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Assessment of Chickens Fed with Solid Wastes in Terms of Heavy Metal Contents in Zaria Metropolis, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author SU designed the study managed the literature searches performed the statistical analyses, discussed the results and wrote the first draft of the manuscript. Author AU approved the designed and supervised the experiments while authors HA and MSS read the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The concentrations of Zn, Pb, Cu, Cd and Hg were spectrophotometrically determined in local chickens that were fed with the solid wastes for three months and dumpsite-soils in both dry and wet seasons. Dumpsite-leachates were analysed in wet season only across the sites. A total of four hundred and thirty two samples of chicken organs, leachates and soil samples were investigated. The trend in the bio-availabilities of the metal ions in the analysed samples was; soils > leachates > organs with the exception of mercury. Overall, the order of the bioavailability of these metals in the analyzed samples across the sites and seasons was; Hg > Cu > Cd > Pb > Zn. The concentrations of mercury, cadmium and lead in the chicken-organs were all above the FAO/WHO (1986) recommended limits for human consumption across the sites. However, the concentrations recorded for copper and zinc were below the safe limits some of the dumpsite chicken organs. Overall, significant differences of the metal ion concentrations in the analysed samples across sites and seasons at $p<0.05$ were recorded, thus, consuming chickens grown in these dumpsites might pose a serious health threats to consumers due to metal ion bioaccumulation through the food chain.

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Keywords: Heavy metals; dumpsite environment; chicken-organs; bioaccumulation.

1. INTRODUCTION

Chicken meat is a major source of protein to the population and is widely used in Nigeria and other countries of the world. The residents of the dumpsites usually rear local chicken that rely on the dumpsites for their feeds on daily basis contaminating their meat products. In Nigeria, chicken meat is among the major source of protein to the population and is widely consumed. It has been found that the main source of metals in chicken and chicken meat is chicken-feeds and drinking water [1].

The risk of heavy metals contamination in meat is of great concern for both food safety and human health because of the toxic nature of these metals at relatively minute concentrations [2,3]. Some heavy metal ions like Al, As, Cd and Pb are known to be potentially toxic than essential metal ions such as Fe, Mn, Cu, Zn, Si, Ni and Co. Toxic elements can be harmful even at low concentrations when ingested over a long period of time [4,5].

In recent times, it has been reported that heavy metals from solid wastes accumulate and persist in soils at environmentally hazardous level [6-8]. Municipal refuse may increase heavy metal concentrations in soil and underground water [9-11] which may have effects on the host soils, crops and human health [12,13]. Thus, the environmental impacts of municipal refuse are greatly influenced by their heavy metal contents. The local chicken owned by the residents of the dumpsites normally feed on the dumpsites on daily basis resulting in the transfer of toxic metals to human through the food chain.

Heavy metals from anthropogenic sources are continually released into aquatic and terrestrial ecosystems and therefore the concern about the effect of man-made pollution on the ecosystem is very alarming [14]. These metals are potential environmental contaminants with the capability of causing human health problems due to their toxicity and bioaccumulation in the food chain [14]. These pollutants often have direct physiological toxic effects because they are stored or incorporated in tissues of both vertebrates (chickens, humans, animals etc) and the invertebrates (the earthworms etc).

Bird population are particularly susceptible to the effects of anthropogenic activities on the environment. Several biological and physiological processes such as eating habits, growths, age, breeding, moulting may influence metal concentrations and distribution in birds [15]. The data on the trace element levels in chicken feeding on dumpsites soils and leachates has been scarce especially in Nigeria.

Zaria metropolis is located at latitude 11°3' N and longitude 07°40' N and is presently one of the most important cites in Northern Nigeria. As at 2007 census, it had a population of 1,018,827 [16]. Like many cities in Nigeria, Zaria faces problems of environmental sanitation such as improper disposal of refuse near residential areas, poor refuse collection and handling etc. For example, it is common practice to find huge refuse dumpsites within residential areas and along some minor and major roads.

The aim of this paper therefore is to report the concentrations of Zn, Pb, Cu, Cd and Hg in dumpsites soils, leachates and chickens fed with the solid wastes both across the sites and seasons with a view to establishing the relationship between these environmental samples and their bioaccumulation which might results in adverse human health effects through the food chain.

2. MATERIALS AND METHODS

Soils, leachates and chicken samples were collected from four main settlements in Zaria metropolis as shown in Fig. 1. The dumpsites, their abbreviations and various activities occurring at these sites are presented in Table 1 and Fig. 2 shows one of the sampling site.

2.1 Quality Assurance

All reagents used were of analytical grade, double distilled de-ionized water was used and All the glasswares and polythene sample bottles were washed with liquid soap, rinsed with water, soaked in 10% HNO_3 for 24 hrs and then rinsed thoroughly with double distilled de-ionized water and dried [17]. The analytical results obtained were validated with spiked samples.

2.2 Calibration Curves

Working standards were prepared from the stock solution of each metal and calibration curves of the standard solutions were plotted. Good linearity of all the calibration curves were obtained and used in the qualitative analysis [18,19].

2.3 Sample Collections

The dumpsite in each case was divided into four quadrants [20] and the samples were collected from each site with the aid of an anger stainless spoon at 0–15 cm depth. The collected samples were placed in polythene bags, labelled and a total of sixty three soil samples were collected across the seasons (dry and wet seasons) were collected February to August, 2011 while leachate samples were collected in the wet season only from across the sites from June to August, 2011 in a well labeled clean polythene bottles that were rinsed with the leachates prior to sample collections. A total of thirty three leachate samples were collected and used for the analyses. The samples for mercury analysis were collected in glass bottles [21]. The chicken samples were bought three months to the sampling periods and then fed with the solid-wastes and leachates. They were slaughtered and various organs were removed and labelled.

