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Research article

Quantification of Heavy Metals in Soil and Water Samples from Major Abattoirs Located in Ibadan, Oyo State, Nigeria

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Abstract
The release of toxic waste materials into the environment poses serious harm that contributes to various diseases. This study assessed the heavy metal contents of soil and water samples collected from residential areas surrounding two major abattoirs in Akinyele and Oranyan, Ibadan, Nigeria. Samples were collected from identified spots in residential areas closest to each abattoir and control samples were taken from different locations. The soil samples were air-dried, ground, sieved and digested with aqua regia. Heavy metals namely Manganese (Mn), Iron (Fe), Zinc (Zn), Cadmium (Cd), Copper (Cu), and Lead (Pb) were determined using atomic absorption spectrophotometer (AAS). Data was analyzed using SPSS 19.0 and results were reported in mean±SD. Results from water analysis were in the order Fe>Mn>Zn>Cu and Fe>Zn>Mn>Cu while it was Fe>Zn>Pb>Cu>Mn>Cd and Fe>Zn>Mn>Cu>Pb>Cd in soil samples from Akinyele and Oranyan respectively. All the heavy metals were significantly higher than at the control site and above permissible limits of WHO/SON. The concentration of Fe was highest in the soil and water samples from both locations. The Fe level from Oranyan was higher than that from Akinyele abattoir. The Cd and Pb were below detectable limit from both abattoirs. A strong positive correlation (r =0.9598 for water samples and r =0.9965 for soil samples) showed that abattoir wastes were the source of pollution. There was no significant relationship across the sampling sites. Activities within the two abattoirs impact negatively on the environment which could have harmful consequences on biodiversity including humans.

Keywords: Abattoir, Environment, Heavy metals, Pollution, Soil, Wastewater

Introduction

Heavy metal pollution of the environment, even at low levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world (Briffa *et al*, 2020). Heavy metals are known to be non-biodegradable and persist for long durations in aquatic as well as terrestrial environments. They might be transported from soil to ground waters or may be taken up by plants, including crops thereby causing different diseases as a result of bioaccumulation and biomagnification (Yan *et al*, 2020; Wuana and Okieimen, 2011). World Health Organization (WHO) estimates that about a quarter of the diseases facing humanity today is as a result of prolonged exposure to environmental pollution and that most of these diseases are not easily detected and may be acquired during childhood and manifested later in adulthood (Daku *et al*, 2019).

An abattoir is a place where different types of animals are slaughtered and processed for meat production and consumption (Mohammed and Musa, 2012). Activities in the abattoir include feeding animals in the queue for slaughtering in the arrival area, slaughtering animals, roasting animal skin, washing roasted animal skin, and separating it into different parts such as bones, intestines, heads, and meats based on demands and specifications (Mamhobu-Amadi *et al*, 2019). Burning of animals using fuel supported by wood or charcoal combined with used plastics and refuse or tires is still commonly practiced (Oyebanji *et al*, 2021). Pollutants from abattoirs include blood, paunch manure, animal feces, animal horns, bones, spent lubricants from machines like generators and detergents used in washing animals after burning (Fadebiyi *et al*, 2011). Wastes generated in various abattoir activities, can be in the form of gas, liquid or solid, causes pollution to air, water as well as soil and can have serious negative effects on humans and the environment (Weobong and Adinyira, 2011). Also, there may be the presence of pathogenic microorganisms, such as *Salmonella*, *Escherichia coli*, *Shigella*, parasite eggs and amoebic cysts (Ogunlade *et al*, 2021; Ezeoha and Ugwuishiwu, 2011). Reports have demonstrated that most abattoirs in Nigeria do not possess proper animal handling and waste treatment facilities (Abiola, 2021; Bala *et al*, 2018).

Evidence has also shown that meats are improperly handled and waste generated is inadequately treated or disposed of which poses public health risks through the transmission of diseases (Bandaw and Herago, 2019; Adewunmi *et al*, 2016; Lawal *et al*, 2013; Ezeoha and Ugwuishiwu, 2011). Heavy metal residues in animals slaughtered for daily human consumption are implicated in serious health challenges such as nephrotoxicity, hepatotoxicity, neurotoxicity, and gastrointestinal disorders (Oyebanji *et al*, 2021).

