Enhancement of Caloric Value of Scirpus Grossus After Phytotoxicity Test of Lead (Pb)

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Abstract—Phytoremediation is one of the methods to clean up the environment from heavy metal contamination. This method has some advantages such as aesthetically pleasing, less disruptive than current techniques, the effectiveness in contaminant reduction, low cost, applicable for wide range of contaminants and an environmental friendly method. However, the most concern is about the amount of produced plant biomass, because this can create another problem on contamination that have to be solved. There are many kinds of plant that could act as a hyperaccumulator and play the important role in phytoremediation process. Several studies has been conducted to use the plant biomass as phytoremediation side product as bioenergy alternative in order to get advantage from the limitation factor of this method. This study aims to get information about the enhancement of caloric value of Scirpus grossus after it is being used in phytotoxicity test of Lead (Pb). The phytotoxicity test was conducted in a single exposure system, by diluting analytical grade of iron salt Pb(NO₃)₂ in deionized water. The concentration of Pb was varied in 0 mg/L (control), 100 mg/L, 200 mg/L, 400 mg/L, and 800 mg/L, and all treatment were done in triplicate. The result of caloric value measurement by using Bomb Calorimeter shows the increase as the Pb concentration increased up to 400 mg/L Pb exposure, and started decreasing by the increase of concentration of Pb exposure (600 and 800 mg/L). The caloric value for the lead exposure of 100, 400, 600 and 800 mg/L was respective 10,200, 14,400, 8,000 and 9,600 J/g. The decreased in 600 and 800 mg/L were expected since in both exposures, all plant were withered. However, all values were still higher than that of plant in control pail (without contaminant) of 6,300 J/g. This result shows that the use of plant as contaminant uptake in phytoremediation can enhance the caloric value of the plant. And this will over rule the limitation of large production of plant biomass whereby it can be used as bioenergy alternative according to the enhancement of its caloric value.

Keywords: caloric value, hyperaccumulator plant, phytotoxicity, phytoremediation

I. INTRODUCTION

Heavy metals are among the most toxic contaminants in the environment. Several methods are already used to clean up the environment from these kinds of contaminants, but most of them are costly and difficult to get optimum results. Currently, phytoremediation is an effective and affordable technological solution used to extract or remove inactive metals and metal pollutants from contaminated soil and water. This technology is environmental friendly and potentially cost-effective. Phytoremediation is defined as an emerging technology using selected plants to clean up the contaminated-environment from hazardous contaminant to improve the environment quality, both organics and inorganics contaminant through phytoremediation technology. For organics, it involves phytostabilization, rhizodegradation, rhizofiltration, phytodegradation and phytovolatilization. Some mechanisms are related to organic contaminant which are not able to be absorbed into the plant tissue. For inorganics, mechanisms that involve are phytostabilization, rhizofiltration, phytovolatilization and phytovolatilization. Some essential processes involve in phytoremediation technology (Prasad et. al, 2003; U. S. Environmental Protection Agency, 2000) are phytostabilization and phytoextraction for inorganic contaminants. The root plants exudates to stabilize, demobilize and bind the contaminants in the soil matrix, thereby reducing their bioavailability. These all are called as phytostabilization process. Certain plant species have used to immobilize contaminants in the soil and ground water through absorption and accumulation by roots, adsorption onto roots, or precipitation within the root zone. This process is for organics and metals contaminants in soils, sediments, and sludges medium.

Specific plant species can absorb and hyperaccumulate metal contaminants and/ or excess nutrients in harvestable root and shoot tissue, from the grown substrate through phytoextraction process. Plant roots take up metal contaminants and/ or excess nutrients from grown substrates through rhizofiltration process. The adsorption or precipitation onto plant roots or absorption into the roots of contaminants that are in solution surrounding the root zone can also occur. According to Sinha et. al. (2007), the plants act both as ‘accumulators’, and ‘excluders’. Accumulators survive despite concentrating contaminants in their aerial tissues. They biodegrade or biotransform the contaminants into inert forms in their tissues. The excluders restrict contaminant uptake into their biomass.

