

## RESEARCH ARTICLE

# GEOCHEMICAL ASSESSMENT OF TRACE METALS IN SOIL, STREAM WATER AND SELECTED FOOD CROPS AT KIBI GOLDFIELDS ENVIRONMENT, GHANA

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## ABSTRACT

This study assesses environmental receptors impacted by alluvial gold mining at Kibi Goldfields Limited in the Eastern region of Ghana to establish trace metals contamination risk. Specific objectives are to determine concentrations of (1) As, Cr, Ni and Pb in soils, drainage and food crops, using X-ray fluorescence, (2) Cl<sup>-</sup> in drainage using standard methods. Mean concentrations of As, Cr and Ni in soils are higher at impacted sites than control sites; while Pb and As concentrations in drainage exceeds the maximum contamination guideline values in drinking water. Using Cl<sup>-</sup> as a conservative tracer, As and Pb are adsorbing from water, while Cr and Ni are desorbing into water. In the food crops, bioaccumulation factors of As and Ni are profound at the impacted site than control sites; Except Cr in cocoyam at impacted sites, translocation factors are negligible in the food crops. Cr bioaccumulates in cocoyam and plantain at the control site, while Ni bioaccumulates in only plantain at the impacted sites. Overall, the metal contamination is of concern in the receptors, except Pd in plants. Results from this study can be used for trace metals risk assessment in the environment.

## KEYWORDS

Bioaccumulation, Translocation, Reclaimed soil, Stream Water, Trace metals.

## 1. INTRODUCTION

Mining activity results in the creation of employment opportunities and generation of foreign exchange for nations (Yeboah, 2008), but equally impacts negatively on environmental receptors such as water, soils and food crops, through trace metals contamination (Asante and Ntow, 2009). Trace metals are commonly mobilized through dissolution and weathering of mine spoils (Bas et al., 2019). In mining environments of Ghana, some of the notable metals associated with mining-related activities are Zinc (Zn), Chromium (Cr), Copper (Cu), Lead (Pb), Iron (Fe), Nickel (Ni), Arsenic (As), Gold (Au), and Silver (Ag) among others (Akabzaa, 2000).

One of the major sources of trace metals in the mining environment is mine tailings, which release the locked-up inorganic contaminants that adversely impact on the environment (Kuranchie, 2015). The trace metals, when released, are taken up by plants from polluted soils through their roots and on the leaves by those that settle on them through their organs (Bas et al., 2019). Through the pathway described above, the trace metals enter the food chain (Zane and Maris, 2012). The mobile metals may also infiltrate water supply systems, as well as other geo-materials (Bonte et al., 2011). In living organisms, trace metals at low doses may serve as vital food nutrients but may bio-accumulate and become harmful to humans (Monisha et al., 2014).

In Ghana, the study of the environmental concerns due to trace metals contamination is seen as very relevant to ensure the safety of the natural resources and maintain quality of life as the result of human dependency

on these resources. In recent years, concerns have been raised by regulatory bodies as well as opinion leaders in society to establish benchmarks for trace metals contamination in mining environments. For example, such concerns served as a basis for the formulation of a risk-based assessment methodology to disburse accrued funds for the supply of amenities to impacted communities within a mining area in Ghana (Foli et al., 2018).

According to Bempah et al. (2013), numerous studies on trace metals impact on environmental receptors have been conducted within reclaimed gold mine sites at some multinational companies. Many of such studies are however not commonly extended beyond the reclaimed sites, which includes adjoining fields that serve as farmlands among other natural resources like water bodies, upon which most of the rural dwellers depend for their daily food.

This study, therefore, seeks to assess the environmental receptors impacted by alluvial gold mining at Kibi Goldfields Limited in the Eastern region of Ghana to establish trace metals contamination risk. The specific objectives were to determine (1) the concentrations of trace metals such as As, Cr, Ni and Pd in soil, stream water and some common food crops such as plantain and cocoyam and (2) chloride (Cl<sup>-</sup>) concentration in stream water for use as a conservative tracer for geochemical process modelling for trace metal activity within the environment. Results from this study will provide useful evidence about the fate of these elements in the environment and the possible evaluation of the risk posed to wildlife and human health.

