FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 12, December (Special Issue), 2025, pp 716 – 724
DOI: https://doi.org/10.33003/fjs-2025-0912-4355

ECOLOGICAL RISK ASSESSMENT OF HEAVY METALS IN SOILS OF SOME CULTIVATED FLOODED PLAINS IN EKITI STATE, SOUTHWEST NIGERIA

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ABSTRACT
A sustainable development goal is adequate supply of safe and quality food; heavy metal contamination of agricultural soil could pose a serious threat to the goal. This study investigates possible heavy metal contamination of some arable cultivated flooded plains by estimating heavy metal levels in soils in order to assess their ecological risks. Soil samples were collected at upper, middle and lower courses of the stream by sampling 0-30cm plough able depth at 5, 25 and 45 m perpendicular to each river. The samples were air-dried, milled, sieved and analyzed for Cd, Cu, Cr, Cd, Zn, Pb and Fe using Atomic Absorption Spectrophotometer (AAS) Perkin Elmer Analyst 400 model. All the metals studied were detected except in few samples. The heavy metal concentration ranges (mg/kg) at Irintan floodplain were: Cr (BDL-0.33), Cu (0.07-0.80), Zn (0.20-2.16), Cd (BDL-0.70), Pb (0.03-0.53), Fe (0.51-2.51). At Omi-Eye floodplain the heavy metal ranges (mg/kg) were: Cr (0.25-2.52), Cu (0.11-8.07), Zn (0.16-3.55), Cd (BDL-0.34), Pb (0.18-0.77) and Fe (0.83-9.05) while at Egbigbu floodplain, the heavy metal ranges (mg/kg) were Cr (0.09-0.79), Cu (0.16-9.70), Zn (0.16-2.27), Cd (BDL-0.12), Pb (0.09-1.02) and Fe (0.72-8.32). The contamination factor, degree of contamination and pollution load index all indicated low pollution status. It is recommended that government should ensure that toxic metals do not build up in our environment through regular monitoring.

Keywords: Heavy metal, Geoaccumulation index, Anthropogenic activities, Pepper

INTRODUCTION
Heavy metals are a group of elements that have relatively high atomic weights and which possess densities greater than 5 gcm^{-3} (Jadaa and Mohammed 2023; El-Sappah *et al*., 2024). They are harmful environmental pollutants that have attracted widespread attention due to health hazards they pose to animals and human beings (Jomova *et al*., 2024, Iorkpiligh *et al*., 2025). Heavy metal pollution of the earth's environment has been on the increase in recent time due to technological advancement, industrialization, urbanization and intensified irrigation agriculture (Rashid *et al*., 2023). Their presence in environment is known to bring about poor soil health, surface and underground water and food contaminations (Sarafi and Salehi, 2025). This has generated a great deal of concerns locally, nationally and internationally due to their non-biodegradable nature as well as their ability to interfere with normal metabolic activities of living organisms (Tahir and Alkherraije, 2023) thus posing hazards to human health (Gupta and Arunachalam, 2024).
The history of floodplain agriculture dates back to ages especially when the Egyptians used Nile Valley to plant food crops (Angelakis *et al*., 2023). Since then, the use of floodplains for agricultural activities has continued to be on the increase in view of population growth especially in developing country like Nigeria. In geographic term, the term floodplain can be described as seasonally flooded areas of land adjacent to streams or rivers that stretch from river banks to the base of the enclosing valley wall (Liu and Liu, 2022). Floodplains are important for both society and nature. For many centuries, people have used floodplain areas to build their settlements in the vicinity of rivers, which provide freshwater for irrigation and domestic use, and serve as shipping routes. However, many rivers have become contaminated, which may affect their many functions and their floodplains (Anh *et al*., 2023). During flooding, rivers often receive storm water from their catchments which can cause over bank deposition at the floodplains may therefore not only fertilize floodplain soils, but may also cause contamination with substances such as organic micro pollutants or heavy metals (Kanianska *et al*., 2022). Over periods of many centuries, most floodplains act as sinks for contaminants most of which are persistent, thus capable of bioaccumulation in tissues of living organisms and thereby causing adverse physiological effects (Skala *et al*., 2018). One of these potentially toxic contaminants is heavy metal which enters food chain via plant feeders and predators (Zayab *et al*., 2022). This may threaten the viability of vulnerable species in the floodplain ecosystem. However, due to modernization and attendant technological developments, there is increased discharge of pollutants including heavy metals into these rivers (Zafarzadeh *et al*., 2018). The deposition of heavy metals on the floodplains can occur when there are overbank floods. Sediment associated metals have a residence time ranging from decades to centuries in soils (Zafarzadeh *et al*., 2018).
Ekiti State is situated in southwestern part of Nigeria; located between latitudes 07^0 15' and 08^0 05' north of equator and 04^0 45' and 05^0 45' east of Greenwich meridian. The State is mainly an upland zone which lies over 250 meters above the sea level. It is dotted with rugged hills from which many notable rivers in South Western Nigeria originate. It enjoys tropical climate with two distinct seasons. These are the rainy season which runs from April to October and the dry season that occurs between November and March (Ademoyega and Oyetunji, 2024). The State is purely agrarian with over 80% of the population engaged in farming activities (Owoeye *et al*., 2023). However, the agricultural activities are strictly rain fed making the production of certain crops a seasonal phenomenon (Dahiru *et al*., 2022). This makes certain food crops difficult to come by during the dry season period, a situation which impacts negatively on the nutrition of the people and the food security of the nation (Food and Agriculture Organization, 2019).

