Int. j. adv. multidisc. res. stud. 2025; 5(5):271-277

Received: 21-07-2025
Accepted: 01-09-2025

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Ecological Risk Evaluation of Heavy Metal Contamination in Soil Due to Abattoir Activities in Akinyele, Oyo State, Nigeria

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Abstract
Various organs of cattle have been found to contain heavy metals, and most abattoirs in Nigeria lack or have inadequate waste management methods. Soil samples were collected from both Akinyele abattoir in Oyo State to determine the presence of heavy metals using Atomic Absorption Spectrophotometry (AAS - model 210/211 VGP). Lead (Pb) concentrations were higher in Sample 1 (5.8 ± 0.4 mg/kg) than in Sample 2 (2.6 ± 0.2 mg/kg), indicating pollution from industrial and slaughterhouse waste. Levels of Cadmium (Cd), Chromium (Cr), Zinc (Zn), and Copper (Cu) were also consistently higher in Sample 1 compared to Sample 2, with Cd at 1.4 ± 0.1 mg/kg versus 0.6 ± 0.1 mg/kg, Cr at 3.7 ± 0.2 mg/kg versus 1.8 ± 0.1 mg/kg, Zn at 112.4 ± 5.7 mg/kg versus 79.2 ± 3.9 mg/kg, and Cu at 34.5 ± 2.3 mg/kg versus 21.7 ± 1.5 mg/kg. The contamination factor (CF) for all heavy metals exceeded their respective background levels; Cd (2800) and Cu (434) had the highest and lowest values, respectively. The overall Pollution Load Index (PLI) was much higher for sample 1 (499.42) than for sample 2 (264.19). The total Ecological Risk Index (ERI) for sample 1 was 42,757.59, and for sample 2, 47,625.56, indicating a greater overall ecological risk and emphasising the need for proper treatment of abattoir waste before disposal to prevent environmental imbalance and loss of biodiversity.

Keywords: Ecological Risk Factor, Heavy Metals, Abattoir, Pollution Load Index

Introduction

Heavy metals are contaminants and pollutants of significant environmental and health concern. However, any toxic metal may be called a heavy metal, regardless of its atomic mass or density (Singh *et al*, 2011) [32]. Based on emission, heavy metals are mainly found in soils and released from their bound states through either the weathering of parent materials (a natural process) or from human activities. According to Amukali *et al* (2018) [5], heavy metals have become a major global concern and pose a serious potential threat to the environment. In the study by Amukali *et al* (2018) [5], this has resulted in reductions in agricultural yield and hazardous health effects as they enter the food chain through accumulation and magnification, respectively. Heavy metals can be present in soils, sediments, or other substrates that are bound together, from which plants can absorb them and later be transferred to animals through the food chain.

The quality and safety of meat products are adversely affected by their association with various toxic pollutants. The intake of heavy metals is a significant health concern because it damages the structural and functional integrity of the ecosystem. The presence of heavy metals in meat products is a serious safety issue and poses a threat to human health, as most of these metals are toxic even at very low levels (Abduljaleel *et al*., 2012; Bratty *et al*., 2018; Wang *et al*., 2019) [1, 4, 34]. Heavy metals such as lead, mercury, cadmium, and arsenic are potentially toxic. Excessive intake of these metals can be toxic if exposure occurs over a long period (Dogan *et al*., 2009; Abduljaleel *et al*., 2012 [1]; Nighat *et al*., 2016 [25]).

However, as meat production and consumption increase, more animals must be slaughtered. Similarly, more abattoirs will be built, or existing facilities will be expanded to meet the demand (Kirui *et al*., 2019) [19], leading to increased liquid waste generation (Wang *et al.,* 2011; Bustillo-Lecompte *et al.,* 2017 [9]). For example, in Nigeria, the number of non-standard abattoirs greatly exceeds the number of standard ones and are rarely inspected by veterinarians or Environmental Health Officers/Scientists (Olawale *et al.,* 2020; Oloruntoba *et al.,* 2021), raising the risk of meat contamination.

