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Studies of Contaminant Factors of Heavy Metals Content in Subsistence Farmlands at Akinyele Local Area in Oyo State, Southwestern Nigeria Using Geochemical Indices

Adetoro Temitope Talabi[1], Rasak Kola Odunaike[1], Oladapo Ajiboye[2]
[1]Department of Physics, Olabisi Onabanjo University, Nigeria
[2]Department of Physics, KolaDaisi University, Nigeria
Corresponding Author: Oladapo Ajiboye; Email: oladapo.ajiboye@koladaisiuniversity.edu.ng

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ABSTRACT

The consumption of heavy metals through the ingestion of food is a growing concern in developing countries where monitoring of the environmental content of heavy metals has not been given the desired attention. This research work aims at determining the public health risks and safety of farm products in terms of their residual heavy metal burdens from five subsistence farmlands in the Akinyele area. Analysis of concentrations of Cd, Cu, Cr, Pb, Fe, and Zn in soil samples from the study area was conducted using a flame atomic absorption spectrophotometer. The pH of the samples was measured in situ using pH meter while soil organic matter was determined using the loss of ignition method. Geochemical indices were used to determine the concentration trend of heavy metals in the soil samples. Correlation analysis was performed to establish the relationship between the metals. The concentrations of all the heavy metals were below the maximum permissible limit stated by WHO/FAO. The soil pH ranged from 7.36 to 8.38 indicating that the study area is slightly alkaline. The soil organic matter content ranged from 1.637% to 2.1% indicating that the soil from the study area are mineral soils. Geochemical indices revealed that all the sampling sites were uncontaminated except Site A, B, and E with moderate contamination of Cd. Correlation studies between the analyzed variables revealed the common origin of all metals. The study area can be recommended for farming purposes. However, more farmlands should be tested to determine their residual heavy metal concentrations.

INTRODUCTION

Heavy metals are naturally occurring substances and are present in our environment. They are present in air, water, and soil which are of high relevance to humans both biologically and industrially. Their multiple industrial, domestic, agricultural, medical, and technological applications have also led to their wide distribution in the environment which raises concern over their potential effects on human health and the environment (Tchounwou et al., 2012).

Heavy metals such as Iron, Copper, and Zinc are essential components of many alloys, pipes, wires, and tires in motor vehicles and are released into the environment as a result of mechanical abrasion on the roads (Atayese et al., 2008). The metallic pollutants in the air eventually precipitated on the ground surface depending on wind flow patterns and increased their concentration in adjacent areas (Al-jibury & Salman, 2016). Accumulation of heavy metals poses negative health effects to humans in excess exposure. They include Arsenic (As), Chromium (Cr), Cobalt (Co), Lithium (Li), Lead (Pb), Mercury (Hg), Cadmium (Cd), and even Iron (Fe).

It is however of note that some heavy metals such as Co, Fe, Zn, and others that are dense and toxic are also required micronutrients in humans and other organisms. These essential heavy metals are needed to support key enzymes in the body. It also acts as cofactors and helps in oxidation-reduction reactions in the body (Asif et al., 2020;

Witkowska et al, 2021). This class of heavy metals are sometimes referred to, as *Trace metals* or *Trace minerals* as they are of health benefits. The major environmental problem with heavy metals is that they are unaffected during the breakdown of organic waste and have toxic effects on living organisms when they exceed a certain concentration. Therefore, heavy metals are known as non-biodegradable and persist for long durations in terrestrial and aquatic environments.

The high concentration of heavy metals in soil is reflected by their concentration in plants, water, animal, and human bodies. They might be transported from soil to ground waters or may be absorbed by plants, including agricultural crops and animals (Zerihun et al., 2015; Rai et al., 2019; Sandeep et al., 2019).

Over the past decades, there had been concerns about the effects of different pollutants such as trace metals, pesticides, oil, and fertilizers and their impacts on environmental compartments with emphasis on soil, plants, and water. Industrialization and urbanization are believed to contribute largely to soil and groundwater contamination and these have great consequences on the environment (Adedosu et al., 2013). Sources of groundwater pollution include industrial waste, leakage from waste containment facilities, leakage of underground storage tanks, and the intersection of surface and groundwater (Latha et al., 2016).

