitable for microbial degradation of organic matter present in the water samples. Studies showed that most aquatic organism could not survive under extreme water pH levels (4<pH>9), although the lower level of pH may increase the rate of mobilization of toxic metals that can be absorbed by a living organism [38, 39, 3].

Reduction Efficiency of Total Suspended Solid (TSS)

Total suspended solid (TSS) are solid particles that are suspended in and does not dissolve in water, including floating or drifting solids from silt, organic decay, sediment, algae, or plankton. The initial TSS concentration in water samples for the present study was 240 mg/L (day 0). After ten days of treatment, significant differences in TSS levels were observed in the treated water samples. WH was found to be more excellent with a significantly greater reduction in TSS, at 63 % (89 mg/L) compared to that of WL at 47% (128 mg/L) (paired *t*-test: $t = 60.2$, df = 1, $p < 0.05$). Figure 5 shows the TSS level recorded in the treated and control water samples WH with long fibrous roots seem to be better at accumulating more TSS compared to WL with short roots [40]. Furthermore, Umar *et al.* [41] stated that aquatic macrophytes are able to attract and trap suspended particles due to the charges present in the root systems.

Bioaccumulation Factor (BAF) Index Analysis

The BAF is a useful variable to measure the potential of plants to accumulate heavy metals. Zacchini *et al.* [42] stated that BAF could also provide useful additional information on plant species' efficiency to extract metal from polluted water. The uptake efficiency of metal depends on the concentration of metal in the river water. In the present study, statistical analysis of Pb concentration in a water sample to the plant's roots showed significant results for both plants. In general, the BAFs index increased from day 3 to day 10 for both plants. WH had the highest BAF, which were 1.7 and 2.4 on days 3 and 10, respectively. This result could be related to the Pb analysis, where the absorption rate of WH was more rapid in the first three days. BAFs index greater than one obtained for the investigated heavy metal absorption indicated that WH and WL are good accumulators ions [22]. Table 6 shows the BAF values for Pb in the roots of WH and WL analyzed on days 3 and 10.

