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A Phyto Analysis of Heavy Metal Pollution in Abandoned Quarry in Mpape, FCT, Abuja, Nigeria

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Abstract

Mining activities are known to cause heavy metal pollution as a result of exposure of the heavy elements to the environment. Thus, this study assessed the heavy metals contaminations in vegetation and soils around the abandoned quarry sites in Mpape, FCT, Abuja. This was achieved by determining the presence of heavy metals in soil and vegetation, compare the concentration of heavy metals with WHO standards and determine the implication of the concentration on the quality of the environment. The sample frame was Julius Berger quarry and data acquired from the site were heavy metals concentration in soil and plants samples of the study area. Seven plant species growing on contaminated mine tailings were harvested from three sampling plots, having geographical coordinates of 9.13539N, 7.48659E, 9.13537N, 7.48659E and 9.13538N, 7.48658E respectively each 10m^2 within the study area, Also Six soil samples comprising of three surface soil A B and C (0-15cm) and three subsurface soils A, B and C(15-30cm) around the roots (rhizosphere) of the harvested plants were collected. The plants parts collected included the root and leaves. Plants collected include; Mesosphaerum suaveolens (Pignut), Ricinus communis (Caster bean), Ageratum conyzoides (Tropical whiteweed), Ipomea aquatica (Water spinach), Arivela viscosa (Asian spider flower), Iberis sempervirens (Evergreen candytuft), and Persicaria Lapathifolia (Pale smartweed) respectively. Mean concentration of heavy metals in plants organs (leaves and roots) were computed using Microsoft Excel 2010 while the mean differences between concentrations of heavy metals in the plants and sediments were compared using Tukey-B One-Way Analysis of Variance (ANOVA) at a significance level of 5% in SPSS version 20 environment. The study revealed that spinach had the highest concentration (0.93mg) of zinc in its leaf while caster bean had the highest concentration of zinc (0.87mg) in it root. Similarly, spinach had the highest concentration (112.3mg and 116.0mg) of copper in its leaf and root respectively. Also, spinach had the highest concentration (0.74mg) of lead in its leaf while caster bean had the highest concentration (0.4mg) of lead in it root. Evergreen candy tuf had the highest concentration (2.32mg and 2.02mg) of iron in its leaf and root accordingly. The study also revealed that surface-soil C and sub-surface A had the highest (0.93mg and 0.9mg) concentration of zinc, surface-soil B and sub-surface B had the highest (81.0mg and 81.0mg) concentration of copper, surface-soil C and sub-surface C had the highest (4.1mg and 3.34mg) concentration of iron and surface-soil B and C and sub-surface A and C had the highest (0.5mg and 0.4mg) concentration of lead in the study area. The study similarly reveals that the concentration of zinc and iron in the study area were within the WHO standard for concentration of zinc in plants and soils. Unlike zinc, the concentration of copper in the study area were not within the WHO standard for concentration of copper in plants and soils. Furthermore, the study reveals that plants like evergreen candy tuf, Arivela viscosa were below WHO standard for lead while plants like pignut and spinach were above the standard for lead in the study area. Base on the aforementioned findings, the study recommends that government should pay attention to environmentally friendly mining policies which will expose the soil and plants of the study area to minimum concentration of heavy metals.

Keywords: Mining, Pollution, Phyto, Heavy Metal, Quarry.

Introduction

Mining activities are known to cause heavy metal pollution as a result of exposure of the heavy elements to the environment. The heavy metals are transferred to different media through acid mine drainage process (Eurostat, 2010 & Fashola et al., 2016).

Heavy metals occur naturally in varying concentrations in all environments, when taken up by plants, ingested or inhaled by animals and humans, may result in poisoning upon accumulation in the tissues. They occupy sites that would ideally be occupied by essential metals leading to a malfunction of the bio-chemical processes in living tissues (Fashola et al., 2016).

Anthropogenic sources negatively affect the environmental quality due to build-up of heavy metals in toxic oxidation states. This poses a challenge to human and animal lives, with mining reported being second to agriculture, as a source of pollution by heavy metals. The heavy metals that are closely associated to mining are of interest because they are found to accumulate in sediments and soils. The probability of absorption of the metals by plants and eventually animals forms the basis for determination of pollution levels (Abdul-Wahab & Marikar, 2012).

Mining activities are well known for their deleterious effects on the environment, due to the deposition of large volumes of wastes on the soil. (Goyal *et al.,* 2008) affirmed that the negative impact of these mining activities on the surroundings is mainly due to the presence of high volumes of tailings (Nouri *et al.,* 2008). These tailings usually have unfavourable conditions to natural vegetation growing on it, such

as low pH (Wong *et al.*, 1998), toxic metal concentrations (Norland and Veith, 1995; Wong *et al.*, 1998; Malakootian *et al.,* 2009; Zvinowanda *et al.,* 2009) low water retention capacity (Henriques and Fernandes, 1991; Norland and Veith, 1995) and low levels of plant nutrients (Wong, 2003). In most cases, tailings present on steep slopes, are unstable and prone to erosion (Henriques and Fernandes, 1991). All these factors contribute to pollution for the soil, ground and surface waters.