Past studies have shown that human exposure to the high concentration of heavy metals leads to their accumulation in the human body. At low concentrations, they also have long-term negative cumulative health effects. For example, bioaccumulation of Lead in the human body interferes with the functioning of mitochondria, thereby impairing respiration and also causes constipation, swelling of the brain, paralysis, and eventual death (Belatar et al., 2018; Ogunmodede et al., 2013; Muiruri et al., 2013).

Crops and livestock grown in polluted environments tend to absorb trace elements at higher concentrations thereby causing a serious risk to human health when such crops or livestock are consumed (Caylak & Tokar, 2012; Oyelola & Babatunde, 2008). The prolonged consumption of unsafe concentrations of heavy metals through ingestion of food may lead to chronic accumulation of heavy metals in the kidney and liver of humans. This disrupts numerous biochemical processes, leading to cardiovascular, nervous, kidney, and bone diseases (Talabi et al., 2020; Ali & Al-Qahtani, 2012). This calls for concern most especially in developing countries where research efforts towards monitoring the environment have not been given the desired attention by the government and other stakeholders.

It is on this note that the assessment of soil samples from the selected farmlands in the study area becomes necessary to ascertain the safety and suitability of the study area for farming as soil nutrients are naturally absorbed in farm products which are subsequently consumed by humans. The areas under study have no industrial activity with little vehicular emission as the farms are at a far distance to heavy traffic routes. The use of herbicides and fertilizers is very minimal and as such they are not expected to contribute to heavy metal concentration levels in the study areas.

Most of the kinds of literature reviewed from different journals attributed the high concentration of heavy metals in their study areas to anthropogenic activities influenced by industrialization and urbanization. Their research was mostly conducted in urban and industrial areas. This study, however, tends to deviate by focusing on rural subsistence farmlands where mechanization and use of technology are minimal. Thus, it is expected that if any significant heavy metal content is found, it will be largely due to the composition of the soil.

This study, therefore, aims to determine the public health risks and safety of farm products from the study area in terms of their residual heavy metal burdens. The objectives of this study are to determine the concentration levels of residual heavy metals in the soil samples from the study area; compare the concentration levels with maximum permissible limits as stated by WHO/FAO and advise and recommend accordingly if the products from these farmlands are suitable for consumption.

MATERIALS AND METHODS

Study Area

Five subsistence farms in the Akinyele district of the Akinyele Local Government District were the subject of the study. The Akinyele district is located between latitudes 7.467° and 7.802°N and 3.743° and 4.002°E, respectively. It is a border settlement between Ibadan and Oyo Town. The study area is predominated by Hausa and Yoruba farmers, traders, artisans, and craftsmen. Nonetheless, it should be noted that the inhabitants of Agede village are mainly Igede people from Benue state. The majority of the farming in these villages is subsistence-based and non-mechanized.

Sample Collection

Five subsistence farmlands with no record of the chemical application nor mechanical input and minimal anthropogenic activities were identified in the study area. Table 1 shows the detailed information about the sampling location.

Table 1. Depicts detailed information of the sampling sites

Site	Description of Location	GPS Coordinate
Site A	Mixed farmland of maize and cassava at the KolaDaisi University farm area	7.625N / 3.911E
Site B	Cassava farmland at Agede village	7.633N / 3.894E
Site C	Maize farmland at Onidundu village	7.626N / 3.923E
Site D	Sweet potato farmland at Apaapa-Odan	7.621N / 3.937E
Site E	Beans farmland at Akinyele settlement	7.622N / 3.917E

Preparation and analysis of samples

The standard methods described by Ojo et al. (2015) for the determination of concentrations of metals in soil and soil pH were adopted. The pH of the soil samples was taken *in situ*. The organic matter content was determined using the loss of ignition method adopted from Ogunmodede et al., (2013). Blanks for all the analyses were prepared and carried through the same experimental procedures as the samples. They were analyzed and subtracted from the results of the samples. This was done to check reagent impurities and other interferences. The digested samples were analyzed for Zn, Cu, Pb, Cd, Cr, and Fe using buck scientific model PG 990 flame atomic absorption spectrophotometer.

