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Full Length Research Article

EVALUATION OF THE IMPACT OF MINING ACTIVITIES AND ENVIRONMENTAL REMEDIATION STRATEGY IN UDEGE-BEKI TOWN, NASARAWA LGA, NASARAWA STATE

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ABSTRACT
A study was carried out to evaluate the impact of mining activities in Undege-mbeki town and ascertain the level of contamination arising from tin, columbite and tantalite mining. Soil and crop samples from farmlands in a derelict mine were collected and analysed for heavy metal concentration using Atomic Absorption Spectrophotometer (AAS). Micro elements were determined using flame photometer and the physicochemical properties of the soil were determined for chemical properties using standard method. Results of the physicochemical and metal concentration of the soil samples showed that pH ranged (6.49 - 7.04); electrical conductivity (28.88 - 138.88 µS/cm); organic carbon content (0.95 - 2.07 %); organic matter (1.44 - 3.16 %), nitrogen (0.12 - 0.73 %); phosphorus (2.68 - 3.20 ppm); sodium (3.36 - 4.69 ppm); potassium (2.79 - 5.49 ppm); magnesium (1.82 - 41.99 ppm); exchangeable acidity (0.12 - 0.73 %); exchangeable bases (11.12 - 18.52 %); cation exchange capacity (11.53 - 18.72 %) and base saturation ranged (74.55 - 96.73 %). For soil heavy metals the concentration of Pb ranged from (0.18-0.39 mg/kg); Cr (0.13-0.33 mg/kg); Cd (0.04-0.20 mg/kg); Ni (0.02-0.11 mg/kg); Zn (0.64-0.91 mg/kg) and Sn (3.94-6.59 mg/kg) while the crops heavy metal concentration showed that Pb ranged from (0.32-0.81 mg/kg); Cr (0.14-0.21 mg/kg); Cd (0.04-0.18 mg/kg); Ni (1.02-3.17 mg/kg); Zn (2.00-10.52 mg/kg) and Sn (2.39-4.91 mg/kg). Pollution assessment of the soil samples using single pollution index/Contamination Factor (CF) and Pollution Load Index (PLI) indicated medium elevation in pollution status in all the soil samples investigated. The significant values of some heavy metals in the crops suggest bio-accumulation due to the uptake of the metals from the soil. The ratio of the metal concentration in the soil to the crops indicated that there is high potential for the transport of heavy metals through the food chain. The levels of Pb, Cu, and Zn were found to be significantly high in both soils and crops when compared to other metals in the entire sampling locations though within the World Health Organization standards of 2 mg/kg, 36mg/kg and Zn 50mg/kg. The result obtained in this study is an indication that continued consumption of crops in the studied area poses severe health risk to the community. The crops cultivated within the mining area are unfit for human consumption and should be discouraged while the use of plant species with ability to bio-accumulate heavy metals should be cultivated as a bioremediation strategy.

Keywords: Analyses, contamination, crop, soil, metals, mine, Udege-Mbeki.

INTRODUCTION
The activities of man through mining have significant negative effects on his immediate environment (Okoro *et al.,* 2013; Amos *et al.,* 2023; Abdulrashis *et al.,* 2024). Mining in Nigeria started as far back as the eighteenth century, with over 500 deposits of different minerals known to exist within the country, and the exploration of some of them being on a small scale (Adegbulugbe *et al.,* 2017). The mining industry generates wastes which contained high concentrations of metals and metalloids that contaminate agricultural soils, air and water. These pollutants can be mobilized, resulting in leaching into the ground and surface water. Most of these heavy metals are highly toxic and are not biodegradable (Ahluwalia *et al.,* 2017). Udege-Mbeki town in Nasarawa State, north central Nigeria is endowed with huge deposit of minerals such as tin, columbite and other associated allied metals. The mining activities are believed to have started around 1962. Over time the mining continued to grow with influx of miners with escalation in mining activities leading to expansion in tin fields which goes on unchecked. The consequences of this unregulated mining activity, has led to pollution of water sources and depletion of agricultural lands by intensive and extensive mechanized mining activities (Mallo *et al.,* 2010). The early columbite miners often overlooked the minerals of tantalite or had a great difficulty in separating them from the tin as well as sand, silt and clay. Consequently, all cassiterite concentrates were contaminated with columbite-tantalite which was hitherto considered as wastes were discarded in mining dump sites (Mallo *et al.,* 2010). The mine tailings from these dumpsites contained heavy metals alongside some minerals that are indiscriminately disposed into farmlands and other nearby vegetation's. Due to lack of enough farm lands, some these dump sites are now being cultivated for growing crops. These activities have negative consequences to the host community. The threats from this unregulated activities is visible in the environment and humans. The mining of columbite/tantalite has a negative effect on the different spheres of the environment notably; hydrosphere, lithosphere, and the atmosphere (Eisler, 2014; Alok *et al.,* 2021). The use of acids in mining is known to cause severe impact on the environment due to acid mine drainage a major source of toxicity of the ecosystem. The presence of metals such as iron, mercury, arsenic, and antimony, in significant concentration in soil, water or plant and other associated sources are potential toxins to humans and animals (Corkhill and Vaughan, 2019; Edwin *et al.,* 2022). Fossil fuels are the major source of energy generation for the miners in the area which releases noxious gases to the surroundings. The large scale mining operations is a potential threat to the ecosystem due to the release of huge amounts of toxic metals into the atmosphere. Series of reactions of these noxious

