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Metal accumulation and Risk assessment of abattoir wastes in soil and leafy vegetables

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Abstract

Globally meat is one of the major sources of protein for human but the processing of animals for meat in abattoirs generates large amount of waste products which in some countries are not properly managed. This research examined the level of trace metals in soil and leafy vegetables impacted by wastes from abattoirs. Levels of Fe, Zn, Cd, Pb and Cu in soils and vegetables from the vicinity of five major abattoirs in Akwa Ibom State were determined using Inductively Coupled Plasma Optical Emission Spectrometer. Soil and vegetables were also collected from a farm that has not been impacted by abattoir wastes and used as Controls. The physicochemical properties of studied abattoir soils and Control were also evaluated. Results indicated that the mean values of all the trace metals, pH and organic matter were higher in studied abattoir soils than in the Control. However, mean values of electrical conductivity and cation exchange capacity of the Control site were higher than in the studied soils. Levels of all metals were higher in studied vegetables than in their Controls. Levels of all the metals in soil were within their safe limits except Fe and Cd. Levels of these metals in vegetables were also within their recommended limits except Cd and Pb. Principal Component analysis revealed two major factors responsible for the availability of trace metals in studied abattoir soils. Results revealed that consumers of

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studied vegetables may be exposed to health problems associated with Cd and Pb toxicities.

Key words: Abattoir-waste impacted soil, trace metals, transfer factor, pollution status, risk assessment, leafy vegetables and Nigeria.

INTRODUCTION

An abattoir is a place where meats are being processed for human consumption and the processing of meat is usually accompanied by large amounts of waste products (Hornby, 2006). These wastes from abattoirs are mostly disposed of either on land or in a water body or both. Globally activities in abattoirs have contaminated and subsequently pollute the air, soil, and aquatic environments tremendously (Adesemoye *et al*., 2006; Nafarnda et al., 2006; Yahaya *et al.,* 2009; Ezeoha and Ugwuishiwu, 2011; Akinyeye *et al*., 2012; Neboh *et al*., 2013; Simeon and Friday, 2017). Reports have shown that improper management of abattoir wastes has resulted in the elevation of toxic metals in soil and aquatic ecosystems impacted by these wastes. Consequently, our edible plants especially vegetables have accumulated a high level of these toxic metals and transferred same to human (Benson and Ebong, 2005; Osu and Okereke, 2015). The contamination of soil, water, and subsequently edible plants by the activities in abattoirs may have resulted in health problems such as diarrhea, pneumonia, typhoid fever, asthma, respiratory, and chest diseases in those exposed to these contaminants (Nwachukwu *et al*., 2011; Mohammed and Musa, 2012). Magaji and Chup (2012) reported that abattoir wastes could result in the reduction of soil fertility and depletion of biodiversity. Unfortunately, farmers cultivating edible plants within the vicinity of abattoirs are using wastes generated there as their source of organic manure notwithstanding the associated health and environmental problems. However, previous studies concentrated on the number of animals slaughtered in a particular within a certain period and on microbial load of abattoir wastes (Opara *et al*., 2005; Offiong *et al*., 2014). Hence, this research was conducted to assess the impact of abattoir wastes on the surrounding soil environment and vegetables cultivated on these soils. This study was carried within Akwa Ibom State where a greater number of abattoirs are situated. This study aimed at evaluating the actual source, pollution status and associated problems of trace metals determined in abattoir-waste impacted soils. This work also determined the number of trace metals transferred from studied soils into vegetables thereby identifying health problems associated with their consumption. It is hoped that the outcome of this study will create awareness on the negative impact of improper management of abattoir wastes on our environments.

MATERIALS AND METHODS

Collection and treatment of soil samples

State, Nigeria. At each abattoir-waste impacted soil, sub-samples were obtained and merged together to form a composite sample for that location. Surface soil samples were also collected from a farm outside the vicinity of an abattoir and used as Control. Sample collection was done once a month for three months between December 2017 and February 2018. A total of forty five (45) sub-samples and fifteen (15) composite soil samples were obtained for Surface soil samples were obtained from five locations which have been impacted by abattoir-wastes namely: Calabar-Itu Road, Itam, Abak, Uyo-Ikot Ekpene Road and Uyo-village Road within Akwa Ibom the research. These samples and Control were air dried for three days, ground and sieved. 1g each of the sieved samples and Control was mixed with Aqua Regia (HCl/HNO_3 3:1) and digested on a hot plate. Then total concentrations of Fe, Zn, Cd, Pb and Cu were determined using Agilent 710 Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES).

Determination of physicochemical properties studied abattoir soils and Control

The pH of studied abattoir soils and Control was examined using pH meter (Hanna instrument model 211) in a 1: 2.5 (v/v) soil/water suspension as proposed by Nabulo *et al.* (2008). Organic matter of studied abattoir soils and Control was determined by wet oxidation methods of Walkley and Black reported by Ebong *et al.* (2014). Electrical conductivity of studied abattoir soils and Control was determined using model 30 Conductivity meter following the procedures of Van Reeuwijk (1993). The procedures of Oviasogie *et al.* (2009) were employed for the determination of Cation exchange capacity of the studied abattoir soils and Control.

