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Comparative Analysis of Heavy Metal Content in Soil and their Transfer to *Ocimum gratissimum* and *Moringa Oleifera* Vegetables Planted in Farms by Bmuko Quarry Sites

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Abstract The concentration of eight heavy (Fe, Zn, Cu, Mn, Cr (III), Ni Cd and Pb) metals in *Ocimum gratissimum* and *Moringa Oleifera* planted in farms around Bmuko quarry site and occasionally irrigated with water from the stream across the quarry site was assessed. Water, soil and plant samples within vicinity of the quarry were collected during dry and rainy seasons. Rainy season mean concentrations of Cr (0.28mg/kg) and Cu (0.40mg/kg) were higher than Food and Agriculture Organization (FAO) maximum recommended limits for irrigation water. Anthropogenic input of heavy metals from quarry activities in soil samples ranged from 0 – 93.20%. Cr had the highest anthropogenic metal input of 93.20% during rainy season at soil depth of 5.0 to 10.0cm. Most of the heavy metals had higher mean concentrations in dry season than in rainy season just as was observed in similar researches [50 - 51]. Correlation coefficient (r) between concentrations of bioavailable heavy metals and soil physicochemical properties for both season showed that Cd (-0.86) and Ni (-0.82) had significant correlation with CEC at $P \leq 0.05$ level, indicating the strong influence of CEC in Cd and Ni availability in soil pore solutions for plant intake. Fe had the highest concentration of bioavailable heavy metals during both seasons. Concentrations of all the heavy metals in both leaves of *Moringa Oleifera* and *Ocimum gratissimum* were within maximum permissible limits set by World Health Organization (WHO) and FAO in vegetables except for concentrations of Cu and Pb which are higher than permissible limits.

Keywords Irrigation, bioavailable, lithogenic, anthropogenic, bioaccumulation

1. Introduction

Heavy metals are any metallic chemical element that has relatively high density, considered to be of sufficient distribution in the environment and is toxic or poisonous at low concentrations [1-2]. Heavy metals can cause damaging effects and pose serious health consequences on chronic exposure [3- 4].

Examples of heavy metals include lead(Pb), Mercury(Hg), Cadmium (Cd), and Chromium (Cr) while less commonly metals including Iron (Fe), Copper (Cu) Zinc, (Zn), Aluminium(Al), cobalt Co, Manganese (Mn) and as may be considered heavy metals [5]. Crushed rock quarrying is known to generate considerable volumes of quarry dust which significantly leads to production of considerable amounts of wastes, harbouring a number of heavy metals [6]. Pollution problem have been known to arise when these heavy metals such as that from crushed rock quarry are mobilized into the soil solution and taken up by plants [7].Vegetable uptake of metals from soil is one of the major pathways that metals enter into food chain and are subsequently accumulated to high concentrations causing serious risk to human health when plant based food stuffs are consumed [8]. Leafy vegetables accumulate higher metal content than others [9]. Prolonged consumption of unsafe level of these heavy metals through foodstuffs may lead to their chronic accumulation in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous system, and kidney and bone diseases [10].

According to some researchers[11-12], the process of plant uptake and bioaccumulation of heavy metals depends upon the concentration and extent of availability of the heavy metals in soil, the climate, soil properties, atmospheric depositions, irrigating water quality and plant physiologic factors. Once in soil, some of these metals are persistent because of their fairly immobile nature, other metals which are more mobile (bio-available) have the potential of being transferred either through soil profile down to ground water aquifer or via plant - root uptake [7].

The bioavailable fraction is most crucial for assessing the environmental quality and possible health risk [13].

The total heavy metal contents can indicate the extent of contamination, but is not usually an accurate indication of the toxicity [14]. Metal toxicity is related to the concentration of bioavailable metal rather than the total metal concentration [15]. Hence, in order to understand how the heavy metals influence the environment, it is important to distinguish between the total quantities in the soil and the amounts that can be transferred into more soluble forms (bio-available). Key factors that affect the availability of heavy metals in soil identified by various researchers [13, 16] and [7] are: pH, Soil Organic Matter (SOM) and clay minerals (Soil texture).

Soil pH is considered one of the most important factors determining the concentration of metals in the soil solution, their mobility and availability to plants [17-18]. In highly acidic soils, the mobility of metallic elements is much higher than in soils with neutral and alkaline reaction [19].

Soil organic matter is the fraction of the soil that consists of plant or animal tissue in various stages of breakdown (decomposition) [20]. An organic matter particle has a net negative charge [20] and is known to form strong complexes with heavy metals [22].

Soil texture plays an important role in mobility of metals in soil and reflects the particle size distribution of the soil [7]. Also Clay soil retains high amount of metals when compared to sandy soil [7, 23]. This is because clay minerals have a comparatively large surface area and a permanent negative charge, along with a high cation exchange capacity (CEC) hence, are very important for the absorption of metals [13].

This study was aimed at providing data for seasonal concentrations of eight heavy metals, Iron, Zinc, Copper, Manganese, Chromium, Nickel, Cadmium and Lead (Fe, Zn, Cu, Mn, Cr (III), Ni Cd and Pb) in leaves of two perennial plants, *Ocimum gratissimum* and *Moringa oleifera* planted in farms around quarry sites and occasionally irrigated with water from the stream across the quarry site in Bmuko. These leaves are usually consumed by the farmers and sold to other consumers.

2. Materials and Methods

2.1. Study Area

Bmuko village is a small community surrounded by Bmuko hills located in Dutse Alhaji, Bwari area council, which is geographically located at the North East of the Federal capital territory (FCT), Abuja (FCTA, ACSS, 2015). Bmuko village is home to a large quarry industry whose activities are very obvious in the village.

