

Distribution and Pollution Assessment of Selected Heavy Metals in Flood-Affected and Unflooded Soils of Jigawa State, Nigeria

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ABSTRACT

Soil samples from selected locations affected by flood within three selected local government areas (Auyo, Hadejia and Malam Madori) of Jigawa State, Nigeria were analysed for some trace metals (Cd, Cr, Cu, Ni, Pb and Zn) level. These parameters were compared with established international standard (WHO/FAO). Cu, Ni, Pb and Zn fall within the stipulated standards, while Cd exceeded the standard limit from all the sampling sites (both flooded and the control) and Cr exceeded the limits, except at TST and GSK. the trace metals (Cd, Cu, Ni, Pb and Zn) were having higher mean concentrations from the control samples than the flooded sampled stations ($4.73 \pm 0.05 \text{ mg/kg}$ and $5.13 \pm 0.03 \text{ mg/kg}$, $12.44 \pm 0.14 \text{ mg/kg}$ and $14.42 \pm 0.07 \text{ mg/kg}$, $29.92 \pm 0.25 \text{ mg/kg}$ and $30.55 \pm 0.16 \text{ mg/kg}$, $18.65 \pm 0.67 \text{ mg/kg}$ and $19.62 \pm 0.53 \text{ mg/kg}$ and $26.22 \pm 0.20 \text{ mg/kg}$ and $26.58 \pm 0.20 \text{ mg/kg}$) respectively while Chromium was observed to be higher in the flooded sampling sites $90.94 \pm 1.35 \text{ mg/kg}$ and $74.64 \pm 0.57 \text{ mg/kg}$. Pollution indices assessed showed that the samples were highly contaminated to extremely contaminated for both flooded and the unflooded sampling sites. The study revealed that not only the flood is a major possible pollution source in the surrounding environment. This underlines the need for appropriate government agencies of the state to initiate possible processes to recover all contamination sources and further reduce the pollution level in the surrounding environment.

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INTRODUCTION

Flood is an overflowing or irruption of a great body of water over land not usually submerged. Flooding was reported to be the most frequent environmental disaster consistently resulting in over 20,000 fatalities annually and negatively impacts about 70 million people worldwide (Umar and Gray, 2023).

Floods have presented a serious threat to people's lives and property all across the world. The pattern is the same throughout the world and in Nigeria. Flooding in many parts of Nigeria has displaced millions of people, wrecked businesses, contaminated water supplies, and raised the danger of disease (Etuonnovbe, 2011).

Etuonnovbe, (2011) reported that heavy rainfall is the primary natural source of natural floods, but dam collapses and disregard for indications from hydrologic systems, like in the Jigawa flood scenario, are man-made causes. Flooding is a crucial mechanism that contributes to the flow of sediment and metals attached to soil particles to the water sources and land, respectively, despite the fact that periodic floods bring with them sand, silt, and debris to enrich the surrounding area. Increased pollutant levels on the flood plains are also a result of contaminants remobilizing after floods (Inengite *et al.*, 2015). Trace metals pollution of the environment is a global problem due to the fact that most of these metals are hazardous to living organisms when allowable concentration thresholds are exceeded (Uwaechia *et al.*, 2018).

Depending on the contaminant, concentration, and exposure, there may be a variety of harmful health impacts when contaminated soil comes into contact with people and other animals through food, dust, or indirectly by seepage into

drinking water (Gordon, 2023). Few comparative studies have been carried out in this area, there by the need to carryout this study.

The specific objectives of this research work are to determine the mean concentrations of some trace metals (Cu, Cr, Cd, Ni, Pb and Zn) from the soils of flooded areas (Auyo, Hadejia and Malam Madori LGA's), to compare the levels of contamination/pollution of the trace metals in the flooded to control (unflooded) sample stations and with standards, to subject the findings to some pollution indices to better understand the contamination/pollution intensities of flooded and unflooded areas.

MATERIALS AND METHODS

Sampling and Sample Analysis

A descriptive study was conducted in the extensive floodplains wetlands in the dry lands of northern Nigeria of Auyo, Hadejia and Malam Madori Local Government Areas of Jigawa State around August and September 2022, the state saw a rise in the quantity and duration of rain. Due to the increasing rainfall, the state's River Hadejia, which is notorious for overflowing practically every rainy season and causing flooding, overflows, drowning people, ruining crops, flooding portable water supplies, and uprooting towns (Sofiullahi, 2022).

