

HEAVY METALS ACCUMULATION IN PADDY CULTIVATION AREA OF KOMPIPINAN, PAPAR DISTRICT, SABAH

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Abstract: Heavy metals contamination in paddy field was conducted using *Oryza sativa*. Paddy plants and their soil were sampled along seven transverse lines of the paddy field before the harvesting time. The paddy plants were separated into roots, stems, leaves and grains. Metal concentrations of the samples were carried out using ICP-OES Spectrometer machine OPTIMA 5300 DV. Metals enrichment factor and translocation were also measured in this study. The results showed that the plant roots of *Oryza sativa* accumulated relatively large amount of lead, cadmium, chromium and copper, while the stem accumulated large amount of zinc. The correlation test showed that there was a strong correlation of zinc and cadmium concentrations in *Oryza sativa* with the paddy soil. Enrichment factor (EF) showed that lead, cadmium and copper were concentrated in the root of *Oryza sativa*, while chromium and zinc metals were more concentrated in the shoot part. In addition, the translocation factor (TF) showed that *Oryza sativa* was able to transfer zinc and chromium from root to the shoot part of *Oryza sativa*.

Keywords: Heavy metals, *Oryza sativa*, enrichment factor (EF), translocation factor (TF), correlation study.

Introduction

The accumulation of heavy metals in agricultural soils is a growing concern to the public as well as government agencies, due to the food safety issues and potential health risks as it has detrimental effects on soil ecosystems (Resvani and Zaefarian, 2011; McLaughlin and Singh, 1999; Yanez *et al.*, 2002). Heavy metals such as arsenic, cadmium, and mercury, are of primary concern in soil and food contamination, particularly in rice cropping system, because of their toxicity (Reeves and Chaney, 2001). These toxic elements accumulate in the soils and induce a potential contamination on food chain, and endanger the ecosystem safety and human health (Bliznakovska *et al.*, 2013; Reynders *et al.*, 2008).

Sources of heavy metals in soil are mainly from natural occurrence, derived from the parent materials and from human activities (anthropogenic sources). Anthropogenic inputs are associated with industrialization and agricultural activities such as atmospheric deposition, vehicle exhaust, waste incineration, waste disposal, urban effluent, fertilizer application and the traditional application of sewage sludge as the fertilizer in agricultural

land (Yap *et al.*, 2009; Bilos *et al.*, 2001; Hlavay *et al.*, 2001; Koch and Rotard, 2001).

Crops have different abilities to absorb and accumulate metals in their different part, and a wide variation in metal uptake and translocation between plant species and even between cultivars of the same species (Kibria and Alamgir, 2012; Singh *et al.*, 2010; Kurz *et al.*, 1999; Arao and Ac, 2003; Liu *et al.*, 2005; Yu *et al.*, 2006). Plants absorb heavy metals from the subsurface of 25 cm depth zone of the soil where roots of most cereal crops are located (Reena *et al.*, 2011; Ross, 1994; Mico *et al.*, 2007). Once the adsorption of the heavy metals in the soil is saturated, more heavy metals would be distributed in the aqueous phase and the bioavailability of the heavy metals would subsequently be enhanced (Sridhara *et al.*, 2008). Heavy metals in soil with high concentration will increase the potential of being taken up by plants. The pollutants will then be translocated from roots to shoots then to the grains, which are consumed by human population. Toxic metals are mostly geochemically mobile where they are readily taken up by plant roots and translocate to aerial parts (Satarug *et al.*, 2003).

In Asia, rice is the most common crop grown on agricultural land (Saadia and Rashid, 2012). The total area of paddy fields has been estimated as over 1 million hectares and up to 50% of these are well cultured with high production of rice (Sharma *et al.*, 2009). According to Kitagishi and Yamane (1981), the dietary cereal intake, mainly rice by Asian is 574 g/day, which is about half of the total dietary intake. Thus, heavy metals existence in rice may have a large influence on metal intake by the human population. Therefore, this study was conducted to determine the extent of heavy metals (Pb, Cd, Cr, Cu and Zn) uptake by paddy plant (*Oryza sativa*) influenced by agricultural soil.

The selected study area are located 500 meters from the main highway and was chosen because it is close to stone quarrying activities for granite extractions that could potentially be a factor of heavy metal pollution in *Oryza sativa*. Quarrying activities that contribute to the release of heavy metals into the atmosphere can spread to nearby areas through weathering

precipitation over the soil and rice plants (Miclean *et al.*, 2013; Hannah *et al.*, 2009). Selection of the location in this study is also based on the busy main road and transportation activities surroundings the area. Heavy metals from vehicles on the road will enter into the soil and roots of the rice plants through absorption (Lorestani *et al.*, 2011; Kebir and Keltoum, 2011). In addition, farmers in the study area also use fertilizers and pesticides for their crops and these can be one of the factors contributing heavy metals contaminations in that area. Waste and sewage from farmers homes can be one source of emissions of heavy metals into the soil which is then absorbed by the rice plants through the roots (Khaer *et al.*, 2010).