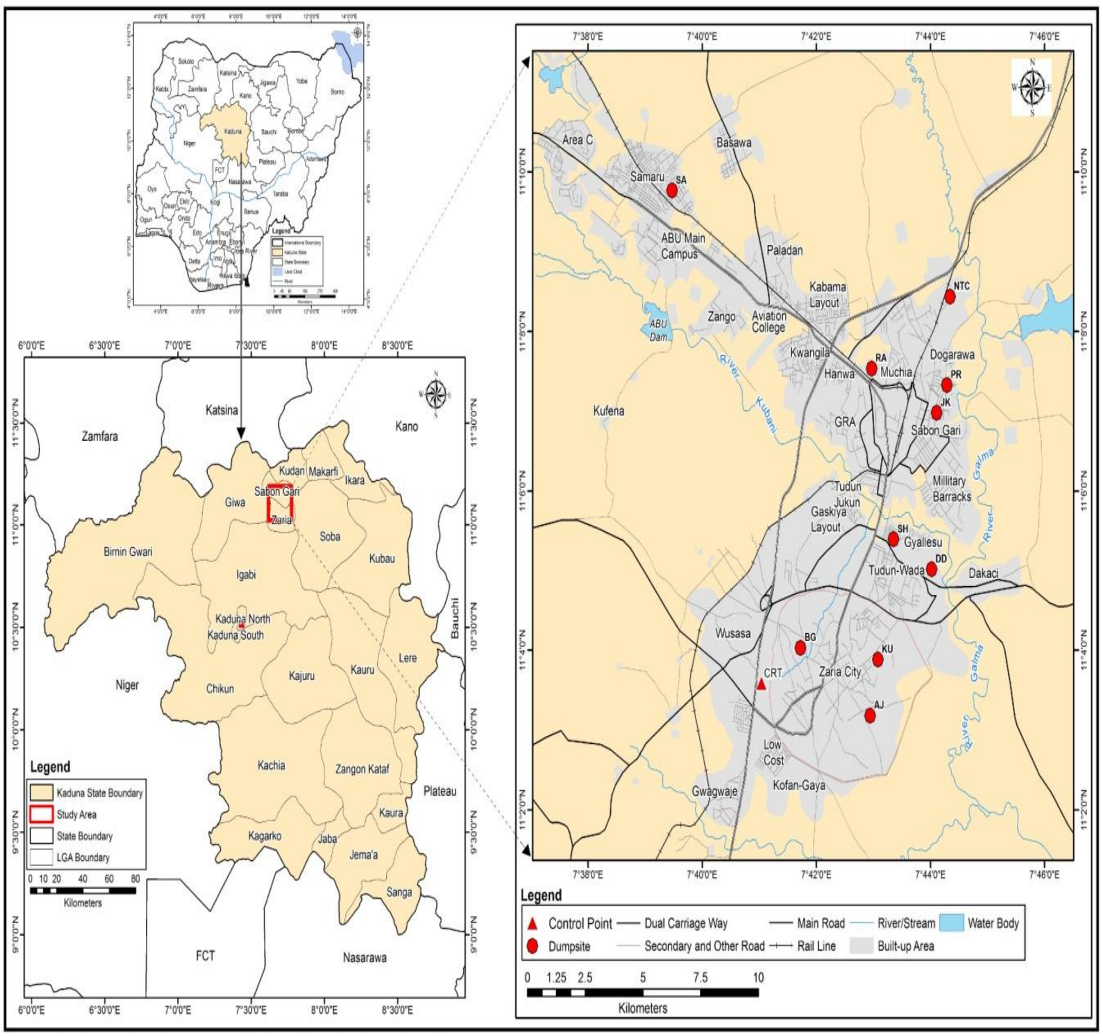

Fig. 1. Map of Zaria showing the sampling sites

Table 1. Shows dumpsites descriptions and their respective abbreviations

Dumpsites	Abbreviations	Descriptions
Railway Station	RA	This dumpsite is located in Sabon Gari L.G. A. Most of the wastes deposited at the dumpsites are from household in Sabon Gari and the saw mill giving rise to a big mountain of garbage.
Samaru	SA	This dumpsite is located at Samaru, Sabon Gari L.G.A. Dumping at the site is unrestricted and domestic wastes are seen all over the dumpsite
Alkali Jae	AJ	This dumpsite is located close to some minor roads. Dumping at the site is restricted to domestic wastes
Prince road	PR	The location of this dumpsite is at Sabon Gari. Tonnes of wastes are deposited on this dumpsite on daily basis. The source is domestic.
Nigerian Tobacco Company	NTC	This dumpsite is located in Sabon Gari. Tonnes of wastes generated by Nigerian Tobacco Company (NTC) are being dumped as well as those from the residential areas.
Dandaji	DD	Dandaji dumpsite located in Tudun Wada, Zaria. Refuse dumps from residential areas are largely the major sources of wastes.
Shafi	SH	This dumpsite is located in Tudun wada, Zaria. Dumping at this site is unrestricted and domestic and agricultural wastes were seen all over the dumpsite.
Kusfa	KU	The dumpsite was located in Zaria city, Zaria. Wastes generated and collected from various locations are deposited on a daily basis.
Jeka da kwarinka	JK	This dumpsite is located in Sabon Gari, Zaria. Dumping at this site is unrestricted and domestic wastes were seen all over the dumpsite.
Babban gwani	BG	This dumpsite is located in zaria city. Dumping at the site is unrestricted and domestic and agricultural wastes are seen over the dump site.
Control	CTR	This is located about 100 m from Kusfa dumpsite and no dumping activities is taking place.

2.4 Samples Pre-treatment

2.4.1 Soil

Soil samples from each site were homogenized and air dried in a circulating air in the oven at 30ºC overnight and then passed through a 2 mm sieve. The sieved soils were placed in polythene bags and then labeled prior to analyses. Leachate samples collected were kept in ice and then transported to the laboratory for analysis [18]

2.4.2 Chicken organs

The chickens were slaughtered and various tissues and organs were separated, kept in the polythene bags and labelled. They were then immediately preserved in a refrigerator prior to digestion [22]. Fig. 3 shows a sample of various organs and tissues of the analysed chickens.

2.5 Samples Digestion

2.5.1 Soil

5.0 g of the soil was weighed into 100 ml beaker, 10 ml concentrated nitric acid was added and the mixture in the beaker was covered with a watch glass and reflux for 45 minutes. The watch glass was removed and the content evaporated to dryness. 5ml aqua-regia was added and the mixture was evaporated to near dryness again. 10 ml of $1MHNO_3$ was added and the suspension was then filtered. The filtrate was diluted to volume with distilled water in a 50 ml volumetric flask. Triplicate digestion of each sample was made together with the blank [18].

2.5.2 Leachates

50 ml of leachate samples was placed in a beaker or flask and 30 ml of concentrated HNO_3 was added and then covered with a watch glass. The flask was then placed on a hot-plate and cautiously evaporated to less than 5 ml ensuring that no area of the flask was allowed to dry. The digest was then allowed to cool, the wall of the flask was rinsed with de-ionised water. 5 ml of concentrated HNO_3 was again added to the flask and placed on the hot-plate. The temperature was increased to allow a reflux to occur which will be noticed when the digest is light colour or does not change in appearance with continued refluxing. 10 ml conc. HCl and 15 ml de-ionised water was added in 100 ml anticipated volume. The solution was then re-heated for additional 15 minutes to dissolve any precipitate or residue. The digest was then cooled filter and made up to 100 ml with distilled water [21].

Fig. 2. One of the dumpsites in Zaria City

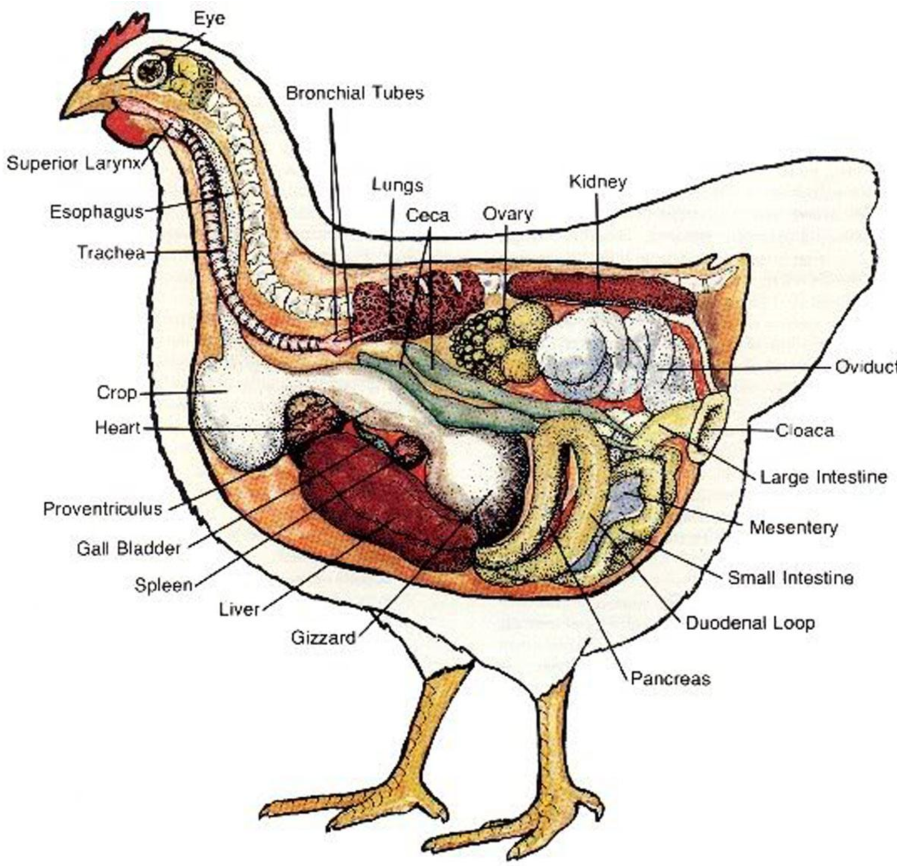

Fig. 3. A chicken sample showing the various tissues and organs analysed

2.5.3 Digestion of chickens' organs

2.0 g of each organ (oesophagus, lungs, bones, kidney, intestine, head, gizzard, feather, wattles, skin, heart, muscles, legs, liver and brain) was weighed into a beaker and then pre-digested with 10 ml concentrated HNO_3 on a hot plate at 135°C until liquor was clear. Then 10 ml of HNO_3, 1 ml concentrated $HClO_4$ and 2 ml H_2O_2 were added and heated on a hot plate still maintaining the temperature at 135ºC for 1hour until the liquor became colorless. The digests were filtered into 100 ml standard flask and diluted to 25 ml with 1M HNO_3 [22].

2.6 Samples Analyses

The digests of the samples were analyzed at Multi-User Science Research Laboratory, Ahmadu Bello University, Zaria by Atomic Absorption Spectrophotometry (AA650 Varian) for Zn, Pb, Cu, Cd and Hg contents.

2.7 Statistical Analysis

The data was analysed by using statistical package for social science (SPSS) package version 12.0 and the Microsoft Excel spreadsheet.

3. RESULTS AND DISCUSSION

The analytical results obtained of the present study were validated with samples spiked with multi-element standard solutions. The analytical precision was confirmed through the triplicate analysis throughout the study and the results of the percentage recoveries computed and presented in Table 2. In the case of soil samples as shown in Table 2, the highest percentage recovery was recorded for Zn metal ion 98.10% while Cu had the least percentage recovery of 85.02%. The trend in percentage recovery of the metals in the soil sample was Zn > Cd > Hg > Pb > Cu. Furthermore, in the case of dumpsite-leachates, the trend was Zn > Cd > Pb > Hg > Cu and the highest and lowest recoveries of

99.98 and 98.40% were recorded for Zn and Cu, respectively.

Table 2. Mean (±SD) percentage recovery of metals for the aqua-regia digestion

Metal	Leachate (%)	Soil (%)
Pb	99.4	90.07
Cu	98.4	85.02
Cd	99.9	97.85
Zn	99.98	98.10
Hg	99.35	95.00

Tables 3-5 showed the concentrations of some selected heavy metals in soils (dry and wet) and leachates (wet season) feeding on the dumpsites. The range of Zn, Pb, Cu, Cd and Hg in the dumpsite-soils of the study areas ranged from 122.575 (DD) – 371.303 $mgkg^{-1}$ (NTC), 18.357 (NTC) – 160.443 $mgkg^{-1}$ (SH), 5.895 (BG) – 60.74 $mgkg^{-1}$ (JK), 0.962 (SH) – 2.958 $mgkg^{-1}$ (AJ) and 85.591 (DA) – 233.993 $mkkg^{-1}$ (BG). These concentrations were all below the permissible limits of 300, 300, 100, 5 and 2 $mgkg^{-1}$. The highest and lowest concentrations were observed at the NTC and DD dumpsites respectively. The highest and lowest concentrations of zinc were recorded at the SA and DD-dumpsites chicken-organs across the sites and season respectively. The metal concentrations during the dry seasons exceed the tolerable limit of 300 $mgkg^{-1}$ while those in the rainy seasons were below this limit, this was attributed to leachability of the metals especially during the rainy season. There was a significant difference between the concentrations of zinc across the sites at $P<0.05$. This showed that the solid wastes at these dumpsites contained significant amount of zinc coming from the same source.