A total of 40 subsite soil samples were collected from the sampling points, which were composited to produce 8 composite samples (Figure 1) from the three selected Local Government Areas (Auyo, Hadejia and Malam Madori) of Jigawa State affected by the 2022 flood disaster.

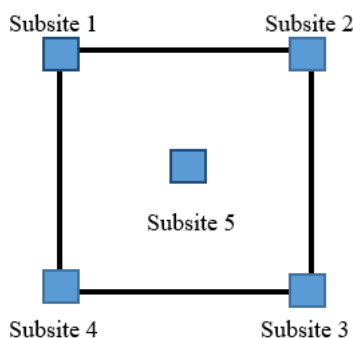


Figure 1: Composite Soil Sampling Scheme (GEMAS Field Manual, 2008)

Soil samples were collected with the aid of a stainless steel soil auger at a depth of 15cm. The soil samples were air dried for 14 days in the laboratory, pulverised using stainless steel mortar and pestle, sieved using 0.2mm mesh, digested and analysed for the concentrations of the trace metals in the samples (Orosun *et al.*, 2020). The trace metals determined from the soil samples were Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni) and Zinc (Zn) using Perkin Elmer PinAAcle 900H Atomic Absorption Spectrophotometer (AAS) at the Bayero University, Kano.

Trace Metals Analysis

For sample digestion, we utilized the EPA Method 3050B method. We transferred 1 g of the sample into a 250 mL flask, added 10 mL of 50% HNO₃, and heated it to 95°C below boiling point. After cooling the mixture, we refluxed it while repeatedly adding 65% HNO₃ until the generation of brown fumes stopped. We then evaporated the solution down to a final volume of 5 mL. After a cooling period, we slowly added 10 mL of 30% H₂O₂ to avoid splattering and refluxed the mixture at 95°C for 15 minutes with 10 mL of 37% HCl (Abdul *et al.*, 2026). Finally, we cooled the solution, passed it through a membrane filter, and brought it to a volume of 50 mL with deionized water in a measuring cylinder (Khattak *et al.* 2019). Trace metals (Cd, Cr, Cu, Pb, Ni and Zn) were determined using Perkin Elmer PinAAcle 900H Atomic Absorption Spectrophotometer (AAS) at the Bayero University, Kano.

Quality Control

Data accuracy was maintained through strict QA/QC protocols, including the use of procedural blanks, sample duplicates, and a soil certified reference material (SQC001-30 G, Sigma-Aldrich). Trace element recovery rates ranged from 92% to 105%. For method validation, limits of detection and quantification were established at 3 and 10 times the blank standard deviation. Only analytical-grade reagents were employed. Before use, all glassware was washed with 10% HNO₃, rinsed three times with deionized water, and dried in an oven. (Abdul *et al.*, 2026).

Pollution Indices Assessment

Six Pollution Indices were applied to the data obtained which comprised of Contamination Factor (C_f), Degree of Contamination (C_{deg}), Ecological Risk Factor (E_r), Potential Ecological Risk index (RI), Index of Geo-accumulation (Igeo)

and Pollution Load index (PLI) to evaluate the soil pollution status (Inengite *et al.*, 2015).

Contamination Factor

The contamination factor is described as the contamination by a given toxic substance as suggested by Hakanson, (1980) and applied by Inengite *et al.*, (2015), as stated in Eqn.1 below;

$$C_f = C_{\text{metal}}/C_{\text{background}} \quad (1)$$

Where C_{metal} is the mean concentration of the heavy metal “C” in at least 5 samples from a site and C_{background} is the pre-industrial reference level for the heavy metal. In this study, the background concentrations for the soil was used as the reference level with respect to the recent flood (Inengite *et al.*, 2015).

Degree of Contamination

The degree of contamination was originally defined as the sum of all contamination factors.

The equation below shows the calculation.

$$C_{\text{deg}} = \sum (C_{f1} + C_{f2} + C_{f3} + \dots + C_{fn}) \quad (2)$$

Where C_f is the single index of contamination factor and “n” is the count of the heavy metal species, (Inengite *et al.*, 2015)

Pollution Load Index (PLI)

The Pollution Load Index (PLI) is obtained as contamination factors (C_f), this C_f is the quotient obtained by dividing the mean concentration of each metal with its control value. The PLI of the place are calculated by obtaining the nth root from the n-C_{fs} that was obtained for all the metals Eqn.3, (Harikumar *et al.*, 2009). Generally pollution load index (PLI) ranges as developed by Tomlinson *et al.*, (1980), is as follows (Eqn.3).

$$PLI = \sqrt[n]{C_{f1} \times C_{f2} \times C_{f3} \times \dots \times C_{fn}} \quad (3)$$

Where,

C_f = contamination factor,

n = number of metals

Ecological Risk Factor

An ecological risk factor E_r is used to quantitatively express the potential ecological risk of a given contaminant. This as suggested by Hakanson, (1980) is given in Eqn4.

$$E_r = T_r C_f \quad (4)$$

Where T_r is the toxic-response factor (Table 1) and C_f is the contamination factor

for a given substance as reported by Zhang *et al.*, (2014).

