



Chemical Speciation and Distributon of Heavy Metals in Alluvial Soils of Ondo State

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Authors' contributions

This work was carried out in collaboration between all authors. Author FPO designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author AFA managed the analyses of the study. Author AOA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Floodplains are very important for agriculture, since it allows planting of arable crops throughout the year. In order to asses pollution levels of the floodplains due to contamination from flooding, soil samples were collected from six locations across each of the floodplain of Owena river, Ogbese river and Ala river in Ondo State. The study investigated the chemical speciation of Cd, Cu, Ni and Zn in the alluvial soil matrix due to deposition of metals as result of inundation of the floodplains. The heavy metals were quantified using Atomic Absorbtion Spectrophotometer. The concentration of heavy metals in exchangeable fraction are in the order of Ni (BDL-0.26 mg/kg) < Cd (BDL - 0.41 mg/kg) < Cu (0.08-1.33 mg/kg) < Zn (0.27-7.08 mg/kg), in carbonate fraction: Ni (BDL-0.53 mg/kg) < Cd (BDL - 1.83 mg/kg) < Cu (0.13-3.02 mg/kg) < Zn (0.64-11.88 mg/kg), in Fe-Mn Oxide fraction: Cd (BDL-0.21 mg/kg) < Ni (BDL-0.53 mg/kg) < Cu (0.68-3.03 mg/kg) < Zn (3.05-17.32 mg/kg), In organic fraction: Cd (BDL-0.15 mg/kg) < Cu (0.51-6.00 mg/kg) < Ni (0.73-7.84mg/kg) < Zn (1.80-21.82 mg/kg), In residual fraction: Cd (0.20-1.28 mg/kg) < Cu (1.18-6.19 mg/kg) < Zn

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(2.77-13.97 mg/kg) < Ni (1.54-13.59 mg/kg). Cd and Ni were most abundant in residual fraction, Cu was found to be predominantly associated with organic and residual fractions while, Zn was predominantly bound to oxidizable and organic fractions. The mean concentration of the heavy metals in the floodplains soil were of the order of Zn > Cu > Ni > Cd. The speciation study further revealed both geogenic and anthropogenic sources contributed to the total metal load of the floodplain soils.

Keywords: Speciation; floodplains; heavy metals.

1. INTRODUCTION

The term floodplain can be defined as an area of land adjacent to a stream or river that stretches from the bank of its channel to the base of the enclosing valleys walls and experiences flooding during periods of high discharge of rainfall. By nature, floodplains are low flat by their nature, periodically flooded lands adjacent to rivers, lakes and oceans and subject to geomorphic (land shaping) and hydrological (water flow) processes [1].

Floodplains are important for both society and nature. For centuries, people have used floodplain areas to build their settlements in the vicinity of the river, which provides freshwater for irrigation and domestic use, and serves as a shipping route. The fertile floodplain soils are widely used for agriculture. Fadama lands (floodplains) support planting of arable crops throughout the year. Afolabi [2], reported that Fadama farming in the Southern part of the country is prevalent along river banks and other wetland areas and the crops mainly grown are vegetables, rice and sugarcane. Floodplains are also vital ecotones [1,3,4,5], which link natural areas along the river with other natural areas in its hinterland. However, many rivers have become contaminated, which may affect the many functions of the rivers and their floodplains.

Overbank deposition may therefore not only fertilize floodplain soils [6], but may also cause contamination with substances such as nutrients [7], organic micro pollutants [8], or heavy metals [9]. Over periods of years of centuries, most floodplains act as sinks for sediment [10,11]. Especially storage of heavy metals represents a problem, since they are persistent i.e. they are not degraded in nature and accumulate in organic tissue. For instance, floodplain vegetation and soil-dwelling organisms [12,13] tend to accumulate these potentially toxic heavy metals. Via the food chain, the heavy metals subsequently reach plant feeders [14] and predators [15]. This may threaten the viability of

vulnerable species in the floodplain ecosystem. Because of their adverse physiological effects, heavy metals also lead to losses in agricultural production [16]. Heavy metals may also reach groundwater after dissolution [17], where they can be transported to a wider area. Thus, deposition of sediments and associated heavy metals merits study, particularly in such important parts of landscape and society as river floodplains.

