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Analysis of Heavy Metals in Soils around Gidan Saru Mining Site, Zamfara State, Nigeria

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Abstract

Diseases and their associated health defects are most often related to the quality of the total environment which in itself is also related to the quality and quantity of wastes generated. This study assessed the level of lead, Chromium, Cadmium, Manganese, Copper, Iron, Zinc and Nickel in soil samples from Gidan Saru village, Bungudu LGA, Zamfara State, Nigeria, in order to assess the influence of mining activities on the environment. Top soil samples (0- 5 cm) were taken at various locations (Grinding mills, Residential premises and Tailings) within the village and analyzed for these metals using atomic absorption spectrophotometer (AAS). The results revealed that only the levels of Cu (173.58±10.65mg/kg, 172.28±3.50mg/kg and 158.31±5.06mg/kg) across three sampling locations (Tailings, Residential premises and Grinding mills site) were found above USEPA maximum permissible limit but the rest were below USEPA, except for Mn at Grinding mills whose value was above Maximum Permissible Limit.

Keyword: *Heavy metals, mining, soil, pollution, Gold.*

1.0 INTRODUCTION

Heavy metal contamination of the soils is a major concern because of their toxicity and threat to human life (Yahaya *et al.*, 2010). With the exception of soils derived from weathering of parent rocks containing elevated levels of trace elements, the presence of elevated metals concentration in the environment is related to man activities (Jung, 2008). Many of the contaminants are continually discharged into the environment through industrial, agricultural, mining and domestic processes (Tolulope, 2004). Mining, smelting and associated activities are one of the most important sources by which soil, plants and surface water are contaminated. Contamination and subsequent pollution of the environment by toxic heavy metals have become an issue of global concern due to their sources, widespread distribution and multiple effects on the ecosystem (Nriagu, 1990). Uncontrolled and illegal mining activities in developing countries have left a lot of environmental hazards, enormous amount of wastes and different types of pollutants on the mining communities. Although there have been along history of illegal mining in zamfara state, little or no study was conducted to assess the extent of contamination and by implication the pollution status of the environment until the Lead pollution crisis of 2010 in the state (Udiba *et al*., 2012a). In 2010,

unregulated small-scale mining in the Zamfara state gave rise to an epidemic of childhood lead poisoning, with at least four hundred children (and probably many more) under the age of five dying within a six-month period. Despite the efforts of development, medical, and environmental experts both nationally and globally, lead contamination continues to afflict large numbers of children (UNEP, 2010). The three stages of minerals development, viz exploration, mining and processing, have caused different types of environmental damages, which include ecological disturbance, destruction of natural flora and fauna, pollution of air, land and water, instability of soil, rock masses and landscape degradation (Aigbedion and Iyayi, 2007). Heavy metal from man-made pollution continues to be released into aquatic and terrestrial ecosystems. However, its contamination is a serious threat because of their toxicity, bioaccumulation and biomagnifications in the food chain (Punama *et al*., 2014).
Since 2010, lead poisoning outbreak in Zamfara, much attention has been given to the collateral health and environmental impacts that arise from Artisanal and Small-Scale Gold Mining (A S G M). The lead exposure is defined by the particular geology of the region; the gold deposits in the Zamfara areas are naturally associated with lead. Because these deposits are primary deposits, they require grinding and milling processes to liberate the gold, which generates dust, and therefore leads to extensive lead exposure (Lisa *et al.,* 2014).

The major heavy metal cases in Nigeria were believed to be associated with lead poisoning. They are mostly severe in young children because their brains and central nervous systems are still being formed. Learning disability, stunted growth, poor brain sensation, behavioral problems, kidney damage and impaired hearing are associated with low level of exposure. High concentrations of lead in the body can result to mental retardation, coma and eventual death. Reported symptoms include constant headache, loss of appetite, vomiting, nausea, irritability or behavioral problem. (Galadima *et al.,* 2012). Recent research indicates that lead is associated with neurobehavioral damage at blood levels of 5 μg/dl and even lower. There appears to be no threshold level below which lead causes no injury to the developing human brain (ATDRS, 2007). Heavy Metals are persistent pollutants that can be biomagnified along the food chain and capable of causing hazards to human health and harm to living organisms or ecological resources (Udiba *et al*., 2012).