Collection and treatment of vegetable samples

At each designated abattoir-waste impacted soils, fresh leaves of *Telfaira occidentalis*, *Talinum triangulare*, *Amarathus hybridus*, and *Ocimum gratissimum* (See English and Ibibio names in Table 1 below) were randomly collected using stainless knife. Vegetables obtained from the farm outside the vicinity of an abattoir were used as Control samples. These vegetable samples and their Controls were stored in polyethylene bags and immediately transported to the laboratory. These samples and their Controls were washed first with tap water and later with distilled water to remove dust particles. The washed samples and Controls were air dried, cut into small pieces and dried in an oven at 60° C for 24h until they were fully dried. The dried samples and their Controls were then ground using blender (Model 33750) into fine powdery form. Each of the ground samples and their Controls was stored in well labeled plastic containers for analyses. One gram of the sieved samples and Control was mixed with Aqua

Regia (HCl/HNO_3 3: 1) and digested on a hot plate. The filtrate obtained was used for the determination of total Fe, Zn, Cd, Pb and Cu using Agilent 710 Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES).

Table 1: English and Ibibio names of studied vegetables

Scientific	English	Ibibio
Telfaira occidentalis,	Fluted pumpkin	Ikong Ubong
Talinum triangulare	Wate rleaf	Mmonmong Ikon
Amarathus hybridus	African spinach	Green
Ocimum gratissimum	Clove basil	Ntong

Source: Emmanuel *et al.* (2013).

Study area

Surface soil and leafy vegetables in Table 1 were obtained from abattoirs and a Control Site in Table 2.

Table 2: Sample location and coordinates

S/N	Location	Coordinate
1.	Calabar-Itu Road Abattoir	Latitude 50º 04!N - 50º 05!N and longitude 70º 55!E - 70º 56!E
2.	Itam Abattoir	Latitude 50º 02!N - 50º 03!N and longitude 70º 53!E - 70º 54!E
3.	Abak Abattoir	Latitude 40º 58!N - 40º 59!N and longitude 70º 46!E - 70º 47!E
4.	Uyo-Ikot Ekpene Road Abattoir	Latitude 50º 06!N - 50º 08!N and longitude 70º 48!E - 70º 49!E
5.	Uyo-Village Road Abattoir	Latitude 50º 03!N - 50º 04!N and longitude 70º 56!E - 70º 58!E
6.	Control	Latitude 50º 05!N - 50º 06!N and longitude 70º 54!E - 70º 55!E

The degree of soil contamination/pollution by trace metals was assessed using the contamination factor (CF) of trace metals determined in studied abattoir soils as described by Mmolawa *et al.* (2011). The contamination factor of trace metals determined was calculated using equations 1 as proposed by Hakanson (1980).

$$CF = \frac{\text{Cm sample}}{\text{Cm background}} \text{ --- } (1)$$

Where Cm sample is the metal concentration in the studied sample and Cm background is the concentration of the same metal in the Control. The different classes of contamination factors (CF) by Hakanson (1980) are as follows: CF < 1 = low contamination, 1 < CF < 3 = moderate contamination, 3 < CF < 6 = considerable contamination and 6 < CF = very high contamination.

Ecological risk factor used for the expression of potential ecological risk for a particular metal was determined using equation 2.

$$E^i_r = Tr \times CF \text{ --- } (2)$$

Where Tr is the toxic-response factor for a particular metal as indicated in Table 1 and CF is the contamination factor (Hakanson, 1980). Toxic response factor for metals as proposed by Hakanson (1980) are Fe (0.00), Pb (5.00), Zn (1.00), Cu (5.00), Cr (2.00) and Ni (5.00).The potential ecological risk factor (RI) of all the metals assessed at a particular location was calculated using equation 3.

$$RI = \Sigma E^i_r \text{ -- } (3)$$

Where ΣE^i_r denotes the summation of multiple trace metals studied at a particular abattoir soil (Cao *et al.*, 2007). The different classifications for ecological risk and potential ecological risk are shown in Table 3 below.

Table 3: Classes of environment by Potential ecological risk index proposed by Yang *et al.* (2009).

Grade	E^i_r values	The Grade of ecological risk of single trace metal	RI	The Grade of a potential ecological risk of the environment
A	$E^i_r < 40$	Low ecological risk	RI < 150	Low ecological risk
B	$40 < E^i_r \leq 80$	Moderate ecological risk	150 < RI < 300	Moderate ecological risk
C	$80 < E^i_r \leq 160$	Appreciable ecological risk	300 < RI < 600	High ecological risk
D	$160 < E^i_r \leq 320$	High ecological risk	RI ≥ 600	Significantly high ecological risk
E	$E^i_r > 320$	Severe ecological risk		

RESULTS AND DISCUSSION

Table 4: Trace metals and physicochemical properties of the studied abattoir soils and Control

Location	Fe (mg/kg)	Zn (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	pH	OM (%)	EC (µS/cm)	CEC (Cmol/kg)
Calabar-Itu Road	662.74	16.04	1.36	0.61	14.74	5.63	7.00	30.05	25.27
Itam	593.51	17.66	1.52	0.83	19.26	5.68	9.45	27.18	21.35
Abak	642.40	36.13	1.25	0.72	20.55	4.89	5.23	16.27	16.00
Uyo-IK	705.28	24.82	1.08	1.16	23.03	5.42	6.35	20.24	12.14
Uyo-Village Road	760.13	21.79	1.27	1.24	16.82	5.82	5.81	18.16	14.53
Min	593.31	16.04	1.08	0.61	14.74	4.89	5.23	16.27	12.14
Max	760.13	36.13	1.52	1.24	23.03	5.82	9.45	30.05	25.27
Mean	672.81	23.29	1.30	0.91	18.88	5.49	6.77	22.38	17.86
SD	63.33	7.96	0.16	0.28	3.22	0.36	1.64	5.95	5.35
CV (%)	9.00	34.00	12.31	31.00	17.00	7.00	24.00	27.00	30.00
Control	367.42	13.70	0.33	0.39	10.31	4.74	4.68	29.56	27.38