Geochemical Indices

This study used the contamination factor (CF) and geo-accumulation index (Igeo) as described by Muller (Amadi and Nwankwoala, 2013). Contamination factor (CF) and geo-accumulation index (Igeo) are quantitative checks used to describe the concentration trend of metals in soils. CF is a quantifier of relative to either the average crustal composition of the respective metal or to measured background values from geologically similar and uncontaminated areas (Tijani et al., 2004).

The contamination factor is expressed as:

$$CF = \frac{Ci}{Bi}$$

Where Ci is the mean concentration of metal *i* in soil and Bi is the background concentration (value) of metal *i*, either taken from the literature (average crustal abundance) or directly determined from a geologically similar material. The categorization of contamination factor is classified as: CF < 0: Not contaminated; 0 < CF < 1: Low contamination; 1 < CF < 3: Moderate contamination; 3 < CF < 6: Considerable contamination; 6 < CF < 9: High contamination; and 9 < CF < 12: Very strong contamination. The categorization was adopted from Olatunde et al., (2015).

Geo-accumulation index (Igeo) was introduced by Muller in 1979 and has been widely employed in trace metal studies. It enables the assessment of environmental contamination by comparing differences between current and pre-industrial concentrations.

$$Igeo = \log 2 \frac{Ci}{1.5Bi}$$

Where Ci (mg/Kg) is the measured concentration of metal *i* in the soil, 1.5 is a factor used to minimize possible variations in the background value of metal *i*, and Bi is the background value for the studied metal. The reference values of Nazzal et al. (2021) were used, and the index of enrichment as defined by Muller (Amadi and Nwankwoala, 2013) was adopted.

Statistical Analysis

Pearson correlation (r) analysis was used to analyze and establish the relationship between the soil's heavy metal contents. All data analyses were performed using Microsoft Excel, 2016.

RESULTS AND DISCUSSION

Table 2 shows the statistical summary of results from the analyses of Cd, Cu, Zn, Cr, Fe, Pb, pH, and soil organic matter (SOM) obtained from each sampling site. The concentrations of the heavy metals were compared with standard permissible limits recommended by WHO/FAO in Table 3. Geochemical indices of the heavy metals were calculated and depicted in Table 4, while Table 5 shows the correlation studies between the analyzed variables.

Table 2. Depicts a statistical summary of the results of the analysis per sampling site

