International Journal of Integrated Engineering, Vol. 4 No. 2 (2012) p. 1-8

Phytoremediation of Metals in Industrial Sludge by *Cyperus Kyllingia-Rasiga, Asystassia Intrusa* and *Scindapsus Pictus Var Argyaeus* Plant Species

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Abstract: Laboratory studies have shown phytoremediation is a feasible method for remediating sludge contaminated with heavy metals. This research focused on the ability of plants to hydroponically treat digested industrial sludge contaminated with aluminium (Al), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), nickel (Ni), manganese (Mn) and zinc (Zn). The sludge used in the study was obtained from the wastewater treatment lagoon of a textile factory. Three species were used in the phytoremediation process. They were *Cyperus Kyllingia-Rasiga, Asystassia Intrusa* and *Scindapsus Pictus Var Argyaeus*. These species were planted in hydroponic pots placed under a transparent roof to allow natural light. In the first batch, pots containing 2 seedlings of each plant were applied with 9.81 mg, 12.83 mg, 15.85 mg, 18.87 mg and 21.9 mg digested dried industrial sludge. In the second batch, the pots planted with 1, 2, 3, 4 and 5 seedlings and were applied with the same amount of 21.9 mg of digested industrial sludge each. The pH and electrical conductance (EC) of hydroponic solution were monitored in this phytoremediation processes. The results showed that the absorption of heavy metals by *Asystassia Intrusa* was in the order of Mn > Al > Cu > Fe > Ni > Zn > Cd > Pb > Cr, with medium pH and EC of 6.90 ± 0.73 and 2.47 ± 1.96 µS/cm respectively . The absorption of heavy metals by *Cyperus Kyllingia-Rasiga* was in the order of Mn > Cu > Ni > Cr > Pb > Zn > Fe > Al > Cd at medium pH 6.87 ± 0.71 and EC 2.72 ± 1.85 µS/cm and the absorption by *Scindapsus Pictus Var Argyaeus* was in the order of Cu > Ni > Mn > Pb > Zn > Cr > Cd > Al > Fe at neutral pH and the EC 2.72 ± 1.71 µS/cm. From the study it was concluded that the plant species used were able to significantly absorb the metals present in industrial sludge.

Keywords: heavy metal, hydroponics, industrial sludge, phytoremediation, rhizosphere

1. Introduction

The final disposal of industrial sludge in Malaysia has become a critical issue due to public concern and the limited availability of land. The most effective strategy is to reduce the quantity of sludge produced by various industrial processes. If this reduction is not feasible, then the reuse of sludge should be considered. If the sludge contains contaminants e.g. high levels of heavy metals, the sludge could then be pretreated using phytoremediation process. Phytoremediation has also emerged as an alternative to the engineering-based methods. In this approach, plants are used to absorb contaminants from the sludge and translocate them to the leaves and shoots [11]. Pollutants are then removed by harvesting the above ground plant tissue for subsequent volume reduction, storage and disposal. Plant species are selected for phytoremediation based on their potential to evapotranspire subsurface water, the degradative enzymes they produce, their growth rates and biomass yield, the depth and distribution of their root zone, and their ability to bio-accumulate metals as contaminants [5].

Researchers have shown that heavy metal uptake by crops are influenced by their initial concentrations in soil or other medium, nutrients available and pH of the medium [6]. Roots withdraw substances from the media, and may also release substances influencing nutrient availability [14]. The rhizosphere, for the first few millimeters of medium in contact with the roots, may have pH value up to 2 units higher or lower than the medium directly around it, which can significantly affect the uptake of most plant nutrients. Plants experiencing an iron deficiency generally increase the hyrogen ions output into the rhizosphere to acidify the medium and release organic acids. Nitrogen tend to acidify their rhizosphere

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because they take up more cations of ammonium than anions of nitrate, which is counterbalanced by the acidifying of pH [9]. It was suggested that the most important factor for the uptake of cationic heavy metals from sludge by plants is the pH of the medium in which they are growing [14]. Elemental sulfur, added to soils contaminated with cadmium and planted with common mustard (scientific name *Sinapis Alba L.*) was shown to acidify the soil and make the cadmium more available to the plant. The study also showed that when high levels of sulfur were added, the pH dropped significantly and plant growth was inhibited. At pH 5 to 5.5 optimum plant growth was achieved, but was accompanied by significantly increased levels of cadmium uptake [14]. The effect of rhizosphere pH and electrical conductivity on heavy metal uptake in hydroponics solution was also investigated.

