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Assessment of Heavy Metals in Agricultural Crops Near Mining Areas in Zambales, Philippines

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ABSTRACT

Agricultural productivity, and food safety and security are among the pressing concerns that continue to permeate and confront an agricultural country like Philippines. This study was conducted to assess and evaluate the heavy metal content of selected rice and vegetable crops near mining areas in Sta. Cruz, Zambales. Physico-chemical characteristics of the soil samples and heavy metal content of the crops were examined and analysed by CRL Laboratory and related to the growth performance of the selected agricultural crops of the study area to ascertain the effects of excess nickel (Ni) and chromium (Cr). Results showed that Ni and Cr concentration on both pre and post-assessments were higher than the accepted standard limit of Food and Agricultural Organization (FAO)/World Health Organization (WHO) and European Union Standards; additionally, the findings of the study revealed significant differences based on *t*-test at alpha level of 0.05. On the other hand, Pearson-r correlation showed a negative correlation between Ni concentration and growth performances of the four vegetable crops. Another statistical treatment was employed and one-way analysis of variance at alpha level of 0.05 showed a significant difference between each growth performance in relation to Ni as well as Cr concentration. Further studies are recommended to be done on reproductively mature vegetable crops and other growth indicators for rice crops, likewise the rehabilitation mechanisms in areas contaminated with heavy metals, particularly in the province.

INTRODUCTION

Food safety and security is a serious issue and unequivocally one of the major concerns of the Millennium Development Goals (MDG) of the United Nations (UN) as well as any country that relies heavily on agricultural sector. Thus, assessment and monitoring of agriculture and agricultural products as well as several factors that affect such productivity are necessary to enhance food safety and security. Agricultural productivity, and food safety and security greatly depend on the soil and water quality. Soil and water are both indispensable environmental factors that may promote or prevent the growth and development of organisms, including humans in an ecosystem. In most cases, an impact on the soil system has a direct impact on water resources.

However, the presence of pollutants on both the environmental factors may hamper the agricultural production which subsequently affects the food safety and security of the country. Several factors such as increasing population, urbanization and industrialization greatly affect the soil and water quality (ADB 2007). On that note, soil and water pollution continue to gain attention, specifically with regard to heavy metal pollution, as these pose a grave threat to our environment.

Metal pollution on soil poses grave danger to our environment mainly due to the increasing amount of metal ions in the soil beyond the accepted standard level. High metal ions in soil causes blockage of some essential functional groups, and additionally it may bind to biomolecules and change its conformation. Metal pollution is a result of several human activities like mining, agriculture, and oil and fuel extraction (Alkorta 2004).

Anthropogenic sources such as mining and smelting, domestic waste and industrial effluent disposal, sewage sludge, and the well documented agrochemical sources decrease both soil and water quality (Guo et al. 2013). Such sources increase intensely the input of heavy metals in the soil and water system which poses threat to the agricultural productivity of farming and fisheries sector. In the same vein, these compromises the soil and water quality and toxicity of plants which subsequently sacrifice the human health due to bioaccumulation (Guo et al. 2013).

In agriculture and health sector, heavy metals pose threat due to their negative effects on the food quality and marketability of the agricultural crops and consequently, the health of consumers (Bacani 2015). Agricultural crops absorb heavy metals, especially when exposed during production, transportation, and promotion from contaminated soil and water (Khanna & Khanna 2011). Furthermore, several studies revealed that agricultural crops such as rice and vegetables continue to acquire heavy metals which eventually become concentrated in the plant body and pose threat to the consuming population (Bacani 2015, Khanna & Khanna 2011, Srinivas et al. 2009, Poniedzialek & Jedrszczyk 2004).

Other studies discovered that both adults and children had ingested a significant amount of heavy metals through eating food crops with accumulated heavy metals (Khan 2007). Heavy metals target soft tissues and organs in human bodies such as kidney, liver and the central nervous system. In addition, the findings of the study revealed that ingestion of heavy metals like nickel causes a vesicular type of hand eczema and type I hypersensitivity response of the body (Orisakwe 2012).