Methodology

Study Area

The paddy fields were located at Kompipinan, Papar district, Sabah near quarries and main highway that link Papar district to Kota



Figure 1: Map of study area located at Kompipinan, Papar distict, Sabah

Table 1: Location of sampling stations for paddy plants and soil sample

| Station No. | Location |
|-------------|----------------------------------|
| 1 | N 05° 42' 08.7" E 115° 57' 15.6" |
| 2 | N 05° 42' 10.6" E 115° 57' 15.0" |
| 3 | N 05° 42' 12.6" E 115° 57' 13.8" |
| 4 | N 05° 42' 12.4" E 115° 57' 13.1" |
| 5 | N 05° 42' 10.6" E 115° 57' 13.8" |
| 6 | N 05° 42' 10.3" E 115° 57' 14.5" |
| 7 | N 05° 42' 08.2" E 115° 57' 15.1" |

Kinabalu, within the area of latitude 05° 42' 08.7" N to 05° 42' 12.6" N and from longitude 115° 57' 15.6" E to 115° 57' 13.8" E. The sampling stations are shown in Figure 1. Seven sampling points within that area were chosen for this study. The exact position and coordinate for each sampling stations are shown in Table 1. Soil samples from the root zone were also taken.

Sample Collection

Random sampling was carried out at the study site and the sampling frequency is three (3) times at each sampling points. The sample collections were analyzed before harvesting time in the paddy field, which a total of twenty-one (21) samples were involved in this study. Acreage of paddy field used for the sampling areas is estimated five (5) acres in total. Each paddy plant was uprooted together with its root, stems, leaves and seed. The soil samples were collected from the surrounding roots of the paddy plant using Ponar Grab sampler at a depth of 0 to 25cm from the soil surface (Machiwa, 2010). The paddy plants and soil samples were inserted into labeled plastic bags and placed on ice while transported to the laboratory, then kept in the refrigerator at 4°C for preservation before analysis.

Sample Preparation

The paddy plants were washed using deionized water to remove residues of impurities, and then separated into the roots, stems, leaves and grains. Each part was cut to smaller sizes

for easier digestion. The grains were finely ground using mortar and pestle to separate the white rice from its husk, and then dried in an oven at 65°C for 24 hours. Soil samples were manually cleaned to remove remnants of roots, stones, twigs and other impurities. The soil samples were then homogenized and dried at room temperature. The dried soil samples were pulverized using mortar and pestle, and sieved to obtain <63µm size.

Digestion

1g dried samples of roots, stems, leaves, seeds from *Oryza sativa* and soil samples were placed into 50ml conical flask. Each parts of the *Oryza sativa* were digested in 10ml of 65% nitric acid solution and heated on a hot plate with temperature of 120°C for 2 hours until it produces clear solution. 1g of soil samples were digested with 10 ml of aqua-regia HNO₃:HCL solution with 3:1 ratio and then heated on a hot plate with 70°C temperature for 4 hours. After cooling the *Oryza sativa* and soil samples were then diluted by 50ml of deionized water and filtered with 45µm size Whatman filter paper. Samples that have been filtered were placed into the polyethylene bottles and kept in 4°C refrigerator until heavy metal analysis were done.

Quantification of Heavy Metals

Heavy metal concentrations were determined using ICP-OES Spectrometer machine OPTIMA 5300 DV for lead, cadmium, chromium, copper and zinc elements. A quality control program was applied which includes duplicate samples, in house reference materials, reagent blanks and certified international reference materials (Ramsey *et al.*, 1987; APHA, 1995; Eaton, 2005). The precision and bias of the chemical analysis was less than 10%.

Enrichment Factor (EF) and Translocation Factor (TF)

Quantification of the enrichment factor and translocation factor are shown in the equation (i) from Lorestani *et al.*, 2011 and equation (ii)

Singh *et al.*, 2010. The value of enrichment factors indicated the mechanism of heavy metals absorption from soil to *Oryza sativa*, however the translocation factor is to examine the transport or transfer of the heavy metals from roots to shoots of *Oryza sativa*. The EF and TF values for heavy metals that were examined in this study are in mg/kg.

$$\text{Enrichment Factor (EF)} = \frac{C_p}{C_s}$$

where: C_p = heavy metal concentration in plant
 C_s = heavy metal concentration in soil (i)

$$\text{Transaction Factor (TF)} = \frac{C_s}{C_r}$$

where: C_s = heavy metal concentration in plants' shoot
 C_r = heavy metal concentration in plants' root (ii)

Results

Concentrations of Heavy Metals in *Oryza sativa*

The mean concentrations of heavy metals in *Oryza sativa* in this study showed that all metals were presence in all parts of the *Oryza sativa* at different levels. Most of the metals concentrated in paddy roots, except for zinc which has the highest concentration in paddy stems as shown in Table 2. Concentrations of cadmium, copper and zinc, except lead, in paddy rice grains were within FAO/WHO (2002) permissible limits for human consumption.

Distribution of chromium in *Oryza sativa* varied, and was in the order of root > leaf > grain > stem (Figure 2). Bhattacharyya *et al.*, (2005) reported a similar result. Chromium concentration was higher in root than the shoot part due to redox reaction that occurs in the plants which causes the movement of chromium from root to the shoot part. In addition, chromium (III) can also react with carboxylic functional groups (-COOH) in plants which prevents the translocation of the metals from root to the shoot, thus the chromium concentration in the shoot part is low (Bhattacharyya *et al.*, 2005).

Copper concentrations varied in descending order from root > grain > leaf > stem (Figure 3). The results obtained in this study were similar to the study conducted by Yap *et al.*, (2009) and Fu *et al.*, (2008). Copper is one of the nutrients needed to process a variety of enzyme activity in plants (Hang *et al.*, 2009). However, the presence of copper metal that exceeded the permissible limits or standards may cause stunted growth of roots and plants (Jiang *et al.*, 2007).