The main purpose in this study was to investigate the capability of three species of plants namely, *Cyperus Kyllingia-Rasiga, Asystassia Intrusa* and *Scindapsus Pictus Var Argyaeus* to absorb aluminium (Al), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), nickel (Ni), manganese (Mn) and zinc (Zn) from hydroponic pots which were contaminated with digested dry sludge from a textile wastewater treatment plant.

2. Materials and Methods

Seeds and sludge sources

The seeds of plant species, *Cyperus Kyllingia-Rasiga* and *Asystassia Intrusa* were collected from a wild population growing in a field. The plants were chosen because they were locally available. The *Cyperus Kyllingia-Rasiga* and *Asystassia Intrusa* species were grown from the seeds in pots of soil placed under a shaded area. The pots were 20 cm in diameter and 40 cm high. The plants were watered three times a week. Upon maturity, the seedlings were then transferred to the hydroponics mediums. Meanwhile for the *Scindapsus Pictus Var Argyaeus* species, seedlings in the form of cut stems were planted directly into hydroponics mediums.

The sludge used in this study was collected from a textile industry wastewater treatment plant. The reaction between trace elements such as heavy metals and ammonia as ammonium anion in the wastewater produces a precipitate which forms the sludge [13]. The ammonium anion presence was due to the synthetic dye used in textile manufacturing which contain cuprammonium ion, $[Cu(NH_3)_4]^{2+}$ [18]. The sludge is settled in the wastewater treatment pond. Contamination is more persistent and may remain for long periods of time by binding strongly to sludge particles. Before the sludge was applied to the plants, it was first digested using nitric acid to get a homogenous solution. In addition, the use of nitric acid (HNO_3) can supply around 50% of the nitrogen needs of the crop without adding excess cations. If extra nitrogen is required, ammonium nitrate can be added to the solution. However, ammonium nitrate was not used in these experiments since it may reduce the uptake of other cations (K, Ca, Mg, and micronutrients) by the plants in hydroponics solutions.

Preparation of Pots, Hydroponics Medium and Plants

The pots were arranged and placed in a shade illuminated with natural light. Two 11 cm diameter polypropylene pots were stacked on top of each other. The plants were placed on the top perforated pot allowing the roots to protrude through the perforations. The roots would then obtain its nutrient from the bottom pot. The bottom pot contained 250 mL of hydroponics medium (digested sludge) when filled to a depth of 10 cm. Washed sand was used to support the plants in the top pot during growth. Oxygen was allowed within the root zone to stimulate aerobic growth [5]. The pots were wrapped with aluminium foil to prevent algae growth and organic photolysis [2]. The pots were spiked with solution containing nutrients as shown in Table 1. There were five replicates for each batch of sample.

Table 1 Constituents of the nutrient solution (Ebbs, *et al*, 2001).

Constituents	Concentration (mM)
KNO_3	6.0
$Ca(NO_3)_2$	4.0
$NH_4H_2PO_4$	0.1
$MgSO_4$	1.0
$CaCl_2$	25.0
H_3BO_3	12.5

The pH of the hydroponics medium was adjusted to approximately 5.5 with hydrochloric acid (HCl) and potassium hydroxide (KOH) [20]. The pots were applied with 9.8 mg, 12.8 mg, 15.9 mg, 18.9 mg and 21.9 mg industrial sludge as digested dried industrial sludge respectively. In another batch of pots planted with 1, 2, 3, 4 and 5 seedlings were applied with of 21.9 mg of digested industrial sludge. The sludge also contained trace elements to provide proper micronutrients for different plant growth needs. Table 2 shows the concentration of metals in digested industrial sludge.

Table 2 : Concentration of metals in digested industrial sludge

Elements	Concentration (mg/L)
Al	47.5
Cr	1.5
Cd	4.9
Mn	1.4
Fe	186.7
Ni	18.0
Cu	13.0
Zn	118.3
Pb	1.4

The plants, *Cyperus Kyllingia-Rasiga, Asystassia Intrusa* and *Scindapsus Pictus Var Argyaeus* were grown hydroponically to study their ability to accumulate heavy metals from the medium through mechanisms of direct uptake and accumulation of contaminants in root cells in rhizosphere zone. The release and exudation of enzymes stimulates microbial activity in the aqueous media [7]. It was suggested that the plants were to be grown and maintained for 28 days in the hydroponics medium to adapt to the environment [17]. Samples were drawn from the hydroponics pots and analysed for heavy metals concentrations every four days starting from day 4. The pH and electrical conductance of the medium were monitored at each sampling to monitor the changes of rhizosphere pH and electrical conductance (EC) of the medium. The concentrations of metals were analyzed using ELAN 9000 Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)(Perkin Elmer, USA). After 12 days, the plants were transferred to new pots containing 250 mL of fresh hydroponics solution of digested sludge with nutrients. The plants remain in the new pots for another 16 days. The uptake of metals into shoots and leaves of plants is influenced by the pH and EC of the medium.