Min = Minimum; Max = Maximum; SD = Standard deviation; CV = Coefficient of variation

Distribution of trace metals in studied abattoir soils and Control

The distribution of trace metals determined in studied abattoir soils are shown in Table 4. Levels of Fe varied between 593.31mg/kg and 760.13mg/kg with a mean value of 672.81±63.33mg/kg. This range is higher than 560.40 – 676.60mg/kg obtained by Chukwu and Anuchi (2016) but lower than 2569.00 – 4130.00mg/kg reported by Yahaya *et al.* (2009) in abattoir wastes contaminated soils. The distribution of Fe in studied abattoir soils indicated very low degree of variability as shown by the coefficient of variation (CV) value of 9%. This could be attributed to the high availability of Fe in the study area (Onyedika, 2015.The mean value of Fe reported is higher than 367.42mg/kg obtained in the Control site. This is an indication of anthropogenic inputs of Fe from abattoir wastes in the studied soils. The mean value obtained is also higher 400.00mg/kg recommended for soil in Nigeria by FEPA (1997). Consequently, Fe could be considered as a pollutant in studied abattoir soils. Thus, a proper waste management method should be adopted for the disposal of wastes generated from abattoirs to avoid Fe toxicity and its attendants' health implications along the food chain.

Table 4 shows the range and mean value of Zn in studied abattoir soils as 16.04 – 36.13mg/kg and 23.29±7.96mg/kg respectively. This range is higher than 18.70 – 21.60mg/kg and 1.1302 – 5.2362mg reported by Neboh *et al.* (2013) and Ubwa *et al.* (2013) respectively in abattoir waste-impacted soils. Variation in the distribution of Zn between the studied abattoirs soils was moderate as indicated by a CV value of 34%. The mean value of Zn obtained is higher than 13.70mg/kg recorded in the Control site. Thus, wastes from abattoir may have added additional Zn to the studied abattoir soils. However, the obtained mean value is lower than 140.00mg/kg limit for an uncontaminated by FEPA (1999). Hence, the level of Zn at each studied abattoir soil could be essential for normal enzymatic activities in plants.

Levels of Cd in studied abattoir soils ranged from 1.08 – 1.52mg/kg with a mean value of 1.30±0.16mg/kg. This range is higher than 0.006 – 0.014mg/kg and 0.43 – 0.74mg/kg reported by Sanda *et al.* (2016) and 0.001 – 0.007mg/kg reported by Simeon and Friday (2017) respectively in abattoir waste-impacted soils. The distribution of Cd in the abattoir soils studied showed a low degree of variability with a CV value of 12.31%. The mean Cd value reported is higher than 0.33mg/kg obtained in the Control site. Accordingly, activities in these abattoirs may have introduced additional Cd into soils studied. The mean value is also higher than 0.80mg/kg recommended for an unpolluted soil in Nigeria by FEPA (1999). Thus, considering its toxic nature, the level our environment should be closely monitored to forestall health problems associated with Cd toxicity along the food chain. The range and mean value of Pb in studied abattoir soils as shown in Table 4 are 0.61 – 1.24mg/kg and 0.91±0.28mg/kg. This range is lower than 7.17 – 12.50mg/kg reported by Chukwu and Anuchi (2016) but higher than 0.18 – 0.83mg/kg obtained by Ubwa *et al.* (2013) in soils contaminated with abattoir wastes.

Levels of Pb obtained in studied abattoir soils varied from 0.61mg/kg to 1.24mg/kg with a mean value of 0.91±0.28mg/kg. This range is lower than 0.185 – 1.676 ppm and 0.001 – 2.900mg/kg reported by Ubwa et al. (2013) and Osu & Okereke (2015) respectively. The distribution of Pb in the studied abattoir soils indicated a fair degree of variability with a CV value of 31%. The mean value of Pb reported is higher than 0.39mg/kg obtained in the Control site. This indicates anthropogenic addition of Pb by abattoir wastes to the studied soils. However, the range obtained is lower than 15.0 – 25.00 recommended for an unpolluted soil in Nigeria by FEPA (1991). Consequently, Pb may not be considered a pollutant in the studied soils but its availability should be observed to avoid bioaccumulation over time with associated problems on the environment.

Levels of Cu in the studied abattoir soils varied from 14.74mg/kg to 23.03mg/kg with a mean value of 18.88±3.22mg/kg (Table 4). The obtained range is lower than 36.46 – 40.60mg/kg reported by Owagboriaye *et al*. (2016) but higher than 0.10 – 0.20mg/kg obtained by Sanda *et al*. (2016) in abattoir soils. The degree of variability in the distribution of Cu between studied abattoir soils was low as indicated by a CV value of 17%. The mean value of Cu reported is higher than 10.31mg/kg obtained in the Control site. This is an indication that waste products from abattoir may have added substantial amounts of Cu to the studied soils. Nevertheless, the mean is lower than 36.00mg/kg recommended for unpolluted soil in Nigeria by FEPA (1999). Thus, Cu levels in studied abattoir soils could be essential for normal plant growth and may not constitute nuisance along the food chain.