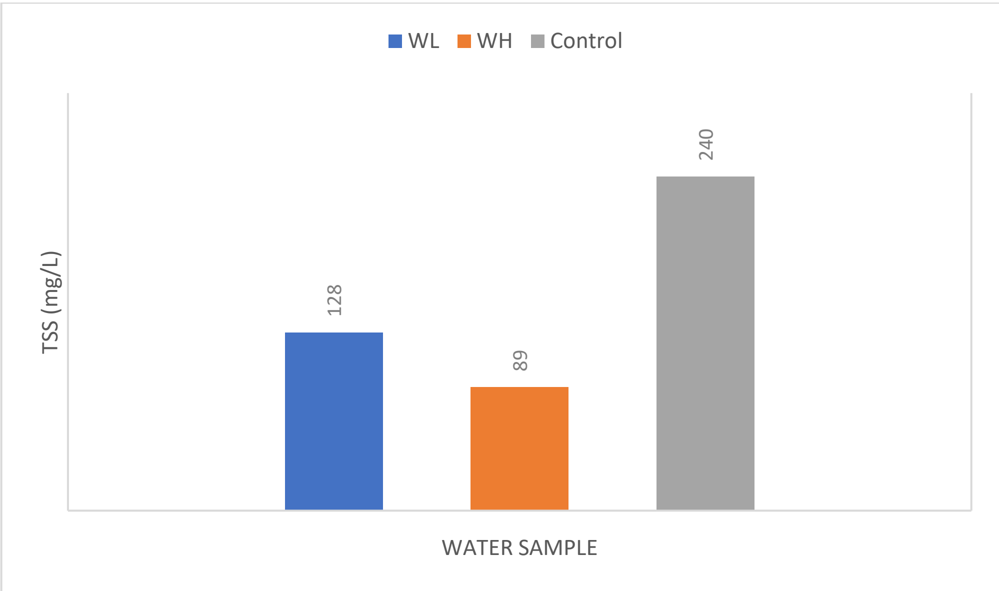

Figure 5. TSS levels recorded in treated water samples and control water sample

Table 6. BAF values for Pb in the roots of WH and WL

Days	BAF	
	WH	WL
3	1.7	0.3
10	2.4	1.9

Water Quality Analysis

Table 7 presents the water quality of the Muar River water samples after phytoremediation by WH and WL for ten days. The initial pH value on day 0 was recorded as 6.86 (class II), and after ten days the pH value for both water samples decreased slightly to class III, which was between 5 to 6. Absorption of pollutants (Pb) by the plants (WH and WL) might be a factor that caused the slight reduction in pH, affected by the microbial activity concerning the BOD and COD values too [29].

The removal of AN and COD was the highest in the treated water samples. COD value of treatment with WH showed a more significant reduction (70%) than WL after the treatment periods. The high COD values in both water samples are due to organic matter resulting from the photosynthesis process in plants [15]. Plants decrease the level of dissolved CO_2 and simultaneously increase the level of dissolved oxygen [29]. However, a contradictory result was recorded in this study where the DO level of treated water samples was slightly decreased, negatively correlated to the removal efficiency of pollutants and DO levels. Nevertheless, the DO values were still at the same level (class I) for both water samples, which indicates an adequate level of dissolved oxygen for plants to support microbial activity.

The concentration of BOD_5 in the WH water sample did not change while the reading recorded was three times higher in the WL water sample compared to the value for the control water sample. Shaharuddin *et al.* [43] stated that BOD_5 concentration is affected by the biodegradable organic matter from aquatic plants and its nutrient. The results related to the good reading values obtained by DO concentration, where the production of oxygen from plants may contribute to the level of oxygen affecting the degradation process in BOD values.

Table 8 presents the computed WQI and their classification. The results showed that treatment by WH and WL were significantly positive. WQI values for sample water treated with WH, WL and control were 49.9, 40.1 and 38.8, respectively. All the WQI values indicated that the Muar River water samples are categorized as *Polluted (*classified under Class IV), even though the water samples treated with WH show improved WQI values. According to the Department of Environment [34], the WQI obtained is suitable for irrigation purposes and needs extensive water treatment for domestic usage.

However, the result obtained may not be suitable for accurate classification of the Muar River's water quality because of the stagnant water condition used in the experiment. It would be more realistic to carry out an on-site phytoremediation study on the Pb pollution present in the Muar River water. Nevertheless, the aquatic plants used in the present study showed that they have the potential to absorb Pb from the water.

Table 8. WQI value and classification

Water sample treated with Aquatic Macrophytes	WQI	Classification
WH	49.9	IV
WL	40.1	
Control	38.8	

Table 7. Water quality data after phytoremediation by WH and WL

Samples/ Parameters	**pH**		**BOD (mg/L)**		**COD (mg/L)**		**DO (mg/L)**		**TSS (mg/L)**		**NH_3-N (AN) (mg/L)**	
	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class
Control	6.63	II	5	III	215	IV	9.10	I	240	IV	0.39	III
WL	6.09	III	16	V	142	V	8.12	I	128	III	0.14	II
WH	5.08	III	5	III	61	IV?	9.08	I	89	II	0.19	II

CONCLUSION

Based on the results obtained, it can be concluded that water hyacinth and water lettuce are good accumulators that have the potential to absorb metal from water with an absorption index greater than 1. However, water lettuce is a better phytoremediation agent compared to water hyacinth. Water lettuce had greater Pb absorption efficiency compared to water hyacinth. The mechanism of metal uptake capacity by both plants appeared to be correlated reductions in pH in the water samples. Although Pb concentration in the tissues increased in water lettuce, the physical observation significantly does not seem to change in exposure under contaminated conditions.

