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Comparative Evaluation of the Levels of Selected Heavy Metals and Index of Pollution Status of the Sub-Soil of Bauchi Main Abattoir, Bauchi State, Nigeria

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Abstract

Activities in abattoirs and direct release of its waste into the environment are on the increase due to the high protein demand and hence there is need for proper assessment of abattoir soil with the aim of evaluating its degree of contamination. This study evaluated the variation in the levels of heavy metals in soil impacted by wastes from Bauchi main abattoir. Soil samples from four different distances away from the abattoir were collected at a depth of 0-20 cm and at distances of: 0-40 cm, 40-80 cm, 80-120 cm and a control (60 m). Soil samples from each distance/location were separately collected, digested and evaluated for the levels of selected heavy metals at their respective wavelengths using Atomic Absorption Spectrophotometry. The observed ranges (mg/kg) are: cadmium (14.90-22.96), cobalt (9.13-11.96), copper (1.13-13.98), chromium (2.93-6.92), iron (556-739),manganese (42.43-71.43), nickel (5.97-11.96),lead (8.00 -30.30) and zinc (0.66-2.97) in the studied area, while the control values (mg/kg) are: cadmium (8.80), cobalt (5.96), copper (0.97), chromium (0.96), iron(34.60), manganese (21.33), nickel (2.96), lead (7.97) and zinc(0.96). The study indicated that, the levels of heavy metals in the studied area decreased as the distance increases. The variations in the concentrations of all the heavy metals both in the studied and control soils were found to be significantly different as revealed by one- way ANOVA and Least Significant Different test ($p \leq 0.05$).The contamination potential of heavy metals were all found to be within than the values stipulated by WHO (2007) and DPR (2022) except for cadmium and iron. This shows that the soil samples from Bauchi main abattoir are not contaminated with most of the heavy metals except for cadmium and iron. The enrichment factor (EF) follows the order: Mn > Cu> Cr > Ni > Pb > Cd > Zn > Co (0 – 40 cm), Co > Mn > Zn > Cr > Cu >Ni > Cd > Pb (40 -80 cm) while at 80 -120 cm the order was: Cr > Mn > Co > Pb > Ni > Cd > Cu > Zn. The order of the contamination factor (CF) was: Cd > Co > Cu > Pb > Ni > Fe > Mn > Cr > Zn at the studied abattoir, while at the control location, the CF follows the order : Cd > Co > Pb > Ni > Mn > Cu > Cr > Fe > Zn. Based on the indices of metal pollution, the soil are classified as very slight contamination to severe pollution. The I-geo index spread from practically uncontaminated to moderately contaminated, the enrichment factor at all distances in all the abattoir soils studied were greater than 1.00 indicating that these heavy metals are from anthropogenic source, while the pollution load index (PLI) in all the locations were found to range from 1.06 – 2.27. The PLI values in all the studied soils are within moderately polluted ($1 < PLI < 2$) category. according to (Olusola *et al.,* 2020).The operations of Bauchi main abattoir are therefore not environmentally friendly based on the levels of iron and cadmium and this can pose health and environmental threats to the residents.

Introduction

Soil provides the means of physical support for all terrestrial organisms [1]. It is a composite mixture of organic and inorganic matter, with distinct constituents that determines its physical, chemical and biological properties. It is an essential sink for nutrients and pollutants [2].The properties of soil can change due to climate change, but mostly due to impact of activities of anthropogenic origin. The pollution of the environment has been found to result from human determination to match desire with production through the establishment of industries with the potentials to pollute the environment [3].Pollution of the environment by anthropogenic activities have become a rampant phenomenon in Nigeria and other developing countries mostly due to non-compliance or absence of strict measures to regulate the activities, leading to various health risks [3].

Abattoirs are premises approved and registered by controlling authorities for hygienic slaughtering, inspecting, processing, effective preservation and storage of meat products for human consumption [4]. The effect of abattoir waste on soil remain a great concern. Wastes like paunch manure, animal blood, animal feaces and abattoir effluents can pollute soil, water bodies etc [5]. Abattoir wastes are hazardous as they contain varied quantities of components which are potentially dangerous to the environment. Abattoirs are known all over the world in polluting the environment directly or indirectly through various processes [6].

The improper disposal of the wastes into the land and water bodies can lead to contamination of the environment [5]. Indiscriminate discharge of abattoir effluents into soils can accumulate metals in receiving soils. Most of these heavy metals not only pollute the soil, but invariably increase toxicity. Concern about heavy metals in soils are not just limited to their toxicity to living organisms inhabiting the soil, but also heavy metals build-up in soils may result in immobilization within different organic and inorganic colloids and mobilization into the flora and fauna and subsequently become available in food chain with harmful health effects [7].