Plant digestion

After four weeks the plants were harvested. The plants were removed from the pots and the roots were rinsed in warm de-ionized water to remove any trace of the hydroponics medium. Then the whole segments of plants were soaked in a 100 mM $CaCl_2$ solution to remove any cell wall associated with free space heavy metals [14]. Plants used for metal analysis were dried in a convection oven for 24 hours at 105 ^{0}C until a constant weight was obtained. After drying, the plants were ground up using a M20, IKA-WERKE grinder. Approximately 1 g of the grounded dried plants were weighed and placed in Anton Paar teflon tubes for digestion. Ten milliliter of concentrated nitric acid was added to each tube and digested in a microwave digester, Antor Paar 3000 [3]. The samples were then analyzed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) (model Perkin Elmer Elan 9000). Reagent blanks and internal standards (EPA 6020A) were used where appropriate to ensure accuracy and precision in the analysis. Internal standards solutions were also parts of diluted sample and capable of making corrections of isobaric interferences of metals.

3. Results

Rhizosphere pH

Figure 1 shows the variation of the average pH of the hydroponics medium containing *Cyperus Kyllingia-Rasiga, Asystassia Intrusa* and *Scindapsus Pictus Var Argyaeus* with respect to the number of plants when applied with 21.9 mg of digested industrial sludge. The results show the average pH values, ranging from 6.78 to 7.64. The trend of the curves was similar for *Cyperus Kyllingia-Rasiga* and *Scindapsus Pictus Var Argyaeus*. The variation of the pH in the hydroponics medium is due to the ability of the plants to match the pH of its environment in order for the plants to absorb metals. The protein and enzyme molecules in a plant are structured in very specific shapes in order to catalyze a chemical reaction to build the plant cells. This means that all the negative and positive charges have to line up exactly. In fact, plants often change their own cellular pH to stop or speed up a certain enzyme reaction. The acidic pH means more hydrogen (+) charges, and basic pH means more hydroxide (-) charges [4]. Plants required the correct balance of positive and negative charges of ions in the roots system mechanism to ensure its ability to absorb metals. The internal pH of the plant species must match closely the pH in its metals valence such as Cu^{2+}, Al^{3+}, Fe^{3+}, Cr^{3+}, Ni^{2+} and Mn^{7+} which can be found in sludge as hydroponics mixture. High level of phosphorous can induce iron and zinc deficiency by plant at a certain range and average of pH and EC of hydroponics.

Figure 1 also showed that the average pH of the medium containing*, Asystassia Intrusa* decreases with the increase of the number of plants in the pots. The increased number of 1 to 4 *Cyperus Kyllingia-Rasiga* in the medium seemed to acidify the solution in the rhizosphere area. This is because of the acidic characteristic of membrane cell roots due to the increase population of microorganism activity [12]. The nutrients, water, metals, nutrients and the gases at the roots have different electrical charges and in continuous interaction with each other. The exchanging positive and negative charges surround the root system was due to the pH and EC value, when the nutrients and metals are absorbed into the roots. The positively charged hydrogen proton (H^+) combines with water and increases the concentration of H_3O^+ ions which corresponds to pH scale.

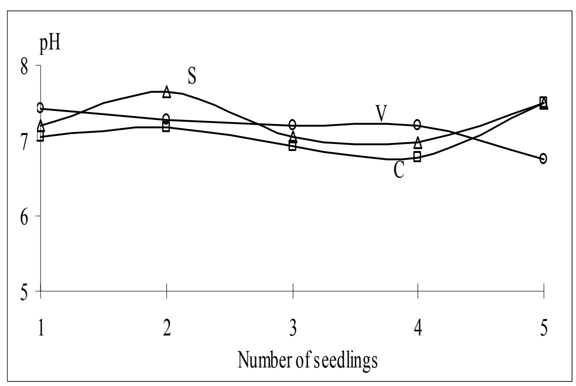

Figure 1: Variation of pH of the medium containing *Cyperus Kyllingia-Rasiga*, (*C*), *Asystassia Intrusa*, (*V*), and *Scindapsus Pictus Var Argyaeus*, (*S*) , with respect to the number of species containing 1, 2, 3, 4 and 5 seedlings when applied with of 21.9 mg of digested industrial sludge

