VALUATION OF HEAVY METAL POLLUTION IN SOILS WITHIN DESIGNATED ABATTOIRS IN IMO STATE, NIGERIA

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ABSTRACT

This research was centered on the valuation of heavy metals pollution in soils within designated abattoirs in Owerri zone Imo State. Soil samples were collected at a depth of 0 – 30 cm at the study areas to determine soil pH, Copper (Cu), Zinc (Zn), Chromium (Cr), Cadmium (Cd), Lead (Pb) and Manganese (Mn) contents using standard methods and analysis of variance (ANOVA) was carried out. The mean pH values of the soil of Egbeada and Nekede abattoirs were found to be 7.760 and 7.170, respectively. This shows that both soils are alkaline soils. The mean concentration of heavy metals of Egbeada abattoir are 0.825 mg kg^{-1} (Cr), 12.500 mg kg^{-1} (Mn), 0.913 mg kg^{-1} (Cd), 12.317 mg kg^{-1} (Cu), 0.515 mg kg^{-1} (Zn), and 0.042 mg kg^{-1} (Pb), respectively while the mean concentration of heavy metals of Nekede abattoir were 0.963 mg kg^{-1} (Cr), 13.150 mg kg^{-1} (Mn), 2.285 mg kg^{-1} (Cd), 14.160 mg kg^{-1} (Cu), 0.200 mg kg^{-1} (Zn), and 0.039 mg kg^{-1} (Pb), respectively. The mean pollution index of heavy metals of Egbeada abattoir were 0.0008 mg kg^{-1} (Pb), 0.0035 mg kg^{-1} (Zn), 0.3441 mg kg^{-1} (Cu), 0.0084 mg kg^{-1} (Cr), 1.1424 mg kg^{-1} (Cd), 0.0145 mg kg^{-1} (Mn), respectively. while the mean pollution index of heavy metals of Nekede abattoir were 0.0007 mg kg^{-1} (Pb), 0.3952 mg kg^{-1} (Cu), 0.0025 mg kg^{-1}, (Zn), 0.0096 mg kg^{-1} (Cr), 2.8566 mg kg^{-1} (Cd), 0.0167 mg kg^{-1} (Mn). The study shows that both abattoirs contained Pb, Cu, Cr, Mn, Cd and Zn. It was also observed that both abattoirs have concentrations of Cu and Mn higher that the rest, which does not pose serious threat to agriculture but, could in no distance time reduce productivity. This could be attributed to the presence of waste carrying higher amounts of these heavy metals and the geological formation of the areas.

Keywords: Concentrations, micronutrients, heavy metals, pollution, soils, abattoirs

INTRODUCTION

Heavy metal pollution is a major problem globally due to its great consequence on human health, plant and the ecosystem. Soil is a mixture of organic matter, minerals, gases, liquids and organisms that together support life (Chesworth, 2008). Soil is a product of several factors; including influence of climate, elevation, orientation, and slope of terrain, organisms; as well the soils parent materials interacting over time. According to Ponge (2015) it continually undergoes development by way of numerous physical, chemical and biological processes, which include weathering with related erosion. Given its complexity and strong internal connectedness, soil ecologists regard soil as an ecosystem. According to Onweremadu (2012), soil is not only a support for vegetation, but it is also the zone beneath our feet of numerous interaction between climate, soil life and its residues, the mineral material of the original and added rock and its position in the landscape. Soil consists of a solid phase of minerals (the soil matrix) and organic matter, as well as a porous phase that holds gases (the soil atmosphere) and water (the soil solution). Consequently, soils are often treated as a three-state system of solids, liquids, and gases. Soil pollution, driven by both natural processes and human activities, has become a widespread issue. In particular, heavy metal contamination—by elements like cadmium (Cd), zinc (Zn), lead (Pb), chromium (Cr), copper (Cu), iron (Fe), and manganese (Mn)—is known to have serious health implications, particularly for crops cultivated in polluted soils. Pollutants, often released into the environment through agricultural, industrial, and other anthropogenic activities, accumulate in soil and can lead to contamination of food crops, thereby impacting the food chain (Ruqia-Nazir et al., 2015). Heavy metals, even in trace amounts, are highly toxic and tend to bioaccumulate in the tissues of both plants and animals. Increased levels of heavy metals have been linked to adverse health outcomes in both ecosystems and human populations as they affect soil's physical and chemical properties (Momodu & Anyakora, 2010). Heavy metal contamination of agricultural soils is a growing concern due to its potential to compromise food safety, soil health, and ecosystem stability (Cui et al., 2004). Metals such as mercury (Hg), lead (Pb), cadmium (Cd), and chromium (Cr) are particularly toxic, while others like zinc (Zn) and copper (Cu), are essential in small quantities but harmful in excess. Heavy metals can accumulate in the soil at toxic levels due to the long-term application of wastewater (Rajesh *et al*. 2007). In the same vein, Edori and Kpee (2017) posited that metals are natural components earth's crust and are contributors to the natural balance of the planet.