The main objective of this research is to measure the concentration of Chromium, Lead, Zinc, Nickel, Cadmium, Manganese, Iron and Copper present in soil samples of the study area using Atomic Absorption Spectrophotometer (AAS). To compare the levels of these heavy metals among the different samples of soil with the respect to locations To identify whether the levels of these heavy metals in soils of the study area are within permissible limits set by USEPA.

2.0 METHODOLOGY

2.1 Description of the Study Area

Gidan Saro is a small community in Bingi north of Bungudu local government comprising not more than three thousand people. It is located about 14 KM away from Danmarken Bungudu motor vehicle park station along major road of Gusau to Sokoto. Gidan Saru village coordinates range between longitude $6^0 18' 05''$N to $6^0 19' 35''$N and latitude $12^0 14' 05''$ to$12^0 15' 35''$. The people in the village engage in mining Gold and Wolfromite. The main mining activities are taking place just 1 kilometer away from the village, and the people of the village make use of soil of the tailings in making bricks for the construction of their buildings.

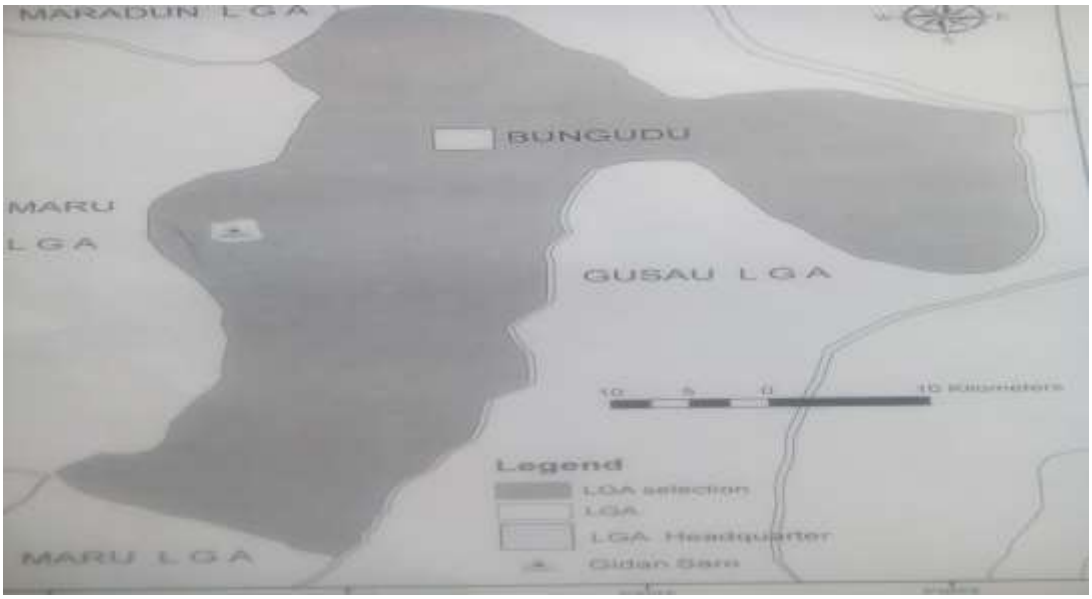

Figure 1. Map of Bungudu local government locating the study area.

2.2 SOIL SAMPLES COLLECTION AND TREATMENT

The stratified sampling technique was adopted for the soil samples collected. The samples were taken from different locations at a depth of 0-5cm from the surface of the soil (Tsafe *et al.*, 2012a). The Soil samples were then packed in polyethylene bags and transported to the laboratory, air-dried, crushed, homogenized, oven dried until a constant weight obtained. Finally, the samples were sieved through a 2 mm stainless steel mesh wire to separate fine earth particles from coarse materials (Tsafe *et al.*, 2012a).

2.3 MEASUREMENT of SOIL pH

2g each of soil sample was soaked in 10 ml of distilled water and mixture was stirred vigorously) after some minutes of deposition. A pH meter was then inserted into the mixture at mid-depth. The soil pH was then recorded Reading were taken three times and average pH values were recorded (Avila *et al*., 2010).

