PHYTOREMEDIATION USING *Typha angustifolia* L. FOR MINE WATER EFFLUENCE TREATMENT: CASE STUDY OF EX-MAMUT COPPER MINE, RANAU, SABAH.

Lo Vun Yen & Kartini Saibeh[*]

Institute for Tropical Biology and Conservation,
Universiti Malaysia Sabah, Locked Bag 2073, 88999 Kota Kinabalu, Sabah
E-mail: k_saibeh@ums.edu.my

ABSTRACT. *This research was carried out to determine the capability of Typha angustifolia L. for accumulation of seven heavy metals (Cd, Cr, Cu, Fe, Ni, Pb and Zn). Typha angustifolia were planted in-situ in the tanks filled with mine water effluence (MWE) from the abandoned copper mine pit. The concentration of heavy metals in three replicates of plant root, stem and leaves were determined at Day 0 and Day 60. Samples of plant tissue were digested using hot concentrated nitric acid and the amounts of heavy metals were determined using Atomic Absorption Spectrometer (AAS). The results showed that at Day 60, the concentrations of heavy metals were decreased in all plant part, except Fe and Cu were increased and Cr was increased in root and stem part.The results obtained from this research can be used as a fundamental data in maximizing the potential usage of T. angustifolia for mine water effluence (MWE) treatment at the ex-Mamut copper mine.*

KEYWORDS. Accumulation, heavy metals, *Typha angustifolia*, mine water effluence

INTRODUCTION

Heavy metal contaminant was a global disaster that is related to human activities. The main source of heavy metals pollution were due to the industries and such as mining, smelting, electroplating, energy and fuel production, power transmission, intensive agriculture, sludge dumpling and military operations. The most common heavy metal contaminants were lead, cadmium, chromium, copper, iron, nickel and zinc. All the heavy metal at high concentration has strong toxic effects to environment as it cannot be degraded and accumulated in water, soil, bottom sediments and living organisms.

Remediation of heavy metal contaminants could be carried out by using physico-chemicals processes such as ion-exchange, precipitation, reverse osmosis, evaporation and chemical reduction. There was another method for remediation of heavy metals called phytoremediation which could remove pollutants from the contaminated environment by using plants. It was considered as simple, effective, low cost, environmentally friendly method. It maintained the biological properties and physical structure of the soil.

According to Yang *et al.* (2005), an ideal plant which utilized for phytoremediation should be fast-growing, have high biomass, extensive root system, easy to harvest and has the ability to tolerate and accumulate great amounts of heavy metals in their harvestable parts. This kind of plant has developed strategies for avoiding toxic concentrations buildup of heavy metals at sensitive sites within the cells (Carraza-Álvarez *et al*., 2008).

Many studies have been conducted in different countries to investigate the ability of plants to accumulate and remove heavy metals in different contaminated environment such as river, wetland and wastewater treatment. The study plants were included *Polygonum thunbergii*, water hyacinth, *Typha angustifolia*, *Potamogeton pectinatus* and *Potamogeton malaianus* in Korea, Taiwan, Thailand and China, respectively.

Proper management of these plants in such areas might significantly contribute to restore the natural environment. However, no single plant was suitable for all areas due to the different conditions. All of these plants were not equally effective in removing of pollutants. Therefore, new studies were necessary to find potential plants that might have phytoremediation properties for specific areas.

Typha angustifolia was monocotyledons plant in the family of Typhaceae, with the common name as narrow-leaves cattail. It was an erect, perennial freshwater aquatic plant which could grow three or more meters in height (Demirezen & Aksoy, 2004). It could be found in damp soil or shallow water. It has rhizomes and seeds reproduction. It was one of the plants commonly used in the system of artificial wetlands to treat wastewater. It has the ability to absorb and accumulate heavy metals in its tissues without damaging its tissues. It also has a tolerance of living in acidic conditions (Ghaly *et al*., 2008). It was a common species and abundantly found in locally.

