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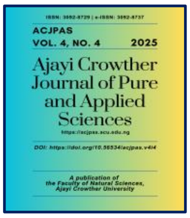

Article

Potential Ecological Risks Assessment of Agricultural Site, Along Asa River Flood Plains, Ilorin, North Central Nigeria

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Abstract

The contamination of agricultural sites by heavy metals poses a serious threat to human health as these metals can enter the human body through food consumption. This study focuses on assessing heavy metal contamination and probable ecological risk in agricultural areas along the Asa River floodplains in Ilorin, Nigeria. Ten soil samples were collected and analyzed using Inductively Coupled Plasma-Mass Spectrophotometer (ICP-MS). Contamination risk index applied are degree of contamination, geo-accumulation index (Igeo), pollution load index (PLI) and potential ecological risk index (PERI). Pearson Correlation matrixes Analysis (PCA) were employed to identify contamination sources and relationships between heavy metals. Results showed varying concentrations of heavy metals with lead exceeding permissible limits in some locations. However, Zinc, Copper, Nickel, Chromium, Cobalt, and Arsenic were within acceptable thresholds, indicating anthropogenic influences. Most of the sampled areas are unpolluted except for KFG 5 polluted with lead. A Low to considerable degree of lead contamination, minimal to significant lead enrichment and low to considerable potential ecological risk of lead was observed. Correlation analysis revealed interdependencies among heavy metals, suggesting common contamination sources. Emphasizing the probable lead contamination in agricultural soil samples along the Asa River floodplains and the need for effective management strategies to protect human health and environment from pollution and eutrophication.

Keywords: Contamination, Agricultural site, Heavy Metals, Ecological risk

1. Introduction

Soil is an important natural resource needed for sustaining human existence. Heavy metal contamination in the environment has been of concern worldwide due to their toxicity, persistence, widespread source and non-biodegradable properties [1]. Humans are exposed to heavy metals in different ways. Heavy metals in soils are directly a treat human health through ingestion, inhalation, and dermal contact [2]. Heavy metals are released naturally into the environment from rock weathering where major and trace elements are released into the environment [3]. Major anthropogenic sources of heavy metals into the environment is increase in industrial revolution, which on daily basis releases heavy metals in to the environment through discharge of effluent, sewage wastewater, burning of fossil fuels, depositions of landfills, and agrochemicals [4,5,6]. Agricultural soil can be contaminated with heavy metal as a result of land application of organic (animal manures, biosolids and compost) and inorganic fertilizer, pesticides and petrochemicals [7, 8] other sources of heavy metals in agricultural site most especially in urban settlement include rapid urbanization, road networks, industrial plant and dissipative consumption such as weathering of paints and pigments, batteries, electronic tubes, plastic wears and weathering of electroplated surfaces and decomposition or combustion of treated wood which are the sources of heavy metal emission in urban and per-urban areas [9] . Anthropogenic sources of heavy metals tend to be more mobile than naturally occurring ones [10, 11].

Major road in Nigeria creates variety of ancillary employment ranging from auto repair workshops, vulcanizer and welders, battery chargers and various dealers in other facilitators of motor transportation. Floodplains and riversides along major road in Nigeria are potential workshops to local block making company, car washes and potential reservoir for dumping of domestic and industrial waste. Industrial pollutants are released into the environment in form of particulate matter, which later settles down on the soil, or through effluent into the river channels, which are being used mainly for irrigation practices [12]. The key ways of determining the effect of these heavy metals on the ecosystem is the use of the contamination indices which are degree of contamination (igeo), pollution load index (PLI), Enrichment factors and most of all is the potential ecological risk index (PERI). ‘several authors have used these indices for monitoring soil quality, pollution contamination and pollution control and reported that they are reliable [13-17].

This study aimed to look into the potential heavy metals present in the agricultural site because of their nearness to heavy road traffic, use of contaminated water, industrial activities and domestic waste for irrigation, and their ecological effect on humans and the environment.

2. Materials and Methods

2.1 Study area

The study was carried out within Ilorin metropolis Southern Kwara State, Nigeria, and lies within latitudes 8^{O}.26′.00″ N, 8^{O}.29′.00″ N and longitudes 4^{O}.32′.00″ E, 4^{O}.34′.00″ E. It covers approximately 56.9km^2 area of Ilorin. It is accessible through a network of major and minor roads (Figure 1).