Table 1: Toxic Response Factors for the given Heavy Metals

S/N	Metals (symbols)	Toxic Response Factor (Tr)
1	Cadmium (Cd)	30
2	Chromium (Cr)	2
3	Copper (Cu)	5
4	Nickel (Ni)	5
5	Lead (Pb)	5
6	Zinc (Zn)	1

Potential Ecological Risk Index (RI)

The potential Ecological Risk Index (RI) was described in the same manner as degree of contamination hence defined as the sum of the risk factors as shown in the equation5 below

$$RI = \sum Er^i \quad (5)$$

Where Er^i is the single index of ecological risk factor and “m” is the count of the heavy metal species. (Inengite et al., 2015)

Index of Geo-accumulation

In order to compare present concentrations with pre-industrial levels and estimate the amounts of metal pollution in sediments, Muller first created the index of geo-accumulation (I_{geo}) in 1969. Equation 6 is used to calculate it below:

$$I_{geo} = \log_2 [C_n / 1.5C_{background}] \quad (6)$$

Where C_n is the measured concentration of the examined metal “n” in the soil and $C_{background}$ is the geochemical

background concentration of the metal “n”. A factor of 1.5 was used to correct possible variations in background values for a given metal in the environment. The geo-accumulation index I_{geo} as defined by Muller, (1969) and applied by Buccolieri et al., (2006)

RESULTS AND DISCUSSION**Results**

The mean values of heavy metals from both flooded and unflooded (Control) locations within the three Local Government areas. Hadejia LGA (Aguyaka-AGU, Cikin-Gari-CKG, Tsohuwar Tasha-TST and Khandahar-KND), Malam-Madori LGA (Azamu-AZA and Gandun-Sarki-GSK) and Auyo LGA (Ganuwar-Kuka-GKK and Unguwar-Magayaki-UNM) of Jigawa State were presented in Table 2 and pollution indices were presented in Table 3 to 5.

Table 2: Heavy Metals mean Concentration of Soil Samples from the Sampling Sites

Locations	Heavy metal concentration (mg/kg)					
	Cd	Cr	Cu	Ni	Pb	Zn
FLOODED SOIL SAMPLING LOCATIONS						
(GKK)	5.23±0.06	113.30±2.30	14.18±0.30	34.83±0.60	22.33±0.92	29.93±0.29
(AZA)	5.38±0.03	75.32±0.53	12.13±0.08	31.33±0.12	18.85±1.03	23.05±0.05
(AGU)	4.03±0.06	94.12±0.42	12.37±0.10	26.35±0.05	18.68±0.50	31.98±0.15
(KND)	4.28±0.03	81.00±2.16	11.07±0.08	27.17±0.25	14.73±0.24	19.90±0.31
CONTROL (UNFLOODED) SOIL SAMPLING LOCATIONS						
(UNM)	5.23±0.03	89.03±1.16	13.83±0.06	32.05±0.13	21.48±0.29	38.08±0.16
(GSK)	5.13±0.03	64.52±0.18	11.27±0.03	30.07±0.12	16.27±0.50	14.85±0.13
(TST)	4.83±0.03	68.32±0.74	15.60±0.10	28.92±0.35	18.62±0.50	16.72±0.23
(CKG)	5.33±0.03	76.68±0.18	16.97±0.10	31.15±0.05	22.12±0.83	36.67±0.13
WHO/FAO (2011)	3.00	75.00	300.00	50.00	50.00	1000.00
(Tsigereda et al, 2024)						

Values are expressed as mean ± standard deviation of triplicate determination

Table 3: Contamination Factor (C_f), Degree of Contamination (C_{deg}) and Pollution Load Index (PLI) for Heavy Metals based on Background Reference Elements from the Soil Sampling Sites