Furthermore, the concentration ranges of lead recorded were highest at the SH-dumpsite and lowest at the NTC dumpsite. The values recorded at the NTC-dumpsite were below the minimum tolerable limit of 100 $mgkg^{-1}$ during the rainy season. However, the concentrations of lead recorded at the dry season were higher than the concentration recorded during the wet season, this was attributed to an increase in the lead-containing constituents such as batteries, plastic materials etc.

Moreover, the concentrations recorded for copper and cadmium in the soils of the rainy season were below the tolerable limit of 100–300 and 3–5 $mgkg^{-1}$ respectively. However, in the dry season both Cu and Cd metals were above the tolerable limits with the highest concentrations recorded at RA and BG-dumpsite respectively. The concentrations of lead in soils at the dumpsites vary significantly across the seasons. The major sources of lead pollution are mostly associated to industrial source [23] and refuse wastes. The significant increase in the concentration of lead at the SH and NTC dumpsites was not surprising as much economic activities were concentrated there such as the presence of Nigerian Tobacco Company and the residential areas. The range of Pb concentrations in the dumpsites soils was reported to have a range of 1340–1693 $mgkg^{-1}$ [24]. In this study, a significant difference among the concentrations of lead in soils across the sites at $p<0.05$ were recorded, this clearly indicates that the solid-wastes at the dumpsites contain significant amounts of lead.

The concentrations of copper were found to be higher in the dry season than those in the wet season and were attributed to the leachability of this metal in the rainy season. It has been reported that a biodegradable waste introduced metallic copper into soil at a level slightly above the natural levels for soils [23], this was attributed to high concentration of copper in soils of these dumpsites especially at sites RA and JK-dumpsites respectively across the seasons.

Similarly, there was significant difference among the concentrations of copper across the sites at $P<0.05$. However, there was no significant difference among the concentrations of copper across the sites. The highest concentrations of cadmium were recorded at RA and AJ-dumpsites during the dry and wet seasons respectively. These concentrations were within the tolerable limits of 3–5 $mgkg^{-1}$. The concentrations recorded in each season across the sites were above those recorded at the control sites. There were significant differences among the concentrations of cadmium across the sites at $P<0.05$ across the seasons as revealed from the results of the analysis of variance (ANOVA).

The concentrations of mercury recorded in the soil of the study areas were all above the USEPA and WHO maximum tolerable limit. The highest concentrations of mercury during the dry and wet seasons were highest at AJ and BG-dumpsites respectively. Furthermore, there were significant differences among the concentrations of mercury across the sites with insignificant differences for the concentrations of other metals across the sites. The concentrations recorded were above the tolerable limits of 3, 0.01, 1, 0.01 and 0.01 ppm for Zn, Pb, Cu, Cd and Hg respectively in water [25]. There was a significant difference between the concentrations of the analyzed metals in the dumpsite soils across the sites except mercury where an insignificant difference at $P<0.05$ was recorded among the environmental samples.

Correlation analysis among the concentrations of these metals across the sites in the plants and soils revealed a positive correlation in all but copper and zinc which were negatively correlated. There were significant differences among the concentrations of the metals in leachate samples across the sites at $P<0.05$, this clear indicates that their metals came from a common source. The concentrations of the analysed metal ions in the leachates samples are presented in Table 5. Correlation analysis among the metals across the sites revealed that all the metals were negatively correlated with the exception of Zn–Cd and Pb–Hg which was positively correlated. Similarly, there was a significant difference in the concentrations of the analyzed metals in both leachates and soils across the sites in the soils at $P<0.05$, a clear indication of their common source of pollution.

Tables 6–15 showed the concentrations of Zn, Pb, Cd, Cu and Hg in the contaminated chicken organs for the dry and wet seasons. The tissues and organs analysed were oesophagus, lungs, feather, bones, kidney, intestine, muscles, leg, liver, wattles and skin. The mean concentration ranges for zinc in oesophagus, lungs, bones, kidney, intestine, head and gizzard, across the seasons as presented in Tables 6 and 7 were: BDL (CTR) – 2.151 (KU), BDL (CTR) – 2.810 (DD); BDL (AJ, BG, CTR, AJ, SA, SH, PR) – 1.960 (RA), BDL (CTR) – 1.317 (DD); BDL (CTR) – 1.317 (DD); 0.166 (PR) – 3.334 (RA); 0.250 (CTR) – 4.501 (RA); BDL (CTR) – 2.373 (JK); BDL (CTR) – 3.640 (DD); BDL (CTR) – 2.530 (AJ); BDL (CTR) – 4.035 (KU); BDL (CTR) – 1.156 (AJ); BDL (CTR, DD, JK, SA, RA, PR, NTC) – 1.628 (SH); 0.498 (PR) – 4.807 (JK); 0.195 (CTR) – 6.489 (JK); 0.073 (CTR) 2.421 (JK); 0.098 (CTR) – 3.095 (RA); BDL (AJ, BG, CTR, JK, PR) – 2.239 (NTC); BDL (AJ, BG, CTR, JK, PR) – 6.002 mg/kg (NTC) for the oesophagus, lungs, bones, kidney, intestine, head, gizzard, feather, wattles, skin and head respectively, where BDL indicates concentrations that are below the detection limits. Other concentration ranges were: BDL (CTR) – 6.531 (JK), BDL (CTR) – 4.907 (RA); 0.446 (CTR) – 3.002 (SH); 0.602 (CTR) – 4.053 (SH); 0.00 (CTR) – 1.540 (RA); BDL (CTR) – 2.579 (SH) and BDL (CTR) – 1.299 $mgkg^{-1}$ (SH). The highest concentrations of zinc in the organs were recorded during the dry season across the sites. The order of average bioavailability of zinc in the analysed organs/tissues followed the pattern. Leg > skin > muscles > oesophagus > gizzard > intestine > feather > heart > head > kidney > liver > lung > brain > bones > wattle.

There was significant correlation in the concentrations of zinc among the different organs and tissues at $P<0.05$. There was positive correlations in the concentration among the different organs analysed. The concentration of this metal in the different chicken organ and tissues were below the World Health Organization [26] tolerable limits.

The mean concentration ranges recorded for lead in oesophagus, lungs, bones, kidney, intestine, head, gizzard, feather, wattles, skin in the wet and dry seasons and BDL (CTR, JK, SA, RA, PR, NTC) – 0.457 (KU); BDL (CTR, JK, SA, RA, PR, NTC) – 0.617 (KU), BDL (CTR, SA, RA, PR, NTC) - 0.566 (KU); BDL (CTR) – 0.557 mg/kg (NTC), BDL (CTR) – 0.752 (NTC); BDL (CTR, DD, DD, JK, SP, PR, NTC) – 0.551 mg/kg (RA), BDL (CTR, AJ, SA, RA, PR) – 0.338 (BG); BDL (AJ, CTR, SA, RA, PR) – 0.587 $mgkg^{-1}$ (KU); BDL (CTR, JK, SA, RA, PR, NTC) – 0.408 $mgkg^{-1}$ (BG) respectively. Other concentration ranges were: BDL (CTR) – 0.826 (PR); BDL(CTR) – 1.108 $mgkg^{-1}$ (NTC); BDL (CTR, DD, RA, PR) – 0.67 $mgkg^{-1}$ (SH); BDL (CTR, DD, RA, PR, NTC) – 0.904 $mgkg^{-1}$ (SH), BDL (CTR, JK, KU, PR, NTC) – 0.818 $mgkg^{-1}$ (RA); BDL (CTR, JK, KU, PR, NTC) – 0.754 $mgkg^{-1}$ (DD), BDL (CTR, BG, JK, SA, RA, PR, NTC) – 0.292 $mgkg^{-1}$ (KU); BDL (CTR, DD, JK, SA, RA, PR, NTC) – 0.394 $mgkg^{-1}$ (KU), BDL (CTR, DD, JK, SA, RA, PR, NTC) – 0.435 (K), BDL (CTR, DD, JK, SA, RA, PR, NTC) – 0.587 (KU), BDL (AJ, KU, SH, RA) – 2.111 (BG), BDL (AJ, SH, RA) – 2.850 $mgkg^{-1}$ (BG) for the heart, muscles, leg, liver and brain respectively. The order of bioavailability of this metal followed the pattern: Brain > skin > muscles > intestine > oesophagus > heart > kidney > liver > feather > leg > wattles > lungs > bones > head.