The study area is characterized by migmatite gneiss; granite gneiss and pegmatite intrusions. The migmatite gneiss consists of porphyroblastic gneiss, Augen gneiss and xenoliths of biotite granite, with leucrocratic and melanocratic minerals in almost equal proportions generally striking in a N-S direction with a moderate to gentile dip. The minerals such as biotite and quartz are small to large grained in texture, the Porphyroblast feldspars present measure about 5-10cm in length, deformed, elongated parallel to foliation.

Majority of the farmers within the study area practice FADAMA farming along the flood plains, using the river water for irrigation. The study area is endowed with lots of industrial activities ranging from pharmaceutical, detergent production, soft drinks Company to road side auto-mechanic workshop, car washes, animal husbandry and block making company. Domestic and industrial wastes find their way into the river utilized by farmers for irrigation.

2.2 Sampling and Sample Preparation

A total of 10 agricultural topsoil at a depth of 0- 20 cm were taken from floodplain upstream (3samples), middle stream (3 samples) downstream (3samples) and control at phase 2 Asa dam (1sample). The geographical coordinate and elevations for each sample location were recorded (Table 1). Using the hand auger the samples were randomly collected, and then placed in a sample bag and labeled appropriately. The collected soil samples were air dried at room temperature at the workshop of Department of Earth Sciences at Ajayi Crowther University Oyo. The air-dried samples were pulverized by pestle and mortal and 5g of the grounded samples was packed in airtight sealed sample bags, labeled for further analysis.

