RESEARCH COMMUNICATION

The aeration effect in pilot reed bed to phytoremediate water containing Lead (Pb)

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Abstract

A pilot reed bed study was conducted with the aid of aeration to remove lead (Pb) contaminated water using *Scirpus grossus* L. f. The plants were grown in sand medium in pilot-scale reed beds, and exposed to water containing Pb in a various concentration (10, 30 and 50 mg/L) with aeration rate of 2 L/min. The samples were taken on day-1, day-14, day-28, day-42, day-70 and day-98. The results showed that Pb concentration in water decreased 74% on day-7, 80% on day-14, 99% on day-28 and reach 100% on day-48 for treatment 10 mg/L. Pb concentration decreased 91% on day-7, 93% on day-14 and then on the day-28 the reduction reached 99% for treatment of 30 mg/L. For Pb treatment of 50 mg/L, the reduction reached 92% on day-7, 96% on day-14, and 99% on day-28. The sand adsorbed Pb up to 7.91×10^{-4} mg/kg for 10 mg/L, 1.07×10^{-3} mg/kg for 30 mg/L and 2.41×10^{-3} mg/kg for 50 mg/L. Pb uptake by plant was 2286 mg/kg on day-98, 4174 mg/L on day-28 and 8297 mg/kg on day-14 for 10, 30 and 50 mg/L, respectively. The highest Bioaccumulation Concentration (BC) was 10618 for 10 mg/L on day-28, 81311 for 30 mg/L and 81467 for 50 mg/L both on day-42, with the Translocation Factor (TF) related to the same day of these BC were 0.13, 0.24, and 0.35 respectively. The highest TF value for 10 mg/L were 0.7 on day-98, 0.38 for 30 mg/L on day-70 and 0.59 for 50 mg/L on day-14.

Keywords: aeration; bioaccumulation; lead; phytoremediation; *Scirpus grossus* reed bed

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Introduction

Phytoremediation becomes a popular method and has been identified as an effective and affordable technological solution for extraction or removal of inactive metals and metal pollutants from contaminated soil and water (Cho-Ruk *et al.,* 2006). Compared to other conventional methods, phytoremediation technology is environmental friendly, low-cost, aesthetically pleasing and less disrupting, effective in reducing contaminant and applicable for wide range of contaminant (Salido, *et al.,* 2003). In this method, plants, particularly those with exceptional metal-accumulating capacity have been known as hyperaccumulator plants (Cho-Ruk *et al.,* 2006).

According to the list of the top ten priority hazardous substances (ATSDR, 2011), lead (Pb), a heavy metal, is on the second place. Due to the widest range of Lead (Pb) sources, this metal also becomes one of the most toxic metals that can be biologically accumulated and concentrated (Sharma and Dubey, 2005). Inorganic Pb is harmful to the nervous system because it can act as an inhibitor enzyme. Pb can enter the human body through drinking water, food or air (Sharma and Dubey, 2005) through its ionic form which is the most toxic.

Reed bed system is a technology to treat wastewater, which is used to activate microbial processes that will stimulate the natural breakdown of polluting compounds in a specific waste water situation. This kind of treatment is possible due to the special characteristics of wetland plants, such as reeds, which can transfer substantial amounts of atmospheric oxygen through their root systems encouraging an extraordinary quantity and species diversity of micro-organisms to flourish around their roots (Ecotechnologies International, 2011). A reed bed is a channel that is filled with gravel and planted with macrophytes *i.e.* reeds, rushes and used to treat wastewater. Inlet and outlet pipes are positioned below the gravel surface, so that the water always remains below the gravel surface, thus excluding human exposure to the wastewater, mosquito breeding and unpleasant odors (Lismore City Council, 2004).