2.4 SOIL SAMPLES DIGESTION

The soil samples were digested according to Akinsola (2004), the soil samples were homogenized and oven dried untill a constant weight was obtained and passed through a 2mm sieve. 1g of each soil sample was digested using 10cm^3 nitric acid and 2cm^3 of perchloric acid. the mixture was heated in fume cupboard until the brown fume disappeared. The mixture was filtered through whatman No 1 filter paper into 50cm^3 calibrated sampling bottle, which was made to the mark with distilled water. For blank sample, a mixture of 10cm^3 of concentrated nitric acid and 2cm^3 of concentrated perchloric acid was heated on hot plate to almost dryness. The heating was stopped after appearance of white dense fume and clear solution. Upon cooling, it was diluted and made to mark in a 50cm^3 volumetric flask (Akinsola, 2007).

3.0 RESULTS AND DISCUSSION

Table 1. Mean± SD of Heavy Metal Concentrations (mg/Kg) in Soils from Gidan Saru mining site (GM, TS and RP)

pH	6.27±0.94	5.65±0.38	6.08±0.60	7.70±0.20
Metals	GM	TS	RP	CONTROL
Mn	^{a}97.42±36.64	^{b}67.78±8.82	^{c}42.79±13.60	ND
Fe	^{b}196.67±164.39	^{a}326.65±35.37	^{b}197.05±30.59	^{a}329.40±0.42
Cr	^{a}54.17±36.08	^{b}37.56±37.82	^{c}22.63±21.87	ND
Cd	^{b}0.71±0.29	^{a}1.25±0.78	^{a}1.98±0.75	^{b}0.94±0.01
Cu	^{a}173.58±10.63	^{A}172.28±3.49	^{b}158.±5.06	ND
Pb	^{a}273.38±32.16	^{a}271.17±2.93	^{b}248.80±2.25	ND
Ni	^{a}24.57±3.69	^{b}19.32±2.50	^{a}20.5±2.47	^{b}17.28±1.90
Zn	^{b}29.35±1.77	^{a}39.04±7.06	^{a}38.21±5.49	^{c}13.73±2.29

ND means not detected

Means with different superscripts are not significantly different.

The results in Table 1 shows pH and heavy metals concentration in (mg/Kg) of soils around three different sampling points of grinding mills, tailing sites and residential premises level as GM, TS and RP. The highest concentration of heavy metal was Pb across the sampling locations and cadmium was the lowest concentration of heavy metals across the sampling locations.

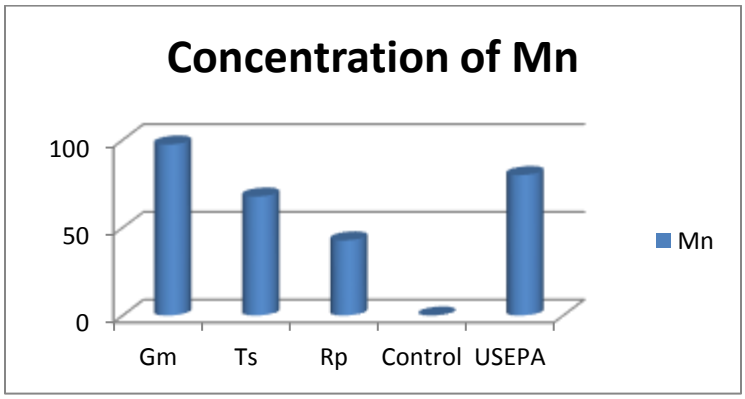

Figure 1. Mn concentration (mg/Kg) in the samples.

