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# HEAVY METAL CONCENTRATION IN WATER, SOIL AND VEGETABLE IN EX-MINING PONDS, JOS SOUTH L.G.A PLATEAU STATE, NIGERIA

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## ABSTRACT

Metal mining contributes to environmental pollution through heavy metals exhumed to soil surface. Heavy metals are natural components of the lithosphere which cannot be degraded when they enter the ecosystem resulting in geo-accumulation and bioaccumulation. This study assessed the concentration of heavy metals (Cu, Cr, Mn, Cd, and Fe) in ex-mining pond, soil and vegetables (cabbage and tomatoes) in Jos South L.G.A. of Plateau State. Water sample taken from the pond for irrigation of vegetables were analyzed for the presence of heavy metals using Atomic Absorbance Spectra (AAS) model No: AA320N. The result showed that all the selected metals were detected in the water sample except cadmium and were within WHO permissible limit. Selected heavy metals were detected in the soil within the range of 0.001-216.50 ppm.

## Introduction:

Metal contamination in abandoned mining sites is a global environmental problem which affects industrialized and developing countries of the world. Uncontrolled and illegal activity in developing countries have generated a lot of environmental hazards and waste (Atafar *et al.*, 2010). Mining of metal ore is one of the largest sources of heavy metal contamination in soil after sewage sludge (Fazekašová and Fazekaš, 2020) and they cause aquatic and terrestrial environmental pollution (Nouri *et al.*, 2012). These metals may be leached from soils to reach ground

Chromium was within WHO limit while Cu, Cd, Mn, Pb and Fe were above WHO limit. Tomato sample concentration ranged from 0.131-3.299 ppm but chromium and cadmium were not detected while Mn, Pb and Fe were above WHO permissible limit. In Cabbage, all heavy metals were detected except chromium and the concentration of the heavy metals were within 0.006-1.900 ppm. Mn, Pb, Cd and Fe were above WHO limit except for Cu. The concentration of heavy metals in the soil was higher than in water sample. Continuous use of mining water for irrigating farmland can result in accumulation of the heavy metals in plants.

**Keywords:** AAS, Heavy metals, Pond, Vegetables, Soil, Water.

Water or may be taken up by plants including agricultural crops (Atafar *et al*., 2010).

Regular consumption of vegetables can render health benefits by preventing disease occurrence and supporting disease treatments (Mercola, 2014). Plants are capable of using metals through different ways such as complexing them in their sedentary nature, binding them into cell wall, and/or combining them to produce certain organic acid or proteins (Galfati *et al*, 2011). Therefore, plant species are considered as good bio-indicators in the early stages of heavy metal pollution.

Heavy metal is defined as any dense molecular weight metal or metalloid with atomic number above 20 and atomic density greater than 5 gcm$^{-3}$ noted for its potential toxicity especially in the environmental context (Srivastava & Goyal, 2010). Depending on the nature of soil, and other environmental factors, the amount of metallic elements in plants is a measure of the level of the metal in the environment in which the plants grow over a period of time (Ahmed *et al*., 2012). The toxic heavy metals entering the ecosystem may lead to geo-accumulation and bioaccumulation (Lokeshappa *et al*., 2012). Heavy metals may enter food chain as a result of their uptake by edible plants, thus the determination of heavy metals in environmental samples is very important (Daniel *et al*., 2014). This study assessed the effect of mining activities on the concentration of some heavy metals (Cd, Cr, Cu, Mn, Fe, Pb) in the pond water, soil and vegetables (cabbage and tomatoes) using Atomic Absorption Spectrophotometer (AAS) with model number: AA320N.

Mining is the extraction of valuable minerals or other geological materials from the earth, usually from an ore body, lode, vein, seam, reef or placer deposit (Elijah *et al*., 2020. Tin mining is the most common ore mining activity taking place in Jos, Plateau. The tin ore itself is a radioactive mineral that contains Zircon, Monazite, Xenotime and Thorite (Ibeanu, 2003). These are uranium, thorium and heavy metal bearing minerals. Heavy metals associated with tin mine tailings include: Zn, Pb, Cu, Sn, and Ni. These metals are toxic to plants and animals when their concentration in farm soil surface and underground water is more than their natural distribution in these geological formations (Olarinoye *et al*., 2021).

## MATERIALS AND METHOD

### Study Area

The study site is located in Jos South Local Government area of Plateau state with latitudes $9^oE$ to $10^oN$ and longitude $8^o30$, E. It is situated at the North Western part of Plateau State with its Headquarter in Bukuru, which is about 15 km from the state capital Jos. It has a total land area of about 1,037 $Km^2$ and a population of 301,096 at the 2011 national population census.