Therefore, this study aimed to assess the ecological risk of heavy metal contamination at Akinyele abattoir, Ibadan. By systematically analysing the presence and levels of various heavy metals in the area surrounding the abattoir, the study aims to highlight the potential environmental dangers posed to local ecosystems and public health. The findings enhance understanding of how heavy metals can build up in soil and water systems, impacting not only flora and fauna but also the human populations that depend on these resources. Furthermore, the study intends to inform stakeholders, including local government, environmental agencies, and the community, about the urgent need for monitoring and regulation to reduce contamination risks. By addressing these critical issues, the research seeks to promote sustainable waste management practices and encourage further research on ecological health in urban environments.

Materials and Methods

Study Area

The Ibadan Central Abattoir is a Public-Private Partnership (PPP) project undertaken by C and E Limited, a local construction firm that specialises in PPP ventures. The abattoir project was conceived and launched in 2009 during the tenure of former governor Adebayo Alao-Akala. It was designed as a build-operate-transfer (BOT) project for a 30-year term. The abattoir provides both modern and traditional slaughtering methods, with quick turnaround times and excellent hygienic conditions, contrasting with the current informal setup that allows for unhygienic slaughtering and meat distribution. The project has the capacity for 1,000 animals (cows, sheep/goats, and pigs) per day and can be expanded to 5,000 animals per day with outstanding ancillary facilities. The abattoir features two manual slaughter slabs averaging 1,500 m^2 each and is well-equipped to cater to over 200 butchers slaughtering cows, pigs, goats, and sheep simultaneously.

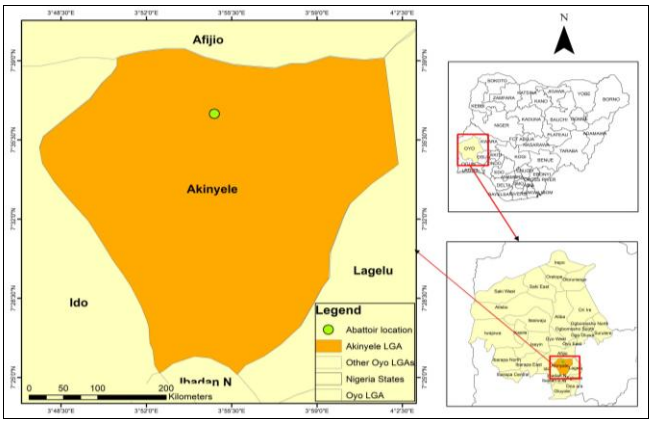

Fig 1: Map of Akinyele Abattoir, Ibadan, Oyo State

Collection of Abattoir Wastewater Samples

Abattoir wastewater samples were collected from two selected slaughterhouses (Ibadan and Ado Ekiti, Nigeria), obtained from the wastewater discharge outlet, soil, and contact surface. Wastewater samples were collected in sterile 500 mL glass bottles, contact surface samples were collected using a swab stick, and soil samples were collected in a polythene bag.

Determination of heavy metals in wastewater

The water samples from each sampling bottle were mixed thoroughly by shaking. A 50 ml filtered aliquot of the water sample was pipetted into a digestion flask. The metal percentage found in the water was determined by digestion in 3 ml concentrated HNO_3 and 3 ml H_2O_2 below 80°C for 1 h until a clear solution was observed. The clear solution was diluted to a 100 ml volumetric flask with distilled water, and blank digestion was also carried out in the same way (Birtukan & Gebregziabher, 2014) [8]. The blank solution contained all reagents except wastewater. All samples were digested in triplicate. The digests were analysed for the toxic heavy metals by using FAAS in the Holeta Agricultural Research Centre Chemistry Lab. The concentration of each metal was calculated using the formula by Birtukan and Gebregziabher (2014) [8].

Abattoir Soil Heavy Metals Determination

A specific weight of each sample was weighed into a beaker, and 10 ml of an acid mixture of nitric and perchloric acid was added. This was covered with a cover slip and subjected to heating or digestion on a hot plate at a regulated temperature for about twenty to thirty minutes under a fume cupboard. A colour change was observed from black to brown until a final colourless state was achieved. The sample was then cooled and made up to a volume of 10 ml with distilled water. The content was analysed using a Buck Scientific Atomic Absorption Spectrophotometry (AAS - model 210/211 VGP) to determine the heavy metals (Pb, Cd, Zn, Cr, and Cu) at various wavelengths following the EPA 3050B method (Peña-Icart *et al.*, 2011) [31].

