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Potential of Water Jasmine (*Echinodorus palaefolius*) In Phytoremediation of Fe in Leachate Jatibarang Landfill

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Abstract

Water Jasmine [*Echinodorus palaefolius* (Ness & Mart.) J.F. Macbr.] is an aesthetic plant, that can purify wastewater containing high metals through phytoremediation. By using constructed wetlands system *E.palaefolius* was used to accumulate Fe (Iron) in leachate. Leachate comes from garbage that was piled up and decomposeds. The purpose of this research was to examine the ability of *E. palaefolius* plants to accumulate Fe in leachate. This study, used a completely randomized experimental design (CRD). The treatment variation were contact time of plants with leachate consisting of 0,7,14, and 21 day after planting. The results showed that Fe accumulated at the root was 10.86 mg/kg with the highest absorption rate occurring at 7 DAP with 1.56 mg/kg/day and BCF of 49.5 ppm. Fe accumulation on the stem was 571 mg/kg, the highest absorption rate at 14 DAP 63.71 mg/kg/day and BCF 3144.54 ppm. The accumulation of Fe in leaves was 696 mg/kg, the highest absorption rate was at 7 DAP with 104 mg/kg/day and BCF value of 3279.28 ppm. The results shows that the duration of contact affects the ability of *E. palaefolius* in accumulating Fe and improving the quality of leachate.

How to Cite

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INTRODUCTION

Fe is a micronutrient for plants that can be toxic if taken in excess (Li et al., 2015). The metals are usually present in acidic and water-containing soils as well as in flooded land (Connolly & Guerinot, 2002; Becker & Asch, 2005). Fe toxicity causes changes in morphological characters and plant physiology. The response of each plant is different, depending on the nature of tolerance or sensitivity of plants to the toxicity of Fe. Some studies show that Fe toxicity causes physiological character changes such as soluble protein levels (De Dorlodot et al., 2005) soluble sugars (Mehraban et al., 2008) the effects of iron toxicity in rice and the possible roles of potassium nutrition in the alleviation of iron toxicity are studied. Rice plants (Oryza sativa L., chlorophyll content, proline and photosynthetic rate (Majerus et al., 2007).

High Fe content can be found in leachate. Leachate comes from landfills that experience decomposition resulting in physical, chemical and biological changes. Leachate water contains organic and inorganic component, microorganisms and heavy metals such as Fe (Lehtonen, 2008). The presence of Fe can be characterized by solid black in leachate water (Pandia & Purba, 2017).

The sanitary landfill system is one of the processing methods used in the Semarang Jatibarang Final Disposal Site. The method has an impact on the environment in the form of seepage of potential leachate as a pollutant (Long et al., 2010). Research by Ulfah & Dewi (2015) stated that metal content Fe leachate Jatibarang Landfill ranged from 267.4 mg/L - 285 mg/L. Another case occurred in Banda Aceh City Landfill with Fe as the highest metal content (10.9191 ppm) in Leachate water compared to mercury (Hg), copper (Cu), zinc (Zn), cobalt (Co), nickel (Ni), chromium (Cr) and lead (Pb) (Pandia & Purba, 2017). In accordance with the quality standard rules determined by Regional Regulation of Central Java No.5 of 2012, the maximum allowable leachate is only 5 mg/L (Regional Regulation of Central Java, 2012).

Before the Jatibarang leachate is flowed into the river, it is necessary to have certain treatments to reduce the levels of heavy metals. At present, one system that can be offered to reduce the high Fe content in leachate water is phytoremediation system. Phytoremediation is the absorption of pollutants mediated by plants, such as trees, grasses, and aquatic plants. Plants will change pollutants to forms that are not harmful to the environment (Rhodes, 2013). This system has some advantages because the treatment is easy, economically and environmentally friendly, and has an aesthetic value from these plants in addition to being a phytoremediator agent (Tangahu et al., 2011). Plants will reduce heavy metals in leachate by restoring natural water quality (self-purification) (Samudro & Mangkoedihardjo, 2010).