Several elements have been identified as heavy metals; some are essential at low concentrations and are required for normal growth and development. These heavy metals include Iron (Fe), Copper (Cu), Zinc (Zn), Cobalt (Co), Vanadium (V), Manganese (Mn), Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Fluorine (F). They become toxic only above the required level. On the other hand, heavy metals such as Arsenic (As), Cadmium (Cd), Mercury (Hg), Beryllium (Be), Aluminium (Al), and Lead (Pb) do not have any beneficial role, they can be toxic even at very low concentrations (Briffa *et al*, 2020). Heavy metals exact toxic effects on soil biota by affecting key microbial processes and decreasing the number and activity of soil microorganisms. They indirectly affect soil enzymatic activities by shifting the microbial community which synthesizes enzymes (Bello *et al*, 2011). In addition, heavy metals in soil can be accumulated in plants which are consumed by animals and continue along the food chain resulting in diverse diseases (Elemile *et al*, 2019). They also have negative effects on biodiversity and activities of soil microbes which play significant roles in the recycling of plant nutrients, maintenance of soil structure, detoxification of noxious chemicals, and the control of plant pests and maintaining soil quality (Yan *et al*, 2020).

Interactions between soil nutrients and heavy metals have been investigated in both non-woody plants and tree roots. Major nutrients like nitrogen (N), phosphorus (P), Potassium (K), Calcium (Ca), and Mg are inhibited by heavy metal pollution. Heavy metals can inhibit mineralization processes in soils, leading to low pools of nutrients (Sanda *et al*, 2016). Soil enzyme activity is considered to be one of the biochemical indicators of soil health. The inhibition of enzyme activity by heavy metals has been well-documented (Briffa *et al*, 2020; Aponte *et al*, 2020; Ashrafi *et al*, 2019). The effects of heavy metals on soil enzyme activity vary with the types and concentrations of the metals, sensitivity of the enzymes and soil properties (Sanda *et al*, 2016). Heavy metals are considered a big threat to aquatic habitats since they easily enter the food chain of an aquatic ecosystem (Pandiyan *et al*, 2020). Contamination of water and soil by heavy metals affects aquatic organisms, therefore, threatening biodiversity and ecological balance (Dwivedi *et al*, 2018). This study, therefore, assessed the levels of heavy metals in soil and water from residential areas closest to two major abattoirs in Ibadan metropolis.

Materials and Methods

Description of Sampling Location

The study area is Ibadan, the capital of Oyo State Nigeria. It is located in the southwestern part of Nigeria and it is the country's second-largest urban agglomeration, with a population of about 3.3 million people (National Population Commission (NPC), 2006). There are about 8 major abattoirs in Ibadan with countless smaller ones out of which Oranyan and Akinyele abattoirs were randomly selected based on size, patronage, population served, and years of usage. Akinyele abattoir was established in 1990 and is located beside Akinyele market. The abattoir is located between latitude 7.3895° and 7°23'22 north and longitude 3.8702° and 3°52'12.6 east. The abattoir has an average daily kill of 10–20 cattle and 5–10 goats and sheep. Solid waste from the abattoir operations is left to pile in the environment forming a huge heap while the waste water is channeled through a drainage system into Alalubosa river.

Oranyan abattoir is located in Orita Apeni Bere Area of Ibadan within the latitude 7.3758°N and longitude 3.9036°E. The abattoir was established in the early 1970s and has a daily slaughtering capacity of over 150 cows. The abattoir has one big open cemented slaughter floor with drainage which channels the blood, water and other waste generated directly into the popular Ogunpa river.

Sampling and Pre-Treatment of Soil Samples

A total of 11 soil samples were collected, 5 from fields around each abattoir and 1 from about 500m away located at a higher elevation to serve as control and labeled C. Soil samples were collected from different points within the depth of 0-5 cm using soil auger and labeled A1, A2, A3, A4, A5 and B1, B2, B3, B4, B5. The letters A and B represent the sampling sites (Akinyele and Oranyan) respectively. The soil samples were air-dried, ground into a fine powder using a mortar and pestle, sieved with 2mm diameter mesh, labeled appropriately before being stored in clean polythene bags and at room temperature for further analysis.

Sampling and Preparation of Water Samples

A total of thirteen (13) water samples were collected from streams located within 0-250 m from both abattoirs and labeled A1, A2, A3, A4, A5, A6 for Akinyele abattoir and B1, B2, B3, B4, B5, B6 for Oranyan abattoir. The letter C is labeled on the sample for control collected at a different location from both abattoirs. The samples were collected in 500 ml PVC plastic containers previously cleaned by washing in non-ionic detergent, rinsed with tap water and later soaked in 10 % nitric acid (HNO_3) for 24 hours and finally rinsed with deionized water before usage. During sampling, sample bottles were rinsed with sampled water three times and then filled to the top leaving a space of about 2cm. After sampling, the collected wastewater samples were correctly labeled and transferred to the laboratory for further analysis.