In view of increased population, it has become necessary for the farmers to explore other ways to boost food production. This prompts the farmers to use the floodplains which abound in the state to plant crops especially the fast maturing ones like vegetables, pepper (Capsicum annuum), okro (Abelmoschus esculentus), tomatoes (Solanum lycopersicum), maize (Zea mays) (Tsoho and Salau, 2012). Food crops planted on these plains are grown on alluvial soils which are deposited at the recession of the flood water that may carry down many pollutants from the catchments (Olawale *et al*., 2017). Globally, heavy metal contamination to widely consumed vegetables has become a major challenge. This is because intake of heavy metals through such contaminated vegetables may pose risk to human health due to their toxicity, bioaccumulation and biomagnifications in the food chains (Musa *et al*., 2017). The prolonged consumption of heavy metals through food stuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes leading to cardiovascular, nervous, kidney and bone diseases (Mitra *et al*., 2022). One of the targets of the Sustainable Development Goals of United Nations in terms of healthy living for masses is adequate supply of safe and quality foods for the human consumption (Akodu *et al*., 2024). Since the crops produced from the farms end up on the table as foods for human consumption, there is the need to assess them for their possible ecological effects in order to achieve this goal. This study is therefore undertaken to provide data on the status of heavy metals on cultivated alluvial soils of some agricultural floodplains in Ekiti State which are noted for dry season farming of vegetables and thus to offer insight into the ecological risk of the floodplain to the people.

MATERIALS AND METHODS

Study Site and Sample Collection

The agricultural floodplains used for the study are Egbigbu floodplain in Ayetoto-Ekiti; Omi-Eye floodplain in Erio-Ekiti and Irintan floodplain in Ise-Ekiti on Longitude - 05^0 09.131'E, Latitude - 07^0 55.457'N (Altitude - 531m); Longitude – 04^0 52.882' E Latitude - 07^0 43.450'N (Altitude - 417m); Longitude – 05^0 22.019'E, Latitude - 07^0 30.528'N (Altitude - 420m) respectively. Soil samples (0-30) were collected at upper, middle and lower courses perpendicular to the river by sampling using stainless auger at 0-30cm plough able depth at 5m, 25m and 45m distance from the stream. A control sample was taken at a distance of a kilometer away from the farm. The soil samples were then taken to the laboratory for analysis after the necessary pretreatments.

Sample Treatment and Analysis

Soil Samples

The soil samples were spread on plastic trays and allowed to air dry in dust free open laboratory until they were loose. They were then disaggregated using mortar and pestle, sieved through 2.0mm BS mesh and kept in PET bottles pending analysis. One gram (1 g) of sample was placed in a 250mL digestion tube and 10mL of Conc. HNO_3 was added. The mixture was boiled gently in a fume cupboard for 30-45minutes to oxidize all easily oxidizable matter. After cooling, 5mL of 70% $HClO_4$ was added and the mixture was boiled gently until dense white fumes appeared. It was cooled again before 20mL of deionised water was added and the mixture was boiled further to release any fumes. The solution was finally cooled, filtered through Whatman No 42 filter paper and transferred quantitatively to a 25mL volumetric flask and made up to mark using deionised water (Zeng-Yei, 2004). The heavy metals were analyzed using Atomic Absorption Spectrophotometer (AAS) Perkin Elmer Analyst 400 model.

Validity of Laboratory Data

As a means of assuring reliability of data, analyses were done in triplicates and means used. Calibration curve for each metal was determined and correlation coefficients were then determined. Correlation coefficients with values less than 0.94 were rejected but those greater than 0.94 were accepted. All correlation coefficient values obtained in this study were ranged between 0.99954 and 0.99989. Thus, the results are taken to be valid.

Contamination Factor (CF)

It is used to illustrate the contamination of a given toxic metal and assess the soil contamination (Saleem *et al*., 2023). The contamination factor is calculated as below:

$CF = C_s/C_b$ (1)

Where C_s is the concentration of metal in the study samples and C_b is baseline concentration as in index of geoaccumulation. (Abata *et al*., 2016) classified the CF as the following: CF < 1 means low contamination; 1 < CF < 3 means moderate pollution; 3 < CF < 6 consideration contamination, and CF > 6 means high contamination.

Degree of Contamination (Cd)

This is defined as the sum of all contamination factors of all the metal studied. The ranges are divided into four categories: Cd < 6 (low degree), 6 ≤ Cd < 12 (moderate degree), 12 ≤ Cd < 24) (considerable) and Cd ≥ 24 (very high).

Pollution Load Index (PLI)

The pollution load index (PLI) is a means used to assess the level of heavy metal pollution (Abata *et al*., 2016). It therefore serves a means of estimating the level of heavy metal pollution rank in different localities (Mekky *et al*., 2019). The PLI is calculated as:

$PLI = n\sqrt{(CF_1 \times CF_2 \times CF_3 \times \ldots\ldots CFn)}$ (2)

Where n is the number of metals and CF is the contamination factor. According to (Hesham *et al*., 2023), the PLI values obtained can be interpreted as below:

PLI > 1 means pollution exists

PLI < 1 means no metal pollution

However, PLI = 1 means heavy metal loads close to the background level.

Data Analysis

The results of analysis of the samples in triplicate were subjected to descriptive statistics to obtain means and standard deviations for each of the parameters using Microsoft Excel 2016 Software. The significant differences ($p<0.05$) of values at each location for the soil depths (one-way ANOVA) were determined using SPSS 16.

RESULTS AND DISCUSSION

The results of soil total heavy metal concentrations at Irintan, Omi-Eye and Egbigbu floodplains are presented in Tables 3.1, 3.2 and 3.3 respectively. All metals studied were detected except a few of them in the farm soils sampled. At Irintan floodplain, the metal ranges (mg/kg) were: Cr (BDL-0.33), Cu (0.07-0.80), Zn (0.20-2.16), Cd (BDL-0.70), Pb (0.03-0.53), Fe (0.51-2.51) and at Omi-Eye floodplain, the ranges (mg/kg) were Cr.(0.25-2.52), Cu (0.11-8.07), Zn (0.16-3.55), Cd (BDL-0.34), Pb (0.18-0.77) and Fe (0.83-9.05) while at Egbigbu floodplain, the ranges (mg/kg) were Cr (0.09-0.79), Cu (0.16-9.70), Zn (0.16-2.27), Cd (BDL-0.12), Pb (0.09-1.02) and Fe (0.72-8.32). The overall means (mg/kg) of the metals at Irintan floodplain were Cr (0.09±0.04), Cu (0.29±0.11), Zn (1.36±0.82), Cd (0.10 ±0.08), Pb (0.41±0.10), Fe, (3.40±1.29). At Omi-Eye floodplain, the overall means (mg/kg) of the metals were Cr (1.04±0.60), Cu (2.44±2.35), Zn (1.36±0.82), Cd (0.10±0.08), Pb (0.41 ±0.10), Fe (3.40 ±1.29) while at Egbigbu floodplain, the overall means (mg/kg) were: Cr (0.44±0.11), Cu (2.47±0.56), Zn (0.88±0.32), Cd (0.05±0.01),Pb (0.42±0.17), Fe (2.90±0.38)

