Jurnal Akta Kimia Indonesia
INDONESIA CHIMICA ACTA

PAPER

View Article Online
View Journal View Issue

Cite this: *Indo. Chim. Acta.*, 2020, **13**, 1.

Absorption of Heavy Metal Lead (Pb) by Water Hyacinth (*Eichhornia crassipes*) and Its Influence to Total Dissolved Solids of Groundwater in Phytoremediation

Received Date:
12th May 2020
Accepted Date:
23rd June 2020

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Abstract. Waste of heavy metal lead (Pb) in waters needs to be addressed through phytoremediation because it is toxic to the environment. The purpose of this study is to determine the effect of water hyacinth (*Eichhornia crassipes*) ability in water to absorb heavy metal Pb and its effects to total dissolved solids (TDS) of groundwater during the phytoremediation process. Using *E. crassipes*, groundwater samples and Pb(NO3)2 as a source of Pb, the initial characterization of the two samples was previously carried out. Created four treatments of ground water, i.e.: P1 contains 2 ppm Pb with *E. crassipes*, P2 contains 4 ppm Pb with *E. crassipes*, P3 contains 2 ppm Pb without *E. crassipes*, and P4 contains 4 ppm Pb without *E. crassipes*. Observation of Pb by method of atomic absorption spectrometry (AAS) and determination of TDS by gravimetric method, each carried out on days 0, 4, 8, and 12. The results show the treatment of 2 ppm Pb, *E. crassipes* is more effective at absorbing Pb which is 96.0% compared to treatment 4 ppm Pb which is 90.0%. While 2 ppm Pb and 4 ppm Pb as control only 18.5% and 17.5%. Treatment of 2 ppm Pb which uses *E. crassipes* shows better water quality than concentration TDS 62.55 ppm compared to treatment of 4 ppm Pb with TDS 70.50 ppm while 2 ppm Pb and 4 ppm Pb as a control does not significantly affect to water quality.

Keywords:
phytoremediation;
lead;
Eichhornia crassipes;
total dissolved solids

DOI:
http://dx.doi.org/10.20956/ica.v13i1.9977

Introduction

Increasingly rapid industrial development does not only improve the economy, but also have an impact on environmental pollution from waste produced (Fahruddin et al., 2018). In addition to the pollution in the form of organic material, there is also pollution in the form of heavy metals which are mostly contained in industrial waste, especially in the electronics industry and mining waste disposal (Fahruddin and Tanjung, 2019). Heavy metal pollution has become a concern because it is toxic which has a negative impact on the environment and human health (Meagher and Heaton, 2005; Fahruddin et al., 2017).

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One of the toxic heavy metals is lead (Pb) which is widely used in industry. Metal Pb is used by industry as raw material, so the wastewater produced also contains heavy metal Pb (Bhuiyan et al., 2015). Based on Government Regulation of the Republic of Indonesia Number 82 Year 2001 Concerning Water Quality Management and Water Pollution Control, standard of heavy metal Pb quality based on class, such as: 0.03 ppm (class I, II and III) and 1 ppm (class IV) (Palapa and Maramis, 2015). Heavy metal Pb have become quality standards on water quality by reason of causing human health disorders that damage the nerves, kidneys, bones, teeth, reduce intelligence, and inhibit the production of hemoglobin (Assi et al., 2016).

Several physical-chemical technologies such as chemical reduction, ion exchange, membrane filtration, and electrodialysis have been used to remove heavy metal (Moussavi and Mahmoudi, 2009). But this technology requires a large amount of chemicals, a large area, and a professional operator to run it. These methods are not efficient both in terms of cost and technicality and are not suitable for the application of small scale industrial waste treatment (Kobya et al., 2005). Therefore, one of the more efficient and effective technologies that can be used as an alternative in reducing heavy metal content is phytoremediation (Ndimele and Jimoh, 2011). Phytoremediation is a more effective method by utilizing plants to reduce heavy metal pollution. Water plant of water hyacinth (Eichhornia crassipes) is widely used in phytoremediation because it is able to absorb heavy metal Pb in water at a concentration of 180 ppm (Ndimele and Jimoh, 2011).