With the current problem about soil pollution, this study focuses on the detection and management of heavy metals in agricultural products, likewise the farmland and river near or on mining areas in Zambales. The results can provide the legislatively useful information to promulgate new laws and strengthen the grasp of old laws in terms of the protection of the agricultural environment. Furthermore, this study will also serve as a basis for future rehabilitation mechanisms.

MATERIALS AND METHODS

Research Design

The researcher utilized an experimental method which is primarily used when research attempts to describe systematically a natural phenomena, mathematical models, experiments and optimization are made. Moreover, it is used to examine a cause and effect relationship as well as to find solutions for the future in a controlled laboratory environment (Human Supervisory Control 2004). Thus, such method was deemed appropriate in the research study.

Research locale: Zambales is a province in Region III with the municipality of Iba as its capital. It is located between the coordinates of 15.333 N and 120.167 E. Sta. Cruz, one of the mountainous municipalities is classified as a first class municipality with 25 barangays, which houses a large amount of mineral ores that are presently being excavated by mining companies (Figs. 1 and 2).

Crops and soils were taken from three study sites near the mining areas. Soil and rice crop samples were taken from Brgy. Tubo-Tubo North and Brgy. Lomboy, while soil samples and vegetable crops were taken from Brgy. Guinabon.

Characterization of the Study Area

Collection of soil samples: Surface soil samples have been gathered from contaminated soil from the three barangays in Sta. Cruz, Zambales. Samples were collected from the soil surface (0-5 cm) and at a depth of approximately 20 cm using trowels and shovels. Composite sampling was employed. The collected samples were placed in sterilized polyethylene bags and stored at 4°C to preserve the contents and concentration of the soil samples for further analysis in the laboratory.

Physico-chemical examination of soil samples: Soil from each barangay was mixed, quartered and dried for two weeks. Collected soil samples were sent to the CRL Laboratory Testing Centre in Pampanga for further examination of the soil pH, electric conductivity, nutrient content, and its chemical components such as nickel and chromium constituents through Flame Atomic Absorption Spectrophotometry (FAAS). The colour and type of the soil sediment were identified and determined using Standard Soil Colour Chart (Munsel Color System 2013). 100 grams of soil samples were sent to the Bureau of Soils in Iba, Zambales for the assessment of the nutrient content such as nitrogen, potassium and phosphate.

Crop Sampling and Analysis

Collection of rice and vegetable samples: Composite sampling was also employed in the collection of rice samples. Samples of rice plant bodies and rice grains have been collected from the areas where the five-point sampling of soil samples were collected and collated together each from Brgy. Tubo-Tubo North and Brgy. Lomboy in an attempt to determine whether the rice and soil samples collected correlates in terms with the presence of heavy metals from field near mining areas in Sta. Cruz, Zambales.

Four common vegetable crops were collected in Brgy. Guinabon which are *Solanum lycopersicum* L. (tomato), *Solanum melongena* L. (eggplant), *Abelmoschus esculentus* L. (lady's finger) and *Ipomoea batatas* L. (Kamote) to determine whether the vegetable crops and soil samples correlate with the presence of heavy metals.

Samples were then placed in sterilized polyethylene bags and stored at 4°C to preserve the contents and concentration for further analysis.

Characterization of rice and vegetable samples: Vegetable plant heights and root lengths were measured in millimetre with the use of a ruler, while stem diameter was measured by vernier calliper. Color of the leaves for the rice and vegetable samples was compared to a Leaf Color Chart.

Crop Analysis

Rice, rice grains and vegetable samples were washed first with tap water, then deionized water to remove debris and ions on the plant body and oven dried at 80°C for 48 hours. Samples were ground without any chemical treatment using mortar and pestle to ensure homogeneity. Powdered rice samples were sent to CRL Laboratory Testing Centre in Pampanga for extraction and further analysis with the use of Flame Atomic Absorption Spectrophotometer (Nouri et al. 2009).

Statistical Treatment

To interpret the data effectively, the researcher employed weighted mean, *t*-test, Pearson r Coefficient and Analysis of Variance, all at $\alpha = 0.05$. The researcher made use of SPSS, a statistical software program in data processing.