Abattoirs, or slaughterhouses, are facilities where animals are processed for meat. As defined by the Abattoir Acts (1998), an abattoir is any establishment used for the slaughter of animals intended for human consumption, excluding farms. Studies have shown that abattoir activities can negatively impact surrounding soil and water quality (Adesemoye et al., 2006). Abattoir waste contains various materials, including blood, urine, feces, and organic tissues, which may contain heavy metals (Osemwota, 2010). Contamination from abattoirs can thus lead to significant environmental pollution, which highlights the need to monitor heavy metal levels in soils surrounding such sites. Therefore, the possibility of environmental contamination and pollution from abattoir cannot be over ruled. The extent of human impact is now so prominent pervasive and profound, that there is need to investigate the levels of heavy metals in soils within abattoir areas in Imo State. The primary aim of this study was to evaluate heavy metal contamination in soils around abattoirs in Imo State, Nigeria. Specifically, the study seeks to assess the levels of heavy metal pollution in soils of two abattoirs and to compare the contamination levels between these locations.

MATERIALS AND METHODS

The study sites are Egbeada and Nekede in Imo State Nigeria. Egbeada is in Mbaitoli local government area of Imo State and it lies on latitude 05^{o} 29' N and longitude 07^{o} 26' E. It is situated along Orlu - Owerri road at an approximate distance of 4km from Owerri capital city of Imo State. It has boundary with the following communities: Akwakuma on the South, Ubomiri on the north, Mbieri on the east and Ohi on the west. It covers an area of 3.32 hectares. A greater proportion of the land surface of Imo State is of flat topography. Nekede abattoir is located in Owerri West L.G.A of Imo State (Figure1). It lies on Latitude 5^{o} 25^{I} 03^{II} N and Longitude 6^{o} 55^{I} 06^{II} E. The second study location was about 3 km from Owerri main town (Obineche *et al.* 2020)