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## 2. MATERIALS AND METHODS

### 2.1 Study area, geological setting and gold mineralization

The study area covers a total land area of about 725 km<sup>2</sup>. The climate of the area is of the wet semi-equatorial type with a double maxima rainfall pattern that starts from April to July and September to October. The amount of rainfall per annum ranges from 1,250 to 1,750 mm, while temperatures range from 26-30°C per annum. The vegetation type is the dense equatorial type (Rae et al., 2009) that are often truncated by intense human activities such as logging and small-scale alluvial gold mining activities.

The area is underlain by the Paleoproterozoic Birimian formations which consist of NE-SW trending anticlinal-structured metasedimentary basin and syncline-structured metavolcanic gold belt (Abouchami et al., 1990). Primary gold associated with common metal sulphides occurs in deep-seated shear zones situated at the contact between the metasedimentary units of the basin and the metavolcanics in the belts. The synclinal basins are occupied by clastic Tarkwaian sedimentary units of Paleoproterozoic age formed from erosional activities of the Birimian rocks. The alluvial gold is mobilized from these sources and deposited in the lower-lying areas (Smith et al., 2016; Rae et al., 2009). A sketch Geological map of the area is presented in Fig. 1.

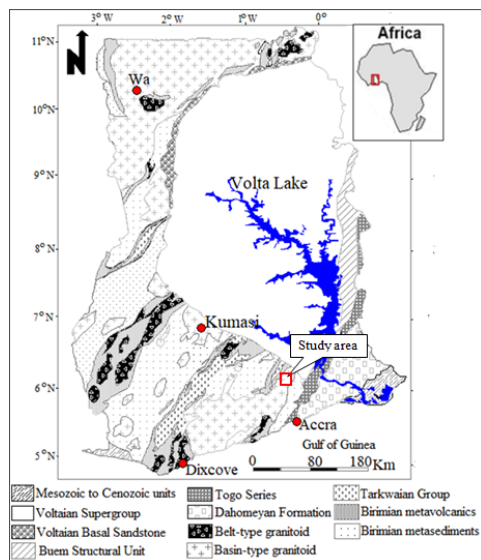


Figure 1: Sketch of Geological map of Ghana showing study area

### 2.2 Sampling design

Soil sampling was done on four sites: site 1-3 being reclaimed sites, while site 4 (un-mined zone outside mine concession) was used as control. For each site 10 bulk samples weighing 500g were obtained from a pit at depth of 40cm from ground surface. From each of the sites, common food crops such as cocoyam and plantain parts were sampled from farms, while 10 water samples were also taken using 500 ml-sized clean plastic bottles along with the profile of a stream running through the area. The sampling area is presented in Fig. 2.