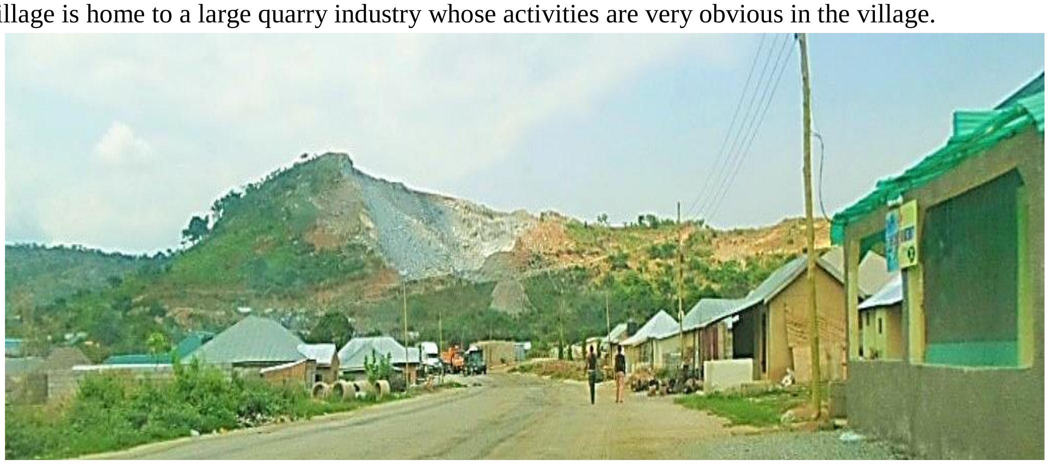

Figure 1: The quarry sited behind Bmuko village

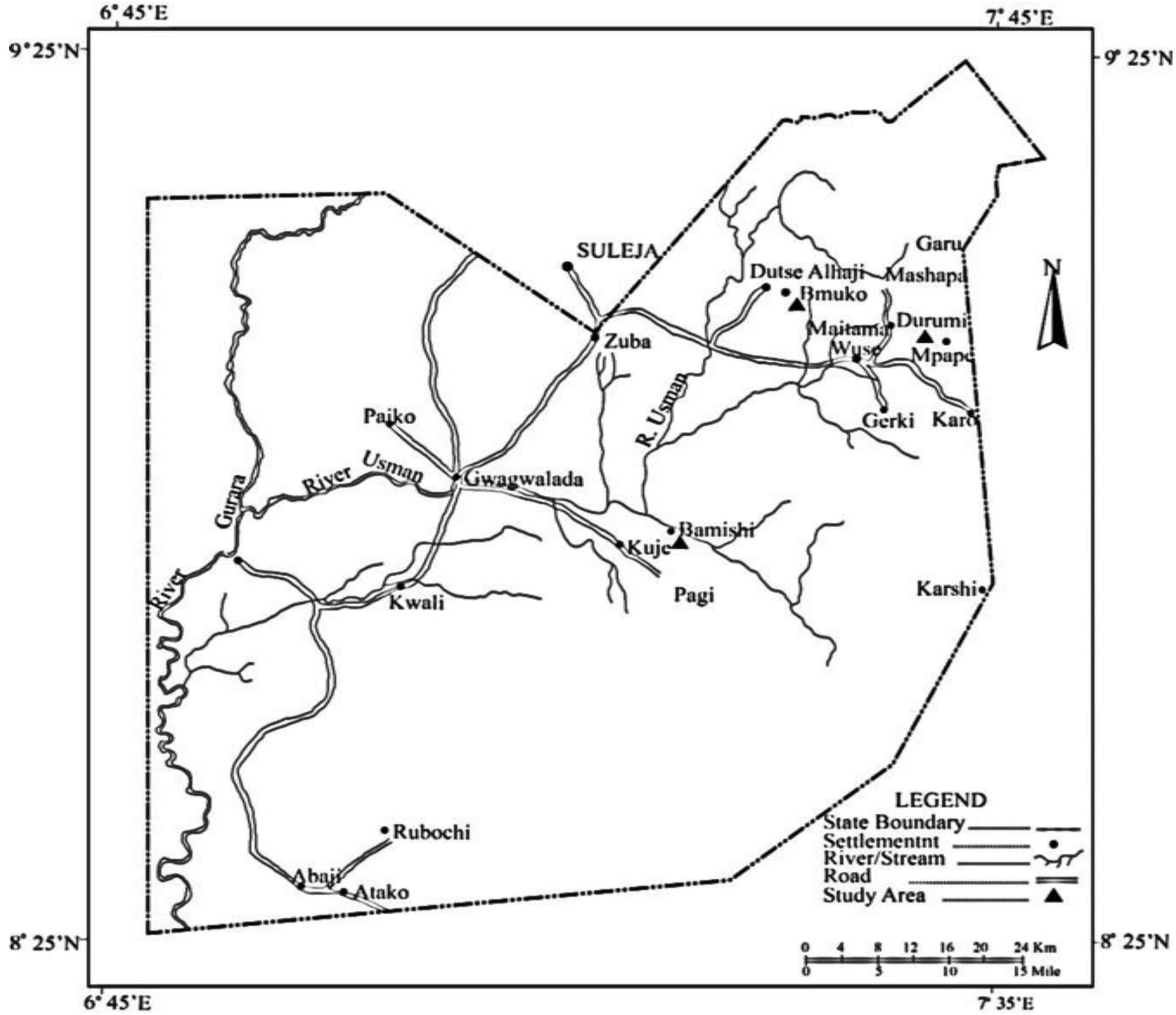

Figure 2: Map of Abuja showing the study area

2.2. Control Areas

A control site at a distance of about 5 km away from the quarry site was chosen. These control area is sited in farms in an area likely not to be affected by the quarry activities in the study area. It was used as source of controls for the plants and soil. Soil and plant samples were collected from these areas at the same period as those from the study areas.

2.3. Plant Samples

The leaves of plants *Ocimum gratissimum* and *Moringa oleifera* were used for this study. They were identified and verified with the help of Abdulahi Omale Ari, Senior Technologist, plant Science and Biotechnology Department, Nasarawa State University, Keffi, Nigeria.

2.3.1. *Ocimum gratissimum* (Clove basil)

Ocimum gratissimum plant is locally known in Nigeria as Nchuawun (Igbo), Efirin (Yoruba), Daidoya (Hausa) and Clove Basil in English language [24].

Basil which belongs in the family *Lamiaceae*, is grown for its leaves which are used as herbs in cooking [25]

Basil plant behaves like an annual in cold weather and can stay alive for several seasons as a perennial in warm climates [26].

2.3.2. *Moringa oleifera* (Moringa)

Moringa oleifera is also known as: "Oduduoyibo , Okweoyibo, Okwe or oku-gara-ite in Igbo language and in Youruba language as "Igiiyanu", "malero", "Ewele, Idagbo" or "Momoye" ; Zogale in Hausa and Moringa in English language [24].

As reported in[27], a recent study of the nutritional value of *M. oleifera* leaves found that the dried leaves are composed of amino acids and several minerals such as calcium, phosphorus, magnesium, potassium, sodium, sulphur, zinc, copper, manganese, iron and selenium. Due to its nutritional and therapeutic and prophylactic benefits, it is widely promoted in poverty stricken areas to counter malnutrition and the effects can be seen within a few days of including it in the diet [24].

2.4. Sample Collection and Pre-treatment

Mallo and Mgbanyi reported that FCT is characterized by six months dry season from November to April and six months rainy season from May to October. Therefore, samples were collected in March/April for the dry season and September/October for the raining season [28].

2.4.1. Plants

The leaves of *Ocimum gratissimum, and Moringa oleifera* were collected from the farms in the vicinity of the quarry. Samples of the same type of plants were combined to give the representative fraction of each of the plants, and packed in separate polythene bags and properly labelled. The samples were pre-treated using the method described by [29] where the plant samples were washed with tap water and rinsed with deionized water to remove any particles attached to the plant surfaces. The samples were separated dried in open air for 5 days and then further dried in oven at 60 °C for 24 hours to constant weight. Dried plant tissues were grounded into fine powder and packed in well labelled plastic bags prior to laboratory analysis.

2.4.2. Soil

Soil samples were collected at depths of 0.0 - 5.0 cm and 5.0 - 10.0 cm from the surface of the earth with the help of soil auger. Each soil samples were collected simultaneously at the same spot where the edible plant parts are collected and mixed thoroughly to give representative samples of the 2 depths, collected. The soil samples were sorted so as to pass through a 2mm sieve; homogenized and stored in labelled plastic bags prior to laboratory test [30].

2.4.3. Water

Water samples were collected at 3 points, namely, M1 (Before the quarry), M2 (At the quarry), and M3 (After the quarry points), along the course of the stream around the quarry. Samples were collected in 1litre polyethylene containers and labelled. The sample and test beakers containers were washed with 20% analytical grade nitric acid and rigorously rinsed with distilled deionized water. Prior to sampling, they were further rinsed with the actual sample and preserved with 5ml of concentrated Nitric acid per litre of sample [31]. This reduces precipitation and sorption losses to the container walls [32]. Samples were then stored under ice on transit and then refrigerated after arriving at the laboratory at a temperature of (4 °C) prior to analysis [33]. All analyses were carried out in triplicates using standard methods.

2.5. Determination of Physicochemical Properties of Soil

2.5.1. pH

A 5 g portion of the air-dried soil was weighed using an analytical balance and 25 cm^3 of distilled water added and agitated for 5 min and the solution left undisturbed for 1hr. The pH was determined using a pH meter by inserting the electrode in each of the sample solutions after the calibration of the pH meter [34].

2.5.2. Total heavy metals in Soil

A 3g portion of the pre – treated soil sample was weighed in a 100 ml round bottom flask. 21 ml of concentrated HCl (35%) and 7 ml concentrated HNO_3 (65%) was added. This was kept at room temperature overnight. A water condenser was attached to the flask and its content and heated to boil for 2 hours. A 25 ml portion of glass distilled water was added. The mixture was filtered through Whatman (No. 42) filter paper into a 100ml volumetric flask. The residue was filtered twice with 5ml of water into the flask and the solution made up to 100ml [35]. This was analysed using Atomic Absorption Spectrophotometer.

2.5.3. Bioavailable Heavy Metal Fraction in Soil

The potentially mobilizable (bioavailable) form of heavy metals was extracted with 0.05M EDTA. A 10 g portion of soil was weighed in a 125 ml Erlenmeyer flask and 100 ml of the reagent was added. The suspension was shaken for 1 h. and then filtered through a Whatman (No. 42) filter and made up to mark with distilled water in the 125ml flask[36]. This was analysed using Atomic Absorption Spectrophotometer

2.6. Total heavy metals in water

Environmental Protection Agency (EPA) vigorous digestion method described [37] as described in [38] was adopted. 10ml of conc.HNO^3 was transferred into each pyrex beaker containing 100mL of each of the representative water samples. The samples were boiled slowly and then evaporated on a hot plate to the lowest possible volume (about 20 ml). The beakers were allowed to cool and another 5ml of conc. Nitric acid was added. Heating was continued with addition of conc. Nitric acid as necessary until digestion was completed. The samples were evaporated again to dryness (but not baked) and then allowed to cooled, followed by addition of 5 ml of HCl solution (1:1 v/v). The solutions were warmed and 5ml of 5M NaOH added, then filtered. The filtrates were transferred to 100 ml volumetric flasks and diluted to the mark with distilled water. These solutions were used for heavy metal analysis using an Atomic Adsorption Spectrophotometer (AAS).