Assessment of Contamination Factor (CF) and Pollution Load Index (PLI)

The contamination factor and Pollution Load Index are potent tools in evaluating heavy metal pollution. CF and PLI give a proper assessment of the degree of contamination of each site by individual metals. The PLI represents the number of times the metal content in the soil exceeds the average natural background concentration, providing a summative indication of the overall level of heavy metal toxicity at a particular site (Eq. 1). The Pollution Load Index (PLI) is obtained by summing the contamination Factors (CFs) of all the analysed heavy metals. This CF is the quotient obtained by dividing the concentration of each metal in the sample by the background concentration of the metal in the sample. The PLI of each site is calculated by obtaining the n-root from the n-CFs that are obtained for all the metals in that site. The pollution load index (PLI) was developed by Thomlinson *et al.* (1980), which is indicated in Eq. 2:

$$CF = C\ metal / C\ background\ value \quad (1)$$

$$PLI = (CF1 x CF2 x CF3 x \ldots x\ CFn)1/n \quad (2)$$

Where,

CF = contamination factor, n = number of metals, C metal = metal concentration in polluted sediments, and C Background value = background value of that metal.

The estimation of the level of contamination, the following claudication applies: The PLI value of > 1 indicates polluted, whereas a value of <1 indicates no pollution. While CF values < 1= low contamination factor; 1 ≤ CF < 3 = moderate contamination factor; 3 = CF < 6 = considerable contamination factor; CF values = 6 = very high contamination factor.

Assessment According to the Potential Ecological Risk Index (ERI)

In 1980, Lars Hakanson reported an ecological risk index for aquatic pollution control; therefore, Hakanson's method has often been used in ecological risk assessment as a diagnostic tool to identify potential ecological risks.

$$ERI = \sum_{i=1}^{n} \left(\frac{C_{metal}}{C_{reference}}\right) \times ERF_{metal} \tag{3}$$

Where,

$ERI = Ecological\ Risk\ Index$

C_{metal} = concentration of the metal

$C_{reference}$ = reference concentration

ERF_{metal} = Ecological Risk Factor for metal

Results and Discussion

Heavy Metal Concentration in Abattoir Wastewater

The current study assessed the ecological risk of heavy metal contamination at Akinyele abattoir, Ibadan. Results showed that the levels of lead (1.85 ± 0.05 mg/L), cadmium (0.65 ± 0.02 mg/L), chromium (3.20 ± 0.08 mg/L), and arsenic (0.98 ± 0.03 mg/L) all exceeded the WHO standard limits (see Fig 2), indicating heavy metal pollution. This may be due to animal feed and supplements, which can be excreted in wastewater, as well as in the equipment used for slaughtering and dressing animals. Our findings agree with previous studies documenting heavy metal contamination (Olarewaju *et al.*, 2014 [28]; Ja'afaru *et al.*, 2021). Additionally, further analysis shows that zinc levels (9.85 ± 0.30 mg/L) and copper (4.25 ± 0.15 mg/L) also surpass the WHO standards. This is in line with similar studies by Olarewaju *et al.* (2014) [28] and Rasa (2020).

These results collectively indicate high levels of heavy metal contamination in the abattoir (Moreroa *et al.*, 2022) [23]. Other factors, apart from animal feeds, such as cleaning and sanitation practices in abattoirs, including the use of disinfectants and sanitisers (Ovuru *et al.*, 2024; Gufe *et al.*, 2025) [30, 13], can also contribute to heavy metals in wastewater. This poses serious environmental health concerns based on ecological risk factors, pollution load index, contamination factors, and ecological risk index (Ayeku *et al.*, 2025) [6], as effluent could kill the soil microbiota or increase the presence of virulent microbes, which often cause diseases in plants, animals, and humans. The soil is a complex ecosystem with many plants. Thus, accumulation of metals has been reported in the soil and plants near the abattoirs (Agboola *et al.*, 2024) [2], underscoring the need for urgent intervention to address poor waste management in the abattoir.

