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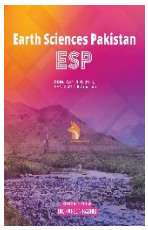

RESEARCH ARTICLE

EVALUATION OF TRACE METAL POLLUTION INDICES OF IRASA ABATTOIR SOILS, SOUTHWESTERN NIGERIA

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ABSTRACT

The study used various indices of pollution to assess the level of soil contamination from Irasa Abattoir in Ado-Ekiti, Southwestern Nigeria. Samples of soil were collected at the surface, 15cm and 30cm depths from effluent, roasting and bone waste areas, so as to evaluate the influence of abattoir activities on the soil quality. The geo-accumulation index (I_{geo}) indicates uncontaminated to moderate contamination for the studied heavy metals, while the PLI > 1 revealed continuous deterioration of the studied sites. The potential ecological risk factor and risk index (RI) of the metals revealed low risk level. However, the study exposed the effect of wastes and other activities on the status of the soils. Therefore, there is need to monitor the deterioration level of the abattoir site.

KEYWORDS

Abattoir Waste, Pollution Indices, Soil Quality, Deterioration, Risk Evaluation

1. INTRODUCTION

Metal (toxic) contamination of soil pose serious challenge globally (Sofianska et al., 2013). Through natural and anthropogenic activities of man, contaminants/pollutants enter the soil environment. In general, increasing awareness showed negative effects of metals on human health, micro-organisms, and environment. A group researcher affirm toxicity of these elements with significant effect on ecology and environment (Nagajyoti et al., 2010; Jaishankar et al., 2014). The non-biodegradable and immobile nature of these metals in the soil has made them a global concern.

An abattoir house is a dedicated place for killing and meat processing (Homby, 2006). Abattoir waste is said to be a class of waste with immense consideration (Ezeoha and Ugwuishiwu, 2011). Abattoir wastes are residual materials obtained from slaughterng of animals. These effluents comprise materials like blood, urine, faces, bones etc (Osemwota, 2010). Many cattle organs have contained heavy metals (Jukna et al., 2006). Around-the-world, abattoirs have been identified as a source of environmental contamination via numerous processes. In Nigeria, infrastructures were not provided for wastewater generated from abattoir activities (Ogbonnaya, 2008). Activities from abattoir usually contained organic and inorganic wastes, and thus far discharged into soils and water bodies around the abattoir surroundings (Steffen et al., 1989; RMAA, 2010). Naturally, soil is a sink for various pollutants; these species change the soil characteristics or properties.

The levels of these toxic metals in soil may increase due to anthropogenic pollution, metal accumulation and weathering of natural high background rocks. Different pollution indices evaluate the soil quality; providing comprehensive geochemical evaluation of soil environment, environmental risk assessment, soil degradation, and help determine if heavy metal accumulation was as a result natural processes or anthropogenic activities. Soil contamination assessment is often based using indices of pollution (Aloupi and Angelidis, 2001; Woitke et al., 2003; Reddy et al., 2004; Selvaraj et al., 2004). The study used various indices of pollution (including enrichment factor (EF), contamination factor (CF), pollution load index (PLI), geo-accumulation indexes (I_{geo}), risk index and ecological risk) to evaluate contamination status of soil out-of Irasa Abattoir in Ado-Ekiti, Southwest Nigeria.

2. MATERIALS AND METHODS

2.1 The study area

Irasa Abattoir is situated in Ado-Ekiti, Southwestern, Nigeria. It has been existing actively for the past 15 years. The abattoir is located on a vast land along Iworoko road, Ado-Ekiti, Nigeria, and it lies on latitude 7° 25 8° 2″ N and longitude 7° 00 6° 00″E (Figure 1). The abattoir is the largest in Ekiti State. It can process over 100 cattle's per week and has various sections such as the Lairage, Kraal (holding ground), slaughter slab, butchering and roasting (dehairing) sections.

2.2 Collection of sample and pre-treatment

Samples of soil (surface; 15 cm and 30 cm depths) were collected from three different areas (Effluent Waste Area (EWA), Roasting Area (RTA) and Bone Waste Area (BWA)). Two sampling spots 10 meters from each other were mapped out for soil sample collection at each sampling location. Using a calibrated soil auger, soil was sampled at the surface, 15 cm, and 30 cm depths from each sample location. Control was taken at about 200 m away from the locations (abattoir). The samples were kept in new clean polythene nylon and correctly labeled before been taken to the laboratory. The samples were later air-dried for about two weeks, ground, sieved properly with 2mm mesh to achieve homogeneity.