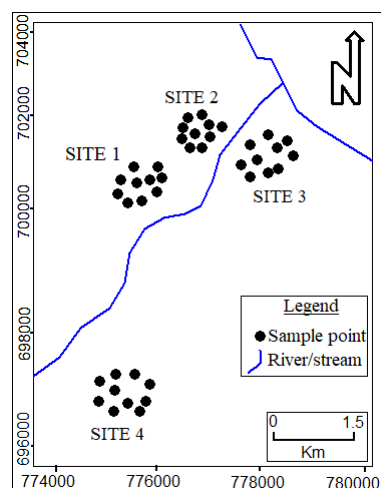


Figure 2: Map showing the sampling locations

### 2.3 Sample preparation and analytical methods

#### 2.3.1 Trace metals determination in samples

The soil samples were oven-dried at 90 °C pulverised and sieved through a 0.4µm-mesh. About 2 g of the pulverized portions were digested in aqua regia containing a mixture of 11.5 N HCl and 15.5 N HNO<sub>3</sub> at 90-100 °C for 1 h and allowed to cool and decanted after some 30 minutes and the solution used for trace metals analyses. Water samples were acid digested and vacuum filtration was used to filter the water samples through cellulose nitrate membrane filters of pore size 0.45 µm and then acidified with concentrated HNO<sub>3</sub> and HCl and heated to 90-95°C at pH 2 to prevent metals from forming precipitates. The water samples were then placed into a volumetric flask made up to the mark and analyzed. The food crop samples were washed with distilled water and dried in the oven at 60 °C, until a constant weight was obtained. 2 g of each sample was digested in a Kjeldahl tube with perchloric, nitric acid and hydrochloric acid in a ratio of 1:2:3 at a temperature of 450 °C over 30-60 minutes.

The trace metals were analyzed using the Atomic Absorption Spectrometer (AAS) SPECTRA AA 220 Air-acetylene Flame from the three sampling media. The results were recorded in mg/kg dry weight of the sample. Water samples were analyzed using ICP-OES at a detection limit of 0.0002 mg/l.

#### 2.3.2 Determination of Cl<sup>-</sup> in water

Chloride (Cl<sup>-</sup>) in water was determined using methods described by Mashulekha and Sunita (2018). A 50 ml portion of filtered water was extracted and delivered into a porcelain disc; a 3-4 phenolphthalein indicator droppings introduced to the filtrate to form a pink coloured solution. Methyl orange indicator was then added until a reddish product was formed. A 0.02 N solution of NaCO<sub>3</sub> was added until the colour changes to orange. The solution was transferred into a 250 ml conical flask and 1ml of K<sub>2</sub>CrO<sub>4</sub> indicator added. A 0.02 N solution of AgNO<sub>3</sub> was added and agitated until a white precipitate of AgCl evolved. The AgNO<sub>3</sub> solution was further added in drop until a permanent reddish-brown colour was obtained. The chloride content was estimated as:

$$\text{Chloride} = \left( \frac{\text{mg}}{\text{l}} \right) \frac{(V_2 - V_1) \times N \times 35.45 \times 1000}{\text{volume}} \quad (1)$$

Where V<sub>2</sub> = volume of the blank sample; V<sub>1</sub> = volume of a water sample; N = Normality.

#### 2.3.3 Bioaccumulation and translocation factors

Translocation factor (TF) and Bioaccumulation factor (BF), defined as trace metal transfer from root to shoot and from soil to plant, respectively, are defined as:

$$\text{TF} = \frac{\text{Concentration of the element in shoot}}{\text{concentration of the element in the root}} \quad (2)$$

TF>1 implies that from the root to shoot, plants can transport metals (Baker and Brooks, 1989).

$$\text{BF} = \frac{\text{Concentration of the element in plant}}{\text{concentration of an element in soil}} \quad (3)$$

BF>1 specifies that plant can accumulate, whereas BF<1, classify the plant as an excluder (Mganga et al., 2011).

#### 2.3.4 Metal ratios and geochemical process modelling

In the environment, metal ratio (MR) of the trace metals is presented as:

$$\text{MR} = \frac{\text{Concentration of the metal in sample}}{\text{background concentration of metal}} \quad (4)$$

By interpretation, MR<1 is defined as small; 1<MR<3 is moderate; 3<MR<6 is considerable and MR> 6 is high (Olatunji et al., 2009). In water, maximum contamination limit (MCL) for trace metals is taken from Wilson and Solomon (2002). Binary plots and Cl<sup>-</sup> values and the metals in water were generated and the pair of the extreme data points linked to explain the mixing line of availability of the metals. A higher percentage of data points above the mixing line indicates leaching of the metal into water and the converse indicates adsorption from water (Svensson et al., 2012; Berger, 2000).

### 2.4 Statistical analysis

Data obtained for trace metals were subjected to descriptive statistics and analysis of variance (ANOVA) using GenStat Release Software, Version 12.1 (2016). Mean differences between concentrations of trace metals in plants were compared using Tukey-B at 5 % significance level.