It was concluded that water quality was significantly improved by phytoremediation by both plants (water lettuce and water hyacinth), as evidenced by the decreases in pH, ammoniacal nitrogen, total suspended solids, and chemical oxygen demand. Therefore, the findings obtained from the present study could lead to an advance study in the future to assess the water removal of water contaminants in an effort to sustain our water supply in terms of quality.

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REFERENCES

1. Mahmud, M. H., Lee, K. E., Mokhtar, M. and Wahid, M. A. (2018) Technical strategy for revitalizing urban river water quality through structural approach at National University of Malaysia (UKM) Bangi campus, Selangor, Malaysia. *Applied Ecology and Environmental Research*, **16(3)**, 2681–2699.

2. Reza, R. and Singh, G. (2010) Heavy metal contamination and its indexing approach for River Water. *International Journal of Environmental Science and Technology*, **7(4)**, 785–792.

3. Mulana, K. N., Abdullah, H. S. and Sao, D. (2015) *Localization and Availability of Cadmium, Lead and Nickel in Muar River, a Preliminary Assessment*, Politeknik Merlimau, Melaka, Malaysia.

4. Lone, M. I., He, Z. L., Stoffella, P. J. and Yang, X. E. (2008) Phytoremediation of heavy metal polluted soils and water: Progress and perspectives. *Journal of Zhejiang University: Science B*, **9(3)**, 210–220.

5. Adesiyan, I. M., Bisi-Johnson, M., Aladesanmi, O. T., Okoh, A. I. and Ogunfowokan, A. O. (2018) Concentrations and human health risk of heavy metals in rivers in Southwest Nigeria. *Journal of Health and Pollution*, **8(19)**, 1–14.

6. Krishnamoorthy, R., Govindan, B., Banat, F., Sagadevan, V., Purushothaman, M. and Show, P. L. (2019) Date pits activated carbon for divalent lead ions removal. *J. Biosci. Bioeng.*, 1–10.

7. Safatian, F., Doago, Z., Torabbeigi, M., Rahmani Shams, H. and Ahadi, N. (2019) Lead ion removal from water by hydroxyapatite nanostructures synthesized from eggshells with microwave irradiation. *Applied Water Science*, **9(4)**, 1–6.

8. Gherasim, C. V., Křivčík, J. and Mikulášek, P. (2014) Investigation of batch electrodialysis process for removal of lead ions from aqueous solutions. *Chemical Engineering Journal*, **256**, 324–334.

9. Pohl, A. (2020) Removal of Heavy Metal Ions from Water and Wastewaters by sulfur-containing precipitation agents. *Water, Air, and Soil Pollution*, **231(10)**, 1–17.

10. Thaçi, B. S. and Gashi, S. T. (2019) Reverse osmosis removal of heavy metals from wastewater effluents using biowaste materials pretreatment. *Polish Journal of Environmental Studies*, **28(1)**, 337–341.

11. Ali, S., Abbas, Z., Rizwan, M., Zaheer, I. E., Yavas, I., Ünay, A., Kalderis, D. (2020) Application of floating aquatic plants in phytoremediation of heavy metals polluted water: A review. *Sustainability (Switzerland)*, **12(5)**, 1–33.

12. Sidek, N. M., Ahmad, N. U., Abdullah, S. R. S. and Draman, S. F. S. (2020) Phytoremediation of ex-mining lake water in constructed wetland by perennial plants. *Chiang Mai University Journal of Natural Sciences*, **19(3)**, 580–594.

13. Truong, P. N. V, Foong, Y. K. and Guthrie, M. (2010) Phytoremediation of heavy metal contaminated soils and water using vetiver grass, in *Handbook of Environmental Engineering: Environmental Bioengineering*, eds. Wang L., Tay J. H., Tay S., Hung Y. T., Humana Press, Totowa, New Jersey.

14. Bello, A. O., Tawabini, B. S., Khalil, A. B., Boland, C. R. and Saleh, T. A. (2018) Phytoremediation of cadmium, lead and nickel contaminated water by *Phragmites australis* in hydroponic systems. *Ecological Engineering*, **120**, 126–133.