RESULTS AND DISCUSSION

The study assessed the heavy metal content of selected rice and vegetable crops on soils from mining areas in Sta. Cruz, Zambales. The gathered soils were analysed for their physical and chemical properties before and after planting method. Furthermore, plants were also analysed for their absorption capabilities of nickel and chromium present in the soil samples.

Physico-chemical characteristics of the soils of the study area: The morphological and chemical characteristics of the soil samples were assessed during the rice and the vegetable planting method as well as rice harvesting season where the plants were removed from the soil. Table 1 presents the characteristics of the rice soil samples from Brgy. Tubo-Tubo North and Brgy. Lomboy respectively, while Table 2 presents the vegetable soil characteristics in Brgy. Guinabon.

Table 1 shows that the soil samples obtained from Brgy. Tubo-Tubo North and Brgy. Lomboy have reddish brown coloration for both 1st and 2nd sampling as well as in Brgy Guinabon (Table 2). All soil samples from the three study areas were classified as clay type since the particle size of the soil is below 0.1 mm (Thompson & Turk 2012).

Variations in pH during the study might be due to exposure of the soils to various kinds of pollutants. This is a viable factor in the increase of heavy metals in plants, because it affects the proton secretion of plant roots as these release H^+ molecules in the soil when more cations are absorbed to keep the ionic balance, leading to a decrease in pH. Similarly, when more OH^- ions are released by the plant roots, pH in the soil increases (Fageria 2012). With that said, soils with low pH induce an increase in heavy metal mobility and solubility in the soil solution (van Herk 2012). Thus, the pH 6.4 to 6.6 of soil samples from the three barangays had possibly promoted the rise of Ni and Cr in vegetable crops. Therefore, the slightly acidic pH of the sampling sites can possibly promote the uptake of heavy metals in *O. sativa* L. (rice), *S. lycopersicum* L. (tomato), *S. melongena* L. (egg plant), *A. esculentus* (lady's finger), and *I. batatas* L. (Kamote).

Table 1: Physico-chemical characteristics of soil from Brgy. Tubo-Tubo North and Brgy. Lomboy, Sta. Cruz.

	Parameters							
	Colour	Odour	Sediment Type	pH	Temperature (°C)	Basic Nutrients N	P	K
1st Sampling								
Brgy. Tubo-Tubo N.	Reddish brown	None	Clay	6.90	23.0	S	S	S
Brgy. Lomboy	Reddish brown	None	Clay	6.09	23.4	S	S	S
2nd Sampling								
Brgy. Tubo-Tubo	Reddish brown	None	Clay	6.40	24.0	S	S	S
Brgy. Lomboy	Reddish brown	None	Clay	6.00	25.6	S	S	S

S for Sufficient

Table 2: Characteristics of soil from mining areas in Brgy. Guinabon, Sta. Cruz.

Parameters									
Colour	Odour	Sediment Type	pH	Specific Conductivity (µS/cm)	Nickel concentration (mg/kg)	Chromium concentration (mg/kg)	Basic Nutrients N	P	K
Reddish brown	None	Clay	6.6	39	13.940	3.060	S	S	S
Standard Limit					50[b]-75[a]	100[b]-150[a]			

[a] based on European Union Standard of 2002; [b] based on World Health Organization/Food and Agriculture Organizations of the United Nations of 2001; S for sufficient.

Based on the accomplished soil analysis, all study areas for rice samples (Table 1) do not have varying temperatures ranging from 23°C to 25.6°C, whereas the toxicity of heavy metals present in soil increases in low temperature (Akande et al. 2006).

Another soil characteristic is the specific conductivity which is equivalent to the amount of solutes present in the soil that may promote or hinder heavy metal uptake (FAO 2001, Nouri et al. 2008). Based on Table 1, the 39 µS/ cm specific conductivity is not high which signifies that there is a low concentration of solutes in the soil, hence the soil is classified as non-saline which has a negligible effect on crops (FAO 2001).

