

Bioaccumulation of lead (Pb) by the common water hyacinth *Eichhornia crassipes* (Mart.) Solms in Batujai Reservoir, Central Lombok Regency, Indonesia

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Abstract. The water pollution impacts on water quality degradation and the population of *E. crassipes* covered almost 30% in Batujai Reservoir area. Among pollutants, heavy metals are one that should be highlighted because they are non-biodegradable, accumulate in the environment, and has been considered as a vital threat to the human health via the food chain. *E. crassipes* is to be a promising candidate for pollutant removal because of rapid growth rate and extensive root system. The purpose of this research is to know the bioaccumulation of heavy metals by *E. crassipes* in Batujai Reservoir, Central Lombok Regency. The water hyacinth was maintained by the mesocosm approach at 5 sites in Batujai Reservoir. The results showed that the concentration of Pb in the water was higher among other heavy metals, it was ranged from 0.14 to 0.24 g mL⁻¹, and has exceeded the drinking-water quality standard of 0.03 g mL⁻¹ of the Government Regulation of Indonesia No. 82/2001 and 0.01 g mL⁻¹ recommended by WHO. The values of the bioaccumulation factor (BAF) Pb in the root of *E. crassipes* has increased at five sampling sites when exposure times were increased. The highest values of BAF Pb in *E. crassipes* was found in the fish cultivation area (S1) on the 6th week (42.11) and the lowest BAF Pb values in *E. crassipes* were found in inlet area (S3) on the 2nd week (19.74). The average value of BAF Pb by the root of *E. crassipes* in exposure time for 42 days on the five sampling sites in Batujai Reservoir was 33.83. Based on the BAF value, *E. crassipes* is a good bioaccumulator for Pb.

Key Words: bioaccumulation factor, heavy metals, mesocosm, water pollution, phytoremediation.

Introduction. The water pollution of the freshwater ecosystem is a serious environmental problem that needs attention from various parties. Soeprbowati et al (2016) reported that freshwater quality problem became a national problem such as sedimentation, pollution, eutrophication, and water quality degradation. These are due to the variety of pollutants that enter and accumulate into the aquatic environment. The pollutants can come from various sources, of which the main ones are: urbanization, high population growth, disposal of domestic waste, excessive use of pesticides and fertilizers in agriculture (Haseena et al 2017).

Among pollutants, heavy metals are very difficult to remove in aquatic ecosystems by self-purification (Nadmitov et al 2015; Harikumar & Nasir 2010). The heavy metals content in the aquatic ecosystem mostly comes from industrial waste, emissions from traffic activities, domestic waste, atmospheric deposition, and others (Wei & Yang 2010). Naturally, heavy metals source is from volcanic activity, weathering of rocks, and forest fires (Soeprbowati & Suedy 2011). WWAP (2017) reported that municipal wastewater consists of millions of tons of heavy metals, solvents, toxic sludge, and other wastes discharged into the water bodies every year and about 80% are not treated. In Indonesia, the problems of heavy metals pollution, such as lead (Pb), cadmium (Cd), chromium (Cr) and copper (Cu) often exceed Water Quality Standards for drinking water, agriculture (Hindarwati et al 2018), fisheries and animal husbandry (Soeprbowati et al 2017) and in a certain time it will potentially threaten human health and ecosystems via

the food chain (Eslami et al 2011). At low levels, some heavy metals are very important for enzymatic activity and biological processes. But heavy metals also become toxic at high concentrations (Kumolu-Jhonson et al 2010).