For distribution of zinc concentration, accumulation occurred in descending order of stem > root > grain > leaf (Figure 4). Zinc accumulated in the plant was due to the absorption of the metal by roots from the plants surrounding soil (Jiang *et al.*, 2007). However zinc is an important nutrient required by plants to synthesis proteins, for hormones growth and reproductive processes of plants. Adequate zinc concentration in the leaves of plant is 15 mg/kg

Table 2: Mean concentrations (\pm SD) of metals (mg/kg) in paddy plants and paddy soils

| Metal | Lead (Pb) | Cadmium (Cd) | Chromium (Cr) | Copper (Cu) | Zinc (Zn) |
|-------------------|-----------------|-----------------|-----------------|-----------------|------------------|
| Root | 7.70 \pm 1.27 | 0.38 \pm 0.09 | 5.46 \pm 2.26 | 4.94 \pm 1.03 | 16.08 \pm 1.67 |
| Stem | 0.04 \pm 0.02 | 0.11 \pm 0.06 | 3.26 \pm 1.87 | 0.38 \pm 0.06 | 29.60 \pm 7.04 |
| Leaf | 0.26 \pm 0.14 | 0.11 \pm 0.05 | 4.34 \pm 2.01 | 0.71 \pm 0.18 | 12.40 \pm 2.72 |
| Grain | 2.06 \pm 2.42 | 0.13 \pm 0.08 | 4.12 \pm 3.17 | 0.74 \pm 0.32 | 12.75 \pm 4.42 |
| FAO/WHO Standards | 0.2 | 0.2 | - | 20 | 50 |
| Paddy soils | 8.03 \pm 1.07 | 0.32 \pm 0.40 | 4.16 \pm 0.68 | 6.62 \pm 0.72 | 13.89 \pm 1.63 |

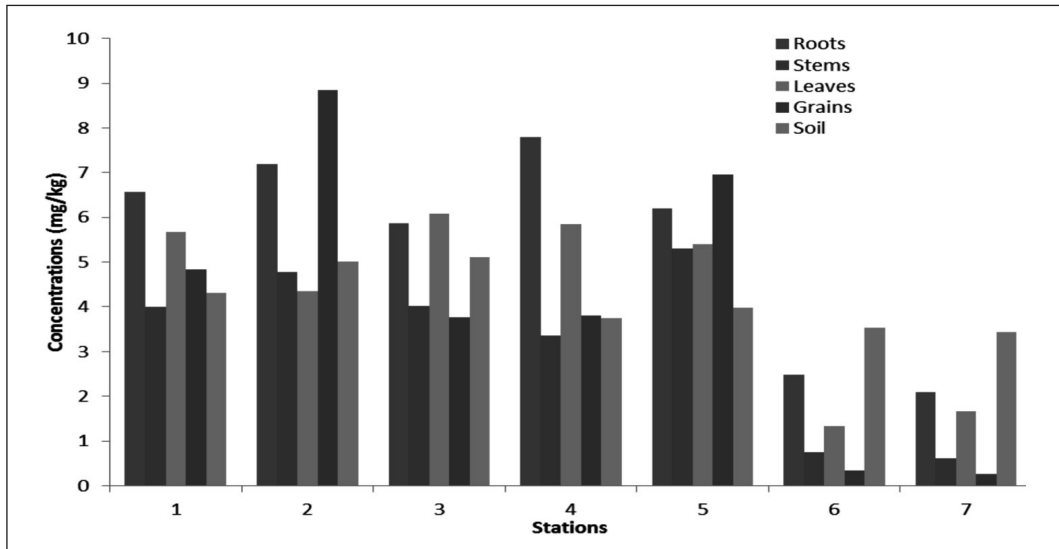


Figure 2: Distribution of chromium (Cr) in *Oryza sativa* and paddy soil

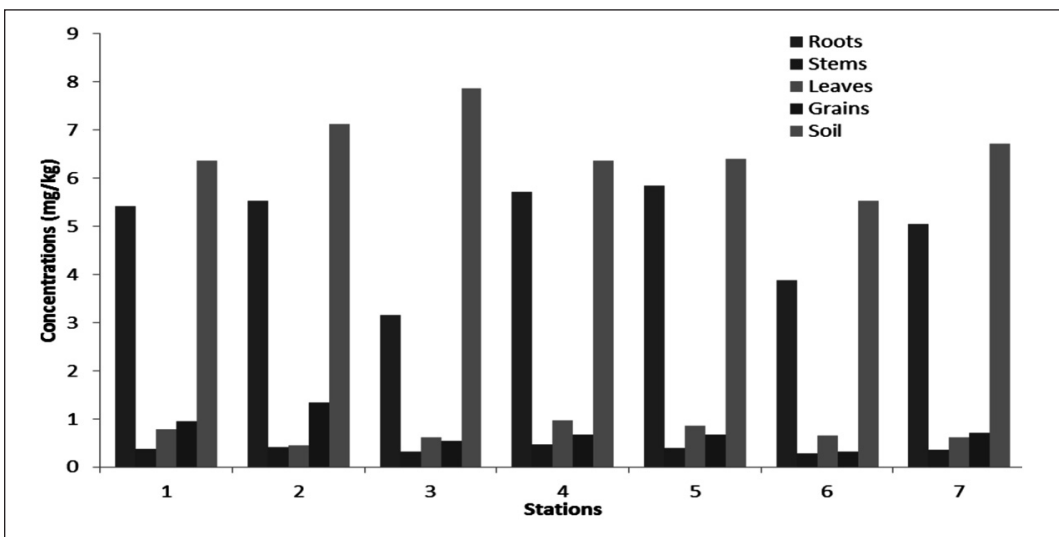


Figure 3: Distribution of copper (Cu) in *Oryza sativa* and paddy soil

to 50 mg/kg. Nevertheless, at levels above 200 mg/kg of zinc will cause toxicity to the plants which can cause the stunted root growth and leaf undersized (Jiang *et al.*, 2007).