Table 2 shows that the Ni and Cr concentrations of the soil samples are 13,940 mg/kg and 3,064 mg/kg of soil respectively. However, the yielded result is alarming since the standard limit for agricultural soil based on WHO/FAO of 2001 and European Union Standard of 2002 should only be between 50 mg and 75 mg of Ni, and 100 mg and 150 mg of Cr per kilogram of soil, respectively (WHO/ FAO 2001, Nouri et al. 2008, Nagajyoti 2010). On that note, the said soil samples are unfit to become an agricultural land because of the presence of huge amount of heavy metals, which may be absorbed and stored by plants in their edible parts and would consequently affect the consumers of plants (van Herk 2012).

Furthermore, soil basic nutrients such as nitrogen (N), phosphorus (P) and potassium (K) are all sufficient to support the rice and vegetable crops based on the results of the soil analysis completed by the Bureau of Soils in Iba, Zambales.

Heavy metal content of soil and crop samples: Table 3 presents the characteristics and the standard limit of the soil samples, rice plant and rice grains from the two sampling sites after the pre and post-heavy metal analysis.

Moreover, Table 3 also shows that the concentrations of Ni and Cr from both the areas where rice samples were obtained exceeded the standard limit for agricultural soil based on the World Health Organization/Food and Agriculture Organization 2001 making the soil unfit for agricultural use in spite of the acceptable concentrations of lead. In addition, it can be observed that the concentrations of heavy metals obtained at Brgy. Lomboy are comparably higher than the samples obtained from Brgy. Tubo-Tubo North.

Table 3: Heavy metal concentrations in soil, rice and grain samples.

	Pre and Post-reading of soils and rice crops					
	Soil Samples		Rice Plant Samples		Rice Grain Samples	
	Ni (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Cr (mg/kg)
Pre-Sampling						
Brgy. Tubo-Tubo North	3.230	797				
Brgy. Lomboy	5.670	1.390				
Post-Sampling						
Brgy. Tubo-Tubo North	2.370	783	208	107	9	31
Brgy. Lomboy	3.090	1.170	273	277	47	40
Standard Limit	50[b]-75[a]	100[b]-150[a]	50[b]-75[a]	100[b]-150[a]	67[a]	0.5[a]

[a] based on European Union Standard of 2002; [b] based on World Health Organization/Food and Agriculture Organizations of the United Nations of 2001

Table 4: Nickel and chromium composition of mining soils and selected vegetable crops.

	Pre and post-reading of soils and vegetable crops					
	Soil samples				Vegetable samples	
	Pre-Reading		Post-Reading		Post-Reading	
	Ni (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Cr (mg/kg)
S. lycopersicum	13.940	3.060	10.900	2.250	551	164
S. melongena			11.400	1.920	216	50
A. esculentus			10.500	1.440	848	110
I. batatas			11.800	2.480	203	58
Standard Limit	50[b]-75[a]	100[b]-150[a]	50[b]-75[a]	100[b]-150[a]	67[a]	0.5[a]

[a] based on European Union Standard of 2002.
[b] based on World Health Organization/ Food and Agriculture Organizations of the United Nations of 2001.

This can be attributed to the low elevation of the study area which makes it a catch basin of the mineral effluents from the nearby water sources probably contaminated by heavy metals from the mining areas.

Table 3 further shows that the concentrations of Ni and Cr in rice plant samples and rice grains, especially Cr, were all above the WHO/ FAO and European Union Standard for maximum allowable heavy metal concentration in plants and foods. These results are alarming since excessive amount of these metals produces cellular and tissue damage, hence leads to a variety of adverse effects and diseases to the consuming humans (Patlolla et al. 2014).

Table 4 presents the characteristics of the soil samples and the four vegetable crops obtained from Brgy. Guinabon, the pre and post-heavy metal analyses, and the standard limit of each. Readings of soil for Ni and Cr prior to planting were 13,940 mg/kg and 3,060 mg/kg, which are higher than the required standards of FAO and WHO.

Table 4 further shows that the pre and post-readings of *A. esculentus* (lady's finger) soil has the highest decrease both in Ni and Cr concentrations, while *I. batatas* (Kamote) soil has the lowest decline for these heavy metals. Accordingly, the result is congruent with the low Ni and Cr content in *I. Batatas* and the hyper accumulation of *A. esculentus* of Ni and Cr in its body. All this could be attributed to the growth performances of individual vegetable crops.