Table 1: Total Heavy Metal Concentration (mg/kg) in Soil Obtained at Irintan Floodplain

R/Course				**Upper**									**Middle**	
Distance		5m			25m			45m			5m			25m	
Depth (cm)	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Cr	0.20^{c}±0.01	0.16^{b}±0.00	0.09^{a} ±0.07	0.02^{b} ±0.00	0.02^{b} ±0.00	BDL	0.06^{c} ±0.01	0.05^{a,b}±0.02	0.03^{a} ±0.00	0.31^{b} ±0.05	0.19^{a} ±0.04	0.13^{a} ±0.01	0.07^{b} ±0.02	0.05^{b} ±0.00	BDL
Cu	0.53^{c}±0.06	0.33^{b}±0.01	0.09^{a} ±0.02	0.37^{c} ±0.02	0.28^{b} ±0.01	0.21^{a} ±0.00	0.26^{b} ±0.02	0.15^{a} ±0.01	0.12^{a} ±0.02	0.29^{c} ±0.07	0.19^{a} ±0.02	0.14^{a} ±0.03	0.32^{a} ±0.06	0.34^{a} ±0.12	0.19^{a} ±0.07
Zn	2.16^{c}±0.03	1.53^{b}±0.07	0.85^{a} ±0.09	1.30^{b} ±0.03	1.22^{b}±0.04	0.58^{a} ±0.10	1.05^{c} ±0.07	0.61^{b} ±0.00	0.33^{a} ±0.00	1.98^{c} ±0.23	1.59^{b} ±0.17	0.91^{a} ±0.05	1.63^{a} ±0.01	1.43^{a} ±0.20	1.59^{a} ±0.03
Cd	0.27^{b}±0.00	0.22^{b}±0.03	0.18^{a} ±0.05	0.28^{c} ±0.00	0.19^{b} ±0.00	0.11^{b} ±0.02	0.09^{b} ±0.03	0.13^{b} ±0.02	BDL	0.36^{b} ±0.01	0.43^{b} ±0.06	0.04^{a} ±0.00	0.26^{b} ±0.05	0.17^{a} ±0.03	0.14^{a} ±0.00
Pb	0.45^{b}±0.12	0.06^{a} ±0.02	0.03^{a} ±0.00	0.33^{b} ±0.01	0.39^{c} ±0.02	0.15^{a} ±0.00	0.45^{b} ±0.00	0.19^{a} ±0.05	0.18^{a} ±0.03	0.39^{c} ±0.04	0.08^{b} ±0.00	0.03^{a} ±0.01	0.26^{a} ±0.00	0.24^{a} ±0.03	0.23^{a} ±0.01
Fe	1.68^{a}±0.55	1.21^{a}±0.14	1.07^{a} ±0.19	1.75^{a,b}±0.07	2.01^{c} ±0.30	1.42^{a} ±0.26	1.88^{c} ±0.12	1.37^{b} ±0.00	0.93^{a} ±0.02	1.37^{c} ±0.13	1.25$^{a, b}$ ±0.08	1.15^{a}±0.07	1.45^{a} ±0.22	1.22^{a,} ±0.03	0.95^{a} ±0.09

BDL = Below Detection Limit

Table 1: Contd: Total Heavy Metal Concentration (mg/kg) in Soil Obtained at Irintan Floodplain

R/Course								**Lower**						**Control**	
Distance		45m			5m			25m			45m				
Depth (cm)	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Cr	0.08^{b}±0.02	0.04^{a}±0.02	0.03^{a}±0.00	0.22^{b} ±0.04	0.33^{c}±0.02	0.15^{a} ±0.01	0.09^{b}±0.03	0.04^{c} ±0.00	BDL	0.04^{b}±0.01	0.02^{a} ±0.00	0.01^{a} ±0.00	0.12^{b} ±0.00	0.19^{c} ±0.03	0.06^{a} ±0.01
Cu	0.30^{b}±0.04	0.13^{a}±0.05	0.07^{a}±0.01	0.64^{b} ±0.11	0.80^{c}±0.05	0.16^{a} ±0.00	0.51^{c}±0.01	0.31^{b} ±0.05	0.24^{a} ±0.02	0.18^{b}±0.07	0.38^{b} ±0.04	0.31^{a} ±0.00	0.39^{b} ±0.12	0.22^{a} ±0.07	0.09^{a} ±0.01
Zn	0.74^{b}±0.02	0.67^{b}±0.00	0.45^{a}±0.10	0.98^{b} ±0.03	1.70^{b}±0.05	1.75^{a} ±0.42	1.15^{b}±0.07	1.09^{a} ±0.16	0.79^{a} ±0.09	0.98^{b}±0.05	0.87^{b} ±0.10	0.20^{a} ±0.05	1.71^{c} ±0.01	0.76^{b} ±0.05	0.23^{a} ±0.02
Cd	0.25^{c}±0.00	0.70^{b}±0.16	BDL	0.42^{b} ±0.03	0.20^{b}±0.01	0.08^{b} ±0.00	0.23^{b}±0.07	0.14^{a} ±0.00	0.10^{a} ±0.02	0.12^{b}±0.04	0.11^{b} ±0.03	BDL	0.45^{c} ±0.10	0.20^{b} ±0.00	0.00^{a} ±0.00
Pb	0.38^{a}±0.17	0.27^{a}±0.08	0.18^{a}±0.00	0.35^{b} ±0.10	0.09^{a}±0.00	0.10^{a} ±0.03	0.53^{a}±0.11	0.40^{a} ±0.05	0.35^{a} ±0.00	0.26^{b}±0.01	0.29^{b} ±0.02	0.16^{a} ±0.07	0.24^{c} ±0.05	0.15^{b} ±0.04	BDL
Fe	1.52^{c}±0.00	1.01^{b}±0.02	0.87^{a}±0.04	2.05^{b} ±0.12	2.31^{a}±0.09	1.29^{a} ±0.13	1.64^{a}±0.15	1.12^{a} ±0.16	1.38^{a} ±0.03	1.65^{c}±0.09	1.09^{b} ±0.00	0.51^{a} ±0.05	1.38^{c} ±0.03	1.19^{b} ±0.00	1.02^{a} ±0.08