Specifically, metals are non-degradable and therefore can persist for long periods in aquatic as well as terrestrial environments (Nouri *et al.,* 2008). These metals may be transported through soils to reach groundwater or may be taken up by plants, including agricultural crops (Atafar *et al.,* 2010).

Statement of Research Problem

Quarrying is a destructive development activity whose socio-economic benefits may be unable to compensate for the overall detrimental effects on natural ecosystems as it produces immediate and long-term undesirable effects in the environment and even long time after which the mine is closed. Crushed rock quarrying activities generates considerable amount of dust and wastes, which contain a number of heavy metals. Heavy metals that are mobilized or dissolved into the soil can be taken up by plants or transported to surface or ground water. Thus, heavy metals enter into food chain and are afterwards accumulated to high amounts instigating acute or chronic toxicity (poisoning) and serious risk to human health when plant foods or plant products are eaten.

Therefore, this study is conducted to determine the presence of heavy metals in vicinity of Mpape in order to assess the level of contamination of the plants and soils.

Study Area

Mpape is approximately 10 minutes' drive from the center of Abuja (Jimoh, 2017). It is one of the districts in Bwari Area Council of the Federal Capital Territory (FCT), Abuja. It lies on the foothills and on the top of the famous Mpape Rocks that are easily sighted from the neighbouring Maitama District (Dawam, 2000). Geographically, Mpape lies between Latitudes 9.175699° and 9.113010°

north of the equator and Longitudes 7.463892° and 7.524349° east of the Greenwich Meridian (Figure 1). It occupies a land area of 44.325 Ha and the largest slum settlement in Abuja and densely populated. With the rural-urban migration reportedly on the rise in Nigeria, the village has grown into an informal settlement with a population tethering over 1.1 million inhabitants without the commensurate infrastructure (Jimoh, 2017).

Mpape is almost predominantly underlain by high grade metamorphism and igneous rocks of Precambrian age generally trending, these rocks consist of gneiss, migmatites, granites and schist belt outcrops along the eastern margin of the area (FCDA, 1979 and 1998). The rocky nature of Mpape makes it suitable for quarry business which thrives here (Jimoh, 2017 and Okeke,2016).