Phytoremediation techniques may also be more publicly acceptable, aesthetically pleasing, and less disruptive than the
current techniques of physical and chemical processes (Salido et al., 2003). Advantages of this technology are its effectiveness in contaminant reduction, low cost, applicable for wide range of contaminants and in overall it is an environmental friendly method. The major advantages of the heavy metals adsorption technology by biomass are its effectiveness in reducing the concentration of heavy metal ions to very low levels and the use of inexpensive biosorbent materials (Rakhshaee et al., 2009). Phytoremediation as possibly the cleanest and cheapest technology can be employed in the remediation of selected hazardous sites (U. S. Environmental Protection Agency, 2000). It encompasses a number of different methods that can lead to contaminant degradation (Rodriguez et al., 2005). Phytoremediation is a low-cost option and inexpensive approach for remediating environmental media, particularly suited to large sites that have relatively low levels of contamination (Ginneken et al., 2007).

On the other hand, there are certain limitations to phytoremediation system. Among them are time consuming method, the amount of generated biomass, root depth, soil chemistry, and level of contamination, age of plant, contaminant concentration, impacts of contaminated vegetation, and climatic condition.

Phytoremediation can be a time consuming process, and it may take at least several growing seasons to cleanup a site. The intermediates formed from those organic and inorganic contaminants may be cytotoxic to plants (Mwegoha, 2008). Phytoremediation is also limited by the growth rate of the plants. More time may be required to phytoremediate a site as compared with other more traditional cleanup technologies. Excavation and disposal or incineration takes weeks to months to accomplish, while phytoextraction or degradation may need several years. Therefore, for sites that pose acute risks for human and other ecological receptors, phytoremediation may not be the remediation technique of choice (U. S. Environmental Protection Agency, 2000; Mwegoha, 2008). Phytoremediation might be best suited for remote areas where human contact is limited or where soil contamination does not require an immediate response (Salido et al., 2003).

Under the best climatic conditions, with irrigation, and fertilization, total biomass productivities can approach 100 t/ha/y. One of the unresolved issues is the trade-off between toxic element accumulation and productivity. In practice, a maximum harvestable biomass yield of 10 to 20 t/ha/y would be likely, particularly for heavy metal accumulating plants. These values for productivity of biomass and heavy metal content would limit annual toxic element removal capacity to about 10 to 400 kg/ha/y, depending on the pollutant, plant species, climatic and other factors. For a target soil depth of 30 cm (4,000 t/ha), this amounts to an annual reduction from 2.5 to 100 ppm in soil toxic element levels. This is often an acceptable rate of contaminant removal, allowing site remediation over a few years to a couple of decades, particularly where the concentration of the contaminant can be lowered sufficiently to meet regulatory criteria. These values for productivity of biomass and heavy metal content would limit annual toxic element removal capacity to between 10 to 400 kg/ha/y, depending on the pollutant, plant species, climatic and other factors (U. S. Department of Energy, 1994). In order to overcome this limitation of phytoremediation, biomass production at the end of phytoremediation process can be used as a bioenergy alternative.

Caloric value refers to combustion heat of specific dry mass. Caloric value has been believed as a coefficient index when biomass is converted into equivalent energy. However, Verduin (1972) pointed out that the calories of plants measured do not make sense of the energy available to growth or reproduction, and he oppugned establishing connections between stressful environments with higher energy content. Other researchers also indicated the limits of applying caloric value in the explanation of ecosystem processes with certain case studies (Hickman and Pitelka, 1975). Although there are some controversies about caloric value, it is believed to be a useful tool to study energy transfer and flow efficiency (Lin and Chao, 2008).

This study was conducted initially to determine the phytotoxicity of lead (Pb) to Scirpus grossus, to get the optimum concentration which can be absorb by its plant and finally to determine the influence of the lead concentration in plant to the enhancement of caloric value of the plant. However, this paper will concentrate on the results of the caloric value enhancement.

II. MATERIALS AND METHOD

A. Phytotoxicity test

The test was conducted on a single exposure system by using several concentration of lead as the contaminant (US-EPA 1996). The variation of lead concentration are 0 mg/L (control), 100, 200, 400, 600 and 800 mg/L (represented by C0, C100, C200, C400, C600, C800) by using Pb(NO3)2; diluted in deionized water. All treatment were done in triplicated. The plants are grown in a bed of inert granular substrate (sand or pea gravel) which had been sieved (0.5 cm) to remove coarse fragments and to get the same size (OECD Guideline for Testing of Chemicals, 1984; Hinchman et al., 1995). Nine plants with the same size were planted in each treatment so that enough samples for the experimental run can be obtained.