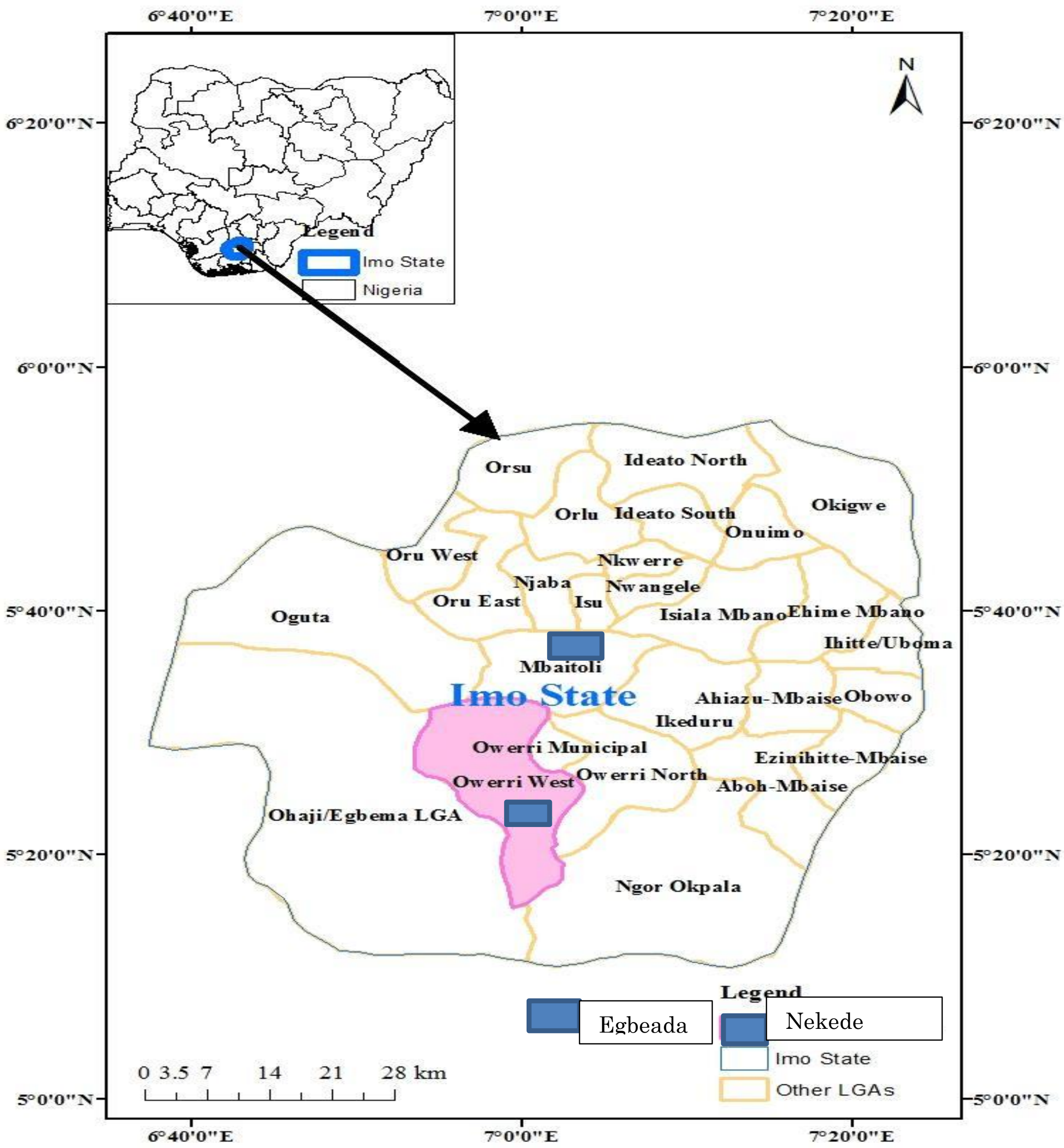

Figure 1: Map of Imo State showing the samples location

Soil Sampling and Collection

Soil samples were gathered from both abattoir sites (Egbeada and Nekede) at a depth of 0–30 cm using a Dutch auger and spatula. Samples were dried at 105°C for 24 hours, ground to particles smaller than 0.25 mm, stored in labeled polythene bags, and then transported to a laboratory for pH and heavy metal analysis (Shams & Purkayastha, 2011).

Determination of soil pH, micronutrients and heavy metals

Soil pH was measured with a pH meter following a solution filtration procedure as outlined by Shams and Purkayastha (2011). For heavy metal analysis, 1 gram of each sieved soil sample was digested using a nitric/perchloric acid mixture. The concentrations of copper (Cu), zinc (Zn), chromium (Cr), cadmium (Cd), lead (Pb), and manganese (Mn) were then determined using an Atomic Absorption Spectrophotometer (AAS) in accordance with the standard methods established by APHA (1995). All analyses were performed in duplicate to ensure accuracy

Pollution index models

The measure of the amount of total contamination in a sample station is known as the Pollution index. A standardized method which involves identifying key pollution parameters as noted by the WHO was utilized in the calculation of PI (pollution index) for each, as stated in equation (1). The calculation of contamination/pollution index (PI), geo-accumulation index (I_{geo}), and ecological risk was applied for the assessment of heavy metals level in soils and sediments.

$PI = (C1 \times C2 \times C3 \times \ldots Cn)^{1/n}$ (1)

Contamination /Pollution Index(C/PI)

The standard employed for the analysis of the contamination /pollution index was as adopted from (Lacutusu, 2000), as well as the Department of Petroleum Resources of Nigeria (DPR, 2002) for maximum allowed concentrations of heavy metals in soil which are used as follows: Cd= 0.8 mg kg^{-1}, Cr=100 mg kg^{-1}, Cu=36 mg kg^{-1}, Pb=85 mg kg^{-1}, Zn 140mg kg^{-1} and Mn=850% derived from crustal abundance expressed as C/PI=concentration of metal in soil/maximum allowed concentration of heavy metal.