Digestion of Soil Samples

Five (5) g each of the air-dried soil samples was weighed and transferred to a 250 ml glass beaker and digested with 8 mL of concentrated sulphuric acid as well as concentrated nitric acid in the ratio of 1:2 (HNO_3 + HCl) on a sand bath for 2 hours. The digestion was completed when the solution became clear and white fumes appeared. This setup was then allowed to cool, filtered through a filter paper, transferred into 100 ml volumetric flasks, and diluted to the mark with distilled water. The solution was then transferred into a screw-capped polyethylene bottle. All analyses were processed in duplicate (Zhaochu, 2014).

Digestion of Water Samples

Metals of the samples were extracted by aqua regia. A 100 mL aliquot of a well-mixed sample was transferred into a beaker. Thereafter, 2 mL of concentrated HNO_3 and 5 mL of concentrated HCl were added. The sample was covered with a ribbed watch glass or other suitable covers and heated on a steam bath, hot plate, or another heating source at 90° to 95° C until the volume has been reduced to 15-20 mL. After cooling and rinsing with 15mL of deionized water, the rinse water was recovered in the digestion flask. Then, the ingests were passed through a pre-washed filter (Whatman No. 540) and the filtrates were used to make a volume of up to 100 ml using distilled water. The prepared samples were refrigerated in acid-washed polyethylene bottles at 4 ºC before the final analysis of the heavy metals content (Eaton et al, 2012).

Instrumental Analysis

Levels of Cd, Cu, Fe, Zn, and Cr in the samples were determined using the Buick 210 model of AAS following standard procedures as described by Khaniki et al., 2017. Working standards were also prepared by further dilution of 1000 ppm stock solution of each of the metals and a calibration curve was constructed by plotting absorbance versus concentration. By interpolation, the concentrations of the metals in sample digests were determined. All quality control and quality assurance protocols were observed throughout the experiment.

Statistical Analysis

Statistical analysis was carried out using SPSS software, version 18. The mean and standard deviation of each heavy metal was reported in mg/kg dry weight of the sample.

Results

The concentration of heavy metals found in the soil samples are shown in Tables 1-3 below while that for water samples is shown in Tables 4-5. Heavy metals detected in soil from the Akinyele abattoir were in the order, Fe> Zn > Pb > Cu >Mn>Cd while those detected in the soil samples from the Oranyan abattoir were Fe> Zn > Mn > Cu >Pb>Cd. The levels of the metals present in the experimental plots were relatively tangible, and this is probably as a result of the wastes discharged from the abattoir. Figures 1-2 show a comparison of the heavy metal contents in soil and water samples from both abattoirs respectively.

Table 1: Concentration (mg/kg) of Heavy Metals in Soil Samples from Akinyele Abattoir (A), Oranyan Abattoir (B) and Control Plot (C)

Sample	Mn	Fe	Cu	Zn	Cd	Pb
A1	0.383	26.855	0.197	1.003	0.005	0.817
A2	0.295	15.382	0.622	3.908	0.008	3.211
A3	0.508	22.02	1.219	0.670	0.007	1.240
A4	0.353	20.644	0.021	0.138	0.001	0.062
A5	0.355	23.115	0.022	0.147	0.001	0.068
B1	0.299	21.706	0.084	0.635	0.001	0.170
B2	0.448	34.701	0.159	1.135	0.004	0.439
B3	0.379	20.725	0.104	1.082	0.002	0.147
B4	0.323	32.912	0.144	14.253	0.001	0.446
B5	0.494	20.220	1.315	2.526	0.001	0.165
Total	3.837	238.280	3.887	25.497	0.031	6.765
Mean	0.384	23.828	0.389	2.549	0.003	0.677
SD	0.076	5.984	0.493	4.270	0.003	0.967
C	0.027	12.513	0.011	2.526	0.002	0.165

SD* Standard deviation

Table 2: Concentration (mg/kg) of Heavy Metals in Soil Samples from Akinyele Abattoir

Sample	Mn (Mg/kg)	Fe (Mg/kg)	Cu (Mg/kg)	Zn (Mg/kg)	Cd (Mg/kg)	Pb (Mg/kg)
A1	0.383	26.855	0.197	1.003	0.005	0.817
A2	0.295	15.382	0.622	3.908	0.008	3.211
A3	0.508	22.020	1.219	0.670	0.007	1.240
A4	0.353	20.644	0.021	0.138	0.001	0.062
A5	0.355	23.115	0.022	0.147	0.001	0.068
Total	1.894	108.016	2.081	5.866	0.022	5.398
Mean	0.379	21.603	0.416	1.173	0.004	1.080
SD	0.079	4.173	0.511	1.572	0.003	1.293
C	0.027	12.513	2.526	2.526	0.002	0.165