The reason for using *E. crassipes* is because this plant has fast growth which has great potential for controlling water pollution and is able to accumulate various types of heavy metal, such as heavy metal Zn and Cr have an efficiency of up to 94% and 84% (Mishra & Tripathi, 2008). Therefore, *E. crassipes* is a water plant that is often used in phytoremediation of heavy metal. In wastewater, this plant is able to adapt to high tolerance and can accumulate heavy metals effectively (Fahruddin et al., 2018).

Many factors affect the ability of plant to absorb and accumulate heavy metals in its tissues, such as plant types, heavy metal concentrations and contact times (Mishra & Tripathi 2008; Fahruddin et al., 2019). According to Ochekwu and Madagwa (2013) that *E. crassipes* that grows in water can remove the turbidity that is detected as TDS (total dissolved solids). TDS in water can be sourced from aquatic plants, namely in the parts of dead plant organs and entering the water become part of organic particles that dissolve in water. Other TDS sources can originate from exudates, both at the root and other plant tissues, can increase TDS and BOD concentrations (Borker et al., 2013). In addition, TDS can originate from irrigation or agricultural drainage systems, settlements, offices and industrial wastewater (Aoi and Hayashi, 1996). Based on this description, a study was conducted on the relationship between absorption of heavy metals by *E. crassipes* and groundwater TDS during the phytoremediation process.

Experimental

Material and Methods

E. crassipes, $Pb(NO_3)_2$, water, atomic absorption spectroscopy (AAS)analysis used for heavy metal analysis, TDS measurements were using gravimetric method.

Sample Preparation

E. crassipes samples were taken from the lake of the Hasanuddin University, Makassar. Furthermore, it is acclimatized by growing in ponds for two weeks with the aim of obtaining plants that have a relatively uniform size and weight and are easily adaptable (Borker et al., 2013; Mishra and Tripathi, 2008). Well water samples for phytoremediation treatment were taken at Experimental Farm, Faculty of Agriculture, Hasanddin University. The heavy metal Pb used by the molecule of $Pb(NO_3)_2$.

Characterization of *E. crassipes* and Groundwater Plants

Initial characterization was carried out on *E. crassipes* by analyzing the Pb heavy metal content using atomic absorption spectrometry (AAS). Physical and chemical initial characterization of groundwater is also conducted, including parameters of turbidity, total suspended solids (TSS), electrical conductivity and pH, as well as nutrient content including carbon (C), nitrogen (N), phosphorus (P) and potassium (K).

Phytoremediation Treatment

Phytoremediation treatment is made by a batch system method or water is not flowing (Tanjung et al., 2019). The treatment is made in a container with a capacity of 10 L with 4 treatments, namely:

P1: groundwater contains 2 ppm Pb with *E. crassipes*

P2: groundwater contains 4 ppm Pb with *E. crassipes*

P3: groundwater contains 2 ppm Pb without *E. crassipes*

P4 groundwater contains 4 ppm Pb without *E. crassipes*

Each treatment was made duplicate and each added one *E. crassipes*. Sampling for observation of heavy metal content and TDS was done every 4 days for 12 days, namely on the 0^{th}, 4^{th}, 8^{th} and 12^{th} days.

Observation of Heavy Metal Pb

Pb observations of total groundwater were carried out using the atomic absorption spectroscopy (AAS). The sample content is in the range of 1 ppm Pb concentration up to 20 ppm, using a wavelength of 217 nm which is equipped with background correction. The concentration of Pb is determined using the equation:

$$\text{Concentration of Pb} = C \times df$$

Where:

C : Concentration of Pb from observations (ppm)

df : Dilution factor.