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gases in the atmosphere convert them into other toxic forms that sometimes end up in water bodies, hence, contaminating it (Adejumoke *et al.,* 2018). Furthermore, seasonal variability in precipitation and temperature has a significant impact on the concentration and mobility of some toxic metals within the environment (Said *et al.,* 2012). As a result of mining activities, Udege-Mbeki plays an essential role in Nasarawa Local Government Area in terms of revenue generation and agricultural activities. The town contributes substantially towards the state government quest for revenue drive coupled with Nigerian government's policy towards aggressively diversifying the economy to reduce it's over dependence on oil revenue. The government drive is mounting pressure on the mining sector which in recent times has seen the influx of local and expatriate miners with registered companies as well as artisanal miners into the old mining town. The over 60 years of sustained mineral exploration and mining activity have severely damaged the fragile local ecological environment and compromised both soil and water quality. The livelihood of the average community depends either on agriculture or agriculture related business (Asante and Ntow, 2019). Recent survey has shown that agricultural lands in Nigeria are increasingly being used for mining. Thus, available agricultural lands are now found within or very close to Mining sites. In Udege-Mbeki, mining activities have deprived most farmers' access to arable lands hence agricultural activities have been affected negatively. The current farming is being carried out on small scale basis due to limited land. Major food crops grown whose yield are low include; guinea corn, maize, yam, beni seed, bambara nut, soya beans. These crops are either consumed or sold by an average household in Udege-Mbeki. The foods constitute an important source of vitamins, protein, iron, calcium, minerals and other nutrients by the community (Maleki and Zarasvand, 2018). The consumption of these foods may be a source of heavy metals which may be essential to the body or toxic at elevated concentration. The concentration of the heavy metals in the food chain varies depending on their bio absorption and their levels in the soil matrix (Arora *et al.*, 2018; Abdulrashid *et al.,* 2024). If these crops contained heavy metals in certain concentrations, their quality will be hampered and can affect the organs of the body when consumed thus disrupting the normal functions in the body (Mapanda *et al*., 2015). It is therefore imperative to carry out a comparative study of soils and crops grown within Udege-Mbeki mining locations and its environs to ascertain the level of contamination. The study also investigates the physiochemical properties of the soil from farmlands and the values compared with established standards for regulatory purposes.

MATERIAL AND METHODS

Study Area

Udege-Mbeki is a town in Nasarawa Local Government area of Nasarawa state, North Central Nigeria. The town is located on latitude 08°19'30'' N and longitude 70°50'80'' E (Fig.1). It has an area of about 400 km^2. The area falls within the tropical guinea savannah with a mean annual rainfall of 1000–1500 mm and a mean temperature of 25.60 °C (Akintola, 2016). Udege-Mbeki mining district is geologically underlain by the cretaceous sedimentary rocks and the Jurassic younger granite of the middle Benue trough (Fig. 2). The Benue trough is a rift basin that extends for about 800 km in length and 150 km in width, it has approximately 6000 m of cretaceous tertiary sediments (Okegye and Gajere 2015). In the study area, the main activities undertaken by the inhabitants are mostly agriculture, mining and rearing of cattle's. However, agricultural activity in the area has greatly dwindled due to mining and insecurity problems associated with it.

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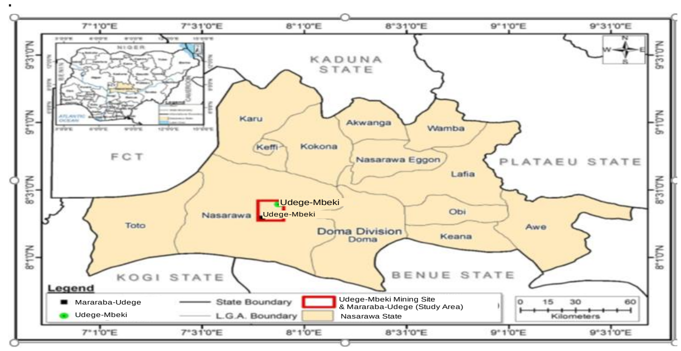

Figure.1: Map of Nasarawa State Showing Udege-Mbeki

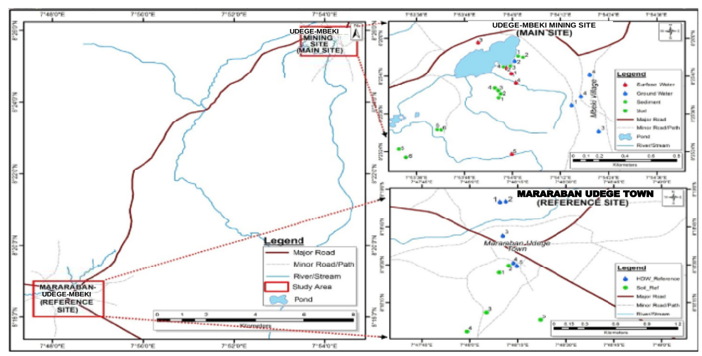

Figure. 2: Map of Udege-Mbeki, showing the locations where the samples were collected.