The objective of this study was to determine the capability of *Typha angustifolia* in accumulating heavy metals in the mine water effluence treatment at ex-Mamut copper mine, Ranau, Sabah.

MATERIALS AND METHODS

Study site

Ex-Mamut copper mine (MCM) was located in district of Ranau, Sabah about 60 km east of Kota Kinabalu. It has been in operation for about 24 years from 1975 to 1999.The mining lease covered an area of 4800 acres of mountains and steep sided valley. The annual rainfall was 4000 mm and the climate was sub-tropical. It was over 200 ha of an area occupied by the mine open pit, process-plant site and waste rock dumping areas. The pit was almost circular with a diameter of about 1200 m and a depth of 100 m with water pH 3.6 to 3.9. The waste rocks were dumped at the West Dump and Nasapang Dump where the soil pH 3.1 to 3.6. The overburden materials were dumped at the Mamut Valley Dump and Lohan Dump where the soil pH 4.5 to 6.9.

Figure 1.The map of study site, ex-Mamut copper mine, Ranau.

(Source: www.google.com, 2012) (No scale)

Sample preparation

A total of 10 *Typha angustifolia* plants with height between 40 cm to 60 cm were collected from Tanjung Lipat. The entire plants were transplanted into a 250 gallon polyvinyl chloride (PVC) tank filled with 100 kg of top soil and 500 kg of calcareous sandstone. The tank was design to receive continuous flow of effluent from the ex-Mamut copper mine's pit. Analysis was performed first to determine the initial concentration of heavy metals contained in the plants tissues just before they are transplanted into the tank (Day 0). Second sampling was performed by choosing the three highest heights of the plants grown in the tank after 60 days exposure to mine water effluent.

The method used to extract heavy metals from roots, stems and leaves of each plant was the modification of wet digestion technique described by Wieteska *et al*. (1996). The 0.2g of samples was digested in boiling 5 cm^3 of acid nitric and perchloric acid mixtures until it became colourless. The residue was dissolve with 1 M of nitric acid and filtered into 25 cm^3 measuring flask and top up with 1 M of nitric acid. The sample solution was then analyzed by using Atomic Absorption Spectrometer (AAS). The studied heavy metals were cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), lead (Pb) and zinc (Zn).

Data analysis

Data was analyzed using Microsoft Excel for mean and standard deviations concentration of heavy metals in the plants part. The translocation factor (TF) was calculated by dividing the metal concentrations in aboveground tissues by the metal concentrations in the root tissues to show the metal translocation properties from the root to the shoots (Stoltz & Greger, 2002).

$$\mathrm{TF} = \frac{[\mathrm{metal}]\mathrm{shoot}}{[\mathrm{metal}]\mathrm{root}}$$

Where, [metal]shoot was the metal concentration in the aboveground tissues (µg/g) and [metal]root was the metal concentration in the root tissues (µg/g). A larger value of TF implied higher translocation capability.

RESULT AND DISCUSSION

The result showed (Table 1) that the highest accumulation of the heavy metal was exhibited in the roots with the concentration of 8495.83±250.42 µg/g Fe. The concentration of Cu was increased in the all plant parts at the end of experiment which were 22.67±2.02 µg/g in roots, 126.67±12.29 µg/g in stem and 21.83±0.58 µg/g in leaves. The concentration of Cr also increased in the root and stem which were 320±17.32 µg/g and 60±6.50 µg/g respectively. However, the concentration of Cd, Ni, Pb and Zn were decreased after 60 days exposed to mine water effluence. The result showed that root was the plant part that could accumulated the highest concentration of heavy metals except for Cu which showed the highest accumulation in stem in Day 60.

Table 1. The concentration (µg/g) of heavy metals in roots, stems and leaves of *Typha angustifolia* in Day 0 and Day 60.