Therefore, bioremediation is one of the ways to remove contaminants from polluted environments. This technique uses biological mechanisms of microorganisms (bacteria, algae, fungi etc.) and several species of plants to remove harmful contaminants, especially heavy metals. There were many studies related to heavy metal bioremediation using microorganisms, such as *Bacillus* sp. (Guo et al 2010), *Aspergillus* sp. (Oladipo et al 2016), *Oscillatoria* (Miranda et al 2012), *Porphyridium cruentum* (Soeprbowati & Hariyati 2013), *Chaetoceros calcitrans*, *Chlorella pyrenoidosa*, *Arthrospira platensis* (Soeprbowati & Hariyati 2014, 2017) and several species of aquatic macrophytes such as water hyacinth (*Eichhornia* sp.) (Okunowo & Ogunkanmi 2010; Ajibade et al 2013), duckweed (*Lemna* sp.) (Singh et al 2012), and water lettuce (*Pistia* sp.) (Gupta et al 2012) has been used to remove heavy metals from wastewater. The plant species used in phytoremediation are biologically active plants and most suitable for removal of heavy metal ions and capable of heavy metals phytoaccumulation of soil and water (Mohanty et al 2010; Herniwanti et al 2013).

Eutrophication is a major problem in several lakes or reservoirs in Indonesia and the real impact of eutrophication is the abundance of *E. crassipes* (Soeprbowati & Suedy 2010). In this case, the growth and covering of *E. crassipes* in the Batujai Reservoir is almost 30% of the reservoir area (Firdaus 2011) and has a negative impact on the function as hydropower, drinking water, agricultural irrigation, fisheries, and tourism. However, *E. crassipes* is one of the macrophytes as a promising candidate for removing pollutants due to rapid growth and extensive roots (Kumari & Tripathi 2014; Olukanni & Kokumo 2013; Rezanian et al 2013) and passive phytoremediators with encouraging results (Nirmal et al 2008). According to Mohamed et al (2015) the heavy metals content had been reduced into <0.05 (Fe), <0.03 (Mn), and <0.005 (Zn) on day 4 with the *E. crassipes* treatment. Therefore, the purpose of this study was to determine the bioaccumulation of heavy metals by *E. crassipes* in the Batujai Reservoir, Central Lombok Regency-Indonesia.

Material and Method

Study area. This research was conducted in January-October 2018 at Batujai Reservoir of Central Lombok, Indonesia. There were 5 research sites which represented whole the waters of Batujai Reservoir. Determination of the sampling sites is at the edge of the reservoir and based on the waste stream from community activities and covering of *E. crassipes* (Figure 1).

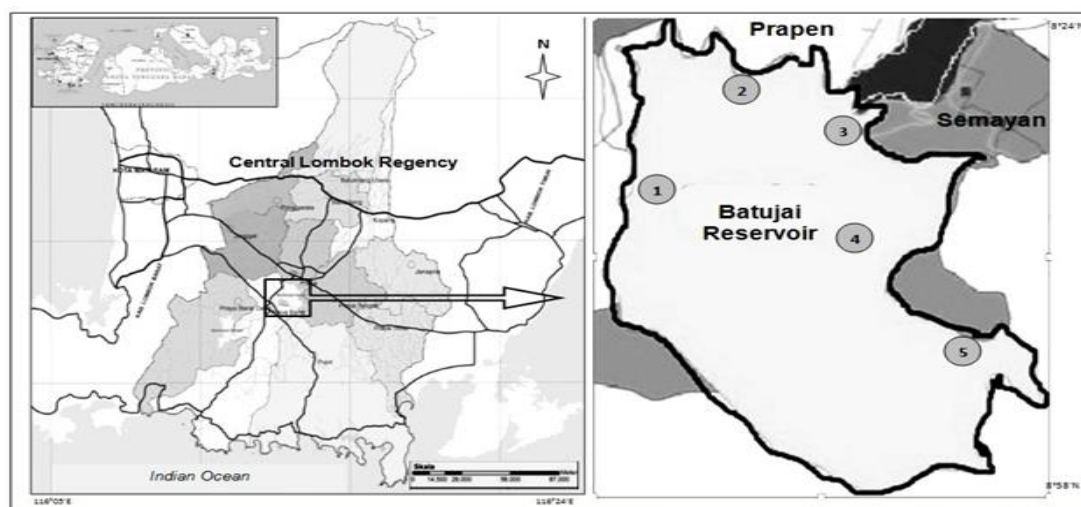


Figure 1. Location of sampling sites in Batujai Reservoir; site 1 (area of fish cultivation), site 2 (area of urban / settlement), site 3 (inlet area), site 4 (middle of the reservoir), site 5 (area of the agriculture).