2.7. Total heavy metals in plant samples

A 0.5 g portion of dried sample of each of the powdered vegetables was digested separately for heavy metal analysis; using 8 ml concentrated HNO_3 and 2 ml $HClO_3$ and kept for 5 hrs. The extracts were filtered and diluted up to 50 ml with distilled water [29].

These solutions were used for further analysis using Atomic Absorption Spectrophotometer.

2.8. Statistical Analysis

Analysis of variance (ANOVA): Single-factor and post hoc analysis using the Bonferroni correction was carried out to evaluate the significant difference in the concentrations of the heavy metals in each of the samples during each season and between the seasons. Correlation analysis at $P \leq 0.05$ level (2 tailed) of significance was also carried out in the samples.

2.9. Anthropogenic Metal

The anthropogenic metal content for each heavy metal was calculated with the equation:

$$\text{Anthropogenic metal} = \frac{\text{X} - \text{Xc}}{X} \qquad (2.1)$$

Where X= Metal content representing the lithogenic metal

Xc = Average concentration of the metal in the soil

The content of the control, which is the background sample, represents the lithogenic metal [39-40].

2.10. Contamination/Pollution Index

The contamination/pollution (C/P) index was calculated using the contamination/pollution index as defined by [41] in [40].

$$\text{C/PI} = \frac{\text{Concentration of metals in soil}}{\text{Target value}} \qquad (2.2)$$

The target (reference)values for maximum allowed concentrations of metals: Cd - 0.8, Cr -100, Cu -36, Ni - 35, Pb-85, Zn- 146, Co- 20, Mn- 437 & Fe- 5000 [42].

The significance of C/P index is given in Table 7. Values greater than unity (1) indicates pollution and valuesless than unity indicate contamination [40].

2.11. Transfer Factor (TF)/Bioaccumulation Factor (BAF)

The Bioaccumulation Factor (BAF) as defined in [11, 43] was used to assess the transfer of heavy metals from soil to the Plants. It is calculated as:

$$BAF = C_p/C_s \quad (2.3)$$

Where: C_p is the total heavy metal concentration in the plant sample and Cs = concentration of the metal in corresponding. BAF>1 means high level of heavy metal contamination in the plant.

3. Results and Discussion

3.1. Concentration of Heavy Metals in Water

Dry and Rainy season concentrations of eight heavy metals - Cr, Cd, Cu, Zn, Mn, Ni, Pb and Fe,- analysed in water samples collected from the three sampling points (M1, M2, and M3) in the stream around the quarry are presented in Tables 1 and 2 respectively. The results show higher concentrations of heavy metals in the rainy season than in the dry season. This is further illustrated in figure 1. The dry season results revealed that only concentrations of Pb and Fe increased at M2, indicating an impact from the quarry activities. While concentrations of Cr, Cu, Cd and Ni were below detection limit, concentrations of Zn was only below detection limit at M2 while Mn concentration was detected only at sampling point M3indicating that the source of Zn and Mn in the dry season was not the quarry activities.

Table 1: Dry Season Concentrations of Heavy Metals (Mg/L) in Water Samples

Parameter	Sampling Point		
	M1	**M2**	**M3**
Cr (mg/L)	ND	ND	ND
Cu (mg/L)	ND	ND	ND
Cd (mg/L)	ND	ND	ND
Zn (mg/L)	0.01 ± 0.01	ND	0.08 ± 0.14
Mn (mg/L)	ND	ND	0.23 ± 0.00
Ni (mg/L)	ND	ND	ND
Pb (mg/L)	0.04 ± 0.03	0.07 ± 0.04	0.04 ± 0.03
Fe (mg/L)	0.07 ± 0.06	0.14± 0.04	0.05 ± 0.03

Key: M1- Before the Quarry, M2- At the quarry, M3- After the quarry, ND – Not Indicated

Table 2: Rainy Season Concentrations of Heavy Metals (Mg/Kg) in Water Samples

Parameter	Sampling Point		
	M1	**M2**	**M3**
Cr (mg/L)	0.69 ± 0.49	0.11 ± 0.00	0.04 ± 0.00
Cu (mg/L)	0.78 ± 0.32	0.05 ± 0.01	0.39 ± 0.16
Cd (mg/L)	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
Zn (mg/L)	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.00
Mn (mg/L)	0.10 ± 0.07	0.13 ± 0.10	0.36 ± 0.26
Ni (mg/L)	ND	ND	ND
Pb (mg/L)	0.09 ± 0.04	0.06 ± 0.02	ND
Fe (mg/L)	0.01 ± 0.00	0.19 ± 0.14	0.04 ± 0.04

Key: M1- Before the Quarry, M2- At the quarry, M3- After the quarry, ND – Not Indicated

In rainy season, the results showed an increase in the concentration of Mn throughout all the three sampling points indicating that run-offs from the quarry contributed to the concentrations of Mn observed. Concentrations of Cd and Zn remained at 0.1 mg/kg in all the sampling points showing no impact from the quarry. Concentrations of Cr and Cu were observed to be highest at M1 and reduced at M2, showing the quarry activities did not contribute to its presence. This indicates that Cr and Cu resulted from run offs from other activities before the quarry site. Cr and Cu have been reported to enter the environment from natural sources such as rock weathering [44- 45].

Just as in the Dry season Pb and Fe concentrations were in the order M1<M2>M3 indicating that run-offs from the quarry activities increased the concentration of these two heavy metals during the rainy season. The range of concentration of heavy metals observed in both seasons was 0.01to 0.78 mg/L.

Table 3 shows a comparison of the mean concentrations of the heavy metals recorded in both dry and rainy season with Food and Agricultural Organization (FAO) recommended maximum levels for irrigation water [46]. This revealed that the mean concentrations of all the heavy metals -Zn, Mn, Pb and Fe- present in the dry season fell within FAO maximum levels for irrigation water however, in rainy season, mean concentrations were higher than the FAO maximum recommended limits of 0.10 mg/L for Cr and 0.20 mg/L for Cu recommended for irrigation water, thus making the water not suitable for irrigation in this season. Mean concentrations of Pb and Fe observed to have increased in the stream due to quarry activities in both season were within the recommended maximum levels of 5.0 mg/L each, for irrigation water. Generally, the concentrations of Cr, Cu, Cd, Zn, Mn, Pb and Fe observed in water samples from this study are not as high as those in a similar study carried out in [47], where heavy metal concentrations (Mg/L) in surface water from Akamkpa stream which is also within quarry environment were in the order: Fe 12.4 > Zn 9.7 > Mn 7.8 > Pb 6.3 > Cu 3.7> Cr 1.8 > Cd 1.3. Only rainy season concentration of Pb is significantly different ($p \leq 0.05$) at sampling point M2 (Sampling point at the quarry) than M3 (Sampling point after the quarry).

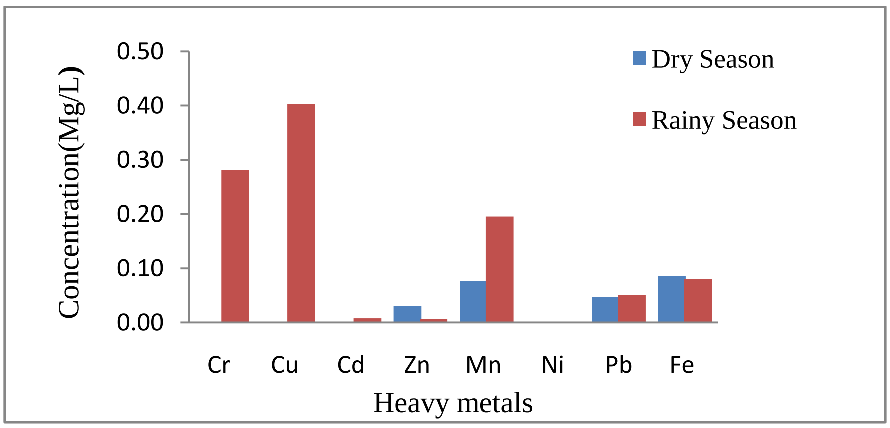

Figure 1: Seasonal comparison of mean concentrations (mg/L) of heavy metals in water samples

Table 3: Comparison of Seasonal Mean Concentrations (Mg/L) of Heavy Metals in Water with FAO Recommendation for Irrigation Water