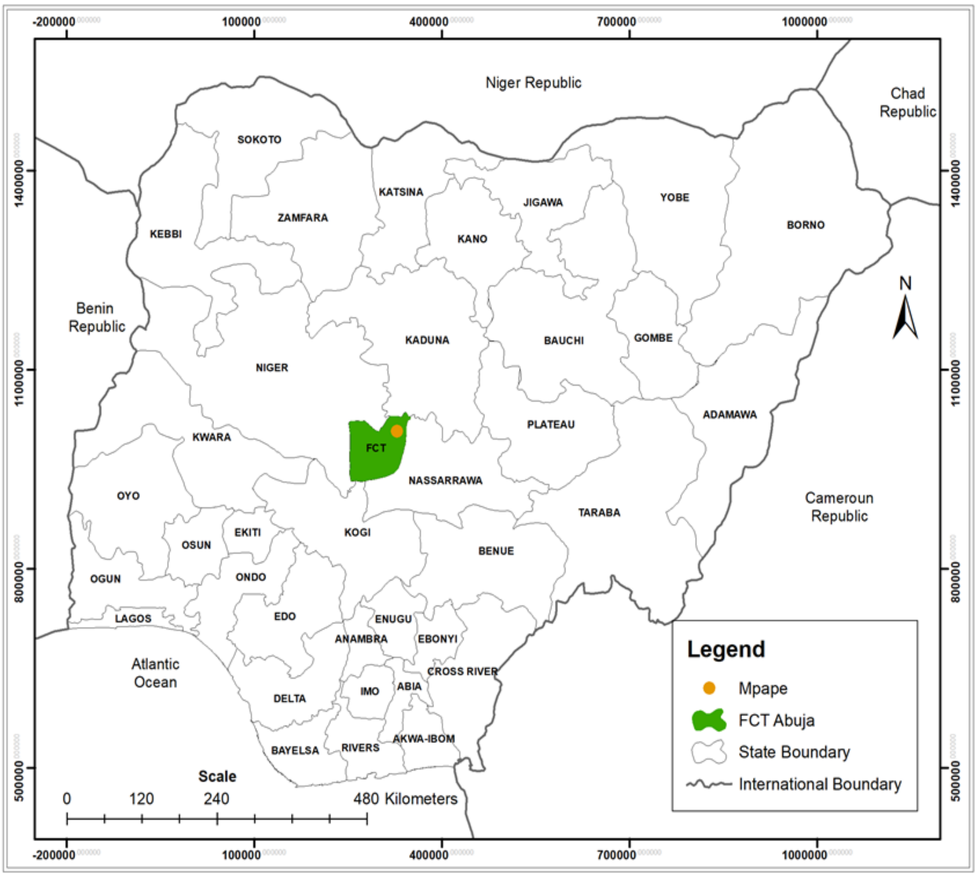

Figure 1.1: Showing FCT, Abuja

Source: Produced by Author on Arc GIS version 10.8

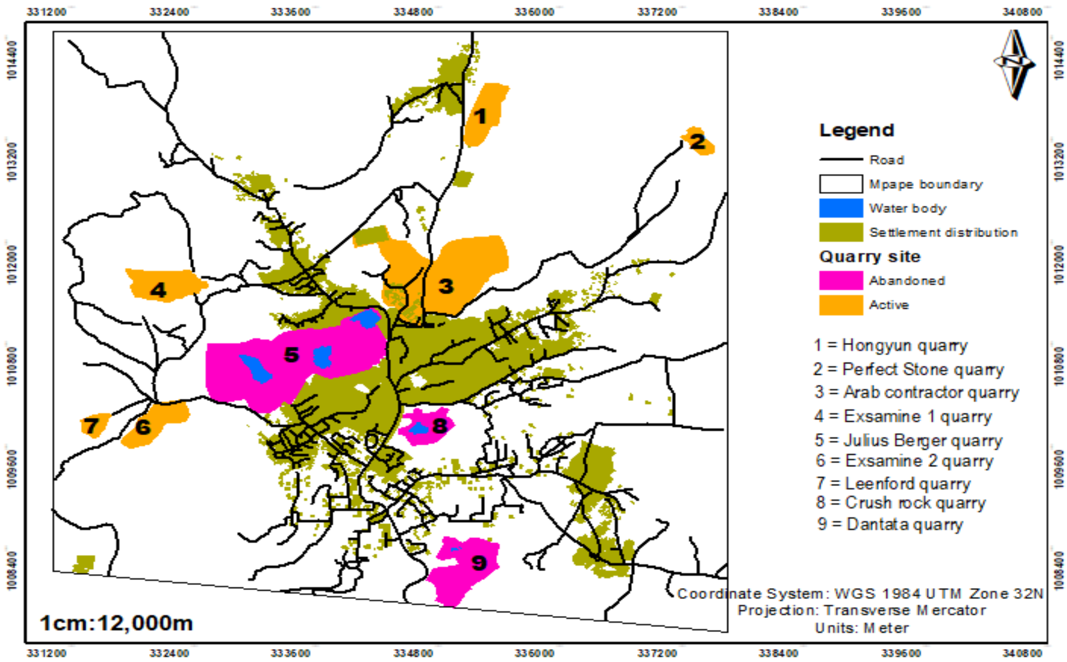

Figure 1.2: Map showing Abandoned and Active Quarry Sites in the study area
Source: Produced by Author on Arc GIS version 10.8

The study area falls within the Guinea Savanna Vegetation Zone of Nigeria. Trees such as A*ntirisern africana, Anthocleistanoblis, Ceibapentandra, Cola gigantea, Celtis spp., Chtorophora excels, Piptadenianum africanum, Lophira on alata, Terminalia ivorensis, Triplochiton scleroxylon and Dracaena arborea* dominate the area (GEHS, 2014).

The soil in the study area shows high level of variability comprising mainly of sand, silt, clay and gravel. Alluvial soils are predominantly found in the valleys of the various Rivers within the area but highly concentrated at the valley of River Usuma. The water table around the area where this soil type dominates is usually very high. It has well decomposed organic matter content in the surface layer; its texture is heavier with depth as the weathered parent material is approached (Balogun, 2001).

Sampling Procedure

Plant species growing on contaminated mine tailings were harvested from three sampling plots, having geographical coordinates of 9.13539N, 7.48659E, 9.13537N, 7.48659E and 9.13538N, 7.48658E respectively each 10m^2 within the study area. Six soil samples comprising of three surface soils (0-15cm) and three subsurface soils (15-30cm) around the roots (rhizosphere) of the harvested plants were collected and homogenized and unwanted materials removed. The plants parts collected included the roots and leaves, the plants collected include; *Mesosphaerum suaveolens* (Pignut), *Ricinus communis* (Caster bean), *Ageratum conyzoides* (Tropical whiteweed), *Ipomea aquatica* (Water spinach), *Arivela viscosa* (Asian spider flower), *Iberis sempervirens* (Evergreen candytuft), and *Persicaria Lapathifolia* (Pale smartweed).

Both plant and soil samples were transported to the laboratory in labelled packets. Plant samples were washed with tap water to remove soil and then rinsed with distilled deionised water. The roots were separated from the shoots with a stainless-steel knife. They were air-dried for one week at room temperature by spreading them on thin cellophane paper, followed by oven drying at 50°C for 48 hours. The homogenized soil sample was air dried for one week at room temperature and oven dried at 50°C for 48 hours to constant weight. The dried soil sample was then pulverized and sieved through 2 mm fine mesh and kept at 4°C in dark plastic bags until analysed. The samples collected were analyzed in the Federal University of Technology, Minna Central Research Laboratory Unit, P.M.B 65, Minna, Niger state, Nigeria.