### Sampling

Exactly 100 g of the soil sample was collected from the farm land irrigated with water from the ex-mining pond within the depth of about 0-15 cm and placed in a labeled polyethylene bag. The water from the ex-mining pond was sampled by using a 1 litre capacity plastic container that was previously rinsed with distilled water and dilute nitric acid after which it was labeled properly. The vegetables (cabbage and tomatoes) were sampled randomly in the farm land using stainless knife and was put in a polyethylene bag and labeled accordingly.

### Sample Pre-Treatment

The soil sample was air dried in the laboratory, grounded with mortar and pestle and was sieved with a 2 mm mesh and stored in a labeled polyethene bag prior to analysis. The water sample collected was taken to the laboratory for preservation after addition of few drops of concentrated nitric acid ($HNO_3$) to prevent microbial attack, precipitation and adsorption of the metal to container. While the harvested cabbage and tomatoes were washed with distilled water and then cut with stainless steel knife and was oven dried at $35^oC$ until stable weight was obtained. It was then grounded in a mortar and sieved and kept until needed.

### Determination of Water pH

About 50 mL of the water sample was placed in a 100 mL beaker and the pH was measured by introducing a glass probe of the pH meter into the water sample and the readings taken and recorded.

### Determination of Soil pH

Exactly 1.0 g of soil sample was weighed and 20 mL of distilled water was added, the suspension was stirred several times with glass rod. The soil suspension was allowed to stand for 30mins. The electrode was calibrated by using buffer solution (standard buffer solution pH 7.0 and 4.0) the electrode of the pH was inserted into the partly settled suspension and the pH was measured.

### Digestion of the Soil Sample and Treatment of Water Sample

Exactly 1.0 g of the soil sample was digested with 12 mL of aqua-regia ($HNO_3$: HCl) to the ratio 3:1 in a pyrex beaker and heated on a hot plate at a temperature 110°C for 3 hours and was evaporated to dryness. The digested sample was further diluted with 20 mL of 2% $HNO_3$, and was filtered using Whatman No.42 filter paper and was then transferred into a 50 mL volumetric flask. Distilled water was added to the mark level and was kept until needed.

### Digestion of the Vegetable Samples

About 1.0 g of vegetable sample was digested with 24 mL of 80% aqua-regia and 5 mL of 30% $H_2O_2$ in a 100 mL pyrex beaker at 80°C on a hot plate until a clear solution was obtained (Wang *et al*., 2014). After cooling, the digested samples were filtered using Whatman No.42 filter paper and diluted to 50 mL with de-ionized water and kept until needed.

### Determination of Heavy Metal Concentration

The digested samples (water, soil and vegetables) were analyzed for the presence of different heavy metals such as copper, cadmium, chromium, manganese, iron and lead using atomic absorption spectrometer (Model: AA320N). Once the signal of each element was detected through their radiation, they were analyzed by the conversion of the calibration curves into their concentrations in part per million (ppm).

### Statistical Analysis

The results were expressed as mean (±) standard deviation of mean with three replicates for each of the parameter measured. The Statistical Package for Social Sciences (SPSS) Version 23 was used for data analyses. Data generated for each of the parameters were subjected to one way Analysis of Variance (ANOVA), using Completely Randomized Design (CRD). Tukey test was used for the separation of means where significant difference of $p < 0.05$ occurred.