Contamination factor (C) = $\frac{Cm}{C_b}$ (2)

Table 1: Significance of intervals of contamination factor/pollution index

C/PI	Significance
<0.1	Very slightly contaminated
0.10-0.25	Slightly contaminated
0.26-0.5	Moderate contamination
0.51-0.75	Severe contamination
0.76-1.00	Very severe contamination
1.1-2.0	Slight pollution
2.1-4.0	Moderate pollution
4.1-8.0	Severe pollution
8.1-16.0	Very severe pollution
>16.0	Excessive pollution

Source: Lacutusu (2000).

Pollution index (PLI) value close to one, indicates heavy metal loads near the background level, while values above one, indicate soil pollution (Liu *et al*. 2005). Consequently, soils with PLI value of more than 1 are polluted, whereas values less than 1 indicate no pollution. The significance of C/PI is indicated in Table 1 above.

Geo-accumulation index (I_{geo})

The formula as suggested by Muller (1981) was used to calculate the geo-accumulation index.

$I_{geo} = \log_2(\frac{Ce}{1.5GB})$ (3)

Where,

Ce = concentration of the element in the soil

GB = geochemical background for the element or world average of the element in shale.

Seven classes (ranging from 0 – 6) of the geo-accumulation index was as proposed by Muller (1981) to classify the level of contamination of the soil or sediment by the metals. These are:

Class 0 = $I_{geo}<0$ (practically uncontaminated)
Class 1 = $0<I_{geo}<1$ (uncontaminated to moderately contaminated)
Class 2 = $1<I_{geo}<2$ (moderately contaminated)
Class 3 = $2<I_{geo}<3$ (moderately to heavily contaminated)
Class 4 = $3<I_{geo}<4$ (heavily contaminated)
Class 5 = $4<I_{geo}<5$ (heavily to extremely contaminated)
Class 6 = $5<I_{geo}>6$ (extremely contaminated)

Any value that falls from 6 and above is classified in the open class. In class the value of the element can be as many folds greater than the background value of the metal or element. The background value taken is considered from world average value in shale (mg kg^{-1}) of the metals determined in the study. The geochemical background values are Zn = 95, Pb = 20, Co = 19, Cu = 45, Cr = 90, Ni = 68, Mn = 850, As = 13 and Cd = 0.3.

Ecological risk assessment: this is the ratio of the toxic response factor to the contamination factor to the contamination factor for a given pollutant or contaminant. The equation as suggested by Hakanson (1980) and (Xu *et al*. 2008) was employed the potential ecological risk index proposed by to evaluate the potential ecological risk of heavy metals. This method comprehensively considers the synergy, concentration of the heavy metals, toxic level and ecological sensitivity of heavy metals (Douay *et al*. 2013).

$Eri = Tri \times PIi$ (4)

Where:

Eri= Ecological risk assessment factor

Tri = Toxic-response factor for a given substance

PIi = Degree of contamination or pollution index
Where, Tri, Toxic-response factor for a given substance for Cu = 5, Cr = 2, Zn = 1, Pb=5, Cd=30, Mn=1); Criteria for degrees of ecological risk caused by heavy metals are shown below:
Eri< 15 Low ecological risk
15 ≤ Eri< 30 Moderate ecological risk
30 ≤Eri< 60 Considerable ecological risk

60≤ Eri< 120 high ecological risk
Eri ≥ 120 Very high ecological risk

Statistical Analysis of Results

Analysis of variance (ANOVA) with multiple comparisons using Duncan Multiple Test was performed to deduce significant difference between the means at a significant level of 0.05. The statistical analysis was performed using SPSS version 2.0. Detected levels of heavy metals were compared.