To evaluate the efficiency of plants used to accumulate heavy metals for phytoremediation, values of bioaccumulation coefficient (BC) and translocation factor (TF) can be calculated. These parameters represent the capability of the plant to absorb, to transport and to store contaminants in the above-ground part of plant (Haque *et al.,* 2008). It is known that hyperaccumulator plants can 10 - 500 times more than non-hyperaccumulator plants (Rotkittikhun *et al.,* 2006). BC is used to evaluate metal accumulation efficiency in the plant, however, TF is related to the translocation ability of the plant and also, it is the ability to transfer heavy metals from root to above-ground parts (Liu, *et al.,* 2009). In different plant, the metal translocation process is an important factor to determine the metal distribution inside the tissues (Singh *et al.,* 2010).

Scirpus grossus L. f. (Cyperaceae) is used in this study due to its potential consideration as a hyperaccumulator plant as shown in our previous study of Pb phytotoxicity test (Tangahu *et al.,* 2013b). This plant has fibrous roots in white to brown color, triangular and solid stems, more than 2 m long leaves, with bisexual flowers grouped together (Weed Science Society of America, 2011). It is a perennial tropical aquatic plant, the common names are *giant bulrush*, *greater club-rush* and *rumput menderong* (Malaysia), *mensiang*, and *walingi* (Indonesia). This plant is also widely used in phytoremediation or in wetland to treat domestic wastewater (Jinadasa, *et al.,* 2006a; Jinadasa, *et al.,* 2006b; Jinadasa, *et al.,* 2008). In our previous study showed that *S. grossus* can phytoremediate Pb-contained water without aeration (Tangahu *et al.,* 2013a) by its accumulation inside the plant tissues. However in this study, aeration is showed to enhance the performance of phytoremediation process.

Table 1. Bioaccumulation Coefficient (BC) and Translocation Factor (TF)

Observation	Treatment					
	10 mg/L Pb		30 mg/L Pb		50 mg/L Pb	
	BC	TF	BC	TF	BC	TF
Day-1	125.31	0.30	49.13	0.25	28.18	0.25
Day-7	555.39	0.31	712.00	0.26	1237.42	0.53
Day-14	809.23	0.33	1193.50	0.27	4231.10	0.59
Day-28	10608.05	0.14	14513.82	0.33	11455.64	0.20
Day-42	N/A	0.20	81311.38	0.24	81467.36	0.35
Day-70	N/A	0.13	N/A	0.38	N/A	0.06
Day-98	N/A	0.70	N/A	0.24	N/A	0.21

N/A= no Pb detected in solution medium

Materials and Methods

A pilot reed bed in a single exposure system using lead as the contaminant was conducted with aeration supply of 2 L/min flow rate using an air compressor pump (Orimas HP2, Malaysia). The contaminant concentrations used were 0 (control), 10, 30, and 50 mg/L using $Pb(NO_3)_2$ (R & M chemicals, U.S.) diluted in tap water. The second generation and same age plants with similar height of around 80 cm were selected to undergo this pilot study. The plants were grown in batch tanks (L180 x W90 x H90cm) in a bed of inert granular substrate (coarse gravel, fine gravel and sand). Ratio of plant number and total mass contaminant which was used in this reed bed tank was 0.002.

The phytoremediation response was observed with the wet and dry weight of plant tissues (root, stem and leaf), Pb concentration in water, sand and plant tissue. The observation was starting on day-0 for water and on day-1 for sand and plant tissue, continuing on day-7, day-14, day-28, day-42, day-70 and day-98.

Results and Discussion

The plant wet weight increased up to day-14 for treatment 0 and 30 mg/L and decreased the day after. For treatment 10 and 50 mg/L, wet weight increased up to day-28 and then decreased the day after. The dry weight measurement also showed the same trends between all treatments.