Cadmium concentration showed a decreasing pattern from root > grain > leaf > stem (Figure 5). Cadmium is one of the major pollutants produced in the industrial area (Horng *et al.*, 2013). It is easily absorbed and spread to the whole paddy plant and its bioavailable in

the soil. Cadmium metal uniformly dispersed in small concentrations due to the nature of cadmium that is readily absorbed by the plant and dispersed to the other plant parts in spite of its properties that does not carry vital nutrients to animals and humans (Yap *et al.*, 2009). Lead concentrations varied in descending order of root > grain > leaf > stem (Figure 6). According to Li *et al.*, (2007), most of the lead that was absorbed in paddy plant is accumulated highly

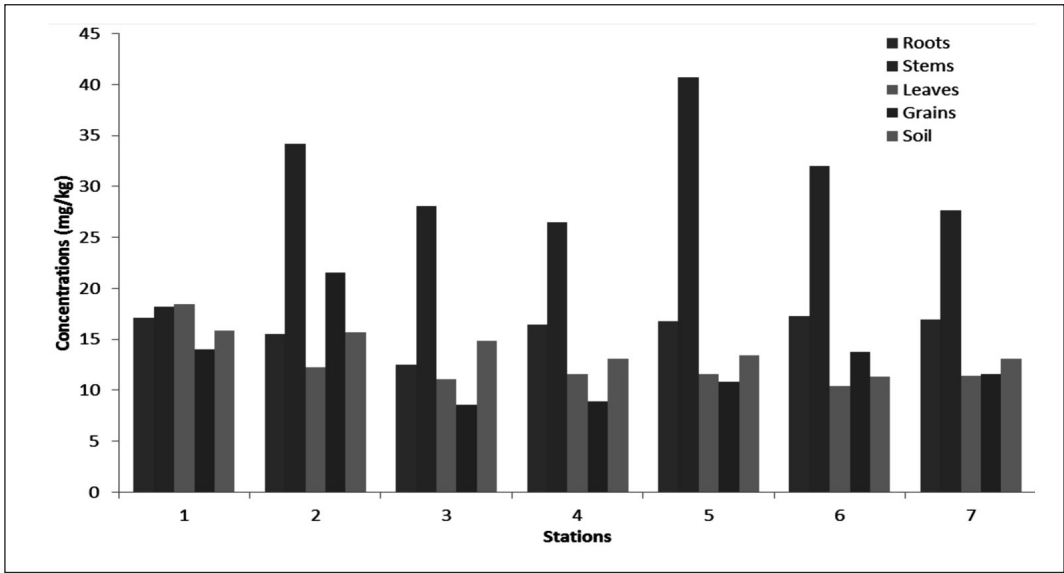


Figure 4: Distribution of zinc (Zn) in *Oryza sativa* and paddy soil

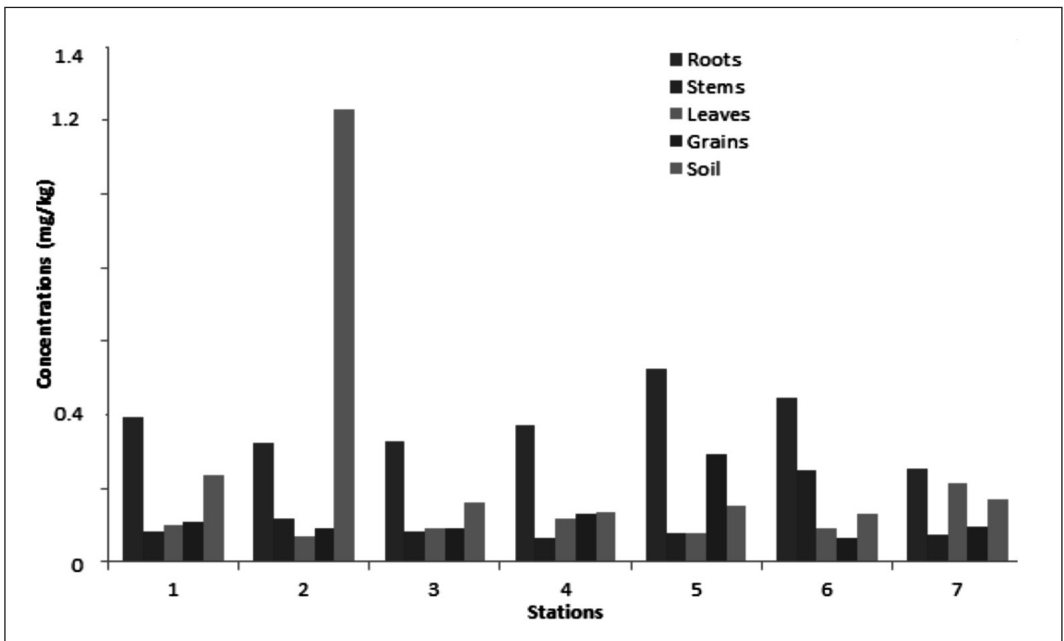


Figure 5: Distribution of cadmium (Cd) in *Oryza sativa* and paddy soil

in roots compared to other parts of the plants. The possibility of lead presence in *Oryza sativa* is believed due from the remnants of quarries and mining activities nearby the agricultural fields (Bliznakovska *et al.*, 2013). The content of heavy metals in the soil also affects the

intake of lead in plants (Kachenko and Singh, 2004). Runoff from the road might also be a major source of lead, which diffused into the soil and subsequently absorbed by plants that grow at the edge of the road (Xuedong *et al.*, 2012).