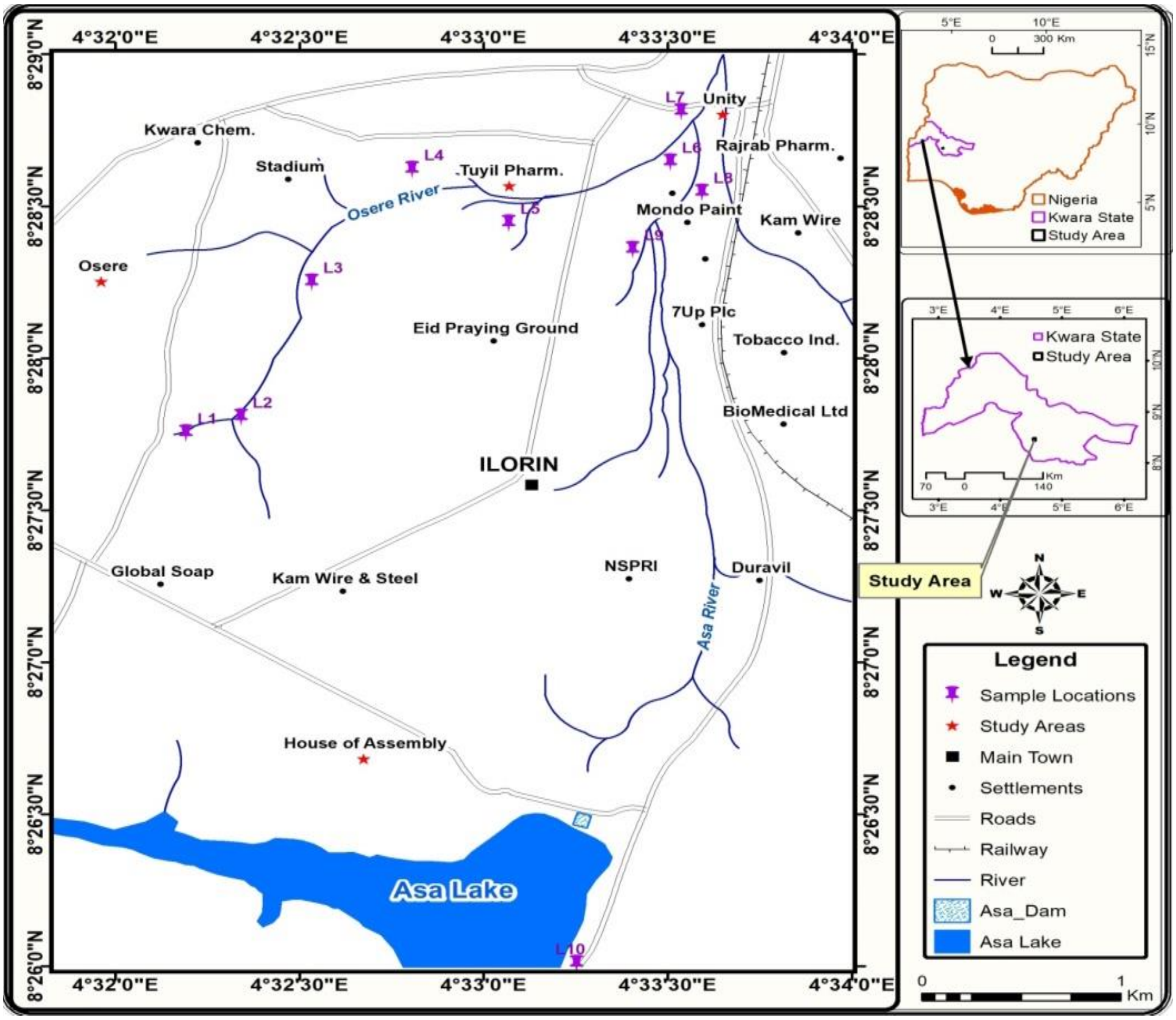

Figure 1. Sample Location Map of the Study Area.

Table 1. Sample Locations

Sampling Point	Location Code	Sample No	Longitude(E)	Latitude(N)	Elevation (M)
Upstream	A	KGF 1	4° 32′ 12.69″	8°27′ 45.51″	304
		KGF 2	4°32′ 16.80″	8°27′ 48.63″	301
		KGF 3	4° 32′ 32.01″	8° 28′ 15.02″	292
Midstream	B	KGF 4	4°33′ 16.21″	8°28′ 37.57″	283
		KGF 5	4° 33′ 22.35″	8°28′38.20″	283
		KGF 6	4° 33′ 29.08″	8° 28′ 40.50″	276
Downstream	C	KGF 7	4° 33′33.58″	8°28′ 39.43″	280
		KGF 8	4° 33′ 28.62″	8° 28′ 41.31″	271
		KGF 9	4° 33′ 05.00″	8° 28′ 29.45″	278
Control	D	KGF 10	4° 33′ 15. 54″	8° 26′ 0.43″	294

2.2.1 Inclusion criteria

1. Adults aged 18 years and above.
2. Residents of Damaturu Metropolis who have lived in the area for at least six months.
3. Individuals willing to provide informed consent.

2.3 Heavy Metals Analysis

The analysis heavy metals of the soil samples were done using ICP-MS. The total digestion of the samples, were carried out in the wet geochemistry Laboratory of the Department of Geological Sciences, University of Cape Town. The heavy metal concentrations of the soil samples were determined by adding 4ml of 4: 1 concentrated HF: HNO_3 to each of the sample in a covered Teflon beaker, and digested on hot plates for 48 hours at 140 ^{0}C in fume cupboard. After 48 hours the digested soil sample were dried out at 140 degrees for at least three hours to ensure maximum drying. 2mls concentrated HNO_3 was then added to the residue in beaker, dried to evaporate off the HF acid from the sample solution. After digestion, samples were loaded into Thermo- Fisher X- series Quadruple ICP-MS one at a time for analysis. The heavy metals and other element were determined and recorded in part per million (ppm).

2.4 Heavy Metal Contamination Assessment

The geo-accumulation index (I_geo) is a quantitative measure used to assess the degree of heavy metal pollution in soils or sediment by comparing the current and pre industrial concentration (background) level (18), It is computed using the equation:

$$\mathrm{Igeo} = \log2\left(\frac{\mathrm{Cn}}{1.5\mathrm{Bn}}\right) \qquad \text{Eqn. 1}$$

Where: Cn is the measured concentration of the elements, Bn is the geochemical background value, and 1.5 is a constant allowed for analysis of natural fluctuations in the content of a given substance in the environment and very small anthropogenic influences. The focus here is between the concentration obtained and the concentration of elements in the earth crust because soil is a part of the layers of the earth crust and the chemical compositions are related and the classification is stated in Table 2.

Table 2. I_geo classifications for Soils [18]

I_geo	Pollution level	Description
≥5	6	Extremely polluted
4≤Igeo<5	5	Highly polluted
3≤Igeo<4	4	Moderately to highly polluted
2≤Igeo<3	3	Moderately polluted
1≤Igeo<2	2	Moderately polluted to unpolluted
0≤Igeo<1	1	Unpolluted
1≤Igeo<0	0	Background concentration

Enrichment Factor (EF) is a tool used to evaluate the degree of anthropogenic impact on heavy metal concentration in soil or sediments. It also distinguishes between metals of geogenic source and those as a result of human activities. The enrichment factor of the soil sampled was calculated using the formula established by [19]:

$$EF = \frac{\mathrm{Cn/Cref}}{\mathrm{Bn/Bref}} \qquad \text{Eqn. 2}$$

Where: Cn= content of the examined element in the examined environment, Cref=content of the examined element in the reference environment, Bn=content of the reference element in the examined environment and Bref=content of the reference element in the reference environment.