RESULTS AND DISCUSSION

The results of the valuations of the soils in two abattoirs are presented in tables 2 to 8. Table 2 presents the micronutrients and metal content of soil samples from the Egbeada and Nekede abattoirs. The data reveal that copper (Cu) was the most prevalent micronutrient in both locations, followed by manganese (Mn), Zinc (Zn) detected least. In the same vein, lead (Pb) was least detected with respect to heavy metals content. Chromium (Cr) concentrations range between 0.825 to 0.035 mg/kg in Egbeada and 0.963 to 0.018 mg/kg in Nekede, which are within the permissible limits set by WHO. Cadmium (Cd) concentrations, however, exceed WHO's acceptable limit, while copper (Cu) and lead (Pb) are within safe levels. Concentration of zinc in soil samples was below the permissible limit set by WHO. In all the soil samples concentration of zinc was recorded below the permissible limit set by WHO.

Table 2: Heavy metal content in the soil within the two abattoirs in Imo State

Abattoirs Metal	Ph	Pb	Cu	Zn	Cr	Cd	Mn
Egbeada	7.760±0.368	0.042±0.001	12.318±0.046	0.515±0.021	0.825±0.035	0.913±0.018	12.500±0.354
Nekede	7.170±0.099	0.039±0.001	14.210±0.014	0.200±0.000	0.963±0.018	2.285±0.050	13.135±0.106
Total	7.465	0.041	13.264	0.358	0.894	1.599	12.818

Note: Data represented as Mean ± SD

Table 3: Spearman's correlation coefficient between micronutrients and metal concentration in Egbeada and Nekede

Variables	Pb	Cu	Zn	Cr	Cd	Mn
Pb	1					
Cu	-0.839	1				
Zn	0.852	-0.994**	1			
Cr	-0.940	0.963*	-0.971*	1		
Cd	-0.836	0.994**	-0.991**	0.957*	1	
Mn	-0.582	0.849	-0.830	0.725	0.870	1

The Spearman correlation analysis presented in Table 3 shows a strong negative correlation between copper (Cu) and lead (Pb), indicating that as one increases, the other tends to decrease. Zinc (Zn) and lead (Pb) exhibit a positive relationship, whereas a significant negative relationship is observed between zinc (Zn) and copper (Cu). Chromium (Cr) shows no significant correlation with lead (Pb) but does with copper (Cu) and zinc (Zn). Cadmium (Cd) has significant correlations with copper (Cu), zinc (Zn), and chromium (Cr), but no notable relationship with

lead (Pb). Manganese (Mn) does show significant correlations with a micronutrient and a metal, suggesting different sources or factors influencing its concentration.
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table 4: Tests of significance Between-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	p-value.
Corrected Model	845.379[a]	13	65.030	3157.431	.000
Intercept	758.660	1	758.650	36835.121	.000
Heavy metal	839.054	6	139.842	6789.848	.000
Abattoirs	1.399	1	1.399	67.932	.000
Heavy metal * abattoirs	4.936	6	.823	39.931	.000
Error	.288	14	.021		
Total	1604.326	28			
Corrected Total	845.677	27			

a. R Squared = 1.000 (Adjusted R Squared = .999)

Table 4 indicates that there is significant difference between the heavy metals. It also indicated that there are significant differences between the abattoirs. There are significant in the interaction effect between the heavy metal and abattoirs. Therefore, we conclude that there is a statistically significant difference between the heavy metals deposited at different abattoirs.

Table 5 Levene's Test for Equality of Variances

Table 5 indicates that there is a significant difference between the abattoirs (Egbeada and Nekede). Therefore, we conclude that, there is no equality of variance between the abattoirs.

	Levene's Test for Equality of Variances		**t-test for Equality of Means**						
	F	p-value	T	Df	p-value (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	0.047	0.829	-0.208	26	0.847	-0.44707	2.15382	-4.87429	3.98015
Equal variances not assumed			-0.208	25.875	0.847	-0.44707	2.15382	-4.87533	3.98118

Table 6: Contamination/pollution index of heavy metals in soil sample of Egbeada and Nekede Abattoirs

Abattoir	**Depth**	**Pb**	**Cu**	**Zn**	**Cr**	**Cd**	**Mn**
Egbeada	0.30cm	0.0008	0.3441	0.0035	0.0084	1.1424	0.0145
		VSC	MC	VSC	VSC	SP	VSC
Nekede	0.30cm	0.0007	0.3952	0.0025	0.0096	2.8566	0.0167
		VSC	MC	VSC	VSC	MP	VSC

The contamination /pollution index of metals from both abattoirs in table 6 showed that Egbeada and Nekede abattoir soil are not contaminated by Pb, Zn, Cr, and Mn. However, Egbeada was found to be moderately contaminated by Cu and slightly polluted by Cd. While Nekede abattoir soil was found to be moderately contaminated by Cu and moderately polluted by Cd.
VSC=very slight contaminated, MC=moderately contaminated, SP=slightly polluted, MP=moderately polluted.