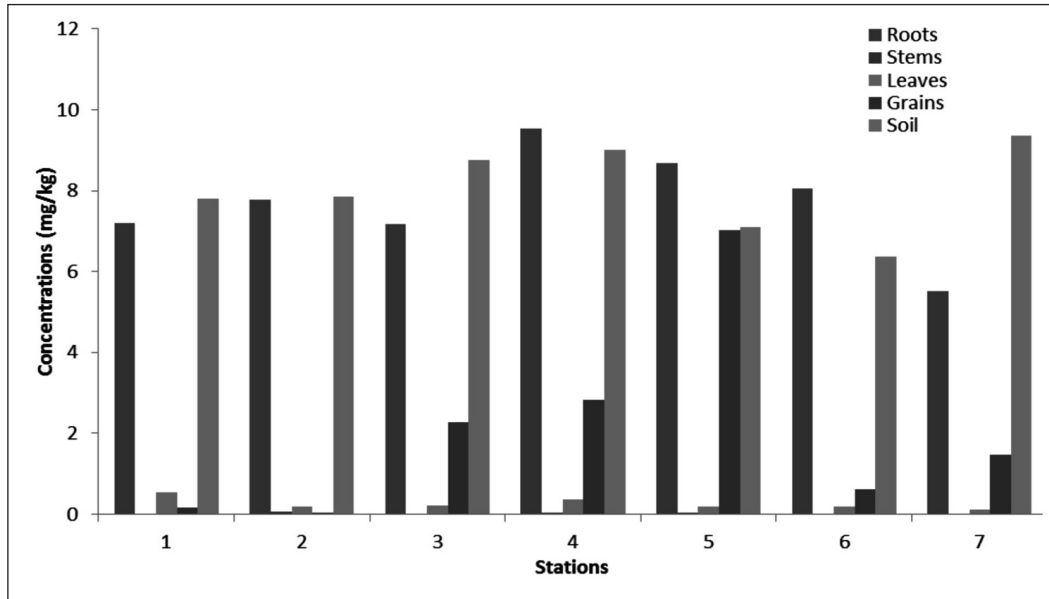


Figure 6: Distribution of lead (Pb) in *Oryza sativa* and paddy soil

Discussion

Concentration of Heavy Metals in Paddy Soil

In this study, chromium concentrations ranged in soil from 3.44 to 5.11 mg/kg. The use of phosphate fertilizers in agriculture activities will increase the chromium metal content in crops as the fertilizer is manufactured from phosphate ore with high content of heavy metals such as chromium, lead and iron (Saadia et al., 2013). Copper concentration in *Oryza sativa* ranged from 5.54 to 7.86 mg/kg. Low level of copper in shoots part of paddy plants might be attributed to low dispersion and bioavailability of this metal in the soil (Fernandes and Fernando, 1990). Zinc concentrations in the soil ranged from 11.36 to 15.82 mg/kg. Zinc is produced in many environments through natural process and released from the earth’s crust (Kennedy and Burlingame, 2003). Cadmium concentrations in the soil ranged from 0.13 to 1.23 mg/kg, while the range for lead concentrations was between 6.37 mg/kg to 9.35 mg/kg. Based on the results obtained, the metal levels in the soil did not exceed the FAO/WHO (2002) permissible limits, except for cadmium and lead.

Enrichment Factor (EF) and Translocation Factor (TF)

The absorption mechanism of heavy metals by *Oryza sativa* can be analyzed using enrichment and translocation factor analysis. Figure 7 shows the enrichment factor of metals from the soil to other parts of *Oryza sativa* which was in decreasing order of Zn (5.16) > Cd (4.12) > Cr (4.00) > Pb (1.28) > Cu (1.03). Based on the results obtained, the enrichment value for all studied metals were greater than 1, which indicates that the *Oryza sativa* is a hyper accumulator plant with high potential to absorb metals from the soil (Lorestani et al., 2011).

Translocation factor for selected metals from the roots to the shoots of *Oryza sativa* is indicated in Figure 8, and the trend showed that metal levels varied in descending order of zinc (3.43) > chromium (1.97) > cadmium (0.94) > copper (0.37) > lead (0.29). The results showed that only zinc and chromium have the translocation factor value greater than 1, which means that *Oryza sativa* was able to hyperaccumulate only zinc and chromium from roots to the shoots (Resvani and Zaefarian, 2011).