Measurement of Total Dissolved Solids (TDS)

TDS measurements were using gravimetric method. Groundwater samples from phytoremediation treatment were homogeneous, then pipetted as much as 100 mL and filtered with a suction pump and filter paper. The filtrate obtained is used to measure the TDS level and transferred to a cup of known permanent weight, then evaporated to dryness in a water bath. After that, the plates were put into the oven at 105 ^oC for 1 hour, then cooled in a desiccator and weighed. This procedure is repeated until a permanent weight is obtained.

Result and Discussion

Initial Characterization of the Sample

Preliminary analysis of lead (Pb) content in *E. crassipes* was carried out before treatment using atomic absorption spectrophotometer obtained Pb of 0.0004 mg/kg. For physical and chemical characteristics in groundwater the results are shown in Table 1. The *E. crassipes* contains Pb because it is able to accumulate heavy metals into its tissue even in small concentrations (Ndimele and Jimoh, 2011). According to Yaqin et al. (2018), the presence of Pb content in *E. crassipes* shows that the lake water in Hasanuddin University has been contaminaded by Pb with an average concentration of 3.906 ppm which can be sourced from domestic waste and hospitals not far from the lake.

Table 1. Groundwater physical-chemical characteristics.

Parameter	Value
Turbidity	0.97 FTU
Total suspended solids	5.7 ppm
Electrical conductivity	0.121 µS/cm
pH	6.78
Carbon (C)	777.03 ppm
Phosphorus (P)	33.53 ppm
Potassium (K)	14.17 ppm
Nitrogen (N)	68.85 ppm

Associated with the nutrient content in groundwater, Chapman and Thornton (1986) states that primary nutrients or major nutrients such as C, N, P and K is needed by plants. The availability of nutrients in groundwater indicates that the growth of aquatic plants including *E. crassipes* can take place well for the ongoing phytoremediation process.

Effect of *E. crassipes* in Absorbing Pb

Changes in the Pb concentration in groundwater in the treatment using *E. crassipes*, day 4 is the most optimum time for a decrease in Pb concentration, reaching 0.64 ppm from 2.00 ppm in the P1 treatment and 0.97 ppm from 4.00 ppm on P2 treatment, while on the 12th day, the decrease in Pb concentration was not significant, ie only 0.08 ppm at P1 and 0.40 ppm at P2 treatment as shown in Figure 1. According to Zayed et al. (1998), *E. crassipes* is able to absorb heavy metal with high efficiency in a short time and their absorption ability decreases with increasing contact time.

Whereas for treatments that do not use *E. crassipes*, changes in the Pb concentration in groundwater until the 12th day are much smaller when compared to treatments using *E. crassipes*, which is only 1.63 ppm from 2.00 ppm at P3 and 3.30 ppm from 4.00 ppm at P4. According to Wolverton (1975) that there is a difference in the concentration of nickel (Ni) in water between experiments using *E. crassipes* and without *E. crassipes* within 24 hours which is 0.538 ppm and 1.900 ppm. According to Fahruddin and Tanjung (2019), there are two possibilities that cause a decrease in the concentration of Pb in the treatment of P3 and P4, namely: the process of biosorption of metals by microorganisms and the process of adsorption of metals by organic substances contained in groundwater.

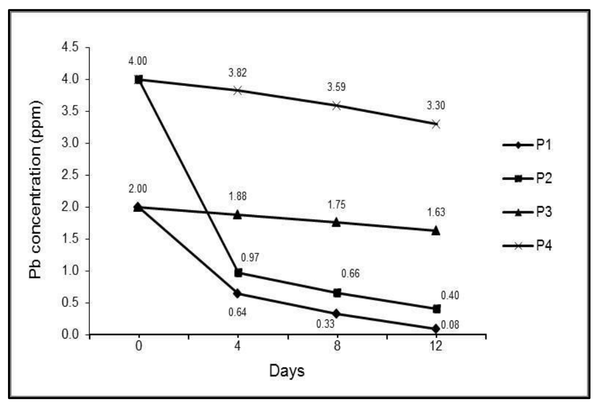

Figure 1. Changes of Pb concentration in groundwater of the treatment: P1 is groundwater contains 2 ppm Pb with *E. crassipes*, P2 is groundwater contains 4 ppm Pb with *E. crassipes*, P3 is groundwater contains 2 ppm Pb without *E. crassipes*, and P4 is groundwater contains 4 ppm Pb without *E. crassipes*.