Heavy metals	Dry	Rainy	Maximum levels [46]
Cr	ND	0.28	0.10
Cu	ND	0.40	0.20
Cd	ND	0.01	0.01
Zn	0.03	0.01	2.00
Mn	0.08	0.20	0.20
Ni	ND	ND	0.20
Pb	0.05	0.05	5.00
Fe	0.09	0.08	5.00

Key: ND- Not indicated

3.2. Total heavy metals in Soils Samples

Tables 4 and 5 present the heavy metal concentrations in soil samples at and controls collected at different soil depths during dry and rainy season respectively. Heavy metals concentrations in the soil samples during dry and rainy seasons are generally higher in the samples than in the controls. However, in dry season, Cr (2.18mg/kg), Mn (2.08mg/kg) and Pd (3.36mg/kg) at soil depth of 0.00 -0.50cm were higher in concentrations in control than soil samples. This was also observed for concentrations of the same heavy metals at soil depth of 0.50 to 10.00 cm where the same heavy metals Cr, Mn and Pb recorded higher concentration in the controls than in the samples at levels of 2.91, 6.34mg/kg and 1.31mg/kg respectively. Rainy season results also showed these deviations, as Cr (0.79mg/kg) and Pb (26.62mg/kg) at soil depth of 0.00 to 5.00cm and Cr (0.78), Ni (1.05mg/kg) and Fe (11.58mg/kg) at soil depth of 5.0 to 10.0 cm had higher concentrations in the control than in the actual soil samples. This observation indicates that the source of heavy metals in soil in the study area is not limited to run offs from the quarry activities or other anthropogenic sources. Heavy metals are naturally always present in the soil, groundwater and surface water and the natural background (lithogenic) values in the soil are usually in the range from 1 - 100 mg/kg, but higher or lower values are possible for some metals [4].

Heavy metals in the environment could also result from geological weathering of rocks [48]. The concentrations of Cr, Cu at soil depths of 5.00 -10.00cm and concentrations of Zn at soil depths of 0.0 -5.00cm were significantly different in sample than control during dry season ($p \leq 0.05$). During rainy season, concentrations of Ni and Pb in soils at depth of 0.0 -5.00cm and concentration of Pb at 5.00 -10cm were significantly different in sample than control. In addition, Table 6 shows the anthropogenic input of metals in soil samples ranging from 0 – 93.20%. Only concentrations of Cr, Mn, Fe and Pb are affected. Cr has the highest anthropogenic metal input of 93.20% during rainy season at soil depth of 5.0 to 10.0cm. The lowest input was in Ni with 5.7% heavy metal from anthropogenic source (mining activities) at soil depth of 5.0 -10.0cm during rainy season. This indicates that the quarry activities imparted on the concentration of some heavy metals in the soil.

The concentrations of heavy metals in the samples at the various soil depths (0.0 – 5.0 cm and 5.0 – 10.0cm) illustrated in figures 2 and 3 for dry and rainy seasons respectively, shows that most of the heavy metals concentrations are higher at soil depth of 0.0 – 5.0cm than at 5.0 -10.00cm during both seasons. These observed higher concentrations of heavy metals in the top soil could be due to a myriad of complex interacting processes influenced by physicochemical parameters such as the total metal content, soil pH, redox conditions and contents of organic matter, clay minerals and oxides as well as contact time with the soil matrix [49].

However, only Cu was significantly lower in dry season for soil samples at depth of 0.0 -5.00cm.

Similar study carried out by [11] showed that soils collected from an abandoned granite quarry at soil depth of 0-15cm had total heavy metal concentrations of Cr(17.71mg/kg), Cu (2.63mg/kg) Cd(ND), Zn (7.01mg/kg), Mn (136.75mg/kg), Ni(3.54mg/kg), Pb(11.92mg/kg) and Fe (6141.25 mg/kg). These levels are higher than observed in this study at a similar depth of 0-10cm(0.0 – 5.0cm and 5.0cm -10cm) except for dry season concentrations of Cd(0.07mg/kg) at soil depth of 0.0 – 5.0cm and Cd (0.04mg/kg), Ni(3.66mg/kg at soil depth of 5.0 – 10cm and rainy season concentrations of Pb(18.98mg/l), Cd(0.10mg/l) at soil depth of 0.0 – 5.0cm and Pb (25,4mg/l), Cd(0.01mg/l) at depth of 5.0-10cm, which had higher concentrations than that observed in the study by [11]

Figure 4 shows the seasonal comparison of mean concentrations of total heavy metals in the soil samples. Most of the heavy metals had higher mean concentrations in dry season than in rainy season. This findings is same as was observed in similar researches [50 - 51] and the low concentrations observed in rainy season is attributed to leaching and runoffs capable of removing toxic metals from soil in wet season [50].

Dry season mean concentrations of Cr(0.75mg/kg), Zn(1,15mg/kg), Mn (2.26mg/kg), Ni (2.50mg/kg) and Fe (7.16mg/Kg) were higher than in rainy season while mean concentrations of only Cu (0.15mg/kg), Cd (0.10mg/kg) and Pb(22.19 mg/kg) were higher in rainy season than dry season. Mean concentrations of Cd and Pb were significantly higher in rainy season than dry season while mean concentrations of Ni were significantly higher in dry season than rainy season.

Contamination / Pollution Index (C/PI)for each heavy metal in soil sample presented in Table 8 was compiled using the standard set for interpreting soil heavy metals by the Department of Petroleum Resources of Nigeria [42] so as to be in line with the statement that standard employed for interpreting soil heavy metals contamination/pollution index varies from country to country based on the chosen factors [41] as in [40].

The C/PI index (Table 8) for each metals showed that the soil in farms at the quarry vicinity are very slightly contaminated with Cr, Zn, Mn, Ni and Fe in both seasons and at both soil depths implored in this study. Slight Cd and Pb contamination was also seen in soils from both soil depths during dry season only. Also slight Pb and Cd contamination was seen during rainy season at soil depth of 0.0-05 and 5.0 to 10.0cm for Pb and 0.0- 5.0cm only for Cd. However, slight contamination of Pb with the a C/PI index of 0.30 at depth of 5.0 – 10.0cm during rainy season was the highest C/PI ranking for soil samples collected from farms around the quarry sight.

Table 4: Dry Season Mean Concentrations of Total Heavy Metals (Mg/Kg) of Soil Samples

Parameter	**Sample Depth (cm)**		**Control Depth (cm)**	
	0.0- 5.0	**5.0- 10.0**	**0.0- 5.0**	**5.0- 10.0**
Cr(mg/Kg)	1.32±1.19	0.18±0.06[aa]	2.18±1.79	2.91±0.48[aa]
Cu(mg/Kg)	0.06±0.02	0.16±0.04[ab]	0.04±0.02	0.06±0.02[ab]
Cd(mg/Kg)	0.07±0.05	0.07±0.03	0.05±0.05	0.04±0.04
Zn(mg/Kg)	1.36±0.19[ac]	0.93±0.26	0.17±0.17[ac]	0.24±0.00
Mn(mg/Kg)	0.94±0.69	4.26±2.65	2.08±0.79	6.34±1.21
Ni (mg/Kg)	2.56±0.00	2.44±0.00	0.06±0.00	0.32±0.28
Pd mg/Kg)	0.67±0.00	ND	3.36±1.57	1.31±2.06
Fe (mg/L)	5.94±0.00	8.38±7.30	5.42±0.00	12.34±2.62

Key: ND - Not Detected, Mean concentrations with the same superscripts are significantly different ($p \leq 0.05$)

Table 5: Rainy season mean concentrations of total heavy metals (mg/kg) of soil samples

Parameters	**Sample Depth (cm)**		**Control Depth (cm)**	
	0.0 - 5.0	**5.0 - 10.0**	**0.0 - 5.0**	**5.0 - 10.0**
Cr(mg/Kg)	0.46±0.40	0.38±0.31	0.79±0.55	0.78±0.72
Cu(mg/Kg)	0.06±0.02	0.23±0.20	0.05±0.04	0.03±0.03
Cd(mg/Kg)	0.10±0.01	0.10±0.06	0.09±0.01	0.05±0.04
Zn(mg/Kg)	0.18±0.08	0.51±0.27	0.11±0.05	0.18±0.04
Mn(mg/Kg)	1.17±0.21	0.99±0.14	0.81±0.09	0.78±0.09
Ni (mg/Kg)	1.12±0.19[ac]	0.99±0.55	0.36±0.08[ac]	1.05±0.58
Pd mg/Kg)	18.98±2.92[a]	25.40±0.74[a]	26.62±1.45[ab]	5.73±3.13[ab]
Fe (mg/Kg)	6.76±3.23	6.87±2.46	3.03±1.81	11.58±5.67