The observation was performed during 95 days and the sampling time were on day-1, 7, 21, 35, 65 and 95. The analyzed parameters were Pb concentration inside the plant, and inside the medium of water and sand. The medium (water and sand) temperature, pH, DO and ORP were also monitored.

B. Determination of caloric value

Caloric value of plants were determined by using IKA Bomb Calorimeter C 5000 (Germany). One plant was taken from each tank on the last day of exposure. The plants were all dried and milled into fined powder. Then, the caloric value of the plants were determined using the bomb calorimeter.

III. RESULTS AND DISCUSSION

A. Pb exposure on Scirpus grossus

The result of plant responses shows that during 95 days observation there is no plant withered on Pb concentration up to 200 mg/L. The responses of plant withered was started to be observed on day-7 for Pb concentration of 400 mg/L and higher. The 100% plant withered was observed on Pb concentrations of 600 and 800 mg/L. These occured on day-65 and day-95 respectively. It could be concluded that, the highest Pb concentration that can be adapted by plant is up to 400 mg/L, who is the same concentration used by Qu et al. (2003) which did study on Pb uptake by root of four Turfgrass species.
in hydroponic cultures. Figure 1 shows the result of Scirpus grossus withered responses on phytotoxicity test of Pb.

![Figure 1. Respons of plant withered during observation](image)

**B. Pb uptake by Scirpus grossus**

The result of Pb uptake by Scirpus grossus as shown in Figure 2 was increasing with the time. Similar trends shown by plant in the higher Pb concentration, even though the plants were withered by Pb exposure as on 600 and 800 mg/L. Some studies on Pb uptake by plant shows that the accumulation of Pb ions in plants was correlated with the stimulation of lipoxygenase activity which was responsible for lipid degradation and biosynthesis of jasmonates. The enhancement of jasmonic acid accumulation in response to heavy metals seems that it involved in plant defense reactions against the abiotic stress (Piotrowska et al., 2009). A variety of metal ions, including Pb²⁺ have the ability to induce phytochelatins (PCs) synthesis in plants, complex with the metals themselves and thus detoxifying them (Brooks, 1998). These findings could explain why high concentration of Pb exposure on plant did not inhibit their growth.

![Figure 2. Pb concentration in plant](image)

**C. Caloric value of the plant**

The caloric value of plant after being used in the phytotoxicity test was analyzed, and the result shows that the caloric value of plant has increased with increasing Pb concentration up to 400 mg/L, and decreased on 600 and 800 mg/L of Pb concentration (Figure 3). The decreased caloric values of 600 and 800 mg/L exposure was due to withered plants. In both tanks, all plants were fully withered showing that they could not survive in these concentration. Figure 3 depicts that the caloric value of plant sample reached 14,400 J/g, twice higher than the initial caloric value from the control tank (with no Pb exposure). According to Lin and Chao (2008), several researchers mentioned that caloric value in plant parts are affection by environmental factors. It was found that plants growing in high light environment had higher caloric values. Also, the change of energy transfer and storage of plant parts have induced by the season, which consequently leads to variations in caloric value of plants. This explains the cause of the caloric value varied between each tank. The result also shows that caloric values of lower part of plant are less than its upper part.

![Figure 3. Caloric value of plant parts after phytotoxicity test in various Pb concentrations](image)

**IV. CONCLUSIONS**

The result of caloric value measurement shows the increase in which it increased when the Pb concentration in plant tissue increased, and decreasing by the increase of concentration of Pb exposure (600 and 800 mg/L). The caloric value in Pb exposure of 100 mg/L is 10,200 J/g and reach of 14,400 J/g in Pb exposure of 400 mg/L. The decreasing caloric value on Pb exposure of 600 and 800 mg/L was caused by the plant withered in this concentration. However, the caloric values reached as 8,000 and 9,600 J/g respectively for the two concentrations were still higher than caloric value of control tank as 6,300 J/g.

The findings prove that the use of plant as contaminant uptake in phytoremediation can enhance the caloric value of plant and hence the generated biomass at the end of phytoremediation process can be used as alternative bioenergy instead of being the burden for the remediation technology.

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