Heavy metals are natural components of soil and most of the elements are only present in minimal or insignificant eco-toxicological concentrations in an undisturbed area. Heavy metals that are essential to the body are also toxic above certain levels [8].Heavy metals can persist and accumulate in the environment especially soils. These metals especially lead, zinc, copper, manganese and iron are potentially toxic and environmentally important [8].

Heavy metals in abattoir soil can come from various activities such as the use of metallic equipment and improper disposal of animal blood and waste [4].In Nigeria, abattoir create varieties of necessary employment such as livestock slaughtering, meat packaging, animals handling and butchering. These activities may lead to deposition of heavy metals into the soil, which can be absorbed by plants on such soil [9].There is a relationship between heavy metals concentrations in abattoir soil and those in close proximity to the abattoir. Heavy metals are of environmental importance because there are various ways through which they find their way into the environment. Some of the ways are increased industrialization, traffic roads, extensive agricultural practices or activities [8]. The aim of this study is to compare the levels of selected heavy metals in the surface soil within and at distances away from Bauchi main abattoir, Bauchi State, Nigeria.

MATERIALS AND METHODS

Materials

Distilled water and chemicals of analytical reagent grade purity were used throughout the research work. All the glass ware used were thoroughly washed with clean hot detergent solution, soaked in 20.00 mol dm^{-3} trioxonitrate (V) acid for 24 hours ,rinsed with aqua - regia, tap water and finally with distilled water. The glass ware were dried in a hot oven at 105 ^{o}C.

Methods

Sampling and Treatment of Soil Samples

Figure1: Map of Bauchi State indicating the Location of the Abattoir

Soil samples were collected from the four cardinal points (North, East, West and South) of Bauchi main abattoir by the use of a soil auger, at a depth of 0-20 cm. The four sub-soil samples obtained were mixed to obtain a composite representative of the soil sample transferred into a clean polyethylene bag, and labelled as BMA_1.Moving a distance of 40 cm away from site $BMA_{1,}$ another four sub-soil samples were collected, it was homogenized to form a composite, transferred into another polyethylene bag and labelled as BMA_2. Four sub-soil samples were again collected at another distance of 40 cm away from BMA_2 at the same depth as BMA_1 and BMA_2 and was homogenized and transferred into another clean polyethylene bag and labelled as BMA_3.The same procedure was adopted to obtain a background (control) sample 60 m away from the abattoir at a depth of 0-20 cm and labelled as BMA_0. The four composites (BMA_1, BMA_2, BMA_3 and BMA_0) obtained were transferred to the laboratory, air-dried separately for three days to drive off moisture. Each sample was separately ground to powder using a previously cleaned wooden pestle and mortar, sieved through a 2 mm mesh and kept in well labelled containers prior to laboratory analyses

Digestion of Soil Sample

The soil sample was digested based on the method adopted by badamasi *et al.*, 2022[10]. Soil sample (0.05 g) was placed in a 200 cm^3 beaker and 30.00 cm^3 of concentrated HNO_3, HF and $HClO_4$ were added in equal volume ratio. The mixture was heated on an electric hot plate at 180°C until the solution was almost dry. The beaker was cooled to room temperature. A volume of 5.00 cm^3 of concentrated HNO_3, 5.00 cm^3 of HF and 5.00 cm^3 of $HClO_4$ were added and the mixture boiled until dense white fumes appeared. The beaker and its content was cooled, 15.00 cm^3 of deionized water was added, boiled for 5 minutes and allowed to cool. The digest was filtered using Whatman Filter Paper Number 42 into a 50 cm^3 volumetric flask. The wall of the beaker was quantitatively washed with 10.00 % dilute trioxonitrate (V) acid. And the solution was made up to the mark with the 10.00 % trioxonitrate (V) acid for heavy metals determination. The sample solutions were transferred into screw-capped and labelled polyethylene sample bottles.

Determination of Heavy Metals

The levels of selected heavy metals (zinc, copper, iron, nickel, chromium, lead, cadmium, manganese and cobalt) in the four different sample solutions were determined at their respective wavelengths using Buck Scientific Atomic Absorption Spectrophotometer Model VGP 210.

Determination of Pollution Status of Heavy Metals in Bauchi Abattoir.