Similar pH trends were shown by the species *Cyperus Kyllingia-Rasiga* and *Asystassia Intrusa.* Figure

2 also shows no apparent correlation between pH and weight of sludges. Thus, the effects of pH and sludge contents are not straight forward, and perhaps reflect the underlying complexities of metal-water reactions in digested sludge interactions. Generally Figure 1 and 2 showed all species have grown and developed within pH range of 6 to 8. Different types of plants have different need of average and optimum of pH. Plants have shown signs of nutrient deficiencies at both low and high pH. The availability of Mn, Cu, Zn and especially Fe are greatly reduced at higher pH, but at lower pH, there is only a small decrease in availability of P, K, Ca, Mg [6]. On the other hands, the phosphate ion has the ability to absorb and desorb hydrogen ions to stabilize the pH. Unfortunately, phosphorous is quickly removed from the solution at higher pH. Iron (Fe) uptake generally decreases with increasing pH because it precipitates out of the solution and is deposited on the root at higher pH levels [4].

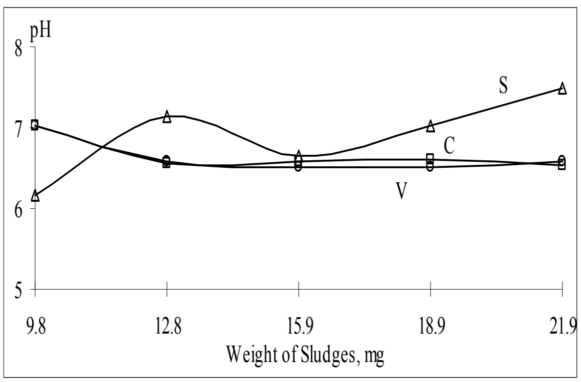

Figure 2: Variation of pH of the medium containing *Cyperus Kyllingia-Rasiga*, (*C*), *Asystassia Intrusa*, (*V*), and *Scindapsus Pictus Var Argyaeus*, (*S*) , with respect to increasing application (weight) of industrial sludge

Rhizosphere EC

The high production of H_3O^+ ions due to high quantity of cation metals in the hydroponic medium will increase the EC. The EC is defined as the conductivity of electrolytes due to the movement of free ions when the substances are in an aqueous solution. The hydroponics medium with the lowest rhizosphere pH had the highest total of metal-hydrogen bonding as shown by the high conductivity.

The total amount of nutrients and metals in solution may be estimated and monitored by measuring the electrical conductance of the hydroponics medium. However, because of the differential non biological rate of plant uptake for each pot, conductivity is a rough approximation of the trace elements remaining in hydroponics solution. In general, metal conductance in hydroponics is very low. Overall, the electrical conductance, (EC) in the pots planted with 1, 2, 3, 4 and 5 plants are higher than in the pots applied with increasing weights of industrial sludge. For comparison, the EC of deionized water is 0.02 µS/cm and the EC of the hydroponics medium before the addition of digested sludge is 0.34 µS/cm. In general a high EC would indicate high concentrations of cations and anions in the solution [19].

The range of EC as shown in Figure 3 is from 2 to 5 µS/cm. There is an increase in EC for the plants with 1 to 2 and 4 to 5 species when 21.9 mg of digested sludge were applied to the medium. The EC measured is low due to the movement of cation or metal with positive charge in hydroponic medium as electrolyte. The metal-sludge in solid state does not conduct electricity because the ions are held in the lattice and do not move freely. However, digested metal-sludge in the nutrient can conduct electricity because the cations are moving freely in solution. The lowest EC value in Figure 3 and 4 would indicate the probability of reduced amount of cations in the medium, and at this point, it can be said that the metals were being absorbed by the plants.