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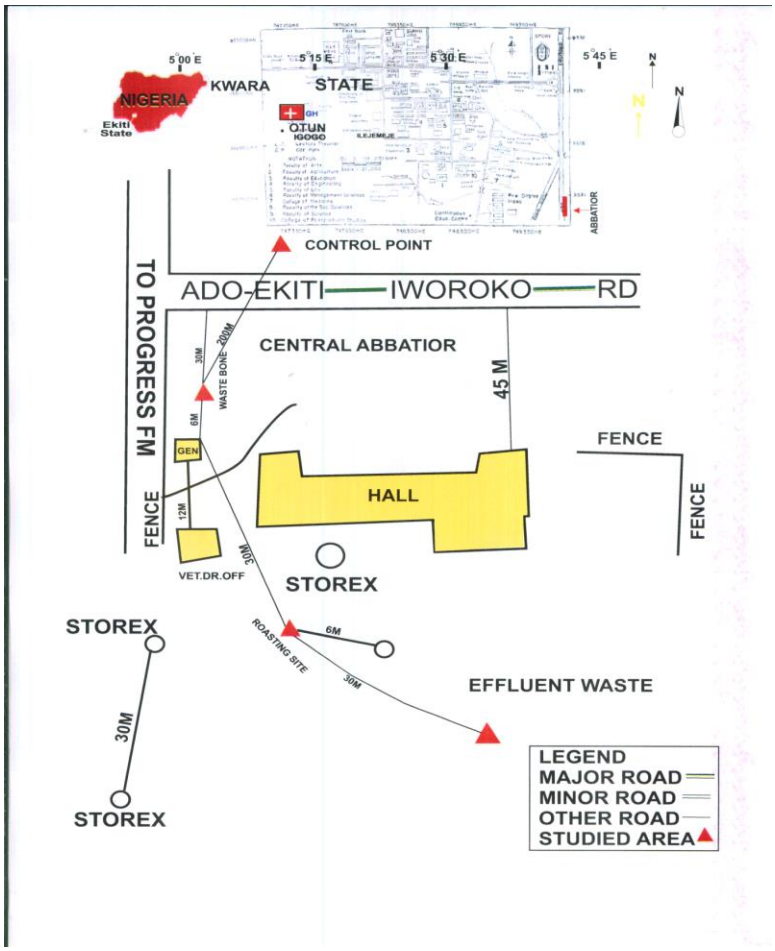

Figure 1: Map of the study area showing the sampling locations

2.3 Heavy metal analysis

One gramme (1.0 g) of air-dried soil sample was weighed and placed in a 100ml conical flask, 30 ml Aqua regia (HCl: HNO_3) was added. The solutions were digested for two hours and evaporate to dryness on a hot plate under a fume cupboard. 5 ml of deionised water were added to the digested samples, filtered into 100 ml standard flask and later made up to a 100 ml mark with the de-ionized water before transferring into sample bottles. The toxic metals were identified and quantified using Atomic Absorption Spectrophotometer (AAS) ((PG 990) at Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Nigeria.

2.4 Indices of pollution

The following indices (Enrichment factor (EF), contamination factor (CF) and degree of contamination (Cd), pollution load index (PLI), geoaccumulation Index (I*geo*), potential ecological risk factor (Eir) and risk index) were employed in assessing the level and contamination status of heavy metals in soil of the study area.

2.5 Contamination factor (CF) and degree of contamination (C_d)

Demie employed CF in providing degree of overall contamination of a particular sampling site (Demie, 2015). The **Contamination factor** is the ratio of metal level in the studied soil sample to that of control:

$$CF = \frac{Cmetal}{Cbackground} \quad (1)$$

The C_{metal} is metal level in the analysed soil sample; $C_{background}$ is the metal background value (control) of the metal.

The CF are classified as thus: very high contamination (CF ≥ 6); considerable contamination (3 ≤ CF< 6); moderate contamination (1 ≤ CF<3) and low contamination (CF < 1).

The Cd is the total of the each contamination factor (Hakanson, 1980). The equation below to computes the degree of contamination (Hakanson, 1980):

$$Cd = \sum_{i=1}^{n} Cfi \quad (2)$$

where Cf showed contamination factor of each metal; n is the total number of metals under study. Abrahim and Parker (2008) utilize Hakanson (1980) equation to get modified overall degree of contamination and shown by the equation:

$$mCd = \frac{\sum_{i=1}^{n} Cfi}{n} \quad (3)$$

where mCd = modified degree of contamination, n = number of analyzed elements, and Cf*i* = contamination factor. Abrahim and Parker (2008) classified mCd in this way: $mCd \geq 32$ means ultra-high, $16 \leq mCd < 32$ (extremely high), $8 \leq mCd < 16$ (very high), $4 \leq mCd < 8$ (high), $2 \leq mCd < 4$ (moderate), $1.5 \leq mCd < 2$ (low) and $mCd < 1.5$ (nil–very low).