Sampling and Sample Preparation

Soil and crops samples were collected from three different farmlands designated A, B and C in derelict mines (Tables 1 and 2, Fig. 1). The samples were collected 200 metres away from each other within the columbite/tantalite mining pits. 2kg of top soil samples were collected by scooping using auger hand trowel at a depth of 0-15 cm based on soil depths principle described by Awofolu (2005) in order to make a composite sample. A control sample was collected from a location with no columbite/tantalite mining activities. The crop samples were purchased from farmers with farmlands within the sampling location. The collected samples were air-dried (for the soil) and ground into fine particles using mortar and pestle. The ground soil samples were then digested according to the method described by Boamponsem *et al.* (2010). The crop samples were properly washed with clean water and then oven-dried at 65°C for 48 h to a constant weight. The dried samples were then ground into fine powder and digested according to method described by AOAC (2010).

Table 1: Designation of Soil Samples Collected and their Locations

S/N	Sample Code	Sample Location
1.	SA$_1$	Farmland A
2.	SA$_2$	Farmland A
3.	SA$_3$	Farmland A
4.	SB$_1$	Farmland B

5.	SB_2	Farmland B
6.	SB_3	Farmland B
7.	SC_1	Farmland C
8.	SC_2	Farmland C
9.	SC_3	Farmland C
10.	CSS	Control Site

Table 2: Designation of Crop Samples Collected and their Locations

S/N	Crop	Sample Code	Sampling Location
1.	Yam	AAY	Farmland A
2.	Maize	AAM	Farmland A
3.	Soya beans	AAS	Farmland A
4.	Beni seed	BBS	Farmland B
5.	Beans	BBB	Farmland B
6.	Guinea corn	BBG	Farmland B
7.	Millet	CCM	Farmland C
8.	Bambara nut	CCB	Farmland C
9.	Okra	CCO	Farmland C
10.	Cassava	CCS	Control Site

Analysis

Heavy Metal Analysis of Soil and Crop Samples

Sample Digestion and Analyses

To each powdered sample, 1g was weight into a 100 cm^3 beaker and $10cm^3$ of aqua regia (mixture of HCl and HNO_3) in ratio 3:1 were added to the content in the beaker and covered with a watch glass and left to stand for 12 h as described by FAO (2019). The digestion of the sample was enhanced using a thermostatically electric heating mantle at a temperature of 85˚C in a fume cupboard until the volume of the content reduced to 5 mL (Amos *et al.,* 2020; Amos *et al.,* 2023). A further addition of $15cm^3$ of the aqua regia solution was then made and the content evaporated to obtain a clear solution of 5 cm^3. The content was then cooled to room temperature and the solution filtered using filter paper (Whatman No. 540) to remove any impurities such as waxy solids. A further dilution was made up to volume of 50 cm^3 using deionized water and the solution run on an SP 1900 Pye Unicam Atomic Absorption Spectrophotometer equipped with an air-acetylene burner. For every set of analyses a blank solution was run in duplicate to assess the precision of the data. The instrument setting and operating conditions were carried out according to the manufacturer's specifications. The micro elements (Na and K) were determined using Flame photometer, while N, Mg, P, Ca, Sn, Pb, Cr, Cd, Ni and Zn was determined using Atomic Absorption Spectrophotometer. In each case the determination of the crop samples was done according to the method by AOAC (2010).

Physicochemical Analysis of Soil

On-site analyses were carried out for pH and Electrical Conductivity according to the methods of American Public Health Association (APHA, 2010) and American Society for Testing and Materials (ASTM, 2010). A digital pH meter (model HI98130, Hanna Instruments) was used for pH determination using standard solutions. The organic carbon and matter were simultaneously determined using Walkley-Black method as described by ASTM (2010) and APHA (2010) and the values were expressed in terms of percentage organic matter. The total nitrogen in the samples was determined using the Kjeldahl method described by Daniel (2014). The exchangeable acidity of the soil was determined using titrimetric method as described by Alfredsson *et al.* (2018). The contamination factor (CF) for each heavy metal (soil and crops) was calculated individually using the ratio of concentration of the metal in sample to the background concentration of the metal according to the method by Boamponsem *et al. (*2010). Pollution load index (PLI) was obtained according to the method described by Bhupander *et al.* (2011) while the number of contamination factor was determined using the relationship described by Ong *et al*. (2012) where PLI value > 1 indicated pollution and PLI value < 1 suggests no pollution as shown in the relationship.

$$PLI = \sqrt[n]{CF1 \times CF2 \times CF3 \ldots . CFn} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Data Analyses

The data obtained from the analyses were in triplicate. In each case, the data were all subjected to statistical tests of significance using analysis of variance (ANOVA) and the Student t-test at $p < 0.05$). In each case the data were subjected to a one-way analysis of variance.

RESULTS AND DISCUSSION

The results of the samples collected in Tables 1 and 2 from Udege-Mbeki were evaluated. Physicochemical properties of the soil and heavy metal content of the soil and crop samples as well as their pollution indices, contamination factor (CF) or Single Pollution Index, Pollution Load Index (PLI) and bioaccumulation ratio are presented in the Tables 3-8. The analysis revealed contrasting results which varied according to the location and sample type. The soil samples showed similar pattern of metal distribution different from the crops which showed variation in the metal content according to the crop type.

Physicochemical Properties of farmland Soil and micro element analysis of Samples The physicochemical analysis of the soil samples for certain properties that include; pH, concentrations of electrical conductivity, organic carbon, organic matter, nitrogen, phosphorus, calcium, sodium, potassium, magnesium, exchangeable acidity, exchangeable bases, cation exchange capacity and base saturation is presented in Table 3.