Metal Pollution Index (MPI)

This index was used to determine which heavy metals represent the highest threat for a soil environment. This also indicates the relationship between metals concentration in studied area and in the reference soil. Metal pollution index was calculated based on the equation [11].

$$MPI = \frac{\text{Concentrationof metal in the study soil}}{\text{Concentration of metal in control soil}} \quad - \quad - \quad - \quad 1$$

Enrichment Factor (EF)

This is used to measure the possible impact of anthropogenic activities on the concentration of heavy metals in soil. Reference elements are usually Fe, As, Ca, or Ti [11]. The enrichment factor was evaluated using the formula below:

$$EF = \frac{\left[\frac{\text{Cmetal}}{\text{Creference}}\right] \quad Sample}{\left[\frac{\text{Cmetal}}{\text{Creference}}\right] \quad Background} \quad - \quad - \quad - \quad 2,$$

where $\left[\frac{\text{Cmetal}}{\text{Creference}}\right]$ sample is the content of analyzed heavy metal (Cn) and one of the following metals: Fe, As, Ca and Ti (Creference) in the sample and $[\frac{\text{Cmetal}}{\text{Creference}}]$ for the background. If the values of the enrichment factor falls within the range of 0.50 - 1.50, this shows that the level of the particular heavy metal in the soil is caused by natural processes, but if the values exceed 1.50 it shows that there is possibility that the heavy metals contamination occurred as a result of anthropogenic activities [12].

Geo-Accumulation Index (Igeo)

To assess the degree of heavy metal contamination in the abattoir, the geo-accumulation index was calculated [11]:

$$\text{I-geo} = \text{Log}_2 \left(\frac{\text{Cn}}{1.5 \text{ X Bn}} \right) \quad - \quad - \quad - \quad 3,$$

where Cn is the concentration of the individual metal in the studied area, Bn is the background value of the individual heavy metal, 1.5 is a constant introduced to analyse natural fluctuation in the content of a given substance in the environment and very small anthropogenic influence. When Igeo < 0 = unpolluted, 0 – 1 = unpolluted to moderately polluted, >1 – 2 = moderately polluted, > 2 – 3 = moderately to strongly polluted, > 3 – 4 = strongly polluted, > 4 – 5 strongly to extremely and Igeo > 5 = extremely.

Contamination Factor (CF)

The evaluation of heavy metal and levels of contamination in the sub-soil of the abattoir requires pre-anthropogenic knowledge of metal concentration to act as pristine values. A number of different enrichment calculation methods and reference material were reported [12].The level of contamination of the abattoir soil by heavy metal was expressed in terms of contamination factor [12].

$$CF = \frac{\text{Concentration of the metal in soil}}{\text{target value}} \qquad - \quad - \quad - \qquad 5$$

The target value was obtained by using the standard [13], for maximum allowed concentration of heavy metals.

Pollution load Index (PLI)

Each soil sample was assessed for the level of metal pollution by employing the method based on the PLI [4] as follows:

By [4]:

$$PLI = (Cf1 * Cf2 * Cf3 * \ldots Cf9)^{1/9} \qquad - \quad - \quad - \qquad 4,$$

where, n is the number of metals and Cf is the contamination factor. The Cf is the metal concentration in soil/background values of the metals. The PLI is a potent tool used in heavy metal pollution assessment. The different categories of PLI used [11] are: No pollution (PLI < 1), moderate pollution (1> PLI > 2), heavy pollution (2 < PLI < 3) and extremely heavy pollution (3 < PLI) [11].

RESULTS AND DISCUSSION

Results

The levels of selected heavy metals (zinc, copper, iron, nickel, manganese, cobalt, chromium, cadmium and lead) were determined in Bauchi main Abattoir and the variations in the levels of the heavy metals from four different distances away from the abattoir are shown in Table 1.