Sample collection. The samples of *E. crassipes* were collected around the Batujai Reservoir and selected based on uniform morphology, the initial wet biomass averaged 135 g and the number of leaves of 7 sheets and then grown in the mesocosm 1x1 meter using a net and bamboo as its stake (Figure 2). The mesocosm approach is an experiment conducted in-situ and in natural conditions (Foekema 2013).



Figure 2. The 1 x 1 meter plot of *Eichhornia crassipes* sampling in Batujai Reservoir.

After 14 days of grown on the plot, the heavy metals concentration in the roots tissue of *E. crassipes* was analyzed. In general, most studies reported that higher levels of metals were accumulated more in roots compared to other tissues. The accumulation of heavy metals in *E. crassipes* increased linearly with the concentration of the solution in the order of leaves<stems<roots (Hasan et al 2007; Mane et al 2011). Analysis of heavy metals concentration in the roots tissue was done 3 times in 2 weeks time interval using atomic absorption spectrometry flame (AAS Flame) in The Analytical Chemistry Laboratory of Mathematics and Natural Sciences Faculty, Mataram University.

Data analysis. Bioaccumulation factor (BAF) is defined as the ratio of the steady-state metal ions concentrations in the plant and the concentration in the water which gives information about the ability of the plants to accumulate metal in their tissue. BAF is calculated by the following mathematics equation (Gobas et al 2009):

$$\text{BAF} = \frac{\text{Concentration of metal in the plant tissue (g mL}^{-1}\text{)}}{\text{Concentration of metal in the water (g mL}^{-1}\text{)}}$$

Results and Discussion

The concentration of heavy metal in the water. The study was limited to one type of heavy metal based on the highest concentration in water (pre-study). The result of the heavy metal analysis showed that the concentration of Pb was higher among other heavy metals, ranged between 0.14 and 0.24 g mL⁻¹. The concentration of Pb in the water of sampling sites in the Batujai Reservoir has exceeded the drinking-water quality standard of 0.03 g mL⁻¹ (Government Regulation (PP) No. 82/2001) and 0.01 g mL⁻¹ (WHO 2008).

The data presented in Figure 3 shows that S3 has the highest concentration of Pb in the water than other sites. This can be attributed to its location in the area near the Surabaya or Srigangga River as the largest inlet of the Batujai Reservoir with the rate of flow 3,461 m³/s. It allows pollutants especially Pb from urban community activities and some settlements to be wasted in large volumes along the Surabaya or Srigangga River.

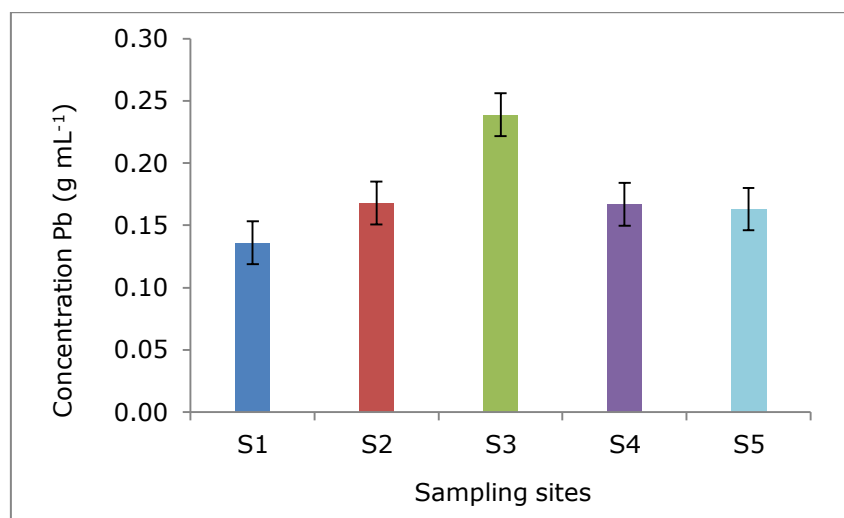


Figure 3. The concentration of lead (Pb) in the water at sampling sites.