The result obtained for pH in the sampled farmland soil and control soil ranged from 5.49 – 7.04 with mean value of 5.83 as shown in the Table 3. Excluding sample SB_1, other samples had pH value below 7.0. This showed that the pH level is approximately neutral and within acceptable limits by WHO (2010) and EPA (2010). This suggests that the soil was good for farming activities although the distance where the samples were collected from a mining pit is less than 1.05 km. The effect of such decrease in soil pH is reported to result in an increase in heavy metals absorption by plants due to dissolution of heavy metal carbonate complexes releasing metals into solution during rainy season (Mapanda *et al.,* 2008).

The electrical conductivity is an important parameter of soil use to measure the total salt content in soil and also an indicator of soil quality and soil salinity. It also used to ascertain overall level of macro and micronutrients in the soil. The values obtained (Table

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3) are relatively low in the samples. Although, the soil samples showed low salinity; it may be suitable for agricultural uses in certain locations. The electrical conductivity values of samples SA_1, SA_2 and SA_3 ranged from 128.99 µ/cm – 138.88 µ/cm with mean value of 72.36 µ/cm, which are higher than other sampling locations. The least value was obtained in the control soil sample (28.88 µ/cm). The level of conductivity of soil does not suggest any adverse effect when compared with Sekabira *et al.* (2016) with value for electrical conductivity from industrial discharge outfit waste water which ranged from 390.0 – 1884.0 µS/cm. However, the high range of electrical conductivity values in samples SA_1, SA_2 and SA_3 is probably due to the release of ions which ordinarily will be bound to rocks but not broken down and washed off during the tin-columbite mining process.

The values obtained for organic carbon of the farmland and control soil sample ranged from 0.95 to 2.07 % showing significant concentration. Sample SB_1 recorded the highest value of organic carbon of 2.07 %, while organic matter values ranged from 1.44 to 3.16 %. The control soil sample recorded the least value (1.44 %). Organic carbon and organic matter content of the analyzed farmland soil are all within the permissible range for agricultural cultivation of 2 to 5 % (FAO, 2013).

Nitrogen values are shown (Table 3) for the farmland soils which ranged from 0.20 to 0.42 % indicating a medium concentration. The value of (0.20 %) for Nitrogen was least in sample SB_3 while samples SA_1 and SA_3 showed significant concentrations of 0.42 % and 0.41 %. The result agrees with Donkor *et al.* (2015) who report on soil nitrogen from some mining areas.

Available phosphorus values recorded ranged from 2.68 to 3.45 ppm indicating a low concentration. Sample SB_2 had higher value than the control sample which recorded the least value of 2.68 and 3.45 ppm, respectively. This result conformed to the findings by Abiya *et al.* (2018).

Micro Elements

The results of some micro elements that include; K, Mg, Ca, Na from the farmland soils is also shown in Table 3. The values for K ranged from 2.79 to 5.49 ppm, Mg values ranged from 1.82 to 41.99 ppm, Ca values ranged from 2.27 to 3.55 ppm and Na values ranged from 3.20 to 4.69 ppm. Values obtained for these micro elements falls within moderate range which are enough to sustain plant growth and retain soil nutrients. The results obtained agreed with Obasi *et al.* (2013). When considered in terms of requirement for plant sustainable and growth range, all the samples micro elements analyzed are within the required limit for cultivation of crops and vegetables outlined by FAO (2013).

The distribution of soil exchangeable acidity, exchangeable bases, cation exchange capacity and base saturation is presented in Table 3. Exchangeable acidity soil samples ranged from 0.12 to 0.73 Cmol/kg, while base saturation ranged from 11.12 to 18.52 Cmol/kg. Cation Exchange Capacity (CEC) values also ranged from 11.53 to 19.52 Cmol/kg. The base saturation ranged from 74.55 to 94.89 Cmol/kg. Closely related to CEC is the base saturation, which is the fraction of exchangeable cations that are base cations (Ca, Mg, K and Na). The higher the amount of exchangeable base cations, more acidity can be neutralized in the short time perspective in the soil. Thus, the soil with high CEC takes longer time to acidify (as well as to recover from an acidified status) than a site with a low CEC (assuming similar base saturations) as was found by Amos *et al.* (2023).

The CEC represents the ability of the soils to absorb or release cations, consequently, it is an important parameter in sites contaminated by heavy metals. Organic matter and clay minerals are responsible for the CEC. According to Conesa (2017), pH and EC's are the most important factors because under acidic conditions the tailings matrix will dissolve more salts. Due to the moderately acidic and saline conditions of the soil, pH and EC's could be the limiting factors for plant establishment in the studied zone.