BDL = Below Detection Limit

Table 2: Total Heavy Metal Concentration (mg/kg) in Soil Obtained at Omi-Eye Floodplain

R/Course					**Upper**									**Middle**	
Distance		5m			25m			45m			5m			25m	
Depth (cm)	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Cr	0.89^{a}±0.00	0.34^{a}±0.02	0.66^{b} ±0.07	1.73^{b} ±0.71	0.83^{a} ±0.03	0.84^{a} ±0.05	2.12^{c} ±0.03	0.70^{b} ±0.17	0.44^{a} ±0.04	1.39^{c} ±0.00	0.25^{a} ±0.10	1.07^{b} ±0.01	1.94^{c} ±0.17	1.22^{b} ±0.03	0.70^{a} ±0.09
Cu	8.07^{b}±1.06	2.15^{a}±0.54	0.80^{a} ±0.02	4.69^{c} ±0.03	2.33^{b} ±0.01	0.94^{a} ±0.10	2.57^{c} ±0.08	0.60^{b} ±0.04	0.11^{a} ±0.00	7.74^{c} ±1.21	1.85^{b} ±0.03	0.39^{a} ±0.30	5.43^{c} ±1.39	2.30^{b} ±0.21	0.65^{a} ±0.05
Zn	1.82^{c}±0.01	1.19^{b}±0.11	0.58^{a} ±0.05	0.71^{b} ±0.06	0.88^{c} ±0.05	0.16^{a} ±0.00	2.89^{b} ±0.01	3.11^{b} ±0.67	0.59^{a} ±0.08	3.55^{c} ±0.07	1.53^{b} ±0.01	0.35^{a} ±0.00	1.23^{b} ±0.07	0.50^{a} ±0.15	0.32^{a} ±0.00
Cd	0.28^{c}±0.01	0.09^{b}±0.03	BDL	0.19^{b} ±0.00	0.26^{b} ±0.07	0.07^{a} ±0.01	BDL	BDL	BDL	0.24^{c} ±0.03	0.11^{b} ±0.05	BDL	0.34^{c} ±0.05	0.15^{b} ±0.01	0.03^{a} ±0.02
Pb	0.77^{b}±0.04	0.59^{b}±0.08	0.25^{a} ±0.01	0.39^{a} ±0.09	0.51^{a} ±0.00	0.24^{a} ±0.09	0.38^{b} ±0.00	0.29^{a} ±0.03	0.59^{a} ±0.02	0.50^{c} ±0.04	0.27^{a} ±0.02	0.35^{b} ±0.05	0.65^{b} ±0.02	0.30^{a} ±0.10	0.29^{a} ±0.00
Fe	7.66^{b}±0.07	9.05^{b}±1.96	4.46^{a} ±0.95	4.22^{a} ±0.13	2.96^{b} ±0.08	0.83^{a} ±0.05	4.75^{c} ±2.27	2.17^{a,b}±0.00	1.19^{a} ±0.09	5.07^{b} ±0.40	8.77^{c} ±0.56	2.75^{a} ±0.41	3.60^{c} ±1.15	2.43^{a,b}±0.00	1.41^{a} ±0.19

BDL = Below Detection Limit

Table 2: Contd: Total Heavy Metal Concentration (mg/kg) in Soil Obtained at Omi-Eye Floodplain

R/Course			**Lower**		**Control**
Distance	45m	5m	25m	45m	

Depth (cm)	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Cr	$2.52^{c}\pm0.39$	$1.39^{b}\pm0.03$	$0.32^{a}\pm0.00$	$1.39^{c}\pm0.05$	$0.40^{a}\pm0.01$	$0.87^{b}\pm0.03$	$1.69^{c}\pm0.10$	$0.99^{b}\pm0.00$	$0.39^{a}\pm0.07$	$1.93^{b}\pm0.03$	$0.51^{a}\pm0.00$	$0.59^{a}\pm0.02$	$0.93^{b}\pm0.00$	$0.00^{a}\pm0.00$	BDL
Cu	$2.13^{c}\pm0.11$	$0.68^{b}\pm0.00$	$0.33^{a}\pm0.09$	$6.26^{c}\pm0.06$	$1.35^{a}\pm0.11$	$0.50^{a}\pm0.00$	$5.80^{c}\pm2.71$	$2.63^{a,b}\pm0.75$	$1.45^{a}\pm0.02$	$3.19^{c}\pm0.06$	$0.90^{b}\pm0.00$	$0.27^{a}\pm0.02$	$2.19^{b}\pm0.58$	$0.55^{a}\pm0.11$	$0.22^{a}\pm0.01$
Zn	$3.06^{c}\pm0.13$	$2.24^{b}\pm0.28$	$1.26^{a}\pm0.01$	$2.48^{b}\pm0.24$	$0.73^{a}\pm0.04$	$0.89^{a}\pm0.00$	$1.20^{c}\pm0.01$	$0.59^{b}\pm0.00$	$0.27^{a}\pm0.03$	$2.59^{c}\pm0.05$	$1.53^{b}\pm0.09$	$0.38^{a}\pm0.00$	$2.49^{c}\pm0.01$	$0.63^{b}\pm0.03$	$0.49^{a}\pm0.00$
Cd	BDL	BDL	BDL	$0.15^{c}\pm0.02$	$0.05^{b}\pm0.01$	BDL	$0.32^{b}\pm0.03$	$0.24^{b}\pm0.07$	$0.09^{a}\pm0.02$	BDL	BDL	BDL	$0.09^{c}\pm0.01$	$0.05^{b}\pm0.00$	BDL
Pb	$0.51^{b}\pm0.01$	$0.49^{b}\pm0.13$	$0.29^{a}\pm0.08$	$0.44^{b}\pm0.00$	$0.69^{c}\pm0.00$	$0.31^{a}\pm0.11$	$0.51^{b}\pm0.06$	$0.49^{b}\pm0.02$	$0.18^{a}\pm0.00$	$0.33^{b}\pm0.00$	$0.33^{b}\pm0.04$	$0.18^{a}\pm0.03$	$0.26^{c}\pm0.00$	$0.19^{b}\pm0.01$	BDL
Fe	$4.31^{c}\pm0.06$	$1.95^{b}\pm0.23$	$0.95^{a}\pm0.00$	$3.39^{a}\pm0.06$	5.93 ± 2.06	$3.03^{a}\pm0.02$	$1.29^{a}\pm0.33$	$2.06^{c}\pm0.14$	$1.67^{a,b}\pm0.00$	$3.49^{b}\pm0.05$	$1.47^{a}\pm0.01$	$0.94^{a}\pm0.11$	$3.74^{c}\pm0.04$	$2.14^{b}\pm0.01$	$0.62^{a}\pm0.14$

