PHYTOREMEDIATION OF HEAVY METAL CONTAMINATED WASTES FROM GOLD MINE USING *PTERIS VITTATA*

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Abstract

Mining activities in the Philippines pose various environmental impacts and threaten the surrounding ecosystem especially from the release of toxic heavy metals. The green technology, phytoremediation has been shown to remove heavy metals from tailings material and therefore could be viable solutions to the problem. In this study, phytoremediation of heavy metal (Arsenic) contaminated wastes: mine tailings and adsorbents used for the treatment of wastewater from gold mine processing plant was conducted using arsenic hyperaccumulator, *Pteris vittata* (Chines e Brake fern). Translocation factor and % uptake of As by ferns were measured for 1st period and 5th period. Plant growth in tailings mixture plant box and control soil were also determined. According to results, arsenic from mine tailings mixture was effectively removed by *Pteris vittata*. Plants grow well in mine tailings mixture plant box without showing phytotoxicity.

Key words: Phytoremediation, mine wastes, translocation factor, ICP-OES

Introduction

Mining for precious metals, coal, and other commodities forms an important part of the economies many countries. Mining activities affect health of miners through the methods of extraction; contaminating local water sources as well as having harmful effects on the environment such as reducing biodiversity or fish populations (Jadia 2009; WHO 2008).

The Philippines is considered as one of the highly mineralized countries per unit area of land. Mining activities are concentrated in Baguio Mining District, Benguet, Luzon where metallic reserves such as gold, silver, and copper are the largest in the nation (Briones 1987). Gold is the third most important commodity in the Philippine export trade done by both small-scale and large-scale industry. The small-scale gold processing site for this research discharged mining wastes (solid wastes- tailings and liquid waste-effluents). Mine tailings are stabilized in the tailings pond. Coco peat and polycaprolactone-montmorillonite (PCL-MMT) nanofiber composite were used as adsorbents for the treatment of mining effluents (Diaz et al. 2017). At a certain point, the spent adsorbent- coco peat and nanofiber membrane with heavy metals have to be properly disposed to minimize impacts on the surrounding environment. Heavy metals are the major environmental contaminants and pose a severe threat to human and animal health by their long-term persistence in the environment. On the other hand, As is highly toxic and carcinogenic, and therefore the restoration of As contaminated sites is imperative. It is a naturally occurring toxic metalloid and can be ubiquitous in the environment (Ali et al. 2013).

Mine tailings can be burdened with significant quantities of heavy metals. For this reason, finding new and improving existing tailings treatment techniques is very important. Several remediation technologies have been developed to treat contaminated soil, mainly

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mechanically or physio-chemically based remediation protocols (Marques et al. 2009). The phytoremediation technology is employed over polluted sites and have served to help and assist in pollution cleanup efforts (Mganga 2014). Phytoremediation is a developing technology in which plants and microorganism associated with plant roots are the active agents for uptake and or degradation of toxic inorganic and organic compounds in soil and water. Phytoremediation of heavy metal contaminated soil relies on the ability of plants to accumulate metals at concentration substantially above those found in the soil in which they grow. This approach has significant economic advantages over mechanically intensive technologies.

The criteria used for selecting plants for phytoremediation are: high metal tolerance, high bioaccumulation factor, short life cycle, high propagation rate, wide distribution and large shoot biomass (Visoottiviseth et al. 2002). Native ferns species that can also grow naturally in mine sites is *Pteris vittata*. The ferns is arsenic hyperaccumulator (Ma et al. 2001; Chen et al. 2002; Francesconi et al. 2002). *P. vittata* accumulated up to 6000 mg As kg^{-1} (Visoottiviseth et al. 2002). The highest level of As accumulation in *P. vittata* was 6042 mg/kg (in the fronds); 3756 mg/kg (in the roots), respectively (Anh et al. 2014). In the present study, an attempt was to study the phytoremediation of heavy metal contaminated mixture of mine tailings, coco peat and nanofiber membrane using ferns as *P. vittata*.