Anil [18] as well as Ure [19] defined the term speciation as the process of identification and quantification of the different forms or phases (inorganic, organometallic or organic species) of an element/chemical in the environment. Chemical speciation is an important aspect of environmental analysis. The biological activity, e.g. toxicity, of an element may vary widely on the species. Thus, Hg^0 is not very toxic but $(CH_3)_2Hg$ is highly toxic, likewise if total As concentration in palatable seafood dish may be 10mg/l or more, but fortunately for the seafood consumers As in marine organisms is tied up largely as arsenobetaine, $CH_3)_3 AS^+CH_3COO^-$ which is not toxic but if the As was present in inorganic form as arsenite, AsO_2^- it would have toxic effects. Thus accurate determination of the total concentration of an element in a sample is not enough: the concentration of all the species of the element must be known in order to assess its impact on the organism/environment [18]. Heavy metals generally exist in two phases in river waters, i.e. in the dissolved phase in the water column and in the particulate phase adsorbed on the sediments. The behaviour of heavy metals in the aquatic environment is strongly influenced by adsorption on organic and inorganic particles. The dissolved fraction of heavy metals may be transported via the process of advection-dispersion [20]. Total metal content is a measure in assessing risk of a contaminated site, total metal content does not provide predictive insights on the bioavailability, mobility, and fate of metal contaminant [21,22] while chemical speciation provide insights on bio-availability, bioactivity, biogeological

distribution/ transportation, uptake, transport in the organism, toxicity and thus, the fate impact of the toxic elements will be dictated by the particular species or forms in which they are present in the sample [21]. Therefore, Speciation information to complement total toxic element determinations is increasingly demanded for in environmental analysis. Hence, the focus of this research was to determine the speciation of some heavy metals contaminants present in alluvial soils of Owena, Ogbese and Ala floodplains respectively.

2. MATERIALS AND METHODS

2.1 Description of Study Areas

2.1.1 Owena River

Owena river is a major source of domestic water supply to the people of Akure and neighbouring towns. Owena river is under the control of Benin-Owena River Basin Development Authority. It flows within an area bounded by Longitude 5° 01'E and Latitude 7° 17' N and Longitude 5° 45' E and Latitude 8° 15' N. The drainage area of Owena River is 790 sq kilometres [23]. The average annual rainfall and temperature of the area are 100±40cm and 28±3°C respectively [24]. The river has her source in the hills in the Northwest of the catchment area around Efon Alaye in Ekiti State and flows directly Southwards to be joined by the Ofosu and Aden Rivers north of the Siluko village in Ondo State and then as the Siluko River, flows into the estuarine creek area [23]. Cultivation of crops like rice, potatoes, plantains e.t.c., and artisanal fisheries activities are practised in this area.

2.1.2 Ogbese River

The river Ogbese is a major tributary of river Osse, it is located in the Northern district of Ondo State. It flows for approximately 22km from its source (through the derived savanna zone) to meet the river Osse which discharges into the Atlantic Ocean through an intricate series of creeks and lagoons [25]. The Ogbese community has undergone great economic development in recent years. In fact, it is notably one of the fastest growing, economically important communities in Ondo State and handles a considerable number of micro-industries. The very popular market (Ogbese market) and the timber business coupled with unequalled agricultural practices have drawn people from several cultural backgrounds to the community to

make the settlement inter-tribal. The river is located on latitude 7° 16' N and longitude 5° 23' E at Ogbese village (near Akure) South western Nigeria (Fig. 1). The River lies entirely within the community of Ogbese. It has an annual rainfall of about 160cm to 210cm, which covers the month of April to October and drainage area of 2039km². The mean daily maximum temperatures range from 30°C to 35°C, while the mean daily minimum temperatures range from 21°C to 26°C [26]. Cultivation of crops like rice, sugarcane, potatoes, plantains e.t.c. and fishing are practised in this area.

2.1.3 Ala River

Ala river is a major river that transverses through the entire length of Akure metropolis, in Ondo State, Nigeria (Fig. 1). Ala river has a length of about 57 km, it has a length of about 14.81km within Akure township. It took its source from north-western part of Akure town and flows towards south-eastern part of the town. Akure township dominated the upstream of Ala river while rural towns such as Ilado, Ehinala, Ajegunle, Owode Aiyetoro and Araromi are located in downstream. By virtue of its location, it has become a major sink to municipal run off and cocktail of domestic and municipal wastes that are indiscriminately disposed at its banks. The study area experiences a frequent rainfall between April and July with a short break in August and continues between September and November, with the heaviest rainfall in July. The average daily temperatures ranges from 22°C during harmattan to 32°C in March which is the peak temperature [27]. Cultivation of crops and fishing activities take place at different locations along the floodplains soil and water from the river in some areas is used for irrigation and supply to earthen fish pond operation.

2.2 Sampling and Sample Pre-treatment

Soil samples were collected from six locations along the floodplains each of Owena river, Ogbese river and Ala river with the aid of soil auger to a depth 0-20 cm. The locations were geo-referenced with Geographical Position System (GPS) Germin 12 model for ease of reference. Collected samples were kept in cleaned and well-labeled polythene bags and transferred to the laboratory. In the laboratory, samples were air-dried for two weeks. They were then ground into fine particles in a mortar, sieved through a 2 mm mesh and about 200 g of the sieved samples were sub-sampled by quartering for analysis.