BDL = Below Detection Limit

Table 3: Total Heavy Metal Concentration (mg/kg) in Soil Obtained at Egbigbu Floodplain

R/Course					**Upper**									**Middle**	
Distance		5m			25m			45m			5m			25m	
Depth (cm)	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Cr	$0.57^{a,b}\pm0.13$	$0.66^{c}\pm0.31$	$0.22^{a}\pm0.00$	$0.72^{b}\pm0.03$	$0.79^{b}\pm0.08$	$0.60^{a}\pm0.95$	$0.64^{c}\pm0.12$	$0.50^{a,b}\pm0.01$	$0.49^{a}\pm0.03$	$0.63^{c}\pm0.00$	$0.31^{b}\pm0.00$	$0.17^{a}\pm0.03$	$0.59^{b}\pm0.07$	$0.56^{b}\pm0.04$	$0.42^{a}\pm0.01$
Cu	$4.40^{c}\pm1.26$	$2.79^{a,b}\pm1.03$	$1.55^{a}\pm0.09$	$9.70^{c}\pm0.49$	$5.34^{b}\pm0.95$	$0.30^{a}\pm0.00$	$3.27^{b}\pm0.09$	$0.34^{a}\pm0.02$	$0.53^{a}\pm0.00$	$7.03^{c}\pm0.29$	$2.05^{b}\pm0.15$	$1.18^{a}\pm0.10$	$8.07^{c}\pm2.66$	$2.70^{b}\pm0.15$	$0.64^{a}\pm0.15$
Zn	$2.27^{b}\pm0.03$	$0.76^{a}\pm0.21$	$0.92^{a}\pm0.11$	$1.79^{a}\pm0.16$	$1.60^{a}\pm0.22$	$1.13^{a}\pm0.40$	$1.27^{c}\pm0.04$	$0.63^{b}\pm0.09$	$0.40^{a}\pm0.13$	$1.33^{b}\pm0.04$	$1.48^{b}\pm0.37$	$0.30^{a}\pm0.05$	$1.05^{a}\pm0.21$	$0.59^{a}\pm0.04$	$0.78^{a}\pm0.00$
Cd	$0.09^{c}\pm0.01$	$0.06^{a,b}\pm0.03$	$0.04^{a}\pm0.02$	$0.12^{b}\pm0.00$	$0.07^{a}\pm0.01$	$0.08^{a}\pm0.01$	$0.11^{b}\pm0.00$	$0.09^{b}\pm0.00$	$0.04^{a}\pm0.02$	$0.05^{c}\pm0.01$	$0.02^{b}\pm0.00$	$0.04^{a,b}\pm0.02$	$0.06^{b}\pm0.00$	$0.11^{c}\pm0.01$	$0.05^{a}\pm0.02$
Pb	$0.71^{a}\pm0.06$	$0.95^{b}\pm0.13$	$0.55^{a}\pm0.00$	$1.02^{b}\pm0.30$	$0.59^{a}\pm0.07$	$0.23^{a}\pm0.07$	$0.57^{c}\pm0.02$	$0.43^{b}\pm0.00$	$0.09^{a}\pm0.00$	$0.57^{a}\pm0.20$	$0.37^{a}\pm0.08$	$0.41^{a}\pm0.00$	$0.79^{b}\pm0.18$	$0.46^{a}\pm0.03$	$0.27^{a}\pm0.00$
Fe	$6.58^{c}\pm0.04$	$3.27^{b}\pm0.97$	$1.22^{a}\pm0.05$	$3.85^{a}\pm0.14$	$4.52^{a}\pm0.03$	$3.11^{a}\pm0.88$	$3.25^{a}\pm0.79$	$3.03^{a}\pm0.07$	$8.32^{a}\pm1.46$	$2.81^{a}\pm0.55$	$2.47^{a}\pm0.18$	$2.16^{a}\pm1.09$	$4.21^{c}\pm1.21$	$2.30^{b}\pm0.13$	$1.97^{b}\pm0.34$

Table 3 Contd: Total Heavy Metal Concentration (mg/kg) in Soil Obtained at Egbigbu Floodplain