Table 3: Concentration of Heavy Metals in Soil Samples from Oranyan Abattoir

Sample	Mn (Mg/kg)	Fe (Mg/kg)	Cu (Mg/kg)	Zn (Mg/kg)	Cd (Mg/kg)	Pb (Mg/kg)
B1	0.299	21.706	0.084	0.635	0.001	0.170
B2	0.448	34.701	0.159	1.135	0.004	0.439
B3	0.379	20.725	0.104	1.082	0.002	0.147
B4	0.323	32.912	0.144	14.253	0.001	0.446
B5	0.494	20.220	1.315	2.526	0.001	0.165
Total	1.943	130.300	1.806	19.631	0.009	1.367
Mean	0.389	26.053	0.361	3.926	0.002	0.273
SD	0.082	7.120	0.534	5.810	0.001	0.154
C	0.027	12.513	0.011	2.526	0.002	0.165

Table 4: Levels of Heavy Metals Detected in Water Samples Collected around Oranyan Abattoir

Sample	Mn (Mg/L)	Fe (Mg/L)	Cu (Mg/L)	Zn (Mg/L)	Cd (Mg/L)	Pb (Mg/L)
B1	2.654	35.192	0.259	6.408	ND	ND
B2	2.527	36.300	0.261	7.317	ND	ND
B3	1.056	2.218	0.009	ND	ND	ND
B4	0.956	2.471	ND	0.019	ND	ND
B5	1.047	2.273	ND	ND	ND	ND
B6	2.568	36.295	0.265	7.347	ND	ND
Total	11.860	117.032	0.794	21.092	ND	ND
Mean	1.690	17.720	0.113	3.013	ND	ND
C	1.052	2.283	ND	0.001	ND	ND

ND – Not Detected

Table 5: Levels of Heavy Metals (mg/L) Detected in Water Samples Collected around Akinyele Abattoir

Sample	Mn	Fe	Cu	Zn	Cd	Pb
A1	11.583	21.400	0.338	2.333	ND	ND
A2	3.608	5.541	0.136	0.610	ND	ND
A3	4.397	23.883	0.174	1.048	ND	ND
A4	1.479	15.625	0.071	0.346	ND	ND
A5	2.212	17.708	0.098	0.480	ND	ND
A6	11.546	21.450	0.345	2.365	ND	ND
Total	34.825	105.607	1.162	7.182	ND	ND
Mean	5.804	17.601	0.194	1.197	ND	ND
C	1.052	2.283	ND	0.001	ND	ND

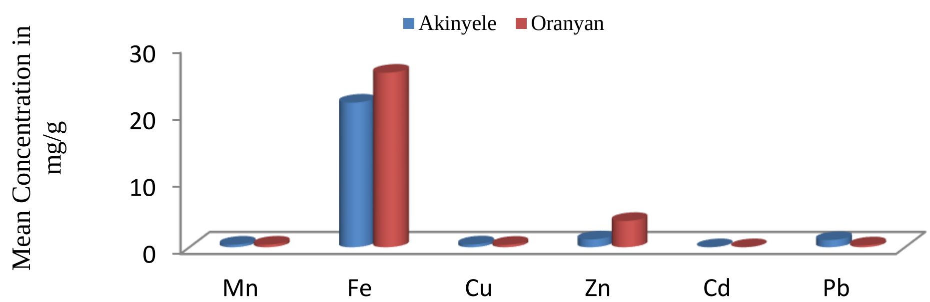

Figure 1: Comparison of Heavy metals content in soil samples from both Akinyele and Oranyan abattoirs...

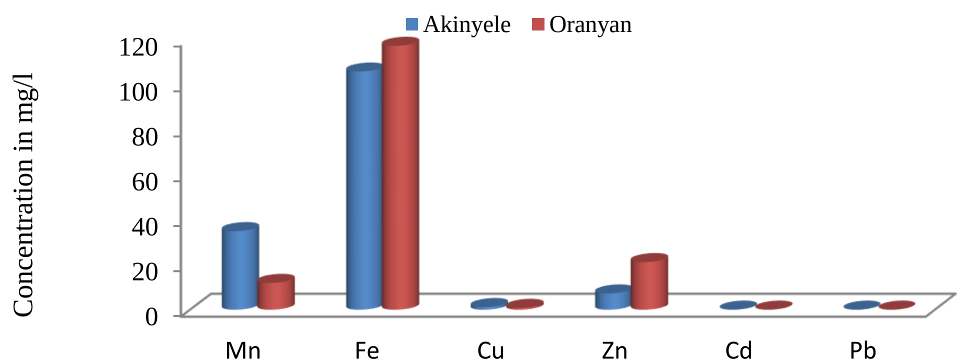

Figure 2: Comparison of heavy metals in water samples around Akinyele and Oranyan abattoirs