Table 3: Result of Soil Physicochemical Parameters

Sample Code	pH	EC (µS/cm)	OC (%)	OM (%)	N (%)	P (ppm)	Ca (ppm)	Na (ppm)	K (ppm)	Mg (ppm)	EA (cmol/kg)	EB (cmol/kg)	CEC (cmol/kg)	BS (cmol/kg)
SA1	6.49±0.66	134.41±2.17	1.70±0.10	2.87±0.22	0.42±0.06	3.24±0.39	2.27±0.35	3.79±0.24	2.79±0.31	1.82±0.18	0.4±0.10	11.12±0.66	11.53±0.69	94.68±1.15
SA2	6.49±0.62	128.99±7.12	1.50±0.31	2.82±0.36	0.33±0.07	3.45±0.19	2.42±0.40	3.64±0.43	2.79±0.34	2.01±0.16	0.36±0.09	11.60±0.56	12.04±0.59	95.36±1.08
SA3	6.66±0.48	138.88±5.49	1.45±0.31	2.46±0.57	0.41±0.06	3.04±0.48	2.33±0.52	3.71±0.42	2.81±0.34	1.86±0.27	0.37±0.05	11.59±0.55	12.06±0.51	96.18±0.57
SB1	7.04±0.37	27.66±2.03	2.07±0.11	2.97±0.73	0.27±0.04	3.08±0.66	2.30±0.59	3.20±0.76	3.49±0.54	2.47±0.39	0.73±0.34	13.25±0.59	13.58±1.16	88.17±4.56
SB2	6.63±0.67	31.07±1.45	1.92±0.25	3.08±0.54	0.22±0.05	3.19±0.53	2.69±0.33	3.36±0.81	3.65±0.43	2.20±0.53	0.50±0.32	12.60±1.08	13.68±0.93	88.14±5.87
SB3	6.49±0.73	29.71±1.26	1.68±0.36	3.16±0.34	0.20±003	3.16±0.69	2.68±0.47	3.74±0.34	3.29±0.80	2.25±0.60	0.71±0.19	13.34±0.70	14.36±0.55	87.46±7.73
SC1	6.79±0.53	51.16±1.93	1.34±0.21	2.21±0.59	0.26±0.17	3.20±0.52	2.84±0.52	3.69±0.74	3.53±0.88	41.99±1.42	0.23±0.12	14.51±0.97	14.63±1.14	89.5±6.95
SC2	6.58±0.78	52.25±1.95	1.27±0.23	2.12±0.68	0.35±0.12	3.18±0.69	3.12±0.41	4.07±0.54	3.79±0.65	2.83±0.37	0.31±0.10	14.50±1.14	15.38±0.78	93.79±3.98
SC3	6.51±0.86	50.54±2.66	1.24±0.22	2.17±0.38	0.28±0.12	2.94±0.61	3.13±0.44	4.49±0.47	3.71±0.60	3.66±0.044	0.27±0.10	16.35±0.67	16.52±0.87	94.89±3.92
CSS	6.6±071	28.88±1.56	0.95±0.09	1.44±0.32	0.23±0.11	2.68±0.47	3.55±0.61	4.69±0.44	5.49±0.78	3.47±0.78	0.12±0.04	18.52±1.03	18.72±0.89	74.55±22.00

Key: TDS-Total Dissolved Solid, **EC**-Electrical Conductivity, **OC**-Organic Carbon, **OM**-Organic Matter, **N**-Nitrogen, **P**-Phosphorus, **Ca**- Calcium, **Na**- Sodium, **K**-Potassium, **Mg**- Magnesium, **EA**- Exchangeable Acidity **EB**-Exchangeable Bases, **CEC**- Cation Exchange Capacity, **BS**- Base Saturation

Heavy Metal Concentrations in the Soil

The concentration of heavy metals in the soil samples is presented in Table 4. Pb was detected in all the soils from the farm land farms in significant quantity in some of the locations. The mean concentration range of 0.21 to 0.31 mg/kg was obtained. Soil in Farmland B was more significant than the rest with range values of 0.34 to 0.39 mg/kg. The control site sample (CSS) had the least value for Pb (0.18 mg/kg). Farmlands A and C did not show significant difference ($p<0.05$) in terms of concentrations. The average concentration of Pb in soil ranges from 17-26 mg/kg (Cunningham, 2011). It is the most immobile of all the common

heavy metals. It is strongly absorbed by soils under neutral to basic conditions. The lead content of the soil analyzed from the farmland can be attributed to leaching via underground water movement from the mining pit during rainy seasons as observed in s study by Suruchi and Khana (2011). Although the metal has certain uses, it is known to be a source of poison and major cause of anaemia due to its interference with the formation of haemoglobin. It also prevents iron uptake. High concentration of Pb may produce permanent brain damage and kidney dysfunction (National Environmental Policy Institute, 2010; Essa, 2011). The presence of the metal in the soil analysed could lead to its bio-absorption and uptake by food crops or leaching to water bodies thus causing severe heath risk when in contact.
Chromium values obtained in the soil samples are shown in Table 4. The values ranged between (0.13 – 0.37) mg/kg. The least value recorded was in sample CSS (Control), while the rest samples had values that ranged from 0.26- 0.37) mg/kg with significant value obtained in farm C. However, all the soil contained the metal in concentration that exceeded the WHO (2010) acceptable guideline line standard concentration for Cr in soil. Cr a non-essential element, it's significant concentration in agricultural soil may be a source of uptake or repository to aquatic habitat thus affecting the ecosystem. Toxicity from Cr is capable of causing nervous, cardiovascular, bone and kidney diseases (Jarup, 2013). The mean concentrations of Cd in the soils were significantly different ($p<0.05$). The elevated level of Cd recorded (Table 4.2) is obtained from in soil from Farmland B (samples SB_1, SB_2 and SB_3) with concentrations of 0.20, 0.17 and 0.19 mg/kg, respectively. However, the concentrations of Cr in all the samples were higher than WHO (2010) permissible limit with the exception of the control soil sample (CSS) whose value was 0.04 mg/kg. Cadmium is heavy metal of major environmental concern because of its mobility and the small concentration at which it can adversely affect plants and animal's metabolism. Also, it has adverse impact on soil biological activity (Kabata, 2014). Diet is the major source of Cd intake because of Cd bio-accumulation in the food chain, especially in plants and sea food. Critical toxic endpoint after ingestion is kidney damage (Davies *et al.,* 2015). The results for the metal ranged between 0.11-0.20 mg/kg in the entire samples with some samples showing significant concentration above the guideline limits.
The result of Ni showed that Farmland C had concentrations that ranged from 0.07 -0.11 mg/kg for samples SC_1-SC_3, respectively. Other samples showed variation between 0.02 to 0.09 mg/kg. Significant difference exists between the mean of the samples ($p>0.05$). All the samples are below WHO permissible limit of between 1-5 mg/kg (WHO, 2010). Most agricultural soils contained Ni at levels of between 8.5 to 15 mg/kg. Nickel is considered likely to be an essential micronutrient (Celabrese *et al.,* 2015). Exposure to nickel toxicity produces a specific form of dermatitis and may affect the stomach lining and nasal cavity (Miroslav, 2010).
The samples contained Zn in farmland A- C with values that ranged from 0.64 to 0.91. The result (Table 4) showed the soil varied with Zn content. The low values suggest poor Zn enrichment. Factors that could have contributed in the low accumulation of the metal include high percolation of acid mine residue which are transported majorly by underground water into the surrounding farmland. The result in this study compared well with investigation by Kabir *et al.* (2017) on Pb-Zn mine where Zn recorded a mean value of 50.00 mg/kg in the least soil. The high value obtained certain soil samples in the study was 6.59 mg/kg location C (SC_3). Close to that are samples SC_1 and SC_2 with values of 6.13 and 6.47 mg/kg, respectively. A study by Noubissie (2017), revealed a similar value of 6.14 mg/kg. However, all the samples analyzed fell between WHO (2010) tolerable concentrations of the metal in soil.