Rubidium (Rb) was chosen as a reference element because of the stability of the element in soil and does not undergo anthropogenic alteration. Other authors use Fe, Mn [20]

Enrichment factor classifications by [21] (Table 3) were used in this study and a subsequent increase in EF values could correspond to the contributions of the anthropogenic origin of contamination.

Table 3. Classification of Enrichment Factor [21]

S/N	Enrichment Factor	Status
1.	EF < 2	Deficiency to minimal enrichment
2.	EF 2-5	Moderate enrichment
3.	EF 5-20	Significant enrichment
4.	EF 20-40	Very high enrichment
5.	EF > 40	Extremely high enrichment

2.5 Pollution Load Index (PLI)

The Pollution Load Index (PLI) is obtained as contamination Factors (CF). This CF is the Quotient obtained by dividing the concentration of each metal. The PLI of the place are calculated by obtaining the n-root from the n-CFs that was obtained for all the metals with the PLI obtained from each place. Generally, pollution load index (PLI) as developed by [22], which is as follows:

CF= C metal/C background value PLI=n √ (CF1xCF2xCF3x…xCFn) *Eqn. 3*

Where: CF= contamination factor, N = number of metals, C metal = metal concentration in polluted sediments, C Background value = background value of that metal.

The PLI provides simple comparative means for assessing soil quality as stated in Table 4.

Table 4. Pollution Load Index Classifications [23].

S/N	Pollution load index	Status
1.	PLI < 1	perfection (no pollution)
2.	PLI = 1	Presents, but only in baseline levels of pollutants
3.	PLI > 1	indicate pollution

2.6 2.5 Potential Ecological Risk Index (PERI)

The potential ecological risk for a given contaminant was calculated according to [23].

$$\boldsymbol{E_f^i = C_f^i * T_f^i} \qquad \textit{Eqn. 4}$$

Where T_f^i is the toxic response factor for a given heavy metal is; C_f^i the contamination factor. The T_f^i for Pb, Zn, Cu, As, Ni, Co and Cr are 5, 1, 5, 10, 5, 5 and 2, respectively are used to determine the potential ecological risk index for this study. The potential ecological risk of heavy metals is classified into five levels (Table 5).

Table 5. Potential Ecological Risk Index Classification [23]

S/N	Potential ecological risk index	Status
1.	E_f^i< 20	Low
2.	20-40	Moderate
3.	40-80	Considerable
4.	80-16	High
5.	> 160	very high

3. Results and Discussion

3.1 Heavy Metals Concentration in the Studied Soil Samples

The study assessed the concentrations of heavy metals in soil samples, focusing on lead, zinc, copper, nickel, chromium, cobalt, and arsenic which are generally within the permissible limits set by the World Health Organization (WHO). Lead concentrations ranged from 19.31ppm to 220.2ppm, with KGF5 exceeding the WHO permissible limit for agricultural soils, indicating contamination from anthropogenic activities, such as traffic and industrial discharges (Table 6). Zinc concentrations, ranging from 62.88ppm to 160.1ppm (Table 6) were above upper crust values but within WHO limits, With the suspected source probably from fertilizers and industrial wastes. Copper concentrations, between 10.19ppm and 28.59ppm, and this is below WHO limits, but contamination was linked to industrial waste and agrochemicals. Nickel ranged from 4.84ppm to 13.57ppm remaining within permissible limit but higher concentrations were observed location KGF 7, 8, and 9. Chromium concentrations (10.20ppm to 48.41ppm) Cobalt levels, ranging from 4.49ppm to 9.96ppm, Arsenic concentrations, between 1.31ppm and 2.77ppm, are all within WHO limit, though Arsenic is slightly elevated in KGF9, suggesting anthropogenic influences such as fertilizer and pesticide uses (Table 6), as stated in similar research by [24, 25, 26].

Table 6. Heavy Metal Concentration within the Sampled Area.