2.5.1 Enrichment factor (EF)

In evaluating contamination in an environment, EF is a good indicator. EF evaluates the respective contributions of anthropogenic and natural toxic metal loads to soil (Adamo et al., 2005; Valdes et al., 2005). EF also indicate the level of pollution or contamination or both (Rubio et al., 2000). It's calculated as:

$$EF = \frac{(Cn/Cref)\ sample}{(Bn/Bref)\ background} \quad (4)$$

C_n is the concentration of the analysed metal in the studied environment; C_{ref} is the concentration of the reference metal in the studied environment; B_n is the background (control) value of the examined element; and B_{ref} is the background level/value of the reference metal. Reference elements usually used are Fe, Mn, Sc, and Al (Loska et al., 1997). Fe was used as reference for this study. Iron was chosen, because of its conservative nature during digenesis (Chapman and Wang, 2001). Values EF close to unity specify crusted origin; likely mobilization or depletion of metals (EF < 1.0), while anthropogenic origin (EF > 1.0) (Zsefer et al., 1996).

2.5.2 Geoaccumulation index (Igeo)

The *I*geo evaluate the level of metal pollution in soil by contrasting the current level with pre-industrial values (Muller, 1969). The *I*geo is evaluated follows:

$$I_{geo} = \log_2 \left(\frac{Cn}{1.5Bn}\right) \quad (5)$$

where, Cn is the evaluated concentration of the soil sample for n metal (n); and Bn is the background value of metal (n). The correction factor; 1.5 accounted for possible variability in background data due to lithogenic effects. Muller (1969) suggested these descriptive categories for I*geo* values: I*geo* > 5 (extremely contaminated); 4 <I*geo*< 5 (strongly to extremely contaminated); 3 < I*geo* < 4 (strongly contaminated).; 2 <I*geo*< 3 (moderately to strongly contaminated); 1< I*geo* < 2 (moderately contaminated); 0 < I*geo* < 1 (uncontaminated to moderately contaminated) and I*geo* = 0 (uncontaminated).

2.5.3 Pollution load index (PLI)

PLI indicates the amount of times by which metal concentrations exceed the background level in soil and gives a cumulative assessment of the total level of metal toxicity at a particular site. The PLI was calculated (Tomlinson et al., 1980). The PLI of the site was estimated by getting the n-root from the n-CFs. PLI is calculated as:

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots\ldots\ldots CF_n)^{1/n} \quad (6)$$

n is the number metals = 6 and CF is the contamination factor.

According to Tomlinson et al. (1980), a PLI of 0 indicate perfection; PLI < 1 (no pollution); PLI = 1 (close to background level), and PLI > 1 (deterioration of site quality).

2.5.4 Potential ecological risk factor (Eir) and risk index (RI)

The *Eir* quantifiably indicates the potential ecological risk of a contaminant in a study area. The Equation 7 exhibit potential ecological risk factor. The risk inde (Equation 8) showed the total effect of numerous metals on the environment (Li et al., 2015).

$$E_r^i = T_r^i \times \frac{Ci}{Co} \quad (7)$$

$$RI = \sum_{i=1}^{n} E_r^i \quad (8)$$

where *Tir* is the toxic-response factor for a metal, *Ci* is the contamination factor, and *Co* is the metal's background value in the *n* soil. Hakanson in 1980 established the *Tir* or Mn, Zn, Cr, Ni, Pb, Cu and Cd as 1,1, 2, 5, 5, 5 and 30, respectively. The level of *Eir* is defined as: *Eir* < 40 (low), 40 ≤ *Eir* ≤ 80 (moderate), 80 ≤ *Eir* ≤ 160 (considerable), 160 ≤ *Eir* ≤ 320 (high), and *Eir* ≥ 320 (very high). The potential ecological risk index indicates: RI < 150 (low ecological risk), 150 ≤ RI > 300 (moderate ecological risk), 300 ≤ RI >600 (considerable ecological risk) and RI > 600 (very high ecological risk).

2.6 Quality assurance

Validation of the digestion method and certification of the instrument as good enough for the analysis was done by carrying out recovery experiment using standard addition method, where known amount of heavy metals were added to the samples and then analyzed for total metals. Five samples were spiked with mixtures of heavy metal standard solutions (10 and 15 ppm). The spiked samples were permitted to stand for some hours and digested and analyzed as described in the method above. The mean percentage recovery values ranged from 70.1±2.9 (Ni) to 82.7 ± 3.7 (Cr). The recovery obtained was within the recommended standard for recovery of heavy metals. The determined results showed the method of digestion used for the soil was reproducible, efficient, and adequate.

3. Results And Discussion

3.1 Distribution of the heavy metals

The concentration of the toxic metals in control samples are depicted in Table 1. The study showed a series of trends in the metal's accumulation with concentration (mg/kg) range of 1.30 (Mn) to 152.0(Fe), 1.60(As) to 170.0(Fe), and 0.90(As) to 155.0(Fe) at the surface, 15 and 3 0cm depths, respectively. The analysed metals concentration in the effluent waste area is presented in Table 2.