Moreover, there is a significant difference between the amount of Ni in the soil as well as with Cr in the soil prior to planting and after harvesting with 99.8% noticeable decrease in the amount of Ni and 98.1% decrease in the Cr amount among the four vegetable crops based on *t*-tests at $\alpha = 0.05$. However, the amounts of Ni and Cr in mg/kg are still at an alarming high which is 10 to 20-fold higher than the standard limit for Ni and Cr.

In the same vein, it was found that the heavy metal concentration in the vegetable crops was higher than the standard limits likewise the heavy metal concentration of the soil which renders it unfit for planting of crops.

Growth performance of the selected vegetable crops: Fig. 3 shows that all the vegetable crops have grown until they were collected for chemical analyses. Fig. 3 further shows that in terms of mean height, *I. batatas* showed higher mean height with *A. esculentus* having the shortest height increase. However, in terms of root length, *S. lycopersicum* has the longest roots followed by *S. melongena*, while *I. batatas* and *A. esculentus* have almost the same root lengths.

Based on one way analysis of variance at $\alpha = 0.05$, one vegetable crop is significantly different in relation with Ni and Cr content of the different vegetable crops, both for plant height and root length. Moreover, post-hoc tests at $\alpha = 0.05$ for root length showed that all the four crops are significantly different except for *I. batatas* and *A. esculentus.*

In connection, *A. esculentus* has the highest amount of Ni and Cr content in the body, while *I. batatas* has the lowest Ni and Cr content (Table 4). Therefore, it can be observed that higher the amount of Ni and Cr in the vegetable crop, the shorter is its height through time, which could be attributed to the fact that the high amount of Ni and Cr in the body of *A. esculentus* had become toxic to the plant causing a retardation of its height.

The researcher employed Pearson-r Correlation to test whether there is a relationship between the variables and strength of the linear relationship. The results yielded a negative correlation at $\alpha = 0.05$ between the mean heights of the plants and the Ni content in their bodies with the value of $p = -0.412$. In addition, findings of the study revealed a negative correlation between the root length of the plants and the Ni content which implies that as the Ni concentration in the body of the plant increases, there is a decrease in the height and root length of the vegetable crop. Despite the fact that the other characteristics of the soil were in the accepted limit, especially the nutrient content, the increase of Ni and Cr content in the body of the plant continued to affect the decline in height and increase in root length of the crops.

Plant leaf coloration as consequence of heavy metal uptake: During the course of the research, changes in leaf color were observed which denote possible effects of Ni and Cr on selected rice and vegetable crops. Changes in coloration and state were noticeable during the latter days of the vegetable crops in comparison with the premature stage of the plant.

Based on Fig. 4, presented for the four vegetable crops, it can be concluded that the leaves change in color from green to yellow to brown as well as white for *S. lycopersicum* (A.2). Furthermore, color changes were seen in sequence of yellow to violet to brown which shows that the leaves and their chloroplast disintegrate as shown by necrosis which is likewise seen on the margins and some parts of the leaves of the four crops. Dark spots are seen on both primary and secondary veins of the leaves.

The yellowish color of the rice leaves coupled with necrosis is prevalent in all the plants during the 1^{st} and 2^{nd} sampling, which is far from the standard green or dark green colour of leaf and suggests a deficiency in the uptake of N, P, K needed for plant growth.

The basic nutrients such as nitrogen, phosphorus and potassium are necessary and sufficient for the plants as given