Most heavy metals are initially absorbed by suspended particles in water through a series of processes naturally and then deposited into the sediment (Suresh et al 2012). However, due to certain disturbances, it is still possible for heavy metals to be released back to water, which can cause serious effects on the ecological system (Varol & Sen 2012). The heavy metals e.g. lead (Pb) occurs naturally in earth surface and released during the weathering process. However, human activities such as disposal of industrial and domestic wastewater, car emissions, Pb acid batteries wastes, paints and treated woods and the use of various organic and mineral fertilizers are the main sources of Pb contamination (Srivastava et al 2015; Steinnes 2013) and it is used from several industrial products such as batteries, cables, pigments, pipes and ceramics, gasoline, tobacco, solder and steel products, food packaging glasses and pesticides (Tangahu et al 2011).

The concentration of heavy metal in the *E. crassipes*. Pollution of Pb in the water can affect the existence of biota life through the absorption process by plant tissue. Through the uptake of water contaminated with Pb will enter the plant and accumulate in the plant tissue because it is not metabolized (Pezzarossa et al 2011). The result of the analysis of Pb concentration in the root tissue of *E. crassipes* every 14-day interval can be seen in Figure 4.

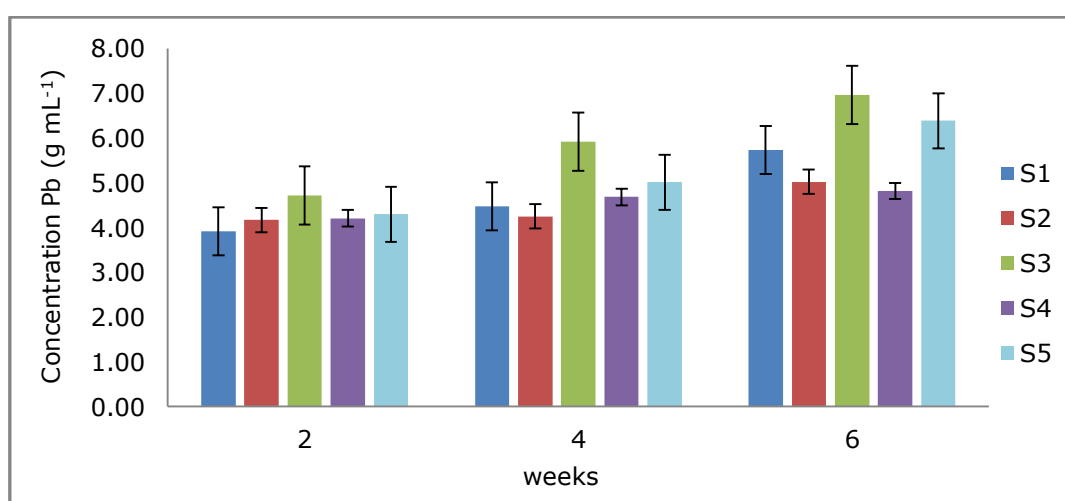


Figure 4. Concentration lead (Pb) by the root of *Eichhornia crassipes* at the sampling sites.

The ability to absorb metal contaminants from soil or water occurs through the roots and then accumulates and transplants to other plant tissues called phytoextraction, also known as phytoaccumulation, phytoabsorption or phytosequestration (Ali et al 2013). *E. crassipes*) has been widely used for heavy metal phyto remediation in constructed wetlands (Liao & Chang 2004). This is a fast-growing floating plant with more biomass production, and the root system spreads as the absorption of pollutants is relatively higher. Many researchers report the main way in the mechanism of removal of heavy metals in aquatic plants was heavy metal uptake by the roots of *E. crassipes* (Zheng et al 2016; Li et al 2016). Pillai & Tharayil (2017) reported water hyacinth has a tremendous potential to reduce the maximum amount of lead within 15-days under the electrically stimulated condition and maximum concentration of Pb was attained by roots.