15. Sidek, N. M., Abdullah, S. R. S., Ahmad, N. U., Draman, S. F. S., Rosli, M. M. M. and Sanusi, M. F. (2018) Phytoremediation of abandoned mining lake by water hyacinth and water lettuces in constructed wetlands. *Jurnal Teknologi*, **80(5)**, 87–93.

16. Tangahu, B. V., Sheikh Abdullah, S. R., Basri, H., Idris, M., Anuar, N. and Mukhlisin, M. (2011) A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. *International Journal of Chemical Engineering*, 1–31.

17. Lad, J. and Pamnani, A. (2018) Treatment of domestic wastewater by aquatic plants. *International Journal of Creative Research Thoughts (IJCRT)*, **6(2)**, 974–983.

18. Ismail, Z. and Beddri, A. M. (2009) Potential of water hyacinth as a removal agent for heavy metals from petroleum refinery effluents. *Water, Air, and Soil Pollution*, **199**, 57–65.

19. Singh, J. and Kalamdhad, A. S. (2013) Assessment of bioavailability and leachability of heavy metals during rotary drum composting of green waste (Water hyacinth). *Ecological Engineering*, **52**, 59–69.

20 .Malar, S., Sahi, S. V., Favas, P. J. C. and Venkatachalam, P. (2014) Mercury heavy-metal-induced physiochemical changes and genotoxic alterations in water hyacinths [*Eichhornia crassipes (Mart.)*]. *Environmental Science and Pollution Research*, **22(6)**, 4597–4608.

21. Michael, P. S. (2019) Phytoremediation of heavy metals by water hyacinth in sewage wastewater stabilization ponds under humid lowland tropical climatic conditions. *International Journal of Environment*, 30–42.

22. Wickramasinghe, S. and Jayawardana, C. K. (2018) Potential of aquatic macrophytes *Eichhornia Crassipes*, *Pistia Stratiotes and Salvinia Molesta* in phytoremediation of textile wastewater. *Journal of Water Security*, **4**, 1–8.

23. Novita, V. Z., Moersidik, S. S. and Priadi, C. R. (2019) Phytoremediation potential of *Pistia Stratiotes* to reduce high concentration of Copper (Cu) in acid mine drainage in *IOP Conf. Series: Earth and Environmental Science*, **355(1)**, 1-8.

24. Lu, Q., He, Z. L., Graetz, D. A., Stoffella, P. J. and Yang, X. (2011) Uptake and distribution of metals by water lettuce (*Pistia stratiotes L.)*. *Environmental Science and Pollution Research*, **18(6)**, 978–986.

25. Zhou, Y. Q., Li, S. Y., Shi, Y. D., Lv, W., Shen, T. B., Huang, Q. L. and Wu, Z. L. (2013)

Phytoremediation of chromium and lead using water lettuce (*Pistia stratiotes L.). Applied Mechanics and Materials*, **401–403**, 2071–2075.

26. Ching, Y. C., Lee, Y. H., Toriman, M. E., Abdullah, M. and Yatim, B. Bin (2015) Effect of the big flood events on the water quality of the Muar River, Malaysia. *Sustainable Water Resources Management*, **1(2)**, 97–110.

27. Huang, Y. F., Ang, S. Y., Lee, K. M. and Lee, T. S. (2015) Quality of water resources in Malaysia, Research and Practices in Water Quality, IntechOpen, London.

28. Rusli, N. and Majid, M. R. (2012) Investigating leaf area index of palm oil and rubber on hydrologic response: A research methodology, in *Proc. International Technical Conference 2012, Kuala Lumpur*, 1–8.

29. Saha, P., Shinde, O. and Sarkar, S. (2017) Phytoremediation of industrial mines wastewater using water hyacinth. *International Journal of Phytoremediation*, **19(1)**, 87–96.