Table 1: Levels of Heavy Metals (mg/kg) in Bauchi Main Abattoir, Bauchi State

Heavy metals	Concentrations (mg/kg)					
	(0-40cm)	**(40-80cm)**	**(80-120cm)**	**(control)**	**WHO**	**DPR**
Cd	$22.96^{a} \pm 0.05$	$16.96^{b} \pm 0.05$	$14.90^{c} \pm 0.01$	$8.80^{d} \pm 0.26$	3.00	0.80
Co	$11.96^{a} \pm 0.05$	$10.30^{b} \pm 0.34$	$9.13^{c} \pm 0.32$	$5.96^{d} \pm 0.05$	NA	20.00
Cu	$13.98^{a} \pm 0.10$	$3.98^{b} \pm 0.10$	$1.13^{c} \pm 0.11$	$0.97^{d} \pm 0.04$	36.00	36.00
Cr	$6.92^{a} \pm 0.13$	$4.90^{b} \pm 0.10$	$2.93^{c} \pm 0.05$	$0.96^{d} \pm 0.05$	100.00	100.00
Fe	$739^{a} \pm 1.00$	$707^{b} \pm 0.58$	$556^{c} \pm 0.58$	$34.60^{d} \pm 0.41$	425.5	5000.00
Mn	$71.43^{a} \pm 0.30$	$54.23^{b} \pm 0.72$	$42.43^{c} \pm 0.07$	$21.33^{d} \pm 0.06$	2000	476.00
Ni	$11.96^{a} \pm 0.05$	$7.96^{b} \pm 0.05$	$5.97^{c} \pm 0.06$	$2.96^{d} \pm 0.05$	35.00	3500.00
Pb	$30.30^{a} \pm 0.35$	$8.97^{b} \pm 0.05$	$8.00^{c} \pm 0.06$	$7.97^{d} \pm 0.06$	85.00	85.00
Zn	$2.97^{a} \pm 0.06$	$0.96^{b} \pm 0.05$	$0.66^{c} \pm 0.29$	$0.96^{b} \pm 0.05$	50.00	140

Values are mean ± standard deviation (n =3). Values on the same row with different superscript letters are significantly different as revealed by one-way analysis of variance (ANOVA) and least significant different test ($p \leq 0.05$). NA- Not Available.

Discussion

Levels of heavy metals in Bauchi Main Abattoir

The levels of Cd as shown in Table 1 range from: 8.80 mg/kg (control) to 22.96 mg/kg (which is the main abattoir) with the levels of 16.96 mg/kg (40-80 cm) and 14.90 mg/kg (80 - 120 cm) falling in between. The observed values in this present study at all distances are comparatively higher than 0.0011 to 0.0067 mg/kg found in soil from three abattoirs (Agip, Iwafa and Mile III) in Portharcourt [14].The observed values of both the studied soil and control are higher than the target and intervention values (3.00 and 12.00 mg/kg) of soil [15]. The high levels of observed cadmium might be as a result of processing animals that were fed with certain grains and vegetables that contain cadmium such that cadmium can enter the soil through waste product [16]. Applications of fertilizer containing cadmium on the soil close to the studied area might also be responsible for the elevated levels of cadmium in the studied location. High levels of cadmium can also be caused by the use of cadmium-containing materials such that when these materials corrodes over time, they can contaminate the soil. The observed values in this study might pose health risk to the inhabitants of Bauchi main Abattoir and environment. Increase in soil cadmium might result in an increase in uptake by vegetables. Table 2 revealed that statistical significant differences exist ($p \leq 0.05$) between the levels found at different distances away from the main abattoir.

Table 2: Treatment Mean Differences of Cadmium at Four Different Distances ($LSD_{0.05}$ = 2.07)

	BAM_1: 22.97	BAM_2:16.96	BAM_3: 14.90	BAM_O: 8.8
BAM_1: 22.97		6.01	8.07	14.17
BAM_2: 16.96			2.06	8.16
BAM_3: 14.90				6.00

The concentrations of cobalt spread from 5.96 mg/kg which is distance of 80-120 cm away from the main abattoir to 11.96 mg/kg which was the main abattoir.

The levels of cobalt (10.30 mg/kg) at distances 40-80 cm and (9.13 mg/kg) at distances of 80-120 cm are within the observed range. The observed values of cobalt are lower than 13.20- 30.02 mg/kg found in the seasonal variations of heavy metals concentration in abattoir dumping site soil at Yauri, Nigeria [17], but comparatively higher than 0.63- 3.57 mg/kg found in soil along Kubanni Stream Channel in Zaria, Kaduna State, Nigeria [18] and 0.434-1.030 mg/kg [15]. The concentration of cobalt at each distance in the present research is within the maximum allowed limit of 20.00 mg/kg [13]. The analytical results: 5.96 mg/kg, 9.13 mg/kg, 10.30 mg/kg and 11.98 mg/kg indicated that cobalt concentrations are within the literature level of a typical soil which is not a cause for concern. Cobalt is used as a supplement in animal feed and residue from the feed can be present in organs and tissue of animals. The increase in the levels of cobalt in soil may be as a result of disposing of wastes from the processing of animals. Cobalt can react with other elements or compounds in the soil to form insoluble minerals, this reaction can make cobalt less available in the study soil effectively reducing its concentration. Statistical significant difference between the levels of observed cobalt at different distances away from the studied location are depicted in Table 3.