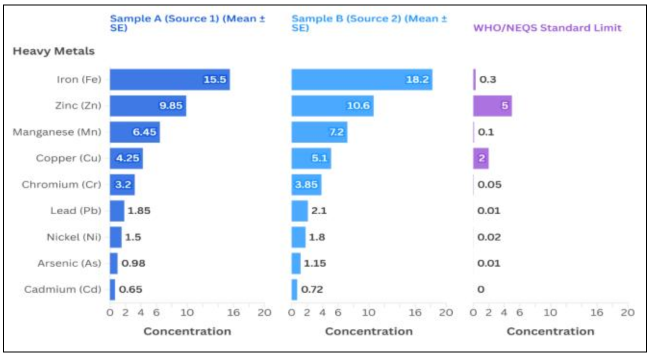

Fig 2: Heavy Metals present in Abattoir Wastewater

Contamination Factor of Heavy Metals in Water Samples

Regarding the contamination factor of water (Table 1), Lead (Pb) has a CF of 185, indicating a significant level of contamination. Cadmium (Cd) is of particular concern, with CF values of 216.67, signifying extreme pollution. Similarly, chromium (Cr) and arsenic (As) show high contamination levels, with CF values ranging from 64 to 77 and 96 to 115, respectively, suggesting potential environmental hazards posed by these toxic metals in environmental media, which can lead to ecological imbalance. Zinc (Zn) and copper (Cu) display moderate contamination, with CFs of 98.5 to 106 and 2.125 to 2.55, respectively, reflecting a noteworthy but less critical level of pollution. Nickel (Ni) indicates moderate contamination, with CFs of 21.43 and 25.71. Conversely, iron (Fe) exhibits CFs of 31 and 36.4, suggesting higher contamination relative to its background level, while manganese (Mn) shows no significant contamination, with CFs of 6.45 and 7.2. Overall, these water samples reveal elevated contamination levels for many metals, particularly cadmium, arsenic, and lead, which originate from sources such as animal intestines, the detergent (alkylbenzene sulfonate) used in abattoir cleaning, and the equipment employed in carcass dressing (Ahmed & Al-Mahmood, 2023; Ovuru *et al.*, 2024; Gufe *et al.*, 2025) [3, 30, 13].

Table 1: Contamination factor of Heavy Metals in water samples (mg/L)

Heavy Metal	*Sample A*	*Sample B*	*Background values*	*CF - Sample A*	*CF - Sample B*
Lead (Pb)	1.85	2.1	0.01	185	210
Cadmium (Cd)	0.65	0.72	0.003	216.67	240
Chromium (Cr)	3.2	3.85	0.05	64	77
Arsenic (As)	0.98	1.15	0.01	98	115
Zinc (Zn)	9.85	10.6	0.1	98.5	106
Copper (Cu)	4.25	5.1	2	2.125	2.55
Nickel (Ni)	1.5	1.8	0.07	21.43	25.71
Iron (Fe)	15.5	18.2	0.5	31	36.4
Manganese (Mn)	6.45	7.2	0.1	64.5	72

Contamination factor of Heavy Metals in soil samples

The contamination factor (CF) The levels of heavy metals in the soil samples (Table 2) vary across different samples, indicating varying degrees of environmental pollution. Lead (Pb) shows no contamination, with CF values of 0.145, reflecting no contamination. Similarly, Cadmium (Cd) with CFs of 0.465 is below the background level. Chromium (Cr) also shows low contamination, with CF values of 0.037. Zinc (Zn) exhibits significantly low contamination with CFs of 0.375. These findings align with those of Ali *et al.* (2024). Furthermore, Copper (Cu) demonstrates low contamination, with CFs of 0.345, indicating a relatively low level of pollution, lower than that of cadmium or zinc. Therefore, the soil shows no contamination levels for heavy metals like lead, cadmium, and zinc, suggesting that concerns for soil health do not significantly affect plant and animal life. This may be due to most parameters being present in the wastewater, which is directed straight to the storage, as observed in Akinyele abattoir.