Water Jasmine (*E.palaefolius*) is a herbaceous, semi-aquatic and perennial plant that grows floating (Sin et al., 2010). This plant is said to be a heavy metal accumulator for several types of heavy metal such as arsenic (As) and iron (Fe) (Prum et al. 2018). The plant has strong root system on the bottom of the water, fast growth and can absorb water a lot in quick time (Sriprapat et al., 2011). The plants also have root nodules associated with rhizosphere bacteria (Rhodes, 2013). These characteristics make this plant is suitable for used in the phytoremediation process.

This research was expected to provide a solution to reduce the level of Fe heavy metals contamination in leachate by an environmentally friendly method.

METHODS

The tools used were plastic reactor tub (measuring 50 cm in diameter, 25cm in height), AAS (Atomic Absorption Spectrometer) testing tool for Fe content in samples of roots, stems, and leaves. The materials used were leachate from Jatibarang landfill and *E. palaefolius* plant. To see the arrangement of the reactor constructed wetland can be seen in (Figure 1).

Preparation and Treatment

E. palaefolius plants were selected, which had a uniform size. A selection is based on plant height, the uniform number of stems and leaves. Then the plants will be acclimatized for 2 weeks, aiming to be able to adjust to the environmental conditions of the experiment. After the acclimatization is complete, the preparation of the reactor tub is made in the form of a bucket. The bucket reactor was given soil media from the Jatibarang landfill as a place to grow and leachate, a ratio of 1: 1, 10 kg of soil, 10 L of leachate water, then planted with 5 plants *E.palaefolius*. During the treatment, reactor maintenance was carried out by controlling the volume of leachate to remain the same in all reactors, with the addition of leachate, as well as controlling plant pests and diseases.

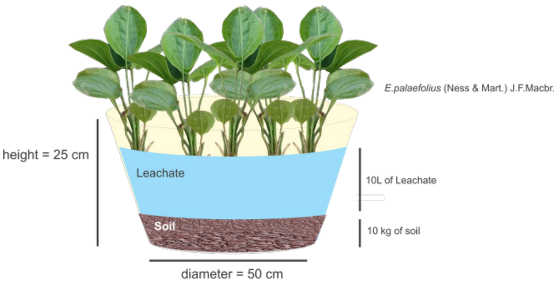

Figure 1. Constructed Wetlands design

Research Design

The research method used was experimental method with a completely randomized design (CRD). The treatment variation were contact time of plants with leachate consisting of 0 DAP (Control) (P_0), 7 DAP (P_1), 14 DAP (P_2) and 21 DAP (P_3), with 3 times replications. This research used a constructed wetland system and with *E. palaefolius* planted as the phytoremediation agent. Observations were made based on the effect of contact time of the roots, stems, and leaves of *E. palaefolius* plants on the absorbance of Fe in leachate. Leachate water, roots, stem, and leaves samples were tested for Fe content in accordance with SNI 06.6989.4-2009 using the AAS (Atomic Absorption Spectrometry) method.

Calculation

Absorption rate of Fe

The absorption rate of Fe by plants was determined based on the dry weight of metals (mg/kg) absorbed by plants (mg/kg/day) calculated using the following equation:

$$\text{Absorption rate} = \frac{\text{dry weight of plants x Fe absorbed by plants}}{\text{dry weight of plants x contact time}} \quad (1)$$

BCF in Plants

The BCF (Bioconcentration Factor) was calculated by measuring the concentration of Fe in plants (mg/kg dry weight) divided by the initial Fe concentration (mg/L) according to the following equation:

$$\text{BCF} = \frac{\text{(Fe absorbed by plants)/(Early Fe leachate)}}{\text{dry weight of plants x contact time}} \quad (2)$$

Data analysis

The data obtained were analyzed using ANOVA (Analysis of Variance) to see the effect of the contact time with the accumulation of Fe metal on the test plants (on stems, leaves, and roots samples). Duncan's New Multiple Range Test (DMRT) test was used if there was a significant effect on each treatment at 95% confidence level.