There was significant difference at $P<0.05$ for lead concentrations among the analyzed chicken-organs. The concentrations recorded for lead across the sites were all below the WHO tolerable limit of 2 $mgkg^{-1}$ [26]. However, the highest and lowest concentrations were recorded in the skin of NTC-dumpsite (1.108 $mgkg^{-1}$). The concentration ranges for copper in the analysed chicken-organs (oesophagus, lungs, bones, kidney, intestine, head, gizzard, feather, wattles, skins, heart, muscles and leg) were BDL (CTR, PR) – 30.746 (NTC); BDL (CTR, PR) – 41.506 (NTC); BDL (CTR, KU) – 0.438 (SH); BDL (CTR) – 0.406 (SH); BDL (CTR) – 1.432 (NTC); BDL (CTR) – 1.933 (NTC); BDL (CTR) – 6.255 (NTC); BDL (CTR) – 1.933 (NTC); BDL (CTR) – 66.148 (NTC); BDL (CTR) – 89.299 (NTC); BDL (CTR) – 128.017 (NTC); BDL (CTR) – 172.823 (NTC); BDL (CTR, NTC, RA) – 0.112 (SA); BDL (CTR, RA, NTC) – 0.099 (AJ); BDL (AJ, BG, DD, KU, SA, PR, NTC) – 0.167 (SH); BDL (CTR, NTC) – 0.183 (JK), BDL (CTR, NTC) – 0.950 (DD); BDL (AJ, BG, CTR, JK) – 0.301 (SA); BDL (CTR, AJ, BG, JK, KU, PR) – 0.337 (NTC); BDL (CTR) – 7.217 (NTC) mg/kg. Other mean concentration ranges were; BDL (CTR) – 20.744 (NTC); BDL (CTR, RA) – 319.376 (NTC); BDL (CTR) – 431.15 mg/kg (NTC) and BDL for livers and brains respectively. Overall the order of bioavailability of copper in different chicken-organs respectively were; Liver > gizzard > head > oesophagus > leg > muscle > kidney = lungs = bones = kidney = heart > feather = wattles = brain respectively.

The highest concentration of copper was found in the liver of NTC-dumpsite followed by gizzard, head, oesophagus, leg and muscle and the least concentration was recorded in the brain, most of the recorded values were below the detection limit.

One-way ANOVA showed a significant difference in the copper concentrations recorded at $P<0.05$. Furthermore, there was a positive correlation among the tissues and organs with the exception of brain–wattles, brain–gizzard and oesophagus–brain which were negatively correlated. Overall the concentrations of copper in some of the analysed tissues and organs were above the WHO tolerable limits in chicken muscles. The organs and sites that were exposed to copper toxicity were oesophagus, head, gizzard, liver and brain of the chicken samples in the NTC dumpsites across the seasons (dry and wet).

Tables 12 and 13 showed the concentrations of cadmium in various tissues and organs of the chicken samples analyzed across the sites and seasons. The WHO tolerable limit of cadmium is 0.05-1.0 $mgkg^{-1}$. The mean concentration ranges of cadmium recorded in this study were; BDL (CTR) – 0.086 (RA); BDL (CTR) – 0.116 (RA); BDL (CTR) – 0.090 (NTC); BDL (CTR) – 0.106 (SA); BDL (AJ, BG, CTR, DD, JK, KU, SH, PR) – 0.109 (RA); 0.02 (CTR) – 0.075 (RA); 0.027 (CTR) – 0.073 (NTC); 0.02 (CTR) – 0.082 (RA); 0.003 (CTR) – 0.110 (RA); BDL (CTR) – 0.059 (DD); BDL (CTR) – 0.085 (AJ); 0.021 (CTR) – 0.071 (SH, JK); BDL (CTR) – 0.094 (SA); BDL (CTR) – 0.072 (KU); BDL (CTR) – 0.097 (KU); BDL (CTR, DD, JK, SA, SH, RA, PR, NTC) – 0.068 (KU); BDL (CTR, DD, JK, SA, SH, RA, PR, NTC) – 0.091 (KU); 0.021 (CTR) – 0.066 (PR); 0.028 (CTR) – 0.089 (RA); BDL (AJ, BG, CTR, KU, SH, PR) – 0.076 (NTC); BDL (AJ, BG, CTR, KU, SH, PR) – 0.102 $mgkg^{-1}$ (NTC) for the concentrations in the wet and dry seasons in oesophagus, lungs, bones, kidney, intestine, head, gizzard, feather, wattles, skin and heart respectively. Other concentration ranges were 0.002 (CTR) – 0.073 (BG); 0.003 (BG, CTR) – 0.099 (BG); BDL (CTR) – 0.065 (BG); BDL (CTR) – 0.087 (BG); BDL (CTR) – 0.055 (BG); BDL (CTR, RA) – 0.090 (SH); BDL (AJ, BG, CTR, DD, KU, SH, RA, NTC) – 0.062 (PR); BDL (AJ, BG, CTR, DD, KU, SH, RA, NTC) – 0.083 $mgkg^{-1}$ (PR) for muscles, leg, liver and brain in the wet and dry seasons respectively. In all the analyzed samples, the concentrations were below WHO tolerable limit [27]. However, the highest concentration of Cd averagely was found in the oesophagus of the RA–dumpsites (0.110 $mgkg^{-1}$) followed by muscles and then the lowest concentration was found in the control site (CTR) which was not detected. One-way ANOVA showed that cadmium concentrations were significantly different across the sites at $P<0.05$ and it was positively correlated across the sites in the different tissues and organs. Overall, the order of availability of cadmium across the sites and season averagely, followed the pattern; lungs > muscles > gizzard > kidney > oesophagus > intestine > leg > skin > feather > head > liver > heart > wattles > bones > brains.

The concentration of mercury recorded in the chicken organs and tissues across the sites were all above the safe limit for human consumption as presented in Tables 14 and 15 with the exception of those samples from the control site. In addition, copper concentrations were also above the safe limit in the oesophagus, head and gizzard of NTC dumpsites as presented in Tables 10 and 11 Overall, the order of bioavailability of the analysed metals in the tissue and organs across the sites and seasons was Hg > Cu > Cd > Pb > Zn the sampling.

Table 3. Total metal concentrations (mg/kg) of the dumpsite waste soils for the dry season

Soil	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
Zn	347.528±6.962	333.499±3.321	194.13325±6.525	251.436±8.438	429.417±7.371	932.339±5.625	1135.270±8.438	394.965±6.390	462.127±24.107	276.137±6.462	761.647±11.925	300
Pb	22.288±1.103	14.414±0.351	20.891±4.919	27.013±5.387	23.599±4.068	18.009±1.337	27.013±1.440	20.458±2.493	77.179±280.953	20.68±2.754	38.179±5.972	100
Cu	3.529±0.635	1.123±0.315	15.747±0.540	17.245±0.662	13.024±0.673	4.278±0.761	4.6103±0.923	7.981±1.040	899.505±1.076	8.817±0.707	19.118±0.567	100
Cd	2.051±0.028	1.0183±0.014	1.745±0.024	2.138±0.029	2.174±0.030	2.458±0.033	2.982±0.041	3.360±0.046	3.476±0.047	2.283±0.031	1.832±0.025	5
Hg	731.364±1.412	120.275±1.981	189.383±1.927	216.493±12.363	169.596±6.361	207.607±2.647	212.087±2.041	283.351±9.946	192.626±1.952	203.157±9.282	214.555±1.462	0.13

BDL = Concentrations that were below detection limits, all the concentrations in the tables are reported as the mean concentrations of the triplicate digests plus minus the standard deviation (mean±standard deviation)

Table 4. Total metals concentrations (mg/kg) of the dumpsite waste soils for the dry season

Soil	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
Zn	169.420±6.143	162.58±5.895	115.052±7.798	122.57±4.445	209.34±7.591	454.51±16.482	553.44±20.069	192.54±6.982	225.28±8.169	134.61±4.881	371.30±13.464	300
Pb	1.172±0.768	1.197±9.050	5.130±2.419	2.297±1.926	3.409±1.692	4.722±2.497	1.443±5.634	1.949±7.990	24365±1.486	2.976±1.717	1.357±0.654	100
Cu	9.749±0.354	5.895±2.779	6.025±2.841	6.585±3.105	60.74±28.635	34.495±16.261	37.293±17.580	1.235±0.580	14.906±7.027	15.54±7.326	46.006±21.688	100
Cd	2.958±0.107	1.292±1.268	0.718±1.758	1.586±1.556	1.791±1.758	2.335±2.291	2.717±2.665	0.962±0.944	2.276±2.233	2.217±2.176	1.93±1.902	5
Hg	125.526±2.761	233.993±1.459	33.391±4.322	85.591±6.522	68.546±4.470	100.778±7.261	111.727±7.003	182.98±12.389	114.819±2.190	130.623±2.365	90.86±1.251	0.13

