IJAAR PUBLISHING®

African Journal of Environment and Sustainable Development | ISSN: 3027-2718
Vol. 3, Issue 3 (2025) | www.ijaar.org

Assessment of Ecological Risk Factors of Heavy Metal Contamination from Akinyele Abattoir, Ibadan, Nigeria

Kayode Micheal Ogunyemi
Ekiti State College of Health Sciences and Technology, Ijero Ekiti
k.ogunyemy@gmail.com

Dr. Sawyer, Olawale
Senior Lecturer, Kwara State University, Malete, Nigeria
hsawyerr@gmail.com

Abstract
Various cattle organs have been found to contain heavy metals, and most abattoirs in Nigeria lack proper waste management, raising concerns about meat contamination. This study evaluated the ecological risk of heavy metals at Akinyele abattoir in Ibadan. Soil samples from the abattoir in Oyo State were analysed for heavy metals using Atomic Absorption Spectrophotometry (AAS - model 210/211 VGP). Results indicated that Lead (Pb) had the highest levels (5.8 ± 0.4 mg/kg), suggesting pollution from industrial and slaughterhouse waste. Cadmium (Cd), Chromium (Cr), Zinc (Zn), and Copper (Cu) levels were also notably high, with Cd at 1.4 ± 0.1 mg/kg, Cr at 3.7 ± 0.2 mg/kg, Zn at 112.4 ± 5.7 mg/kg, and Cu at 34.5 ± 2.3 mg/kg. The Pollution Load Index was significantly high at 499.42, as was the Ecological Risk Index at 42,757.59, indicating substantial ecological risk and highlighting the importance of proper waste treatment at abattoirs to prevent ecological imbalance and biodiversity loss. In summary, these findings reveal the potential danger of heavy metal contamination in meat and meat products at the abattoir, providing critical insights for policy measures aimed at safeguarding public health.

Keywords: Ecological Risk, Heavy Metals, Environmental Contamination, Abattoir Pollution, Akinyele Abattoir, Ibadan, Nigeria

Ogunyemi, K.M., and Sawyer, O. (2025). Assessment of Ecological Risk Factors of Heavy Metal Contamination from Akinyele Abattoir, Ibadan, Nigeria. *African Journal of Environment and Sustainable Development. 3*(3), 88-101. DOI: https://doi.org/10.5281/zenodo.17098303

Introduction

Heavy metals are contaminants and pollutants of significant environmental and health concerns. However, any toxic metal may be referred to as a heavy metal, irrespective of its atomic mass or density (Singh *et al*, 2011). Based on the emission, heavy metals are primarily contained in soils and liberated from their bound states through either the weathering of parent materials (a natural process) or from anthropogenic activities. According to Amukali *et al* (2018), heavy metals have become a primary worldwide concern and pose a serious potential threat to the environment. In the study by Amukali *et al* (2018), this has led to losses 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 food chain contamination.

As such, the quality and safety of meat products are negatively impacted by their association with the presence of various toxic pollutants. Heavy metals intake is a significant health concern because it affects the structural and functional integrity of the ecosystem, the presence of heavy metals in meat products is a serious concern for food safety and it is a threat to human health because most of these metals are toxic even at very low levels (Abduljaleel et al., 2012; Bratty et al., 2018; Wang et al., 2019). Heavy metals such as lead, mercury, cadmium, and arsenic are potentially toxic. Excessive amounts of base metals can be toxic if exposed to the body for long periods of time (Dogan et al., 2009; Abduljaleel et al., 2012; Nighat et al., 2016).

However, as meat production and consumption rise, more animals need to be slaughtered. Likewise, more abattoirs will be built, or existing facilities will be expanded to meet the demand (Kirui et al., 2019), leading to increased liquid waste generation (Wang et al., 2011; Bustillo-Lecompte et al., 2017). For instance, in Nigeria, the number of non-standard abattoirs far outnumbered the few standard ones and are rarely inspected by veterinarians or Environmental Health Officers/Scientists (Olawale *et al*, 2020; Oloruntoba *et al*, 2021), increasing the risk of meat contamination.