RESULTS AND DISCUSSION

The leachate inundation in the Jatibarang landfill WWTP (Wastewater Treatment Plant) Semarang can form soil sediments that will release a number of ions, such as Fe. In inundated soil, oxygen diffusion is 10,000 times lower, this condition results in the utilization of NO^{3-}, Mn^{4+}, Fe^{3+} and SO_4^{2-} as electron sources for anaerobic microbes (Armstrong & Armstrong, 2005). This process causes the change of Fe^{3+} to Fe^{2+} with higher solubility. This condition is toxic to plants. The level of Fe toxicity in plants is influenced by several factors associated with the conditions of growing media such as soil, water, soil mineral content, the amount of Fe ions that can be exchanged, and pH (Becker & Asch, 2005). Research by Elfidasari et al. (2018) showed that the changes in colour, changes smell, heavy metals content, toxic materials, temperature and pH are the indicator of polluted water.

The use of constructed wetlands system aims to purify Jatibarang landfill leachate water using *E. palaefolius* before being channeled into the Kreo River. The process takes place by imitating purification of water in natural wetlands or swamps (Vymazal, 2011). *E. palaefolius* plants are known to be able to reduce nutrient levels (eutrophication) in waters (Lehtonen, 2008). The quality of leachate in Jatibarang landfill is currently below the quality standard determined by Minister of Environment Regulation No.59 of 2016. Research by Rezagama et al. (2016) showed that the quality of Jatibarang landfill leachate was as follow: BOD (Biological Oxygen Demand) value of 1600 mg/L, COD (Chemical Oxygen Demand) value of 4000 mg/L and TSS (Total Suspended Solid) value of 522 mg/L. The color of concentrated leachate was also an indication of high Fe metal content that can cause toxicity (Prabowo et al., 2017).

During the phytoremediation process, there was an increase in absorption of Fe in the roots, stems and leaves of *E. palaefolius* from 0 DAP to 7 DAP. Absorption peak occurred at 14 DAP, then decreased at 21 DAP (Table 1). Fe gradually accumulates in the tissues of the roots, stems, and leaves. The results of Analysis of Variance (ANOVA) shows that there is a significant effect of the contact time of *E. palaefolius* on the accumulation of Fe from leachate. Each has the

Table 1. The average yield of Fe metal accumulation from leachate in *E. palaefolius*

The parameter of Fe Accumulation (mg/kg)	P0	P1	P2	P3
	0 DAP	7 DAP	14 DAP	21 DAP
Root	$7.81^{a} \pm 1{,}15$	$10.99^{b} \pm 0.05$	$15.25^{c} \pm 0.01$	$10.86^{bc} \pm 0.03$
Stem	$1.48^{a} \pm 0.08$	$1.30^{a} \pm 0.01$	$892^{b} \pm 1.00$	$571^{c} \pm 0.61$
Leaves	$7.50^{a} \pm 1.50$	$728^{c} \pm 0.06$	$892^{d} \pm 0.05$	$696^{b} \pm 0.10$

Description: The data displayed is ± SD. Figures with the same superscript letter on the same line show no significant difference (P> 0.05). P0: 0 DAP (control), P1: 7DAP, P2: 14 DAP, P3: 21DAP

same significan value, namely sig. 0.00 (5%). Then, from the Duncan test it was known that the optimum absorption of roots, stems, and leaves occur at 14 DAP. The optimum absorption occurred at the roots by 15.25 mg/kg, stems and leaves by 829 mg/kg (Table 1). Contact time affects the ability of plants to absorb Fe metal, this is also related to the age of the plant. The increasing age of the plant will also increase the absorption rate that will reach maximum condition at a certain time and decrease after reaching its peak (Sriprapat et al., 2011).

It is known that *E. palaefolius* absorption of Fe divided into three continuous processes, namely metal absorption by roots from the environment, metal translocation from roots to other parts of the plant, and metal localization to certain cell parts in plants to prevent it from inhibiting plant metabolism (Chaney et al., 2010). Absorption of leachate to the root epidermis of the *E. palaefolius* plant is carried out by *Iron-Regulated Transporter 1* (IRT1) via the symplastic pathway connected by plasmodesmata (Barberon et al., 2014). When in the root epidermis, IRT 1 works in conjunction with *Natural Resistance - Associated Macrophage Protein 1* (NRAMP 1) in absorbing Fe through the apoplastic pathway formed by the cell wall of the epidermis and cortex to reach the endodermis, then, Fe is translocated to plant tissue such as stems and leaves (Castaings et al., 2016). This condition can be seen from the results of this study that find that the highest Fe metal accumulation studies is in the stem and leaves sections of *E. palaefolius* inundated by leachate water (Table 1).