Table 6: Anthropogenic input (%) for Heavy Metals in Soil from farms around the Quarry Site

Soil Depth	**Season**	**Cr**	**Cu**	**Cd**	**Zn**	**Mn**	**Ni**	**Pd**	**Fe**
0.0 - 5.0cm	Dry	39.32	-60.61	-53.66	-687.18	54.80	-4140.50	ND	-9.45
5.0 - 10.0cm	Dry	93.70	-143.10	-54.95	-292.93	32.84	-674.03	ND	32.07
0.0 - 5.0cm	Rain	42.13	-31.82	-12.20	-63.26	-44.46	-215.29	28.71	-122.80
5.0 - 10.0cm	Rain	51.84	-703.78	-109.09	-191.19	-27.47	5.71	-343.07	40.65

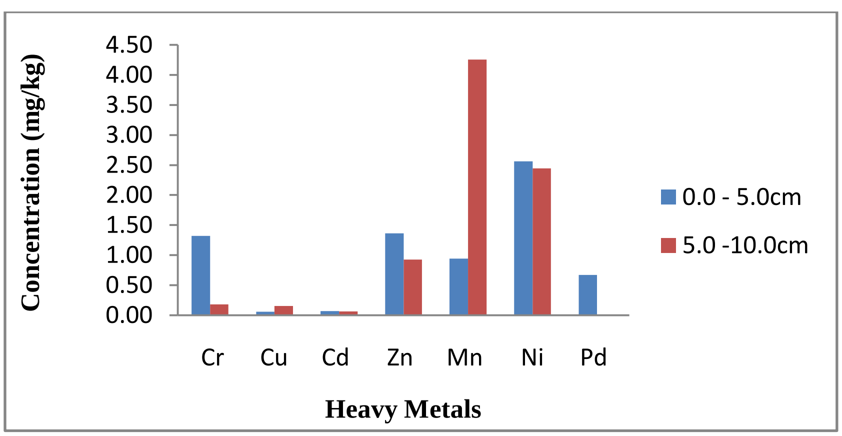

Figure 2: Mean concentrations of Total Heavy Metals in the Soil Samples at the Two Soil Depth during Dry Season

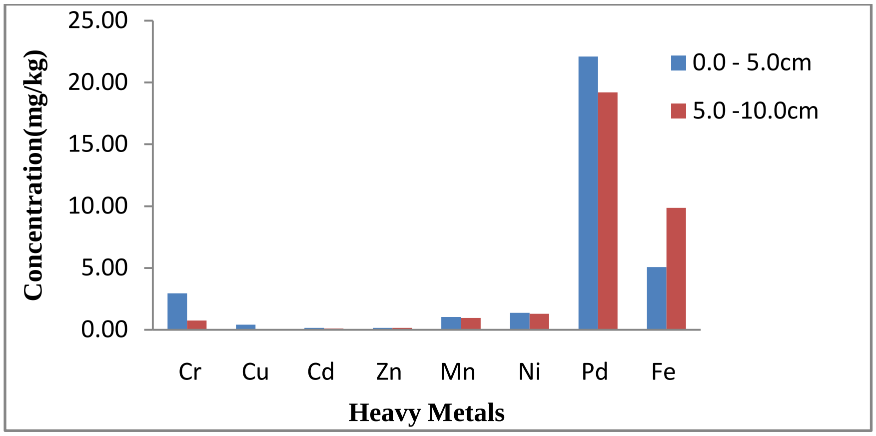

Figure 3: Mean concentrations of Total Heavy Metals in the Soil Samples at the Two Soil Depth during Rainy Season

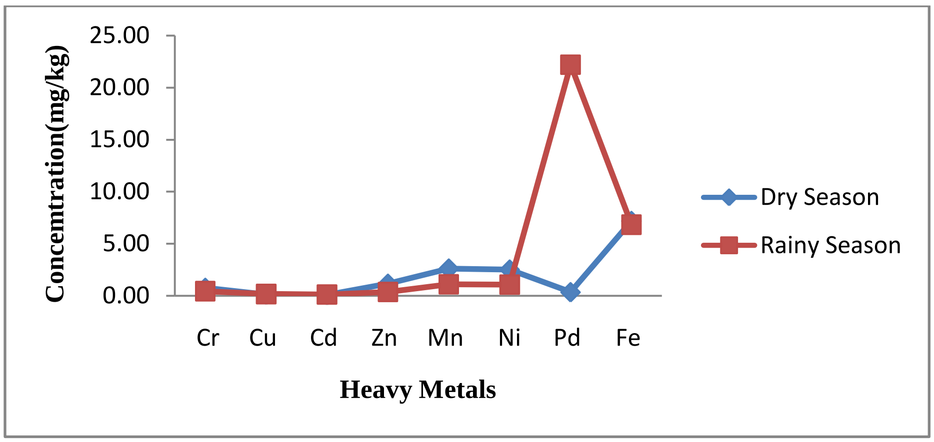

Figure 4: Seasonal Comparison of Mean Concentrations of Total Heavy Metals Analysed in Soil Samples

Table 7: Significance of interval of contamination/pollution(C/P) index value

C/P	Significance
<0.1	Very slight contamination
0.10–0.25	Slight contamination
0.26–0.50	Moderate contamination
0.51–0.75	Severe contamination
0.76–1.00	Very serve contamination
1.1–2.0	Slight pollution
2.1–4.0	Moderate pollution
4.1–8.0	Severe pollution
8.1–16.0	Very severe pollution
>16	Excessive

Table 8: Contamination / Pollution Index of Heavy metals in soil

	Soil Depth	Cr	Cu	Cd	Zn	Mn	Ni	Pb	Fe
Dry Season	0.0 - 5.0cm	0.01	0.00	0.09	0.01	0.00	0.07	0.01	0.00
Dry Season	5.0 - 10.0cm	0.00	0.00	0.08	0.01	0.01	0.07	0.00	0.00
Rainy Season	0.0 - 5.0cm	0.00	0.00	0.13	0.00	0.00	0.03	0.22	0.00
Rainy Season	5.0 - 10.0cm	0.00	0.01	0.13	0.00	0.00	0.03	0.30	0.00

3.3. Bioavailable Heavy Metals in Soil samples

An organism is adversely affected only by the biologically available (bioavailable) fraction of the total metal content in soil [49] hence, the need to quantify the environmentally bioavailable heavy metals in the soil samples. Tables 9 and 10 show the results of bioavailable metal in the soil samples for dry and rainy season respectively.

In the dry season the highest concentration of Bioavailable heavy metal is Fe with concentrations of 0.95mg/kg and 3.34mg/Kg at depth of 0.0-5.0 cm and 5.0 -10cm respectively while in rainy season, Fe also recorded the highest concentrations of 0.81mg/kg at soil depth of 0.0-5.0cm and 2.09mg/kg at soil depth of 5.0 -10cm.

Figure 5 shows seasonal comparison of mean concentrations of total and bioavailable heavy metals. Bioavailable heavy metals are lower than total heavy metal. This is expected to be the case since environmentally bioavailable heavy metals is simply a fraction of the concentration of dissolved metal species in the pore water which can be taken up by plant roots or other soil organisms [49].

Table 9: Dry Season Mean Concentrations (Mg/Kg) of Bioavailable Heavy Metals in Soil, from Different Depth

Element	**Sample depth (cm)**	
	0.00 – 5.00	**5.00 – 10.00**
Cr (mg/Kg)	0.49±0.15	ND
Cu (mg/Kg)	0.01±0.01	0.03±0.01
Cd (mg/Kg)	0.03±0.01	0.03±0.03
Zn (mg/Kg)	ND	0.81±0.19
Mn (mg/Kg)	0.46±0.10	0.46±0.06
Ni (mg/Kg)	0.05±0.05	0.01±0.09
Pd (mg/Kg)	0.46±0.41	ND
Fe (mg/Kg)	0.95±0.84	3.34±3.0

Key: ND- Not Detected

Table 10: Rainy Season Mean Concentrations (Mg/Kg) of Bioavailable Heavy Metals in Soils from Different Depth

Element	**Sample depth (cm)**	
	0.00 – 5.00	**5.00 – 10.00**
Cr(mg/Kg)	ND	ND
Cu(mg/Kg)	0.03±0.02	0.03±0.01
Cd(mg/Kg)	0.01±0.01	0.03±0.01
Zn(mg/Kg)	0.09±0.02	0.04±0.00
Mn(mg/Kg)	0.17±0.04	0.18±0.04
Ni (mg/Kg)	0.03±0.08	0.34±0.04
Pd mg/Kg)	1.16±0.83	0.66±0.15
Fe (mg/Kg)	0.81±0.70	2.09±1.82