Manganese is a mineral element that is both nutritionally essential and potentially toxic (Udiba *et al.*, 2012a). Recorded data from this study as indicated in figure 1, grinding mills have the highest level of 97.42mg/kg, followed by tailings of 67.78mg/kg. But the lowest level of 42.79mg/kg was detected at residential premises. No Manganese level was detected around the control area. there is significant across the locations. The results revealed that the trend in soil Manganese concentration across three locations was grinding mills>tailings>residential premises. The levels of residential premises of this study was lower than 66.93mg/kg for residential compounds in dareta reported by Udiba *et al*, (2012a) and all the values obtained were much lower than 1132.6mg/kg reported for soil around an old mercury mine in Turkey by Aysen, (2013). High mean value of 142.91mg/kg was documented in

soil around mining site of Yargalma village, Zamfara state by tsafe *et al.*, (2012b). The values obtained in this work were also below 973.7mg/kg around soil near Coal mining in Gujarat reported by Kiran *et al*, (2013). The United States Environmental Protection Agency (USEPA, 2007) Maximum Permissible Limits for Manganese in soil is 80ppm. The values recorded in Residential premises and Tailings in this study were lower than USEPA except grinding mills which has highest concentration up to 97.42mg/kg. Occupational Health and Safety Administration (OSHA) has established a ceiling limit (concentration that should not be exceeded at any time during exposure) of 5 mg/m^3 for Mn in work place (NIOSH, 1999; cited In Udiba *et al*, 2012a)

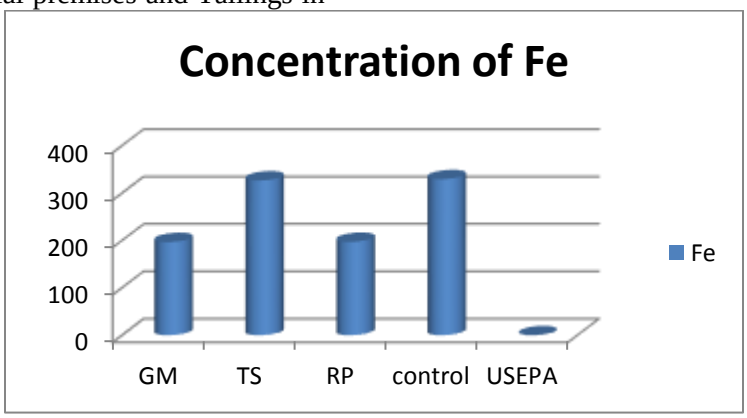

Figure 2. Fe concentration (mg/Kg) in the samples.

Iron is a commonly occurring metallic element, comprising 4.6% of igneous rocks and 4.4% of sedimentary rocks (ATDRS, 2007). It is an essential metal to the body and is central element of the heme molecule, which is a critical part of hemoglobin and essential for oxygen transport (Zecca *et al.*, 2004). From figure 2, Soil iron level in this work, tailings have the highest level 326.65mg/kg compared to grinding mills and residential premise. Iron levels across the sampling points follow the order: tailings>residential premises>grinding mills. Statistically there was no significant difference between residential premises and grinding mills. Surprisingly, control area has the highest value of 329.30mg/kg. This might be due to natural deposits of the mineral in the control area. Lower mean value 4.59mg/kg reported for soil around an old mercury mine in Turkey by Aysen, (2013). The values obtained at residential premises and grinding mills in this work were similar to soil Iron levels 195.25mg/kg in soil around mining site in Yargalma village of Zamfara state as reported by Tsafe *et al.*, (2012a), 289mg/kg observed in soil around the Copper-Nickel Mine in the Selebi Phikwe Region, Eastern Botswana as reported by Alfred *et al.*, (2013) was higher than the values obtained at residential premises and grinding mills. Yet no permissible limit criterion for Iron set by US EPA. However,

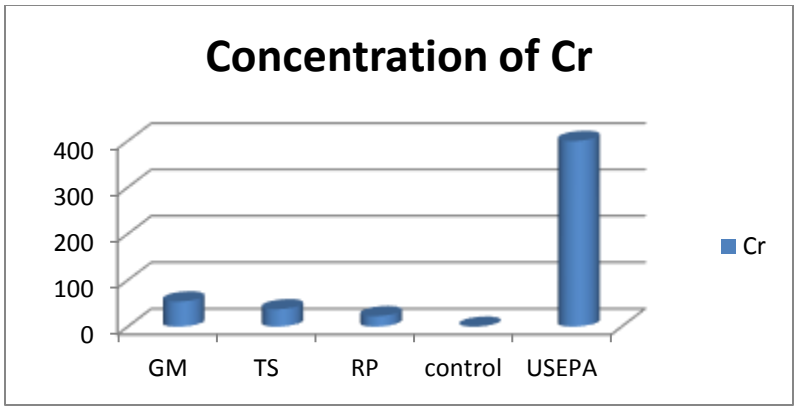

Figure 3. Cr concentration (mg/Kg) in the samples.