30. Baird, B., R., Eaton, A., D. and Rice, E. W. (2017) Standard methods for the examination of water and wastewater (Revision 23rd), American Public Health Association (APHA), The United States of America.

31. Mahmud, M. H., Lee, K. E. and Goh, T. L. (2017) On-site phytoremediation applicability assessment in Alur Ilmu, Universiti Kebangsaan Malaysia based on spatial and pollution removal analyses. *Environ Sci Pollut Res*, 1–12.

32. Keeflee, S. N. K. M. N., Zain, W. N. A. W. M., Nor, M. N. M., Jamion, N. A. and Yong, S. K. (2020) Growth and metal uptake of spinach with application of co-compost of cat manure and spent coffee ground. *Heliyon*, **6**, 1–7.

33. Zhao, C., Xie, H., Xu, J., Zhang, J., Liang, S., Hao, J. and Wang, J. (2016) Removal mechanisms and plant species selection by bioaccumulative factors in surface flow constructed wetlands (CWs): In the case of triclosan. *Science of the Total Environment*, **547**, 9–16.

34. DOE (2017) Malaysian Environmental Quality Report 2006, Water Quality Index Classification, Ministry of Natural Resources and Environment Malaysia, Putrajaya, Malaysia.

35. Hamzah, N., Diman, C. P., Ahmad, M. A. N., Lazim, M. I. H. M., Zakaria, M. F. and Bashar, N. M. (2018) Water quality assessment of abandoned mines in Selangor, in *AIP Conf. Proc.* **2020,** 020046-1-020046-8.

36. Das, S., Goswami, S. and Talukdar, A. Das. (2014) A study on cadmium phytoremediation potential of water lettuce. *Pistia stratiotes L, Bulletin of Environmental Contamination and Toxicology***, 92(2)**, 169–174.

37. Abed, S. N., Almuktar, S. A. and Scholz, M. (2019) Phytoremediation performance of floating treatment wetlands with pelletized mine water sludge for synthetic greywater treatment. *Journal of Environmental Health Science and Engineering*, **17(2)**, 581–608.

38. Gensemer, R. W., Gondek, J. C., Rodriquez, P. H., Arbildua, J. J., Stubblefield, W. A., Cardwell, A. S. and Nordheim, E. (2018) Evaluating the effects of pH, hardness, and dissolved organic carbon on the toxicity of aluminum to freshwater aquatic organisms under circumneutral conditions. *Environmental Toxicology and Chemistry*, **37(1)**, 49–60.

39. Kleinhappel, T. K., Burman, O. H. P., John, E. A., Wilkinson, A. and Pike, T. W. (2018) The impact of water pH on association preferences in fish. *Ethology*, 1–8.

40. Nizam, N. U. M., Hanafiah, M. M., Noor, I. M. and Karim, H. I. A. (2020) Efficiency of five selected aquatic plants in phytoremediation of aquaculture wastewater. *Applied Sciences (Switzerland)*, **10(8),** 1–11.

41. Umar, K., Muhammad, M., Sani, N., Muhammad, S. and Umar, M. (2015) Comparative study of antioxidant activities of the leaves and stem of *Ipomoea aquatica* forsk (Water Spinach). *Nigerian Journal of Basic and Applied Sciences*, **23(1),** 81.

42. Zacchini, M., Pietrini, F., Scarascia Mugnozza, G., Iori, V., Pietrosanti, L. and Massacci, A. (2009) Metal tolerance, accumulation and translocation in poplar and willow clones treated with cadmium in hydroponics. *Water, Air, and Soil Pollution*, **197,** 23–34.

43. Shaharuddin, S., Zakaria, N. A., Ghani, A. and Wan Maznah, W. O. (2019) Assessing phytoplankton distribution and water quality in constructed wetlands during dry and wet periods: A Case Study in USM Engineering Campus, in *IOP Conf. Series: Earth and Environmental Science*, **380**, 1-15.