Table 2: Contamination factor of heavy metals in soil samples (mg/L)

Parameter	*Sample A*	*Sample B*	*Background Value*	*CF - Sample A*	*CF - Sample B*
Lead (Pb)	5.8	2.6	40.00	0.145	0.065
Cadmium (Cd)	1.4	0.6	3.00	0.467	0.2
Chromium (Cr)	3.7	1.8	100	0.037	0.018
Zinc (Zn)	112.4	79.2	300	0.375	0.264
Copper (Cu)	34.5	21.7	100	0.345	0.217

Pollution Load Index of Heavy Metals in Water Samples

Results of the Pollution Load Index (PLI) for heavy metals in water samples (Table 3) revealed serious environmental risks due to high Lead (Pb) contamination factors, with CF values of 180 for Source A and 210 for Source B, indicating significant pollution. Similarly, Cadmium (Cd) had an extremely high CF value of 216.67, indicating severe contamination. Additionally, chromium (Cr) and arsenic (As) show notable pollution, with CF values ranging from 64 to 77 for chromium and 196 to 230 for arsenic, while Zinc (Zn) and copper (Cu) exhibit moderate contamination levels, with CFs of 98.5 to 106 for zinc and 85 to 102 for copper, suggesting pollution, but not to the same extent as cadmium and arsenic. Overall, the PLI for the water samples from the abattoir indicates moderate to high levels of pollution, posing environmental threats and potential health risks. These results align with similar studies reporting high to moderate PLI levels in water samples from an abattoir (Woolhouse *et al*., 2015; Ogunlade *et al*., 2021) [35, 27].

Table 3: Pollution Load Index of Heavy Metals in water samples (mg/L)

Heavy Metal	*Sample A*	*Sample B*	*Background values*	*CF - Sample A*	*CF - Sample B*
Lead (Pb)	1.85	2.1	0.01	185	210
Cadmium (Cd)	0.65	0.72	0.003	216.67	240
Chromium (Cr)	3.2	3.85	0.05	64	77
Arsenic (As)	0.98	1.15	0.01	98	115
Zinc (Zn)	9.85	10.6	0.1	98.5	106
Copper (Cu)	4.25	5.1	2	2.13	2.55
Nickel (Ni)	1.5	1.8	0.07	21.43	25.71
Iron (Fe)	15.5	18.2	0.5	31	36.4
Manganese (Mn)	6.45	7.2	0.1	64.5	72
PLI				**131070.98**	**200880**

Pollution Load Index of Heavy Metals in Soil Samples

Further results revealed varying degrees of contaThe pollution load index of soil (see Table 4) measures contamination. Findings show low pollution levels in most cases, with Lead (Pb) having a much lower contamination factor, ranging from 0.145 to 0.07. Cadmium (Cd) shows no contamination, with CF values of 0.47. Similarly, Chromium (Cr) indicates no severe contamination, with CF values of 0.04, while Zinc (Zn) also exhibits lower contamination in both sources, with CFs of 0.37. Copper (Cu) shows no significant contamination, with CF of 0.35. The overall PLI for the soil samples is significantly lower for sample A (0.0707) compared to Source B (0.117), indicating less contamination in Source A. All values in both abattoirs are below the standards set by the WHO. This suggests that no environmental health risks are posed by heavy metals such as cadmium, lead, and zinc in either source, particularly in the soil, consistent with a previous study (Zainab *et al*., 2023) [36].

Table 4: Pollution Load Index of Heavy Metals in Soil Samples (mg/L)

Parameter	*Sample A*	*Sample B*	*Background Value*	*CF - Sample A*	*CF - Sample B*
Lead (Pb)	5.8	2.6	40.00	0.145	0.07
Cadmium (Cd)	1.4	0.6	3.00	0.47	0.2
Chromium (Cr)	3.7	1.8	100	0.04	0.02
Zinc (Zn)	112.4	79.2	300	0.37	0.26
Copper (Cu)	34.5	21.7	100	0.35	0.22
PLI				**0.0707**	**0.117**

Ecological Risk Index of Heavy Metals in Water Samples

The Ecological Risk Index (ERI) for heavy metals in the water samples shows different levels of ecological risk across various metals (see Table 5). Lead (Pb) has a notable ERI value of 9.25, indicating a significant ecological risk. Cadmium (Cd) presents an even higher risk, with ERI values of 6500.1 for sample A and 7200 for sample B, reflecting severe contamination. Chromium (Cr) also poses considerable ecological risk, with ERI values of 384 for sample A and 462 for sample B. Arsenic (As) follows, with ERI values of 980 for sample A and 1150 for sample B, indicating an elevated level of contamination in both sources. Zinc (Zn) and Copper (Cu) display moderate ecological risks, with ERI values of 98.5 and 106 for zinc, and 21.3 and 25.5 for copper, reflecting their toxic potential in both sources. In contrast, iron (Fe) and Manganese (Mn) show minimal ecological risks, with low ERI values of 31 and 36.4 for iron, and 6.45 and 7.2 for manganese, respectively. The total ERI for sample A is 8,195.8. For sample B, the value is 10,230.4, indicating a higher overall ecological risk due to the elevated contamination levels of cadmium and arsenic, which contribute to the contamination load.