Site/Parameters (mg/Kg)		Cd	Cu	Cr	Fe	Pb	Zn	pH	SOM
Site A	Sample 1	1.341	0.016	0.039	0.028	2.610	0.101	7.740	1.730
	Sample 2	1.002	0.024	0.055	0.033	0.200	0.136	7.920	1.650
	Sample 3	1.709	0.020	0.034	0.052	2.191	0.098	7.860	1.710
	Mean	1.350	0.020	0.043	0.038	1.667	0.112	7.840	1.697
	Variance	0.125	0.000	0.000	0.000	1.658	0.000	0.008	0.002
	S. D	0.354	0.004	0.011	0.012	1.288	0.021	0.092	0.042
	Max	1.709	0.024	0.055	0.052	2.610	0.136	7.920	1.730
Site B	Sample 1	1.002	0.066	0.081	0.100	2.002	0.11	7.400	1.730
	Sample 2	0.088	0.045	0.069	0.103	0.431	0.043	7.360	1.580
	Sample 3	0.094	0.051	0.066	0.092	3.001	0.061	7.710	1.810
	Mean	0.395	0.054	0.072	0.098	1.811	0.071	7.490	1.707
	Variance	0.277	0.000	0.000	0.003	1.678	0.001	0.037	0.014
	S. D	0.526	0.011	0.008	0.006	1.296	0.035	0.192	0.116
	Max	1.002	0.066	0.081	0.103	3.001	0.110	7.710	1.810
Site C	Sample 1	0.053	0.107	0.048	0.108	0.200	1.050	8.370	1.630
	Sample 2	0.051	0.121	0.073	0.068	1.090	1.063	7.920	1.740
	Sample 3	0.089	0.100	0.070	0.098	1.139	1.017	8.020	1.540
	Mean	0.064	0.109	0.064	0.091	0.810	1.043	8.103	1.637
	Variance	0.000	0.000	0.000	0.000	0.279	0.001	0.056	0.010
	S. D	0.021	0.011	0.014	0.021	0.529	0.024	0.236	0.100
	Max	0.089	0.121	0.073	0.108	1.139	1.063	8.370	1.740
Site D	Sample 1	0.059	1.632	0.050	0.046	1.503	0.085	7.860	1.860
	Sample 2	0.063	2.116	0.041	0.510	1.108	0.054	7.940	1.930
	Sample 3	0.091	1.649	0.058	0.048	1.469	0.077	7.830	2.100
	Mean	0.071	1.799	0.050	0.201	1.360	0.072	7.876	1.963
	Variance	0.000	0.075	0.007	0.071	0.048	0.000	0.003	0.015
	S. D	0.017	0.275	0.009	0.267	0.219	0.016	0.057	0.123
	Max	0.091	2.116	0.058	0.510	1.503	0.085	7.940	2.100
Site E	Sample 1	0.099	0.09	0.101	1.098	0.082	0.045	7.940	1.870
	Sample 2	1.983	0.081	0.043	1.100	1.066	0.061	8.130	1.920
	Sample 3	1.141	0.079	0.029	0.314	0.079	0.052	8.380	1.680
	Mean	1.074	0.083	0.057	0.837	0.409	0.053	8.150	1.823
	Variance	0.891	0.003	0.001	0.205	0.324	0.006	0.049	0.016
	S. D	0.944	0.006	0.038	0.453	0.569	0.008	0.221	0.127
	Max	1.983	0.090	0.101	1.100	1.066	0.061	8.380	1.920

The concentration of Cd in the study ranged from 0.059mg/Kg in Site C to 1.983mg/Kg in site E. Cadmium is a naturally occurring metallic element and it is one of the most toxic metals. It is extremely toxic and the use of soil high in Cd in cultivating vegetables and other food crops could cause adverse health effects such as renal disease and cancer (Occupational Safety and Health Administration [OSHA], 2013). When ingested, Cd accumulates in the intestine, liver and kidney, and chronic exposure of Cd results in kidney, bone, and lung disease (OSHA, 2013).

Copper is a trace mineral for healthy soils and plant growth (Adriano, 2001). It is released into the atmosphere through fossil fuel combustion, phosphate production, industrial settings, landfills, and waste disposals. The concentration of Cu in the study ranged from 0.016mg/Kg in Site A to 2.116mg/Kg in Site D. Copper toxicity in plants and soil can inhibit iron uptake and stunt growth. Excess soil copper can inhibit seed germination (Iqbal et al., 2018).

Chromium is carcinogenic by inhalation and corrosive to tissue (Ugwu et al., 2016). The concentration of Cr in the study ranged from 0.029mg/Kg to 0.101mg/Kg with both on Site E. The concentration of Pb in the study ranged from 0.079mg/Kg on Site E to 3.001mg/Kg on Site B. Pb is non-essential for plants and animals. It is toxic by ingestion. Its toxicity leads to anaemia by impairing haemo-biosynthesis and accelerating the destruction of red blood cell. In addition, it reduces sperm count, damages kidney, liver, blood vessels, nervous system, and other tissues in humans (Amadi & Nwankwola, 2013). Zinc is a common element in the earth's crust which is an essential element for normal crops' growth. The concentration of Zn in the study ranged from 0.043mg/Kg on Site B to 1.063mg/Kg on Site C.