Method of Data Analysis

Mean concentrations of heavy metals in the plants parts (leaves and root) and also in the sediments were computed using Microsoft Excel 2010. Mean differences between concentrations of heavy metals in the plants and sediments were compared using Tukey-B One-Way Analysis of Variance (ANOVA) at a significance level of 5%. The ANOVA was run using SPSS version 20. Also, descriptive statistics such as mean and standard deviation were also utilized in analyzing the lab result.

Discussion of results

The concentration of Zinc in the study area were examined and the result is presented in Figure 1.3

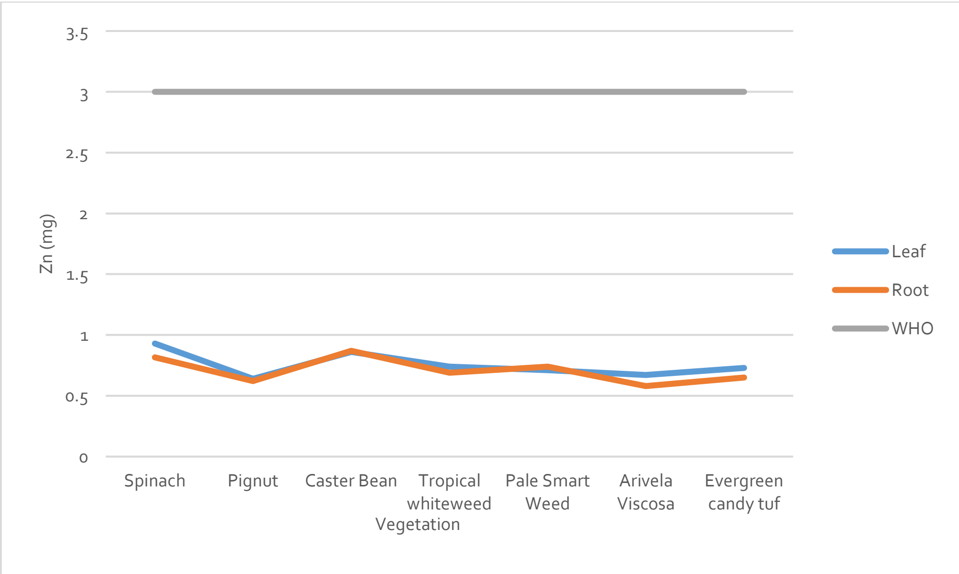

Figure 1.3: Comparing Concentration of Zinc with WHO Standard
Source: Author's Analysis (2021)

Figure 1.3 reveals that the concentration of zinc in the study area were within the WHO standard for concentration of zinc in plants. Zinc is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. Concentration of zinc in water samples ranged between 0.9 to 0.5mg. The permissible limit of zinc in plants according to WHO standards is 3mg. In all the collected plant samples concentration of zinc was recorded below the permissible limit. The result is similar with the findings of Shah et al., (2011) who examined heavy metal concentration in some soils in Romania.

The concentration of copper in the study area were examined and the result is presented in Figure 1.4.

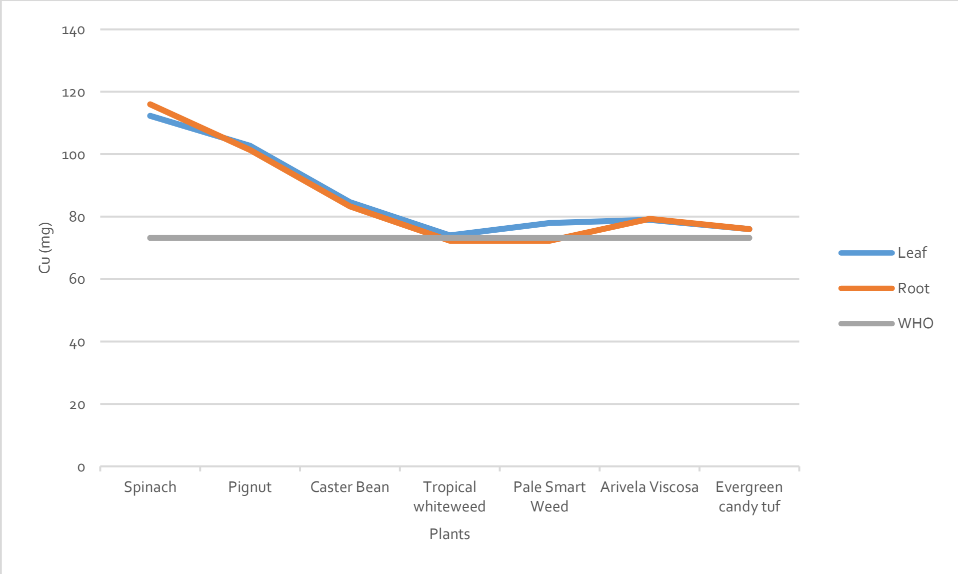

Figure 1.4: Comparing Concentration of Copper with WHO Standard
Source: Author's Analysis (2021)