Therefore, this study aimed to examine the ecological risk of heavy metal contamination in Akinyele abattoir, Ibadan. By systematically analysing the presence and concentration of various heavy metals within the vicinity of the abattoir, the study seeks to highlight the potential environmental hazards posed to local ecosystems and public health. The findings contribute to a deeper understanding of how heavy metals can accumulate in the soil and water systems, affecting not only the flora and fauna but also the human population relying on these resources. Moreover, the study intends to inform stakeholders, including local government, environmental agencies, and the community, about the urgent need for monitoring and regulatory measures to mitigate contamination risks. By addressing these critical issues, the research aims to promote sustainable practices in waste management and encourage further studies focused on ecological health in urban settings.

Materials and Methods

Study Area

The Ibadan Central Abattoir is a Private-Public-Partnership (PPP) project undertaken by C and E Limited, a local construction company that specialises in PPP ventures. The abattoir project was conceived and initiated in 2009 during the tenure of former governor Adebayo

Alao-Akala. It was planned as a build-operate-transfer (BOT) project for a 30-year term. The abattoir offers both modern and traditional slaughtering methods, with rapid turnaround times and excellent hygienic conditions, in contrast to the current informal structure that leaves room for unhygienic slaughtering and meat distribution. The project has the capacity for 1,000 heads of animals (cows, sheep/goats, and pigs) per day and is expandable to 5,000 heads per day with excellent ancillary facilities. The abattoir features two manual slaughter slabs with an average area of 1,500 m² each and is well-equipped to accommodate over 200 butchers slaughtering cows, pigs, goats, and sheep simultaneously.

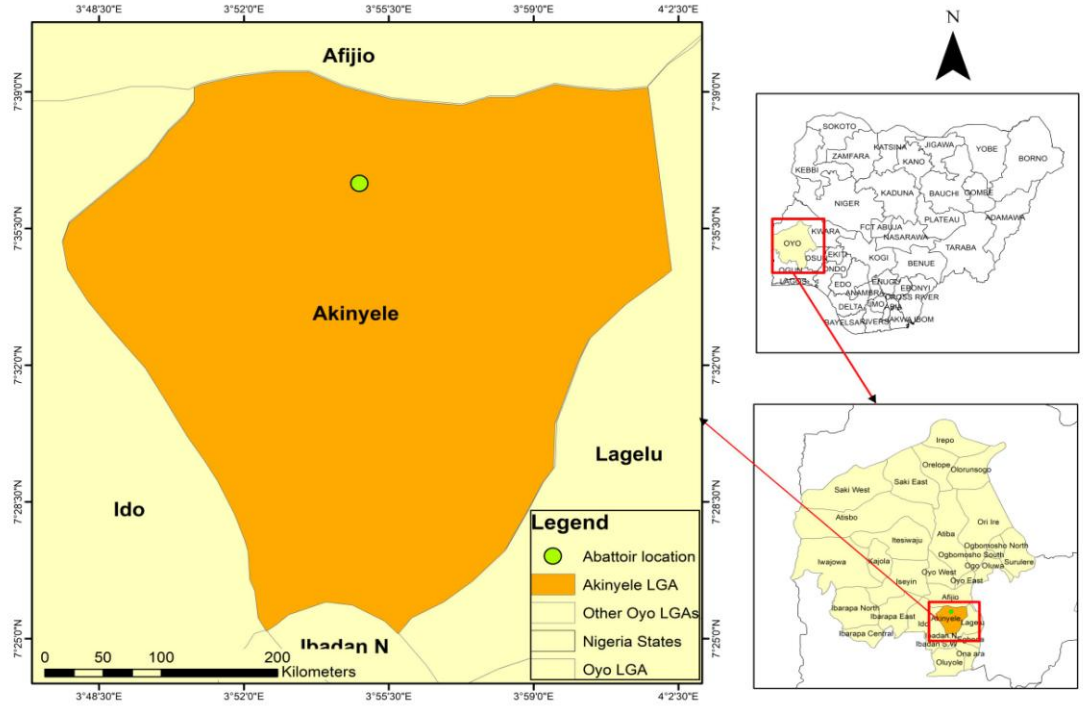


Fig. 1 Map of Akinyele Abattoir, Ibadan, Oyo State

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 HNO3 and 3 ml H2O2 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). 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).