In the application of different weights of sludge, it was shown in Figure 4 that only a small change of electrical conductance between of 0.4 to 3.0 µS/cm has occurred. The application of 9.8 mg, 12.8 mg, 15.9 mg and 18.9 mg of sludge to the medium had caused the EC to increase especially in species C and V. But, for more than 18.9 mg of sludge application, the EC was observed to drop except for the S species. The absorption of metal is strongly a function of plant species and of plant organs (root system) in the hydroponics medium. It is also a good indicator of heavy metal mobility in plant-hydroponics system. The metals may also leached out from the root via the plants tissue into the medium to increase the EC value as shown by the pots planted with 2 and 4 species in Figure 3 and the application of 18.9 mg of sludge in Figure 4. The old and unstable roots were also assumed to decay in the hydroponics medium. It can also be seen from Figure 4 that the pots planted with S species resulted in almost linear EC relation due to weakening and decreasing metals uptake.

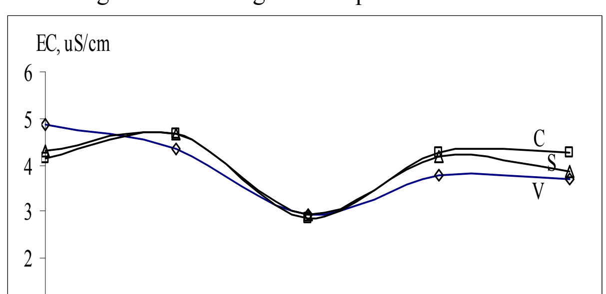

Figure 3: Variation of EC of the medium containing *Cyperus Kyllingia-Rasiga*, (*C*), *Asystassia Intrusa*, (*V*), and *Scindapsus Pictus Var Argyaeus*, (*S*) , with respect to the number of species containing 1, 2, 3, 4 and 5 seedlings when applied with of 21.9 mg of digested industrial sludge.

Some part of the curve showed that the pH value would be increased as EC increases. This is consistent with earlier findings suggesting that the decrease of pH was due to the production of H_3O^+ ions from the hydrolysis of the NH_4^+ ions which causes the medium to be acidic. One of the main sources of nitrogen element is from NH_4^+ ions through the cationic hydrolysis process. The high content of metal cations with high charge density such as Cu^{2+}, Al^{3+}, Fe^{3+}, Cr^{3+}, Ni^{2+} and Mn^{7+} could also contribute to the low pH. These results can be explained by considering the metals cations can act as proton donors such as shown in the equations 1, 2 and 3 below.

$$[Cu(H_2O)_6]^{2+} + H_2O \rightarrow [Cu(H_2O)_5(OH)]^{+} + H_3O^{+} \quad (1)$$
$$[Al(H_2O)_6]^{3+} + H_2O \rightarrow [Al(H_2O)_5(OH)]^{2+} + H_3O^{+} \quad (2)$$
$$pH = -\log [H_3O^{+}] \quad (3)$$

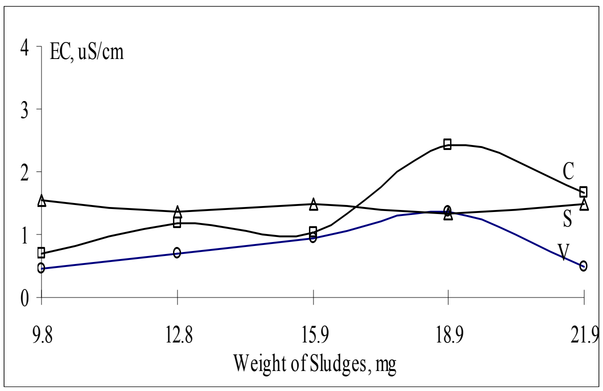

Figure 4: Variation of EC of the medium containing *Cyperus Kyllingia-Rasiga*, (*C*), *Asystassia Intrusa*, (*V*), and *Scindapsus Pictus Var Argyaeus*, (*S*) , with respect to increasing application (weight) of industrial sludge.

Absorption of Metals

The potential of the species to absorb metals through the reduction of metals in the digested hydroponics sludge medium, were investigated. The results showed a differential absorption of metals by plant tissue of the three species as shown in Figure 5 and the absorption are influenced by the change of pH and electrical conductivity during the 28 days of growth period. The results showed that 73% and 80% of manganese were absorbed by *Assystasia Intrusa* and *Cyperus Kyllingia-Rasiga* species respectively. Dissolved Mn is an essential element for higher plant systems and is involved in photosynthesis and activation of different enzyme systems but large amounts of Mn(II) absorbed can interfere with the uptake of other trace metals (Marble, *et. al*., 1998). The percentage of absorption was calculated in equation 4 as follows:

$$\% \text{ Absorption} = \frac{A-B}{A} \times 100 \quad (4)$$

Where, A = initial amount of metal weight in medium
B = final amount of metal weight in medium