From Figure 1.4, it can be observed that the concentration of copper in the study area were not within the WHO standard for concentration of copper in plants. The permissible limit of copper for plants is 73.2mg recommended by WHO (Hassan et al., 2012). In all the collected plant samples concentration of copper was recorded above the permissible limit. The finding is similar to the result of Hassan et al., (2012) who also reported high concentration of copper in the plants. The high concentration of copper may be found in soil because dust or waste from mining activities are disposed of on the soil. The concentration of lead in the study area were examined and the result is presented in Figure 1.5.

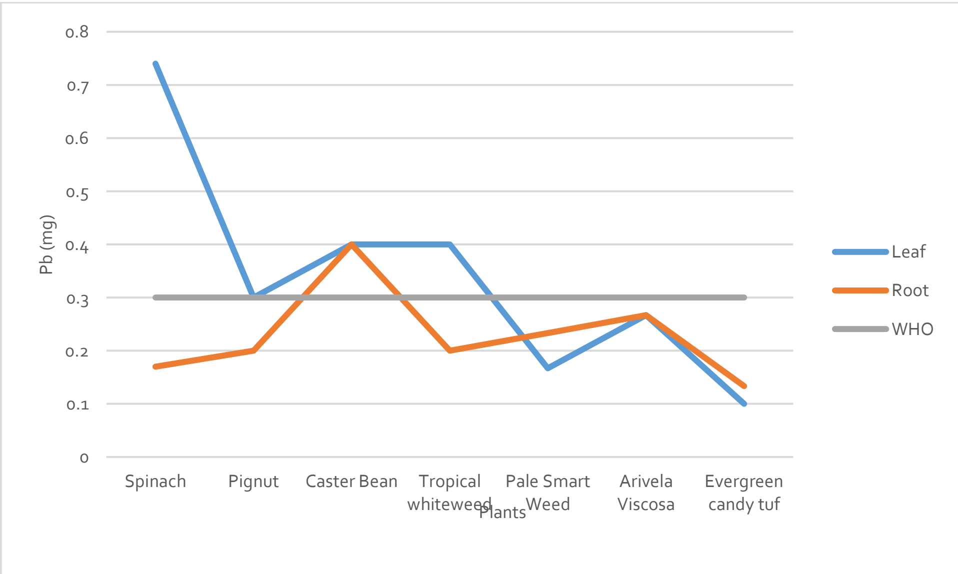

Figure 1.5: Comparing Concentration of Lead with WHO Standard
Source: Author's Analysis (2021)

Figure 1.5 reveals that plants like evergreen candy tuf, Arivela Viscosa were below WHO standard while plants like pignut and spinach were above the standard in the study area. The result is similar with the report of Nazir, (2015) which reported that some of the lead found in vegetation of Tanda Dam Kohat varies as the concentration is lower than WHO standard while in other plants it was higher than the standard. Although lead is a non-essential element for plant, high concentration of the metal negatively affects various physiological processes. Such processes include photosynthesis, respiration, mineral nutrition membrane structure and properties and gene expression.
The concentration of iron in the study area were examined and the result is presented in Figure 1.6.

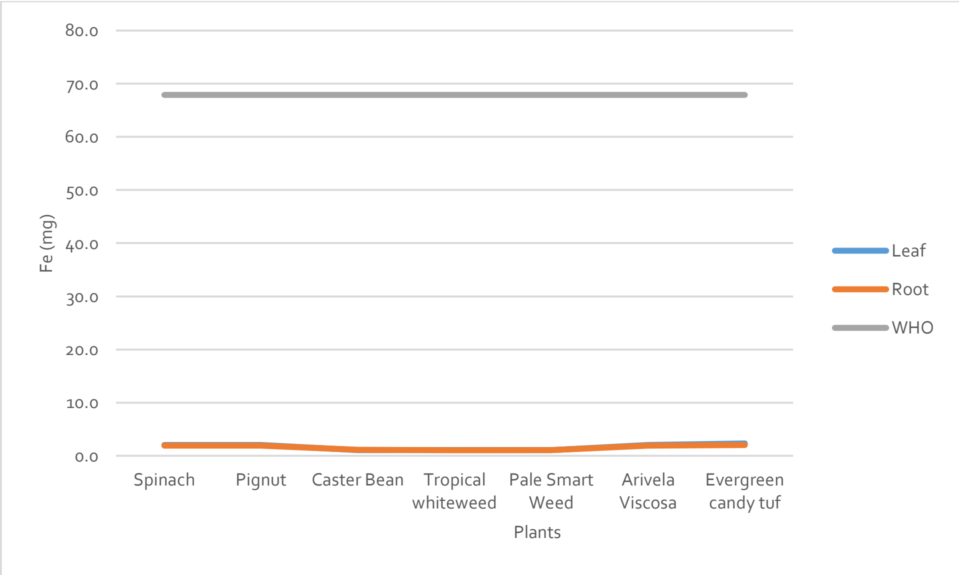

Figure 1.6: Comparing Concentration of Iron with WHO Standard
Source: Author's Analysis (2021)