Soil pH and the amount of soil organic matter are among the significant variables which control the distribution and enrichment of heavy metals in soils (Rahaman et al., 2015; Amadi and Nwankwola, 2013; Ogbonna et al., 2013). The soil pH was between 7.36 to 8.38 which indicated that the study area was slightly alkaline while the soil organic matter content ranged from 1.637% to 2.1% indicating that the soil from the study area are mineral soils according to the classification of soils by Pao-Tsung et al. (2009). Soil pH has been reported in several kinds of literature to be a major factor influencing the absorption of heavy metals by plants. The pH of soil solution maintained at neutral to slightly alkaline conditions showed low mobility of all heavy metals. Generally, the mobility of heavy metals in alkaline soils decreases in the order Cd > Zn > Cr > Cu >Pb and is highly variable and strongly dependent on the content and type of organic ingredients present in the soil (Zhang and Wang, 2007; Dorota et al., 2015). Sperdouli (2022) reported that though heavy metals may be present in the soil, they may not be available for plants absorption, hence have no effects on plants. Several factors determine the bioavailability and effects of heavy metals on plants which includes soil pH, soil organic content, and soil texture. Grubinger et al., (2011) also affirmed that the actual toxicity of heavy metal is largely affected by the soil texture, soil organic matter, and soil pH. Osakwe & Okolie (2015) reported that soil pH, amount of organic content (SOM), proximity to the vehicular road, and soil texture are factors that define the extent of heavy metal accumulation and distribution in soil. Ekmekyapar et al. (2012) also reported that high pH, organic matter content, and clay content increase the binding and accumulation of heavy metals in soil.

Soil organic matter is the organic component of soil which consist of organic materials from plant and animal residues that have been converted by micro-organisms in the soil at different stages of decomposition (Lavallee et al., 2020; Weng et al., 2022). It has direct benefits for agricultural and forestry production. Healthy soils with stable levels of soil organic matter are also better equipped to prevent and fight soil-borne diseases (Simpson & Simpson, 2017).

The values of all the analyzed heavy metals from this study were below the maximum permissible limits recommended by regulatory bodies such as World Health Organization (WHO) and the Food and Agricultural Organization (FAO) (Grubinger et al., 2011). Table 3 depicts these limits.

Table 3. Depicts maximum permissible limit of heavy metal concentrations in soil

Regulatory Bodies	Pb	Cd	Zn	Cr	Fe	Cu
WHO / FAO	100.0	3.0	300.0	100.0	50000.0	100.0
Dutch	85.0	0.8	50	100	-	36
China	80.0	0.5	250	-	-	-
Canada	200.0	3.0	500.0	-	-	-
US EPA	400.0	70	23,600.0	230	-	-
NYS -DEC	400	0.86	2200.0	22	-	270

NYS DEC – New York Department of Environmental Conservation
US EPA - US Environmental Protection Agency (Grubinger et al., 2011).

The contamination factors and geo-accumulation indices of the analyzed heavy metals in the study are detailed in Table 4.

Table 4. Depicts metal contamination factor and geo-accumulation index in the study area

	Ci (mg/Kg)	Bi(mg/Kg)	CF (Ci/Bi)	Igeo	Summary of contamination level
Site A					
Cd	1.350	0.15	9.0	2.584963	Highly contaminated
Cu	0.02	70.0	0.000286	-12.3581	Uncontaminated
Cr	0.043	122.0	0.000352	-12.0552	Uncontaminated
Fe	0.038	150.0	0.000253	-12.5316	Uncontaminated
Pb	1.667	16.0	0.104188	-3.84771	Uncontaminated
Zn	0.112	75.0	0.000848	-10.7878	Uncontaminated
Site B					
Cd	0.395	0.15	6.680	0.811928	Moderately contaminated
Cu	0.054	70	0.000943	-10.9251	Uncontaminated
Cr	0.072	122	0.000664	-11.3116	Uncontaminated
Fe	0.098	150	0.000687	-11.1649	Uncontaminated
Pb	1.811	16	0.187563	-3.72818	Uncontaminated
Zn	0.071	75	0.000833	-11.4454	Uncontaminated
Site C					
Cd	0.064	0.15	0.593333	-1.338	Uncontaminated
Cu	0.109	70	0.001729	-9.761	Uncontaminated
Cr	0.064	122	0.000598	-11.292	Uncontaminated
Fe	0.091	150	0.00072	-11.025	Uncontaminated
Pb	0.81	16	0.071188	-4.397	Uncontaminated
Zn	1.043	75	0.008053	-7.541	Uncontaminated
Site D					
Cd	0.071	0.15	0.473333	-1.66403	Uncontaminated
Cu	1.799	70	0.0257	-5.86705	Uncontaminated
Cr	0.05	122	0.00041	-11.8376	Uncontaminated
Fe	0.837	150	0.00558	-8.07048	Uncontaminated
Pb	1.36	16	0.085	-4.14136	Uncontaminated
Zn	0.072	75	0.001	-11.4252	Uncontaminated