The absorption and accumulation ability of Pb by *E. crassipes* can also be described by the removal efficiency. The calculation of removal efficiency in this study was based on a decrease in the concentration of Pb in groundwater for 12 days of observation. The results of the calculation of the removal efficiency of heavy metal Pb in all treatments are shown in Table 2.

Table 2. The removal efficiency of heavy metal Pb in all treatments.

Treatments	Initial Concentration Pb (ppm)	Final Concentration Pb (ppm)	Removal Efficiency (%)
P1	2.00	0.08	96.00
P2	4.00	0.40	90.00
P3	2.00	1.63	18.50
P4	4.00	3.30	17.50

The addition of *E. crassipes* and Pb concentration affect the efficiency of the allowance. The efficiency of Pb absorption in treatments using *E. crassipes* is 96.00% in P1 and 90.00% in P2. Whereas for treatments that do not use *E. crassipes* the efficiency of Pb absorption are much smaller, namely only 18.50% at P3 and 17.50% at P4. Therefore, P1 and P2 treatments have higher removal efficiency compared to P3 and P4 treatments because *E. crassipes* effectively absorbs heavy metals (Mishra and Tripathi, 2008). The higher the concentration of Pb, the efficiency of *E. crassipes* in absorbing Pb decreases. According to Ingole and Bhole (2003), heavy metal at a concentration of 5 ppm has a greater absorption efficiency than at a concentration of 10 ppm.

TDS (Total Dissolved Solids) Concentration

On observation of TDS concentration in groundwater, there is a difference in the TDS concentration between the 2 ppm Pb treatment and 4 ppm Pb treatment on day 0, where the 2 ppm Pb treatment has a smaller TDS concentration when compared to the 4 ppm Pb treatment, which is 109.95 ppm on the 2 ppm Pb treatment (P1 and P3) and 113.60 ppm on the 4 ppm Pb treatment (P2 and P4) treatment as shown in Figure 2.

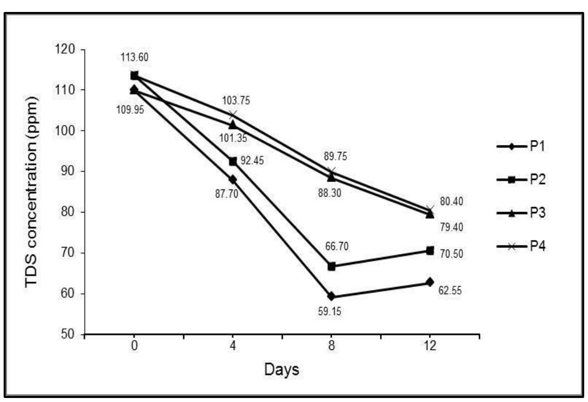

Figure 2. Changes of TDS concentration in groundwater of the treatment: P1 is groundwater contains 2 ppm Pb with *E. crassipes*, P2 is groundwater contains 4 ppm Pb with *E. crassipes*, P3 is groundwater contains 2 ppm Pb without *E. crassipes*, and P4 is groundwater contains 4 ppm Pb without *E. crassipes*.