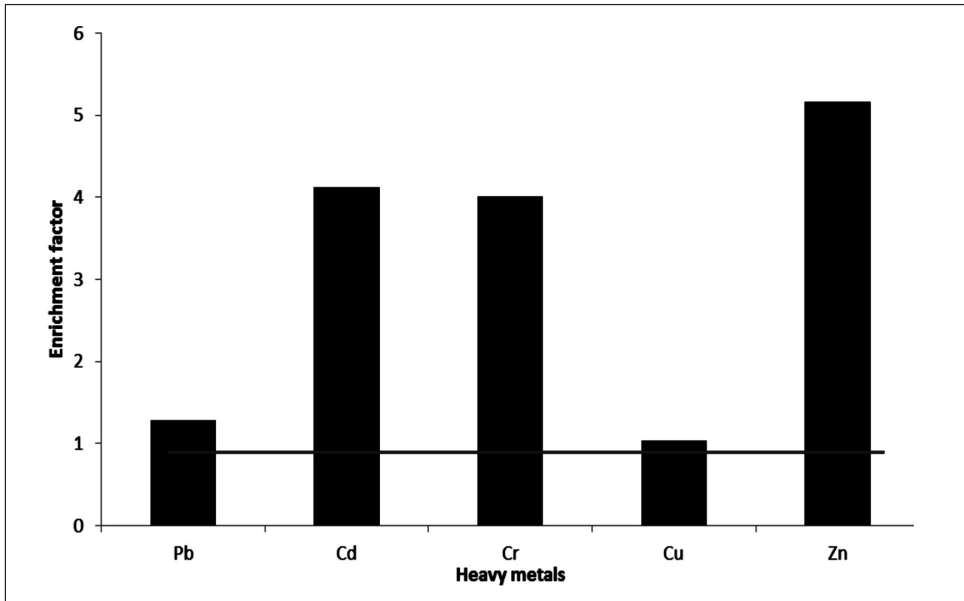


Figure 7: Enrichment factors of heavy metals from paddy soil to *Oryza sativa*

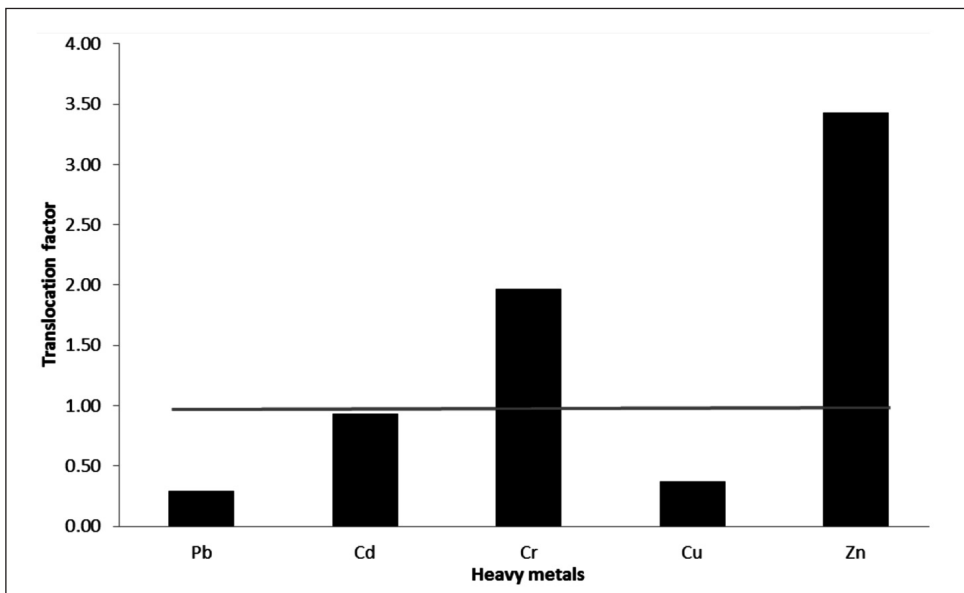


Figure 8: Translocation factor of heavy metals from the roots to shoots of *Oryza sativa*

Statistical Analysis

Correlation analysis ($P < 0.05$) was carried out to study the correlation of metals from *Oryza sativa* parts with the paddy soil. The results obtained show that there were strong

correlations for chromium in roots with stems ($r = 0.87$), leaves ($r = 0.90$) and grains ($r = 0.80$). Similarly, there was strong correlation for chromium in the stems with leaves ($r = 0.85$) and grains ($r = 0.93$). However, for copper, there was no significant correlation between all parts,

except between roots and stems ($r=0.81$). There was a negative correlation between leaves and stems for zinc metal with ($r=0.07$). Cadmium showed a moderate correlation for roots and grains ($r=0.67$). Correlation analysis showed that chromium, lead and copper in *Oryza sativa* did not correlated significantly with the paddy soil. Studies conducted by Horng *et al.*, (2013) indicated that chromium showed no significant correlation between roots and other parts of *Oryza sativa*. However, the chromium concentration showed a significant correlation between the stems, leaves and grains with each other. Miclean *et al.*, (2013) reported a significant correlation for lead, cadmium and copper in plants and its surrounding soil.

According to Horng *et al.*, (2013), the significant relationship between parts of *Oryza sativa* and paddy soil was due to the presence of some residual soil particles in the plants during the analysis, and most of the heavy metals absorbed by plants were derived from the soil.

Conclusion

Heavy metals in this study accumulated abundantly in the root compared to other parts of *Oryza sativa*, except for zinc which showed the highest concentration in the stem. The analysis of enrichment factor showed that lead, cadmium and copper were accumulated more in the root part while chromium and zinc were accumulated more in the shoot part. Each heavy metal was presence in a different concentration in every parts of the plant. The metal content in the *Oryza sativa* and paddy soil in this study does not exceed the permissible standard set by the FAO/WHO except for cadmium and lead. The translocation factor analysis showed that *Oryza sativa* was able to transfer only zinc and chromium metals from the root to the shoot. The heavy metals concentration of paddy plants and soil in this study will provide as a baseline data and there is a need for extensive research, in terms of water quality and air quality monitoring can be added to this field of study.