Table 1: Concentrations (mg/kg) of heavy metals in the Control Sample (background level)

	Surface	15cm (Depth)	30cm (Depth)
Cr	4.00±0.20	5.40±0.10	2.10±0.00
Cd	4.00±0.00	4.30±0.20	2.60±0.10
Zn	4.00±0.10	2.20±0.20	4.41±0.20
As	1.40±0.15	1.60±0.10	0.90±0.15
Cu	2.00±0.20	2.00±0.25	2.60±0.20
Mn	1.30±0.10	1.70±0.15	1.00±0.15
Ni	3.80±0.15	2.30±0.10	2.70±0.10
Fe	152±4.00	170±0.70	155±.5.00

Table 2: Concentration (mg/kg) of heavy metals in soil samples from the Effluent Waste Area

	Surface	15cm (Depth)	30cm (Depth)
Cr	5.65±0.55	3.15±0.15	3.15±1.05
	(9.73%)	(4.76%)	(33.3%)
Cd	2.10±0.80	1.85±0.55	2.50±0.40
	(38.1%)	(29.7%)	(16.0%)
Zn	4.25±0.85	4.90±0.00	3.35±0.55
	(20.0%)	-	(16.4%)
As	2.25±0.15	2.10±0.10	1.75±0.05
	(6.67%)	(4.76%)	(2.86%)
Cu	3.25±0.35	3.40±0.60	2.95±0.75
	(10.8%)	(17.7%)	(25.4%)
Mn	2.25±0.45	1.65±0.35	2.55±0.35
	(20.0%)	(21.2%)	(13.7%)
Ni	4.30±0.50	5.45±0.95	5.65±1.25
	(11.6%)	(17.4%)	(22.1%)
Fe	123.0±7.00	98.0±5.00	116.5±16.5
	(5.69%)	(5.10%)	(14.2%)

Mean ± SD (CV%)

The result revealed the contamination pattern in order: Fe > Cr>Ni>Zn>Cu>As=Mn>Cd at the surface, Fe>Ni>Zn>Cu>Cr>As>Cd>Mn at 15cm depth, while 30cm depth reflected Fe>Ni>Zn>Cr>Cu>Mn>Cd>As. Cr and as revealed decreasing patterns down the depth. Only Ni showed an increasing pattern, while Cd, Zn, Cu, Mn, and Fe disclosed irregular patterns down the depth of the effluent area. A low level of spatial variation was mostly recorded among the metals and sampling depths, as shown in the calculated coefficient of variation.

Table 3 shows the concentration of the metals in the studied soils of the roasting area. The result revealed the contamination pattern in order: Fe>Zn>Cu>Ni>Cr>Cd>Mn>As at the surface, Fe>Ni>Zn>Cr=Cd>Cu=Mn>As, at 15 cm, while 30 cm depth presented Fe>Ni>Cd>Zn>Cr>Cu>Mn>As. The result showed similar trends in heavy metal concentration (mg/kg), with As and Fe showing the least and highest all the depth.

Table 3: Concentration (mg/kg) of heavy metals in soil samples from Roasting Area

	Surface	15cm (Depth)	30cm (Depth)
Cr	3.20±0.90	2.85±0.15	4.15±2.35
	(28.1%)	(5.26%)	(56.6%)
Cd	2.60±0.30	2.85±0.15	4.50±0.10
	(11.5%)	(5.26%)	(2.22%)
Zn	5.30±0.90	4.50±0.30	4.35±0.65
	(17.0%)	(6.67%)	(14.9%)
As	1.55±0.25	1.50±0.00	1.35±0.35
	(16.1%)	-	(25.9%)
Cu	4.00±0.40	2.10±0.10	3.20±0.10
	(10.0%)	(4.76%)	(3.12%)
Mn	2.25±0.35	2.10±0.10	3.15±0.35
	(15.6%)	(4.76%)	(11.1%)
Ni	3.55±0.35	5.75±1.55	5.30±1.50
	(9.85%)	(27.0%)	(28.3%)
Fe	147.0±25.0	115.5±5.50	90.0±6.00
	(17.0%)	(4.76%)	(6.67%)

Mean ± SD (CV%)

A low degree of variation was also observed in the metal distribution, as shown in the calculated coefficient of variation. Fe, As and Zn showed decreasing patterns down the depth. Only Cd revealed an increasing pattern, while Cr, Cu, Mn, and Ni showed an irregular pattern down the depth. Studies of reported higher concentration for most metals except Cr were reported compared with the present study (Dan et al., 2009; Ebong et al., 2020). The concentration of metals in the soil of the bone waste areas is depicted in Table 4. It revealed the contamination pattern of Fe>Zn>Ni>Cr>Cd>Mn>Cu>As at the surface, Fe>Ni>Cu>Zn>Mn>Cr=Cd>As at 15cm depth, and Fe>Cu>Zn>Ni>Mn>Cr=Cd>As at 30cm depth.