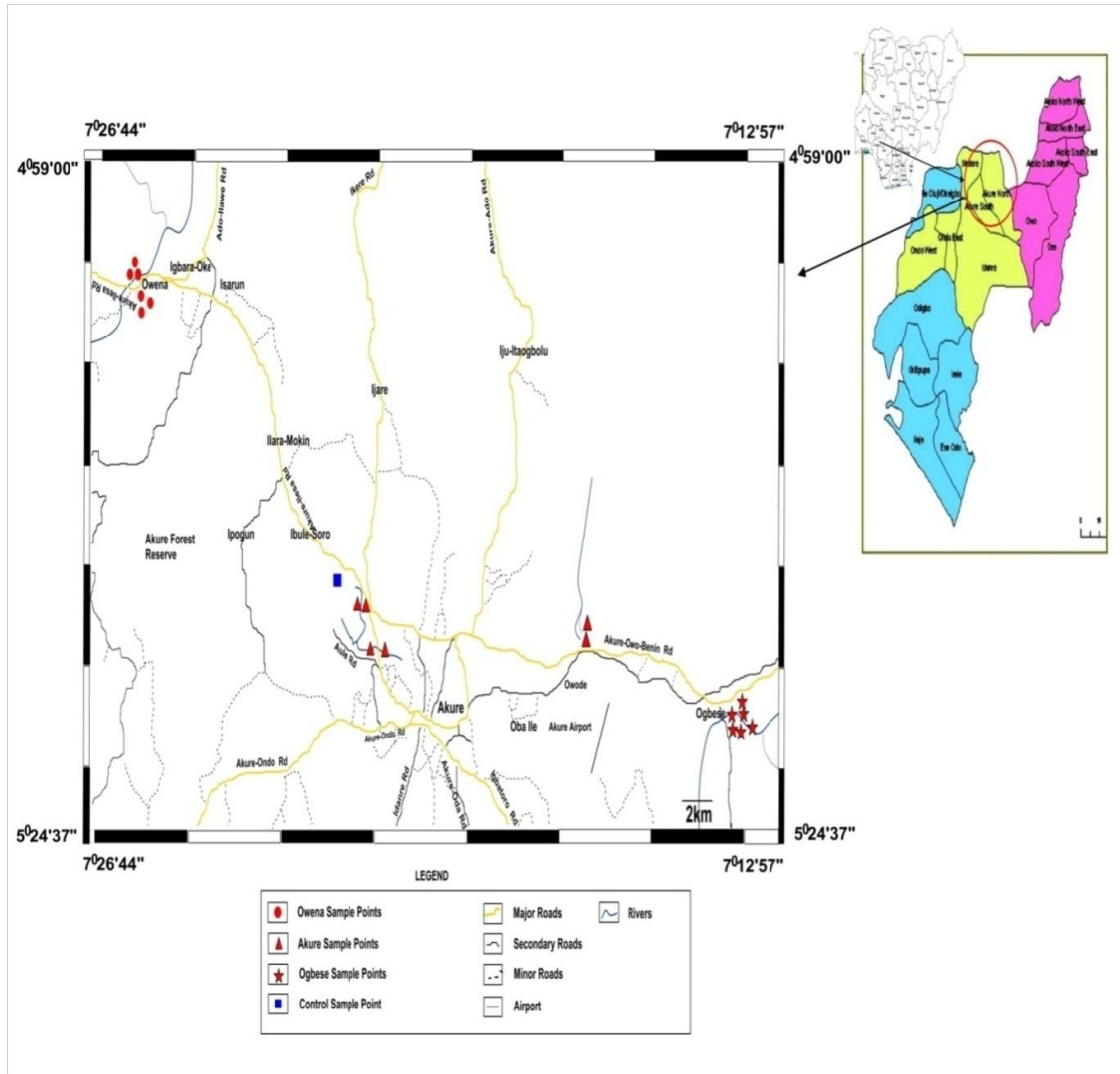


Fig. 1. Map of study area

2.3 Sequential Extraction

Trace metals in the soil from the different soil samples were sequentially extracted into different chemical forms (fractions). Each sample was treated in triplicate. Air-dried sample 1 g was weighed into platinum crucible.

The sequential extraction described by Tessier et al. [28] and Aiyesanmi et al. [22] was used for the chemical fractionation of metals in the soil.

Fraction I – Exchangeable fraction: The soil sample was extracted with 8 cm³ of 1M MgCl₂ (pH 7.0) for 1h at room temperature. Soil and

extraction solution were thoroughly agitated throughout the extraction using a centrifuge at 6,000 rpm. The supernatant were decanted into acid washed polyethylene bottles and refrigerated at 4°C prior to analysis.