References

- APHA. (1995). *Standard Methods for the Examination of Water and Wastewater* (20). Washington, D.C: American Public Health.
- Arao, T. & Ac, N. (2003). Genotypic Variations in Cadmium Levels of Rice Grain. *Soil Science and Plant Nutrition*, 49: 473-479.
- Bhattacharyya, P., Chakraborty, A., Chakrabarti, K., Tripathy, S. & Powell, M. A. (2005). Chromium Uptake by Rice and Accumulation in Soil Amended with Municipal Solid Waste Compost. *Chemosphere*, 60: 1481-1486.
- Bilos, C., Colombo, J. C., Skorupka, C. N. & Rodriguez, P. M. J. (2001). Sources, Distribution and Variability of Airborne Trace Metals in La Plata City area, Argentina. *Environmental Pollution*, 111: 149-158.
- Bliznakovska, B., Arsovski, D., Goran, N., Eftimij, H. & Nikola, N. (2013). Assessment of the Agricultural Soils Pollution by Heavy Metals in Probishtip Region, Republic of Macedonia. *Natura Montenegrina*, 7(2): 569-574.
- Eaton, A. D. (2005). *Standard Methods for Examining Water and Wastewater*. (21st Ed.) APHA AWWA WEF. 9-59.
- Fernandes, J. C. & Fernando, S. H. (1990). Heavy Metal Contents of Paddy Fields of Alcacer Do Sal, Portugal. *The Science of the Total Environment*, 90: 89-97.
- FAO/WHO. (2002). Schedule 1 Maximum and Guideline for Contaminants and Toxins in Food. Codex Alimentarius-General Standards for Contaminants and Toxins In food. Joint FAO/WHO Food Standards Programme, Codex Committee, Rotterdam. Reference CX/FAC 02/16
- Fu, J., Zhou, Q., Liu, J., Liu, W., Wang, T., Zhang, Q. & Jiang, G. (2008). High Levels of Heavy Metals in Rice (*Oryza sativa*) from a Typical e-waste Recycling Area in Southeast China and Its Potential Risk to Human Health. *Chemosphere*, 71: 1269-1275.

- Hannah, S., Murray, M. & Harrison, E. (2009). *Sources and Impacts of Contaminants in Soils*. Cornell Waste Management Institute.
- Hang, X., Wang, H., Zhou, J., Ma, C., Du, C. & Chen, X. (2009). Risk Assessment of Potentially Toxic Element Pollution in Soils and Rice (*Oryza Sativa*) in a Typical Area of the Yangtze River Delta. *Environmental Pollution*, 157(8-9): 2542-2549.
- Hlavay, J., Polyak, K. & Weisz, M. (2001). Monitoring of the Natural Environment by Chemical Speciation of Elements in Aerosol and Sediment Samples. *Journal of Environmental Monitoring*, 3: 74-80.
- Hornig, Y. G., Tseng-sen, L., Chian-liang, C., Chi-feng, C. & Paul-Frans, R. (2013). Prediction of Heavy Metal Uptake by Different Rice Species in Paddy Soils Near Contaminated Sites of Taiwan, Taiwan Agricultural Research Institute, Department of Soil Science, The Netherlands.
- Jiang, W., Struik, P. C., Lingna, J., Van-Keulen, H., Ming, Z. & Stomph, T. J. (2007). Uptake and Distribution of Root-applied or Foliar-applied Zinc after Flowering in Aerobic Rice. *Annals of Applied Biology*, 150: 383-391.
- Kachenko, A. & Singh, B. (2004). *Heavy Metals Contamination of Home Grown Vegetables Near Smelters in NSW*. Supersoil 2004: 3rd Australian New Zealand Soils Conference, 5-9 December 2004, University of Sydney, Australia.
- Kebir, T. & Keltoum, B. (2011). Effects of Heavy Metals Pollution in Soil and Plant in the Industrial Area, Algeria. *Journal of the Korean Chemical Society*, 55(6): 231-250.
- Kennedy, G. & Burlingame, B. (2003). Analysis of Food Composition Data on Rice from a Plant Genetic Resources Perspective. *Food Chemistry*, 80(4): 589-596.
- Khaer, M. R. R. A., Syed Mohammad, H. & Akramuzzaman, M. M. (2010). Distribution of Heavy Metals in Rice Plant Cultivated in Industrial Effluent Receiving Soil. *EnvironAsia*, 3(2): 15-19.
- Kibria, M. G. & Alamgir, M. (2012). Influence of Waste Water Irrigation on Heavy Metal Accumulation in Soil & Plant. *International Journal of Applied and Natural Resources*, 71(1): 1269-1275.
- Kitagishi, K. & Yamane, I. (1981). *Heavy Metal Pollution in Soils of Japan*. Tokyo: Japan Scientific Societies Press.
- Koch, M. & Rotard, W. (2001). On the Contribution of Background Sources to the Heavy Metal Content of Municipal Sewage Sludge. *Water Science and Technology*, 43: 67-74.
- Kurz, H., Schulz, R. & Romheld, V. (1999). Selection of Cultivars to Reduce the Concentration of Cadmium and Thallium in Food and Fodder Plants. *Journal of Plant Nutrition and Soil Science*, 162: 323-328.
- Li, J. X., Yang, X. E., He, Z. L., Jilani, H., Sun, C. Y. & Chen, S. M. (2007). Fractionation of Lead in Paddy Soils and Its Bioavailability to Rice Plants. *Geoderma*, 141: 174-180.
- Liu, J. G., Zhu, Q. S., Zhang, Z. J., Xu, J. K., Yang, J. C. & Wrong, M. H. (2005). Variations in Cadmium Accumulation among Rice Cultivars and the Types and the Selection of Cultivars for Reducing Cadmium in the Diet. *Journal of Science and Food Agricultural*, 85: 147-153.
- Lorestani, B., Cheraghi, M. & Yousefi, N. (2011). Accumulation of Pb, Fe, Mn, Cu and Zn in Plants and Choice of Hyperaccumulator Plants in the Industrial Town of Vian, Iran. *Arch. Biol. Sci., Belgrade*, 63(3): 739-745.
- Machiwa, J. F. (2010). Heavy Metal Levels in Paddy Soils and Rice (*Oryza sativa*) from Wetlands of Lake Victoria Basin, Tanzania. *Tanz. J. Sci.*, 36: 1711-1720.
- McLaughlin, M. J. & Singh, B. R. (1999). *Cadmium in Soil and Plants: A Global Perspective. Cadmium in Soils and Plants*. The Netherlands: Kluwer Academic Publishing.
- Mico, C., Peris, M., Recatala, L. & Sanchez, J. (2007). Baseline Valued for Heavy Metal in Agricultural Soils in An European