The high Pb concentrations in the water damage barrier function of plasmalemma so Pb gets into the cells in large numbers (Sharma & Dubey 2005). The plants take up metals by absorption and translocation which take place by exchange of cations in the cell wall and the accumulation of heavy metals by plant tissue by absorption the anionic in the cell walls. This is the reason that wetland plants can accumulate high magnitude of heavy metals in plant parts compared to the surrounding environment (Lu et al 2004).

Bioaccumulation factor (BAF) Pb by the root of *E. crassipes*. Bioaccumulation is an absorption process of the chemical compound from the environment by the organism through respiratory surface and dietary uptake, and chemically elimination process through the respiratory exchange, fecal egestion, chemical parent substance biotransformation and increasing of tissue volume (Arnot & Gobas 2006). The ability of plants to accumulate metals from water can be estimated using BAF and that is an indicator of the capacity of heavy metal accumulation by plant species (Ahmad et al 2016). The result of the calculation of Pb accumulation in the water bodies by the root of *E. crassipes* can be seen in Figure 5.

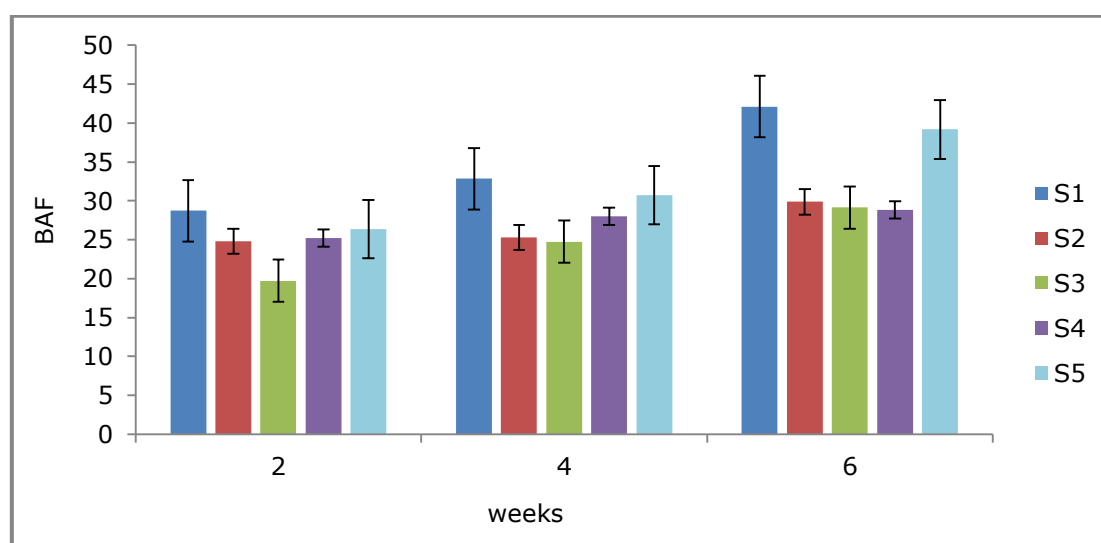


Figure 5. Bioaccumulation factor (BAF) of Pb by the root of *Eichhornia crassipes*.

Figure 5 shows that the values of BAF Pb by the root of *E. crassipes* has increased at five sampling sites when exposure times were increased to 6>4>2 weeks. On the 2nd week, BAF Pb values by water hyacinth at S1>S5>S4>S2>S3 were 28.75, 26.35, 25.19, 24.79, 19.74 (dry weight), respectively and the average of BAF values was 24.96. Comparing with other research, Seoprobowati & Hariyati (2014) reported that BCF of Pb by *C. calcitrans* in the 9th day was low, but after 14 days the BCF of Pb was higher than others metals.