LOCATION	Cr(ppm)	Co(ppm)	Ni(ppm)	Cu(ppm)	Zn(ppm)	As(ppm)	Pb(ppm)
KGF1	33.39	6.158	5.938	14.43	104.0	1.604	22.64
KGF2	32.63	5.828	6.075	14.61	85.85	1.501	26.63
KGF3	28.91	4.500	4.503	10.19	62.88	1.442	19.31
KGF4	46.25	9.966	10.99	28.59	134.2	2.026	47.90
KGF5	48.49	6.405	13.57	28.46	160.1	1.958	220.3
KGF6	33.10	6.354	7.435	14.47	75.76	1.319	27.93
KGF7	28.96	7.554	8.455	18.76	100.9	2.076	40.66
KGF8	35.51	7.447	9.931	14.43	63.04	1.451	23.76
KGF9	43.94	9.705	10.05	22.46	145.4	2.775	47.22
KGF10	10.20	4.499	4.844	16.46	135.3	1.494	23.35
Minimum	10.20	4..49	4,84	10.19	62.88	1.31	19.31
Maximum	48.49	9.96	13.57	28.59	160.1	2.77	220.2
Average	34.14	6.84	8.18	18.29	106.74	1.76	49.97
UCC	92.0	17.3	47.0	28.0	67.0	2.1	17.0
WHO permissible limit for agricultural soil.(2002)	100	50	50	100	300	25	85
Intervention value (DPR-EGASPIN, 2002)	360.00		720.00	10.00		625.00	210.00

3.2 Heavy Metal Contamination of the Agricultural Site Along Asa River Flood Plains

The pollution and contamination level of heavy metals in the sampled soil was determined using the contamination indices such as Degree of Contamination, Geo Accumulation Factor (I_geo), and Enrichment Factor, Pollution Load Index (PLI).

The geo-accumulation (I_geo) of heavy metals within the sampled area ranged from background, moderate to highly pollute. Cr, Co, Ni, and As are within the background concentration having geo-accumulation value of 1≤ i_geo<0 (-1.50 to-3.7,-1.38 to -2.52, -2.37 to -3.96 and -0.18 to -1.25) respectively. Zinc (Zn) accumulation within the studied area is fairly higher than background concentration with geo accumulation value -0.22 to 0.53(0≤i_geo<1) hence termed unpolluted but the concentration of lead (Pb) accumulation within the sampled location ranged from moderate to highly polluted with geo-accumulation range of -0.12 to3.11(3≤I_geo<4) (Figure 3, Table 7).

Table 7. Geo-accumulation Level of Soil Samples with Heavy Metals

Heavy metals	Range	Igeo	Pollution level	Description
Cr	-1.50 to -3.7	1≤Igeo<0	0	Background concentration
Co	-1.38 to -2.52	1≤Igeo<0	0	Background concentration
Ni	-2.37 to -3.96	1≤Igeo<0	0	Background concentration
Cu	-3.96to -3.96	1≤Igeo<0	0	Background concentration
Zn	-0.22to 0.53	0≤Igeo<1	1	unpolluted
As	-0.18 to -1.25	1≤Igeo<0	0	Background concentration
Pb	-0.12to 3.11	3≤Igeo<4	4	moderately to highly polluted