Table 3: Treatments Mean Differences of Cobalt at Four Different Distances ($LSD_{0.05}$ = 0.45)

	BMA_1:	**BMA_2:**	**BMA_3:**	**BMA_0:**
	11.96	10.30	9.13	5.96
BMA_1: 11.96		1.66	2.83	6.00
BMA_2:10.30			1.17	4.34
BMA_3:9.13				3.17

The levels of copper ranged from: 0.97 mg/kg (the control) to 13.98 mg/kg (main abattoir).The levels (3.98 mg/kg) of copper at distances of 40-80 cm and 1.13 mg/kg at 80 -120 cm away from the main abattoir are within the observed range. The concentration of copper in the control location is lower than the permissible limit of 36 mg/kg set by WHO, 2001 [15] and DPR, 2002 [13]. This revealed that the control location is not contaminated with atmospheric deposited copper through air borne particles from vehicles exhaust or long-ranged transport of dust containing copper. The experimental values are fairly in good agreement with reported literature value of 9.07 mg/kg [14]. It is evident from the results that the levels of copper decrease with increase in distance away from the abattoir. This therefore shows that, the observed levels of copper across all distances and locations will not pose health risk to the inhabitants of the main abattoir for the time being. Nonetheless, bioavailability of copper cannot be confirmed based on total concentration alone. Statistical significant difference was found in levels of copper at varied distances away from the abattoir (Table 4).

Table 4: Treatments Mean Difference of Copper at Four Different Distances (LSD$_{0.05}$= 0.15)

	BMA$_1$:	BMA$_2$:	BMA$_3$:	BMA$_0$:
	13.98	3.96	1.13	0.93
BMA$_1$:13 98		10.02	12.85	13.05
BMA$_2$: 3.96			2.83	3.09
BMA$_3$:1.13				0.20

The experimental values of chromium ranged from 0.96 mg/kg (control) to 6.92 mg/kg (main abattoir) with 4.90 mg/kg and 2.93 mg/kg at distances of 40 - 80 cm and 80 -120 cm respectively found in between the spread values. The level of chromium analyzed was higher than the values of 0.00- 0.05 mg/kg found in soil from major road networks of Dass, Bauchi State, Nigeria [19] and 0.009 mg/kg found in soil of residential area [1]. It is evident from the results that, as the sampling distance increases away from the abattoir, the levels of chromium decreases. Chromium salts such as chromium sulphate are used in tanning processes. In an effort to reduce contamination of soil with chromium, this method can be used to switch to alternative tanning processes such as vegetables tanning which can significantly decrease chromium level in soil [20]. The cumulative levels of chromium (14.75 mg/kg) in the studied area and that of the control (0.96 mg/kg) are lower than the permissible dose of 100.00 mg/kg [13]. This indicates that there is no chromium contamination in both the abattoir and control soil presently. Table 5 shows that significant difference exist in the concentrations of chromium observed at different distances away from the studied site.

Table 5: Treatment Mean Difference of Chromium at Four Different Distances (LSD$_{0.05}$ = 0.19)

	BMA$_1$: 6.90	BMA$_2$:4.98	BMA$_3$:2.90	BMA$_0$: 0.98
BMA$_1$: 6.90		1.92	4.00	5.92
BMA$_2$:4.98			2.08	4.00
BMA$_3$:2.90				1.92

The concentrations of iron evaluated spread from 34.60 mg/kg (control) to 739 mg/kg (main abattoir). The values recorded at distances of 40-80 and 80-120 cm are 707.00 mg/kg and 556.00 mg/kg respectively. These observed values in the studied abattoir are greater than 34.60 mg/kg recorded in the control site, which indicates the presence of iron in waste materials in the studied abattoir. The levels of iron in soil can fluctuate at certain distances, due to certain factors such as: variation in waste disposal, soil composition, water flow and drainage pattern [21]. The levels of iron observed in both the studied and control soil are lower than 2569- 4130 mg/kg found in abattoir dumping side soil [17]. The observed values of iron are much greater than reported literature value of 1.287 mg/kg [22] and the cumulative value (19.27 mg/kg) of iron found in soil of the middle Hanjiang River [23].The spread values of iron in this study are comparatively much higher than 425.50 mg/kg [15], but lower than 5000 mg/kg permissible limit [13]. Table 6 reveals that statistical significant difference exist in the concentrations of iron at different distances away from the main abattoir.