Table 4: Concentrations (mg/kg) of heavy metals in soil samples from Bone Waste Area

	Surface	15cm (Depth)	30cm (Depth)
Cr	3.80±0.80	2.20±0.30	1.90±0.00
	(21.1%)	(13.6%)	-
Cd	3.70±0.90	2.20±0.30	1.90±0.00
	(24.3%)	(13.6%)	-
Zn	4.00±0.60	3.80±0.60	3.45±0.45
	(15.0%)	(15.8%)	(13.0%)
As	1.30±0.30	1.70±0.40	1.25±0.15
	(23.1%)	(23.5%)	(12.0%)
Cu	3.25±0.25	3.95±0.05	4.05±1.05
	(7.70%)	(1.27%)	(25.9%)
Mn	3.50±0.20	2.90±0.55	2.10±0.60
	(5.71%)	(19.0%)	(28.6%)
Ni	3.90±0.60	4.25±1.35	2.35±0.15
	(15.4%)	(31.8%)	(6.38%)
Fe	97.5±2.50	86.5±7.50	126.5±27.5
	(2.44%)	(8.67%)	(21.7%)

Mean ± SD (CV%)

The Cr, Cd, Zn, and Mn showed decreasing patterns down the depth, while Fe, Ni, and As showed an irregular pattern down the depth. Chukwu and Anuchi reported a lower Cd and a higher concentration of other determined metals as compared to current study (Chukwu and Anuchi, 2016). The Fe reported in this study was lower than what Yahaya et al. (2009) and Ebong et al. (2020) reported in soils of the abattoir, but higher than Simeon and Friday (2017). The Zn range reported in this study was similar to Ubwa et al. (2013), while those reported for abattoir waste-impacted soils by Yahaya et al. (2009) and Ebong et al. (2020) were higher. Cu from the current study was lower than Osu and Okereke (2015) (0.05 – 1.70 mg/kg), while, the level (36.5 – 40.6 mg/kg) and (15.7 – 19.3 mg/kg) by Ebong *et al.* (2020) were higher to the present study. The level of Cr (4.25 – 5.86 mg/kg) by Chukwu and Anuchi (2016) showed a similar range with the present study, while those of Ebong et al. (2020) and Ubwa et al. (2013) were higher and lower, respectively.

3.2 Estimated pollution indices

The CF of the metals at the effluent waste area (EWA), bone waste area (BWA) and roasting waste area (RTA) were presented in Table 5. The CF value of Fe and Cd were generally <1 and thus reflected low contamination at the surface, 15 and 30 cm depths, while Ni, Mn, Cu, As, and Cd revealed moderate (> 1) contaminations of effluent area. Cr varied from low to moderate (0.58 – 1.50) at the effluent area.

Table 5: Contamination factor (CF) of heavy metals in soil samples from the study areas (Effluent Waste Area, Roasting Area and Bone Waste Area)

	EWA-S	EWA-15	EWA-30	RTA-S	RTA-15	RTA-30	BWA-S	BWA-15	BWA-30
Cr	1.41	0.58	1.50	0.80	0.53	1.98	0.95	0.41	0.90
Cd	0.53	0.43	0.96	0.65	0.66	1.73	0.93	0.51	0.73
Zn	1.06	2.23	0.76	1.33	2.05	1.00	1.00	1.73	0.78
As	1.61	1.32	1.94	1.11	0.94	1.50	0.93	1.06	1.39
Cu	1.63	2.13	1.13	2.00	1.05	1.23	1.63	1.98	1.56
Mn	1.73	1.00	2.55	1.73	1.24	3.15	2.69	1.24	2.10
Ni	1.13	2.37	2.09	0.93	2.50	1.96	1.03	1.85	0.87
Fe	0.81	0.58	0.75	0.97	0.68	0.58	0.64	0.51	0.82

EW-S= Effluent waste area at surface; EWA-15= Effluent waste area at 15cm depth; EWA-30 = Effluent waste area at 30cm depth; RT-S= Roasting area at surface; RTA-15= Roasting area at 15cm depth; RTA-30 =roasting area at 30cm depth; BW-S= Bone waste area at surface; BWA-15= Bone waste area at 15cm depth; BWA-30 =Bone waste area at 30cm depth.

The roasting area reflected low to moderate Ni, As, Cd, and Cr contamination. Fe (< 1) revealed low contamination, while Mn, Cu, and Zn showed moderate contamination class at the roasting area. As reflected, a special considerable contamination at 30 cm at the roasting area. The bone waste area showed low contamination (< 1) of Fe, Cd, and Cr generally at the surface, 15 and 30 cm depths, while Mn, and Cr revealed moderate contamination. Low to moderate contamination were exhibited for As and Ni and Zn

For degree of contamination (*mCd*), the bone and effluent waste areas of the studied abattoir site reflected nothing to very low degree of contamination as revealed by *mCd*) (Table 6). The roasting area at 30 cm depth (RTA-30) depicted low degree contamination, while RTA-S and RTA-15 reflected nil to low degree of contamination. The PLI depicted progressive deterioration of the soil quality in the bone, effluent waste, and bone waste areas of Irasa abattoir as shown in the calculated PLI (Tomlinson et al., 1980). The calculated PLI of the studied areas generally depicted PLI > 1.