Table 5. Concentrations (mg/L) of total heavy metals in the dumpsites leachates

Metals	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
Zn	0.338±0.001	0.455±0.032	0.351±0.025	0.530±0.038	1.525±0.01	4.119±0.029	2.719±0.019	2.819±0.02	0.830±0.05	1.009±0.072	1.262±0.089	5.000
Pb	0.379±0.027	0.379±0.025	BDL	0.296±0.021	0.329±0.023	0.388±0.028	0.334±0.024	0.378±0.02	0.386±0.027	0.328±0.023	0.320±0.022	0.001
Cd	BDL	0.068±0.05	0.0315±0.02	0.062±0.04	0.059±0.044	0.029±0.02	0.0736±0.05	0.0537±0.04	0.0208±0.01	0.025±0.02	0.031±0.02	0.003
Cu	0.002±0.001	0.205±0.015	BDL	1.598±0.014	0.329±0.023	0.104±0.007	0.069±0.005	0.396±0.028	0.499±0.035	0.597±0.042	0.077±0.06	1.500
Hg	2.72±0.005	1.157±0.08	BDL	0.915±0.065	1.240±0.08	14.961±0.11	1.713±0.11	0.716±0.051	1.445±0.01	1.616±0.011	2.735±0.019	0.001

Table 6. Concentrations (mg/kg) of zinc in the contaminated chicken organs for the wet season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OER	0.756±0.005	0.781±0.006	BDL	4.134±0.029	1.064±0.008	4.271±0.030	2.760±0.020	0.776±0.006	0.103±0.001	0.529±0.004	0.154±0.001	5.000
LUR	BDL	BDL	BDL	2.013±0.014	1.241±0.009	0.098±0.001	2.89±0.021	BDL	BDL	BDL	1.449±0.010	5.000
BOR	BDL	BDL	BDL	BDL	BDL	1.051±0.007	BDL	BDL	3.892±0.028	BDL	1.639±0.012	5.000
KIR	0.755±0.747	0.967±0.957	BDL	1.324±1.311	0.986±0.976	1.004±0.994	0.751±0.743	0.856±0.847	0.494±0.489	1.093±1.082	0.852±0.843	5.000
INTR	0.972±0.007	1.388±0.010	0.185±0.001	0.721±0.005	0.997±0.007	1.210±0.009	1.109±0.008	1.146±0.008	3.334±0.024	0.166±0.001	3.159±0.022	5.000
HR	0.946±0.007	1.051±0.007	BDL	2.992±0.021	1.063±0.008	1.189±0.008	1.694±0.012	0.496±0.004	0.117±0.001	0.133±0.001	3.214±0.023	5.000
GIR	1.372±0.010	1.303±0.009		0.412±0.003	2.373±0.017	1.312±0.009	2.696±0.019	1.918±0.014	0.147±0.001	0.907±0.006	1.960±0.014	5.000
FER	2.529±0.018	1.657±0.012	BDL	0.420±0.003	2.415±0.017	2.988±0.021	0.468±0.003	1.912±0.014	0.131±0.001	0.89±0.006	0.349±0.002	5.000
WR	1.156±0.008	0.631±0.004	BDL	BDL	BDL	0.347±0.002	BDL	1.205±0.009	BDL	BDL	BDL	5.000
SKIR	0.916±0.007	0.999±0.007	0.144±0.001	0.629±0.004	4.806±0.034	0.830±0.006	1.995±0.014	1.224±0.009	4.553±0.032	0.497±0.004	0.889±0.006	5.000
HER	BDL	BDL	BDL	2.236±0.016	BDL0.000	0.551±0.004	1.919±0.014	1.973±0.014	2.560±0.018	BDL 0.000	4.445±0.032	5.000
MUR	0.672±0.005	0.119±0.001		0.822±0.006	6.551±0.047	0.507±0.004	1.662±0.012	0.434±0.003	3.634±0.026	2.726±0.019	0.130±0.001	5.000
LER	1.821±0.013	0.569±0.004	0.445±0.003	0.664±0.005	2.816±0.020	2.573±0.018	1.473±0.010	3.002±0.021	1.236±0.009	2.314±0.016	1.311±0.009	5.000
LIR	0.751±0.005	1.046±0.007	BDL 0.000	0.175±0.001	0.123±0.001	1.232±0.009	0.492±0.003	1.910±0.014	1.540±0.011	1.449±0.010	0.209±0.001	5.000
BRR	BDL	BDL	BDL	BDL	BDL	0.000	2.429±	BDL	BDL	BDL	4.622	5.000

Table 7. Concentrations of zinc (mg/kg) in chicken organ for dry season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OED	1.021±0.007	1.054±0.007	BDL	5.581±0.040	1.437±0.010	5.767±0.041	3.726±0.026	1.048±0.007	0.139±0.001	0.715±0.005	0.208±0.001	5.000
LUD	BDL 0.000	BDL 0.000	BDL 0.000	2.717±0.019	1.675±0.012	0.131±0.001	3.913±0.028	BDL	BDL	BDL	1.957±0.014	5.000
BOD	BDL	BDL	BDL	BDL	BDL	1.418±0.010	BDL 0.000	BDL 0.000	5.254±0.037	BDL 0.000	2.214±0.016	5.000
KID	1.019±1.009	1.305±1.292	BDL 0.000	1.787±1.770	1.331±1.318	1.355±1.342	1.0138±1.004	1.155±1.144	0.666±0.660	1.475±1.461	1.150±1.139	5.000
INTD	1.312±0.009	1.874±0.013	0.249±0.002	0.974±0.007	1.348±0.010	1.635±0.012	1.498±0.011	1.547±0.011	4.501±0.032	0.224±0.002	4.265±0.030	5.000
HD	1.277±0.009	1.418±0.010	BDL	4.040±0.029	1.436±0.010	1.605±0.011	2.287±0.016	0.670±0.005	0.159±0.001	0.179±0.001	4.338±0.031	5.000
GID	1.852±0.013	1.759±0.013	BDL	0.557±0.004	3.204±0.023	1.771±0.013	3.639±0.026	2.589±0.018	0.198±0.001	1.225±0.009	2.646±0.019	5.000
FED	3.415±0.024	2.237±0.016	BDL	0.568±0.004	3.261±0.023	4.035±0.029	0.633±0.004	2.582±0.018	0.177±0.001	1.203±0.009	0.471±0.003	5.000
WD	1.561±0.011	0.852±0.006	BDL	BDL	BDL	0.468±0.003	BDL	1.628±0.012	BDL	BDL	BDL	5.000
SKID	1.237±0.009	1.349±0.010	0.194±0.001	0.850±0.006	6.489±0.046	1.122±0.008	2.693±0.019	1.652±0.012	6.146±0.044	0.671±0.005	1.201±0.009	5.000
HED	BDL	BDL	BDL	3.019±0.021	BDL	0.744±0.005	2.591±0.018	2.663±0.019	3.456±0.025	BDL	6.002±0.043	5.000
MUD	0.908±0.006	0.161±0.001	BDL	1.111±0.008	8.844±0.063	0.685±0.005	2.244±0.016	0.585±0.004	4.907±0.035	3.681±0.026	0.176±0.001	5.000
LED	2.458±0.017	0.768±0.005	0.602±0.004	0.896±0.006	3.803±0.027	3.474±0.025	1.988±0.014	4.053±0.029	1.668±0.012	3.124±0.022	1.770±0.013	5.000
LID	1.014±0.007	1.412±0.010	BDL	0.236±0.002	0.167±0.001	1.662±0.012	0.663±0.005	2.579±0.018	2.079±0.015	1.957±0.014	0.283±0.002	5.000
BRD	BDL	BDL	BDL	BDL	BDL	BDL	3.280±0.023	BDL	BDL	BDL	6.239±0.044	5.000

Table 8. Concentrations of lead (mg/kg) in chicken organs for wet season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OER	0.268±0.0019	0.245±0.0017		0.473±0.0034	BDL	0.456±0.0032	BDL	0.247±0.0018	BDL	BDL	BDL	0.010
LUR	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.010
BOR	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.010
KIR	0.157±0.0011	0.33±0.0024	BDL	0.124±0.0009	0.110±0.0008	0.355±0.0025		0.296±0.0021	BDL	BDL	BDL	0.010
INTR	0.243±0.0017	0.203±0.0014	BDL	0.449±0.0032	BDL	0.259±0.0018	BDL	0.215±0.0015	BDL	BDL	0.557±0.0040	0.010
HR	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.010
GIR	0.308±0.0022	0.159±0.0011	BDL	BDL	BDL	0.253±0.0018	BDL	0.379±0.0027	0.407±0.0029	BDL	BDL	0.010
FER	BDL	0.338±0.0024	BDL	0.019±0.0001	0.132±0.0009	0.434±0.0031	BDL	0.298±0.0021	BDL	BDL	0.0646±0.0005	0.010
WR	BDL	0.407±0.0029	BDL	BDL	BDL	0.246±0.0018	BDL	0.238±0.0017	BDL	BDL	BDL	0.010
SKIR	0.320±0.0023	0.316±0.0022	BDL	0.3666±0.0026	0.307±0.0022	0.131±0.0009	0.578±0.0041	BDL	BDL	0.825±0.0059	0.820±0.0058	0.010
HER	0.337±0.0024	0.135±0.0010	BDL	BDL	0.0477±0.0003	0.335±0.0024	0.005±0.001	0.669±0.0048	BDL	BDL	0.084±0.0006	0.010
MUR	0.314±0.0022	0.344±0.0024	BDL 0.0000	0.558±0.0040	BDL	BDL	0.428±0.0030	0.198±0.0014	0.817±0.0058	BDL	BDL	0.010
LER	0.254±0.0018	0.163±0.0012	BDL	BDL	BDL	0.291±0.0021	BDL	0.199±0.0014	BDL	BDL	BDL	0.010
LIR	0.187±0.0013	0.283±0.0020	BDL	BDL	BDL	0.434±0.0031	BDL	0.4151±0.0030	BDL	BDL	BDL	0.010
BRR	BDL	2.111±0.0150	2.213±0.0157	0.807±0.0057	1.501±0.0107	BDL	0.478±0.0034	BDL	BDL	1.925±0.0137	0.807±0.0057	0.010