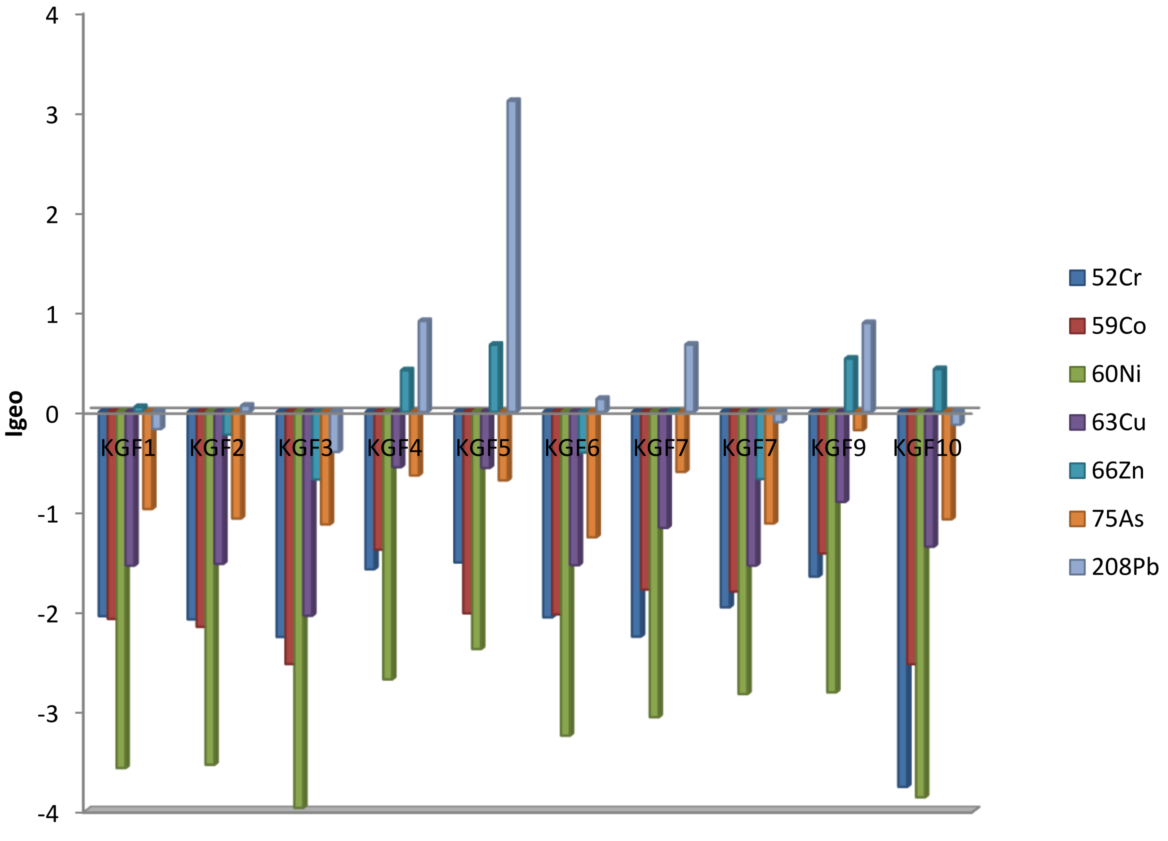

Figure 3. Geo- Accumulation of Heavy Metal within the Sampled Area

3.3. Heavy Metal Enrichment of the Sampled Area

The heavy metal enrichment in the agricultural site ranges from minimal to significant. Cr (1.1189), Co (1.2387), and Ni (0.6514) enrichment respectively indicate minimal enrichment. Cu, Zn and As showed minimal to moderate enrichment, while lead enrichment ranged from minimal to significant. The location with significant enrichment is found in location KGF5 (EF 29.2419) (Figure 4) which may result from several pollution sources within the site. These sources include the major roadway with heavy traffic, a nearby mechanic workshop, discharge of industrial and domestic waste from nearby industries and resident. These pollutants enter into the river used for irrigation in the area contributing the high enrichment level at this location (Table 9). The heavy metal enrichment within the sampled area showed an order of Pb>Zn>As>Cu>Co>Cr>Ni (Table 9)

Table 9. Mean Classification of Heavy Metals Enrichment in the Soil Samples

ELEMENT	EF (MIN)	EF (MAX)	DESCRIPTION
Cr	0.13253	1.189142	Minimal Enrichment
Co	0.310915	1.238702	Minimal Enrichment
Ni	0.123232	0.651416	Minimal Enrichment
Cu	0.70282	2.293151	Minimal to Moderate Enrichment
Zn	1.833712	5.392235	Minimal to Moderate Enrichment
As	0.850366	2.918226	Minimal to Moderate Enrichment
Pb	1.642313	29.24192	Minimal to Significant Enrichment