Table 7: Geo-accumulation index of heavy metals in soil sample of Egbeada and Nekede Abattoir

The geo-accumulation index (I_{geo}) of the metals in soils of both abattoirs in table 7 above shows that the soils are uncontaminated by Zn, Cu, Mn, Pb, and Cr nevertheless, moderately contaminated with Cd.

Metals	Egbeada	Nekede
Zinc (Zn)	0.0012	0.0003
Copper (Cu)	0.0550	0.0632
Manganese (Mn)	0.0030	0.0033
Chromium (Cr)	0.0018	0.0023
Cadmium (Cd)	0.6108	1.5275
Lead (Pb)	0.0004	0.0005

The latent ecological risk valuation of heavy metals in both abattoir soils in table 8 showed that Zn, Pb, Cr, Cu, and Mn do not pose any ecological risk to the environment. However, Cd poses a low/considerable potential ecological risk to the environment.

Table 8: Ecological risk factor of various metals at Nekede and Nekede Abattoir

Metals	Toxic Response Value	Egbeada	Nekede
Lead (Pb)	5	0.0027	0.0025
Copper (Cu)	5	1.7107	1.9676
Zinc (Zn)	1	0.0035	0.0013
Chromium (Cr)	2	0.0168	0.0194
Cadmium (Cd)	30	34.240	85.699
Manganese (Mn)	1	0.0148	0.0157

CONCLUSION AND RECOMMENDATIONS

This study reveals that soils from both Egbeada and Nekede abattoirs contain lead (Pb), copper (Cu), chromium (Cr), manganese (Mn), cadmium (Cd), and zinc (Zn). The concentrations of copper (Cu) and manganese (Mn) are particularly high, which could be due to local waste disposal practices and the natural geological composition of the region. At present, the levels of these metals do not pose a significant risk to human health, as they fall within WHO's acceptable limits. The applied index models suggest that the heavy metals in the soils originate primarily from human activity. While cadmium (Cd) was observed to contribute to moderate pollution levels, other metals posed minimal ecological risks. Despite these findings, there is a need for regular monitoring of these areas to prevent potential future contamination issues. However, it will be recommended that continuous training with respect to environmental health and its like should be taking into consideration. The result from the two sites shows little or no variations as it relates to soil contamination risks. Zn was below the permissible WHO limits in the locations, while the spearman correlation analysis shows inconsistencies in the outcome among the metals. It was observed that the selected heavy metals does not pose a threat to the soil, in addition, from the study as shown in the ecological risk factor, no risk or threat was found on the soil. It will be recommended that to increase the soil productivity of the soils around the abattoirs, support from government and private agencies are needed to maintain certain environmental conditions to regulate, and implement the abattoirs Act of 1998.

REFERENCES

Abattoir Acts (1998): Retrieved 2003 from http//www.Irishstatutebook.i.e/1988/en/act/pub/0008/index.hhtml.

Adesemoye, A.O., Opere, B.O., Makinde, S.C.O. (2006). Microbial content of abattoir wastewater and its contaminated soil in Lagos, Nigeria African *Journal of Biotechnology*, 5: 1963-1968.

American Public Health Association (APHA) (1995): American Public Health Association. Standard Methods for the Examination of Water and Waste Water, 19th edn.APHA-AWWAWPCF, Washington, DC.pp. 525-987.

*Chesworth, Ward, ed. (2008).*Encyclopedia of soil science(PDF). *Dordrecht, The Netherlands:*

Springer. ISBN 978-1-4020-3994-2. Archived(PDF) *from the original on 2018-09-05*. Retrieved 2019-01-14.