### 3. RESULTS AND DISCUSSION

#### 3.1 Concentration of trace metals in soils

Results of the trace metals determined in soils at surficial levels are presented in Table 1.

Site	As	Cr	Ni	Pb
1	0.106 ± 0.021	0.453 ± 0.256	0.758 ± 0.304	0.83 ± 0.937
2	0.070 ± 0.032	1.084 ± 0.282	0.212 ± 0.170	2.21 ± 0.757
3	0.082 ± 0.019	0.139 ± 0.026	0.061 ± 0.020	1.52 ± 0.453
Mean	0.086	0.558	0.343	1.52
4 (Control)	0.050 ± 0.002	0.077 ± 0.025	0.055 ± 0.031	2.39 ± 0.842

From Table 1, the average As concentrations (0.086 mg/kg) for impacted areas was found to be above the reference value (0.050 mg/kg). This is an indication that mining activities have increased the concentrations of As. The elevated levels of As in reclaimed mine soils site may be due to sulphide minerals such as arsenopyrite in the soil (Fashola et al., 2016). Similar results have been reported by Jinman et al. (2013) where mean values of As were up to 8.88 mg/kg for reclaimed gold mining area.

The mean value of Cr for the impacted areas is 0.558 mg/kg and they were above the reference value (0.077 mg/kg). However, the higher concentrations in Cr above the control could be attributed to the operations of mining (Wenhao et al., 2018). Comparatively, higher concentrations (66.1 mg/kg) were found in reclaimed gold mine soils in Heidaigou mine (Jinman et al., 2013).

Mean Ni concentrations at impacted areas was 0.343 mg/kg and was found to be above the reference value of 0.055 mg/kg. The high mean concentration of Ni in the impacted sites could be attributed to mining activities which released locked-up chemical constituents into the environment and absorbed onto the soil particles which has become immobile as a result (Yang et al., 2014). Comparatively, higher concentrations (27.32 mg/kg) were observed in a reclaimed gold mine soils (reclaimed) in Heidaigou opencast gold mine (Jinman et al., 2013).

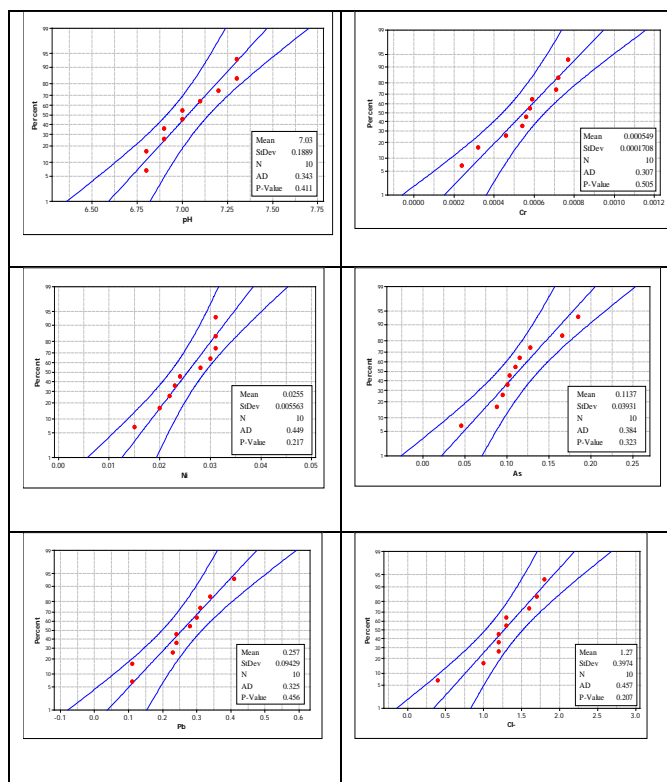
The mean concentrations of Pb (1.52 mg/kg) at the impacted areas were below the control value of 2.39 mg/kg. Pb occurs in the form of galena (PbS) with elevated levels determined by high concentration of sulphide, hence the low levels of Pb at the reclaimed sites could be attributed to the absence of PbS in the (Kanmani et al., 2013). The higher concentrations of Pb at the control area could, therefore, be due to the absorption of lead in soil due to various anthropogenic activities such as vehicle emissions in the nearby areas, among others (Papa, 2010).