## RESULTS AND DISCUSSION

### Copper Concentration of Experimental Samples

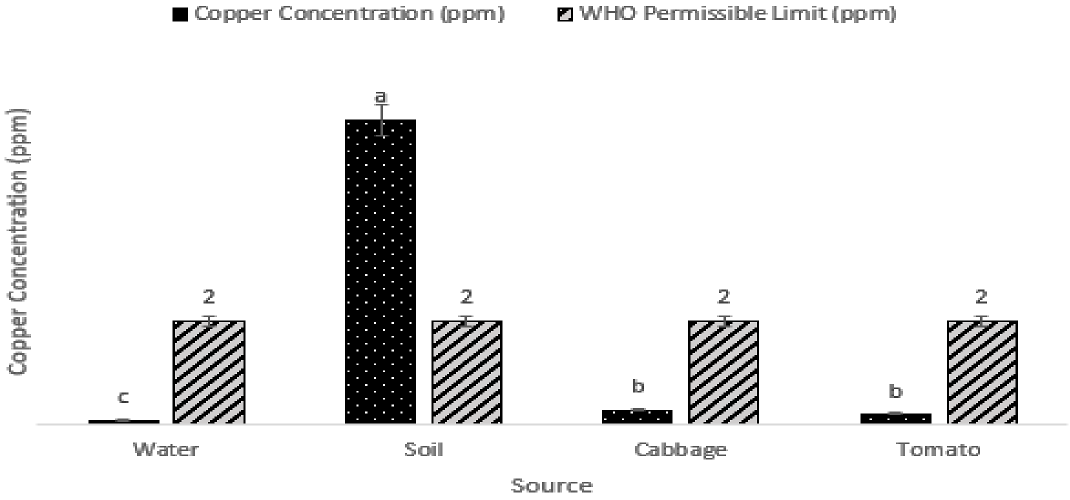

**Figure 1:** Copper Concentration in Water, Soil, Cabbage and Tomato

The result of the concentration of copper in water, soil, cabbage and tomato is shown in Figure 1. The result showed that significant differences occurred among the four (4) samples at $p \leq 0.05$. The concentration of copper in the soil sample showed significant difference from that of water, cabbage and tomato samples (Figure 1). Cabbage and tomato samples are however statistically similar to each other and are significantly different from that of water sample. The highest mean value occurred in soil, while water sample produced the lowest mean value and the WHO permissible limit is 2 ppm.

The soil sample gave a high concentration of copper than the water sample. Since mining of the heavy metals took place from within the soil, this might have contributed to the higher concentration of copper in the soil sample which may be attributed to the type of parent material that make up the soil. This has not affected the level of copper in the vegetables above the WHO permissible limits. Similar work carried out in Dhaka, Bangladesh, India showed copper concentration in water to be 0.527 ppm and its concentration in cabbage to be 0.145 ppm which are higher than the value reported in this work. The concentration of copper in soil earlier carried out and reported is 0.605 ppm and 5.01 ppm in tomatoes (Ahmad and Goni, 2009) which are lower than the values (5.83 and 0.214) respectively reported in this work (Boamponsem *et al.*, 2012) and also showed a lower level of copper concentration in irrigation water and consumables (cabbage and tomato). This wouldn't have affected the vegetables and makes them eatable based on WHO permissible limits.

## Chromium Concentration of Experimental Samples

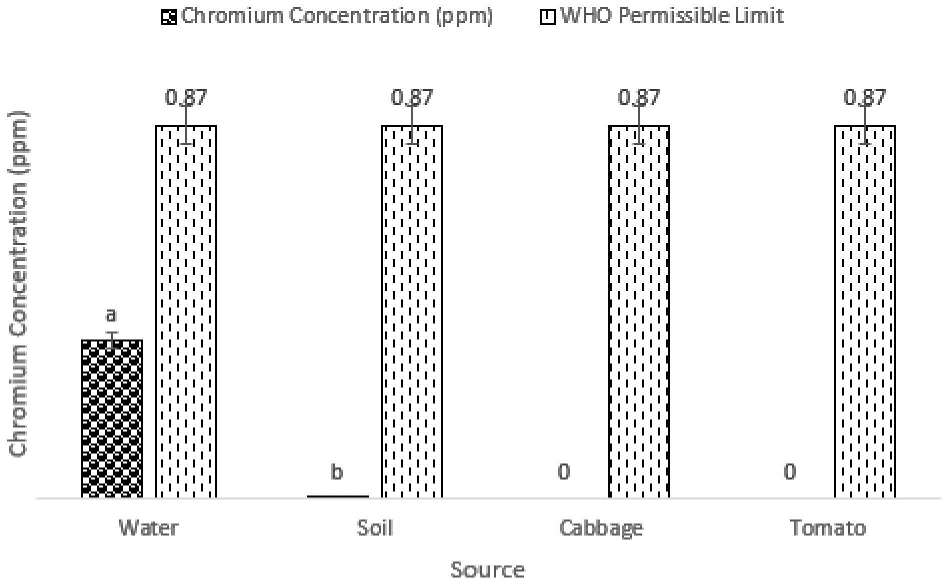

**Figure 2:** Chromium Concentration in Water, Soil, Cabbage and Tomato

The chromium concentration in water, soil, cabbage and tomato is displayed in Figure 2. The result showed that significant difference occurred between the concentrations in water and that of soil. The analysis of chromium metal in the vegetable sample showed no presence of this metal in the samples. The amount of chromium present in the water and soil samples were found to be below the WHO permissible limit.