Discussion

The essential elements studied, Zn, Cu, Fe, and Mn, are required for normal growth and development but only in minute quantities while Cd and Pb have no known benefits. Their high deposition in soil and water leads to accumulation in bones and other tissues through the food chain and there has been a major health concern as they are persistent contaminants in the environment as they cannot be easily be decomposed (Osemwota *et al*, 2010). This study found higher concentrations of Fe in both soil and water samples collected around the two abattoirs as shown in Tables 1-5. Iron is recognized to play a special role in causing disease as a result of forming oxides in contact with oxygen. A wide range of harmful free radicals is formed when the absorbed iron fails to bind to the protein, which in turn severely affects the concentration of iron in mammalian cells and biological fluids. These free irons penetrate cells of the heart, liver, and brain. Due to the disruption of oxidative phosphorylation by free iron, the ferrous iron is converted to ferric iron which releases hydrogen ions, thus increasing metabolic acidity. The free iron can also lead to lipid peroxidation, which results in severe damage to mitochondria, microsomes, and other cellular organelles (Jaishankar *et al*, 2014). Lipid peroxidation in the membranes of cells have been implicated in ailments such as cardiovascular diseases, chronic kidney diseases, diabetes, cancer and several other neurodegenerative diseases (Adeniji *et al*., 2022).

The mean±SD values of Fe in the soil was 21.603±4.173 mg/kg and 26.053±7.120 mg/kg from Akinyele and Oranyan abattoirs respectively which is very high when compared to WHO standard of 0.02 mg/g. In water samples, the values of Fe ranged from 2.218-36.300 mg/l which is also higher than the permissible limit by WHO (0.3 mg/l). This agrees with a study by Sambo *et al*. (2016) which observed a high concentration of Fe in the water and soil samples studied in Abattoirs located in Kano, Nigeria. Although they found Zinc concentration to be the lowest, this study found Zn next to Fe in soil samples from both abattoirs and water samples from only the Oranyan abattoir. The value observed for Fe concentration in this study is lower than that observed by Ebong *et al*. 2020 (623.88 - 887.80 mg/kg), Simeon and Friday, 2017 (59.36 - 81.70 mg/kg), and Yahaya et al, 2009 (2569.00 - 4130.00 mg/kg) but higher than that observed by Ogunlade *et al*. 2021 (300.50 - 342.94 mg/kg). The rumen of animals contains green grasses that are still in their early stage of digestion and blood which are regularly and generously spilled is rich in Fe which may be the reason for the high deposition of Fe in the samples.

From both abattoirs studied, the mean values of Cu in water samples (Oranyan = 0.113; Akinyele = 0.194 mg/L) are within the permissible limits of WHO (0.5-2.0 mg/L) and Standard Organization of Nigeria (SON) (1.0 mg/L). This agrees with the research of Edori and Kpee, 2016, where the Cu levels (0.027±0.00 mg/L and 0.069±0.01 mg/L) in both abattoirs they sampled in Port Harcourt were below the set limits. Ebong *et al*. (2020), observed Cu mean levels in the range of 15.66 and 19.34 mg/kg with a mean of 17.49 ± 1.40 mg/kg in the soil samples around the abattoirs in Akwa Ibom state which is higher than we observed in this study. Soils naturally contain copper without which plants will fail to grow properly. Copper may accumulate due to the application of sewage sludge or application of copper-based pesticides. Toxic copper level (100–1000 mg L^{-1}) reduces seed germination, plant vigor and iron intake (Cruz *et al*., 2022). The mean concentration of copper in the soil samples ranges between 0.113 - 0.194 mg/g which is higher than the WHO permissible limit of 0.036 mg/g.

The Zn in water samples around Akinyele abattoir (1.197 mg/L) is within both WHO (1.0-3.0 mg/L) and SON (3.0 mg/L) permissible limits while Zn level in water around Oranyan abattoir (3.013 mg/L) is slightly above the permissible limits of both regulatory bodies. Zinc is needed by plants for normal growth and production of chlorophyll. Its deficiency causes a type of leaf discoloration called chlorosis and anemia in humans. Excessive concentration of zinc has an adverse impact on microbial growth and the activity of soil enzymes thus retarding the breakdown of organic matter (Daniel *et al*., 2021). The concentration of zinc in the soil samples ranged from 0.4162-3.9262 mg/g compared to the WHO standard of 0.05 mg/g. This result disagrees with the research conducted by Olayinka *et al*. (2017) and Daniel *et al*. (2021) which reported that abattoirs were severely polluted with Zn. In addition, Edori and Kpee (2016) also observed that Zn and Mn exceeded the permissible limits in water which also aligns with the findings of this study.