Heavy metals	Part of Plants	Day 0	Day 60
Cd	Root	7.50±4.33	1.25±0.00
	Stem	2.50±0.00	1.25±0.00
	Leaves	5.00±0.00	1.25±0.00
Cr	Root	151.67±5.91	320±17.32
	Stem	38.33±1.91	60±6.50
	Leaves	46.67±6.17	43.33±1.44
Cu	Root	14.17±0.72	22.67±2.02
	Stem	11.67±3.61	126.67±12.29
	Leaves	14.58±3.61	21.83±0.58
Fe	Root	3445.83±331.98	8495.83±250.42
	Stem	24.58±2.89	103.75±10.83
	Leaves	20.00±2.17	23.75±2.5
Pb	Root	16.25±0.00	9.17±1.44
	Stem	10±0.00	4.17±1.91
	Leaves	14.58±3.82	5.00±2.17
Ni	Root	166.25±68.75	45.42±0.72
	Stem	62.92±0.72	42.08±5.20
	Leaves	82.08±0.72	42.50±1.25
Zn	Root	491.67±7.21	145.83±28.87
	Stem	150±43.30	116.67±7.21
	Leaves	204.17±14.43	70.83±7.21

In the uncontaminated environment, the plants acquire macronutrients and micronutrients to grow and complete the life cycle. The mechanism of uptake and translocation of ion was different. In the contaminated environment, nutritional imbalance caused by the interference of non-essential metal nutrients with essential metal nutrients in both uptake and translocation processes (Gandonou *et al*., 2011) and the changes in the availability of nutrients cause perturbations in accumulation of others (Solti *et al*., 2011). The non-essentials metal nutrients could compete with essential metal nutrients by chelators with other transporter translocated into the root of plants (Solti *et al*., 2011)

Ever though the result showed that the concentration of Fe, Cu and Cr were increased, the other heavy metals were decreased in the end of experiment. According to the study of Welch *et al*. (1993), in the deficient in Fe or Cu condition, root could reduce the ions metal by specific plasma membrane bound metal reductases, which might increase metal availability with reduce Fe^{3+} and Cu^{2+}, then the uptake of Fe, Cu, Mn and Mg also increase. It was exhibited that *Typha angustifolia* accumulated high concentration of Fe and Cu since both of these metals were macronutrients for plants.

This study showed that *T. angustifolia* was not a hyperacumulator species as none of the metals concentration in all of its plant part was higher than 1000 mg/kg. According to Baker and Brooks (1989), hyperaccumulators were defined as plants that accumulate than 1000 µg/g of Cu, Co, Cr, Ni or Pb, or more than 10,000 µg/g of Fe, Mn or Zn in the shoots. However, the ability of this plant tolerance to heavy metals might be useful for phytostabilization.

In this study, translocation factor was used to estimate the plant's potential for phytoremediation purpose. The result showed that (Table 2) the translocation factor (TF) values for Fe and Cr in the end of experiment were 0.02 and 0.32, respectively, indicated that those metals were largely accumulated in roots. Although the TF values for Cd (2.00), Cu (6.55), Pb (1.86), Ni (1.00) and Zn (1.29) were more than 1, the total concentration of these heavy metals were lower than 1000 mg/kg and the roots was the highest accumulation compared to stem and leaves, which indicated the accumulated metals retained in roots.

In the contaminated environment, the tolerance plant could grow on soil with concentrations of a particular element that were toxic to most other plants. Toxic concentrations of heavy metals for various plant species were 300 µg/g for Pb, 500 µg/g for Fe, 20 µg/g for Cu and 100 µg/g for Zn (Levy *et al.*, 1999), 5 µg/g for Cd (Kabata-Pendias & Pendias, 1984), 5 µg/g for Ni and 0.5 µg/g for Cr (Allen, 1989). In the end of this experiment, the total concentration of Cr (423.33 µg/g), Cu (171.17 µg/g), Fe (8623.33 µg/g), Ni (130 µg/g) and Zn (333.33 µg/g) in all plant part were higher than the toxic level. This finding indicated that *T. angustifolia* was able growing in the heavy metals contaminated site with tolerance of these metals.