PARAMETERS/ LOCATIONS	(C_f)						(C_{deg})	(PLI)
SAMPLES	Cd	Cr	Cu	Ni	Pb	Zn		
AGU (Flooded)	13.43	18.82	2.74	13.18	9.34	31.98	89.49	11.67
CKG (Control)	17.78	15.34	3.39	15.58	11.06	36.67	99.82	13.28
KND (Flooded)	14.27	16.20	2.21	13.59	7.37	19.90	73.54	9.94
TST (Control)	16.10	13.66	3.12	14.46	9.31	16.72	73.37	10.65
GKK (Flooded)	17.43	22.66	2.84	17.42	11.17	29.93	101.45	13.53
UNM (Control)	17.43	17.81	2.77	16.03	10.74	38.08	102.86	12.60
AZA (Flooded)	17.93	15.04	2.43	15.67	9.43	23.05	83.55	6.99
GSK (Control)	17.10	12.90	2.25	15.04	8.14	14.85	70.28	6.19
Tr (toxic-risk factor)	30	2	5	5	5	1		
Background								
(Waziri et al., 2013)	0.3	5	5	2	2	1		

Table 4: Ecological Risk Factor (E_r) and Potential Ecological Risk Index (RI) of the Heavy Metals from the Sampling Sites

(E_r)							(RI)
Locations/ Heavy Metals	Cd	Cr	Cu	Ni	Pb	Zn	
AGU (Flooded)	409.90	37.64	13.70	65.90	46.70	31.98	605.82
CKG (Control)	533.40	30.68	16.90	77.90	55.30	36.67	750.85
KND (Flooded)	428.10	32.4	11.05	67.95	36.85	19.90	596.25
TST (Control)	438.00	27.32	15.60	72.30	46.55	16.72	616.49
GKK (Flooded)	522.90	45.32	14.20	87.10	55.85	29.93	755.30
UNM (Control)	522.90	35.62	13.85	80.15	53.70	38.08	744.30
AZA (Flooded)	537.90	30.08	12.15	78.35	9.43	23.05	690.96
GSK (Control)	513.00	25.80	11.25	75.20	40.70	14.85	680.80
Tr (Toxic-risk factor)	30	2	5	5	5	1	
Background (Waziri <i>et al.</i> , 2013)	0.3	5	5	2	2	1	

Table 5: Geo-Accumulation Index (I_{geo}) for the Heavy Metals from the Sampling Sites

GEO-ACCUMULATION INDEX (I_{geo})						
Sampling Stations	Cd	Cr	Cu	Ni	Pb	Zn
AGU (Flooded)	2.70	3.78	0.50	2.64	1.87	6.42
CKG (Control)	3.56	3.08	0.68	3.13	2.22	7.36
KND (Flooded)	2.86	3.25	0.44	2.73	1.48	3.99
TST (Control)	3.23	2.74	0.63	2.90	1.87	3.36
GKK (Flooded)	3.50	4.55	0.57	3.49	2.24	6.01
UNM (Control)	3.50	3.57	0.55	3.22	2.16	7.64
AZA (Flooded)	3.60	3.02	0.49	3.14	1.89	4.63
GSK (Control)	3.43	2.60	0.45	3.02	1.63	2.98

Discussion

The mean values of triplicate readings of the trace metals concentration of the flood affected areas with their control from Hadejia, Malam Madori and Auyo Local Government Areas of Jigawa State were shown in Table 2 and Table 3 to 5 shows results of pollution indices and discussed below:

Cadmium (Cd)

The highest mean value of cadmium recorded in soil samples of flooded area was found to be $5.38 \pm 0.03 \text{ mg/kg}$ at AZA and $4.03 \pm 0.06 \text{ mg/kg}$ was the least recorded at AGU sampling site which are both flooded areas (Table. 2). All the experimental values obtained exceeded the standard value of 0.8 mg/kg for WHO/FAO (2011) maximum limits of Cadmium in the soil. Possible sources includes application of phosphate fertilizers, the disposal of batteries, mining and metallurgy, electronics, PVC goods, and industrial incinerator dust and fumes contributing to the elevated level of Cd as reported by Andrzej, (2011), and Odukoya, *et al.*, (2001), it is possible that Cd might have found their way into the surrounding soils from their various sources as a result of the flood event.