Fraction II – Bound to carbonates: The residue from exchangeable fraction was leached at room temperature with 8 cm³ of 1 M sodium acetate solution (adjusted to pH 5.0 with acetic acid) for 5 hours at room temperature with continuous agitation using a centrifuge at 6,000 rpm. The extract were decanted from the residue into acid washed polyethylene bottles and refrigerated at 4°C prior to analysis.

Fraction III – Bound to iron and manganese oxides:

The residue from carbonate fraction was extracted with 20 cm³ of 0.04M hydroxylamine hydrochloride in 25% (v/v) acetic acid at 96°C with occasional agitation for 6 h. The metals extract were decanted from the residue into acid washed polyethylene bottles and refrigerated at 4°C prior to analysis.

Fraction IV – Bound to organic matter and sulphide:

The residue from Fe-Mn oxide fraction was leached with 3 cm³ of 0.02M HNO₃ and 5 cm³ of 30% (v/v) hydrogen peroxide (adjusted to pH 2 with HNO₃). The mixture was heated to 85°C for 2 h, with occasional agitation and allowed to cool down. Another 3 cm³ of 30% hydrogen peroxide, adjusted to pH 2 with HNO₃, was then added. The mixture was heated again at 85°C for 3 h, with occasional agitation and allowed to cool down. Then 5 cm³ of 3.2M ammonium acetate in 20% (v/v) HNO₃ was added and samples diluted to 20 cm³ with de-ionized water and agitated continuously for 30 minutes. The metals extract were decanted from the residue into acid washed polyethylene bottles and refrigerated at 4°C prior to analysis.

Fraction V – Residual or inert fraction:

Residue from organic fraction was digested with a mixture of 5 cm³ Concentrated nitric acid, 10 cm³ of hydrofluoric acid and 10 cm³ of perchloric acid in Platinum Crucible. The digestate was decanted into acid washed polyethylene bottles and refrigerated at 4°C prior to analysis.

The digested soil samples from fraction 1 to fraction 5 were analysed for Cd, Cu, Zn and Ni using Atomic Absorption Spectrophotometer of Perkin Elmer, A. Analyst 400 model. All extractions were conducted in triplicate.

2.4 Data Analysis

Samples were prepared in triplicate to provide data for statistical analysis. The statistical calculations reported included: mean, standard deviation and analysis of variance (ANOVA). Data generated on heavy metal concentrations of each metal were analysed for spatial variation using one way analysis of variance (ANOVA) with SSPS version 20 package. One level of significance was considered in the results interpretation. Bar charts were also used in comparing the data.

3. RESULTS AND DISCUSSION

3.1 Heavy Metal Distribution in Floodplain Soil Matrix

The mean concentrations of the analysed heavy metals (Cd, Cu, Ni and Zn) in the various fractions are presented in Tables 1-3.

3.2 Owena Floodplain Soil

The distribution of Cd had highest concentration in residual fraction, followed by oxide fraction and least concentration at the Organic fraction. Ramirez et al. [29] reported that cadmium ions are mostly associated with the residual phase and metals present in the residual fraction constitute low degree of pollution. The concentration of Cd is least at exchangeable fraction with oxide fraction having highest distribution among the non-residual fractions thus, suggesting low possibility of Cd being leached into the soil, since the exchangeable fraction is the most mobile fraction. It has been reported that Cd does not appear to form stable organic complexes [30], hence lowest distribution was observed in the organic fraction. These results could be explained by the low solubility of cadmium carbonate and low adsorption constant of the complex formed with the Organic matter [30,31] related the residual fraction and the non-residual fractions of heavy metals in soil to natural and anthropogenic sources respectively, which suggests significant anthropogenic sources to the Cd level measured in Owena floodplain soils. This may be from contribution due to activities around the area such as auto-mechanic workshops, car wash centre and panel beating that make use of metal scraps, engine oil, diesel oil, detergents, paints/pigment and leachate from heaps of solid wastes are discharged indiscriminately into the river. The distribution of Cd among the fractions follow the order of Residual (45%) > Oxide (29%) > Carbonate (15%) > Exchangeable (9%) > Organic (2%). As presented in Fig. 2, the residual fraction had the highest amount of Cd (45%) followed by oxide (29%) and carbonate fraction. Concentration of cadmium associated with the mobile fraction (exchangeable, carbonate, reducible and oxidizable) constitute more than 50% of the total and represent the bioavailability of Cd.