As shown in Fig. 1, Pb concentration in water decreased starting from the day-7 and became 0 mg/L on day-42 for all treatment. For treatment of 10 mg/L, Pb concentration decreased by 74% on day-7, and become 80% on day-14, 99% on day-28 then reach 100% on day-48. For the treatment of 30 mg/L, Pb concentration decreased by 91%

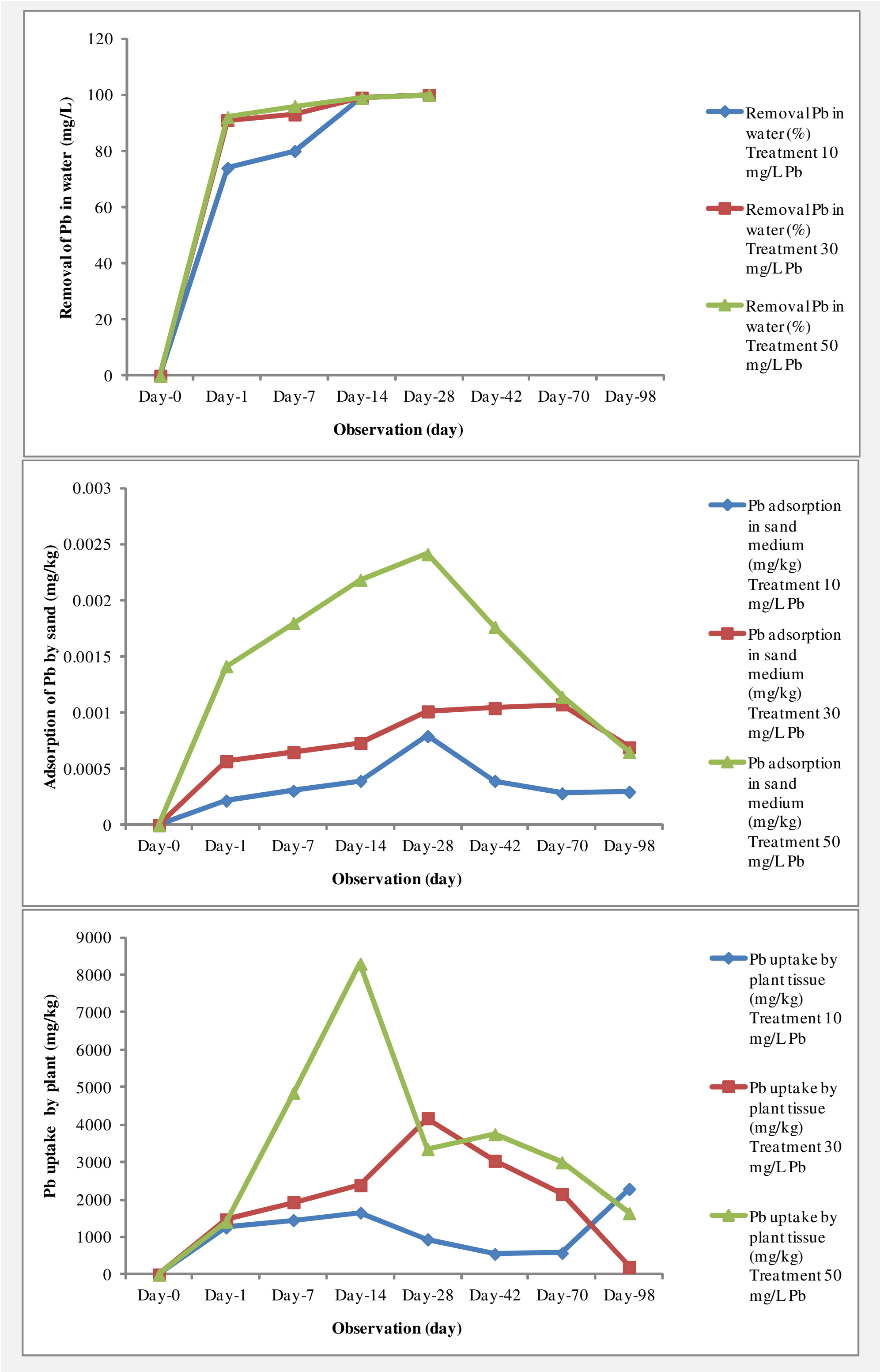

Fig. 1. Pb removal in water, Pb adsorption by sand and Pb uptake by plant

on day-7, the reduction became 93% on day-14 and then on the day-28, reduction reach 99%. On treatment 50 mg/L, reduction reach 92% on day-7 and become 96% on day-14, then reach 99% on day-28.