Distribution of physicochemical properties in studied abattoir soils and Control

The pH of studied abattoir soils ranged from 4.80 to 5.82 with a mean value of 5.49±0.36 (Table 4). This pH range is more acidic than 6.49 – 7.63 reported by Sumayya *et al.* (2013) and 6.30 – 6.33 obtained by Akinyeye *et al.* (2012) in abattoir waste-impacted soils. The pH range obtained is lower than 6.0 – 7.5 and may not support the availability of essential minerals for optimal plant growth (Sanchez *et al.*, 2003). However, the mean pH value reported in studied abattoir soils is higher than 4.74 obtained in the Control site. This is similar to the results obtained by Yahaya *et al.* (2009) during their study in abattoir waste-contaminated soils. Thus, the presence of abattoir waste products may have influenced pH of the studied soils. The degree of variability in pH level of studied abattoir soils was low as indicated by a CV of 7.00%.

Organic matter (OM) content of studied abattoir soils varied between 5.23% and 9.45% with a mean value of 6.77±1.64%. Range of OM obtained is lower than 6.45 – 11.76% but higher than 1.87 – 2.85% reported by Neboh *et al.* (2013) and Abukabar (2014) respectively in abattoir waste-contaminated soils. The mean OM value reported in studied abattoir soils is higher than 4.68% obtained sample from Control site. This is agreement with the findings by Owagboriaye *et al.* (2016) in abattoir waste-impacted soils. This could be attributed to the impact of abattoir waste products on the studied soils. The distribution of OM in studied soils indicated a fair degree of variability with a CV value of 24%.

Electrical conductivity (EC) of studied abattoir soils ranged from 16.27µS/cm to 30.05µS/cm with a mean of 22.38±5.95µS/cm. The obtained EC range is lower 733.44 – 5438.92µS/cm but higher 13.20 – 18.53µS/cm obtained by Sumayya *et al.* (2013) and Rabah *et al.* (2010) respectively in abattoir waste-impacted soils. The mean EC is lower than 29.56µS/cm obtained in the Control soil. This finding is consistent with the results obtained by Chukwu and Anuchi (2016) in abattoir waste-contaminated soils. This could be attributed to the impact of organic matter in studied soils as reported by Rahimia *et al.* (2000). Consequently, abattoir waste products may have impacted negatively on the properties of studied soils. The EC of studied abattoir soils showed moderate degree of variability with a CV value of 27%.

The cation exchange capacity (CEC) of studied abattoir soils varied from 12.14Cmol/kg to 25.27Cmol/kg with a mean value of 17.86±5.35Cmol/kg. The range of CEC obtained in this study is higher than 12.54 – 16.84 Cmol/kg and 8.62 – 8.80Cmol/kg reported by Neboh *et al.* (2013) and Abubakar (2014) respectively in abattoir waste-impacted soils. The mean CEC value reported is lower than 27.38Cmol/kg obtained in the Control site. This could be a direct impact of organic wastes in the studied abattoir soils as confirmed by Jones *et al.* (2002). This lower CEC level in the Control is in agreement with the report by Iwegbue *et al.* (2006). This affirms the negative impact of abattoir wastes on the availability of mineral elements for plants growth in studied abattoir soils. The degree of variability in the distribution of CEC in studied soils was moderate as indicated by a CV value of 30%.

Table 5: Trace metals levels (mg/kg) in vegetables from Calabar – Itu Abattoir soil and Control

Location	Vegetable	Fe	Zn	Cd	Pb	Cu
	TF	7.32	1.42	0.05	0.03	1.16
Calabar-Itu	TT	4.51	0.84	0.03	0.07	0.43
	AH	13.21	1.14	0.04	0.09	0.82
	OG	11.40	2.16	0.06	0.02	0.37
	TF	13.17	1.13	0.08	0.05	1.32
Itam	TT	6.73	0.94	0.13	0.06	0.73
	AH	10.21	0.73	0.05	0.07	0.27
	OG	6.04	1.64	0.16	0.06	0.48
	TF	12.16	1.17	0.02	0.07	0.36
Abak	TT	8.10	0.43	0.01	0.03	1.04
	AH	7.41	0.96	0.06	0.09	0.74
	OG	6.23	1.06	0.08	0.03	0.66
	TF	10.36	1.44	0.07	0.03	1.36
Uyo-Ikot Ekpene	TT	5.78	1.08	0.05	0.06	1.02
	AH	13.89	0.87	0.06	0.06	0.84
	OG	7.54	1.25	0.05	0.05	0.91
	TF	8.62	1.56	0.03	0.05	1.22
Uyo Village	TT	11.58	0.64	0.02	0.06	1.27
	AH	8.63	0.88	0.04	0.06	0.83
	OG	7.14	1.16	0.05	0.07	0.71
	MIN	4.51	0.43	0.01	0.02	0.27
	MAX	13.89	2.16	0.16	0.09	1.36
	MEAN	9.00	1.13	0.06	0.06	0.83
	TF	1.81	0.23	0.00	0.01	0.16
Control	TT	1.23	0.11	0.00	0.01	0.09
	AH	6.15	0.31	0.01	0.00	0.20
	OG	4.21	0.12	0.01	0.00	0.24
	MEAN	3.35	0.19	0.01	0.01	0.17

TF = *Telfaira occidentalis;* TT = *Talinum triangulare;* AH= *Amarathus hybridus;* OG = *Ocimum gratissimum*

Distribution of trace metals in vegetables from studied abattoir soils and Control