Figure 1.6 indicates that the iron concentration for all the plants in the study area were below the standard stipulated by WHO for plants. The findings disagree with the result of Nazir, (2015) who reported concentration of iron that are higher than WHO standard in Tanda Dam Kohat. Iron is an essential micronutrient for almost all living organisms because of it plays critical role in metabolic processes such as synthesis, respiration and photosynthesis. the low concentration reported in this study imply that the plants will have problem with the synthesis of chlorophyll which is essential for the maintenance of chloroplast structure and function.

Presence of Heavy Metals in Soils of the Study Area
The concentration of zinc in the soil of the study area was conducted and the result is presented in Figure 1.7.

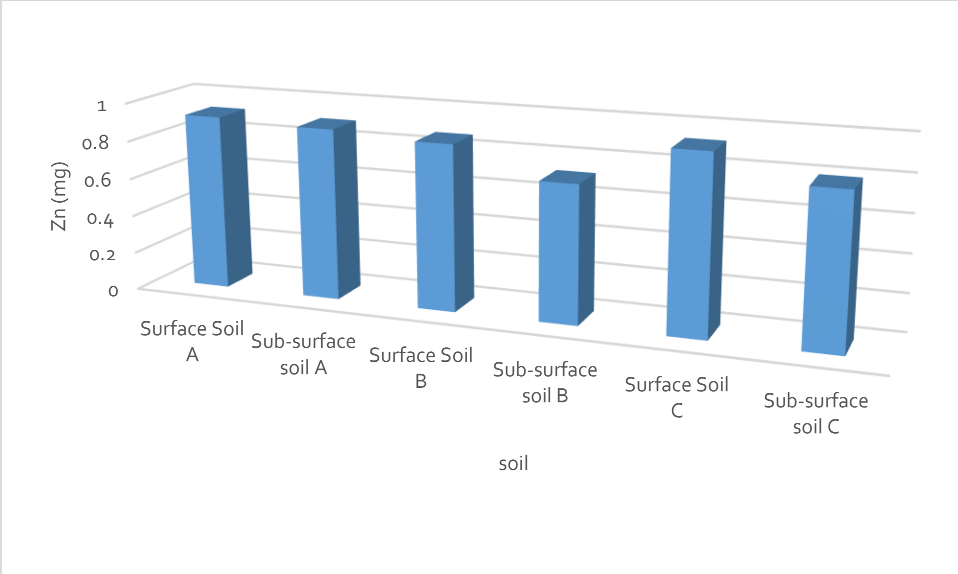

Figure 1.7: Concentration of Zinc in Soil of the Study Area

Source: Author's Analysis (2021)

Figure 1.7 reveals that surface-soil C (9.13538N, 7.48658E) and sub-surface A (9.13539N, 7.48659E) had the highest (0.93mg and 0.9mg) concentration of zinc in the study area. On the other hand, surface soil B (9.13537N, 7.48659E) and sub-surface soil B (9.13537N, 7.48659E) had the lowest (0.87mg and 0.72mg) concentration of zinc in the study area. The result is completely different from the findings of Ekpo, Nzegblue, and Asuquo, (2011) who conducted a comparative analysis of influence of heavy metals on soil and crops growing within quarry environments at Akamkpa, Cross River State, Nigeria. Although there is a difference in the concentration of zinc in soil for both studies, the amount of zinc found are still safe for the soil. This was further affirmed by Landon (2001) and O'Sullivian et al., (2007) who stated that zinc concentrations above 150mg corresponded to severe stunting, whiles concentrations as high as 900mg are measured in severely affected plants. Ekpo, Nzegblue, and Asuquo, (2011 further speculated that in soil, a DTPA-extractable Zn concentration above 10 mg/kg is considered potentially harmful in acid soils. 'Total Zn' concentrations in soil (perchloric acid extractable Zn) usually fall in the range 10 to 300 mg/kg, with concentrations above 150 mg/kg regarded as high and likely to result in reduced plant growth.

The concentration of copper in the soil of the study area was examined and the result is presented in Figure 1.8.