The concentration of Cu had high distribution between organic fraction and residual fraction with organic fraction having the highest, hence

large distribution was observed at non-residual fraction. Copper can easily complex with organic matters because of the high formation of organic–copper compounds [32], thus, resulting to high distribution of Cu in organic fraction. Heavy metals bound to organic matter and sulphides are more available than the heavy metals in the residual fraction. The distribution of Cu had the least concentration in exchange fraction compared to other mobile fractions. The distribution of Cu among the fractions follow the order of Residual (33%) = Organic (33%) > Oxide (14%) > Carbonate (12%) > Exchangeable (8%) as shown in Fig. 2, Cu has equal distribution between residual fraction and organic phase (33%). The occurrence of copper (Cu) in the soil could be attributed to both geogenic and anthropogenic with high concentration in the organic fraction compared to other non-residual fractions. This is in agreement with [33] who reported similar result.

The majority of distribution of Ni was observed in residual fraction as shown in Table 1 and then by organic fraction while, other fractions constitute low concentrations. It had been reported that Ni in soil has a moderate tendency of binding to the silicate [22,34], thus, resulting to high distribution in residual fraction.

The distribution of Ni follows the order of Residual (69%) > Organic (27%) > Oxide (3%) > Carbonate (1%) > Exchangeable (0%), Ni preferentially bound to residual phase (67%) and to organic phase (30%), while meagre contributions were found in the non-residual fraction. Hence, it implies that Ni concentrations in the soil samples are mainly derived from natural processes such as weathering and soil formation. This is in agreement with Jing [33] who reported similar result in sediment of Yanghe river, China.

The concentrations of Zn were high across the five fractions with highest concentration observed in organic fraction. The high percentage of Zn in the organic fraction can be related to the tendency of the metal to be readily absorbed by organic molecules [34,35]. The distributions of Zn among the fractions follow the order of Organic (31%) > Residual (28%) > Oxide (21%) > Carbonate (18%) > Exchangeable (2%). Zinc was mostly concentrated in the non-residual fraction constituting 72% of the total Zn concentration, although a significant amount was also present in the residual fraction, thus, this implies the contribution is more of anthropogenic sources to geogenic.

3.3 Ogbese Floodplain Soil

The assessment of the concentration of heavy metals in analysed soils showed significant differences between metals in different fractions (Table 2). Distribution of Cd were high in Organic fraction and exchangeable fraction while other fractions contribute low concentrations, while distribution in Owena is different, the contribution from exchangeable fraction is low, hence this suggests Cd can easily be leached into the floodplains soil of Ogbese since the proportion is high in exchangeable fraction. The high concentration of Cd in the exchangeable fraction supports earlier reports that Cd is easily leached into soil solution, since the exchangeable fraction is the most mobile [21,36]. The distributions of Cd among the fractions follow the order of Residual (50%) > Exchangeable (28%) > Oxide (9%) = Carbonate (9%) > Organic (4%) as shown in Fig. 3. The occurrence of Cd in the soil could be attributed to both geogenic and anthropogenic, with the highest concentration recorded in the residual fraction.

Results from the study showed Cu distribution is more of geogenic as the highest value was observed in residual fraction. The distribution of Cu among the fractions follow the order of Residual (36%) > Oxide (23%) > Organic (21%) > Carbonate (16%) > Exchangeable (4%) as shown in Fig. 3, Cu in the soil could be attributed to both geogenic and anthropogenic with the highest concentration in residual fraction.

Exchangeable (4%) as shown in Fig. 3, Cu in the soil could be attributed to both geogenic and anthropogenic with the highest concentration in residual fraction.

The highest concentration of Ni was observed in residual fraction and this implies is from lithogenic source. There is similarity with distribution in Owena as it followed the same trend. Nickel found in the soil is largely of geogenic or natural source since it is mostly concentrated in the residual fraction. High level of nickel in this fraction was also reported by [34]. The distributions of Ni among the fractions follow the order of Residual (65%) > Oxide (17%) > Organic (16%) > Carbonate (1%) > Exchangeable (1%). The high concentration of Ni found in this fraction, however not likely to be available for plant uptake or enter the food chain since the residual fraction is very stable, less reactive and less-bio-available. Heavy metals found in this matrix are believed to be trapped and occluded within crystal lattice of layer of silicate and well crystallized oxide minerals [12].

There was a significance increase in Zn concentration distribution from exchangeable fraction to Organic fraction, with Organic fraction having the highest concentration. The result is similar to the distribution of Zn in Owena as the concentration also increases from fraction 1 to 4. The concentrations of Zn among the fractions follow the order of Organic (35%) > Oxide (26%) > Residual (18%) > Carbonate (16%) > Exchangeable (5%). Concentration of Zn in the soil could be attributed to more of anthropogenic than geogenic with the highest proportion in the non-residual fraction (82%). The high percentage of Zn in the organic fraction can be related to the tendency of the metals to be readily absorbed by organic molecules [35,36]. High level of Zn in this fraction was also reported by [30].