Chromium (Cr)

The highest mean value of Chromium recorded in the soil of flooded area were mostly found to be above the standard limits except at GSK and TST sampling stations. The highest concentration recorded was found to be $113.30 \pm 2.30 \text{ mg/kg}$ at GKK and $64.52 \pm 0.18 \text{ mg/kg}$ was the least recorded at GSK sampling site. The result obtained is similar to that reported by Anake *et al.*, (2009). The experimental values obtained at GSK and TST were within the standard value of 75 mg/kg (WHO/FAO, 2011) maximum permissible limits, while the other sampling stations exceeded the limits stipulated by

WHO/FAO (2011). Natural phenomena and human activities including mining, smelting, and other industrial operations, pesticides, car exhaust, metal processing, and widespread fertilizer use, particularly organic animal and poultry manure are all possible sources for higher Cr concentration in the environment (Shu'an, *et al.*, 2023).

Though chromium pollution is not of global concern but excessive concentrations in the soil, water, or the atmosphere may be of concern (Yang *et al.*, 2022). Possible sources of chromium include leather tanning Cr plating, pigment production, wood preservation, and chromium application as a corrosion inhibitor in cooling towers, leaching of chromium during weathering ultramafic rocks (Shanker *et al.*, 2005, Ao *et al.*, 2022). Anthropogenic activities such as phosphate fertilizers, battery disposal, mining, metallurgy, electronics, PVC goods, industrial incineration, dust, and fumes could be possible sources for the greater amount of the Cr that was discovered (Andrzej, 2011).

Copper (Cu)

Highest level of Copper concentration recorded were $16.97 \pm 0.10 \text{ mg/kg}$ at CKG sampling site and $11.07 \pm 0.08 \text{ mg/kg}$ was recorded as the least from KND sampling site which contradict the findings of Inengite *et al.*, (2015) which showed the opposite which might be due to the high mobility of Cu, it is possible that it has been leached beyond the soil depth (15cm) of this study. The levels of copper in all the sampling sites were observed to be within the WHO/FAO (2011) permissible limit of 300.00 mg/kg for copper in the soil. The increased concentration of copper found in the soil samples may be the result of human activities such as the disposal of electrical and electronic waste, pesticides, paint

and pigment, mining and metallurgy, plating, and waste from the textile industry.

Nickel (Ni)

Nickel concentration from all the samples falls within the maximum permissible limits (50 mg/kg) of Nickel in the soil (WHO/FAO, 2011). The highest Nickel concentration was observed from GKK (34.84±0.60 mg/kg) sampling station, and AGU (26.35±0.05 mg/kg) gave the lowest concentration of Nickel in the soil. Overall lower mean concentration of Nickel (29.92±0.26 mg/kg) was observed from flooded soil while a higher mean concentration of Nickel (30.55±0.65 mg/kg) was observed from unflooded soils which is above the concentration reported by Uwaechia *et al.*, (2018) and lower than the concentrations observed by Jose *et al.*, (2018). Even though the solubility of the Nickel compounds and the exposure mode determine the toxicity of Nickel, (Reaves and Baker, 2000).

Lead (Pb)

From Table 2, the results of the study showed GKK (22.33±0.92) recording the highest concentration and KND is having the lowest value of 14.73±0.24 mg/kg. All the Lead levels observed in this study areas were below the stipulated maximum permissible levels by WHO/FAO (2011) of 50 mg/kg. Lead is utilized in a variety of items, including shot, rolled, and extruded products, alloys, paint pigments, and cables sheathing. (Anake *et al.*, 2009). These are all potential sources of lead that could wash into nearby soils from dumps with higher concentrations. Anthropogenic factors such as mine waste, the dumping of heavy metal waste, agricultural practices, and emissions from the fast growing industrial districts may be to blame for the presence of lead in soil, (Truit, *et al.*, 1999).

Zinc (Zn)

From Table 2, Zinc had its highest value of 38.08±0.16 mg/kg at UNM sampling site and its least value 14.85±0.13 mg/kg at GSK sampling site. The level of Zinc in this study does not exceed the 1000 mg/kg set by WHO/FAO, (2011). AZA and AGU flooded sampling sites were having higher Zinc concentrations in the soil while higher concentrations of Zinc were observed at CKG and UNM unflooded sampling sites (Table 2). High levels of zinc in soils may result from human activities such as fertilizer use, the dumping of industrial waste, the plating of iron and steel, electroplating, and galvanization. (Jose *et al.*, 2019).