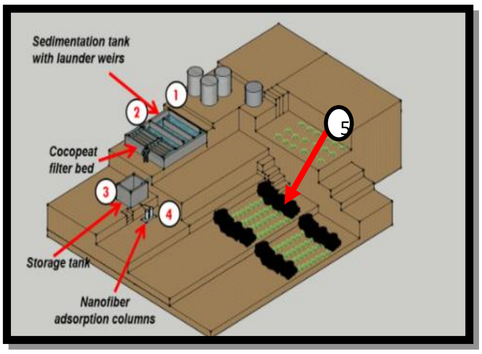

Fig 1. Small scale gold mine processing plant

Fig2. Mine wastes from gold mine processing plant

2.Experimental

Mine tailings mixture was prepared to be treated with ferns and natural soil also was used as control. Mine tailings, contaminated coco peat and nanofiber membrane were collected from small-scale gold mine processing site in Kias, Benguet. Natural soil or garden soil that used as control was purchased from landscaping supplier. The ferns with 4 or 5 fronds stage were collected and transplanted from the nursery bags to the plant boxes. For planting, two plant distance (20 cm) and plot height (15 cm) were assigned for each plant box. 25 plants were grown in one plant box. Experiment time was 5 months and Five samples were collected from each plant box at every monitoring schedule. Weekly checking and measuring of fern height were conducted to evaluate their growth in the tailings mixture. After harvesting, root length and dry weight of ferns were also measured every month.

The total amount of As in the tailings mixture and control soil was determined using a method modified from ASTM D 5198-09. Two (2) g of thoroughly mixed sample was digested with (25) ml of 1:1 nitric acid solution on the hot plate for two hours. The temperature of the solution was maintained at 90 to 95°C. The digested samples were then filtered, diluted to 50 ml using deionized water, and stored prior to analysis. Dry ashing method was used for the digestion of fern samples (Kalra 1998). Approximately (0.5) g of frond and root samples were separately placed into porcelain crucibles and then into a muffle furnace. The furnace temperature was slowly increased from room temperature to 500˚C. The samples were ashed for 6 hours forming a white or grey ash residue. The residue was dissolved in 10 ml of dilute acid mixture of 300 ml HCl and 100 ml HNO_3 in 1000 ml water and the mixture was warmed to dissolve the residue on the hot plate at 300˚C for one hour. The solution was filtered and transferred to a 25 ml volumetric flask and made up to 20 ml volume with deionized water. The metal concentrations were analyzed by Teledyne Leeman Labs Prodigy 7 Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES).

Fig 3. Experiment site and *Pteris vittata* plant boxes

Fig 4. Heavy metal analysis of mine tailings mixture and ferns

3. Results and Discussion

In phytoremediation, natural soil (garden soil) was used as control. During the planting time, the growth of the ferns in control plant box and mine tailings mixture plant box were studied. In Figure 5 and 6, root length, dry weight of ferns and frond height after 1st harvesting period and 5th harvesting period are presented. As shown, root length, dry weight and frond height of *P. vittata* in both plant boxes increased significantly from 1st to 5th period. In general, plant growth factors- root length, dry weight and frond height of control were generally higher than that of ferns grown in tailings mixture plant boxes. The natural garden soil had enough nutrients that supported the growth of the ferns. It was expected though that better and higher fern growth can be observed in control soil. The difference of plant growth can be assumed that the tailings mixture has significant amount of heavy metal but controls just had a background concentration of the metal in the soil. The ferns in the control boxes suffered less metal stress compared to the ferns grown in contaminated tailings mixture.

The percent uptake of heavy metal (As) by ferns in control and tailings mixture plant boxes for 1^{st} and 5^{th} periods are presented in Figures 7. The fern As uptake is related to the As concentration of fern and dry biomass (Ma et al. 2001). As shown, percent uptake of As by ferns in tailings mixture plant box was significantly increased from 1^{st} period to 5^{th} period. The ferns grew well in tailings mixture according to plant growth data shown in figure 5 and figure 6. Therefore, the ferns could uptake metal significantly from tailings mixture. Although the amount of heavy metal in control was very low compared to tailings mixture, the ferns showed uptake of As. However, the uptake of arsenic by ferns in control plant box was decreased from 1^{st} period to 5^{th} period. There might be a reason was that the control soil had just a background level of heavy metals so that data on uptake was not consistent although all the plants were grown under identical environmental conditions. The various physical and chemical properties of the control soil may have an effect on heavy metal uptake.