For Chromium soil concentrations from figure 3, grinding mils have the highest level of 54.17mgkg, followed by 37.56mg/kg in tailings and the lowest level of 22.83mg/kg was found in residential premises 22.83mg/kg. The concentrations with the respect to locations followed a trend; grinding mills>tailing site>residential premises. The values obtained in this work were higher than the values 3.99±3.90mg/kg, 3.83±2.90mg/kg and1.07±0.99mg/kg recorded in residential premises, grinding mills and play ground of dareta mining site after post remediation by Udiba *et al*, (2012a). Another work was conducted in yargalma village and 16.93mg/kg of the soil was reported by Tsafe *et al*, (2012b); Kiran *et al*., (2013) have reported 49.6±6.20mg/kg around soil near Coal mining in Gujarat, the value was much higher than the values obtained at residential premises and tailing site of this work. The Maximum Permissible Limits for Chromium in soil is 400ppm (USEPA, 2007). The level of Chromium recorded in this work across the sampling locations was below the USEPA Maximum Permissible Limit. Chromium was therefore not implicated in this work. Meanwhile, When Chromium concentrations obtained from this work is compared to other similar studies in some countries, the values were lower than 160.78mg/kg reported for soil around an old mercury mine in Turkey by Aysen, (2013).

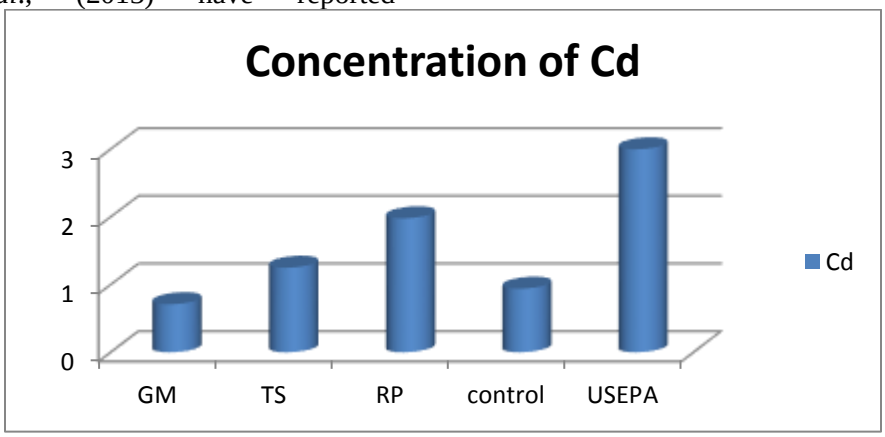

Figure 4. Cd concentration mg/Kg) in the samples.

The values of 0.71±0.30, 1.25±0.80 and 1.98±0.75mg/kg were obtained for Cadmium in grinding mills, tailing site and residential premises as recorded in figure 4. However, the

concentration 0.94mg/kg detected at control area show no significant difference at 95% confidence level with respect to three locations of the study area. Both concentrations were lower compared to the maximum permissible limit (3ppm) set for chromium by USEPA, (2007). This indicating severe pollution of the soil in the vicinity of Gidan Saru mining site yet to be implicated by chromium. However, despite the concentrations are below USEPA maximum permissible limits it could still lead to serious health problems considering its toxicity and classified as human carcinogenic (ATSDR, 2007). Thus, constant routine checkup for the concentration of cadmium in the village is needed. Concentration of cadmium across locations of the study area might be increase due to anthropogenic activities by Gold Artisanal miners taking place in the study area. The values across three locations of the study area and control area are lower than 3.8±3.2mg/Kg reported for soil around the Imcheon Au–Ag mine, Korea by Jung (2001). Similarly, Mouhsine *et al*, (2013) have detected 67.67mg/kg of cadmium in the Tailings, in the Zinc-Lead Sidi Bou Othmane Abandoned Mine Marrakech, Morocco. The values are lower than 3.92mg/kg observed in soils around Dabaoshan mine in Guangdong, China by Zhuang *et al*, (2009). The cadmium concentrations of soil of this work are also lower than finding (4.98mg/kg) in soil around an old mercury mine in Turkey by Aysen (2013).