It can be seen in Figure 3 that there is an increase in the rate of absorption of *E. palaefolius* in accumulating Fe metal from leachate water in 21 DAP on various roots, stems and leaves. The highest increase in absorption rate occurred at 7 DAP and 14 DAP. It is known that the rate of absorption in the roots reaches 1.56 mg/kg/day at 7 DAP, in the stem reaches 63.71 mg/kg/day, and in the leaves reaches 104 mg/kg/day. However, it

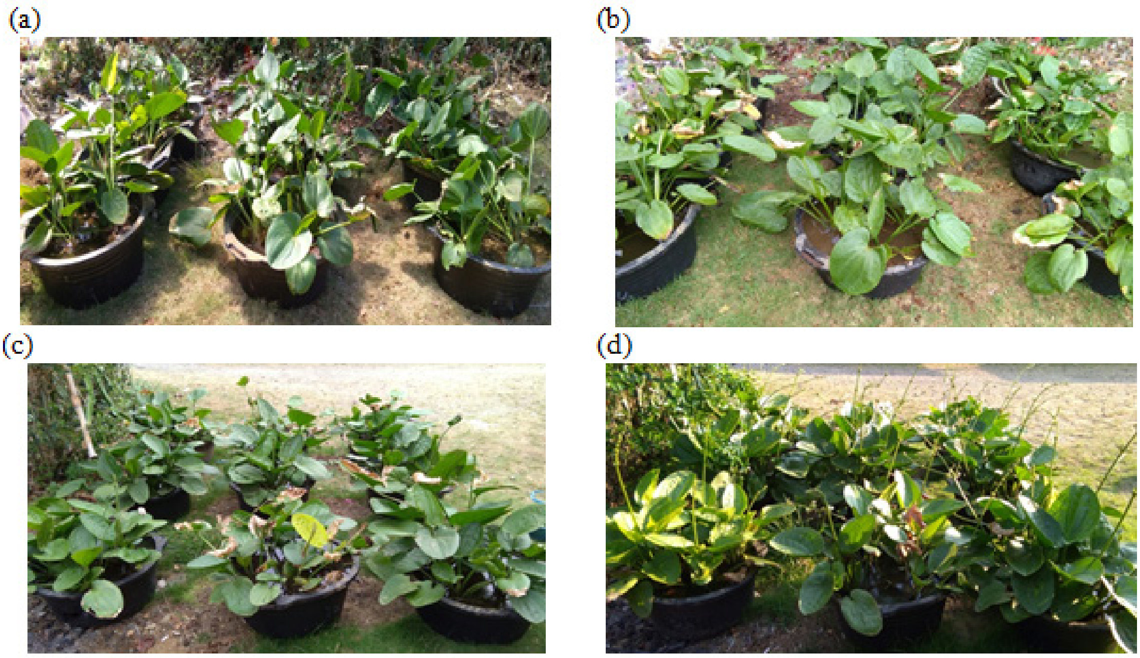

Figure 2. Growth of *E. palaefolius* during the phytoremediation
0 DAP (a), 7 DAP (b), 14 DAP (c), 21 DAP (d)

decreased at 21 DAP, which at the root became 0.52 mg/kg/day, on the stem 27.18 mg/kg/day and leaves 33.14 mg/kg/day. It can be seen that the length of contact time affects the rate of absorption of plants. This condition is also very influenced by the age of the plant during the phytoremediation process (Jin et al. 2006). In addition, several factors that affect plants in absorbing metals are including the number of roots, plant weight, temperature, growing media and the age of the plant itself. The longer plant life will affect the plant growth, size of roots, stems and leaves, provide more weight. So that the concentration of absorbing metals becomes larger and plant becomes able to accumulate high levels of Fe metal (Mangimbulude et al., 2009). This finding is also supported by the research by Sriprapat et al. (2011) and Prum et al. (2018) resulted that absorption of heavy metals in contaminated wastewater is strongly influenced by plant age and absorption time.