Table 5: Ecological Risk Index of Heavy Metals in water samples (mg/L)

Heavy Metal	*Sample A*	*Sample B*	*Background values*	*ERF*	*ERI-Sample A*	*ERI-Sample B*
Lead (Pb)	1.85	2.1	0.01	5	9.25	1050
Cadmium (Cd)	0.65	0.72	0.003	30	6500.1	7200
Chromium (Cr)	3.2	3.85	0.05	6	384	462
Arsenic (As)	0.98	1.15	0.01	10	980	1150
Zinc (Zn)	9.85	10.6	0.1	1	98.5	106
Copper (Cu)	4.25	5.1	2	10	21.3	25.5
Nickel (Ni)	1.5	1.8	0.07	5	107.15	128.55
Iron (Fe)	15.5	18.2	0.5	1	31	36.4
Manganese (Mn)	6.45	7.2	0.1	1	64.5	72
ERI					**8,195.8**	**10,230.5**

Ecological Risk Index of Heavy Metals in Soil Samples

Regarding the Ecological Risk Index (ERI) for heavy metals in the soil samples from samples A and B, results revealed no significant contamination and no ecological risk (Table 6). Lead (Pb) shows a low risk in sample A, with an ERI value of 0.725 compared to 0.35 in sample B, suggesting no contamination in Source A. Cadmium (Cd) presents no risk, with ERI values of 14.1 for sample A and 6 for sample B, indicating extremely low or no pollution in both sources. Similarly, Chromium (Cr) exhibits no ecological risk, with ERI values of 0.4 for sample A and 0.2 for sample B. Also, Zinc (Zn) presents no significant contamination, with ERI values of 0.37 for sample A and 0.26 for B, indicating no environmental risk. Copper (Cu) presents no risk in sample A, with an ERI of 3.5, and a lesser risk in Source B, with an ERI of 2.2, indicating no potential toxicity of copper in the soil. The overall ERI for Source A is 19.095, which is significantly lower than Source B's ERI of 9.01, indicating that sample A is less contaminated with metals like cadmium, lead, and copper, posing no ecological risk to the environment as reported by (Jolaosho *et al*., 2024) [18].

Table 6: Ecological Risk Index of Heavy Metals in Soil Samples (mg/L)

Heavy Metal	*Sample A*	*Sample B*	*Background Value*	*ERF*	*ERI-Sample A*	*ERI-Sample B*
Lead (Pb)	5.8	2.6	40.00	5	0.725	0.35
Cadmium (Cd)	1.4	0.6	3.00	30	14.1	6
Chromium (Cr)	3.7	1.8	100	10	0.4	0.2
Zinc (Zn)	112.4	79.2	300	1	0.37	0.26
Copper (Cu)	34.5	21.7	100	10	3.5	2.2
ERI					**19.095**	**9.01**

Conclusion

The levels of all heavy metals in the soil samples were within the safe limits established by WHO, indicating that the contamination factors and pollution load index do not pose any ecological risks. Conversely, wastewater samples exceeded these standards, with cadmium (Cd) exhibiting the highest concentration among the heavy metals, including Lead (Pb), Chromium (Cr), Arsenic (As), Zinc (Zn), Copper (Cu), Nickel (Ni), Iron (Fe), and Manganese (Mn). The contamination factor and pollution load index values suggest a serious ecological and potential health risk if not adequately treated before being discharged into the environment, which could impact the food chain. The abattoir industry must adopt more environmentally responsible practices to support ecological restoration, protect ecosystem integrity, promote wildlife health, and safeguard human health.

Competing interest

The authors declare no conflict of interest.

Funding

None.