Levels of Fe in vegetables obtained from studied abattoir soils varied between 4.51mg/kg to 13.89mg/kg with a mean value of 9.00±2.80mg/kg (Table 5). Range of Fe in vegetables reported is lower than 70.55 – 211.64µg/g obtained by Amusan *et al*. (2005) but consistent with 5.25 – 13.02mg/kg obtained by Ekpo (2017). The highest level of Fe was obtained in *Amarathus hybridus* from Uyo-Ikot Ekpene Road abattoir soil while the lowest was recorded in *Talinum triangulare* from Calabar-Itu Road abattoir soil. This is an indication that *Amarathus hybridus* has a high potential for accumulating Fe from the studied abattoir soils. The mean value of Fe in vegetables from studied abattoir soils is higher than 3.35mg/kg obtained in the Control site. Thus, the lower levels of Fe in Control may have affected directly the level of Fe absorbed by vegetables. However, the mean value of Fe in vegetables from studied abattoir soils is lower than 425.50mg/kg recommended limit by FAO/WHO (1999) for leafy vegetables. Thus, levels of Fe in vegetables from studied abattoir soils could be essential for normal growth of the vegetables and may not pose any risk to the consumers (Rout and Sahoo, 2015). The distribution of Fe varied between plant species and abattoir soils with a CV value of 31%.

Zn in vegetables from studied soils ranged from 0.43mg/kg to 2.16mg/kg with a mean value of 1.13±0.39mg/kg (Table 5). This range is similar with 1.000 – 2.340mg/kg reported in leafy vegetables by Otitoju *et al.* (2012) but lower than 21.46 – 140.61mg/kg obtained by Kayastha (2014). The highest Zn level was obtained in *Ocimum gratissimum* from Calabar-Itu Road abattoir soil while the lowest level was in *Talinum triangulare* in Abak abattoir soil. Thus; *Talinum triangulare* has a low ability to absorb Zn from studied abattoir soils while *Ocimum gratissimum* exhibits a very high potential for accumulating Zn. The mean level of Zn reported is higher than 0.19±0.10mg/kg obtained in vegetables from the Control site. However, the mean obtained in vegetables from studied soils is lower than 100.00mg/kg recommended limit in leafy vegetables by FAO/WHO (2001). Consequently, levels of Zn obtained in vegetables may be necessary for their growth and enzymatic activities (Hafeez *et al*., 2013). The consumers of vegetables obtained from studied abattoir soils may not be exposed to Zn toxicity and its attendants' effects. Distribution of Zn between the different plant species and abattoir soils showed a moderate level of variability with a CV value of 35%.

Levels of Cd in vegetables from studied soils ranged from 0.01mg/kg to 0.16mg/kg with a mean level of 0.06±0.04mg/kg. The range obtained is lower than 0.34 – 5.44mg/kg and 0.11 – 6.00mg/kg reported in leafy vegetables from contaminated soils by Akan *et al*. (2013) and Lawal *et al*. (2017) respectively. However, the range is consistent with 0.01 – 0.11mg/kg obtained by Radman and salama (2006). The highest level of Cd was obtained in *Ocimum gratissimum* from Itam abattoir soil while the lowest was obtained in *Talinum triangulare* from Abak abattoir soil. Hence, *Ocimum gratissimum* has a higher ability of absorbing Cd from studied soils than other metals determined in this study. The mean value of Cd reported in studied vegetables is higher than 0.01±0.01mg/kg obtained in vegetables from the Control site. The mean is also higher than 0.1mg/kg recommended limit for leafy vegetables by FAO/WHO (2001). Accordingly, Cd may be considered as a pollutant in studied vegetables and the consumers could be exposed health problems associated with Cd toxicity as reported by Verougstraete and Lison (2003) and Sharma *et al*. (2015). Distribution of Cd exhibited a very high degree of variability in vegetables studied with a CV value of 67%.

The distribution of Pb in the different vegetables studied ranged from 0.02mg/kg to 0.09mg/kg with a mean value of

0.06±0.02mg/kg. This range is lower than 0.18 – 1.59mg/kg reported by kananke *et al.* (2014) but higher than 0.003 – 0.005mg/kg obtained in leafy vegetable by by Otitoju *et al.* (2012). The lowest Pb was obtained in *Ocimum gratissimum* from Calabar- Itu Road abattoir soil while the highest level was obtained in *Amarathus hybridus* from Calabar- Itu Road and Abak abattoir soils. Consequently, *Amarathus hybridus* has higher potential of bio-accumulating Pb from abattoir soils than other vegetables studied. The mean value of Pb in vegetables studied is higher than 0.01±0.01mg/kg obtained in vegetables from the Control site. This is an indication that activities in these abattoirs may have contributed to the elevated levels of Pb in studied abattoir soils. The obtained mean is also higher than 0.30mg/kg safe limit for leafy vegetable by FAO/WHO (2001). Thus, the consumption of vegetables from these locations may result in Pb-toxicity and associated health problems in the consumers (ATSDR, 2007, Wani *et al.*, 2015). The degree of variability in the distribution of Pb among vegetables studied was moderate as indicated by the CV value of 33%.