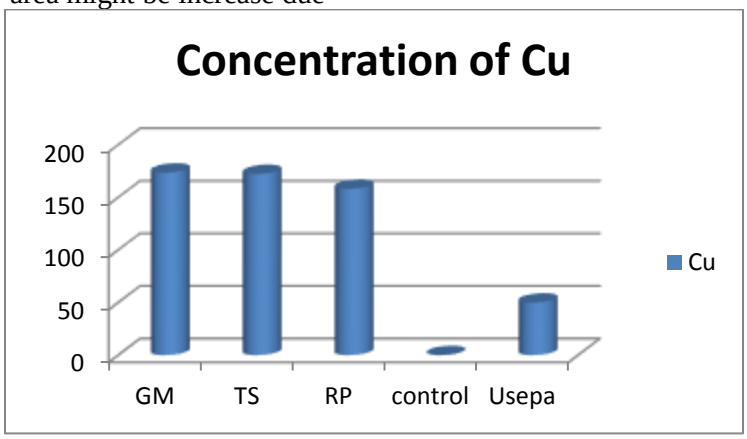

Figure 5. Cu concentration (mg/Kg) in the samples.

From Figure 5, the values of copper across the sampling locations range between 158.31 - 173.58. The lowest value was found in residential premises when compared to levels detected in grinding mills and tailings. No significant difference exists between grinding mills and tailings. Hence, the values across locations follow the trend; grinding mills> tailings> residential. The values obtained in this work are higher than the maximum permissible limit (50ppm) set for copper by USEPA, (2007). This indicating severe pollution of the soil in the vicinity of Gidan Saru mining site is totally implicated by copper. The values are far higher than 1.13mg/kg observed in soil of Yargalma mining site by Tsafe *et al*, (2012b), 2.16 ± 1.03mg/kg recorded around the Copper-Nickel Mine in the Selebi Phikwe Region, Eastern Botswana by Alfred *et a*, (2013), 32.79mg/kg observed in soils using xrf technique by antoaneta *et al*, (2010), 52.86mg/kg reported for Soils around an Old Mercury Mine in Turkey by Aysen, (2013) and 167mg/kg found in mine area of Draa Lasfar (Morocco) by Avila *et al*, (2012). However, the concentration of copper of this work was far less than the finding (502mg/kg) in soil around Dabaoshan mine in Guangdong, China by Zhuang *et al*, (2009), as well as 6293mg/kg and 16811mg/kg in the Soil and the Tailings, in the Zinc-Lead Sidi Bou Othmane Abandoned Mine Marrakech, Morocco by Mouhsine *et al*, (2013).

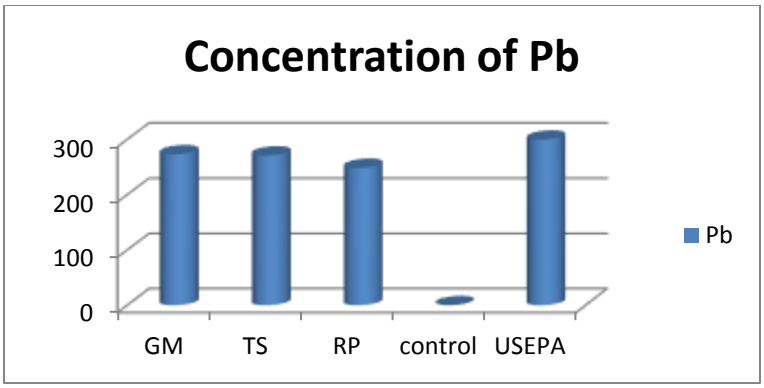

Figure 6. Pb concentration (mg/kg) in the samples.