The addition of Pb metal in each treatment can affect the TDS concentration. Borker et al. (2013) in his research stated that the concentration of TDS in the treatment Cd 25 ppm, Cd 50 ppm and Cd 75 mm on day 0, respectively, it was 175.1 ppm, 260.0 ppm and 349.3 ppm. The hair of the root of *E. crassipes* is electrically charged so that the dissolved solid which is the opposite charge will be pulled until it sticks to the roots and finally absorbed slowly by microorganisms and plants (Wolverton, 1989; Brix and Schierup, 1990; Detenbeck et al., 1993). *E. crassipes* also absorb organic contaminants and nutrients from the water column (Aoi and Hayashi, 1996). This is what causes the highest allowance for TDS concentrations in treatments P1 and P2 that use *E. crassipes* is greater than the treatments for P3 and P4 without *E. crassipes*, which reaches 46.20% in P1, 41.29% in P2, 27.79% in P3 and 29.23% in P4.

In treatments P1 and P2, the TDS concentration from day 4 to day 8 decreased whereas on the 12th day, TDS concentrations increased. Increased concentration of TDS can be caused by an adaptation process, where the roots that have developed will be separated from the stem. Decaying leaves and stems can also increase TDS concentration. In addition, the increase in TDS concentration is caused by exudates released by *E. crassipes* that have been accumulated by heavy metal (Borker et al., 2013).

TDS concentrations in the treatment of P3 and P4 as control are higher because there is no absorption by plants (Tanjung et al., 2019). The TDS concentration in the control decreases with increasing observation time. TDS reduction occurs because the treatment container can act as an equalizer. Interactions Pb(NO3)2 and organic-inorganic in groundwater allows colloidal particles to form sediment (Yadav et al., 2011).

From this description, treatments using *E. crassipes*, namely P1 and P2 treatments, are more effective in absorbing Pb compared to P3 and P4 treatments without *E. crassipes*, because *E. crassipes* can accumulate Pb into the tissues from the process of absorption by the root, translocation to localization (Fahruddin and Tanjung, 2019). Meanwhile, the decrease in Pb concentration in the treatment without *E. crassipes* is only through the process of metal biosorption by microorganisms and the process of metal absorption by organic matter contained in groundwater (Fahruddin and Tanjung, 2019).

Pb absorption both treatment using *E. crassipes* and treatment without *E. crassipes* have a relationship to the concentration of groundwater TDS. TDS shows better in treatments with *E. crassipes* with lower TDS indicators in treatments using *E. crassipes*, because plants actively absorb cations and anions in groundwater (Borker et al., 2013; Gupta et al., 2015). The TDS concentration in the treatment using *E. crassipes* is smaller because the hair root of *E.*

crassipes is electrically charged so that the dissolved solids which are opposite charge will be pulled up to stick to the roots and with increasing contact time these will be absorbed slowly by microorganisms and plants (Brix and Schierup, 1990; Johnston et al., 1993). While the decrease in TDS concentration occurs because the treatment container can act as an equalization tank (Yadav et al., 2011). The addition of Pb metal can increase pH and TDS. In addition, the presence $Pb(NO_3)_2$ can increase nutrient content and affect BOD and COD. Thus, the smaller the concentration of Pb in each treatment, the greater the efficiency of Pb removal and the relationship to changes in water quality will be better (Tanjung et al., 2019).

Likewise, other parameters will have an effect, such as changes in water quality, namely pH value and BOD concentration which is better in the treatment without *E. crassipes* (Tanjung et al., 2019). Lead removal efficiency in 4 ppm Pb treatment is smaller than 2 ppm Pb treatment because Pb can cause plant morphology and physiology disturbance (Malar et al., 2014).

Conclusion

From the results of the study, it was concluded that the highest value of Pb absorption efficiency was treatment 2 ppm Pb with the addition of one *E. crassipes* plant that is 96.00%; treatment 2 ppm Pb with the addition ofone *E. crassipes* plant shows better water quality TDS 62,55 ppm. This is because lead (Pb) at higher concentrations can inhibit the mechanism of *E. crassipes* roots in improving water quality.

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