BioConcentration Factor (BCF) is said to be an indicator of the ability of plants to absorb heavy metals from the environment into plant tissues (Li & Yang, 2008). As seen in Figure 4, the BCF value is influenced by the contact time of the roots, stems, and leaves of *E. palaefolius* while absorbing Fe metal. The BCF value at the root has an optimum increase at 14 DAP from 1.41 ppm (0 DAP) to 53.77 ppm and decreasing at 21 DAP. The optimum BCF value of the stem occurred at 14 DAP by 3144.54 ppm then decreased at 21 DAP to 1214.3 ppm. In contrast to roots and stems, the optimum BCF value on leaves is at 7 DAP by 3279.28 ppm and decreased at 21 DAP to 1513.04 ppm. Decreasing BCF values can be used as an indication of a decrease in levels of Fe metal contamination in plant tissues (Arnot & Gobas, 2006).

Enrique & Cecchetti (2003) stated that BCF values > 1 ppm indicate the plants as heavy metal accumulators and if the BCF value is > 1000 ppm, it is said to be a good accumulator. Considering the results in Figure 4, the optimum BCF value of each root network is 53.77 ppm which indicates that it is a metal accumulator. While the stem and leaves considered as good accumulator due to the BCF value of 3144.54 ppm and 3279.28 ppm respectively. Looking at the BCF values of each tissue, it can be seen that the use of *E. palaefolius* is very appropriate to remediate the leachate in the Jatibarang landfill.

Based on the data obtained, it was proved that all parts of *E. palaefolius* such as roots, stems and leaves can accumulate Fe metal. Beneficial effect of this plant can improve the quality of leachate for the better.

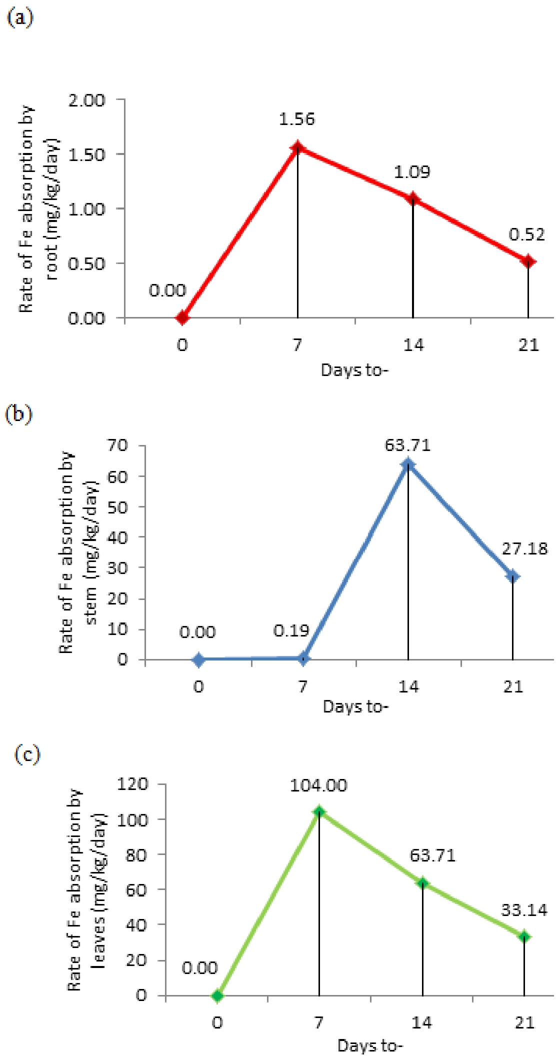

Figure 3. Fe absorption rate in the root (a), stem (b) leaves (c) of *E. palaefolius* during phytoremediation

CONCLUSION

E. palaefolius has potential as phytoremediation agent for leachate in Jatibarang Landfill. Contact time affects the accumulation of Fe. The highest accumulation occurred at 14 DAP in stems and leaves (892 and 892 mg/kg respectively).

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