Table 2.Tanslocation factors (TF) for heavy metals in *Typha angustifolia* grown in the Day 0 and Day 60.

Heavy metals	Day 0	Day 60
Cd	1.07	2.00
Cr	0.56	0.32
Cu	1.85	6.55
Fe	0.01	0.02
Ni	1.46	1.00
Pb	0.87	1.86
Zn	0.74	1.29

The plants tolerance mechanism could be divided into three groups according to the metal concentration found in their tissues (Baker & Brooks, 1989). The first group was the accumulator, of which was capable to uptake very high concentration of metals and have evolved specific mechanisms to detoxifying high metal levels accumulated in the tissues. The second group was the indicator, characterized by its capability to take up metals at a linear rate relative to the concentration of metal in the soil. The extent of metal accumulation reflects metal concentration in the rhizospheric soil. It has been used for mine prospecting to find new ore bodies (Raskin *et al,* 1994). The third group was the excluder, which took up metals but restricts increased concentrations in the shoots until a critical level was reached, above which metal concentrations start to increase in the shoots. In this study, *T. angustifolia* was considered as metal-excluding plants. It could survive in the toxic environment, but the contents of heavy metals accumulated in aboveground tissues were low even though the concentrations in roots might be very high (Wei *et al.*, 2005). The study by Taylor and Crower (1983) suggested that the exclusion of metals from aboveground tissues was the metal tolerant strategy of *T. latifolia*.

Typha angustifolia could use for phytostabilisation purpose; it was one of the phytoremediation techniques, where metal tolerant or accumulating plants might be effective in reducing the mobility of heavy metals within the soil and rendering them harmless. These plant species might increase soil organic matter, which played an important role in immobilizing heavy metals, improving soil structure, increased soil fertility and reduced erosion (Yoon *et al.*, 2006). So phytostabilisation was not exactly the cleaning-up techniques, but more on a management strategy for contaminants stabilizing consequently reducing the risks presented by contaminated soil (Vangronsveld *et al.*, 2009).

More study should be done for investigate the potential of plants in remediation of pollutants. It was suggested that the metal-rich plant tissue (roots) should be harvested in a period of time and replanting it in large amount with continuity. Besides that, it could be inferred that different plants have different effective in removing or accumulating for pollutants, utilizing different types of plants in specific contaminated environment might useful.

CONCLUSION

From the obtained result showed that *Typha angustifolia* was a metal excluder plant species when grown in mine water effluence at ex-Mamut copper mine, Ranau. It accumulated high amount of Fe in the roots but low concentration in aboveground tissues. It could use for phytostabilisation which very useful in revegetation plan for high toxicity areas such as stagnant water areas and bench of the pit.

ACKNOWLEDGEMENT

This research was supported by the Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah. We would also like to thank Department of Minerals and Geosciences, Sabah for the financial support.

REFERENCES

Allen, S. E. 1989. *Analysis of Ecological Materials*, second ed. Blackwell Scientific Publications, Oxford.

Baker, A. J. M. & Brooks, R. R. 1989. Terrestrial Higher Plants which Hyperaccumulator Metallic Elements. A Review of Their Distribution, Ecology and Phytochemistry.*Biorecovery*, **1(2)**: 81-126.

Carranza-Álvarez, C., Alonso-Castro, A. J., Torre, M. C. A. L., & Cruz, R. F. G. L. 2008. Accumulation and Distribution of Heavy Metals in *Scirpusamericanus* and *Typhalatifolia* from an Artificial Lagoon in San Luis Potosi, Mexico. *Water, Air, Soil Pollut*, **188**: 297-309.

Demirezen, D. & Aksoy, A. 2004. Accumulation of Heavy Metals in *Typhaangustifolia* (L.) and *Potamogetonpectinatus* (L.) Living in Siltan Marsh (Kayseri, Turkey). *Chemosphere*, **56**: 685-696.