Table 9. Concentrations of lead (mg/kg) in chicken organs for dry season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OED	0.362±0.0026	0.331±0.0024	BDL	0.639±0.0045	BDL	0.616±0.0044	BDL	0.334±0.0024	BDL	BDL	BDL	0.010
LUD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.010
BOD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.010
KID	0.250±0.0528	0.539±0.1136	BDL	0.198±0.0418	0.176±0.0371	0.566±0.1193	BDL	0.472±0.0996	BDL	BDL	BDL	0.010
INTD	0.329±0.0023	0.275±0.0020	BDL	0.607±0.0043	BDL	0.350±0.0025	BDL	0.291±0.0021	BDL	BDL	0.752±0.0053	0.010
HD	BDL	BDL	BDL	BDL	BDL	0.001±0.003	BDL	BDL	BDL	BDL	BDL	0.010
GID	0.416±0.0030	0.214±0.0015	BDL	BDL	BDL	0.342±0.0024	BDL	0.511±0.0036	0.550±0.0039	BDL	BDL	0.010
FED	0.4000±	0.456±0.0032	BDL	0.026±0.0002	0.178±0.0013	0.587±0.0042	BDL	0.402±0.0029	BDL	BDL	0.087±0.0006	0.010
WD	BDL	0.550±0.0039	BDL	BDL	BDL	0.333±0.0024	BDL	0.322±0.0023	BDL	BDL	BDL	0.010
SKID	0.432±0.0031	0.427±0.0030	BDL	0.494±0.0035	0.415±0.0029	0.177±0.0013	0.780±0.0055	BDL	BDL	1.114±0.0079	1.108±0.0079	0.010
HED	0.455±0.0032	0.182±0.0013	BDL	BDL	0.064±0.0005	0.452±0.0032	0.006±	0.904±0.0064	BDL	BDL	0.112±0.0008	0.010
MUD	0.424±0.0030	0.464±0.0033	BDL	0.753±0.0054	BDL	BDL	0.578±0.0041	0.267±0.0019	1.104±0.0078	BDL	BDL	0.010
LED	0.343±0.0024	0.220±0.0016	BDL	BDL	BDL	0.393±0.0028	BDL 0.0000	0.268±0.0019	BDL	BDL	BDL	0.010
LID	0.252±0.0018	0.382±0.0027	BDL	BDL	BDL	0.587±0.0042	BDL	0.561±0.0040	BDL	BDL	BDL	0.010
BRD	BDL	2.850±0.0203	2.988±0.0212	1.090±0.0078	2.026±0.0144	BDL 0.0000	0.646±0.0046	BDL	BDL	2.599±0.0185	1.091±0.0078	0.010

Table 10. Concentrations of copper (mg/kg) in chicken organs for wet season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OER	0.049±0.0004	0.087±0.0006	BDL	0.093±0.0007	0.104±0.0007	0.038±0.0003	0.101±0.0007	0.036±0.0003	0.187±0.0013	BDL	30.745±0.2185	2.000
LUR	0.209±0.0015	0.126±0.0009	BDL	0.258±0.0018	0.134±0.0010	BDL	0.109±0.0008	0.438±0.0031	0.126±0.0009	0.142±0.0010	0.107±0.0008	2.000
BOR	0.300±0.0021	0.221±0.0016	BDL	BDL	BDL	BDL	0.063±0.0004	0.300±0.0021	0.269±0.0019	0.221±0.0016	0.128±0.0009	2.000
KIR	0.026±0.0002	0.082±0.0006	BDL	BDL	BDL	0.069±0.0005	0.215±0.0015	0.064±0.0005	0.082±0.0006	0.234±0.0017	1.432±0.0102	2.000
INTR	0.059±0.0004	0.031±0.0002	BDL	0.195±0.0014	0.325±0.0023	0.068±0.0005	0.209±0.0015	0.059±0.0004	0.097±0.0007	0.214±0.0015	6.255±0.0444	2.000
HR	0.136±0.0010	0.147±0.0010	BDL	0.246±0.0017	0.0269±0.0002	0.159±0.0011	0.306±0.0022	0.181±0.0013	0.279±0.0020	0.334±0.0024	66.148±0.4701	2.000
GIR	0.077±0.0005	0.028±0.0002	BDL	0.143±0.0010	0.174±0.0012	0.033±0.0002	0.143±0.0010	0.084±0.0006	0.0229±0.0002	0.173±0.0012	128.017±0.9098	2.000
FER	0.074±0.0005	0.085±0.0006	BDL	0.3045±0.0022	0.089±0.0006	0.046±0.0003	0.112±0.0008	0.076±0.0005	BDL	0.041±0.0003		2.000
WR	BDL	BDL	BDL	BDL 0.0000	BDL	BDL	BDL	0.123±0.0009	BDL	BDL	BDL 0.0000	2.000
SKIR	0.059±0.0004	0.059±0.0004	BDL	0.703±0.0050	0.183±0.0013	0.002±	0.052±0.0004	0.024±0.0002	0.071±0.0005	0.068±0.0005	BDL	2.000
HER	BDL	BDL	BDL	0.201±0.0014	BDL	BDL	0.301±0.0021	0.269±0.0019	0.082±0.0006	BDL	0.249±0.0018	2.000
MUR	0.024±0.0002	0.173±0.0012	BDL	0.027±0.0002	0.10±0.0007	0.019±0.0001	0.296±0.0021	0.019±0.0001	0.045±0.0003	1.259±0.0089	7.217±0.0513	2.000
LER	0.019±0.0004	0.0009±0.0002	BDL	0.138±0.0030	0.103±0.0022	0.049±0.0011	0.138±0.0030	0.013±0.0003	0.123±0.0027	0.082±0.0018	15.366±.3309	2.000
LIR	0.064±0.0014	0.148±0.0032	BDL	0.171±0.0037	0.149±0.0032	0.191±0.0041	0.195±0.0042	0.184±0.0040	BDL	0.0029±0.0001	319.378±6.8782	2.000
BRR	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.000

Table 11. Concentrations of copper (mg/kg) in chicken organs dry season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OED	0.0677±0.0005	0.117±0.0008	BDL	0.125±0.0009	0.141±0.0010	0.0523±0.0004	0.137±0.0010	0.048±0.0003	0.253±0.0018	BDL	41.506±0.2950	2.000
LUD	0.283±0.0020	0.171±0.0012	BDL 0.0000	0.349±0.0025	0.181±0.0013	BDL 0.0000	0.148±0.0011	0.591±0.0042	0.171±0.0012	0.191±0.0014	0.145±0.0010	2.000
BOD	0.406±0.0029	0.298±0.0021	BDL	BDL	BDL	BDL	0.085±0.0006	0.406±0.0029	0.364±0.0026	0.298±0.0021	0.173±0.0012	2.000
KID	0.035±0.0002	0.11±0.0008	BDL	BDL	BDL	0.094±0.0007	0.290±0.0021	0.086±0.0006	0.110±0.0008	0.315±0.0022	1.933±0.0137	2.000
INTD	0.081±0.0006	0.042±0.0003	BDL	0.263±.0019	0.439±0.0031	0.092±0.0007	0.283±0.0020	0.081±0.0006	0.130±0.0009	0.289±0.0021	8.443±0.0600	2.000
HD	0.184±0.0013	0.199±0.0014	BDL	0.332±0.0024	0.036±0.0003	0.214±0.0015	0.414±0.0029	0.244±0.0017	0.377±0.0027	0.451±0.0032	89.299±0.6346	2.000
GID	0.103±0.0007	0.038±0.0003	BDL	0.193±0.0014	0.235±0.0017	0.045±0.0003	0.193±0.0014	0.113±0.0008	0.031±0.0002	0.233±0.0017	172.822±1.2282	2.000
FED	0.099±0.0007	0.114±0.0008	BDL	0.411±0.0029	0.119±0.0008	0.062±0.0004	0.152±0.0011	0.102±0.0007	BDL	0.055±0.0004	BDL	2.000
WD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.166563±0.0012	BDL	BDL	BDL	2.000
SKID	0.079±0.0006	0.081±0.0006	BDL	0.949±0.0067	0.247±0.0018	0.0027±0.0000	0.069±0.0005	0.032±0.0002	0.095±0.0007	0.091±0.0006	BDL	2.000
HED	BDL	BDL	BDL	0.272±0.0019	BDL	BDL	0.407±0.0029	0.363±0.0026	0.110±0.0008	BDL	0.337±0.0024	2.000
MUD	0.032±0.0002	0.234±0.0017	BDL	0.036±0.0003	0.141±0.0010	0.026±0.0002	0.400±0.0028	0.025±0.0002	0.062±0.0004	1.699±0.0121	9.743±0.0692	2.000
LED	0.030±0.0005	0.001±0.001	BDL	0.186±0.0040	0.139±0.0030	0.066±0.0014	0.186±0.0040	0.017±0.0004	0.166±0.0036	0.110±0.0024	20.744±0.4468	2.000
LID	0.086±0.0019	0.199±0.0043	BDL	0.231±0.0050	0.201±0.0043	0.257±0.0056	0.263±0.0057	0.248±0.0054	BDL	0.004±0.0001	431.158±9.2855	2.000
BRD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.000