3.4 Ala Floodplain Soil

The highest concentration of Cd was observed in most mobile fractions (exchangeable and carbonate) as shown in Table 3. This is not similar with Owena as Cd highest concentration was observed in residual fraction while this is similar to the distribution in Ogbese with most mobile fractions contributing a significant concentration. Concentration of Cd in Ala floodplains soil could lead to stunted growth and chlorosis of the crops and also high concentration intake of Cd can cause itai itai disease in man [37]. The distributions of Cd among the fractions follow the order of Carbonate (46%) > Residual (35%) > Organic (10%) > Exchangeable (8%) > Oxide (1%) (Fig. 4). Cadmium in the soil mostly present in the non- residual fraction constituting (65%) with carbonate fraction having the highest percentage and least fraction in oxide fraction. Cadmium level, determined as a sum of the exchangeable and carbonate fraction was more than 50% on average of the total and implies high bioavailability of Cd. These results agree with [22]

and [27] who reported similar report in sediment of Ala river. High concentration of Cd in the non-residual fraction may be attributed to the activities of auto-mechanic workshop and heap of wastes dump close to the river in most areas along the course of the river and generally municipal runoff which ultimately end up in the river during raining season.

Copper concentration increased down the fraction with highest concentration observed in Organic fraction. There is similarity in distribution with both Owena and Ogbese as non-residual fractions constitute bulk of the distribution. The distributions of Cu among the fractions follow the order of Organic (35%) > Exchangeable (19%) = Residual (19%) > Oxide (18%) > Exchangeable (9%). Copper in the soil could be attributed to more of anthropogenic than geogenic with the highest proportion in non-residual fraction (81%). The organic fraction is said to be relatively stable (slowly mobile, poorly available) [38]. It follows, therefore, that Cu in the organic fraction can be released into the soil under favourable environmental conditions, thus, under this condition, Cu will be more bioavailable for possible plant uptake. The high percentage of Cu with organic fraction may be due to high formation constants of organic Cu complexes [32].

The concentration of Ni increased significantly from fraction 1 to 5 and with residual fraction having the highest concentration. The distribution in Ala is similar to both Owena and Ogbese. Nickel was mostly concentrated in the residual fraction, although a significant amount was also present in the organic fraction and minor contribution in the oxide fraction. The distributions of Ni among the fractions follow the order: Residual (55%) > Organic (32%) > Oxide (11%) > Carbonate (2%) > Exchangeable (0%). The high

Table 1. Heavy metals fractionation in Owena river floodplain soil

Fraction	Heavy metals			
	Cd	Cu	Ni	Zn
F ₁	0.07 ^b ±0.01	0.57 ^a ±0.02	BDL	0.74 ^a ±0.06
F ₂	0.13 ^c ±0.01	0.81 ^b ±0.01	0.09 ^a ±0.01	5.58 ^b ±0.42
F ₃	0.23 ^d ±0.02	0.92 ^c ±0.01	0.38 ^a ±0.02	6.49 ^c ±0.02
F ₄	0.02 ^a ±0.00	2.18 ^d ±0.02	3.94 ^b ±0.04	9.70 ^e ±0.32
F ₅	0.36 ^e ±0.01	2.22 ^e ±0.02	10.10 ^c ±0.06	8.89 ^d ±0.30

n=3 (Triplicate analysis), Superscripts with the different letters down the column show significant variation, while those with the same letter does not at p < 0.05. F₁= exchangeable metal concentration, F₂= metal concentration bound to carbonate fraction, F₃= metal concentration bound to Fe-Mn oxide fraction, F₄= metal content bound to organic matter fraction, F₅ = Residual metal content fraction