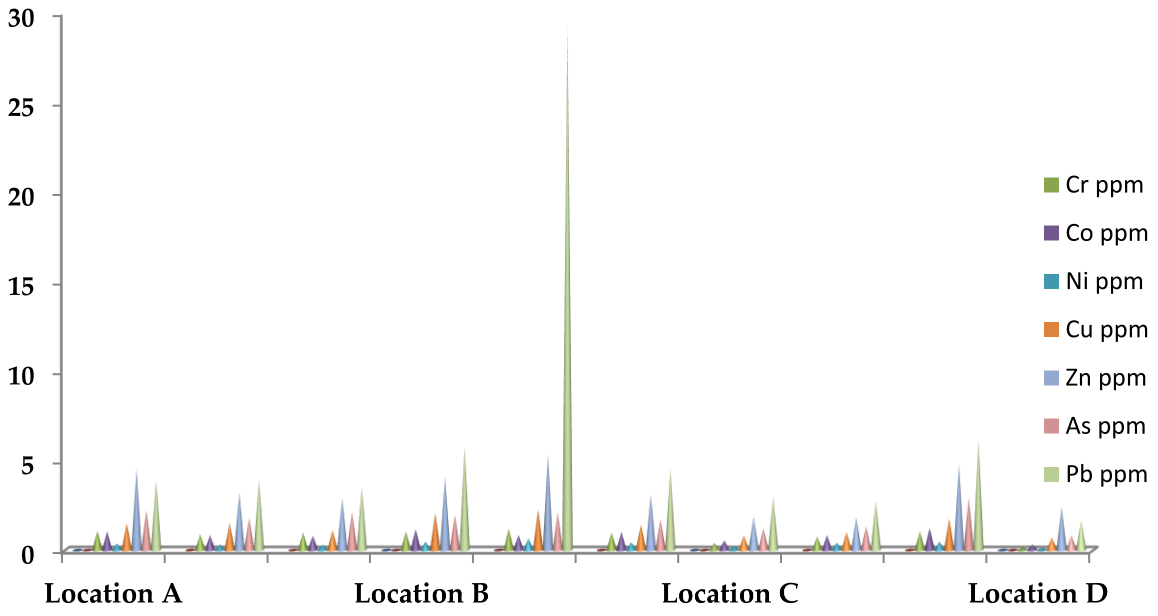

Figure 4. Heavy Metals Enrichment within the Sampled Locations

3.4 Degree of Contamination and Pollution Load Index

The degree of heavy metal contamination within the agricultural site investigated, ranged from low to a considerable degree. The soil samples from location KGF1,2,3,7,8 and 10 showed low degree of contamination, while location KGF4 and 9 have moderate heavy metal contamination (8.1186 and 8.2343) respectively. Soil sample in location KGF 5 possesses a considerable degree of contamination (18.4861) (Figure 4). With this level of heavy metal contamination and the calculated pollution load index, the location is termed polluted (1.0745) while the other locations are unpolluted (Table 10).