Levels of Cu in the studied vegetables varied between 0.27mg/kg and 1.36mg/kg with a mean value of 0.83±0.34mg/kg. This range is higher than 0.1- 0.29mg/kg reported by Sohrabi *et al.* (2015) but consistent with 0.72 – 1.37mg/kg obtained by Bahemuka and Mubofu (1999) in leafy vegetables. The highest level of Cu was obtained in *Amarathus hybridus* from Itam abattoir soil while the lowest was recorded in *Talinum triangulare* from Uyo-Ikot Ekpene Road abattoir soil. Thus, *Amarathus hybridus* has the tendency of absorbing more Cu from abattoir soils than of other leafy vegetables studied. The mean concentration of Cu obtained is much lower than 40.00mg/kg safe limit by FAO/WHO (1999). Thus, the level of Cu obtained may not be sufficient for the proper functioning of these vegetables thus may also not constitute a nuisance to the consumers. However, the mean value of Cu obtained is higher than 0.17±0.06mg/kg obtained in vegetables from the Control site. Consequently, activities at these abattoirs may have contributed substantial quantities of Cu to the surrounding soil environment thereby transferring same into vegetables grown on these soils. The distribution of Cu among vegetables studied indicated a fairly high degree of variability with a CV value of 41%. Generally, the accumulation of trace metals by vegetables varied with species and location.

Table 6: Transfer factor of trace metals in vegetables from studied abattoir soil and Control

Location	Vegetable	Fe	Zn	Cd	Pb	Cu
	TF	0.01	0.09	0.04	0.04	0.08
Calabar-Itu	TT	0.08	0.05	0.02	0.11	0.03
	AH	0.02	0.08	0.03	0.15	0.06
	OG	0.02	0.13	0.04	0.03	0.03
	TF	0.02	0.06	0.05	0.06	0.07
Itam	TT	0.01	0.05	0.09	0.07	0.04
	AH	0.02	0.04	0.03	0.08	0.01
	OG	0.01	0.09	0.11	0.07	0.02
	TF	0.02	0.03	0.02	0.10	0.02
Abak	TT	0.01	0.01	0.01	0.04	0.05
	AH	0.01	0.03	0.05	0.13	0.04
	OG	0.01	0.03	0.06	0.04	0.03
	TF	0.01	0.06	0.06	0.03	0.06
Uyo-Ikot Ekpene	TT	0.01	0.04	0.05	0.05	0.04
	AH	0.02	0.04	0.06	0.05	0.04
	OG	0.01	0.05	0.05	0.04	0.04
	TF	0.01	0.08	0.02	0.04	0.07
Uyo Village	TT	0.02	0.03	0.02	0.05	0.08
	AH	0.01	0.04	0.03	0.05	0.05
	OG	0.01	0.05	0.04	0.06	0.04
	MIN	0.01	0.01	0.01	0.03	0.01
	MAX	0.08	0.13	0.11	0.15	0.08
	TF	0.01	0.02	0.00	0.03	0.02
Control	TT	0.003	0.01	0.00	0.03	0.01
	AH	0.02	0.02	0.03	0.00	0.02
	OG	0.01	0.01	0.03	0.00	0.02

TF =*Telfaira occidentalis;* TT =*Talinum triangulare;* AH=*Amarathus hybridus;* OG = *Ocimum gratissimum*

Results for the Transfer factor (TF) of trace metals determined in studied vegetables cultivated in abattoir-waste impacted soils are shown in Table 6. Transfer factor denotes the relation between metal in vegetable and that of soil. TF is an appropriate and reliable method for computing the quantity of a metal readily available for plant uptake (McEldowney *et al*., 1994). High transfer factor indicates relatively poor retention capacity of a metal in soil or greater potential of plants to absorb such metal (Tasrina *et al.*, 2015). Low transfer factor signifies a significant binding capacity of soil for the metal (Coutate, 1992). Results in Table 3 indicate the following ranges for the TF of metals the vegetables from the different abattoir soils: Fe (0.01 - 0.08), Zn (0.01 – 0.13), Cd (0.01 – 0.11), Pb (0.03 – 0.15), and Cu (0.01 – 0.08). Thus, these vegetables may not be suitable for phyto-extraction and phyto-remediation as their TF values are not ≥1 (Blaylock *et al.*, 1997). However, lower ranges were obtained for these metals in studied vegetables obtained at the Control site. These ranges are as follows: Fe (0.003 – 0.02), Zn (0.01 – 0.02), Cd (0.00 – 0.03), Pb (0.00 – 0.03), and Cu (0.01 – 0.02). This low TF values in vegetable from Control site may be attributed to the low level of total metals and low organic matter (Kachenko and Singh, 2006; Agbaire and Emoyan, 2012). Generally, Zn and Pb showed higher TF values than other metals thus, they were high accumulators among the metals determined. The trend for trace metals in vegetables from studied abattoir soils in the order Pb> Zn > Cd > Fe = Cu.

Table 7: Correlation coefficient between metals and physicochemical properties of studied abattoir soils

		Fe	Zn	Cd	Pb	Cu	pH	OM	EC	CEC
	Fe	1.000								
	Zn	.024	1.000							
	Cd	-.646***	-.508	1.000						
	Pb	.747*	.008	-.512	1.000					
Correlation	Cu	-.103	.572	-.530	.352	1.000				
	pH	.308	-.897*	.366	.370	-.529	1.000			
	OM	-.642***	-.686**	.761*	-.229	-.108	.495	1.000		
	EC	-.472	-.834*	.631***	-.526	-.526	.509	.745*	1.000	
	CEC	-.570	-.593	.773*	-.794*	-.716	.272	.558	.874*	1.000