References

1. Abduljaleel SA, Shuhaimi-Othman M, Babji A. Assessment of trace metals contents in chicken (Gallus gallus domesticus) and quail (Coturnix coturnix japonica) tissues from Selangor (Malaysia). Journal of Environmental Science and Technology. 2012; 5(6):441-451.
2. Agboola OE. Assessment of Physicochemical Properties and Heavy Metals Concentration of Abbatoir Effluent on Oko Oba River in Agege, Lagos Nigeria. Master's thesis, Kwara State University, Nigeria, 2024.

3. Ahmed AH, Al-Mahmood OA. Food safety programs that should be implemented in slaughterhouses. Journal of Applied Veterinary Sciences. 2023; 8(2):80-88.
4. Alhazmi HA, Alnami AM, Arishi MA, Alameer RK, Al Bratty M, Rehman ZU, *et al*. A fast and validated reversed-phase HPLC method for simultaneous determination of simvastatin, atorvastatin, telmisartan and irbesartan in bulk drugs and tablet formulations. Scientia Pharmaceutica. 2018; 86(1):1.
5. Amukali O, Bariweni PA, Imaitor-Uku EE. Spatial distribution of heavy metal contamination indexes in soils around auto-mechanic workshop clusters in Yenagoa metropolis, Bayelsa State, Nigeria. Global Journal of Earth and Environmental Science. 2018; 3(4):23-33.
6. Ayeku PO, Ajibare AO, Ogungbile PO. Health Risk Assessment and Potential Ecological Risk of Trace Metals of Ogunpa River, Oyo State, Nigeria. Advances in Environmental Health Sciences and Toxicology. 2025; 1(2).
7. Baquedano FG, Zereyesus YA, Valdes C, Ajewole K. International food security assessment, 2021-31.
8. Birtukan A, Gebregziabher B. Determination the level of some heavy metals (Mn and Cu) in drinking water using wet digestion method of Adigrat Town. International Journal of Technology Enhancements and Emerging Engineering Research. 2014; 2(10):32-36.
9. Bustillo-Lecompte C, Mehrvar M. Slaughterhouse wastewater: Treatment, management and resource recovery. In R. Farooq & Z. Ahmad (Eds.), Physico-Chemical Wastewater Treatment and Resource Recovery, 2017.
10. Çelik U, Oehlenschläger J. High contents of cadmium, lead, zinc and copper in popular fishery products sold in Turkish supermarkets. Food Control. 2007; 18(3):258-261.
11. Dogan Y, Ugulu I, Durkan N. Wild edible plants sold in the local markets of Izmir, Turkey. Pakistan Journal of Botany. 2013; 45(S1):177-184.
12. Eze EJ, Phil-Eze PO. Abattoir effluents and population health risks. Journal of Environmental Science, Toxicology and Food Technology. 2020; 14(4):49-52.
13. Gufe C, Chari TA, Jambwa P, Dinginya L, Mahlangu P, Marowero ST, *et al*. A review on the occurrence of antibiotic-resistant bacteria found in abattoir effluent from resource-limited settings: The necessity of a robust One Health framework. Sustainable Environment. 2025; 11(1):2464419.
14. Hassana AL, Nuradeen LT. Evaluation of the efficiency of constructed activated carbon for the treatment of abattoir wastewater. Science World Journal. 2021; 16(2):172-178.
15. Henchion M, Moloney AP, Hyland J, *et al*. Review: Trends for meat, milk and egg consumption for the next decades and the role played by livestock systems in the global production of proteins. Animal. 2021; 15:100287.
16. Hwang TI, Ahn TH, Kim EJ, Lee JA, Kang MH, Jang YM, *et al*. Monitoring heavy metals in meat and meat products. Korean Journal of Food Science and Technology. 2011; 43(5):525-531.
17. Ja'afaru MI, Pola BJ, Pukuma MS, Ijabani E. Screening of Heavy Metals Tolerance among Beta-Lactamase Producing Bacteria from Contaminated Soil and Waste Water of Some Abattoirs in Adamawa State. UMYU Journal of Microbiology Research (UJMR). 2025; 10(3):1-11.