Table 6: **Treatment Means Difference of Iron at Four Different Distances ($LSD_{0.05}$ = 1.22)**

	BMA_1: 739.67	**BMA_2:708.33**	**BMA_3:556.00**	**BMA_0: 34.90**
BMA_1: 739.67		31.34	183.67	704.77
BMA_2:708.33			152.33	673.43
BMA_3:556				521.10

The levels of manganese across all distances in Bauchi main abattoir spread from 21.33 mg/kg (control) to 71.43 mg/kg (which is the main abattoir).The distances of 40-80 cm and 80-120 cm recorded a manganese levels of 54.23 mg/kg and 42.43 mg/kg respectively. The observed values in the studied abattoir are higher than that of the control location and this shows that, there is no previous use of agricultural fertilizer, pesticides or animal feed containing manganese in the control soil. This, practice may leave residual manganese on soil. The investigated values are greater than literature values of 1.15-2.88 mg/kg [24] but lower than 263.01-608.00 mg/kg reported [17].The total observed values (168.09 mg/kg) is within the target value of 2000.00 mg/kg [15].Manganese is one of the essential micronutrients for plants, required for photosynthesis, nitrogen metabolism and lignin synthesis. Deficiency of manganese in crops can lead to significant yield loss if not properly corrected. Table 7 shows the statistical significant differences ($p \leq 0.05$) in the levels of manganese at different distances away from the abattoir (Table 7)

Table 7: Treatments Mean Difference of Manganese at Four Different Distances ($LSD_{0.05}$= 2.805)

	BMA_1:	BMA_2:	BMA_3:	BMA_0:
	71.43	54.23	42.43	21.33
BM_1: 71.43		17.50	29.90	50.13
BM_2: 54.23			11.80	32.90
BM_3: 42.43				21.10

The concentration of nickel in the sample collected ranged from 2.96 mg/kg (the control) to 11.96 mg/kg (main abattoir). The levels of 7.96 mg/kg (40 -80 cm) and 5.97 mg/kg (80 -120 cm) fall between the extreme observed values. The levels of nickel found in this study are in fairly good agreement with reported literature value of 8.24 mg/kg [25], but lower than 170.00 mg/kg found in the background concentration in soil of Cuba [26].The experimental values in the present research are greater than the observed values (1.23- 3.88 mg/kg) evaluated from the roadside dust along Major Traffic Roads in Jos metropolis [24]. Nickel concentration in Bauchi main abattoir is less than the target values of 35 mg/kg [15] and it is also far less than 35 mg/kg stipulated by DPR,2002 [13]. This shows that the studied abattoir soil are not overloaded with nickel even though other parameters need to be evaluated to really ascertain the status of the abattoir soil. Table 8 shows that statistical significant differences ($p \leq 0.05$) exist in the levels of nickel at different distances away from the abattoir (Table 8).

Table 8: Treatments Means Difference of Nickel at Four Different Distances ($LSD_{0.05} = 0.094$)

	BMA_1:	BMA_2:	BMA_3:	BMA_0:
	11.96	7.96	5.97	2.96
BMA_1:11.96		4.00	5.99	9.00
BMA_2:7.96			1.99	5.00
BMA_3:5.97				3.01

Table 1 shows that the concentrations of lead (mg/kg) determined ranged from 7.97 (control) to 30.30 (main abattoir). The lead concentrations at distances of

40-80 cm and 80-120 cm are 8.97 mg/kg and 8.00 mg/kg respectively. Other values with that of the control are respectively lower than the observed value in the main abattoir, which indicates the impact of abattoir activities on the soil. The levels of lead recorded are in fairly good agreement with the values 15.60 - 30.09 mg/kg found in soil of abattoir dumping site in Nigeria [17] and also lower than the target values of 85 mg/kg [13], but greater than the values of 0.005-0.051 mg/kg found in soil of Bauchi Metropolis, Nigeria [1]. Lead do not have known bio-importance in human biochemistry, physiology and consumption of lead even at a very low concentration can be toxic [17].The inhabitants of Bauchi main abattoir might not therefore be at risk of lead contamination for now. Significant differences ($p \leq 0.05$) were found to exist between the observed levels of lead found at different distances away from the main abattoir (Table 9)

Table 9: **Treatment Means Difference of Lead at Four Different Distances (LSD $_{0.05}$ = 0.34)**

