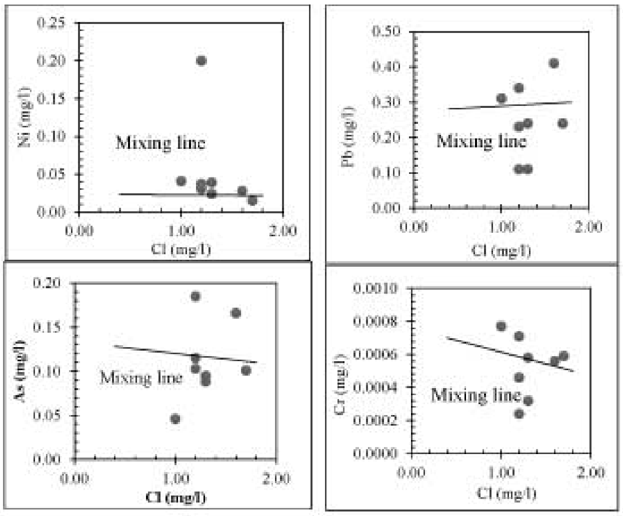

Figure 5: Process model plots for trace metals using Cl as the conservative tracer

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

		Cocoyam				Plantain			
Trace Metals	**Sites**	**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 kg/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
Cocoyam								
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
Plantain								
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 Bi-accumulation Factor (BF)>1 whiles 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) whiles 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; whiles 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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