The absorption depends not only on the pH and EC of the metals acidity in the hydroponics, but also on the toxicant in the industrial sludge. Differences in responses of metals uptake by plant species may be due to differences in the assay conditions, the growth forms, physiology of the plant organisms or previous environment conditions. Therefore, plant species that absorb high iron and manganese will perform efficiently at low pH. *Scindapsus Pictus Var Argyaeus* was able to absorb 76% Cu from the industrial sludge. Figure 5 also showed that , *Cyperus Kyllingia-Rasiga* absorbed the lowest amount of Cd from the industrial sludge. Contrary to Mn, little information is available on Cd absorption, and no accepted high-attraction as transporter in gene of the plant has been identified in plants yet. But, in a few species, Cd has been found in the apoplast and in the vacuole. The physiological mechanism of Cd tolerance is not based on an enhanced synthesis of phytochelatins but on a preferential compartmentation of the metal in the plant [8]. In plants, Cd^{2+} transport in the xylem sap was reported to be coordinated with oxygen or nitrogen ligands [10]. These differences in metals absorption as shown in Figure 5, may reflect different uptake mechanisms due to the growth rates of root.

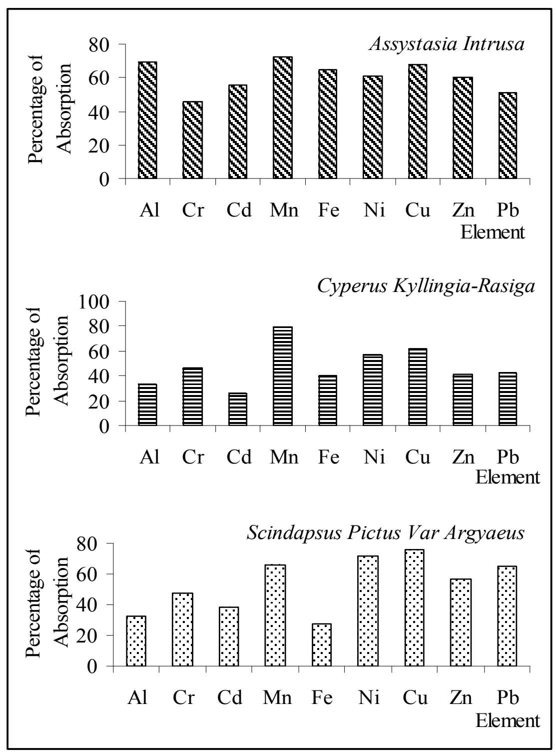

Figure 5: The percentages of metal reduction from medium by the absorption of species.

In this study, the relative absorption percentages of metals Al, Fe, Zn, Cd, Cr, Ni, Pb, Cu and Mn in industrial sludge by *Cyperus Kyllingia-Rasiga, Asystassia Intrusa* and *Scindapsus Pictus Var Argyaeus* species were compared. The absorption of metals in textile industrial sludges by *Asystassia Intrusa* were respectively 73% Mn, 69% Al, 68% Cu, 65% Fe, 61% Ni, 60% Zn, 56% Cd, 51% Pb and 46% Cr. These potential rates of element removal are merely estimates based on data obtained from hydroponically grown plants for 28 days. Micro-nutrients are found at much lower concentrations in the tissue than macro-nutrients and include iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B) and molybdenum (Mo). There are several other nutrients that are considered as essential for normal growth including sodium (Na), chloride (Cl), Nickle (Ni) and possibly chromium (Cr). However, these nutrients are not required by plants in large amounts. Furthermore they are often found as contaminants in a number of different fertilizer sources [4]. The highest percentage of metals absorption in textile industrial sludges by *Cyperus Kyllingia-Rasiga* was Mn followed by Cu, Ni, Cr, Pb, Zn, Fe, Al and Cd with 80%, , 62%, 56%, 46%, 43%, 42%, 40%, 33% and 26% of the plant respectively. Then, the removal potential of 9 elements in textile industrial sludges by *Scindapsus Pictus Var Argyaeus* were estimated as 76% Cu, 72% Ni, 66% Mn, 65% Pb, 57% Zn, 47% Cr, 38% Cd, 33% Al and 27% Fe. The absorption of metal by the plant species studied is a function of the concentration of the metals, pH of medium, electrical conductance of medium and the genetic of plant species or cultivars.