R/Course								**Lower**						**Control**	
Distance		45m			5m			25m			45m				
Depth (cm)	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Cr	$0.49^{c}\pm0.11$	$0.63^{a,b}\pm0.05$	$0.37^{a}\pm0.05$	$0.52^{b}\pm0.03$	$0.16^{a}\pm0.09$	$0.09^{a}\pm0.02$	$0.27^{b}\pm0.03$	$0.17^{a}\pm0.01$	$0.33^{c}\pm0.02$	$0.46^{b}\pm0.04$	$0.39^{b}\pm0.05$	$0.16^{a}\pm0.04$	$0.12^{b}\pm0.01$	BDL	BDL
Cu	$2.10^{c}\pm0.06$	$0.65^{b}\pm0.10$	$0.16^{a}\pm0.03$	$7.67^{b}\pm0.43$	$1.21^{a}\pm0.35$	$0.80^{a}\pm0.07$	$0.85^{b}\pm0.38$	$0.91^{b}\pm0.16$	$0.19^{a}\pm0.00$	$1.65^{b}\pm0.39$	$0.43^{a}\pm0.01$	$0.25^{a}\pm0.09$	$3.59^{b}\pm0.66$	$0.61^{a}\pm0.20$	$0.54^{a}\pm0.12$
Zn	$0.90^{a}\pm0.03$	$1.04^{b}\pm0.17$	$0.22^{a}\pm0.00$	$0.59^{c}\pm0.06$	$1.02^{b}\pm0.03$	$0.37^{a}\pm0.00$	$1.03^{c}\pm0.57$	BDL	$0.40^{a,b}\pm0.19$	$0.56^{a,b}\pm0.03$	$0.71^{c}\pm0.22$	$0.32^{a}\pm0.00$	$1.84^{c}\pm0.03$	$0.70^{b}\pm0.09$	$0.12^{a}\pm0.03$
Cd	$0.07^{a}\pm0.00$	$0.07^{a}\pm0.00$	$0.05^{a}\pm0.00$	$0.03^{b}\pm0.02$	BDL	BDL	$0.02^{a}\pm0.00$	BDL	BDL	BDL	$0.02^{b}\pm0.01$	$0.02^{a}\pm0.00$	$0.09^{b}\pm0.05$	BDL	BDL
Pb	$0.59^{c}\pm0.03$	$0.16^{b}\pm0.03$	$0.17^{a}\pm0.02$	$0.37^{c}\pm0.09$	$0.20^{b}\pm0.04$	$0.29^{a,b}\pm0.05$	$0.41^{c}\pm0.05$	$0.26^{b}\pm0.04$	$0.10^{a}\pm0.00$	$0.20^{a}\pm0.09$	$0.23^{a}\pm0.08$	$0.19^{a}\pm0.05$	$0.16^{c}\pm0.00$	$0.07^{b}\pm0.05$	BDL
Fe	$2.83^{a}\pm0.18$	1.91 ± 0.82	$2.29^{a}\pm0.53$	$2.21^{a}\pm0.00$	$2.29^{a}\pm0.74$	$3.01^{a}\pm0.04$	$2.69^{b}\pm1.17$	$2.84^{b}\pm0.30$	$0.76^{a}\pm0.23$	$1.60^{a}\pm0.17$	$1.32^{a}\pm0.47$	$1.48^{a}\pm0.11$	$3.74^{c}\pm0.00$	$2.69^{a,b}\pm1.08$	$1.55^{a}\pm0.02$

BDL = Below Detection Limit

Table 4: Comparison of Mean Heavy Metal Level at the Sites with International Standards (mg/kg)

H/Metal	**Irintan**	**Omi-Eye**	**Egbigbu**	**Austria**	**Canada**	**Poland**	**Japan**	**UK**	**Germany**	**Nigeria (DPR)**
Cr	0.09	1.04	0.44	100	75	100	-	50	200	100
Cu	0.29	2.44	2.47	100	100	100	125	100	50	36
Zn	1.12	1.36	0.88	300	400	300	250	300	300	140
Cd	0.19	0.10	0.05	5	8	3	-	3	2	0.8
Pb	0.25	0.41	0.42	100	200	100	400	100	500	85
Fe	1.38	3.40	2.70	NA	NA	NA	NA	NA	NA	NA

H/Metal= Heavy metal, DPR = Dept. of Petroleum Resources (Nigeria), UK = United Kingdom

(Source: Aiyesanmi and Idowu, 2012)

It could be observed that the values obtained at the study sites show a low concentration of metal as compared to similar studies reported by (Quishlaqi and Moore, 2007) who reported a level of 124.50mg/kg for Cr, 96.90 mg/kg for Cu, 5.20 mg/kg Cd and 254.60 mg/kg for Pb in their study of agricultural floodplain soil of Khoshk River banks of Shiraz in Iran.

A higher concentration of metals in similar agricultural soils were equally reported by (Bhatti *et al*., 2016) who recorded a range of 5.0-25.0 mg/kg for Cr, 6.0-47.0 mg/kg for Cu, 5.0-7.0 mg/kg for Pb in agricultural soil of Punjab, India and (Olawale *et al*., 2017) who recorded 1.39 mg/kg for Cd, 11.49 mg/kg for Cu and 35.0 mg/kg for Zn at Ala river floodplain in Akure, Ondo State. Generally, the metal values obtained from all the sites are lower compared with national and international standards (Table 3.4).

Cd recorded the lowest mean value at each site (Fig. 3.1) except at Irintan floodplain where Cr recorded the lowest level. Cadmium is considered as one of the ecotoxic heavy metals. It is known to exhibit an adverse effect on soil health, plant metabolism, biological activity and health of animals and human beings (Sun *et al*., 2016). The mean concentration of Cd at Irintan, Omi-Eye and Egbigbu floodplains was 0.19, 0.10 and 0.05 mg/kg respectively. The low level of Cd in the floodplain soils generally may be attributed to inability of the metal to adhere to soil particles due to its solubility under a set of environmental conditions and thus making it to be potentially available for plant uptake (Salem *et al*., 2020). The values of Cd in this study is similar to BDL-0.11 mg/kg reported by (Farid *et al*., 2015) for floodplain soils of Madina town of Faisalabad and to 0.003-0.103 mg/kg reported for Nanxum County floodplain, Southeast China (Zhao *et al*., 2015).

Equally, Fe was found to record the highest value of metals studied. The mean Fe content recorded at Irintan, Omi-Eye and Egbigbu floodplains was 1.38, 3.40 and 2.70 mg/kg respectively. In the current study, the mean concentration agrees with 0.91 mg/kg reported for heavy metals in agricultural soils in Lafia, Nigeria by (Opaoluwa *et al*., 2012) but lower than the one reported by (Yaradua *et al*., 2020) for agricultural soil in Katsina, Nigeria. Iron is an essential metal; its deficiency in man causes anaemia which is a global health issue frequently encountered in daily clinical practice (Kolars *et al*., 2025).