The low concentration of chromium in the water and soil samples might be due to the low level of this heavy metal in the experimental site. The non-detection of the heavy metal in the vegetable samples could be as a result of the plants' low absorption ability and the minimal amount of the metal present in the pond. Similar work conducted at Eastern Gangetic plains of India showed the concentration value of Cr in water to be 0.005 ppm (Singh *et al.*, 2010) which is lower than the concentration of 0.368 ppm recorded in this study. Higher concentrations of chromium were detected in Nairobi River (0.245 mg/L) (Njuguna *et al.*, (2017) and Chinese Loess Plateau (5.13 mg/L) (Xiao *et al.*, 2019).

### Manganese Concentration of Experimental Samples

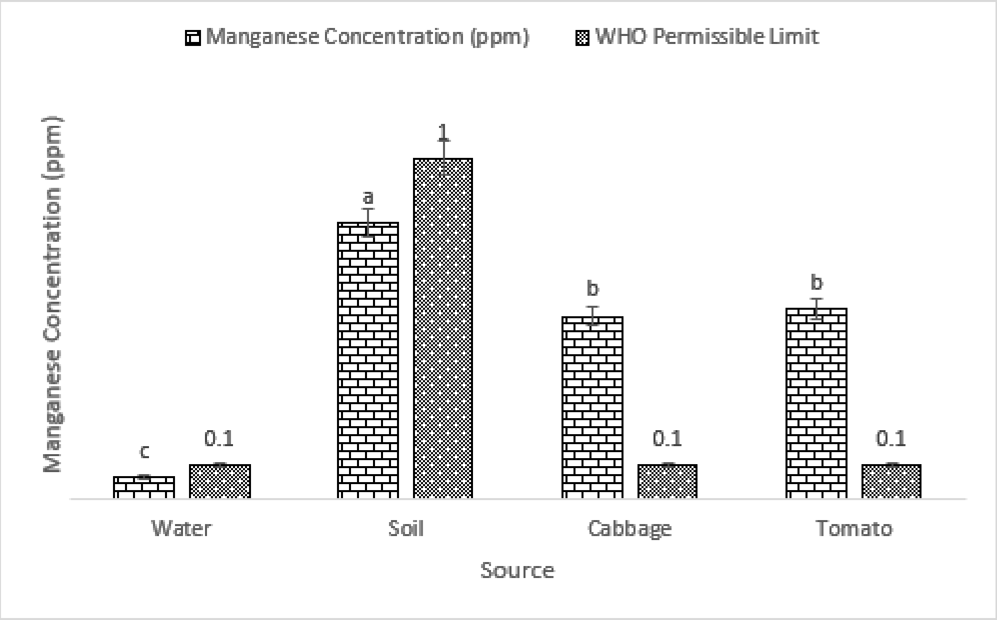

**Figure 3:** Manganese Concentration in Water, Soil, Cabbage and Tomato

The result of the concentration of manganese in water, soil, cabbage and tomato showed variations (Figure 3). The results showed significant difference at $p \leq .0.05$ in the samples. The result of the soil sample can be seen to be significantly different from that of water, cabbage and tomato samples (Figure 3). Manganese concentration in water is also significantly different from cabbage and tomato, while that of cabbage and tomato were not significantly different from each other. The WHO permissible limit also varied between the different sources as it is 1.0

ppm for soil sample and 0.1 ppm for water, cabbage and tomato respectively (Figure 3).

The higher Mn concentration in the soil may be due to the concentration of Mn in the parent material. Similar work conducted at Nagodi mining site, Ghana showed Mn concentration in water to be 2.11 ppm and 5.47 ppm (soil) which are higher than the value reported in this work (Boamponsem *et al.*, 2012). However, the value for Mn in both water and soil samples were above the WHO permissible limit. The higher concentration of manganese observed in the two vegetables might have been as a result of the addition of the manganese in the ex-mining pond water to those present in the soil where the vegetables were grown. This therefore led to the over accumulation of manganese in the soil and its high absorption by the vegetables.