Site E					
Cd	1.074	0.15	7.160	2.25499	Moderately contaminated
Cu	0.083	70	0.00119	-10.305	Uncontaminated
Cr	0.057	122	0.00047	-11.6486	Uncontaminated
Fe	0.837	150	0.00558	-8.07048	Uncontaminated
Pb	0.409	16	0.02556	-5.87479	Uncontaminated
Zn	0.053	75	0.00040	-11.8672	Uncontaminated

CF- contamination factor; Igeo- geo-accumulation index; Ci- mean concentration of the metal in the soil; Bi - average background value in uncontaminated soil, adopted from (Dineley et al., 1976). The calculated geochemical indices showed that Site A is highly contaminated with Cd at a CF value of 9.0. Site B and E are moderated contaminated with Cd at CF values of 6.680 and 7.160 respectively. Site C and D are uncontaminated. The geochemical indices for the other metals were below the contamination index value.

Table 5. Depicts the correlation analysis of all the variables from the study

	Cd	Cu	Cr	Fe	Pb	Zn	pH	SOM
Site A								
Cd	1							
Cu	-0.479	1						
Cr	-0.950	0.729	1					
Fe	0.757	0.210	-0.516	1				
Pb	0.758	-0.936	-0.923	0.148	1			
Zn	-0.889	0.828	0.987	-0.374	-0.972	1		
pH	-0.305	0.982	0.587	0.391	-0.852	0.708	1	
SOM	0.704	-0.96	-0.890	0.069	0.997	-0.951	-0.891	1
Site B								
Cd	1							
Cu	0.962	1						
Cr	0.981	0.891	1					
Fe	0.248	-0.024	0.432	1				
Pb	0.133	0.398	-0.062	-0.927	1			
Zn	0.967	0.999	0.899	0.759	0.813	1		
pH	-0.402	-0.138	-0.572	-0.987	0.854	-0.156	1	
SOM	0.179	0.439	-0.016	-0.909	0.999	0.423	0.829	1
Site C								
Cd	1							
Cu	-0.786	1						
Cr	0.359	0.296	1					
Fe	0.322	-0.839	-0.768	1				
Pb	0.5	0.143	0.988	-0.659	1			
Zn	-0.973	0.906	-0.135	-0.530	-0.288	1		
pH	-0.261	-0.392	-0.995	0.830	-0.967	0.033	1	
SOM	-0.861	0.991	0.167	-0.759	0.011	0.954	-0.268	1

Site D								
Cd	1							
Cu	-0.369	1						
Cr	0.782	-0.868	1					
Fe	-0.397	0.999	-0.882	1				
Pb	0.325	-0.999	0.843	-0.997	1			
Zn	0.157	-0.976	0.738	-0.968	0.985	1		
pH	-0.625	0.956	-0.975	0.965	-0.941	-0.869	1	
SOM	0.985	-0.204	0.664	-0.234	0.158	-0.015	-0.482	1
Site E								
Cd	1							
Cu	-0.806	1						
Cr	-0.798	0.999	1					
Fe	-0.059	0.639	0.649	1				
Pb	0.832	-0.342	-0.33	0.504	1			
Zn	0.991	-0.72	-0.710	0.074	0.899	1		
pH	0.485	-0.909	-0.914	-0.902	-0.081	0.364	1	
SOM	0.137	0.476	0.488	0.981	0.663	0.267	-0.8	1