Key: ND – Not Detected

Table 11: World Health Organizations and Food (WHO) and Agriculture Organizations (FAO) Maximum Allowable Limits (mg/Kg) of Heavy Metals in soils and vegetables [52]

Chemical Element	**Maximum Permissible Level in Soil**	**Maximum Permissible Levels in Vegetables**
Cr	100	-
Cd	3	0.1
Cu	100	73
Zn	300	100
Mn	2000	500
Ni	50	67
Pb	100	0.3
Fe	50000	425

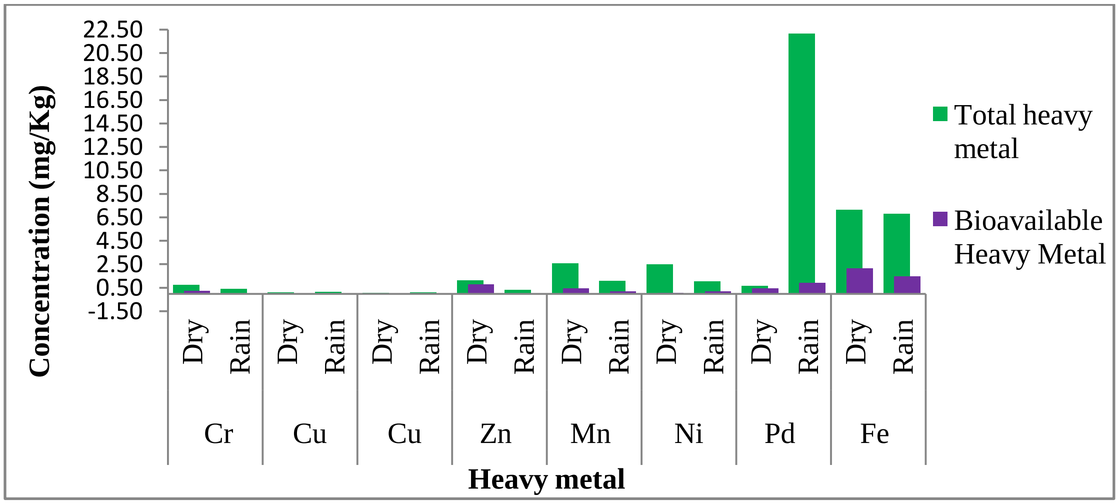

Figure 5: Seasonal Comparison of Mean Concentrations of Total and Bioavailable Heavy Metals

3.4. Physico Chemical Properties of Soil

Various physico chemical propertied of soil have been identified in ensuring the availability and mobility of heavy metals for plant uptake [7, 49, 53]. Physico chemical properties of soil samples collected in farms around the quarry are shown in tables 12 and 13. Table 12 shows the fractions of sand, clay and silt, and soil texture class of the soil samples at the two soil depths of 0.0-5.0 cm and 5.0 -10cm. At both depths the soils are sandy. Unlike clay soils, sandy soils do not retain heavy metals [7, 58].The soil texture class(Sand) for both sample and control are same showing that they are from the same source and from the same geological region [54].

Table 13 shows the levels of pH, Cation Exchange Capacity (CEC) and Organic matter (OM). The pH for soils samples and control in both seasons ranged from 6.01 to 6.87(slight acidity). This trend will not enhance availability and mobility of heavy metals in this soil since generally, most metals do not exist in free form in the pH range of 6.0 to 9.0 [54-55]. Organic matter(OM) in both soil sample and control ranges from 0.63 to 1.29%. This is close to values (1.12 to 2.01%) obtained in a similar study [11].

Table 12: Particle Size Distribution and Texture Class of Soil

Parameters	**0.0 - 5.0**	**5.0 - 10.0**	**0.0 - 5.0**	**5.0 - 10.0**
Sand%	92.47	92.05	92.36	92.03
Clay%	1.08	1.17	0.72	0.72
Silt%	7.09	6.78	6.92	7.25
Texture Class	Sand	Sand	Sand	Sand

Table 13: Physico chemical Parameters of soil

Seasons	**Parameters**	**Soil Depth (cm)**			
		Sample		**Control**	
		0.0 -5.0	**5.0 - 10.0**	**0.0 -5.0**	**5.0 - 10.0**
Dry	pH	6.87 ± 0.23	6.52 ± 0.29	6.21± 0.77	6.76 ± 0.16
	OM (%)	0.63 ± 0.06	0.66 ± 0.01	1.12 ± 0.07	0.74±0.15
	CEC(meq/100g)	10.46 ± 2.50	6.30 ± 3.00	12.71±3.67	12.75±4.48
Rainy	pH	6.19 ± 0.52	6.01 ± 0.74	6.21 ± 0.77	6.76 ± 0.21
	OM (%)	0.71 ±0.16	0.73 ± 0.18	1.29 ± 0.12	0.78 ± 0.35
	CEC(meq/100g)	10.20 ± 1.08	7.07 ± 2.22	16.02 ± 2.28	13.69 ± 3.32

Key: OM- Organic Matter, CEC- Cation Exchange Capacity

Cation Exchange Capacity (CEC) of the soils also ranges from 6.30 – 16.02meq/100g.Soil OM has a major influence on the chemical properties of a soil, and in general has a very high cation exchange capacity. The cation exchange capacity is a measure of the soil's ability to hold positively charged ions, resulting in a strong adsorption of metal cations [13]. Hence, the low OM observed in this study suggest low adsorption and retention of heavy metals within the soil. Levels of most of the soil properties apart for the low pH indicate little or no interference with the availability and mobility of heavy metals in the soil. However, the level of soil pH (6.01 – 6.87) tends towards neutral hence, may reduce both the concentration of heavy metals in soil solution and the leaching of heavy metals further towards the subsoil thus making it less available for plant uptake[17-18].

Table 14: Correlation Coefficient Rating

Correlation Coefficient	
(r) value	**Rating**
Exactly 1	Perfect
9.9 to 0.90	Very strong
0.91 to 0.70	**S**trong
0.69 to 0.50	Moderate
<0.5	Weak
Positive (+)	Uphill linear relationship
Negative (-)	Downhill linear relationship

Adapted from [41] and [56]

Table 15: Correlation Coefficients (r) at P≤0.05 level (2 –tailed) of Concentrations of Bioavailable Heavy Metals with Values of Soil properties at depth of 0.0-5.0 and 5.0-10.0cm during Dry season

Heavy Metal	**Soil Properties**			
	pH	**CEC**	**SOM**	**CLAY**
Cr	0.50	0.80	-0.65	-0.24
Cu	-0.73	-0.21	0.48	0.22
Cd	0.56	0.47	0.08	-0.47
Zn	-0.50	-0.70	0.45	-0.01
Mn	-0.49	-0.42	0.69	0.55
Ni	-0.71	-0.66	0.31	0.49
Pd	0.10	0.63	-0.14	-0.17
Fe	-0.31	-0.76	0.15	0.21

Table 16: Correlation Coefficients (r) at P≤0.05 level (2 –tailed) of Concentrations of Bioavailable Heavy Metals with Values of Soil properties at depth of 0.0-5.0 and 5.0-10.0cm during Rainy season

Heavy Metal	**Soil Properties**			
	pH	**CEC**	**SOM**	**CLAY**
Cr	0.00	0.00	0.00	0.00
Cu	-0.61	0.04	-0.05	0.31
Cd	-0.22	-0.86*	-0.14	0.09
Zn	-0.20	0.74	0.05	-0.03
Mn	0.74	0.01	0.16	-0.52
Ni	-0.07	-0.82*	-0.12	0.23
Pd	0.26	0.27	-0.52	-0.22
Fe	0.72	-0.66	-0.39	-0.60

*Correlation is significant at P≤0.05 level (2 –tailed)

Table 15 shows the correlation coefficient (r) between concentrations of bioavailable heavy metals and soil physicochemical properties for dry season. There was no significant correlation. The pairs of Cr/CEC, Mn/OM and Cu/pH, Zn/CEC, Ni/pH, Fe/CEC had strong uphill (positive) and downhill (negative) linear relationship respectively. While Cr/pH, Cd/pH, Mn/OM, Pb/CEC and Cr/OM, Zn/pH, Ni/CEC had moderate uphill and downhill linear relationship respectively. None of the correlations was significant. Other pairs had weakly uphill or downhill relationships. During rainy season (Table 16), pairs of Cd/CEC, Ni/CEC and Mn/pH, Fe/pH has strong downhill and uphill linear relationship respectively but Cu/pH, Fe/CEC, Pb/OM, Mn/CLAY and Fe/Clay all had moderate downhill relationship. Other pairs had weakly uphill or downhill.