The Accumulation of Metals in Plant Tissues

The results of the heavy metals analysis of plants also showed a differential accumulation of heavy metals in the plant tissue due to the root-metals uptake patterns of different plant species as a function of pH and EC. The weight of metals in the dry matter recovered from whole plant tissue expressed as $mgkg^{-1}$ was summarized in Figure 6. Different plant species also have different rates and abilities to take up and accumulate various trace elements in their tissues. Ideally, all plant species should be of the same size and growth stage when exposed to element treatments in order to compare among them for their ability to remove various elements under study. However, the final plant weights still did not correspond to the initial weights due to differential rates of biomass accumulation of individual plant species [17]. The metal moves into the plants during active transpiration across a concentration gradient and once in the plant, it moves readily through the xylem in the transpiration stream and accumulates at the point where water is lost through stomata in the leaf. Biologically, through accumulation, the xylem loading and translocation of metals in the plants is considered to be proportional to the amount of water transpired and the soluble metal concentration present in the hydroponics medium [16].

Scindapsus Pictus Var Argyaeus species tested showed a high degree of metals accumulation in their plants compare to another two species studied. Of all 9 elements studied, Fe accumulated, was the highest concentration in *Scindapsus Pictus Var Argyaeus* which up to 111000 mg Fe per kg of dried weight. This species also accumulated 5300 mg Cd per kg of dried weight, higher than in *smooth cordgrass* species, 5 mg Cd per kg of dried weight [17]. *Assystasia Intrusa* accumulated the highest Fe concentration in plants of 3000 mg Fe per kg of dried weight. *Brassica Juncea* accumulated lower Ni concentration of 465 mg Ni kg^{-1} of dried weight compared to *Assystasia Intrusa* accumulated Ni concentration of 580 mg Ni per kg of dried weight [20]. The highest Cr concentration in plant of 2500 mg Cr per kg of dried weight was attained by *Scindapsus Pictus Var Argyaeus* plants with the next highest Cr concentration of 250 mg Cr per kg of dried weight accumulated by *Cyperus Kyllingia-Rasiga* followed by *Assystasia Intrusa* accumulated Cr concentration of 210 mg Cr per kg of dried weight. In previous research identified *water hyacinth* as a good accumulator (3951 mg Cr per kg of dried weight) and *duckweed* as a modest accumulator (2870 mg Cr per kg of dried weight) of Cr [17].

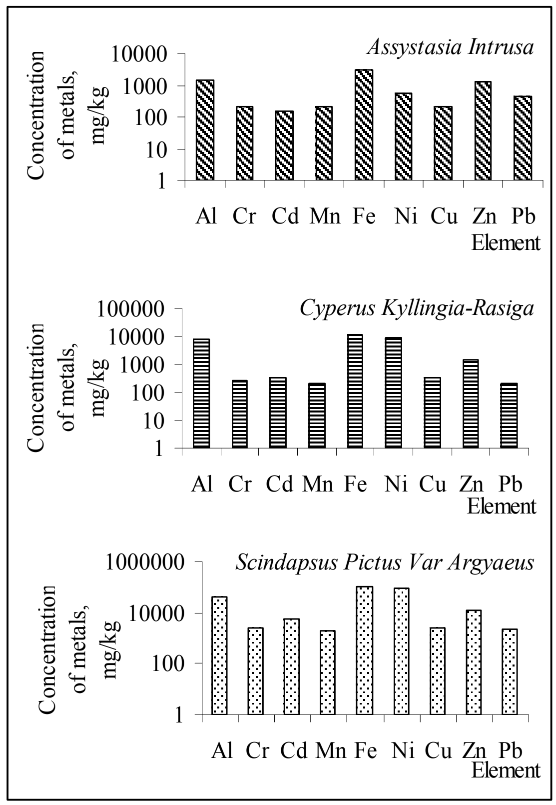

Figure 6 : The accumulation of metal in plant

One strategy for increasing the efficiency of phytoextraction is to increase metal translocation to the shoot by increasing plant transpiration. Earlier research showed that wind enhances metal flux to the shoots, while abscisic acid compounds that block transpiration and block metal accumulation in shoots. These plants were cultivated under the same conditions of area, weather, temperature and natural wind movement.