On the 4th week, values of BAF Pb by water hyacinth at S1>S5>S4>S2>S3 were 32.85, 30.73, 28.04, 25.29, 24.74 (dry weight), respectively and the average of BAF values was 28.33. While on the 6th week, BAF Pb values by *E. crassipes* at S1>S5>S2>S3>S4 were 42.11, 39.17, 29.88, 29.14, 28.83 (dry weight), respectively

and the average of BAF values was 33.82. In general, the highest values of BAF Pb in *E. crassipes* was found in the fish cultivation area (S1) on the 6th week to 42.11 and the lowest BAF Pb values in *E. crassipes* were found in inlet area (S3) on 2nd week to 19.74.

The average value of BAF Pb by the root of *E. crassipes* at all sampling sites was more than 1. This value proves that *E. crassipes* tends to absorb and accumulate Pb primarily at the root and indicate that this plant is a good Pb accumulator. Zayed et al (1998) stated that plants are able to accumulate heavy metals up to $>1,000 \text{ mg kg}^{-1}$ are known as hyperaccumulators. Whereas if the value of BAF >1 is known as plant accumulator (Baker 1981). An efficient Pb accumulation mechanism in *E. crassipes* roots could represent a new and interesting phenomenon for the establishment of phytoremediation strategies, in which higher levels of the contaminant remain tightly attached to plant tissues.

The interesting result of this study is that the Pb concentration in water and in the root of *E. crassipes* was higher but the values of BAF were lower and contrary. In this case, the BAF values are inversely proportional to the concentration of Pb in the water and the root of *E. crassipes*. It seems to depend on the distribution of the Pb concentration values in the water to *E. crassipes*. In metal hyperaccumulation, the biomass production level depends on the concentration of the metals and duration of exposure. In general, bioaccumulation of Pb by plants is affected by many factors such as variations in plant species, the growth stage of the plants and element characteristics control absorption, translocation of Pb, and physiological adaptations control toxic metal accumulations by sequestering metals in the roots (Nouri et al 2009).

Dry and fresh weights are important parameters used to determine toxicity symptoms of *E. crassipes* exposed to Pb. Duman & Koca (2014) reported that exposure to heavy metals at high levels reduces the biomass of the plant and inhibits plant growth. The high concentration of Pb can inhibit photosynthesis and enzyme activity, damages membrane structures, and disturbs the balance of water and mineral nutrients. Therefore, all of these factors indicate toxicity symptoms including stunted growth and chlorosis in plants (Sharma & Dubey 2005).

E. crassipes also does tolerance and detoxification by accumulating heavy metals in vacuoles in its cell structure. Vakuola is a safe place to accumulate metals because vacuoles are far from metabolic processes (Hall 2002). Tolerance to heavy metals in plants can be achieved by the accumulation of objectives into tissues that favor metal uptake such as those used in non-functional parts as indicators of tolerance under adverse influence conditions such as wind, precipitation, temperature fluctuations etc. Which indicate the greater accumulated capabilities (Mane et al 2010).

Conclusions. Pb concentration in the Batujai Reservoir ranged between 0.14 and 0.24 g mL⁻¹ and has exceeded the drinking-water quality standard of 0.03 g mL⁻¹ of the Government Regulation of Indonesia No. 82/2001 and 0.01 g mL⁻¹ recommended by WHO. The values of the bioaccumulation factor (BAF) of Pb by root of *E. crassipes* increased at five sampling sites when exposure times were increased. The highest values of BAF Pb in *E. crassipes* was found in the fish cultivation area (S1) on the 6th week which was 42.11 and the lowest BAF Pb values in *E. crassipes* was found in inlet area (S3) on the 2nd week which was 19.74. The average value of BAF Pb by the root of *E. crassipes* in exposure time for 42 days at five sampling sites in Batujai Reservoir was 33.83. According to the results of the present study, *E. crassipes* root is a good Pb accumulator from water bodies.

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