The level of Mn in water samples around both abattoirs was above the permissible limits of WHO and SON (0.4 and 0.2 respectively). Manganese plays a key role in several processes, including the formation of blood clotting factors, bones, connective tissues, sex hormones, regulation of blood sugar, absorption of calcium and carbohydrate metabolism and photosynthesis in plants (Chen *et al*., 2018). The range of manganese concentration of the soil samples from both abattoirs is between 0.3788-0.3886 mg/g which is higher compared to the standard limit of WHO in soil (0.01-0.02mg/g). Olayinka *et al*., (2017) also reported slightly increased concentrations of Mn in soil from the abattoir they studied in abattoir surface soil in Abeokuta. High Mn concentration at an abattoir may be a result of the disposal of rumen which contains green grasses that are still in their early stage of digestion, which contains chlorophyll-rich Mn.

Cadmium in soils is derived from both natural and anthropogenic sources. Excessive cadmium affects the microbial biomass and its activity. It is toxic to kidneys and the liver and causes poisoning in various tissues and organs (Adeyemo *et al*., 2019). The concentration of cadmium in the soil samples ranged between 0.0018-0.4162mg/g which is higher when compared to the WHO standard of 0.0008mg/g. Increased cadmium content in soil contaminates and threatens its quality, causing harm to plant physiological functions, such as photosynthesis, water interactions, and essential mineral uptake. It can also cause metabolic changes in plants. Consequently, bioaccumulating in the food chain and threatening the health of humans and animals (Usman *et al*., 2022). The level of Cd observed in this study corroborates with the research by Olayinka *et al*. (2017) which reported that abattoir soils are moderately contaminated with cadmium.

The lead concentration in the soil samples obtained ranges from 0.062 - 3.211 mg/g which is high when compared with the WHO standard limit of 0.085 mg/g. A lead concentration greater than 1.0 mg kg-1 is generally indicated as a local source of pollution. It can enter the body through food, air, and water causing negative impacts on the central nervous system and leading to growth impairment both physically and mentally in children (Adeyemo *et al*., 2019). This result contradicts that of Daniel *et al*., (2022) who observed a high deposition of Pb in soil samples from slaughterhouses in Southern Nigeria. The WHO permissible limit for Cd and Pb in water is 0.005 and 0.015 mg/L respectively. Both Cd and Pb were below the detection limit (BDL) in the water samples analyzed in this study which is in agreement with Adeyemo *et al*. (2019). All parameters measured in soil and water samples were found to be higher at both abattoirs than at control sites. The order of heavy metal presence in the sampled abattoirs was Oranyan Abattoir >Akinyele Abattoir as shown in Figures 1 and 2. This may be attributed to the fact that the Oranyan abattoir has been in existence for a long time before the Akinyele abattoir, increased activities are proportional to increased use and generation of pollutants such as lubricants, wastes, and detergents among others that have accumulated in the environment overtime.

Conclusion

The study revealed that soil and water samples from Akinyele and Oranyan abattoirs in Ibadan are contaminated with heavy metals. Waste products from abattoirs have the possibility of elevating the concentration of Fe, Pb, Zn, Cu, Cd, and Mn in soil and water. Proper waste management methods that are sustainable and eco-friendly should be employed for the disposal of waste from abattoirs generally to prevent contamination of the environment. Agricultural practices close to abattoirs and the use of untreated wastes from abattoirs as organic manures should be discouraged to reduce the associated problems of accumulation of toxic heavy metals along the food chain.

Conflict of Interest

We declare that there is no conflict of interest among all authors and we have no financial, professional or personal conflict with other persons or organizations that can inappropriately influence any part of this manuscript.