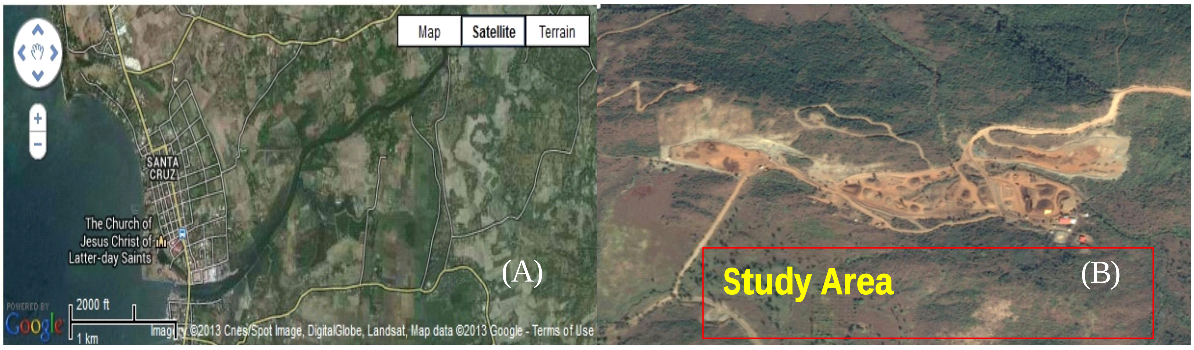

Fig. 1: (A) Satellite map of the municipality of Sta. Cruz and (B) Map showing the mining area in Sta. Cruz, Zambales.

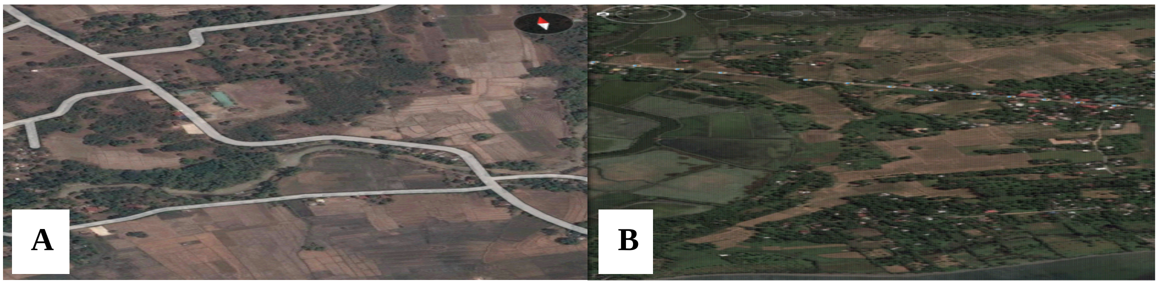

Fig. 2: Satellite map of (A) Barangay Tubo-Tubo North and (B) Barangay Lomboy Sitio Almasin in Sta. Cruz, Zambales.

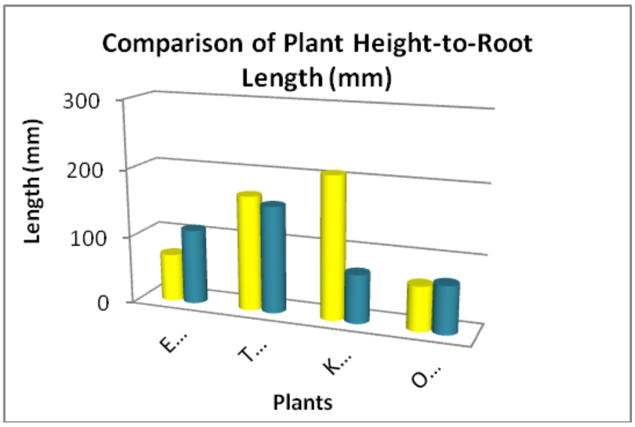

Fig. 3: Height and rootl ength performances of the vegetable crops on soil samples.

in Table 2. With that said, there are other soil factors observed that contribute to the changes in leaf coloration of the vegetable crops such as the high concentrations of Cr and Ni.

The inconsistency of the results implies that the concentration of heavy metals present in the soil inhibits the rice plant from taking the macro elements as observed through the two mechanisms. These include the following: (i) similarities in the nutrient cations which result from the

Fig. 4: Leaf colouration of *S. melongena* (A.1), *S. lycopersicum* (A.2), *I. batatas* (A.3) and *A. esculentus* (A.4).

competition for absorption at root surface evident in the Table 3 and Table 1, where the heavy metals competed with N, P, K and were absorbed more by the plant due to the soil pH which facilitates the heavy metals' mobility and solubility; and (ii) generation of reactive oxygen species (ROS) due to interaction of heavy metals with electron transport activities, particularly in the chloroplast resulting in oxidative stress in plants causing cell death which is evident in the presence of necrosis on the yellowed leaves of the rice plant (Singh 2015, Ryter et al. 2007).