Pb absorbed in sand medium was starting on the day-1 and increased on day after. The adsorption was highest on the day-28 for treatment 10 mg/L and 50 mg/L and decreased until the end of observation. For treatment 30 mg/L, the adsorption was stable from day-14 to day-42 and decreased on day after. The highest Pb adsorption was 7.91×10^{-4} mg/kg for treatment 10 mg/L, for treatment 30 mg/L was reach 1.07×10^{-3} mg/kg and 2.41×10^{-3} mg/kg for treatment 50 mg/L (Fig. 1).

It is also shown on Fig. 1, Pb concentration in *S. grossus* tissues at treatment 10 mg/L, increased up to day-14 and started to decrease the day after, but became higher at the end of observation on day-98. For treatment 30 and 50 mg/L, Pb concentration increased up to the highest on day-28 and day-14, respectively, and then decreased the day after. The highest Pb uptakes were 2286 mg/kg, 4174 mg/L and 8297 mg/kg for treatment 10, 30 and 50 mg/L, respectively. Pb concentration in root was higher than upper side of the plant tissue (shoot and leaf) for all treatments. This trend was also found on the several studies of Pb phytoremediation by *Potamogeton natans* (Fritioff and Greger, 2006), Siam weed *Chromolaena odorata* (L.) King & Robinson (Tanhan *et al.,* 2007), *Phragmites australis* (Baldantoni *et al.,* 2009), *Brassica juncea* (Liu *et al.,* 2000; Meyers *et al.,* 2008). For treatment 30 and 50 mg/L, Pb concentrations in roots were found to reach level indicative hyperaccumulation, which the concentration are >1000 mg/kg for Pb, compared to a study done by Haque, *et al.,* (2008). On treatment 10 mg/L, Pb concentration >1000 mg/kg reached on day-7 and day-98.

Table 1 shows the Bioaccumulation Coefficient (BC) and Translocation Factor (TF). The BC value for all treatment were >1 that was properties of hyperaccumulator plant. The TF values in all treatment were fluctuated; it was caused by the difference of Pb concentration in root and shoot depending on the biochemical and physiological factors contributing to heavy metal accumulation and distribution in the upper vegetative parts (Singh *et al.*, 2010).

Conclusions

The study of aeration effect on phytoremediation of Pb showed that for treatment 10 mg/L, the concentration of Pb in water decreased 100% on day-48. On treatment of 30 mg/L, the Pb concentration decreased 99% on day-28 and the reduction on treatment 50 mg/L reached 99% on day-28. The highest concentration of Pb adsorption by sand was 7.91×10^{-4} mg/kg for treatment 10 mg/L, for treatment 30 mg/L the highest Pb adsorption was reach 1.07×10^{-3} mg/kg and 2.41×10^{-3} mg/kg for treatment 50 mg/L. The highest Pb uptake by plant reach 2286 mg/kg on day-98, 4174 mg/L 90 day-28 and 8297 mg/kg on day-14 for treatment 10, 30 and 50 mg/L respectively. BC values for all treatment are >1, the highest BC were 10618 for treatment 10 mg/L, 81311 for treatment 30 mg/L and 27647 for treatment 50 mg/L. TF value for all treatment were <1, it shows that the transport of Pb from lower part to upper part were low because of the low concentration were exposed. The highest TF value for 10 mg/L were 0.7 on the day-98, 0.38 for 30 mg/L on day-70 and 0.59 for 50 mg/L on day-14.

Competing interests

The authors declare that they have no competing interests.

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