Overall**,** the metals absorption by *Asystassia Intrusa* was in the order of Mn > Al > Cu > Fe > Ni > Zn > Cd > Pb > Cr with the average value of rhizosphere pH 6.90 ± 0.73 (Figure 1 & 2) and EC 2.47 ± 1.96 µS/cm (Figure 3

& 4). But a different sequent for the metals uptake by *Cyperus Kyllingia-Rasiga*, which was Mn > Cu > Ni > Cr > Pb > Zn > Fe > Al > Cd due to the hydroponics condition with the average value of rhizosphere pH 6.87 ± 0.71 as stated in figures 1 & 2 and EC 2.72 ± 1.85 μS/cm in figures 3 & 4. Otherwise, according to the condition with an average of rhizosphere pH 7.08 ± 0.85 and EC 2.72 ± 1.71 μS/cm in solution of *Scindapsus Pictus Var Argyaeus* roots area as shown in Figure 1, 2, 3 and 4 the metals in order of increasing absorption as Cu > Ni > Mn > Pb > Zn > Cr > Cd > Al > Fe.

The uptake process is governed by the chemical and physical properties of the mixture in hydroponics, environment conditions and the plant species growth. Usually, the plant grow equally well between pH 4 and 7, if nutrients do not become limiting. This is because the direct effects of pH on root growth are small; the problem is reduced nutrient availability at high and low pH. The recommended pH for hydroponic culture is in the range of 5.5 to 5.8 because overall availability of nutrients and metals are optimized at slightly acidic pH. The availabilities of Mn, Cu, Zn and especially Fe are reduced at higher pH. There was a small decrease in availability of P, K, Ca, Mg at lower pH. Reduced availability means reduced metals uptake, but not necessarily nutrient deficiency.

4. Conclusion and recommendation

This study showed that metals reduction in medium is due to the absorption in the roots system and are influenced by pH and EC, of the hydroponics solution. Dissolution and mobility of metals in medium are greatly influenced by the pH. It was found that there were also antagonistic interactions of Fe-B, Zn-B and Fe-Zn in the absorption of these elements by the plant [1]. The level of metal in plant species may be affected by any of several physiological factors, including metals uptake from the sludge solution, xylem translocation from root to shoot, sequestration of metals in sub-cellular compartments or as organic complexes and phloem movement into grain during fruit development. Movement of metals from roots to shoots is likely to occur via the xylem and to be driven out by transpiration from the leaves.

These potential rates of element removal are merely estimates based on data obtained for hydroponically grown plants for 28 days. As with all treatment technologies, the pH and conductivity present at medium site will impact the final remediation efficiency of the selected process. Therefore, the presence of the acidic and basic contaminants in industrial sludge compound is a direct result of accumulation of metals uptake in plant. Other industrial sludge may produce different results of absorption rate by these species. *Asystassia Intrusa* was especially effective for remediating Mn and Al. Compared with other species, *Cyperus Kyllingia-Rasiga* had substantially higher rates of trace element absorption for Mn and Cu. However, *Scindapsus Pictus Var Argyaeus* was the highest plant species in Cu and Ni absorption.

Further research will be required, however, in order to develop this information into an effective remediation strategy for metals contaminated sludge. Additional studies should be conducted to better understand the role of microorganism on roots surface in metals accumulation by plants. The effect of microorganism, which produces the natural acid on the solubilization and digestion metals from additional contaminated sludge, differing in mineralogy and elemental content, needs to be studied to understand the role of other sludge factor in metals solubility and mobility in absorption mechanism by the hydroponics plant. This phenomenon may be true in other industrial sludge application to these hydroponics plant where the pH and electrical conductivity results indicates the need to consider its control or treatment. As seen from Figure 5, the percentages absorption of these metals measured were quite significant.

The used of digested sludge as a part of hydroponics medium planted with species studied are the innovative approaches that could be implemented anywhere in the world. The different technologies like air stripping, membrane filtration, chemical precipitation, electrolytic treatment and reverse osmosis are commonly used but operational and maintenance costs are expensive. Therefore, this research suggests that this technology should be considered as a viable option for treating metals in hazardous waste but that additional research should be conducted before this approach is implemented. These technologies also open the doors to the environmental value-added, non food agricultural uses of plants, which will continue to expand in the newly developed country.

Acknowledgements

The authors would like to acknowledge Universiti Tun Hussein Onn Malaysia (UTHM) for funding this research through Grant Vote Number 0171 and also to the Centre For Environment, Construction and Transportation Studies (CECTUS-UTHM), for the instrumentation used throughout the studies.

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