Cadmium showed a strong positive correlation with Pb and SOM in Site A; Cu, Cr, and Zn in Site B; Cr and SOM in Site D, and Pb and Zn in Site E. However, it showed a strong negative correlation with Cr and Zn in Site A; Cu, Zn, and SOM in Site C, and; Cu and Cr in Site E as shown in Table 5. Copper had a strong positive correlation with Cr, Zn, and pH in Site A; Cd, Cr, and Zn in Site B; Zn and SOM in Site C; Fe and pH in Site D and Cr and Fe in Site E. It showed a strong negative correlation with Pb and SOM in Site A; Cd and Fe in Site C; Cr, Pb, and Zn in Site D, and Cd, Zn, and pH in Site E.

Chromium had a strong positive correlation with Pb in Site A; Zn in Site B; Pb in Site C; Cd, Pb, and Zn in Site D, and Cu in Site E. However, it showed a strong negative correlation with Cd, Pb, and SOM in Site A; Fe and pH in Site C; Cu, Fe, and pH in Site D and; Cd, Zn, and pH in Site E.

Iron showed a strong positive correlation with Cd in Site A; Zn in Site B; pH in Site C; Cu and pH in Site D and; SOM in Site E. However, it showed a strong negative correlation with Pb, pH, and SOM in Site B; Cu, Cr, and Pb in Site D and; pH in Site E.

Lead showed a strong positive correlation with Cd and SOM in Site A; Zn, pH, and SOM in Site B; Cr in Site C; Cr and Zn in Site D and; Cd and Zn in Site E. However, it showed a strong negative correlation with Cu, Cr, Zn, and pH in Site A; Fe in Site B; pH in Site C, and; Cu, Fe, and pH in Site D.

Zn showed a strong positive correlation with Cu, Cr, and pH in Site A; Cd, Cu, Cr, Fe, and Pb in Site B; Cu and SOM in Site C; Cr and Pb in Site D and; Cd and Pb in Site E. However, it showed a strong negative correlation with Cd, Pb, and SOM in Site A; Cd in Site C; Cu, Fe, and pH in Site D and; Cu, and Cr in Site E.

The soil pH had a strong negative correlation with Pb in Site A, B, C, and D. Its correlation with Pb was positive in Site C. A strong correlation was also observed between soil pH and Cu in Sites A, D, and E. Soil organic matter showed a strong positive correlation with Cd and Pb in Site A; Pb and pH in Site B; Cu and Zn in Site C; Cd in Site D and; Fe in Site E. It showed a strong negative correlation with Cu, Cr, Zn, and pH in Site A; Fe in Site B; Cd and Fe in Site C; Cd in Site D and; pH in Site E.

CONCLUSION

The findings from this research showed very low concentration levels of all the assessed heavy metals as against the permissible maximum limit by WHO. The low standard deviation and variance of all the heavy metals indicated a homogeneous distribution of the metals in the study area. The mean concentration values of all the heavy metals obtained from all the sampling sites were below the average crustal abundance (Bi) in uncontaminated soil except Cd in Site A, B, and E. The calculated CF and Igeo for all the sampling sites indicated that the soil at the sampling sites was uncontaminated except Cd in Site A, B, and E. This is largely due to the absence of anthropogenic activity around the study area. It is however necessary that there should be regular monitoring of our environment to detect heavy metal pollution. Also, steps should be taken to reduce human activities that generate heavy metals. Agricultural farmlands should be tested to determine their heavy metal content and ensure that they are within safe limits. Like-wisely, agricultural farms should not be located close to highways to prevent excessive build-up of heavy metals from the vehicular exhaust. Lastly, further extensive sampling is advised in similar sampling areas to ascertain heavy metal concentration levels on our farmlands.

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