Table 4: Result of Heavy Metals in Soil Samples (mg/kg)

	Metals					
Sample Code	**Pb**	**Cr**	**Cd**	**Ni**	**Zn**	**Sn**
SA1	0.25±0.10^{g}	0.15±0.10^{g}	0.14±0.10^{f}	0.06±0.02^{f}	0.80±0.03^{e}	5.81±1.02^{d}
SA2	0.23±0.08^{h}	0.17±0.11^{f}	0.18±0.08^{c}	0.08±0.03^{d}	0.77±0.02^{h}	5.50±0.95^{e}
SA3	0.21±0.09^{i}	0.20±0.09^{d}	0.17±0.07^{d}	0.05±0.02^{g}	0.79±0.03^{f}	4.11±0.88^{h}
SB1	0.39±0.12^{a}	0.14±0.06^{h}	0.20±0.10^{a}	0.05±0.02^{g}	0.91±0.03^{a}	3.94±0.73^{j}
SB2	0.34±0.11^{c}	0.18±0.08^{e}	0.17±0.07^{d}	0.06±0.02^{f}	0.88±0.03^{b}	5.16±0.90^{g}
SB3	0.38±0.13^{b}	0.14±0.06	0.19±0.11^{b}	0.09±0.03^{c}	0.82±0.03^{c}	5.18±0.90^{f}
SC1	0.28±0.10^{f}	0.26±0.10^{c}	0.16±0.08^{e}	0.11±0.04^{a}	0.81±0.03^{d}	6.13±1.06^{c}
SC2	0.31±0.11^{e}	0.37±0.13^{a}	0.11±0.04^{g}	0.10±0.03^{b}	0.81±0.03^{d}	6.47±1.11^{b}
SC3	0.33±0.11^{d}	0.33±0.11^{b}	0.14±0.05^{f}	0.07±0.02^{e}	0.78±0.02^{g}	6.59±1.13^{a}
CSS	0.18±0.09^{j}	0.13±0.08^{i}	0.04±0.00^{h}	0.02±0.00^{h}	0.64±0.02i	4.02±0.86^{i}

Heavy Metal Concentrations in the Crops
Food crops obtained from the same farm land where soil samples were sampled were also investigated for heavy metal content to ascertain the variability and correlation. Results however, showed contrasting variations which may be due to the nature of crops or soil location. The value for Pb determined in the crops (Table 5) showed concentration ranging from 0.32 to 0.80 mg/kg. Farmland A had significant concentration that varied from 0.62-0.81 mg/kg in the Yam (AAY), followed by Maize (AAM) and Soya beans (AAS), respectively. Farmland B and C showed relatively low concentrations. The ranking of Pb according to their respective concentration in the farmlands is C<B<A. The relatively high level of Pb in the crop may have resulted from the accumulation of Pb through inorganic insecticides application such as lead arsenate during cultivation or from deposits on the farm lands as a result of the mining activities. Although, the values of the metal detected in the crops grown in farmlands A, B and C are within the permissible limit for Pb in crops (WHO, 2010). Reports from various studies

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have also implicated Pb accumulation in vegetative plant part declining with distance from possible contamination site (Little, 2015).

Concentration of Cr determined in beni seed in farm B (BBB), yam in farm A (AAY), guinea corn in farm B (BBG), and Bambara nut in farm C (CCB) did not varied suggesting no variation in terms of concentration (Table 5). Okra (CCO) in farmland C recorded the least mean concentration with a value of 0.11 mg/kg (Table 5). The value obtained for the metal in all the crops exceeded the WHO (2010) permissible limit of 0.05 mg/kg. Consumption of the affected crops will certainly pose a health with severe consequences which may include kidney and liver damage, skin rashes, stomach upset and ulcer, respiratory problems and lung cancer and alteration of genetic materials (Miroslav, 2010).