***Correlation is significant at the 0.01 level (2-tailed); ** Correlation is significant at the 0.02; *** Correlation is significant at the 0.05 level (2-tailed).**

Results for Pearson correlation analysis of relationship among trace metals and physicochemical properties of abattoir soil are shown in Table 7. As indicated in Table 4, Fe exhibits a weak positive correlation with Zn and pH but a weak negative correlation with Cu at $p < 0.05$. Fe related positively and significantly with Pb at $p < 0.01$ but negatively and strongly with Cd and OM at $p < 0.02$. Fe also correlated negatively but moderately with EC and CEC at $p < 0.05$. Zn showed a very strong negative correlation with pH and EC at $p < 0.01$ but with OM at $p < 0.02$. Zn also correlated negatively but moderately with Cd and CEC at $p < 0.05$. The relationship between Zn and with Cu was a positive but moderate one at $p < 0.05$. However, Zn exhibited a very weak positive relationship with Pb at $p < 0.05$. Cd correlated positively and significantly with OM and CEC at $p < 0.01$ but with EC at $p < 0.05$. Cd showed a weak positive correlation with soil pH at $p < 0.05$. However, Cd exhibited a moderate negative relationship with Pb and Cu at a 95% confidence limit. Results in Table DD show a strong negative correlation with CEC at $p < 0.05$. Pb also related negatively but insignificantly with OM and EC at $p < 0.05$. Pb correlated positively and insignificantly with Cu and pH at $p < 0.05$. Cu showed a strong negative relationship with CEC at $p < 0.01$but a weak negative association with pH, OM, and EC at $p < 0.05$. Soil pH correlated positively but insignificantly with OM, EC, and CEC at $p < 0.05$. Organic matter of studied abattoir soils correlated positively and significantly with EC at $p < 0.01$. OM also showed a positive relationship but moderately with CEC at $p < 0.05$. EC exhibited a very strong positive correlation with CEC at a 99% confidence limit.

Table 8: Total variance explained for parameters determined in the studied abattoir soils

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.041	56.008	56.008	5.041	56.008	56.008	3.265	36.283	36.283
2	2.323	25.808	81.816	2.323	25.808	81.816	2.982	33.136	69.419
3	1.186	13.176	94.992	1.186	13.176	94.992	2.302	25.574	94.992
4	.451	5.008	100.000						
5	1.846E-016	2.051E-015	100.000						
6	9.448E-017	1.050E-015	100.000						
7	5.384E-017	5.982E-016	100.000						
8	-1.959E-016	-2.177E-015	100.000						
9	-2.561E-016	-2.845E-015	100.000						

Extraction Method: Principal Component Analysis.

Table 9: Matrix of the major principal components

	COMPONENTS		
	F1	F2	F3
EC	.932	.060	.026
CEC	.931	-.202	-.296
Cd	.864	-.151	.089
OM	.797	.014	.602
Zn	-.782	-.585	-.103
pH	.518	.845	.112
Fe	-.560	.755	-.339
Pb	-.572	.730	.352
Cu	-.635	-.311	.682

The source of parameters determined in studied abattoir soils was identified using Principal component analysis (PCA) as reported by Wu and Kuo (2012). Table 8 gives results for PCA analysis of parameters determined in studied abattoir soils. Results in Table 8 indicate three key factors with Eigenvalues higher than one with a significant 94.99% of the total variance. The first Factor (F1) contributed 56.01% of the total variance with strong positive loadings on EC, CEC, Cd, and OM but strong negative loadings on Cu and Zn (Table 9). This represents the negative impact of agrochemicals and abattoir wastes on the quality of studied soils (Yin *et al*., 2010). The second factor (F2) contributed 25.81% of the total variance with significant positive loadings on soil pH, Fe, and Pb (Table 9). This factor signifies the impact of natural and automobile emissions on the soil quality (Huang *et al*., 2009). As in Table 6

Factor three (F3) contributes 13.18% of the total variance with strong positive loadings on OM and Cu representing the impact of anthropogenic activities in abattoirs on the soil quality (Ha *et al*., 2014).

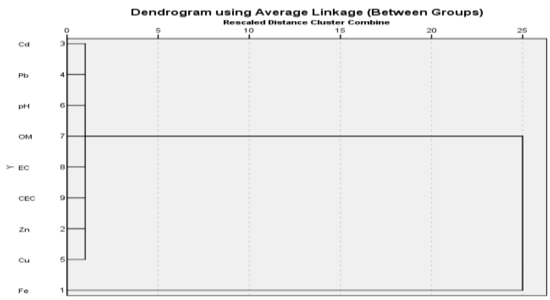

Fig. 1: Hierarchical clusters formed among parameters determined in studied abattoir

The relationships among parameters determined in the studied abattoir soils are also illustrated in Hierarchical cluster analysis (HCA) in figure 1. HCA in figure 1 indicates two main clusters namely: Cluster one linking all the parameters determined together except Fe. This confirms that these parameters in cluster one may have emanated mainly from anthropogenic activities within and around the studied abattoirs. The second cluster that links with Fe alone signifies that the metal may have originated principally from the natural source.