The mean concentration obtained for Zinc was 1.12 mg/kg at Irintan, 1.36 mg/kg at Omi-Eye, and 0.88 mg/kg for Egbigbu. These values are higher than 0.30-0.40 mg/kg reported by (Opaoluwa *et al*., 2012) but lower than 20.19-38.34 mg/kg reported for similar work by (Yaradua *et al*., 2020). Zn is a trace metal that is essential for human health (Allyson *et al*., 2014). Higher intake of the metal can lead to suppression of Cu and Fe absorption, gastrointestinal irritation and interference of physiological processes (Sahu and Kacholi, 2016).

The mean concentration for Cr at Irintan, Omi-Eye and Egbigbu floodplains was 0.09, 1.04 and 0.44 mg/kg respectively.

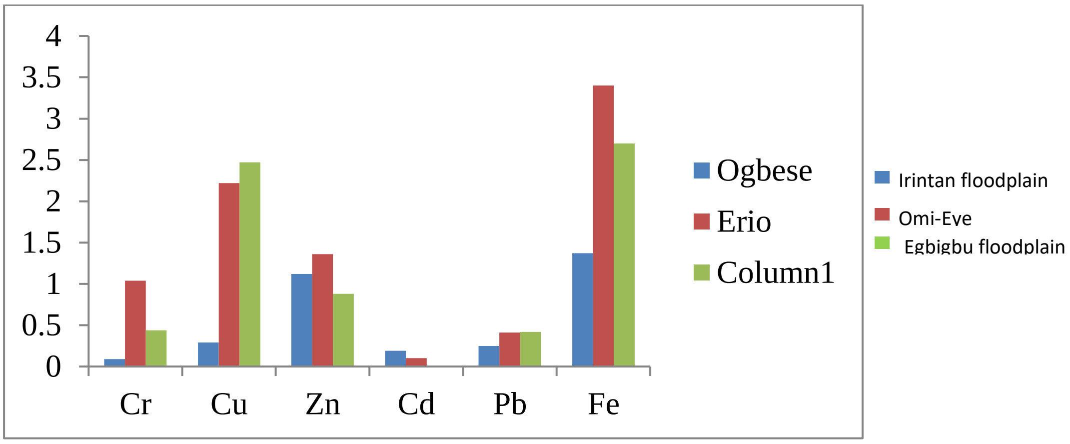

Figure 1: Comparison of Heavy Metal Overall Mean Concentration at the Sites

The values are consistent with similar works reported by Ahaneku and Sodiq, (2014) with the range 0.12-0.16 mg/kg and (Yaradua *et al*., 2020) with the range of 0.09-0.34 mg/kg, but lower than the ones reported by (Ekmekyyapar *et al*., 2014) with 14.0-108.0 mg/kg and (Mihaileanu *et al*., 2019) with 14.0-98.0 mg/kg. Chromium is one of the less common elements and does not occur naturally in elemental form but only in compounds (Musa *et al*., 2017). Major sources of Cr contamination include releases from electroplating processes and disposal of Cr containing wastes (Shanker *et al*., 2005; Musa *et al*., 2017).

The mean concentration of Pb at Irintan, Omi-Eye and Egbigbu floodplains was 0.25, 0.41 and 0.42 mg/kg respectively. The values are similar to 0.31 mg/kg reported for agricultural soils in Lafia, Nassarawa State by (Opaluwa *et al*., 2012), Maiduguri, Borno State Nigeria and by (Abdulateef *et al*., 2014) with 0.43 mg/kg. But the values are lower than those reported for Pb concentration in agricultural soils in Bosso, Chanchaga, GidanKwano in Minna, Nigeria (Ahaneku and Sodiq, 2014) with the range of 6.42-26.32 mg/kg. The values are equally lower than 6.77 mg/kg obtained for soil in Faisalabad, Suxian County, South China (Farid *et al*., 2015). Lead is particularly a dangerous metal due to its ability to accumulate in organisms (Musa *et al*., 2017).

The mean concentration of Cu at Irintan, Omi-Eye and Egbigbu was 0.29. 2.44 and 2.47 mg/kg respectively. The values are comparable with the report of (Ahaneku and Sodiq, 2014) with 7.99mg/kg but far less than the one reported by (Quishlaqi and Moore, 2007) with the range of 24.8-188.2 mg/kg. Copper is an essential micronutrient required in growth of both plant and animals (Wuana and Okieimen, 2011). In plants, Cu is especially important in seed production, disease resistance and regulation of water. Cu in high doses can cause anaemia, liver and kidney damage and stomach and intestinal irritation in man (Rahimzadeh *et al*., 2024).

The generally low metal values at the sites could be attributed lack of industries in the study areas. Heavy metal contamination of agricultural soils is known to be exacerbated by rapid urbanization and impacts of industrialization among other factors (Li *et al*., 2022, Kholikulov *et al*., 2025). Ekiti State is mainly an agrarian state with no industry comparable to those in Lagos, Kano or Rivers which are considered as industrialized states of Nigeria. Metals enter into environmental matrices from a variety of natural and anthropogenic sources with the largest release from industrial establishments (Saria, 2016). Increase in environmental concentrations of metals has been linked to effluent release mainly from metallurgical, refractory and chemical industries (Saria, 2016; Rahimzadeh *et al*., 2024). The overall site mean concentration of each metal was compared between floodplains (Fig. 3.1). It was observed that the highest mean values were recorded at Omi-Eye floodplain for Cr, Zn and Fe; Irintan recorded the highest mean values for Cd while Egbigbu recorded the highest mean for Cu and Pb. The mean concentration of metals at Irintan is in the order Fe > Zn > Cu >Pb> Cd > Cr as against the order in both Omi-Eye and Egbigbu which is Fe > Cu > Zn > Cr>Pb> Cd. Irintan floodplain was found to record the lowest mean concentration for a good number of the metals. This could be attributed to the location of the sites. Irintan floodplain, for instance, is located far away from the road when compared with both Omi-Eye and Egbigbu floodplains which are closer to the road. According to Yildiz *et al*., 2022, concentration of heavy metals on soils and vegetation reduces as the distance increases from the road.