Table 6: Pollution Load Index (PLI) and Modified Degree of Contamination (mCd) of heavy metals in soil samples at the Surface, 15cm depth and 30cm depth from the study areas (Effluent Waste Area, Roasting Area, Bone Waste Area)

	EWA-S	EWA-15	EWA-30	RTA-S	RTA-15	RTA-30	BWA-S	BWA-15	BWA-30
PLI	1.16	1.10	1.33	1.12	1.05	1.48	1.11	1.10	1.07
mCd	1.23	1.33	1.46	1.19	1.21	1.64	1.23	1.16	1.14

The enrichment factor (Table 7) revealed deficiency to minimal enrichment of Cr, Cd, Zn, and Ni at the sampling depths from effluent waste area, while As, Cu and Mn showed moderate enrichment majorly at the surface and 30 cm depth. Ni generally showed moderate enrichment in the roasting area, while Cr and Cd showed deficiency to minimal enrichment.

Table 7: Enrichment factors (EF) of heavy metals in soil samples at the Surface, 15cm depth and 30cm depth from the study areas (Effluent Waste Area, Roasting Area, Bone Waste Area)

	EWA-S	EWA-15	EWA-30	RTA-S	RTA-15	RTA-30	BWA-S	BWA-15	BWA-30
Cr	1.75	0.83	1.48	1.01	0.78	0.80	2.00	3.40	1.11
Cd	0.65	0.67	1.44	0.75	0.98	1.01	1.28	2.98	0.90
Zn	1.31	1.37	1.56	3.86	3.01	1.73	1.07	1.70	1.00
As	2.00	1.11	1.45	2.28	1.38	2.09	2.59	2.58	1.70
Cu	2.01	2.07	2.53	2.95	1.55	3.88	1.51	2.12	1.91
Mn	2.13	1.79	4.20	1.68	1.82	3.35	3.39	5.43	2.57
Ni	1.40	1.01	1.60	4.11	3.68	3.63	2.78	3.38	1.06

Bone waste area revealed moderate enrichment of most metals at the surface and 15cm depth. Cr, As, Mn, and Ni depicted moderate enrichment in the surface soil and 15 cm depth at the bone areas, while deficiency-minimal enrichment were majorly observed at 30 cm depth. A significant enrichment (5 <EF< 20) of Mn was observed at bone waste area at 15 cm depth. Table 8 shows the geoaccumulation index of the metals from the studied abattoir soils. The results obtained were generally between 0 < Igeo < 1, which depicted uncontaminated to moderate contamination of the studied metals.

Table 8: Geo-accumulation Index (I_{geo}) of heavy metals in soil samples at the Surface, 15cm and 30cm depth from the study areas (Effluent Waste Area, Roasting Area, Bone Waste Area)

	EWA-S	EWA-15	EWA-30	RTA-S	RTA-15	RTA-30	BWA-S	BWA-15	BWA-30
Cr	0.28	0.16	0.19	0.12	0.11	0.08	0.39	0.40	0.18
Cd	0.11	0.13	0.19	0.09	0.13	0.10	0.35	0.35	0.15
Zn	0.21	0.27	0.20	0.45	0.41	0.35	0.15	0.20	0.16
As	0.32	0.22	0.19	0.26	0.19	0.21	0.39	0.30	0.28
Cu	0.33	0.40	0.33	0.34	0.21	0.40	0.23	0.25	0.31
Mn	0.35	0.35	0.54	0.19	0.25	0.34	0.51	0.63	0.42
Ni	0.23	0.19	0.21	0.48	0.50	0.37	0.42	0.39	0.17
Fe	0.16	0.19	0.13	0.12	0.14	0.10	0.50	0.12	0.16

The ecological risk factor results are shown in Table 9. The for Cr varied from 0.15 to 1.89, thus belonging to class of low ecological risk. The for Cd, Zn, As, Cu, Mn, and Ni ranged from 3.00 to 19.96, 0.17 to 1.01, 5.88 to 21.56, 2.17 to 5.33, 0.57 to 3.15 and 1.22 to 5.43, respectively and as such belong to the low ecological risk class. However, the accumulation of these metals should be monitored due to the toxic and persistent nature of metals. The RI values were also presented in Table 10. The RI were used to assess the possible or potential risk associated with determined heavy metals in the impacted soils.