The lead concentrations as in figure 6 are 273.4, 271.20 and 248.80 in grinding mills, tailings and residential premises respectively. No significant difference exists between grinding mills and tailings. However, the values obtained in this work were below 300ppm maximum permissible limit set for Pb in soil (USEPA, 2007). The degree of contamination by Lead to such extent was not surprising, because mining activity is one of the most important sources of Heavy metals in the environment (Mouhsine *et al*, 2013). Mining and milling operations, together with grinding, concentrating ores and disposal of tailings, provide obvious sources of contamination in the surface environment (Jung, 2008), yet, the values obtained are lower compared to 4252±3339mg/kg in soils (tailings) around the Imcheon Au–Ag mine, Korea by Jung, (2001), 515mg/kg reported for farmlands of affected mine area of Abare village of Zamfara by Abdu and Yusuf, (2013); 278mg/Kg recorded in soil around Dabaoshan mine in Guangdong, China by Zhuang *et al*, (2009). However, when the concentration of chromium obtained from this work are compared with the levels of lead from other similar studies, the value was in many folds above than findings in gujarat India (15.2±2.10mg/kg) by Kiran *et al*, (2013); 17.79mg/kg was detected in Artisanal Gold Mining Soils by Girigisu *et al*, (2012) 58.96±36.35mg/kg reported for Soils around an Old Mercury Mine in Turkey by Aysen, (2013); also, 29.66mg/kg was recorded in a soil around Yargalma mining community by Tsafe *et al*, (2012a) and 0.34mg/kg observed in soil near Copper-Nickel Mine in the Selebi Phikwe Region, Eastern Botswana by Alfred *et al*, (2013); UNEP, (2010) have documented a range of 100-27000mg/kg, 1080-34800mg/kg,<100-15300mg/kg and>100-37500mg/kg in soils of lead poisoning affected communities of Abare, Suke, Bagega and Dareta of Anka and Bukyum.

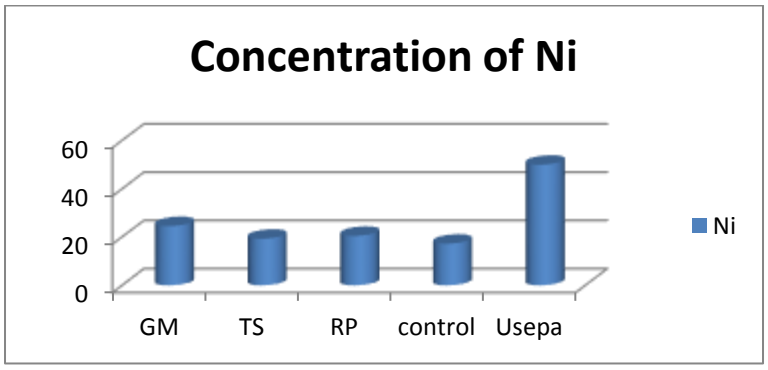

Figure 7. Ni concentration (mg/Kg) in the samples.

For Nickel concentrations, grinding mills have the highest level of 24.57mg/kg and lowest level of 19.32mg/kg was detected in tailings as in figure 7. Thus, Nickel concentrations are according to the order to the trend grinding mills>tailings>residential premises. However, 17.28±1.09mg/kg was detected around control area; there was no significant difference across control area, tailings and residential premises. The Environmental Protection Agency (USEPA) Maximum Permissible Limits for Nickel in soil is 50ppm (USEPA, 2007). Anthropogenic activities have resulted in the wide spread atmospheric deposition of Nickel from burning of oil and coal, smelting and mining (Udiba *et al*., 2012a). The Nickel concentration obtained in this work at tailings and residential premises are in agreement to 19.19mg/kg observed in soil of Abare village of Zamfara by Tsafe *et al*, (2012a). Many findings were recorded by many authors, the findings are lower when compared to this work, 2.31ppm was reported by Aremua *et al*., (2010) for Azara derelict barite mining area of Nasarawa,1.373mg/kg, 11.22mg/kg and 0.475mg/kg reported for residential premises, grinding mills and playground in soil of Dareta mining area of Zamfara by Udiba *et al*., (2012a), 1.15±0.71mg/kg was recorded for soil around Copper-Nickel Mine in the Selebi Phikwe Region, Eastern Botswana by Alfred *et al*, (2013). When the values compared to other similar findings, the values are lower than 62.67mg/kg was reported for soil by Antoaneta *et al*, (2009); Kiran *et al*, (2013) have documented 82.6±8.4mg/kg in soil near coal mining in Gujarat India. The values obtained from this work are below Maximum Permissible Limit (50ppm) for Nickel in soil (USEPA, 2007).