The analysis of variance (ANOVA) indicate that significant differences exist between the concentration of trace metals of control values and in the reclaimed sites because p-value < 0.05 at 5% confidence interval. These differences could be due to physicochemical factors (texture of soil) in the soil samples

#### 3.2 Concentration of trace metals in water

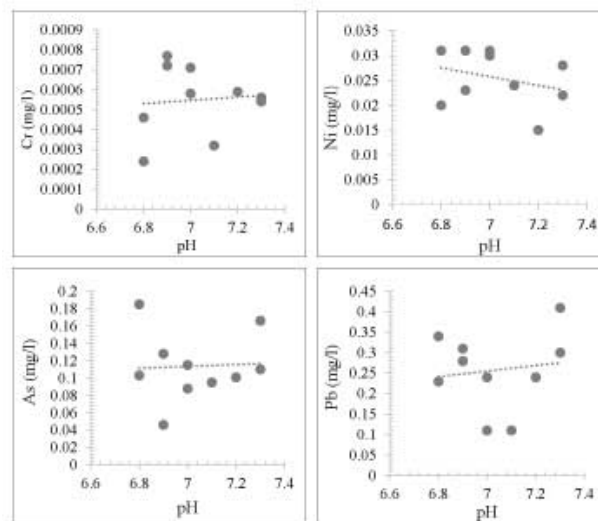
The trace metals concentrations in water samples are presented in Table 2 and further tested for normality at a 95 % confidence limit (CL) for validity as shown in Fig. 3.

Locations	pH	Cr	Ni	As	Pb	Cl-
1	6.9	0.00077	0.031	0.046	0.31	1.0
2	6.8	0.00046	0.031	0.103	0.23	1.2
3	7.0	0.00058	0.030	0.088	0.24	1.3
4	7.0	0.00071	0.031	0.115	0.11	1.2
5	7.1	0.00032	0.024	0.095	0.11	1.3
6	6.9	0.00072	0.023	0.128	0.28	0.4
7	7.3	0.00054	0.022	0.110	0.30	1.8
8	7.2	0.00059	0.015	0.101	0.24	1.7
9	7.3	0.00056	0.028	0.166	0.41	1.6
10	6.8	0.00024	0.020	0.185	0.34	1.2
Mean	7.03	0.00055	0.0255	0.1137	0.257	
MCL		0.1mg/l	0.05mg/l	0.015mg/l	0.020mg/l	



**Figure 3: Probability plot of parameters performed at 95% Confidence Level**

Considering the metal concentrations, Pb recorded the highest mean value of 0.257 mg/kg while Cr had the least (0.00055 mg/kg). As and Pb concentrations in water were beyond 1° MCL points of 0.015 mg/l and 0.020 mg/l respectively whereas, concentrations of Cr and Ni were below 1° MCL points of 0.1 mg/l and 0.005 mg/l. The metal ratio (MR) of 0.14 for Cr specifies low water pollution, while MR for Ni, As, and Pb were 8.66, 14.14, and 68.57 respectively; indicating very high contamination. However, among the numerous influencing factors, pH is one of the main factors which affect trace metals and can be of great significance to the migration and transformation of metals (Huang et al., 2016). The mean pH of the water is 7.0 meaning it is neutral.