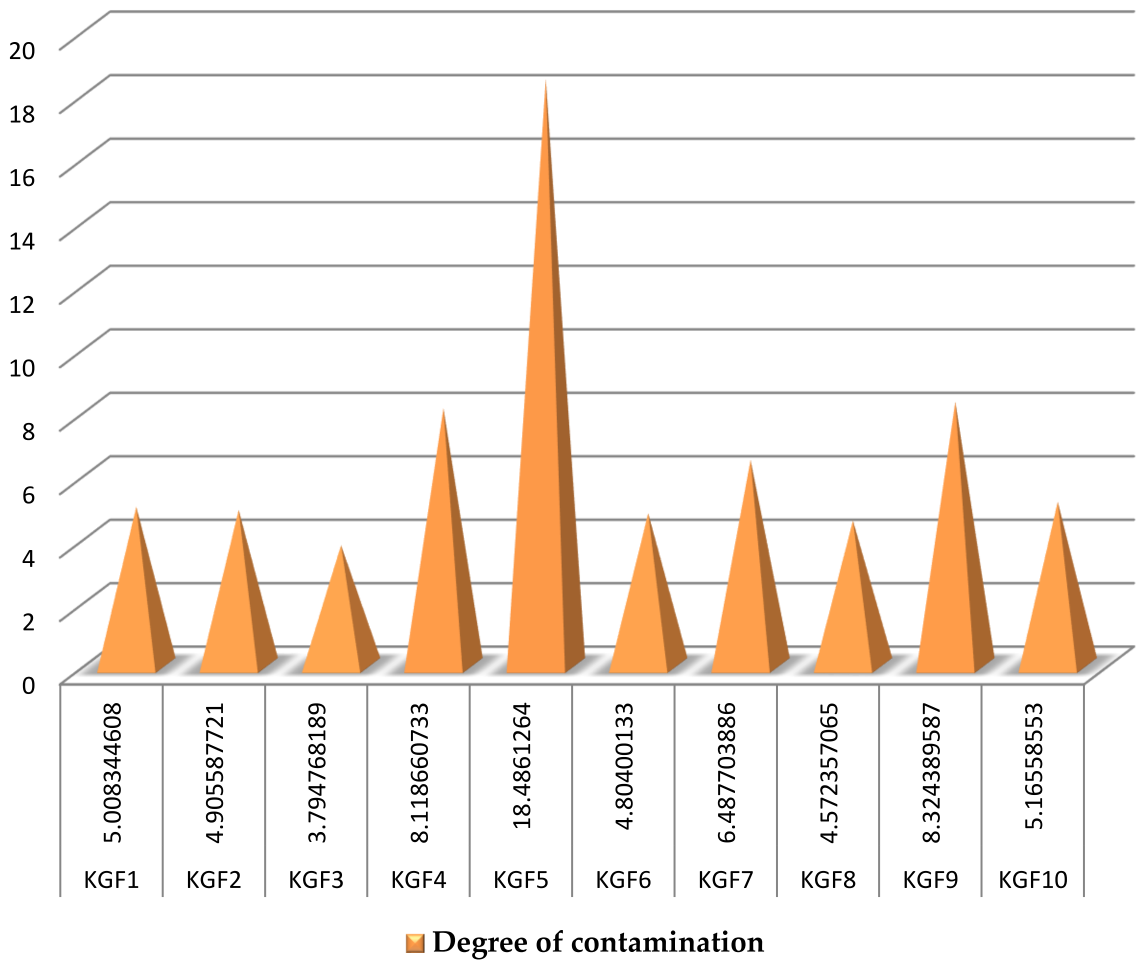

Figure 4. degree of heavy metal contamination within the sampled location

Table 10. Pollution Load Index Value for the Soil Samples in Different Locations

Location	Pollution Load Index	Description
KGF1	0.5395	No pollution
KGF2	0.5289	No pollution
KGF3	0.4141	No pollution
KGF4	0.8697	No pollution
KGF5	1.0745	Polluted
KGF6	0.5355	No pollution
KGF7	0.6675	No pollution
KGF8	0.5561	No pollution
KGF9	0.8663	No pollution
KGF10	0.4449	No pollution

3.3 Potential ecological risk assessment

Based on Hakanson potential ecological risk index, the estimated ecological risk assessment of the sampled site indicates a low to considerable risk with lead (Pb), and low ecological risk with Chromium, Copper, Zinc, Cobalt Nickel and Arsenic. The potential ecological risk assessment of lead in all the location varies; it ranges from low to considerable indicating variation of the location to pollution source (Table 11).

Table 11. Potential Ecological Risk Classification of Heavy Metals in soil samples

S/N	Heavy metals	Range	Potential ecological risk index	Status
1	Cr	0.22-1.05	$E_f^i < 20$	Low
2	Co	1.30-2.80	$E_f^i < 20$	Low
3	Ni	0.47-1.44	$E_f^i < 20$	Low
4	Cu	1.81-5.10	$E_f^i < 20$	Low
5	Zn	0.94-2.17	$E_f^i < 20$	Low
6	As	6.28-13.21	$E_f^i < 20$	Low
7	Pb	5.67-64.80	40-80	Low- Considerable

3.4 Relationship Between the Heavy Metals

The correlation matrix reveals the relationships between heavy metal concentrations in the soil samples. A correlation coefficient of 1 denotes a perfect positive correlation, while -1 indicates a perfect negative correlation, and 0 signifies no correlation. A moderate to very strong positive correlation exits between chromium and other heavy metals such as Cobalt, Nickel, Copper, Arsenic and Lead. This correlation indicates common source and interdependency of the heavy metals. The relationship between Cr and Zn is positively weak showed indicating a slight tendency for the increase in concentration of one of the metal to cause increase in the other and may share partly a common source. Cobalt has high relationship with arsenic and copper and nickel (0.748, 0.652 and 0.672) respectively. Nickel, copper, and zinc have positive high relationships with one another while the relationship between arsenic and lead is very weak (Table 12). Generally, strong positive correlations between most heavy metals in the sampled soil, is suggestive of a common source and co-accumulation in the soil [27, 15].

Table 12. Pearson Correlations Matrix Among the Heavy Metals in Soil Samples

Table 12. Pearson Correlations Matrix Among the Heavy Metals in Soil Samples

Variables	Cr	Co	Ni	Cu	Zn	As	Pb
Cr	1						
Co	.689	1					
Ni	.809	.672	1				
Cu	.650	.653	.842	1			
Zn	.304	.364	.533	.835	1		
As	.521	.748	.552	.660	.668	1	
Pb	.547	.074	.736	.691	.620	.297	1

4. Conclusion

The heavy metal assessment of the agricultural soil along the flood plain of Asa River indicates a low to moderate concentration of Cr, Co, Cu, Ni, Zn, As and low to considerable concentration with Pb. The application of various factors, including contamination factor, enrichment factor, pollution load index, index of geo accumulation and degree of contamination showed a low to moderate contamination and potential ecological risk index indicate a low to considerable ecological risk due to lead (Pb), and may be a threat to ecological and human health. The principal component analysis (PCA) analysis suggests that these heavy metals share anthropogenic or geogenic common source.

Farming activities should be done far away from road, industrial and domestic waste dumping in to river channels should be monitored for compliance to environmental management regulations.

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