Authors' contribution

All authors contributed to this research work

Research Data

The data is available from the corresponding author on request

References

Abiola, S. S. (2021): Assessment of abattoir and slaughter slab operations in Oyo state, Nigeria. *Nigerian Journal of Animal production,* 23(1):82-84

Adeniji C. B., Akinosun M. O. and Ighodaro O. M. (2022): Assessment of Some Oxidative Stress Biomarkers in Automobile Mechanics in Selected Local Government Areas in Ibadan, Oyo state, Nigeria, *International Journal of Recent Research in Interdisciplinary Sciences*, 9 (2), 72 -80. doi.org/10.5281/zenodo.6637499

Adewumi, J. R., Babatola, J. O., and Adejuwon, E. O. (2016): Assessment of Abattoir Waste Management Strategy in Akure southwest Nigeria. *Futo Journal Series,* 2(1):186-194

Adeyemo, O.K., Adeyemi, I. G., and Odunsi, O. O. (2019): Physicochemical, heavy metals and microbial pollution of surface and groundwater in Bodija Municipal Abattoir and its Environs. *International Journal of Environment, Agriculture and Biotechnology,* 4(6): 1720-1725.

American Public Health Association (APHA), (1998). Standard Methods of Examination of Water and Wastewater, 20th Edition, APHA, Washington D.C.

Aponte, H., Meli, P., Butler, B., Paolini, J., Matus, F., Merino, C., Cornejo, P. and Kuzyakov, Y. (2020): Meta-analysis of heavy metal effects on soil enzyme activities. *Science of The Total Environment*, 737: 139744, doi.org/10.1016/j.scitotenv.2020.139744.

Ashrafi, A.M., Sýs, M., Sedláčková, E., Shaaban Farag, A., Adam, V., Přibyl, J. and Richtera, L. (2019): Application of the Enzymatic Electrochemical Biosensors for Monitoring Non-Competitive Inhibition of Enzyme Activity by Heavy Metals. *Sensors, 19*, 2939. doi.org/10.3390/s19132939

Bandaw, T. and Herago, T. (2019): Review of Abattoir waste management. *Global Veterinaria,* 19 (2): 517-524

Daniel, O., John, U. N., Yusuf, M. O. L., and Onyedikachukwu, N. B. (2021): Modelling of Soil Profile Pollutant Yield on Slaughterhouse Wastes Deposited Land. *Journal of Engineering Research and Reports*, 21(8), 16-29.

Bello, M, Lawan, M. K, Kwaga, J. K. P, and Raji, M. A. (2011): Assessment of carcass contamination with E. coli 0157:H7 before and after washing with water at abattoirs in Nigeria. *International Journal of Food Microbiology,* 150(2-3): 184-186.

Briffa, J, Sinagra, E, and Blundell, R. (2000): Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon*, 8; 6 (9): e04691.

Chen, P., Bornhorst, J., and Aschner, M. (2018): Manganese metabolism in humans. *Frontiers in Bioscience-Landmark*, 23(9): 1655-1679

Daku, A. B, Mustapha, S, Salisu, A. I., El-Ta'alu, A. B. (2019): Age-Related Effects of Lead Poisoning on Some Haematological Parameters in Adult Wistar Rats. *Niger J Physiol Sci,* 34 (2): 125 - 130.

Dwivedi, S., Mishra, S., and Tripathi, R. D. (2018): Ganga water pollution: A potential health threat to inhabitants of Ganga basin. *Environ Int,* 117: 327-338.

Eaton, A. D., Clesceri, L. S. and Rice, E. W. (2012). Standard Methods for the Examination of Water and Wastewater, 22nd, American Water Works Association (AWWA), Washington DC, (Part 5000).

Ebong, G. A., Ettesam, E.S. and Dan, E. U. (2020): Impact of Abattoir wastes on trace metal accumulation, speciation and human health-related problems in soils within southern Nigeria. *Air, soil and water research,* 13. doi:10.1177/1178622119898430

Edori, O. S. and Kpee, F. (2016): Physicochemical and Heavy Metal Assessment of Water Samples from Boreholes near Some Abattoirs in Port Harcourt, Rivers State, Nigeria. *American Chemical Science Journal,* 14(3): 1-8

Elemile, O. O., Raphael, O. D., Omole, D. O., Oloruntoba, E. O, Ajayi, E. O and Ohwavborua, N. A. (2019): Assessment of the impact of abattoir effluent on the quality of groundwater in a residential area of Omu-Aran, Nigeria. *Environmental Sciences Europe,* 31:16. doi:10.1186/s12302-019-0201-5

Ezeoha, S. L. and Ugwuishiwu, B. O. (2011): Status of abattoir waste research in Nigeria. *Nigerian Journal of Technolog,* 30 (2): 143-148

Fadeyibi, A., Halilu, A., and Osunde, Z. D. (2011): Analysis of physicochemical properties of abattoir wastewater for irrigation in Minna, Niger State. *Continental J. Water, Air and Soil Pollution,* 2 (2): 12 – 15.