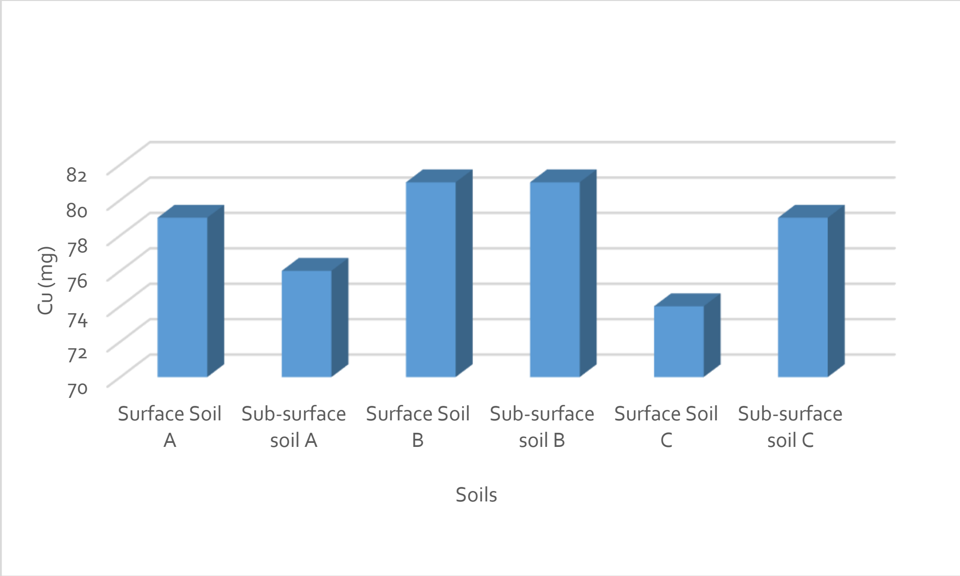

Figure 1.8: Concentration of Copper in Soil of the Study Area
Source: Author's Analysis (2021)

Figure 1.8 reveals that surface-soil B (9.13537N, 7.48659E) and sub-surface B (9.13537N, 7.48659E) had the highest (81.0mg and 81.0mg) concentration of copper in the study area. Equally, surface soil C (9.13538N, 7.48658E) and sub-surface A (9.13539N, 7.48659E) had the lowest (74.0mg and 76.0mg) concentration of copper in the study area in the study area. The minimum and maximum values of copper reported in this study is greater than the values reported by Ochelebe, Nkebem, and Kudamnya, (2020) who assessed heavy metals concentration and enrichment levels in soils around quarries and barite mine sites in part of Akamkpa and Biase Area, of South-eastern Nigeria.
The concentration of iron in the soil of the study area was investigated and the result is presented in Figure 1.9.

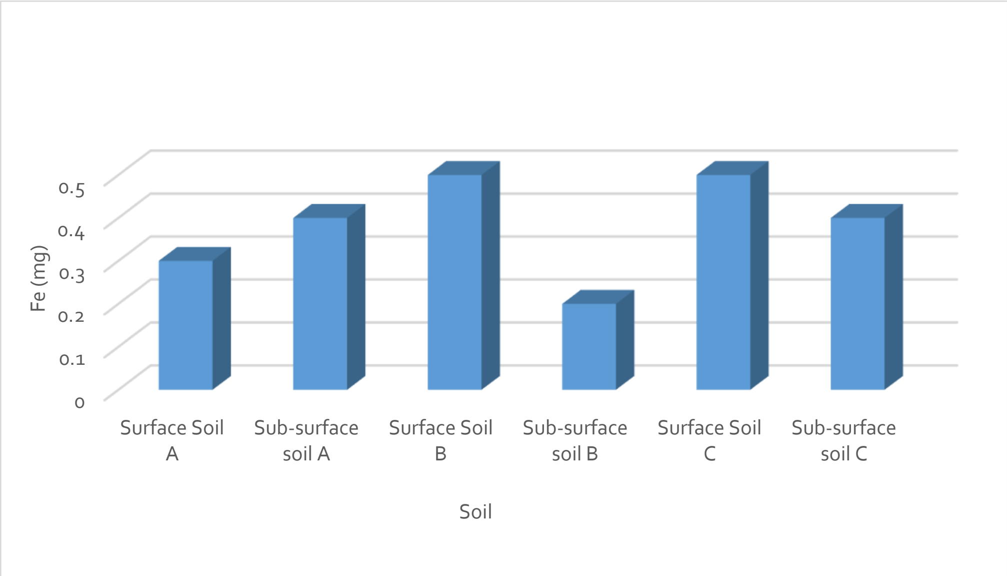

Figure 1.9: Concentration of Iron in Soil of the Study Area
Source: Author's Analysis (2021)

Figure 1.9 reveals that surface-soil C (9.13538N, 7.48658E) and sub-surface C (9.13538N, 7.48658E) had the highest (4.1mg and 3.34mg) concentration of iron in the study area. Correspondingly, surface-soil A (9.13539N, 7.48659E) and sub-surface soil A (9.13539N, 7.48659E) had the lowest (3.12mg and 2.93mg) concentration of iron in the study area. The result is dissimilar to the result of Mashi, Yaro, and Haiba (2004) who reported a very high concentration of iron in soil of Shika area of Giwa LGA of Kaduna state and attributed the result to human activity in the area. On that basis, it can be concluded that mining activities practiced in the study area alters the iron level in soil of the study area.

The concentration of lead in the soil of the study area were examined and the result is presented in Figure 1.10.