Table 9: Ecological Risk Factor and Risk index (RI) of heavy metals in soil samples at the Surface, 15cm depth and 30cm depth from the study areas (Effluent Waste Area, Roasting Area, Bone Waste Area)

	EWA-S	EWA-15	EWA-30	RTA-S	RTA-15	RTA-30	BWA-S	BWA-15	BWA-30
Cr	0.71	0.22	1.43	0.40	0.20	1.89	0.48	0.15	0.86
Cd	3.96	3.00	11.08	4.88	4.60	19.96	6.98	3.56	8.42
Zn	0.27	1.01	0.17	0.33	0.93	0.22	0.25	0.79	0.18
As	11.50	8.25	21.56	7.93	5.88	16.67	6.64	6.63	15.44
Cu	4.08	5.33	2.17	5.00	2.63	2.37	4.08	4.95	3.00
Mn	1.33	0.57	2.55	1.33	0.73	3.15	2.07	0.73	2.10
Ni	1.49	5.15	3.87	1.22	5.43	3.63	1.35	4.02	1.61
RI	23.34	23.53	42.83	21.09	20.40	47.89	21.85	20.83	31.61

The RI varies from 23.34 – 42.83, 20.40 – 47.89, and 20.83 – 31.61 for effluent, roasting and bone waste area, respectively. In Consequence, the RIs of were in low ecological risk in the bone waste area. In contrast, effluent and roasting areas reflected low to moderate ecological risk class according to (Hankanson, 1980).

4. Conclusion

The study revealed low spatial variation along with the depth in most cases in soil of roasting, bone waste and effluent waste areas of the studied abattoir. An irregular pattern of distribution of the metals was also observed down the depth. The variation and distribution pattern could be attributed to sampling depth, physic-chemical properties of soil and various chemical forms of the metals. From the indices of pollution, the study revealed that the anthropogenic activities of the abattoir and loads of wastes generated have greatly contributed/influenced the current toxic levels of metal pollution and soil deterioration. The contamination factor (CF) disclosed low to moderate contamination of the studied metals. Consequently, the PLI depicted continuous deterioration of the soil characteristics. Hence, wastes and activities on the abattoir have negatively impacted the soil quality and proper monitoring, measures and controls should be put in place to avoid continuous and permanent deterioration of the soil abattoir.

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References

Abrahim, G.M.S. and Parker, R.J., 2008. Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. Environmental Monitoring Assessment, 136, Pp. 227-238.

Adamo, P.M. Arienzo, M., Imperato, D., Naimo, G., Nardi, G., and Stanzione, D., 2005. Distribution and partition of heavy metals in surface and sub-surface sediments of Naples City Port. Chemosphere, 61, Pp. 800 -809.

Aloupi, M., and Angelidis, M.O., 2001. Geochemistry of natural and anthropogenic metals in the coastal sediments of the Island of Lesvos, Aegean Sea. Environmental Pollution, 113, Pp. 211- 219.

Chapman, P.M. and Wang, F., 2001. Assessing sediments contamination in Estuaries. Environmental Toxicology and Chemistry, 20, Pp. 3 - 22.

Chukwu, U.J. and Anuchi, S.O., 2016. Impact of Abattoir wastes on the physiochemical properties of soils within Port Harcourt metropolis. The International Journal of Engineering and Science, 5 (6), Pp. 17 – 21.

Dan, E., Fatunla, K., and Shuaibu, S., 2018. Influence of abattoir wastes on soil microbial and physiochemical properties. Research Journal of Chemical Sciences, 8 (12), Pp. 1 - 14.

Demie, G., 2015. Analyzing soil contamination status in garage and auto mechanical workshops of Shashemane City: implication for hazardous waste management. Environment Systems Research, 4 (15), Pp. 1 - 9.

Ebong, G.W., Ettesan, E.S., and Dar, E.U., 2020. Impact of abattoir wastes on trace metal accumulation, speciation and human health-related problems in soils within southern Nigeria. Air, soil and Water Research, 13, Pp. 1 - 14.

Ezeoha, S., and Ugwuishiwu, B., 2011. Status of abattoir waste research in Nigeria. Nigeria Journal of Technology, 30 (2), Pp. 143- 148.

Hakanson, L., 1980. An ecological risk index for aquatic pollution control, a sedimentological approach. Water Research, 14, Pp. 975 - 1001.

Jaishankar M., Mathew, B.B., Shah, M.S., and Gowda, K.R.S., 2014. Biosorption of Few Heavy Metal Ions Using Agricultural Wastes, Pp. 2(1), Pp. 1– 6.

Jukna, C., Jukna, V., Korsukovas, A., Sangiuniene, J. and Skemaite, M., 2006. Freezing and storage influence on meat quality. Veterinarijaizootechnika, 33, Pp. 39 - 42.

Li P., Qian, H., Howard, K.W. and Wu. J., 2015. Heavy metal contamination of Yellow river alluvial sediments, northwest China. Environmental Earth Sciences, 73 (7), Pp. 3403 - 3415.