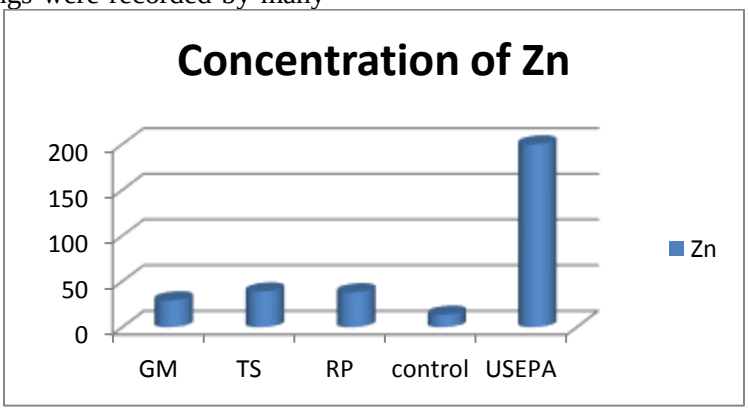

Figure 8. Zn concentration (mg/Kg) in the samples.

For the Zinc concentration in grinding mills, tailings and residential premises are 29.35±1.77mg/kg, 40.03±7.05mg/kg and 38.20±5.49mg/kg; while 13.73±2.29mg/kg was observed in control area as shown in figure 7. The Concentration across the sampling points follow the order; Tailings>residential premises>grinding mills. There is no significant difference between tailings and residential premises. The recommended daily Zinc intake for adults is between 9 and 11 mg per day. However, exposure to excess amount of Zinc can result to Zinc toxicity, such toxicity starts between 35 to 40mg daily (Downey, 2001; cited in Udiba *et al*, 2012). It is estimated that the median values of worldwide emissions of Zn into soils was 1,372 106 kg yr-1, more than half of this metal was associated with base metal mining and smelting activities (Jung, 2008). The United States Environmental Protection Agency (USEPA) maximum permissible limit for Zinc in soil is 200ppm. The values reported in this work were below USEPA maximum permissible limits. Thus, the study area was not polluted by Zn. Several studies have been documented by many authors; higher mean concentration up to 22641mg/kg and 42514.28mg/kg were reported for Soil and Tailings, in the Zinc-Lead Sidi Bou Othmane Abandoned Mine Marrakech, Morocco by mouhsine *et al*, (2013), 1100mg/kg was recorded for soil in a study conducted near

Mining Area in South China by Zhuang *et al*, (2014).

4.0 CONCLUSION

Based on the work carried out and the results presented, the higher levels of Fe, Mn and Cu in the analysed samples are above the United States Environmental Protection Agency (USEPA) maximum permissible limit. This showed that there is heavy metals contamination at the vicinity of Gidan Saro, such could be attributed due to the continuous artisanal gold mining activities in the study area. Thus, the study area may likely to have immediate and long term health risks to the exposed populations. The hazard is not limited to the artisanal gold miners only, but because of the unprofessional practice of the miners, the whole village community may be equally at risk. Therefore, all possible measures should be carried out to avoid the occurrence of incidence related to heavy metals. However, constant monitoring is very necessary because, that is the only way of knowing when acceptable limit is exceeded.

4.1 RECOMMENDATION

Base on the results obtained, the following recommendations are made:-

I. The government should provide wet milling machines to minimize the production of lead dust.
II. Miners should be encouraged to wash their bodies and clothes before returning to their communities from the processing sites.
III. Routine checking of heavy metals in the area should be made, because it the only way of knowing when the level exceeds the permissible limit.
IV. Miners should be educated, and trained on accepted safe mining practices.

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