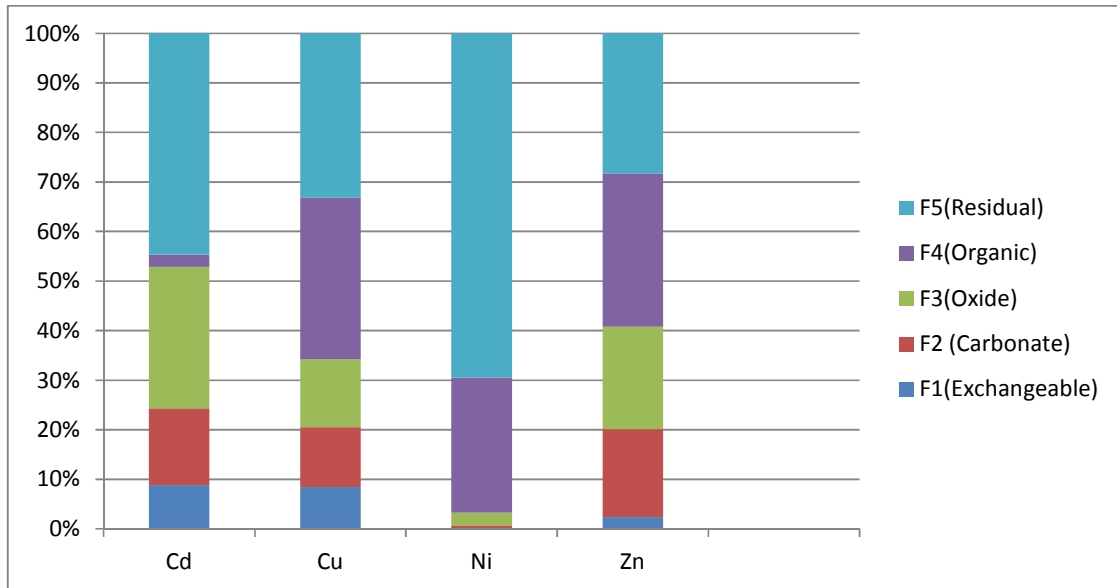


Fig. 2. Relative partitioning of heavy metals fractions in Owena floodplain soil

Table 2. Heavy metals fractionation in Ogbese river floodplain soil

Fraction	Heavy metals			
	Cd	Cu	Ni	Zn
F ₁	0.21 ^c ±0.02	0.36 ^a ±0.01	0.05 ^a ±0.00	1.29 ^a ±0.12
F ₂	0.07 ^b ±0.01	1.32 ^b ±0.03	0.09 ^b ±0.01	3.68 ^b ±0.15
F ₃	0.05 ^{ab} ±0.00	1.96 ^c ±0.04	1.15 ^d ±0.01	6.10 ^d ±0.10
F ₄	0.03 ^a ±0.01	1.83 ^c ±0.30	1.12 ^c ±0.00	8.28 ^e ±0.22
F ₅	0.36 ^d ±0.02	3.08 ^d ±0.92	4.38±0.01	4.13 ^c ±0.06

n=3 (Triplicate analysis) Superscripts with the different letters down the column show significant variation, while those with the same letter does not at p < 0.05

Table 3. Heavy metals fractionation in Ala river floodplain soil

Fraction	Heavy metals			
	Cd	Cu	Ni	Zn
F ₁	0.12 ^b ±0.02	0.09 ^a ±0.22	BDL	3.46 ^a ±0.04
F ₂	0.64 ^d ±0.04	2.20 ^c ±0.05	0.15 ^a ±0.02	7.00 ^b ±0.52
F ₃	0.01 ^a ±0.01	2.10 ^b ±0.22	0.75 ^b ±0.03	9.77 ^c ±0.23
F ₄	0.13 ^b ±0.02	4.01 ^d ±0.00	2.27 ^c ±0.03	6.98 ^b ±0.05
F ₅	0.49 ^c ±0.01	2.20 ^c ±0.31	3.87 ^d ±0.04	6.74 ^b ±0.18

n=3 (Triplicate analysis) Superscripts with the different letters down the column show significant variation, while those with the same letter does not at p < 0.05

percentage of Ni in the residual fraction agrees with earlier findings on similar studies that Ni in soil and sediment has a moderate tendency of binding to the silicate [22,33].

The distribution of Zn varied among the fractions with each fraction contributing a significant concentration and highest concentration observed in oxide fraction. The distribution differ from Owena and Ogbese as both had highest

distribution in Organic fraction while Ala had highest distribution in Oxide fraction. Zinc was mostly concentrated in the non- residual fraction, although significant amount was also present in the residual fraction. The highest concentration was observed in Oxide fraction. This is in agreement with [39] and [33]. The distributions of Zn among the fractions follow the order of Oxide (29%) > Carbonate (21%) > Organic (20%) = Residual (20%) > Exchangeable (10%).