	BM_1:30.30	**BM_2:8.97**	**BM_3:8.00**	**BM_0: 7.97**
BM_1:30.30		21.33	22.30	22.33
BM_2:8.97			0.97	1.00
BM_3:8.00				0.03

The levels of zinc in the present study varied from 0.66 mg/kg for soil at distances of 80- 120 cm to 2.97 mg/kg which is the main abattoir, with 0.96 mg/kg (the control) fall in between the extreme observed values. The observed values of zinc are higher than literature values of 0.156-0.380 mg/kg [16]. The values in the main abattoir are relatively higher than the value found at the control location. However, the experimental range are within the 50.00 mg/kg target value in soil [15]. Low zinc levels found in the present findings when compared with the permissible limit of 140.00 mg/kg [13] in soil is lower. This is plausible because zinc though very essential in soil is needed by plants in trace amount. The chemical nature of zinc and its interaction with other elements or substances in the soil determines its availability in the soil for vegetables or plants. Table 10 indicates that significant differences ($p \leq 0.05$) exist between the observed concentrations of zinc found at different distances away from the main abattoir.

Table 10: Treatments Mean Difference of Zinc at Four Different Distances ($LSD_{0.05}$ = 0.288)

	BMA₁:	BMA₂:	BMA₀:	BMA₀:
	2.97	0.96	0.96	0.66
BMA_1: 2.97		2.01	2.01	2.31
BMA_2: 0.96				0.30
BMA_3:0.66				

Pollution Status of Heavy Metals in Bauchi Abattoir and Control Soil

To assess the pollution status of the studied abattoir and control soils, metal pollution index (MPI), heavy metals enrichment factor (EF), geo-accumulation index (Igeo), contamination factor and metal pollution load (PLI) were evaluated.

Metal pollution index (MPI) was used to determine which heavy metal represents the highest threat in a soil environment. This also indicates the relationship between metals concentration in studied area and the reference soil. The different categories of MPI as indicated in Table 11 shows that cadmium recorded MPI values ranging from 1.69 – 2.60 at different measured distances and within the abattoir soils indicating slight pollution of the studied abattoir soils by cadmium. Consequently, negative impact on soil, plants and the environment are predicted in and around studied abattoir soils. Although, cadmium is not an essential element, and the level of pollution was very minimal and therefore the effect may not be alarming.

Table 11: Metal Pollution Indices (MPI) of Some Heavy Metals in Sub-Soil of Bauchi Main Abattoir, Bauchi State, Nigeria

	Metal Pollution Indices								
Distances	Cd	Co	Cu	Cr	Fe	Mn	Ni	Pb	Zn
BM_1	2.60	2.00	14.41	7.20	21.35	3.35	4.04	3.80	3.09
BM_2	1.93	1.73	4.10	5.10	20.43	2.54	2.69	1.13	1.00
BM_3	1.69	1.53	1.16	3.05	16.01	1.99	2.02	1.00	0.68

Results in Tables 11 also indicates that MPI of Zn, Co, Mn, Ni and Pb are moderately polluted (2.00 – 4.00) as shown in table 11, while Cu, Cr and Fe are of severe pollution (2.10 – 4.00) in the soil sample within the abattoir, but at distances of 40- 80 cm and 80 -120 cm, the MPI all the metals are in slight to moderate pollution category except for Fe which shows excessive pollution. This means that Zn, Cd, Cu, Pb, Cr and Ni have slightly polluted the studied abattoir soils and can affect the soil, plants and the studied environment negatively.

Enrichment factors (EF) was used to measure the possible impact of anthropogenic activities based on the concentrations of heavy metals in soil. Fe was used as the reference element for normalization.

Table 12: Enrichment Factor (EF) of Some Heavy Metals in Sub Soil of Bauchi Main Abattoir, Bauchi State, Nigeria

Distances	Enrichment Factor							
	Cd	Co	Cu	Cr	Mn	Ni	Pb	Zn
BM_1	1.13	1.09	1.67	1.34	3.16	1.18	1.18	1.15
BM_2	1.09	2.08	1.19	1.24	2.13	1.13	1.05	2.05
BM_3	1.11	2.10	1.07	2.18	2.13	1.11	2.06	1.04

EF of Cd, Co, Cr, Cu, Pb, Mn, Ni and Zn at all distances in all the abattoir soils studied as shown in Table 12 are greater than 1.00 indicating that the heavy metals are from anthropogenic sources.