## Cadmium Concentration of Experimental Samples

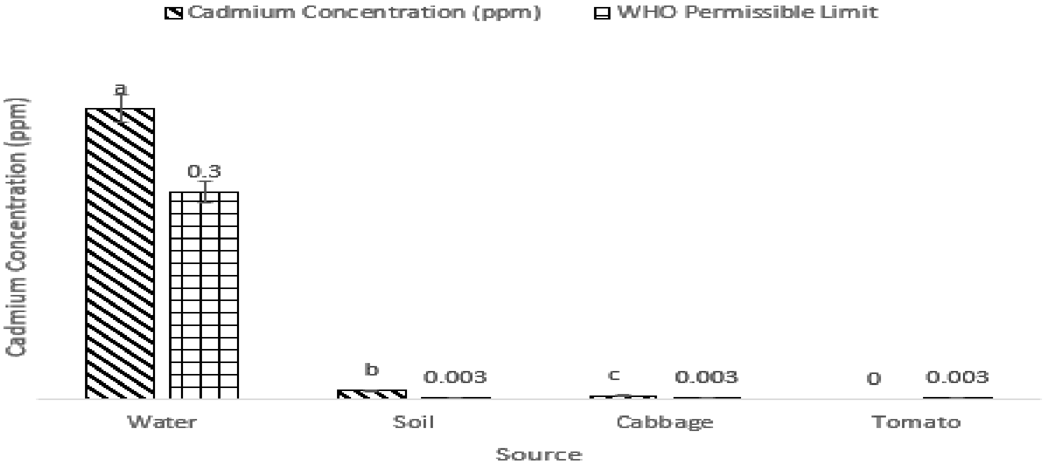

**Figure 4:** Cadmium Concentration in Water, Soil, Cabbage and Tomato

Figure 4 shows the concentration of cadmium in water, soil, cabbage and tomato. The result shows that significant differences occurred between the different sources of cadmium at $p \leq 0.05$. Cadmium concentration in water is significantly different from that of soil and cabbage (Figure 4), while that of soil was also observed to be significantly different from cabbage. Cadmium in water produced the highest mean value, followed by the one from soil and then cabbage. The concentration of cadmium was not detected in tomato while WHO permissible limit in water is 0.3 and that of soil, cabbage and tomato is 0.03.

The presence of Cd in the soil and water sample can be attributed to the ones mined which have found their way into the water used for irrigation on the farm land. The amount of this heavy metal present in the cabbage sample could have been through the irrigated water taken up by the vegetable. The cadmium present in the water, soil and cabbage are above the WHO permissible limit. Long term exposure to cadmium has been reported to cause cadmium poisoning which causes cancer and organ toxicity (Rafati *et al.*, 2017). Similar work reported by Wang *et al.* (2014) gave a value of 0.21 ppm to be present in cabbage through irrigated ex-mining pond water.

### Lead Concentration of Experimental Samples

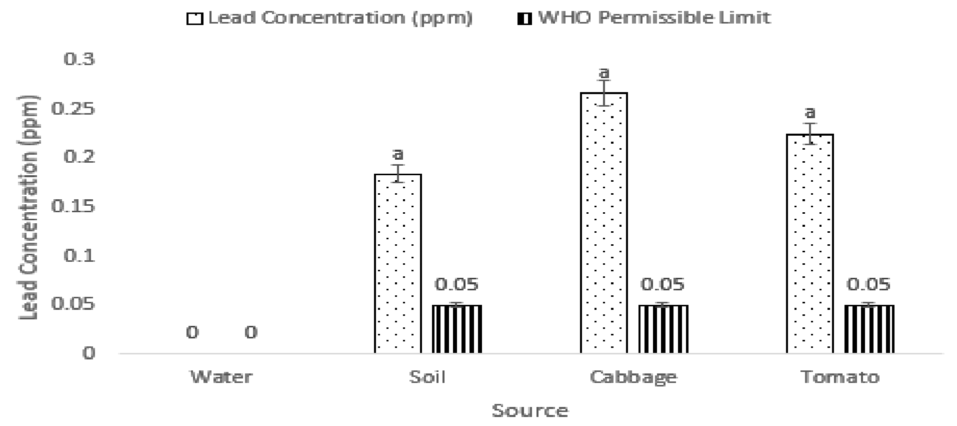

**Figure 5:** Lead Concentration in Water, Soil, Cabbage and Tomato

Figure 5 displays the concentration of lead in water, soil, cabbage and tomato samples. Significant difference did not occur among the results obtained. The highest mean value however occurred in cabbage sample, followed by the concentration in tomato, the lowest mean value occurred in soil. Water had no traces of lead detected in water sample the WHO permissible limit is 0.05 ppm.
The soil sample gave higher concentration of Pb than the water sample, which may be attributed to the type of parent material that makes up the soil. Similar work carried out Nagodi mining site, Ghana showed Pb concentration in soil to be 1.775 ppm which is higher than the value reported in this paper (Boamponisem *et al.*, 2012). The values obtained for lead in the water and soil samples were above the WHO permissible limit of 0.05 ppm. Exposure to lead has

been reported to produce toxic effects which cause damage to kidney, lungs, liver and neurological body system (Gauerra *et al.*, 2021).