Even though Cd is a non-essential metal, the value of the metal ranged from 0.04 to 0.18 mg/kg as shown in Table 5. The highest value obtained was in farmland A (Sample AAM). However, the entire sample had values below permissible level. Cd is a mobile element, easily absorbed by plant roots and transported to the shoots where it is uniformly distributed in plant (Sekara *et al.,* 2015). Consumption of these crops will not result in any Cd related problems. Cd contaminated crops are known to result to bone fracture, diarrhea, severe vomiting and reproductive failure.

Nickel plays vital function in higher plants; the highest value recorded for Ni was obtained in sample CCB located in farmland C with a mean value of 3.17 mg/kg, as shown in Table 4.3 the values falls under the WHO (2010) permissible limit of 1-5 mg/kg. Other samples recorded values that ranged between 1.02-3.14 mg/kg. Ni is usually found at the top layer of soil that is rich in organic matter or relatively high content of clay. Wide application of various types of pesticides and fertilizers may be a contributor to the increased availability of Ni in the crops (Daniel *et al.,* 2014).

Zinc concentration shown in Table 5, ranges from 2.00 to 10.52 mg/kg, with the highest concentration obtained in the control crop sample (CSS). The result obtained in this study was lower than Latif *et al.* (2018) and Alshebi *et al.* (2019). Zinc is an essential trace element for both animals and humans. Natural background of Zinc ranges from 10-300 mg/kg (Celabrese *et al.,* 2015). A deficiency of Zn is marked by retarded growth, loss of taste and decreased fertility in males. Toxicity in human may occur if Zn concentration approaches 350 mg/kg. The concentrations of Zn in all the crops evaluated are all within the WHO (2010) permissible limit.

Concentration of Sn obtained ranged from 2.39 – 4.93 mg/kg, Sample BBG (Guinea corn) grown on farm B had the least concentration (2.39 mg/kg) while Soya beans (AAS) recorded the highest Sn concentration. The significant concentration may not be unconnected with the mining activities been carried out within the vicinity of the farm lands.

Table 5: Results of Heavy Metals in Crop Samples (mg/kg)

	Metals					
Sample Code	Pb	Cr	Cd	Ni	Zn	Sn
AAY	0.80±0.12b	0.20±0.08b	0.04±0.01i	1.50±0.22i	2.00±0.26j	4.52±0.89e
AAM	0.81±0.13a	0.18±0.06d	0.18±0.06a	1.82±0.24g	3.19±0.31h	4.93±0.94a
AAS	0.61±0.12d	0.14+0.05g	0.16±0.06b	1.72±0.23h	3.05±0.32i	4.61±0.91c
BBS	0.72±0.12c	0.16±0.06f	0.06±0.04h	1.84±0.24f	4.21±2.32g	4.22±0.75g
BBB	0.35±0.09h	0.21±0.09a	0.15±0.05c	1.99±0.25e	5.18±2.46f	4.28±0.73f
BBG	0.32±0.09i	0.20±0.07b	0.08±0.02g	2.10±0.27d	8.02±2.90e	2.39±0.58j
CCM	0.41±0.10g	0.17±0.07e	0.14±0.01d	2.42±0.28c	8.48±2.93d	3.98±0.62h
CCB	0.59±0.10e	0.20±0.07b	0.11±0.01f	3.17±0.36a	9.06±3.00c	3.52±0.60i
CCO	0.46±0.10f	0.11±0.03h	0.14±0.01d	3.14±0.31b	9.12±3.01b	4.76±0.92b
CCC	0.41±0.10g	0.19±0.07c	0.13±0.01e	1.02±0.19j	10.52±3.04a	4.53±0.89d

Comparison of Heavy Metals concentrations in Soils and Crops

A comparison of heavy metals in soils and crops in Tables 4 and 5 showed that all the crops contained Pb concentration so also the soil samples. Cr was only significant in the soil samples while As and Cd, had concentrations that varies in the samples investigated. Ni recorded very significant concentration in the crop samples, particularly Maize, Bambara nut, and Okra compared to the soils. Zn level in the crop were far higher than in the soil samples analyzed. Concentrations of Sn appear to be similar in both soils and crops samples, notably in farmland location A while other samples differ slightly in concentration of the metal. This suggests that the concentration of the Sn was evenly distributed and well leached into the soil. Correlatively, the observation is that the metal content in the food crops are a result of their concentration in the soil which act as a reservoir for the metal uptake by the plants and stored in the food.

Contamination Factor/Single Pollution Index (CF) and Pollution Load Index (PLI)

Table 6 presents the contamination factor (single pollution index) of the metals in the soil samples which ranged from low value of 0.01 for samples containing Zn to a high of 7.40 for all samples containing Chromium (Cr). The increasing trend in pollution level in the soil is Zn < Sn < Cd < Pb < Ni < Cr in the soil samples in the studied locations.

Pollution Load Index (PLI) of the soil analyzed ranged from 0.35 to 0.78. This means that the presence of these metals in the earth crust was low (Pradhan and Kumar, 2014) and their pollution in the soil is very minimal. Control sample was least polluted by all the six heavy metals which is due to less concentration of mining activities in the location.