18. Jolaosho TL, Elegbede IO, Ndimele PE, Falebita TE, Abolaji OY, Oladipupo IO, *et al*. Occurrence, distribution, source apportionment, ecological and health risk assessment of heavy metals in water, sediment, fish and prawn from Ojo River in Lagos, Nigeria. Environmental Monitoring and Assessment. 2024; 196(2):109.
19. Kirui L, Karugia JT. Economic viability of abattoirs in arid and semi-arid land (ASAL) counties of Kenya. ILRI, 2019.
20. Massé DI, Masse L. Characterization of wastewater from hog slaughterhouses in Eastern Canada and evaluation of their in-plant wastewater treatment systems. Canadian Agricultural Engineering. 2000; 42(3):139-146.
21. Mittal GS. Characterization of the effluent wastewater from abattoirs for land application. Food Reviews International. 2004; 20(3):229-256.
22. Mohammed AI, Ahmed AA, Dauda TE. Determination of levels of heavy metals and physicochemical parameters in waste water of Kasuwan Shanu abattoir, Maiduguri. Journal of Chemistry Letters. 2020; 1(2):84-88.
23. Moreroa M, Basitere M. The challenges and treatment of abattoir effluents: A South African perspective. Water Practice & Technology. 2022; 17(12):2598-2613.
24. Nandomah S, Tetteh IK. Potential ecological risk assessment of heavy metals associated with abattoir liquid waste: A narrative and systematic review. Heliyon. 2023; 9(8).
25. Nighat S, Nadeem MS, Mahmood T, Kayani AR, Mushtaq M, Hassan M. Estimation of heavy metals in Indian flying fox Pteropus giganteus (Brünnich, 1782) from Punjab, Pakistan. Pakistan Journal of Zoology. 2016; 48(6).
26. OECD & FAO of the United Nations. OECD-FAO Agricultural Outlook 2020-2029. OECD Publishing, 2020.
27. Ogunlade TM, Babaniyi BR, Afolabi FJ, Babaniyi GG. Physicochemical, heavy metals and microbiological assessment of wastewater in selected abattoirs in Ekiti State, Nigeria. J. Environ. Treat. Tech. 2021; 9(4):788-795.
28. Olarewaju AJ. Estimation of blast loads for studying the dynamic effects of coeffcient of friction on buried pipes by simulation. GEOMATE Journal. 2014; 7(13):1017-1024.
29. Osibanjo O, Adie GU. Impact of effluent from Bodija abattoir on the physicochemical parameters of Oshunkaye stream in Ibadan City, Nigeria. African Journal of Biotechnology. 2007; 6(15).
30. Ovuru KF, Izah SC, Ogidi OI, Imarhiagbe O, Ogwu MC. Slaughterhouse facilities in developing nations: Sanitation and hygiene practices, microbial contaminants and sustainable management system. Food Science and Biotechnology. 2024; 33(3):519-537.
31. Peña-Icart M, Tagle MEV, Alonso-Hernández C, Hernández JR, Behar M, Alfonso MSP. Comparative study of digestion methods EPA 3050B (HNO3–H2O2–HCl) and ISO 11466.3 (aqua regia) for Cu, Ni and Pb contamination assessment in marine sediments. Marine

Environmental Research. 2011; 72(1-2):60-66.
32. Singh A, Prasad SM. Reduction of heavy metal load in food chain: Technology assessment. Reviews in Environmental Science and Bio/Technology. 2011; 10(3):199-214.
33. Tomlinson DL, Wilson JG, Harris CR, Jeffrey DW. Problems in the assessment of heavy-metal levels in estuaries and the formation of a pollution index. Helgoländer Meeresuntersuchungen. 1980; 33(1):566-575.
34. Wang X, Zhang Y, Geng Z, Liu Y, Guo L, Xiao G. Spatial analysis of heavy metals in meat products in China during 2015-2017. Food Control. 2019; 104:174-180.
35. Woolhouse M, Ward M, Van Bunnik B, Farrar J. Antimicrobial resistance in humans, livestock and the wider environment. Philosophical Transactions of the Royal Society B: Biological Sciences. 2015; 370(1670):20140083.
36. Zainab N, Mehmood S, Shafiq-ur-Rehman A, Munir A, Tanveer ZI, Nisa ZU, *et al*. Health risk assessment and bioaccumulation of potentially toxic metals from water, soil, and forages near coal mines of district Chakwal, Punjab, Pakistan. Environmental Geochemistry and Health. 2023; 45(7):5441-5466.