Gandonou, C. B., Bada, F., Gnancadja, S. L., Abrini, J., & Skali-Senhaji, N. 2011. Effects of NaCl on Na^+, Cl^- and K^+ Ions Accumulation in Two Sugarcane (*Saccharum* sp.) Cultivars Differing in Their Salt Tolerance. *International Journal of Plant Physiology and Biochemistry*, **3(10)**: 155-162.

Ghaly, A. E., Snow, A., & Kamal, M. 2008. Manganese Uptake by Facultative and Obligate Wetland Plants Under Laboratory Conditions. *American Journal of Applied Sciences*, **5(4)**: 392-404.

Kabata-Pendias, A. & Pendias, H. 1984. *Trace Elements in Soils and Plants*. CRC Press, Florida.

Levy, D. B., Redente, E. F., & Uphoff, G. D. 1999. Evaluating the Phytotoxicity of Pb–Zn Tailings to Big Bluesteam (*Andropogon gerardii vitman*) and Switchgrass (*Panicum virgatum* L.). *Soil Sci*, **164**: 363–75.

Raskin, I., Nanda, K. P. B. A., Dushenkov, S., & Salt, D. E. 1994. Bioconcentration of Heavy Metals by Plants. *Current Opinion in Biotechnology*, **5(3)**: 285-290.

Solti, A., Sarvari, E., Toth, B., Basa, B., Levai, L., & Fodor, F. 2011. Cd Affects the Translocation of Some Metals Either Fe-like or Ca-like Way in Poplar. *Plant Physiology and Biochemistry*, **49**: 494-498.

Stoltz, E. & Greger, M. 2002. Accumulation Properties of As, Cd, Cu, Pb and Zn by Four Wetland Plant Species Growing on Submerged Mine Tailings. *Environmental and Experimental Botany*, **47**: 271-280.

Taylor, G. J. & Crower, A. A. 1983. Uptake and Accumulation of Heavy Metals by *Typhalatifolia* in Wetlands of the Sudbury, Ontario Region. *Canadian Journal of Botany*, **61**: 63-73.

Vangronsveld, J., Herzig, R., Weyens, N., Boulet, J., Adriaensen, K., Ruttens, A., Thewys, T., Vassilev, A., Meers, E., Nehnevajova, E., van der Lelie, D., & Mench, M. 2009. Phytoremediation of Contaminated Soils and Groundwater: Lessons from the Field. *Environmental Science and Pollution Research*, **16**: 765-794.

Wei, S. H., Zhou, Q. X., & Wang, X. 2005. Identification of Weed Plants Excluding the Uptake of Heavy Metals. *Environment International*, **31**: 829-834.

Welch, R. M., Norvell, W. A., Schaefer S. C., Shaff, J. E., & Kochian, L. V. 1993. Induction of Iron (III) and Copper(II) Reduction in pea (*Pisumsativum* L.) Roots by Fe and Cu Status: Does the Root-cell Plasmalemma Fe(III)-chelate Reductase Perform a General Role In Regulating Cation Uptake? *Planta*, **190**: 555-561.

Wieteska, E., Zioek, A., & Drzewinska, A. 1996. Extraction as a Method for Preparation of Vegetable Samples for the Determination of Trace Metals by Atomic Absorption Spectrometry. *AnalyticaChimicaActa*, **330**: 251-257.

Yang, X., Feng, Y., He, Z., & Stoffella, P. J. 2005. Molecular Mechanisms of Heavy Metal Hyperaccumulation and Phytoremediation. *Journal of Trace Elements In Medicine Biology*, **18**: 339-353.

Yoon, J., Cao, X. D., Zhou, Q. X., & Ma, L. Q. 2006. Accumulation of Pb, Cu, and Zn in Native Plants Growing on a Contaminated Florida Site. *Science of the Total Environment*, **368**: 456-464.