Table 6: Result of Soil Contamination Factor/Single Pollution Index and Pollution Load Index (PLI)

Location	Crop Type	Sample Code					Metals
			Pb	Cr	Cd	Ni	Zn	Sn
Farm	Yam	AA	3.	1.	0.	25.	2.5	0.
A	Maize	Y	20	33	29	00	4.1	78
	Soya	AA	3.	1.	1.	22.	4	0.
	Beans	M	52	06	00	75	3.8	90
		AA	2.	0.	0.	34.	6	1.
		S	90	70	94	40		12
Farm	Beni	BB	1.	1.	0.	36.	4.6	1.
B	Seed	S	85	14	30	80	3	07
	Beans	BB	1.	1.	0.	33.	5.8	0.
	Guine	B	03	17	88	17	9	83
	a	BB	0.	1.	0.	23.	9.7	0.
	Corn	G	84	43	42	33	8	46
Farm	Millet	CC	1.	0.	0.	22.	10.	0.
C	Bamb	M	46	65	88	00	47	65
	ara	CC	1.	0.	1.	31.	11.	0.
	nut	B	90	54	00	70	19	54
	Okra	CC	1.	0.	1.	44.	11.	0.
		O	40	33	00	86	69	72
Cont	Cassa	CC	2.	1.	3.	51.	16.	1.
rol	va	C	28	46	25	00	44	13

Bioaccumulation Ratio

The bioaccumulation ratio was determined in terms of the ratio of the concentration of a heavy metal in the crops to that of the same heavy metal in the soil (Table 7). Of all the crops samples, the bioaccumulation ratios in relation to the heavy metals in the crops ranged from 0.29 – 51.00. Nickel has the highest bioaccumulation ratio in all the crop samples studied (22.00 – 51.00), whilst Cadmium had the least bioaccumulation ratio of 0.29 in Yam sample closely followed by Beni seed with a value of 0.30 and Guinea corn 0.42. The trend of heavy metals bioaccumulation in all the crops in decreasing order is: Ni>Zn>Pb>Cr>Sn>Cd (Table 7). In the control samples the highest heavy metals bioaccumulation ratio was in Cassava, whilst in Farm B has the least bioaccumulation ratio. The trend of heavy metals bioaccumulation in decreasing order is: Cd>Sn>Cr>Pb>Zn>Ni.

Bioaccumulation ratio is an important parameter that gives an indication of an organism's ability to accumulate metals in its tissues. It also helps to know whether an organism is a hyper accumulator of metals. Hyper accumulators are organisms that have a bioaccumulation ratio greater than 1. Due to bioaccumulation and bio magnification through food chains and webs, when plants are polluted with heavy metals, toxic burden of these heavy metals in humans becomes higher as some livestock can also consume them. Based on this study, the whole crops had higher concentrations of heavy metals than the soils except for Ni. The higher concentrations of the heavy metals in the crops indicated that there is a high potential for their transport through the food chain. Similar findings were also reported by Cunningham (2011), that toxins that are dilute in the environment can reach dangerous levels in the cells and tissues of organisms through bioaccumulation process. Also, all the seeds used in cultivation on all four farms were from previous harvest and may account for the high heavy metal levels in the plants than the soils.

Lower bioaccumulation ratio is an indication that translocation of the metals from the soils to the crops was low and may be influenced by plant factors, differences in metal characteristics and plant cells mechanisms (Cunningham, 2011; Bitala, 2018).

Table 7: Results of Bio-accumulation Ratio in Crops

			Metals				
Sample Code	Pb	Cr	Cd	Ni	Zn	Sn	PLI
SA1	2.50	3.00	1.40	3.00	0.01	0.17	0.61
SA2	2.30	3.40	1.80	4.00	0.01	0.16	0.66
SA3	2.10	4.00	1.70	2.50	0.01	0.12	0.61
SB1	3.90	2.80	2.00	2.50	0.01	0.12	0.63
SB2	3.40	3.60	1.70	3.00	0.01	0.15	0.67
SB3	3.80	2.80	1.90	4.50	0.01	0.15	0.71
SC1	2.80	5.20	1.60	5.50	0.01	0.18	0.78
SC2	3.10	7.40	1.10	5.00	0.01	0.19	0.78
SC3	3.30	6.80	1.40	3.50	0.01	0.19	0.77
CSS	1.80	2.60	0.40	1.00	0.01	0.12	0.35

Conclusion

The analysis of physicochemical properties of the soil indicated that the soil meet certain acceptable standards while the values of Pb, Cr, Cd, Ni, Sn, Cu and Zn in soil and crops in the studied area revealed concentration of these metals that varied in according to the type of sample. Comparative analysis of the content of these metals in both soil and crops showed a pattern that suggest bioaccumulation of the metals in the crops as a result of the metal concentration in soil where the crops are grown. The crops grown within the four sampling farmlands around mining sites in Udege-Mbeki are at risk of pollution with certain heavy metals due to hyper accumulators by these heavy metals. The crops investigated; Bambara nut, Okra and Cassava crops are good candidates of phytoextractors of the selected heavy metals in the study area. On the other hand, Yam and Maize crops are good excluders of heavy metals. Sn was found to bio-accumulate mostly by all the crops followed by Zinc. The observation could be due to the proximity or location of the study area a long a mineralized zone of these metals, disposal of waste from mining activities or leaching. Pollution studies (single pollution index/contamination factor and pollution load index) also showed that the soils were at the verge contamination above moderate level. Being that all the crops are commonly and widely consumed by the inhabitants in the area, continuous consumption of the crops with high levels of these heavy metals pose severe health risk if not curtail. Remediation strategies that involve the use of species of plants with ability to remove heavy metals will reduce the heavy metal levels in the soil.

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Conflicts of Interest

There are no conflicts of interest relating to the publication of this paper.

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