- Mediterranean Region. *Science Total Environment*, 378: 13-17.
- Miclean, M., Cecilia, R., Erika, L., Marin, S., Bela, A. & Emil, C. (2013). Heavy Metals Availability for Plants in a Mining Area from North-Western Romania, Research Institute for Analytical Instrumentation 67 Donath, Romania.
- Ramsey, M. H., Thompson, M. & Banarjee, E. K. (1987). Realistic Assessment of Analytical Data Quality from Induced Coupled Plasma Atomic Emission Spectrometry. *Analytical Procedure*, 24: 260-265.
- Reena, S., Gautam, N., Mishra, A. & Rajiv, G. (2011). Heavy Metals and Living Systems: An Overview. *Journal of Pharmacology*, 43(3): 246-253.
- Reeves, P. G. & Chaney, R. L. (2001). Mineral Nutrients Status of Female Rats Affects the Absorption and Organ Distribution of Cadmium from Sunflower Kernels (*Helianthus annuus L.*). *Environmental Research*, 85: 215-225.
- Reynders, H., Bervoets, L., Gelders, M., De Coen, W. M. & Blust, R. (2008). Accumulation and Effects of Metals in Caged Carp and Resident Roach along a Metal Pollution Gradient. *Science of Total Environment*, 391: 82-95.
- Rezvani, M. & Zaefarian, F. (2011). Bioaccumulation and Translocation Factors of Cadmium and Lead in *Aeluropus Littoralis*. *Australian Journal of Agricultural Engineering*, 2: 114-119.
- Ross, S. M. (1994). Toxic Metals in Soil-Plant Systems. Chichester: John Wiley and Sons Inc.
- Saadia, R. T. & Nabila, R. (2013). Multivariate Analysis of Metal Levels in Paddy Soil, Rice Plants, and Rice Grains: A Case Study from Shakargarh, Pakistan. *Journal of Chemistry*, 13: 1288-1295.
- Saturug, S., Baker, J. R., Urbenjapol, S., Haswell-Elkins, M., Reilly, P. E. B. & Williams, D. J. (2003). A Global Perspective on Cadmium Pollution and Toxicity in Non-occupational Exposed Population. *Toxicology Letter*, 137: 65-83.
- Sharma, S. K., Sehkon, N. S., Deswal, S. & John, D. (2009). Transport and Fate of Copper in Soils. *International Journal of Civil and Environmental Engineering*, 1(1): 19-39.
- Singh, J., Upadhyay, S. K., Pathak, R. K. & Gupta, V. (2010). Accumulation of Heavy Metals in Soil and Paddy Crop (*Oryza sativa*), Irrigated with Water of Ramgarh Lake, Gorakhpur, UP, India. *Toxicology & Environmental Chemistry*, 93(3): 462-472.
- Sridhara, C. N., Kamala, C. T. & Samuel, S. R. D. (2008). Assessing Risk of Heavy Metals from Consuming Food Grown on Sewage Irrigated Soils and Food Chain Transfer. *Ecotoxicology and Environmental Safety*, 69: 513-524.
- Xuedong, Y., Fan, Z., Chen, Z., Man, Z., Lochan, P. D. & Tandong, Y. (2012). Relationship between Heavy Metal Concentrations in Soils and Grasses of Roadside Farmland in Nepal. *Int Journal Environ Res Public Health*, 9(9): 3209-3226.
- Yanes, L., Ortiz, D., Calderon, J., Batres, L., Carrizales, L. & Mejia, J. (2002). Overview of Human Health and Chemical Mixtures: Problems Facing Developing Countries. *Environmental Health Perspectives*. 110: 901-909.
- Yap, D. W., Adezrian, J., Khairiah, J., Ismail, B. S. & Ahmad-Mahir, R. (2009). The Uptake of Heavy Metals by Paddy Plants (*Oryza sativa*) in Kota Marudu, Sabah, Malaysia. *American-Eurasian Journal Agriculture and Environment Sciences*, 6(1): 16-19.
- Yu, H., Wang, J., Fang, W., Yuan, J. & Yang, Z. (2006). Cadmium Accumulation in Different Rice Cultivars and Screening for Pollution-safe Cultivars of Rice. *Science Total Environment*, 370: 302-309.