Results of the geo-accumulation index (Igeo) of heavy metals in studied abattoir are presented in Table 13. The results revealed: 0.79 - 0.18, 0.03 - 0.42, 0.36 -1.26, 1.02 -1.26, 2.42 – 2.83, 0.41- 1.83, 0.41 -1.16, 0.42 -1.43, 0.50 -1.34 for Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb and Zn at distances of 0 – 40, 40 – 80 and 80 -120 cm respectively in all the abattoir soils.

Table 13: Geo-Accumulation Indices (Igeo) of Some Heavy Metals in Sub-Soil of Bauchi Main Abattoir, Bauchi State, Nigeria

	Geo-Accumulation Indices								
Distances	Cd	Co	Cu	Cr	Fe	Mn	Ni	Pb	Zn
BM_1	0.79	0.42	1.26	1.26	2.83	1.16	1.43	1.34	1.12
BM_2	0.36	0.20	1.45	1.77	2.76	0.76	0.84	0.41	0.58
BM_3	0.18	0.03	0.36	1.02	2.42	0.41	0.42	0.50	1.04

From these results, the soil in the studied locations are in 0 – 1 class (uncontaminated to slightly contaminated) [25]. Fe at all distances in abattoir soil are in 1-2 class (moderately polluted).

Contamination factor (CF) was determined to assess the extent of contamination of the abattoir soil at four (4) different distances (Table 14). CF at distances varied from: 1.93 – 2.65, 0.30 - 1.01, 0.03 – 0.39, 0.01- 0.07, 0.01-0.15, 0.05 – 0.15, 0.08 – 0.34, 0.09 – 1.00 and 0.01 – 0.02 for Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb and Zn respectively. The varied CF reported in this study from the abattoir soils and control may be attributed to the volume of abattoir wastes and activities in each of these distances.

Table 14: Contamination Factor (CF) of Some Heavy Metals in the Sub-Soil of Bauchi Main Abattoir, Bauchi State, Nigeria

Distances	Contamination Factor								
	Cd	Co	Cu	Cr	Fe	Mn	Ni	Pb	Zn
BM_1	2.65	1.01	0.39	0.07	0.15	0.15	0.34	0.36	0.02
BM_2	1.65	1.02	0.11	0.05	0.14	0.11	0.22	0.10	0.01
BM_3	1.96	0.46	0.03	0.03	0.11	0.09	0.16	1.00	0.01
BM_O	1.93	0.30	0.03	0.01	0.01	0.05	0.08	0.09	0.01

From the CF it can therefore be deduced that the abattoir soils are moderately contaminated ($1 < Cf < 3$) [26].

Results of pollution load indices (PLI) of the four abattoir soils are indicated in Table 15. PLI ranges from 1.06 – 2.27 in the studied soil samples at all distances. PLI of the studied abattoir soils are within the moderate pollution ($1 < PLI < 2$) to heavy pollution ($2 > PLI > 3$) category [4].

Table 15: Pollution Load Indices (PLI) of Some Heavy Metals within and Some Distances Away from Bauchi Main Abattoir, Bauchi Nigeria

Distances	Pollution load	Pollution Status
BM_1	2.27	heavily polluted
BM_2	1.16	moderately polluted
BM_3	1.12	moderately polluted
BM_0	1.06	moderatelypolluted

These PLI obtained in this study, further confirm the findings of contamination factor in the studied abattoir soils. This study therefore shows the negative impact of abattoir wastes on underlying soils with regards to metal accumulation.

STATISTICAL ANALYSIS

All the observed values were subjected to standard deviation and One-Way Analysis of Variance (ANOVA). Observed values that were found to be significantly different were subjected to Least Significant Difference test ($p < 0.05$) in order to determine where the statistical significant difference lies. Values that are statistically different are depicted in Tables 2 – 10.

Conclusion

The result of heavy metals determined in soil sample collected from four different distances away from Bauchi main abattoir indicated that the levels of all the heavy metals generally decreased with increase in distance. The concentrations of all the heavy metals are less than their corresponding permissible limits with the exception of iron and cadmium in which their concentrations are higher than their permissible limits. Levels of heavy metals that are greater than their permissible limits may pose health threats to the inhabitants. Heavy metals pollution studies (MPI, EF, I-geo, CF and PLI) based on empirical pollution models indicated that the activities in Bauchi main abattoir may have direct effect on the soil and may also pose health threats to the inhabitants. It is therefore recommended that routine checks be carried out to forestall heavy metals accumulation above safe levels in these soils.

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