### Iron Concentration of Experimental Samples

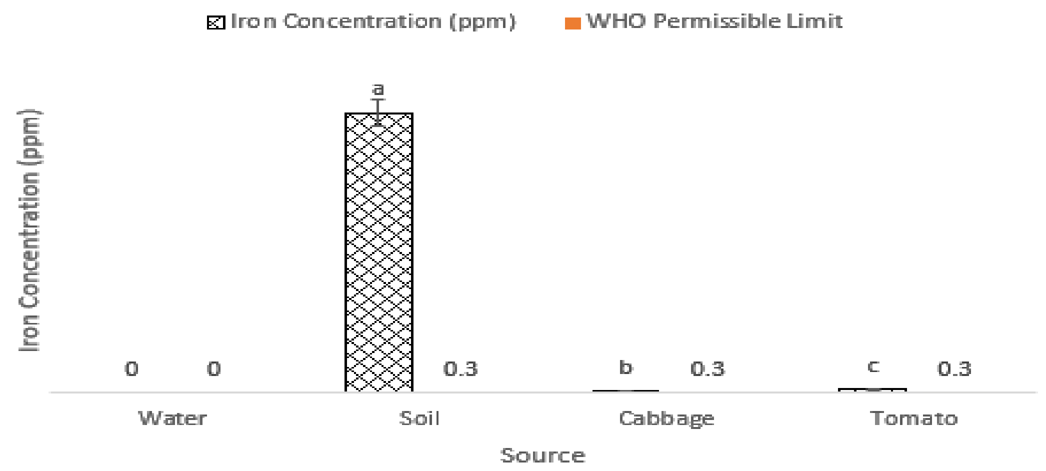

**Figure 6:** Iron Concentration in Water, Soil, Cabbage and Tomato

Figure 6 shows the concentration of iron in water, soil, cabbage and tomato. The result showed significant difference among the samples at $p \leq 0.05$. The concentration of Fe in soil is significantly different from that of cabbage and tomato, while Fe in cabbage is also significantly different from that of tomato. The soil has the highest concentration followed by tomato, and cabbage showed the lowest concentration. The concentration of iron in water sample was not detected the WHO permissible limit for iron in soil, cabbage and tomato is 0.3 ppm.

The higher Fe concentration in the soil than the water could be as due to Fe deposits from the ex-mining ponds. Similar work reported to take place at Nagodi mining site, Ghana shows Fe concentration in water (15.508 ppm) to be higher that the value reported in this work and soil (14.076 ppm) which is lower than the value reported in this work (Boamponisem *et al.*, 2012). Fe concentration in soil, cabbage and tomato were above the WHO limit. Goitom *et al.* (2020) reported accumulation of Fe and some other heavy metals in *C. olitorius* grown with wastewater. Excessive absorption of Fe into the body could cause iron overload and hence, neurodegenerative diseases and organ damage (Abbaspour *et al.*, 2014).

## CONCLUSION

Mining activities in Jos South local government area of Plateau state is a frequent event due to the large deposit of minerals in the area. These activities create large pits which serve as water reservoirs for irrigation purposes during the dry season. Assessment of heavy metals from water, soil and vegetables grown with the ex-mining ponds showed traces of heavy metals were detected in such samples. The heavy metals were mostly detected in soil and water samples and in the vegetables, chromium and cadmium were not detected in tomato sample, while Mn, Pb and Fe were above WHO limits. Cabbage also showed the presence of heavy metals with Mn, Pb, Cd and Fe above WHO permissible limits. Conclusively, the presence of these heavy metals in water used for irrigation must have percolated the root of the vegetables and translocated into the plants' fruiting system thereby leading to the detection of these heavy metals in the vegetable samples.

### Recommendation

Based on the result of these findings, farming activities should not be allowed to take place around mining sites as this could bring the introduction of heavy metals into farm areas. Also, farmers should be discouraged from using ex-mining ponds for irrigation purposes owing to the hazardous health implications this could bring.

### Conflict of Interest

All authors declare that no conflict of interest exist between them.

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