The uphill and downhill relationship between metals and soil properties is an indication of the influence of the soil properties in the bioavailability of the metal according to explanations by various researchers [7, 13,15, 17-19, 57, 58]. This explanation further showed that the bioavailability of heavy metals is favoured by a downhill linear relationship with soil pH, soil OM, CEC and Clay content. It is thus obvious from Table 15 that during dry season, bioavailability of Cr and Pb was favoured by soil OM and Clay content, Cd by only Clay content, Zn by pH, Clay and CEC; and Mn, Cu, Ni and Fe by pH and CEC only. For Rainy season bioavailability of Mn was made available by Clay content only; Pb by soil OM, and Clay content; Fe by soil OM, Clay and CEC; Ni and Cd by soil pH, OM, and CEC; Cu by soil pH and OM only while Zn also by soil pH and clay content only.

During both seasons, only Cd(-0.86) and Ni (-0.82) had significant correlation with CEC at P≤0.05 level (2 –tailed), indicating the strong influence of CEC in ensuring that Cd and Ni were available in soil pore solutions for plant intake during rainy season.

3.5. Total Heavy Metals in Pant Samples

Table 17: Concentrations of Heavy Metals (Mg/Kg) in Samples of Plant Leaves during Dry Season

Parameters	*Ocimum gratissimum*		*Moringa Oleifera*	
	Sample	**Control**	**Sample**	**Control**
Cr(mg/Kg)	1.35±0.38	ND	2.13±0.50	42.17±1.76
Cu(mg/Kg)	0.54±0.22	0.56±0.09	0.41±0.09	1.71±2.51
Cd(mg/Kg)	0.19±0.13	ND	0.26±0.23	0.16±0.10
Zn(mg/Kg)	4.93±1.88	7.20±0.16	5.64±0.49	3.97±1.80
Mn(mg/Kg)	2.46±1.70	0.57±0.33	14.15±11.37	3.96±0.70
Ni (mg/Kg)	ND	7.35±5.76	0.31±0.29	3.63±3.15
Pd mg/Kg)	1.63±1.44	1.60±1.39	6.39±5.53	3.27±2.88
Fe (mg/Kg)	120.81±16..95	68.86±10.95	103.72±23.40	70.97±33.07

Key: D – Not Detected

Table 18: Concentrations of Heavy Metals (Mg/Kg) In Samples of Plant Leaves during Rainy Season

Parameters	*Ocimum gratissimum*		*Moringa oleifera*	
	Sample	**Control**	**Sample**	**Control**
Cr (mg/Kg)	112.89±20.29	31.17±27.46	69.81±60.72	37.05±32.10
Cu (mg/Kg)	0.18±0.07	0.13±0.08	0.18±0.04	0.22±0.12
Cd (mg/Kg)	1.06±0.08	0.34±0.30	0.98±0.02	0.21±0.02
Zn (mg/Kg)	0.63±0.38	1.54±0.82	0.66±0.20	0.87±0.76
Mn (mg/Kg)	54.87±6.07.29	3.82±2.10	103.57±12.76	0.56±0.20
Ni (mg/Kg)	1.08±0.97	1.11±0.97	1.24±1.11	0.31±0.27
Pd (mg/Kg)	1.95±1.16	3.37±2.92	0.97±0.87	204.22±190.29

Table 19: Comparison of Seasonal Mean Concentrations (Mg/kg) of Heavy Metals in Plants with Maximum Permissible limits (Mg/Kg)

Heavy Metal	Dry Season		Rainy Season		WHO/FAO
	Ocimum gratissimum	***Moringa Oleifera***	***Ocimum gratissimum***	***Moringa Oleifera***	**Maximum Permissible Levels in Vegetables [52]**
Cr(mg/Kg)	1.35b	2.13a	112.89b	69.81a	--
Cu(mg/Kg)	0.54	0.41	0.18	0.18	0.10
Cd (mg/Kg)	0.19	0.26	1.06	0.98	73.00
Zn (mg/Kg)	4.93	5.64	0.63	0.66	100.00
Mn (mg/Kg)	2.46	14.15	54.87	103.57	500.00
Ni (mg/Kg)	ND	0.31	1.08	1.24	67.00
Pd (mg/Kg)	1.63	6.39	1.95	0.97	0.30
Fe (mg/Kg)	120.81a	103.72	34.74a	20.28	425.00

Key: ND - Not Detected. Mean concentrations with same alphabets within same row are statistically different (P ≤ 0.05).

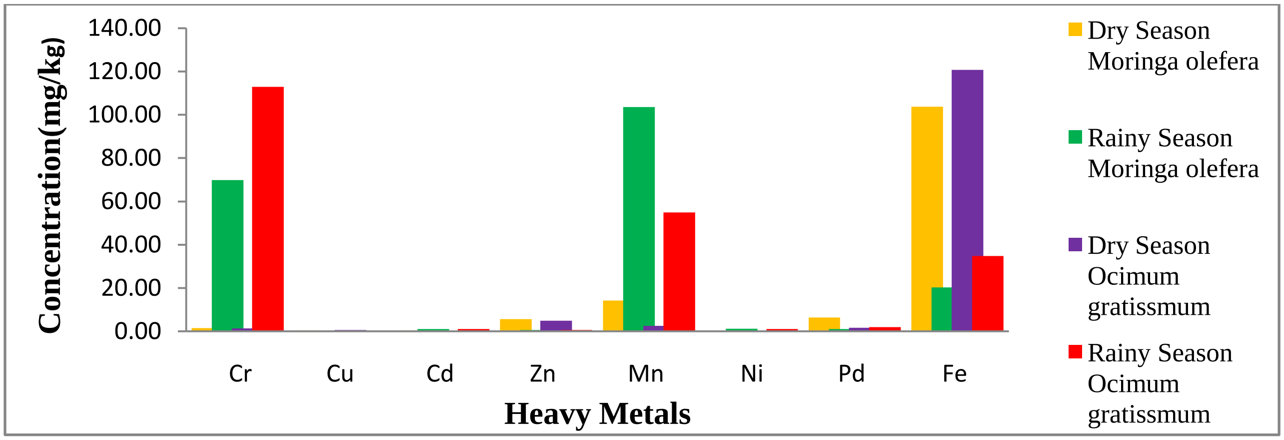

Figure 6: Comparison of Seasonal Mean Concentrations (Mg/Kg) of Heavy Metals in the Plants Leaves

Table 20: Transfer Factor of Heavy Metals from Soils in Farms around the Quarry to the Plant leaves

	Seasons	Plant	Cr	Cu	Cd	Zn	Mn	Ni	Pd	Fe
Control	Dry	*Moringa oleifera*	11.06	33.76	3.65	19.42	0.94	19.31	1.40	7.99
		Ocimum gratissimum	0.00	11.08	0.00	35.19	0.13	39.12	0.69	7.76
	Rainy	*Moringa oleifera*	28.77	5.74	2.95	6.07	0.70	0.45	12.62	3.48
		Ocimum gratissimum	24.21	3.26	4.91	10.77	4.81	1.57	0.21	3.34
Samples	Dry	*Moringa oleifera*	1.88	3.83	5.51	4.92	5.45	0.12	9.51	14.49
		Ocimum gratissimum	1.79	5.00	2.86	4.30	0.95	0.00	2.43	16.88
	Rainy	*Moringa oleifera*	167.54	1.25	9.45	1.90	95.75	1.18	0.04	2.97
		Ocimum gratissimum	270.94	1.23	10.23	1.83	50.73	1.02	0.09	5.10

Table 16 and17 shows the varied concentrations of heavy metals analysed, in samples and controls of plant leaves from the farms around the quarry and farms away from quarries respectively. Leaves of plant samples had heavy metal concentrations range from ND(Ni) to 120.81mg/kg(Fe) in *Ocimum gratissimum* and 0.26mg/kg(Cd) to 103.72mg/kg(Fe) in *Moringa oleifera* during the dry season. In the rainy season the range changed to 0.18mg/kg(Cu) to 112.89mg/kg(Cr) in *Ocimum gratissimum* and 0.18mg/kg(Cd) to 103.57mg/kg in *Moringa oleifera*.