Khaniki, G. J., Mansoor, M. G., Dehghani, M. H., Nazmara, S. (2017): Analysis of toxic and trace metal contaminants in bottled water by using atomic absorption spectrometry, *Food Environ. Saf. J.* 10: 78–83.

Jaishankar, M. Tseten, T., Anbalagan, N., Mathew, B. B., Beeregowda, K. N. (2014): Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, 7(2):60-72.

Lawal, M. K, Bello, M, Kwaga, J. K.P, and Raji, M. A. (2013): Evaluation of physical facilities and processing operations of major abattoirs in North-western states of Nigeria. *Sokoto Journal of Veterinary Sciences,* 11(1): 56 - 61.

Mamhobu-Amadi, W. C. Kinigoma, B. S., Momoh, Y. L., and Oji, A. A. (2019): Abattoir operations and waste Management Options: A review. *International Journal of Advanced Engineering Research and Science*, 6 (12): 226 - 231.

Mohammed, S. and Musa, J. J. (2012): Impact of abattoir effluent on River Landzu, Bida, Nigeria. *Journal of Chem. Biol. Phys. Sci*, 2 (1): 132-136

National Population Commission, (2006). Census count 2006. Demographic and evaluation department, NPC.

Ogunlade, T. M, Babaniyi, B. R., and Orija D. (2021): Microbial and heavy metal analysis on abattoir soils. *International J. of Environmental planning and management*, 7 (2):36-41

Olayinka, O. O, Adedeji, H. O., Akinyemi, A., and Oresanya, O. J. (2017): Assessment of the pollution status of Eleyele lake, Ibadan, Oyo State, Nigeria. *Journal of health and pollution*, 8 (15):51-62

Osemwota, I. O. (2010): Effect of abattoir effluent on the physical and chemical properties of soils. *Environ Monit. Asses*, 167: 399-404

Oyebanji, A. O, Momodu, D. U, Fatoki, T. H, and Alabi, V. J. (2021). Heavy metals (Cd, Pb, and Zn) residue in selected tissue and organs of slaughtered goat meat randomly selected from markets in Ayegbaju-Ekiti, Akure and Owena. *Letters in Applied NanoBioScience,* 10(1): 1896 - 1903.

Pandiyan, J. Mahboob, S., Jagadheesan, R., and Elumalai, K. (2020): A novel approach to assess the heavy metal content in the feathers of shorebirds: A perspective of environmental research. *Journal of King Saud University*, 322 (7): 10-18.

Sanda, A. R., Ahmad, I. and Gaye, C. A. (2016): Heavy Metal Content of Abattoir Waste and Municipal Sludge in Soil and Water along Jakara River in Kano, Kano State, Nigeria. *Open Access Library Journal*, 3: e2896. http://dx.doi.org/10.4236/oalib.1102896

Simeon E. O., and Friday K. (2017): Index models assessment of heavy metal pollution in soils within selected slaughterhouses in Port Harcourt, Rivers State, Nigeria. *Singapore J. Sci Res*, 7:9-15

Usman, Z., Wenting, J., Wang, X., Saddam, H., Muhammad, A., Faisal, M. M., Nauman, A., Muhammad, I., Muhammad, K., Fasih, H., Naila, F., Muhammad, N., Jiri, K., Martin, B. and Adnan, M. (2022): Cadmium Phytotoxicity, Tolerance, and Advanced Remediation Approaches in Agricultural Soils; A Comprehensive Review, *Frontiers in Plant Science*, 13, doi: 10.3389/fpls.2022.773815

Weobong C. A. and Adinyira E. (2011): Operational Impacts of the Tamela abattoir on the environment. *Journal of Public Health and Epidemiology*, 3(9): 386-393

World Health Organization (WHO), (2004) Guideline for drinking water quality, 3rd edn. World Health Organization, Geneva, Pp. 515. ISBN 92-4- 154638-7

Wuana, R. A and Okieimen, F. E. (2011): Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. *Ecology*. 402647, https://doi.org/10.5402/2011/402647

Yahaya, M. I., Mohammed, S., and Abdullahi, B. K. (2009): Seasonal variations of heavy metals concentration in abattoir dumping site soil in Nigeria. *J Appl Sci Environ Manag*, 13:9-13

Yan, A, Wang, Y, Tan, S. N, Yusof, L. M, and Chen, Z. (2020): Phytoremediation: A promising approach for revegetation of heavy metal-polluted land. *Front. Plant Sci.* 11(359): 1-15 doi:10.3389/fpls.2020.00359

Zhaochu, H. (2014): Sample digestion methods. Reference Module in Earth Systems and Environmental Sciences. *Treatise on Geochemistry Sec. Ed.*. 15: 87-109.