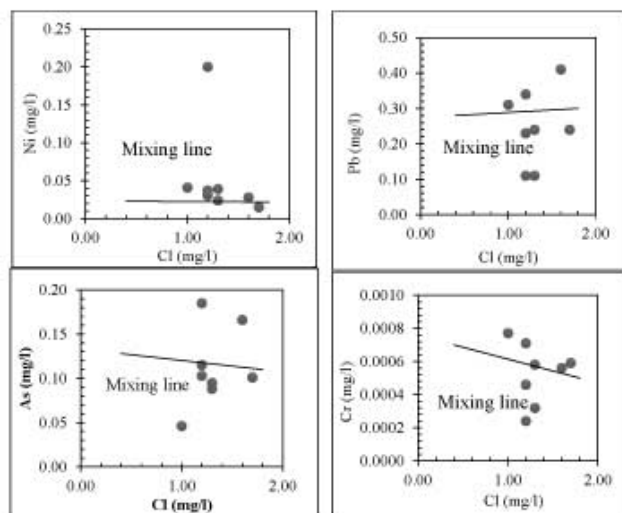
**Figure 4: Binary plots of pH vs the trace metals**

The variation of pH versus trace metal plots (Fig 4) are very minimal and hence; pH may therefore not be entirely responsible for metal movement in the water, hence the consideration of a geochemical process model which explains the effect addition of water in the environment.

#### 3.3 Geochemical process model of trace metals in water

The geochemical model plots for trace metals using Cl- as conservative tracer is shown in Fig. 5. Data plotting values below the mixing line specify ions are being released into the stream.





**Figure 5:** Process model plots for trace metals using Cl as the conservative tracer

Conversely, data values that plots above the mixing line indicates that ions are being added to the stream. When the data points distribution is equal about the mixing line, it demonstrates equilibrium as presented in the two scenarios discussed above. From Fig. 5, point distribution of

data about the mixing and the stability interpretation of As, Cr, Ni and Pb are developed and presented in Table 3.

Table 3: Interpretation of trace metals behaviour in drainage			
Metal	Data points above mixing line	Data points below the mixing line	Process
As	25%	75%	Adsorption
Pb	37.5%	62.5%	Adsorption
Ni	87.5%	12.5%	Desorption
Cr	62.5%	37.5%	Desorption

From Table 3, the process model demonstrates data points above and below the mixing line. Points data under the mixing line specify the release of elements (As and Pb) from the drainage through adsorption. This implies that the concentration of these elements will be removed from the drainage to the surrounding soils or sediments, hence contaminating the surrounding soils or sediments. On the other hand, point data beyond the mixing line signify the addition of elements (Cr and Ni) to drainage through desorption. This implies that the concentration of these elements will increase in water since it is likely to have enough residence time and be readily available for uptake by plants (potentially increasing the concentration of trace metals). Therefore, food crops grown on the banks of the stream or surrounding environment should not be left to overstay its maturity period.

### 3.4 Mean concentrations of trace metals in food crops

The mean concentrations of trace metals in the food crops are presented in Table 4.

Table 4: Mean concentration of trace metals obtained food crops									
Trace Metals	Sites	Cocoyam				Plantain			
		Root	Stem	Leave	Whole plant	Root	Stem	Leave	Whole plant
As	Impact (1)	0.01	0.02	0.01	0.04	0.01	0.01	0.01	0.03
	Impact (2)	0.56	0.00	0.00	0.56	0.10	0.01	0.00	0.11
	Impact (3)	0.01	0.07	0.00	0.08	0.00	0.01	0.00	0.01
	Mean	0.19	0.03	0.00	0.23	0.04	0.01	0.00	0.05
	Control (4)	0.23	0.03	0.10	0.36	0.32	0.18	0.12	0.63
Cr	Impact (1)	0.02	0.16	0.00	0.18	0.01	0.01	0.00	0.02
	Impact (2)	0.12	0.00	0.00	0.12	0.01	0.01	0.00	0.02
	Impact (3)	0.01	0.01	0.00	0.02	0.02	0.00	0.00	0.02
	Mean	0.05	0.06	0.00	0.11	0.01	0.00	0.00	0.02
	Control (4)	0.12	0.03	0.00	0.15	0.42	0.06	0.00	0.48
Ni	Impact (1)	0.08	0.01	0.00	0.09	0.40	0.01	0.00	0.41
	Impact (2)	0.68	0.39	0.07	1.14	0.19	0.01	0.00	0.20
	Impact (3)	0.40	0.51	0.20	1.11	0.26	0.19	0.90	1.35
	Mean	0.39	0.30	0.09	0.78	0.28	0.07	0.30	0.65
	Control (4)	0.05	0.00	0.00	0.05	0.01	0.01	0.00	0.02
Pb	Impact (1)	0.02	0.01	0.00	0.03	0.01	0.00	0.00	0.01
	Impact (2)	0.56	0.00	0.00	0.56	0.10	0.01	0.00	0.11
	Impact (3)	0.09	0.01	0.00	0.10	0.13	0.01	0.00	0.14
	Mean	0.22	0.00	0.00	0.22	0.08	0.01	0.00	0.09
	Control (4)	0.05	0.00	0.00	0.05	0.05	0.01	0.00	0.06