Table 12. Concentrations (mg/kg) of cadmium in chickens organs dry season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OED	0.089±0.0006	0.082±0.0006	BDL	0.056±0.0004	0.082±0.0006	0.073±0.0005	0.069±0.0005	0.073±0.0005	0.116±0.0008	0.056±0.0004	0.068±0.0005	0.05
LUD	0.060±0.0004	0.062±0.0004	BDL	0.075±0.0005	0.063±0.0004	0.101±0.0007	0.106±0.0008	0.082±0.0006	0.113±0.0008	0.099±0.0007	0.121±0.0009	0.05
BOD	BDL	BDL	BDL	BDL	BDL	BDL	0.097±0.0007	BDL 0.0000	0.109±0.0008	BDL 0.0000	0.066±0.0005	0.05
KID	0.074±0.0005	0.089±0.0006	0.027±0.0002	0.067±0.0005	0.056±0.0004	0.081±0.0006	0.069±0.0005	0.083±0.0006	0.1007±0.0007	0.059±0.0004	0.073±0.0005	0.05
INTD	0.082±0.0006	0.064±0.0005	0.003±	0.069±0.0005	0.066±0.0005	0.067±0.0005	0.094±0.0007	0.067±0.0005	0.110±0.0008	0.056±0.0004	0.082±0.0006	0.05
HD	0.085±0.0006	0.062±0.0004	BDL	0.079±0.0006	0.069±0.0005	0.074±0.0005	0.052±0.0004	0.075±0.0005	0.027±0.0002	0.0578±0.0004	0.0712±0.0005	0.05
GID	0.080±0.0006	0.055±0.0004	0.028±0.0002	0.063±0.0004	0.095±0.0007	0.054±0.0004	0.094±0.0007	0.095±0.0007	0.078±0.0006	0.052±0.0004	0.083±0.0006	0.05
FED	0.060±0.0022	0.088±0.0032	BDL	0.057±0.0021	0.068±0.0025	0.097±0.0035	0.063±0.0023	0.074±0.0027	0.054±0.0020	0.061±0.0022	0.063±0.0023	0.05
WD	0.099±0.0007	0.087±0.0006	BDL	BDL	BDL	0.091±0.006	BDL	BDL	BDL	BDL	BDL	0.05
SKID	0.085±0.001	0.081±0.001	0.028±0.002	0.052±0.002	0.083±0.001	0.055±0.002	0.062±0.006	0.071±0.001	0.088±0.001	0.066±0.003	0.077±0.001	0.05
HED	BDL	BDL	BDL	0.082±0.0006	0.048±0.0003	BDL	0.106±0.0008	BDL	0.095±0.0007	BDL	0.102±0.0007	0.05
MUD	0.085±0.0063	0.099±0.0074	0.003±0.0002	0.076±0.0056	0.074±0.0055	0.087±0.0065	0.065±0.0049	0.067±0.0050	0.113±0.0084	0.063±.0047	0.107±0.0080	0.05
LED	0.082±0.0061	0.087±0.0065	BDL	0.053±0.0039	0.069±0.0052	0.082±0.0061	0.055±0.0041	0.081±0.0060	0.086±0.0064	0.086±0.0064	0.068±0.0051	0.05
LID	0.059±0.0044	0.074±0.0055	BDL	0.055±0.0041	0.056±0.0042	0.073±0.0054	0.072±0.0053	0.089±0.0067	BDL	0.063±0.0047	0.060±0.0045	0.05
BRD	BDL	BDL	BDL	BDL	0.074±0.055	BDL	0.078±0.0058	BDL	BDL	0.083±0.0062	BDL	0.05

Table 13. Concentrations of cadmium (mg/kg) in chicken samples for the wet season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OER	0.067±0.0005	0.061±0.0004	BDL	0.042±0.0003	0.061±0.0004	0.054±0.0004	0.051±0.0004	0.054±0.0004	0.086±0.0006	0.042±0.0003	0.051±0.0004	0.05
LUR	0.045±0.0003	0.046±0.0003	BDL 0.0000	0.056±0.0004	0.047±0.0003	0.075±0.0005	0.079±0.0006	0.061±0.0004	0.084±0.0006	0.074±0.0005	0.089±0.0006	0.05
BOR	BDL	BDL	BDL	BDL	BDL	BDL	0.0716±0.0005	BDL	0.081±0.0006	BDL	0.048±0.0003	0.05
KIR	0.055±0.0004	0.066±0.0005	0.019±0.0001	0.049±0.0004	0.041±0.0003	0.059±0.0004	0.051±0.0004	0.062±0.0004	0.075±0.0005	0.044±0.0003	0.054±0.0004	0.05
INTR	0.061±0.0004	0.048±0.0003	0.002±	0.051±0.0004	0.049±0.0003	0.049±0.0004	0.069±0.0005	0.049±0.0004	0.082±0.0006	0.042±0.0003	0.061±0.0004	0.05
HR	0.062±0.0004	0.046±0.0003	BDL	0.059±0.0004	0.052±0.0004	0.055±0.0004	0.039±0.0003	0.056±0.0004	0.019±0.0001	0.043±0.0003	0.053±0.0004	0.05
GIR	0.059±0.0004	0.041±0.0003	0.021±0.0001	0.047±0.0003	0.071±0.0005	0.040±0.0003	0.069±0.0005	0.071±0.0005	0.058±0.0004	0.039±0.0003	0.062±0.0004	0.05
FER	0.045±0.0016	0.065±0.0024	BDL	0.042±0.0015	0.051±0.0018	0.072±0.0026	0.047±0.0017	0.055±0.0020	0.039±0.0014	0.045±0.0016	0.047±0.0017	0.05
WR	0.073±0.0005	0.065±0.0005	BDL	BDL	BDL	0.068±0.0005	BDL	BDL	BDL	BDL	BDL	0.05
SKIR	0.063±0.0004	0.059±0.0004	0.021±0.0001	0.039±0.0003	0.062±0.0004	0.041±0.0003	0.046±0.0003	0.053±0.0004	0.066±0.0005	0.049±0.0003	0.057±0.0004	0.05
HER	BDL	BDL	BDL	0.061±0.0004	0.036±0.0003	BDL	0.079±0.0006	BDL	0.071±0.0005	BDL	0.076±0.0005	0.05
MUR	0.063±0.0047	0.073±0.0054	0.002±0.0001	0.056±0.0042	0.055±0.0041	0.065±0.0048	0.048±0.0036	0.049±0.0037	0.084±0.0062	0.047±0.0035	0.079±0.0059	0.05
LER	0.061±0.0045	0.065±0.0048	BDL	0.039±0.0029	0.051±0.0038	0.061±0.0045	0.041±0.0030	0.059±0.0045	0.064±0.0047	0.064±0.0047	0.050±0.0037	0.05
LIR	0.044±0.0033	0.055±0.0041	BDL	0.041±0.0030	0.042±0.0031	0.054±0.0040	0.053±0.0040	0.067±0.0049	BDL	0.047±0.0035	0.045±0.0033	0.05
BRR	BDL	BDL	BDL	0.000	0.055±	BDL	0.058±	BDL	BDL	0.062±	0.000	0.05

Table 14. Mercury contents (mg/kg) in chicken organs for wet season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OER	1.403±0.030	1.135±0.024	1.029±0.022	2.134±0.046	1.929±0.041	2.614±0.0563	1.577±0.034	4.232±0.091	4.968±0.107	4.377±0.094	1.542±0.033	0.010
LUR	0.944±0.020	0.983±0.021	BDL	1.502±0.032	4.171±0.089	1.283±0.0276	BDL	BDL	BDL	BDL	1.399±0.030	0.010
BOR	BDL	BDL	BDL	BDL	BDL	BDL	2.126±0.0458	2.036±0.0438	1.508±0.033	1.663±0.035	1.319±0.028	0.010
KIR	2.287±0.0493	1.682±0.0362	BDL	0.779±0.0168	8.147±0.1755	1.352±0.0291	3.864±0.0832	1.319±0.0284	12.236±0.2635	2.159±0.0465	2.429±0.0523	0.010
INTR	2.603±0.0561	1.853±0.0399	BDL	1.666±0.0359	0.989±0.0213	2.269±0.0489	1.981±0.0427	1.641±0.0353	6.875±0.1481	3.672±0.0791	1.332±0.0287	0.010
HR	4.153±0.0894	2.332±0.0502	BDL	3.054±0.0658	2.335±0.0503	3.323±0.0716	2.967±0.0639	2.421±0.0521	53.508±1.1524	2.351±0.0506	0.945±0.0203	0.010
GIR	9.139±0.1968	1.579±0.0340	BDL	0.982±0.0211	1.416±0.0305	3.438±0.0740	0.601±0.0129	1.634±0.0352	0.966±0.0208	2.185±0.0471	0.424±0.0091	0.010
FER	1.571±0.0338	1.521±0.0328	0.774±0.0167	2.689±0.0579	35.425±0.7629	1.919±0.0413	1.176±0.0253	1.440±0.0310	35.425±0.7629	1.595±0.0343	5.351±0.1152	0.010
WR	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.010
SKIR	1.342±0.0289	1.525±0.0328	BDL	1.837±0.0396	1.669±0.0359	1.527±0.0329	1.180±0.0254	2.211±0.0476	2.354±0.0507	1.102±0.0237	1.451±0.0312	0.010
HER	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.010
MUR	1.579±0.0340	2.085±0.0449	0.527±0.0113	3.498±0.0753	2.174±0.0468	0.865±0.0186	5.749±0.1238	3.215±0.0692	1.533±0.0330	1.065±0.0229	1.269±0.0273	0.010
LER	1.205±0.0259	1.731±0.0373	BDL	61.572±1.3260	11.937±0.2571	1.302±0.0280	0.842±0.0181	1.172±0.0252	10.097±0.2175	0.792±0.0171	0.866±0.0186	0.010
LIR	1.222±0.0263	2.354±0.0507		6.041±0.1301	0.524±0.0113	2.554±0.0550	1.020±0.0220	1.407±0.0303	6.041±0.1301	2.145±0.0462	1.257±0.0271	0.010
BRR	BDL	BDL	BDL	BDL	BDL	BDL	1.019±0.0220	BDL	BDL	BDL	BDL	0.010