Nickel is a heavy metal essential for both plants and animals in low concentration as it enhances the production of lipids in cell membrane (Shah et al. 2013). However, high amount of Ni in soil and plants poses a threat to the health of the plants because it causes toxicity to the crop and alters the physiological processes of the plant. Excessive Ni concentration causes chlorosis or yellowing of leaves as well as necrosis or death of leaf tissue due to disturbance in the proper function of cell membranes. In the same vein, it causes ion imbalance that may lead to problems in movement of water, consequently wilting and necrosis (Nagajyoti et al. 2010).

Chromium is considered toxic to plants especially if it exceeds 100 µg/kg levels of concentration in soil. It activates the activity of protease in plants thus, impeding germination. Add to that is the fact that chromium affects photosynthesis by influencing the enzymes in electron transport chain, Calvin cycle, and the disorganization of chloroplast. Moreover, chromium also induces alteration of pigments being produced as well as increase in metabolite production such as glutathione which causes yellow to white coloration in the leaves (Table 3). Another thing that chromium greatly affects is the development of root length (Nagajyoti et al. 2010). Poniedzialek et al. (2005) espoused that this is due to the fact that chromium has a heavy atomic mass compared to other heavy metals thus, rendering it immobile in soil or clings at the root surface where it is accumulated hundred times more than the shoot causing retardation of root length.

CONCLUSION AND RECOMMENDATIONS

The agricultural soils in the three Barangays in Sta. Cruz, Zambales are no longer fit for agricultural use due to the high concentration of heavy metals, nickel and chromium, making them unproductive and incapable to sustain plant growth. Based on the quantitative data gathered, the heavy metal concentration in these agricultural soils has exceeded the allowable heavy metal concentrations proposed by the World Health Organization (WHO)/ Food and Agriculture Organization (FAO) and European Union Standard.

The soil samples are reddish to brown clay with 6.4 to 6.9 pH and specific conductivity of 0.000039 dS/cm with sufficient amounts of N, P, K, which promotes the uptake, and growth of the crops. Furthermore, findings of the study revealed that there is a significant difference between the pre and post-reading of Ni and Cr concentration in the soil based on *t*-test at $\alpha = 0.05$.

Although the concentration of N, P and K is sufficient, the excess concentration of heavy metals inhibited crop growth because of competition. Furthermore, Ni and Cr concentrations in rice plants, rice grains and vegetables crops have exceeded the recommended limit of WHO/FAO and European Union Standards except for Ni in rice grains, but may still cause certain diseases to the consumers.

Among the four crops, *I. batatas* (kamote) showed higher mean height and *S. lycopersicum* (tomato) showed longest root length, while *A. esculentus* (lady's finger) being the least among all growth performance factors. Furthermore, all rice and vegetable crops showed changes in leaf coloration observed in sequence of yellow to violet to brown, which shows that the leaves are undergoing necrosis. Dark spots are seen on both the primary and secondary veins of the leaves. The decrease in growth performance could be attributed to increased amounts of Ni and Cr in the plant body since the N, P and K are all in sufficient amounts. Furthermore, there is a negative correlation between the Ni concentration and plant height and root length.

Nickel and chromium are heavy metals essential to plants, but their excessive amounts might cause retardation in their growth performance, which leads to their death, since both heavy metals alter the metabolic processes of plants and composition of cellular membranes of cells and cellular organelles.

Considerations on other heavy metals excavated in the province as well as the phytoremediating capabilities of reproductively mature vegetable crops, ornamental plants and forestry trees are advised. Simply put, rehabilitation and mitigation activities are highly encouraged.

RECOMMENDATIONS

In view of the findings of the study, the following recommendations are proposed:

1. Heavy metals such as copper, iron, manganese and others that are excavated in the province should also be considered for examination as they may also pose a threat to major crops planted in the area.
2. The concentration of each heavy metal per plant per pot and soils per plant per plot are also recommended to be further analysed to fill the dearth in research. This would provide immense help to the stakeholders in maintaining the food safety and security.
3. The study recommends people to continue to be vigilant and scrutinize carefully the vegetable crops sold at the markets and likewise consumed to ascertain that these crops were not planted in parcels of land with heavy metal concentration.

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