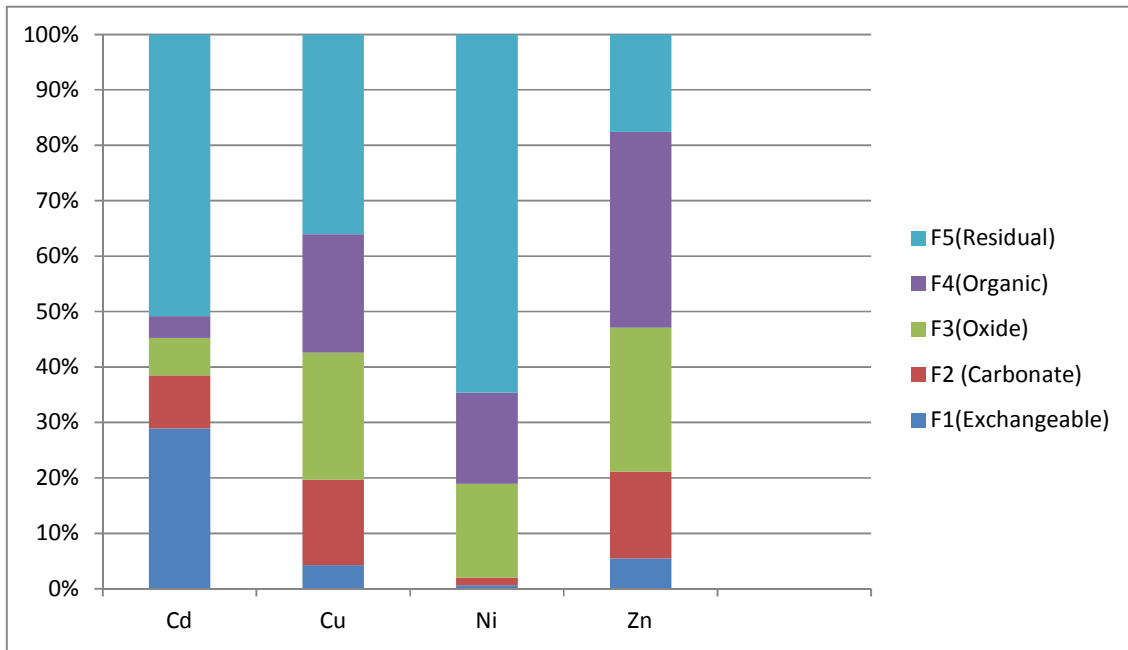


Fig. 3. Relative partitioning of heavy metals fractions in Ogbese floodplain soil

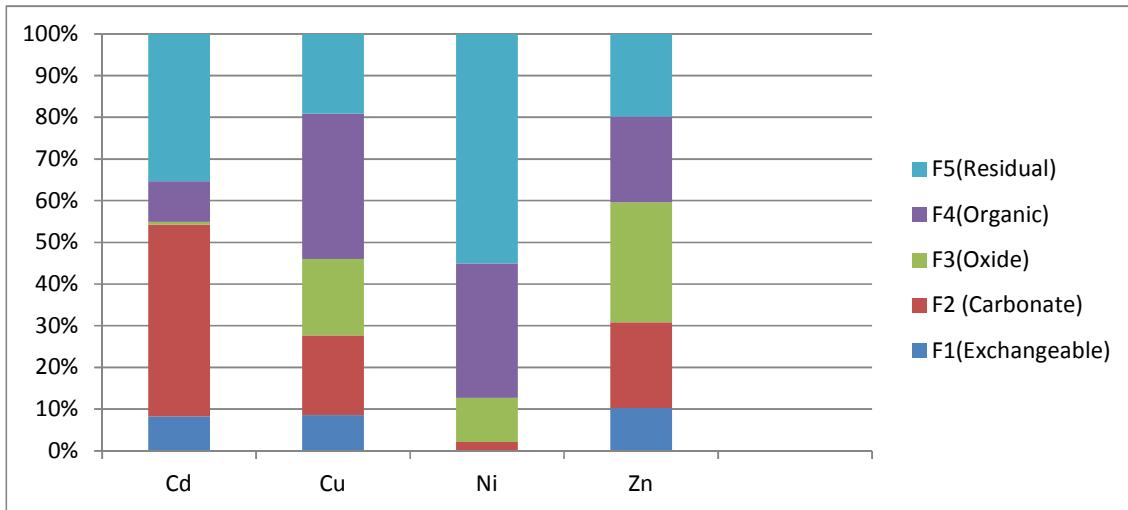


Fig. 4. Relative partitioning of heavy metals fractions in Ala floodplain soil

4. CONCLUSION

The distribution of heavy metals in the selected floodplains soil matrix through sequential extraction led to the detection of varying concentrations of Cd, Cu, Ni and Zn in the soil matrix. Contribution to the total metal content of the soil was from both geogenic and anthropogenic sources. Cadmium concentrations were high in non-residual fractions of the floodplains soils and this implies bioavailability of metal for plant uptake. Copper was least detected

in the carbonate fraction, which is slowly mobile and relatively stable, and does not retain large concentration of metals. Nickel concentrations in the alluvial soils were observed in residual fraction. Ni observed in this fraction are, however, not likely to be available for plant uptake or enter the food chain since the residual fraction is very stable, less reactive and less bio-available. Zinc was highly bound to both organic fraction and oxide fraction which could be release to the alluvial soils under favourable environmental conditions. The study

also provides baseline information on the concentration of the metal in the floodplains with which future anthropogenic influences could be evaluated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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