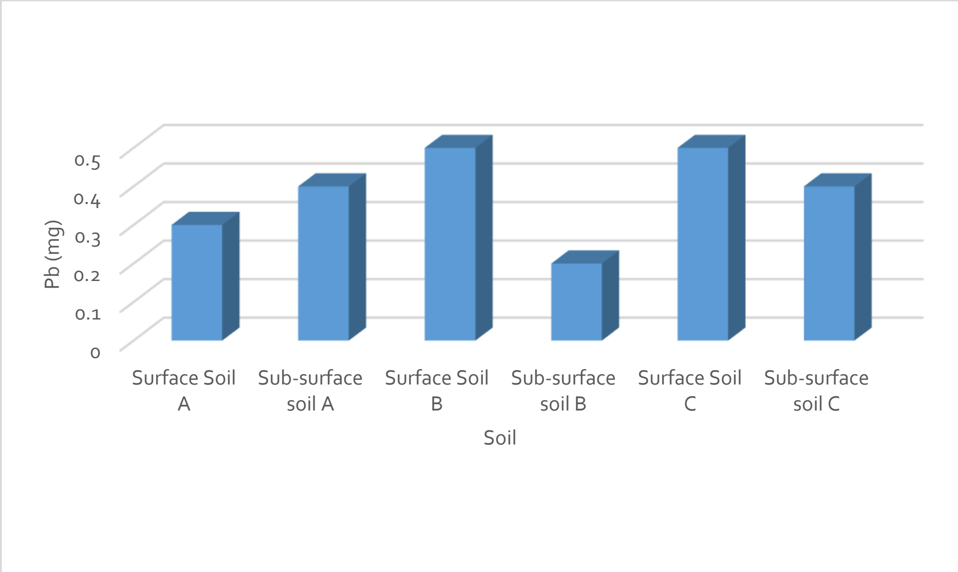

Figure 1.10: Concentration of Lead in Soil of the Study Area

Source: Author's Analysis (2021)

From Figure 1.10 surface-soil B (9.13537N, 7.48659E) and C (9.13538N, 7.48658E) and sub-surface soil A (9.13539N, 7.48659E) and C (9.13538N, 7.48658E) had the highest (0.5mg and 0.4mg) concentration of lead in the study area. Also, surface-soil A (9.13539N, 7.48659E) and sub-surface soil B (9.13537N, 7.48659E) had the lowest (0.4mg and 0.2mg) concentration of lead in the study area. This implies that there is high concentration of lead in the study area. Crushed rock aggregate quarrying generates considerable volume of quarry dust which significantly leads to production of considerable amounts of wastes harboring a number of heavy metals especially lead, this may have accounted for the high value of lead concentration in the surface-soil B (9.13537N, 7.48659E) and C (9.13538N, 7.48658E) and sub-surface soil A(9.13539N, 7.48659E) and C (9.13538N, 7.48658E) in the study area.

To further verify the level of variation of the heavy metal in the roots, leaves and soils, the result were further subjected to analysis of variance (ANOVA), as presented in Table 1.1.

Table 1.1: Result of Analysis of variance (ANOVA)

Source of Variation	SS	df	MS	F	P-value	F-crit
Between groups	1.607	2	0.32	0.111	0.989	2.438

Within groups	121.1	42	2.88
Total	**122.7**	**47**	

Source: Author's Analysis (2021)

Table 1.1 indicates that the F-ratio is 0.111 and F-crit. Is 2.438. it shows that the calculated F-value (0.111) is less than the F-critical (2.438). it therefore implies that the null hypothesis is accepted, we then conclude that there is no significant variation in the concentration of heavy metals with leaf, root of plants and soil of the study area. This implies that the environment is contaminated with heavy metals as a result of the quarrying activities. Remediation measures should be taken so as to restore the environment.

Conclusion

Generally, the study revealed that *Ipomea aquatica* (Water spinach) had the highest concentration of zinc in its leaf while *Ricinus communis* (Caster bean) had the highest concentration of zin in its root, similarly *Ipomea aquatica* (Water spinach) had the highest concentration (112.3mg and 116.0mg) of copper in its leaf and root respectively. Also, the highest concentration of lead was also observed in in the leaf of *Ipomea aquatica* (Water spinach), while *Ricinus communis* (Caster bean) had the highest concentration of lead in it root. In the same vein *Iberis sempervirens* (Evergreen candytuft) had the highest concentration of iron in its leaf and root. Therefore, this finding reveals that *Ipomea aquatica* (Water spinach) and *Ricinus communis* (Caster bean) are good phyto-extractors of zinc, also *Ipomea aquatica* (Water spinach) are good phyto-extractors of copper and lead, similarly *Ricinus communis* (Caster bean) is also a good phyto-extractors of lead respectively.

Recommendations

1. It is not recommended to consume the water spinaches from this study area since the concentration of other heavy metals were high in the plant.
2. Government should pay attention to environmentally friendly mining policies which will expose the soil and plants of the study area to minimum concentration of heavy metals.

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