Table 15. Mercury contents (mg/kg) in chickens organs dry season

SAMPLES	AJ	BG	CTR	DD	JK	KU	SA	SH	RA	PR	NT	STD
OED	1.894±0.0408	1.532±0.0330	1.389±0.0299	2.882±0.0621	2.605±0.0561	3.529±0.0760	2.130±0.0459	5.713±0.1230	6.707±0.1444	5.909±0.1273	2.081±0.0448	0.010
LUD	1.274±0.0274	1.327±0.0286	BDL 0.0000	2.028±0.0437	5.631±0.1213	1.733±0.0373	BDL	BDL	BDL	BDL	1.889±0.0407	0.010
BOD	BDL	BDL	BDL	BDL	BDL	BDL	2.866±0.0618	2.748±0.0592	2.035±0.0438	2.245±0.0483	1.781±0.0383	0.010
KID	3.088±0.0665	2.271±0.0489	BDL	1.052±0.0227	10.998±0.2369	1.826±0.0393	5.217±0.1123	1.782±0.0384	16.518±0.3557	2.915±0.0628	3.281±0.0706	0.010
INTD	3.515±0.0757	2.501±0.0539	BDL	2.249±0.0484	1.336±0.0288	3.063±0.0660	2.674±0.0576	2.215±0.0477	9.282±0.1999	4.957±0.1068	1.798±0.0387	0.010
HD	5.606±0.1207	3.149±0.0678	BDL	4.122±0.0888	3.150±0.0678	4.487±0.0966	4.005±0.0863	3.269±0.0704	72.236±1.5557	3.174±0.0684	1.275±0.0275	0.010
GID	12.337±0.2657	2.132±0.0459	BDL	1.326±0.0286	1.912±0.0412	4.641±0.0999	0.811±0.0175	2.206±0.0475	1.304±0.0281	2.949±0.0635	0.572±0.0123	0.010
FED	2.121±0.0457	2.054±0.0442	1.045±0.0225	3.630±0.0782	47.823±1.0299	2.592±0.0558	1.588±0.0342	1.944±0.0419	47.823±1.0299	2.153±0.0464	7.223±0.1556	0.010
WD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.010
SKID	1.811±0.0390	2.058±0.0443	BDL	2.479±0.0534	2.253±0.0485	2.061±0.0444	1.593±0.0343	2.985±0.0643	3.178±0.0684	1.487±0.0320	1.958±0.0422	0.010
HED	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.010
MUD	2.133±0.0459	2.815±0.0606	0.711±0.0153	4.722±0.1017	2.935±0.0632	1.167±0.0251	7.762±0.1672	4.340±0.0935	2.069±0.0446	1.437±0.0310	1.714±0.0369	0.010
LED	1.626±0.0350	2.336±0.0503	BDL	83.122±1.7902	16.115±0.3471	1.758±0.0379	1.137±0.0245	1.582±0.0341	13.631±0.2936	1.070±0.0231	1.169±0.0252	0.010
LID	1.650±0.0355	3.178±0.0684	BDL	8.155±0.1756	0.707±0.0152	3.448±0.0743	1.378±0.0297	1.899±0.0409	8.155±0.1756	2.896±0.0624	1.697±0.0365	0.010
BRD	BDL	BDL	BDL	BDL	BDL	BDL	1.376±	BDL	BDL	BDL	BDL	0.010

Comparing the concentrations of these metals in the analyzed leachates, soils and chicken-organ samples, the bio-availabilities trend was; soils > leachates > chicken-organs. This apparently revealed that there exists a transfer of metal ions from soil matrix to the plant-grown on the soils and then to leachates and then to the well waters. Consequently, the dumpsite residents are adversely affected due to metals bioaccumulation. Concentrations of Zn, Pb, Cu, Cd and Hg were found to be highest in the dumpsite-soils across the sites and seasons followed by leachates and then chicken-organs. Conversely, elevated levels of mercury were recorded in the analysed samples of soil, leachates and chicken-organs across the sites and seasons. The correlation analysis revealed positive correlations among the samples both across the sites and seasons.

The order of the availability of metals in the dumpsite-soils and leachates across the sites and seasons followed the pattern; Hg > Zn > Cu > Cd > Pb respectively while the average order of the availability in the chicken-organs were Pb > Cu > Zn > Cd > Hg and Hg > Cu > Cd > Pb > Zn across the seasons respectively. The correlation analyses and ANOVA revealed that a strong positive correlation among the metals in soils and leachates exist at $p<0.05$.

4. DISCUSSION

In this study, there was contamination of chicken organs and tissues by mercury, copper and cadmium. It was also noted that the amount of metals in feathers were directly proportional to those found in the internal organs and tissues. Lead was found to accumulate more in the brain, skin, muscles, intestine and oesophagus across the sites and seasons. Cadmium accumulation in the wet and dry seasons were mostly in the in liver, gizzard, head, oesophagus, leg, muscles, kidney and leg, skin, muscle, oesophagus, gizzard, intestines, feather across the seasons respectively. Mercury accumulates more in the leg, feather, head, kidney, oesophagus, intestine etc. The chicken brain was also polluted by the lead metal ions in some samples across the sites with the exception of the RA, Pr and AJ-dumpsites while mercury affects mostly the leg, feather, head and kidney.

Feather in this study were found to occupy the second rank in terms of mercury-pollution, which was in accord with what was reported by [3] in a similar study. Zinc and copper are essential elements and accumulate more in the leg, skin, liver, gizzard and oesophagus the highest concentrations of these elements in the liver might be attributed to their biochemical roles [25]. In addition, lead is considered as one of the major environmental pollutants, it is carcinogenic and affects the liver and thyroid function [28]. In this study lead was found to concentrate more in the brain of the chicken-organs. The concentrations of lead in this study ranged from BDL (CTR) – 0.587 $mgkg^{-1}$ (SH) which was is in good agreement with those reported by [25,29,28,30]. The levels of lead recorded were all below the WHO recommended for internal organs (such as muscle, liver, gizzard and lungs). Cadmium is highly toxic to wildlife, it is carcinogenic and potentially mutagenic [3] with severe sub-lethal and lethal effects at low environmental concentration [24] in the internal organs of chickens, the highest concentration range was recorded in oesophagus, with the concentration range of BDL (CTR) – 0.116$mgkg^{-1}$ (RA) followed by bones with concentration of 0.106 (SA) and then intestine of 0.003 (CTR) – 0.110 mg/kg (RA) respectively.

The least concentration range for cadmium was recorded in the liver during the wet season (0.055 $mgkg^{-1}$) at BG-dumpsite. The highest cadmium concentration recorded in this study was lower than the range of 0.15 – 0.23 $mgkg^{-1}$ recorded by [3]. The concentrations ranges recorded in this study for cadmium was lower than those reported by [28].

The analyses of variance (ANOVA) showed that there were significant differences in the concentrations of the essential metals (Zn, Cu) across the sites in the different organs/tissues and among both the essential and non-essential metals (Cd, Hg, Pb). These interactions perhaps indicates that minerals balance in the body are regulated by important homeostatic mechanisms in which toxic elements interact with the essential metals even at low levels of metals exposure. The knowledge of these correlations may be essential to appreciate the kinetic interactions of metals and their implications in the trace metals metabolism [30,3].

5. CONCLUSION

Generally, the results of this study revealed the highest concentrations of metal ions in the analysed soil solution matrix, leachate and chicken-organs. In addition, the metals were also transferred through the food chain to the chicken organs appreciably. It was revealed that all the dumpsites were heavily polluted by mercury with the concentrations exceeding the tolerable limits. Overall, the concentrations of the metals at the control sites were lowest across the sites. The total metal concentrations recorded in the leachates samples were highest at the study areas (KU, SH, PR, DA and NTC) than those recorded at the control (CTR) site with the exception of Cu, which was attributed to the dumpsites compositions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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