Translocation factor (TF) of As in control soil and tailing mixture plant boxes for 1^{st} and 5^{th} harvesting period can be seen in Figure 8. As shown, TF values of As for both plant boxes were greater than one in 1^{st} period and 5^{th} period. This means that the amount of heavy metals in the frond was higher than the amount in roots and the metals can translocate from root to shoot. The translocation factor (TF) is commonly used to evaluate the heavy metals storage in plant tissues, where TF > 1 indicates the effective translocation of heavy metals from roots to shoot (Abioy et al. 2016; Rezvani and Zaefarian 2011). Theoretically, TF value must be larger from period to period because according to plant growth data, all ferns grew well from 1^{st} to 5^{th} period. But the TF value of all ferns in tailing mixture plant box was higher in 1^{st} period than that of 5^{th} period while the % uptake of As by ferns significantly increased from 1^{st} to 5^{th} period. According to ferns As data shown in figure 9, As contents of frond and root increased thru time. There might be one consideration that although most of the metal translocate to upper part of ferns, some may be volatile because of the action of microorganism (Verdell 2008; Mateos et al. 2006). The phytoextraction ability of As of *P. vittata* could be determined according to translocation factor of this study.

Fig 4. Heavy metal analysis of mine tailings mixture and ferns

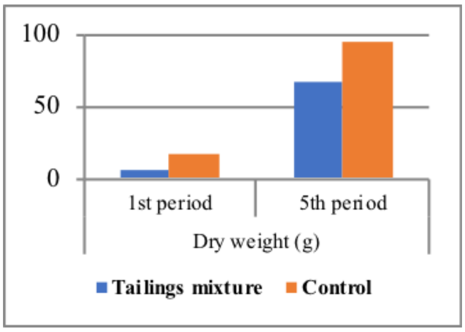

Fig 5. Dry weight of ferms

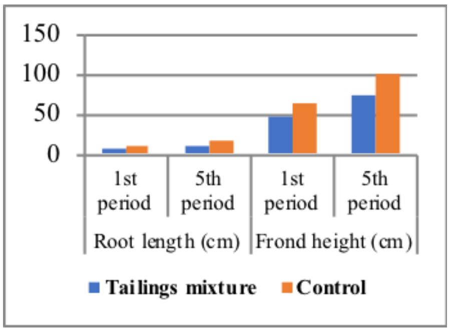

Fig 6. Root length and frond height of ferns

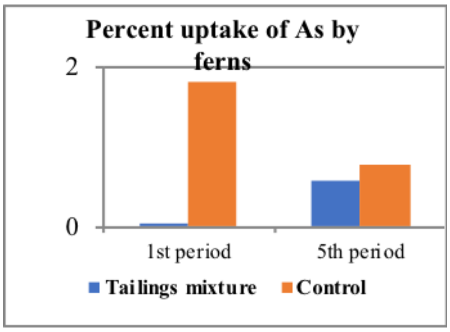

Fig 7. Percent uptake of arsenic by ferns

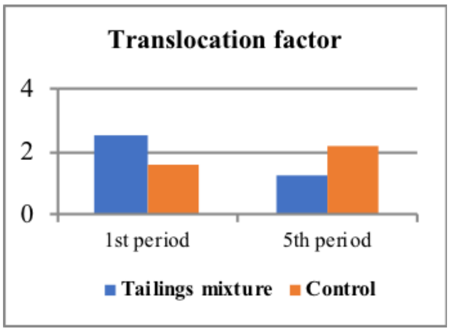

Fig 8. Translocation factor

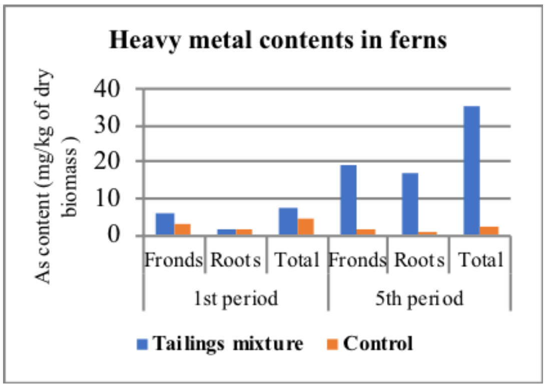

Fig 9. Heavy metal contents in frond and root of ferns

Conclusion

According to % uptake and translocation factor, *P. vittata* could uptake arsenic significantly. *P. vittata* grew well in tailings mixture without the symptom of phytotoxicity. Translocation factor of As of *P.vittata* were higher than one and it could be translocated from root to shoot. Therefore, *P. vittata* can be used for the phytoremediation of the said heavy metal contaminated mine wastes.

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