Primarily and most commonly, As is accumulated in the roots, with low concentrations in the shoot for terrestrial and emergent plants (Di Lonardo et al., 2011). Likewise, the findings from this study indicate that As in both food crops (cocoyam and plantain) decreased in the order of root > stem > leaves. The average mean concentrations of As for cocoyam and plantain were 0.23 mg/kg and 0.05 mg/kg, respectively at the impacted area and were less than control values of 0.36 mg/kg and 0.63 mg/kg respectively. Comparatively, Foli et al. (2019) recorded lower levels of As concentration in plantain which corroborates with the findings of this study.

In plants, the pathway of uptake of Cr is not defined clearly, however, depending on the speciation, the plant takes up the Cr element through various means such as roots, leave or stem (De Andrade et al., 2019). The results from the study show that Cr concentrations accumulated in the following order; Stem > Root > Leaves at the impacted areas. The average mean of Cr at the impacted site for cocoyam (0.11 mg/kg) and plantain (0.02 mg/kg) were less than the control value of 0.15 mg/kg and 0.48 mg/kg respectively. Similar research conducted in Nigeria recorded 0.53 mg/kg for Cr concentrations in food crops (Kalagbor et al. 2015) which is also lower than their control value.

In the case of Ni, average mean concentrations in cocoyam (0.75 mg/kg) and plantain (0.65 mg/kg) at the impacted sites were above the control

value of 0.05 mg/kg and 0.02 mg/kg respectively. Food crops are, therefore contaminated by Ni. The findings of Udosen et al. (2016) recorded lower concentrations of Ni in cocoyam which is dissimilar to the findings obtained from this study. Also, Anim-Gyampo et al. (2013) recorded higher Ni concentrations above the usual value.

The mean Pb concentrations in cocoyam (0.23 mg/kg) and plantain (0.09 mg/kg) at the impacted areas were above the control value of 0.05 and 0.06 mg/kg, respectively. This shows that both food crops are contaminated with Pb. Comparatively, higher concentrations of Pb in cocoyam were recorded by Bansah et al. (2016) which corroborate with the findings of this study. In Ghana, different researches recorded Pb concentrations between 53.9 and 65.0 mg/kg in food crops grown in small-scale gold-mining zones of the Wassa-Amenfi-West District (Anim-Gyampo et al., 2012).

However, various reports have shown that food crops harvested from mining areas could be contaminated with trace metals and therefore could expose consumers of such food to severe health threats (Kabata-Pendias, 2010). The amount of trace metals entering the food crops (cocoyam and plantain) may depend on the type of plant, soil type and plant-soil interactions. According to Park et al. (2011), organic acids in plants also enhances phyto-availability of metals to plants as it increases the dissolution of the metal in soil from insoluble mineral levels. This

dissolution increases the mobility of metals in the roots area; increases trace metals desorption and rare earth elements from soils as well as increases concentrations of metals in the soil solution.

### 3.5 Translocation and Bioaccumulation factors in food crops

The transfer of metals from soil to plant and from root to shoot are presented in Table 5.