Loska K., Cebula, J., Pelczar, J., Wiechula, D. and Kwapuli´nski, J., 1997. Use of enrichment, and contamination factors together with geoaccumulation indices to evaluate the content of Cd, Cu, and Ni in the Rybnik Water Reservoir in Poland. Water, Air, and Soil Pollution 93, Pp. 347 -365.

Muller, G., 1969. Index of geoaccumulation in sediments of the Rhine river. Journal of Geology, 2, Pp. 108-118.

Nagajyoti, P.C., Lee, K.D., and Sreekanth, T.V.M., 2010. Heavy metals, occurrence and toxicity for plants: a review. Environmental Chemistry Letters, 8 (3), Pp. 199–216.

Ogbonnaya, C., 2008. Analysis of groundwater pollution from abattoir waste in Minna, Nigeria. Resources Journal of Diary Sciences, 2 (4), Pp. 74 -77.

Osemwota, I.O., 2010. Effect of abattoir effluent on the physical and chemical properties of soils. Environmental Monitoring Assessment, 167, Pp. 399 - 404.

Osu, C.I., and Okereke, V.C., 2015. Heavy metal accumulation from abattoir wastes on soils and some edible vegetables in selected areas of Umuahia metropolis. International Journal of Current Microbial Applied Science, 4, Pp. 1127 -1132.

Red Met Abattoir Association, 2010. Waste management-Red Meat Abattoir. Retrieved from SON (2003). Standard Organization of Nigeria Safe Water Regulation. http//www.docstoc.com/docs/10330 2144/waste-Management-%EE%9f%a6-Red-Meat-Abattoir.

Reddy, M.S., Basha, S., Kumar, V.G.S., Joshi. H.V., and Ramachandraiah, G., 2004. Distribution, enrichment and accumulation of heavy metals in coastal sediments of Alang-Sosiya Ship Scrapping Yard, India. Marine Pollution Bulletin, 48, Pp. 1055 - 1059.

Rubio, B., Nombela, M.A. and Vilas. F., 2000. Geochemistry of major and

trace elements in sediments of the Ria de Vigo (NW Spain): an assessment of metal pollution. Marine Pollution Bulletin, 40 (11), Pp. 968 - 980.

Selvaraj, K., Mohan, V.R. and Szefer. P. 2004. Evaluation of metal contamination in coastal sediments of the Bay of Bengal, India: Geochemical and statistical approaches. Marine Pollution Bulletin, 49, Pp. 174 - 185.

Simeon, E.O., and Friday, K., 2017. Index model's assessment of heavy metal pollution in soils within selected abattoirs in Port Harcourt, River State, Nigeria. Singapore Journal of Science Research, 7, Pp. 9 - 15.

Sofianska E., Michailidis K., Mladenova, V., and Filippidis, A., 2013. Multivariate statistical and GIS-based approach to identify heavy metal sources in soils of the Drama Plain, Northern Greece. Geosciences Pp. 131- 132.

Steffen, L.C., Roberts, H.Y. and Kirsten, 1989. Water and wastewater management in the red meat industry. 36. WRC Reports No. 145 TT41/89. WRC, Pretoria

Tomlinson, D.L., Wilson, J.G., Harris, C.R., and Effney, D.W., 1980. Problems in the assessment of heavy metal levels in estuaries and the formation of a pollution index. Helgol. Wiss. Meeresunters, 33, Pp. 566 - 572.

Ubwa, S.T., Atoo, G.H., Offem, J.O., Abah, J., and Asemave, K., 2013. Effects of activities at the Gboko abattoir on some physical properties and heavy metals levels of surrounding soil. International Journal of Chemist, 5, Pp. 49-57.

Vald'es, J., Vargas, G., Sifeddine, A., Ortlieb, L. and Guinez, M., 2005. Distribution of enrichment of heavy metals in Mejillones Bay (23°S), Northern Chile: geochemical and statistical approach. *Marine Pollution Bulletin*, 50, Pp. 1558-1568.

Woitke, P., Wellmitz, J., Helm, D., Kube, P., Lepom, P. and Litherty, P., 2003. Analysis and assessment of heavy metal pollution in suspended solids and sediments of the river Danube. Chemosphere, 51, Pp. 633 - 642.

Yahaya, M.I., Mohammed, S. and Abdullahi, B.K., 2009. Seasonal variations of heavy metals concentrations in abattoir dumping site soil in Nigeria. Journal of Applied Science and Environmental Management, 13, Pp. 9 - 13.

Zsefer, P., Glasby, G.P., Sefer, K., Pempkowiak, J. and Kaliszan, R., 1996. Heavy-metal pollution in superficial sediments from the southern Baltic Sea off Poland. Journal Environmental Science Health, Part A: Environmental Science and Engineering and Toxicology, 31, Pp. 2723 - 2754.