Cojocaru,V., Pantelica,A., Pincovschi, E., Georgescu, I.I. (2006). EDXRF *versus* INAA in Pollution Control of Soil, J. Radioanal. Nucl. Chemistry, 268 (1), 71

Cui YL., Zhu, YG., Zhai, RH., Chen, DY., Huang, YZ., Qiu, Y. (2004).Transfer of metals from soil to vegetables in an area near a smelter in Nanning, China. Environ. Int. 30:785-791

Department of Petroleum Resources (DPR) (2002): Environmental guidelines and standards for the petroleum industry in Nigeria. Department of Petroleum Resources, Ministry of Petroleum and Natural Resources, Lagos Nigeria. https//dpr.gov.ng/index/egaspin/.

Douay, F., Pelfrêne, A., Planque, J., Fourrier, H., Richard,A., Roussel, H., Girondelot, B (2013).

Assessment of potential health risk for inhabitants living near a former lead smelter, Part 1: metal concentrations in soils, agricultural crops, and home-grown vegetables. Environmental Monitoring and Assessment, 185(5): 3665–3680.

Edori Onisogen Simeon and Kpee Friday (2017). Index models assessment of heavy metal pollution in Port Harcourt, Rivers State, Nigeria. *Singapore journal of Scientific Research*, 7:9-15. ISSN 2010-006x DOI: 10.3923/sjsres.2017.9.15

Hakanson, L. (1980). An ecological risk index for aquatic pollution control. A sedimentological approach. Water Res., 14:975-1001

Lacutusu, R (2000): Appraising level of soil contamination and pollution with heavy metals. In:

Land information systems for planning the sustainable use of land resources, Heinike, H.J., Eckselman, W; Thomasson, A. J; Jones, R.J.A.; Montanarella ; Buckleley, B. (Eds). Office of official publication of the European Communities, Luxembourg, pp. 393-402.

Liu, X., Zhang, W., Hu, Y., Hu, E., Xie, X., Wang, L., Cheng, H. (2015). Arsenic pollution of agricultural soils by concentrated animal feeding operations (CAFOs). *Chemosphere*, 119: 273–281. https://doi.org/10.1016/j.chemosphere.2014.06.067

Momodu, M., Anyakora, C. (2010): Heavy contamination of groundwater; the Surulere case study. *Research Journal of Environmental Earth Science* 2(1): 29-43.

Muller, G.(1981). Dis schwermetallbelstung der sediment des neckers und seiner nedenflusse: eine estandsaufnahme. Chemiker Zeitung, 105: 157-164

Obineche CI, Igbojionu DO, Ahaneku IE (2020). Assessment of Physicochemical Properties of Soil at Old Nekede Dumpsite Owerri, Imo State, Nigeria. *Turkish Journal of Agricultural Engineering Research (TURKAGER)*, 1(2): 261-270.
https://doi.org/10.46592/turkager.2020.v01i02.004

Onweremadu, E.U. (2012). Soil science an epistemology of a vital discipline in a world of food insecurity and environmental unsustainability. A lecture presented at the 18th Matriculation Ceremony of FECOLART, Owerri.

Osemwota I.O. (2010): Effect of abattoir effluent on the physical and chemical properties of soils. Environ Monit. Asses 167:399404

Ponge, Jean-François (2015). "The soil as an ecosystem" (PDF).Biology and Fertility of Soils. **51** (6): 645–48. doi:10.1007/s00374-015-1016-1. Retrieved 15 September 2024

Rajesh, K.S., Madhoolika, A., Fiona, M.(2007): Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicology and Environmental Safety 66 (2007) 258-266.

Ruqia Nazir, Muslim Khan, Muhammad Masab et al. (2015). Accumulation of heavy metals (Ni,

Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical Parameters of soil and water collected from tanda dam kohat. *Journal of Pharmaceutical Sciences & Research*. Vol. 7(3), 2015, 89-97. ISSN: 0975-1459

Shams, M.T; Purkayastha, T. (2011): Heavy metal assessment of incinerated medical waste,

Bachelor of Science, Engineering thesis, Department of Civil and Environmental Engineering, Shahjalal University of Science & Technology, Sylhet, Bangladesh

WHO. (1993). *The WHO recommended classification of pesticides by hazard and guidelines to classifications 1992-1993.* Ginebra, World Health Organization.

Xu Z, Ni S, Tuo X, et al. (2008). Calculation of heavy metals toxicity coefficient in the evaluation of potential ecological risk index. Environmental Sciences. 2:112-115