**Table 5: Translocation factors (TF) and Bioaccumulation factors (BF) in food crops**

Trace metal (mg/kg)	Site	Soil	Root	Stem	Leaves	Whole plant	TF	BF
<b>Cocoyam</b>								
As	Mean Impact	0.086	0.19	0.03	0.00	0.23	0.16	2.67
	Control	0.050	0.23	0.03	0.10	0.36	0.13	7.20
Cr	Mean Impact	0.558	0.05	0.06	0.00	0.11	1.20	0.19
	Control	0.077	0.12	0.03	0.00	0.15	0.25	1.95
Ni	Mean Impact	0.343	0.39	0.30	0.09	0.78	0.77	2.27
	Control	0.055	0.05	0.00	0.00	0.05	NA	1.00
Pb	Mean Impact	1.52	0.22	0.00	0.00	0.22	NA	0.15
	Control	2.39	0.05	0.00	0.00	0.05	NA	0.02
<b>Plantain</b>								
As	Mean Impact	0.086	0.04	0.01	0.00	0.05	0.25	0.58
	Control	0.050	0.23	0.03	0.10	0.36	0.13	7.2
Cr	Mean Impact	0.558	0.01	0.00	0.00	0.02	NA	0.04
	Control	0.077	0.12	0.03	0.00	0.15	0.25	1.95
Ni	Mean Impact	0.343	0.28	0.07	0.30	0.65	0.25	1.89
	Control	0.055	0.05	0.00	0.00	0.05	NA	0.90
Pb	Mean Impact	1.52	0.08	0.01	0.00	0.09	0.13	0.06
	Control	2.39	0.05	0.00	0.00	0.05	NA	0.02

The concentrations of As, Ni and Cr (control area) recorded Bioaccumulation Factor (BF)>1 while Pb and Cr (impacted area) recorded BF<1 in cocoyam. Also, plantain crop recorded BF<1 for As (impacted area), Pb, Ni (control) and Cr (impacted) while As and Cr (control area), and Ni (impacted) recorded BF>1. However, food crops with BF>1 indicate that food crops are suitable for phytoextraction of the associated trace metals. It also implies that there is a high potential for their transport through the food chain. Cocoyam recorded translocation factors (TF)<1 for all trace metals except As (control) and Cr (impacted) which recorded TF>1.

Also, plantain recorded TF<1 for all trace metals. Trace metals with TF<1 indicates that food crop could not transport the respective metals within its tissue; while trace metals with TF>1 implies that, from the root up to the shoot, plants can efficiently transport metals (Baker and Brooks, 1989). Hence, the greater the value of the TF, the greater the mobility of the elements. However, all trace metals with BF<1 for food crops are considered excluders in their present situation, nevertheless, when the TF is greater than 1, they may possibly bioaccumulate when not harvested on time.

## 4. CONCLUSIONS

The distribution of the trace metals in the environment suggests that the soil quality has, generally not been restored. Mean concentrations of As, Cr and Ni in soils are higher at impacted sites than control sites; while Pb and As concentrations in drainage exceeds the stipulated maximum contamination (MCL) guideline values for drinking water. Trace metals such as As and Pb are adsorbing from stream water, while Cr and Ni are desorbing into stream water. In the food crops, bioaccumulation factors of As and Ni are profound at the impacted site than control site; except Cr in cocoyam at impacted sites, translocation factors (TF) are negligible in the food crops. Cr bioaccumulates in the crops at the control site, while Ni bioaccumulates in only plantain at the impacted sites. Food crops with TF>1 for the trace metals may bioaccumulate over a prolonged period. Food crops from the reclaimed sites pose a health risk. All food crops with TF>1 suggests that they can be used as a good phyto-translator. Also, food crops found on the banks of the stream should be harvested on time. Overall, the metal contamination is of concern in the receptors, except Pb in plants. Results from this study can be used for trace metals risk assessment in the environment.

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