For leaves of controls plants collected in farms far from quarry activities, the concentration of heavy metals during dry season (Table 16), in *Ocimum gratissimum* ranged from ND (Cr and Cu) to 68.86mg/kg(Fe) and in *Moringa oleifera* the range was 0.16mg/kg (Cu) to 70.97mg/kg (Pb). In rainy season (Table17) the heavy metal concentrations in the controls for *Ocimum gratissimum* ranged from 0.13mg (Cu) to 31.17mg/kg(Cr) while in *Moringa oleifera* the range was 0.22mg/kg (Cu) to 204.22mg/kg (Pb).Only concentration of Cr in *Moringa oleifera is* significantly lower in dry season than in rainy season ($P \leq 0.05$) while concentrations of Cr and Fe in *Ocimum gratissimum were* significantly higher in dry season than in rainy season ($P \leq 0.05$).

Though leaves of control plants were collected from farms free of quarry activities it was observed that the highest heavy metal concentration recorded in this study for plant leaves was Pb (204.22mg/kg) in the controls for *Moringa oleifera* during rainy season. This indicates that though the soils from farms from which the controls were collected were not affected by quarry activities, the plants growing in them are still capable of accumulating high concentrations of heavy metals; this is because apart from anthropogenic activities, background values of heavy meals have been identified [59], to be in the range from 1 - 100 mg/kg with higher or lower values possible for some metals. Also, apart from physicochemical parameters of soil that makes heavy metals available for plant uptake other factors such as plant species, the levels of the metals in the soil and air, and multiple other factors aid the accumulation and distribution of heavy metals in plants [60-61]. *Moringa oleifera* has been confirmed to have Pb concentrations of up to352.01mg/kg from samples collected from regular farms in previous studies [62].

Concentrations of each heavy metal in samples of each plant's leaves are higher than total and bioavailable metals in soils from farms in which the plants were grown. This confirms that levels of heavy metals in soils do not always indicate similar concentrations in plants [61] and that vegetables easily take up and accumulate heavy metals even when in low levels [63]. Concentrations of all the heavy metals in both leaves of *Moringa oleifera* and *Ocimum gratissimum* were within maximum permissible limits set by WHO and FAO (Table 18) in vegetables except for concentrations of Cu and Pb which are higher than permissible limits by WHO and FAO as reported in [52].

Mean concentrations of Cr, Cu and Pb (Table 19) in the plants analyses, though higher than permissible limits other studies [51, 65] show that *Ocimum gratissimum* is capable of accumulating even higher levels of this metals to as much as 14.23mg/kg (Cr), 14.23mg/kg(Cu) and 8.00mg/kg(Pb) and Moringa can accumulate as much as 352mg/kg(Pb), 1.016(Cu) and 2.425mg/kg (Cr) [27, 62]. The Level of Cr (112.89mg/kg) shown in Tables 17, 18 and 19 for *Ocimum gratissimum* is higher than in these previous studies.

Transfer Factor (TF) is referred to as the ability of a metal species to migrate from the soil into plant roots [61].

The accumulation and distribution of this metal species is influenced by many factors such as bioavailability of metals and plant species [60]. Green leafy vegetables (such as *Ocimum gratissimum, Moringa oleifera i*n this study) are known to take up high amount of heavy metals from soil. Table 19 shows the TF of heavy metals in the farms in which the vegetables were planted. The TF values varied for each plant and for each season. In the Dry season TF ranged from Cr and Cd(0.00) for *Ocimum gratissimum* control to Ni(39.2) for *Moringa oleifera* Control and Ni (0.00) for *Ocimum gratissimum* sample to Fe(16.88)for *Ocimum gratissimum* samples also. While in the rainy season TF increased and ranged from Ni (0.45) for *Moringa oleifera* controls to Cr (28.77) for *Moringa Olefera* controls also. For Samples the range was 0.04(Pb) for *Moringa oleifera to Cr (270.94) for Ocimum gratissimum*. This observed increase in TF values may be attributed to the slight drop in pH observed for soils during the rainy season. Total metal content has been observed to be largest at pH 6–8 for soils in the study [49] on contaminated industrial sites. Though Cr, Cd, Mn, Ni and Pb had TF lower than 0.5 during the seasons they were still taken up and accumulated by the plantsthis confirms same findings in similar studies [61, 66].

Generally Low TF observed indicates the strong sorption of metals to the soil while higher transfer factor indicates relatively poor retention of metals in the soil or greater efficiency of vegetables to absorb [61, 63].

Table 21: Pearson Correlation Coefficient(r) showing Relationship between Heavy Metal Concentrations (mg/kg) in Ocimum *gratissimum* and *Moringa Oleifera* during Dry Season

Heavy Metals in *Moringa oleifera*	**Heavy Metals in *Ocimum gratissimum***							
	Cr	**Cu**	**Cd**	**Zn**	**Mn**	**Ni**	**Pb**	**Fe**
Cr	-0.83	0.46	0.77	0.51	0.22	0.00	-0.83	0.91
Cu	-0.05	-0.44	-0.05	-0.38	0.91	0.00	-0.05	0.21
Cd	0.84	-1.00	-0.88	-0.99	0.82	0.00	0.83	-0.73
Zn	0.63	-0.92	-0.70	-0.90	0.95	0.00	0.62	-0.49
Mn	-0.25	-0.24	0.16	-0.19	0.81	0.00	-0.26	0.41
Ni	-0.29	-0.20	0.20	-0.15	0.79	0.00	-0.30	0.44
Pd	-0.63	0.18	0.55	0.24	0.50	0.00	-0.63	0.75
Fe	0.91	-0.60	-0.86	-0.64	-0.06	0.00	0.91	-0.96

Table 22: Pearson Correlation Coefficient(r) showing Relationship between Heavy Metal Concentrations (mg/kg) in Ocimum *gratissimum* and *Moringa Oleifera* during Rainy Season

Heavy Metals in *Moringa oleifera*	**Heavy Metals in *Ocimum gratissimum***							
	Cr	**Cu**	**Cd**	**Zn**	**Mn**	**Ni**	**Pb**	**Fe**
Cr	1.00*	-1.00	-0.42	0.80	0.45	-0.64	-0.43	-0.63
Cu	-0.92	0.90	0.08	-0.96	-0.12	0.34	0.71	0.33
Cd	-0.45	0.50	1.00**	0.21	-1.00*	0.97	-0.65	0.97
Zn	0.68	-0.65	0.34	0.99	-0.31	0.08	-0.94	0.09
Mn	-0.24	0.19	-0.76	-0.80	0.73	-0.56	0.99	-0.57
Ni	-0.22	0.27	0.97	0.45	-0.96	0.87	-0.81	0.88
Pd	-0.74	0.70	-0.26	-1.00*	0.23	-0.01	0.91	-0.01
Fe	-0.02	0.07	0.90	0.62	-0.88	0.75	-0.92	0.76

*. Correlation is significant at the 0.05 level (2-tailed), **. Correlation is significant at the 0.01 level (2-tailed).

Correlation coefficients for heavy metal concentrations in *Ocimum gratissimum* and *Moringa oleifera* during dry and rainy season respectively are shown in Tables 21 and 22. The results show varying correlations. During dry season, heavy metals pairs in Ocimum *gratissimum* and *Moringa oleifera:* Fe/Cr, Cu/Mn, Fe/Pb, Zn/Mn and Cr/Fe had very strong uphill correlation**.** Cd/Cr, Cr/Cd, Cd/Mn, Mn/Mn, Ni/Mn, Cd/Pb, and Fe/Pb had strong uphill correlation while Zn/Cr, Pd/Cd, Cr/Zn, Pb/Mn, had moderate correlation.

During rainy season had perfect uphill correlations between Cr/Cr (100), Cd/Cd (1.00) and perfect downhill correlation between Cr/Cu (-1.00), Pb/Zn (- 1.00), Pb/Ni (-1.00) and Cd/Mn (-1.00). The pairs of Cr/Cr (1.00), Pb/Zn (-1.00) and Cd/Mn (-1.00) were all significantly related at 0.05 level (2 tailed) while Cd/Cd were significant at 0.01 level (2 tailed). The pairs of heavy metals with uphill correlations show that the metals are probably from the same source of contamination resulting from activities from the rock quarry at Bmuko.

4. Conclusion

This study showed that heavy metal content of the stream around Bmuko quarry contained levels of certain heavy metals above FAO recommended limits. Continuous use of this water for irrigation could lead to with pollution of soil. Soil properties in Bmuko favoured the bioavailability of the heavy metals analysed hence making it easy for uptake by *Moringa oleifera and Ocimum gratissimum* plants in farms around the quarry. The leaves of these plants had the tendency of accumulating high concentrations of heavy metal [27, 62] even when planted in soils far away from quarry activities. It is thus very important that these plants leaves are evaluated and monitored regularly to prevent heavy metal toxicity and other health risk to consumers.

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