Assessment of Pollution Indices

Contamination Factor (C_f), Degree of Contamination (C_{deg}) and Pollution Load Index (PLI)

From Table 3, the results obtained for contamination factor, degree of contamination and pollution load index for the trace metals analysed were presented. The trace metals (Cd, Cr, Ni, Pb and Zn) were found to be having a very high contamination factor (C_f>6), while Cu, is having a moderate contamination factor (1 ≤ C_f < 3) from most of the sampling sites except at CKG and TST were a considerate contamination (3 ≤ C_f < 6) was observed. However, the metals presented a very high degree of contamination (C_{deg}>28) all throughout the sampling stations. which similar pattern was also reported by Inengite *et al.*, (2015). To effectively know the measure of degree of overall contamination, Pollution Load Index was determined, values obtained were all observed to be >1 which is classified as having an increasing pollution level as depicted from the PLI ranges. Similar pattern were also obtained by Inengite *et al.*, (2015) for contamination factor

and Degree of contamination, while similar pattern of pollution load index was reported by Bashir *et al.*, (2014).

Ecological Risk Factor (Er) and Potential Ecological Risk Index (RI)

From Table 4, the Ecological Risk Factors were calculated for the trace metals (Cd, Cr, Cu, Ni, Pb, and Zn) that their toxic-response factors were available in Table 3.4, Analysis of the ecological risk factor as stated in Table 4, classified Cu, Cr, and Zn samples together with Pb at KND and AZA as having low potential ecological risk (Er<40) as also reported by Inengite *et al.*, (2015), except Cr at GKK (45.32) which is classified as having a moderate potential ecological risk (40 ≤ Er < 80). Ni and Pb recorded a moderate potential ecological risk (40 ≤ Er < 80) except at GKK and UNM for Ni, AZA and KND for Pb, where a considerate potential ecological risk (80 ≤ Er < 160) was observed. While Cd were having a very high potential ecological risk from all the sampled sites. However, Potential Ecological Risk Index is classified as having a very high ecological risk (RI > 600) from almost all the sampling sites except for KND sampling site recording a considerate ecological risk (300 ≤ RI < 600), which is contrary to the findings of Inengite *et al.*, (2015) where they obtained a low ecological risk index, as shown in the Potential Ecological Risk Index ranges.

Geo-accumulation Index (I_{geo})

From Table 5, Cu with a figure of less than one all throughout were found to be in the unpolluted to moderately polluted range and Pb is recorded to be in the moderately polluted except at CKG, GKK and UNM where Pb was reported to be moderately to strongly polluted range. Cd were strongly polluted except at AGU and KND where they are moderately to strongly polluted. Cr was strongly to extremely polluted at GKK, moderately to strongly polluted at TST and GSK, while strongly polluted from the remaining sampling sites. However Ni were recorded to be moderately to strongly polluted at AGU, KND and TST, while strongly polluted from the remaining sampling sites. Zn were moderately to strongly polluted at GSK, strongly polluted at KND and TST, while extremely polluted at AGU, CKG, GKK and UNM. It is possible that the high values found in the soil samples were due to bioaccumulation over time brought on by anthropogenic and agricultural activity, while the dilution factor brought on by the flood event may have resulted in the lower values found in these sampling sites. (Uwaechia *et al.*, 2018).

CONCLUSION

The study provides information about the distribution of some trace metals in the soil of flood affected areas of Hadejia, Malam Madori and Auyo Local Government areas, of Jigawa State, Nigeria. The extensive agricultural activity and the frequent indiscriminate disposal of trash, anthropogenic practices and natural activities are some of the possible sources of the trace metals in the environment and excessive levels of the trace metals are harmful to the ecosystem. The study found that because these metals have the capacity to bio-accumulate, it would be dangerous to the high population density due to the frequent floods in the locality. Due to the soils inherent ability to purify water, underground water which was generally considered to be the cleanest type available might be greatly endangered. Most of the trace metal values were higher in the unflooded (control) sampling locations, which may be related to the build-up of these toxicants from industrial area emissions, the disposal of high metal wastes, animal manure, sewage sludge, coal

combustion, and the spillage of petrochemicals and pesticides in the soils. It was recommended that regular conducting of quality risk assessment is essential to identify and raise awareness of the potential hazard and other sources of pollutants affecting the study areas and determine effective programs to prevent and minimize health risks, the influence of other metals needs to be studied to ensure the safety of the study area, Limitation of the soil depth in this study did not reveal the possible leaching of the metals beyond 15cm depth and the potential risk of groundwater contamination, the finding of this study suggests that measures should be put in place by concerned agencies like NEMA to help reduce the probability of such heavy floods in future.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

COMPLIANCE WITH ETHICAL STANDARDS

This article does not contain any studies involving Human or animal subjects.

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