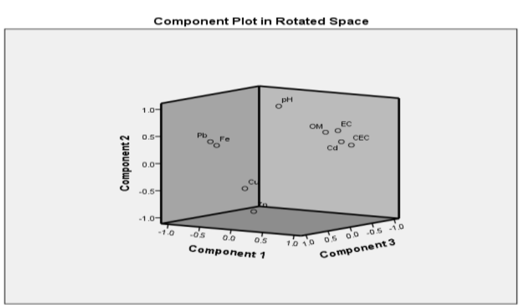

Fig. 2: A plot of major components of PCA in studied abattoir soils

Plotting the three major factors obtained from principal components analysis resulted in three components illustrated in figure 2. Results obtained are normally interpreted according to data in the rotation matrix. Based on the rotation matrix obtained, the first component showed strong positive loadings on OM, Cd, and CEC but significant negative loadings on Fe and Pb representing factor one in PCA. The second component indicated strong positive loadings on OM, pH, and Cu but significant negative loading on Zn. This signifies the second factor obtained from PCA in this study. The third component showed strong positive loadings on Pb and Cu but significant negative loading on CEC representing factor three in PCA. These components signify the common source of these parameters in the studied abattoir soils.

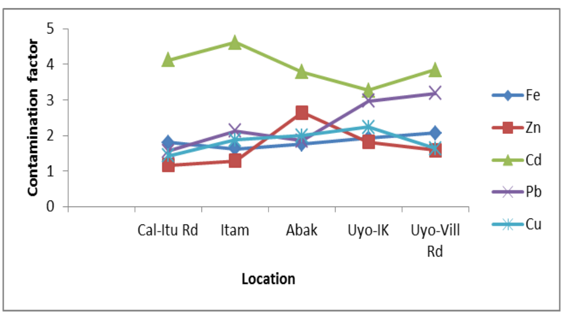

Fig. 3: Contamination factor of trace metals in studied abattoir soils

Results for the contamination factor (CF) of trace metals determined in studied abattoir soils are indicated in figure 3. The mean contamination factor for Fe, Zn, Cd, Pb, and Cu are 1.83, 1.70, 2.93, 2.34, and 1.83 respectively. Based on the different classes of CF by Hakanson (1980), all the elements belong to the moderate contamination class. Thus, these trace metals may have contaminated the studied abattoir soils reasonably. The trend for the mean CF of trace metals in studied abattoir soils is in the order Cd > Pb > Fe = Cu > Zn. Hence, the highly toxic metals (Cd and Pb) showed higher mean CF than the essential metals. This observed trend should be closely monitored and controlled to forestall a devastating situation along the food chain.

Table 10: Ecological risk and Potential ecological risk factor of trace metals.

Location	Fe	Zn	Cd	Pb	Cu	RI
Calabar-Itu Road	0.00	1.17	123.60	7.80	7.15	139.72
Itam	0.00	1.29	138.30	10.65	9.35	159.59
Abak	0.00	2.64	113.70	9.25	9.95	135.54
Uyo-IK	0.00	1.81	98.10	14.85	11.15	125.91
Uyo-Village Road	0.00	1.59	115.50	15.90	8.15	141.14
Min	0.00	1.17	98.10	7.80	7.15	125.91
Max	0.00	2.64	138.30	15.90	11.15	159.59
Mean	0.00	1.70	117.84	11.69	9.15	140.38

Min = Minimum; Max = Maximum

Results for the Ecological risk factor of each trace metal determined in studied abattoir soils are shown in Table 10. Results obtained showed that Fe without toxic respond factor had no ecological risk factor. The E^i_r values for Zn varied from 1.17 to 2.74. The ranges of E^i_r for Pb and Cu are 7.80 – 15.90 and 7.15 – 11.15 respectively. Consequently, Zn, Pb and Cu belong to the low ecological risk class as indicated in Table 3 (Yang *et al.*, 2009). However, the ecological risk factor of Cd varied between 98.10 and 138.30 with a mean value of 117.84. Thus, Cd belongs to the appreciable ecological risk according to Yang *et al.* (2009) classifications. Hence, human beings exposed to this metal directly or indirectly are at the risk of Cd toxicity and its associated health problems. The ecological risk factor of the metals followed the order Cd > Pb > Cu > Zn > Fe.

The potential ecological risk index (RI) of trace metals determined in studied abattoir soils was examined to establish the health problems associated with exposure to these metal (Mugosa *et al.,* 2016). Results for the potential ecological risk index of trace metals determined are also shown in Table 10. Results obtained indicated that RI varied from 125.91 at Uyo-Ikot Ekpene Road abattoir soil to 159.59 at Itam abattoir soil. Following the different classes of RI by Yang *et al.* (2009) all the studied abattoir soils are in the Low ecological risk class except

Itam. Itam abattoir soil with RI value of 159.59 belongs to the moderate ecological risk class (Table 3). Consequently, people exposed to Itam abattoir soil either directly or indirectly are at a higher risk than those exposed to other abattoir soils studied (Yang *et al.*, 2009). This has identified abattoir wastes as one of the potential sources of these trace metals to studied abattoir soils hence, with continuous dumping of these wastes will eventually elevate their RI values.

CONCLUSION

This research has shown that waste products from abattoirs could result in the accumulation of trace metals to a toxic level. Thus, a proper waste management method should be adopted for the disposal of wastes from abattoir. The study has also revealed that the use of wastes from abattoirs as organic manure for the cultivation of edible plants should be discouraged to forestall serious environmental and health problems. However, the PCA has indicated that availability of metals in abattoir-waste impacted soils may not be attributed solely to the wastes as some may be natural or aerial depositions. The risk associated with the cultivation of studied abattoir soils with leafy vegetables and consumption has been exposed. It is hoped that this research will create awareness on the danger associated with improper management of wastes from abattoirs within Akwa Ibom State and beyond.

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