Heavy Metal Pollution Status of the Floodplain Soils

The result of contamination factor (CF), degree of contamination (Deg. C) and pollution load index (PLI) for Irintan, Omi-Eye and Egbigbu floodplains are presented in Tables 3.5, 3.6, 3.7 respectively. The pollution load index (PLI) indicates the multi-elemental pollution load in soils to evaluate the quality of polluted sites, zones, or whole eco-systems (Uddin *et al*., 2021). In this study, the contamination factor, the degree of contamination and the pollution load index are all low for the farm soils (Abata *et al*., 2016). This shows that the sites under study are not contaminated with heavy metals. The low degree of contamination may be attributed to lack of industries in the area under study (Li *et al*., 2022, Kholikulov *et al*., 2025). The low pollution status as observed through this study is good as chances of heavy metals entering into the food chain through crops planted on the floodplains will equally be low. This should be encouraged and promoted by government organs responsible for monitoring the environment.

Table 5: Contamination Factor, Degree of Contamination and Pollution Load Index at Irintan Floodplain Soil

Distance	Depth (cm)	Cr	Cu	Zn	Cd	Pb	Fe	Deg. C	PLI
5m	0-10	0.0026	0.0111	0.0179	0.9000	0.0200	3.69E-05	1.2183	0.0087
	10-20	0.0024	0.0098	0.0170	0.7333	0.0040	3.46E-05	1.0665	0.0062
	20-30	0.0013	0.0029	0.0123	0.2330	0.0025	2.54E-05	0.3627	0.0030
25m	0-10	0.0007	0.0089	0.0143	0.8333	0.0185	3.50E-05	0.8757	0.0060
	10-20	0.0003	0.0069	0.0131	0.5333	0.0017	3.15E-05	0.5553	0.0030
	20-30	-	0.0047	0.0097	0.3667	0.0120	2.72E-05	0.3931	0.0133
45m	0-10	0.0007	0.0053	0.0007	0.0053	0.0007	3.65E-05	0.5337	0.0048
	10-20	0.0004	0.0049	0.0004	0.0049	0.0004	3.15E-05	1.0587	0.0038
	20-30	0.0002	0.0038	0.0002	0.0038	0.0002	1.67E-05	0.0159	0.0027

Deg. C= Degree of Contamination, PLI= Pollution Load Index

Table 6: Contamination Factor, Degree of Contamination and Pollution Load Index at Omi-Eye Floodplain Soil

Distance	Depth (cm)	Cr	Cu	Zn	Cd	Pb	Fe	Deg. C	PLI
5m	0-10	0.0136	0.1633	0.0276	0.7333	0.0285	1.17E-04	0.9664	0.0230
	10-20	0.0037	0.0396	0.0121	0.2667	0.0255	1.72E-04	0.3478	0.0113
	20-30	0.0011	0.0124	0.0064	-	0.0150	7.41E-05	0.0350	0.0068
25m	0-10	0.0198	0.1178	0.0110	0.9333	0.0260	6.74E-05	1.1080	0.0186
	10-20	0.0112	0.0637	0.0069	0.7333	0.0215	5.39E-05	0.8267	0.0181
	20-30	0.0071	0.0224	0.0026	0.2000	0.0115	2.83E-05	0.2436	0.0055
45m	0-10	0.0243	0.0584	0.0299	-	0.0205	9.09E-05	0.1332	0.0207
	10-20	0.0097	0.0162	0.0241	-	0.0185	4.06E-05	0.0685	0.0119
	20-30	0.0050	0.0051	0.0078	-	0.0175	2.24E-05	0.0354	0.0065

Deg. C= Degree of Contamination, PLI= Pollution Load Index

Table 7: Contamination Factor, Degree of Contamination and Pollution Load Index at Egbigbu Floodplain Soil

Distance	Depth (cm)	Cr	Cu	Zn	Cd	Pb	Fe	Deg. C	PLI
5m	0-10	0.0063	0.1416	0.0146	0.2000	0.0275	8.41E-05	0.3901	0.0198
	10-20	0.0042	0.0447	0.0114	0.2000	0.0255	5.83E-05	0.2859	0.0093
	20-30	0.0018	0.0260	0.0056	0.1000	0.0210	4.63E-05	0.1544	0.0054
25m	0-10	0.0059	0.1380	0.0136	0.2333	0.0370	7.78E-05	0.4279	0.0140
	10-20	0.0056	0.0664	0.0081	0.2000	0.0220	7.00E-05	0.3022	0.0095
	20-30	0.0050	0.0084	0.0081	0.0133	0.0100	4.22E-05	0.0448	0.0035
45m	0-10	0.0059	0.0520	0.0096	0.2000	0.0225	5.57E-05	0.2901	0.0095
	10-20	0.0056	0.0104	0.0083	0.2000	0.0135	4.54E-05	0.2378	0.0092
	20-30	0.0038	0.0069	0.0033	0.1000	0.0075	8.76E-05	0.1303	0.0042

Deg. C= Degree of Contamination, PLI= Pollution Load Index

CONCLUSION

All the contamination factors, degree of contamination, and pollution load indices showed that the floodplain soils of the studied sites were not polluted. However, since the metals studied are detected, it may portend danger for food safety if necessary measures are not put in place to forestall metals build up in the floodplains. To this end, it is recommended that regulatory authorities should be more proactive in monitoring our environment to ensure that heavy metal concentrations are kept low in order to safeguard public health. They should also ensure regular education of the people on danger of indiscriminate dumping of wastes in our city erosion line drainages as such wastes eventually end up polluting our rivers and floodplains. Aside these, government is encouraged to explore the use of remediation techniques to mop up the metals so as to ensure food produced from the floodplains are safe for the teeming population. Moreover, further researches on assessing heavy metals concentration in floodplain soils in the state are suggested to include other toxic metals not covered in this study.

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