Abattoir Soil Heavy Metals Determination

A specific weight of each sample was weighed into a beaker and 10mls of an acid mixture of nitric/perchloric acid was added, this was covered with a cover slip and allowed to undergo 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 colour of colourless was obtained. This was allowed to cool and brought to a volume of 10ml with distilled water. The content was read on a Buck Scientific Atomic Absorption Spectrophotometry (AAS - model 210/211 VGP) to determine the heavy metals (Pb, Cd, Zn, Cr, and Cu) analysed at various wavelengths following the EPA 3050B method (Peña-Icart et al., 2011)

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 (1)

PLI= (CF1xCF2xCF3x…x CFn)1/n (2)

Where, CF = contamination factor, n = number of metals, C metal = metal concentration in polluted sediments, 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 been often used in ecological risk assessment as a diagnostic tool to penetrate one of many possible avenues towards a potential ecological risk index.

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

Where $ERI = Ecological\ Risk\ Index,$ $C_{metal} = concentration\ of\ the\ metal,$ $C_{reference} = reference\ concentration,$ *and* $ERF_{metal} = Ecological\ Risk\ Factor\ for\ metal$

Results and Discussion

Heavy Metal Concentration in Abattoir Wastewater

The current study examined the ecological risk of heavy metal contamination in Akinyele abattoir, Ibadan. Findings revealed that the heavy metals 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) were all considerably above the WHO standard limits (see Figure 2), suggesting heavy metal pollution. This could be attributed to animal feed and supplements, which can then be excreted in wastewater, as well as in the equipment used for killing and dressing animals. Our findings are consistent with previous studies documenting heavy metal contamination (Olarewaju *et al*., 2014; Ja'afaru *et al*., 2021). Similarly, further analysis shows that Zinc levels (9.85 ± 0.30 mg/L) and copper (4.25 ± 0.15 mg/L) both surpass the WHO standard. This aligns with similar studies by Olarewaju *et al*. (2014) and Rasa (2020).

These results collectively indicate high levels of heavy metal contamination in the abattoir (Moreroa *et al.*, 2022). 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), 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), as effluent could kill the soil microbiota or increase the presence of virulent microbes, which often causes diseases to plants, animals, and humans. The soil is a complex ecosystem of many plants. Thus, accumulation of metals has been reported in the soil and plants close to the abattoirs (Agboola *et al*, 2024), underscoring the need for urgent intervention to address poor waste management in the abattoir.

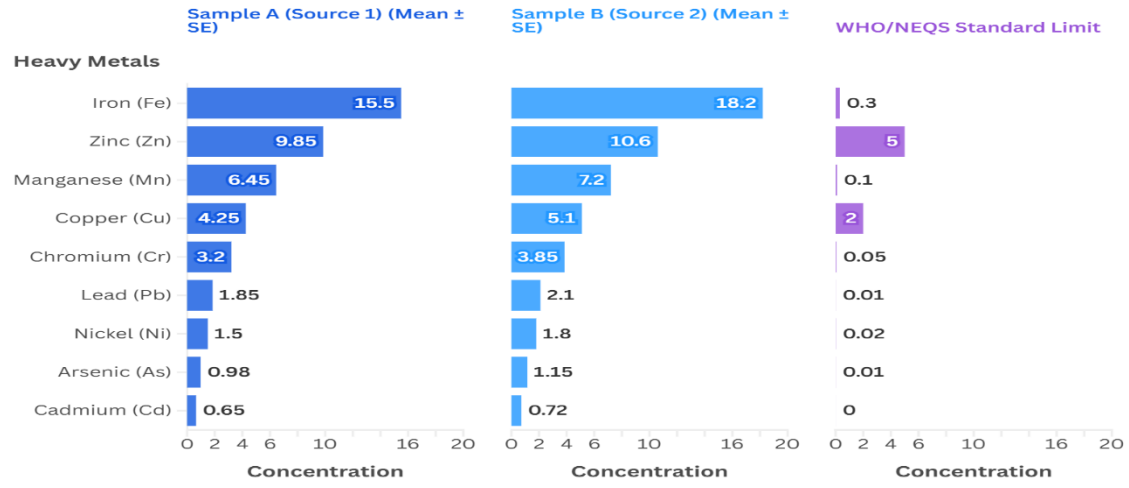


Fig. 2 Heavy Metals present in Abattoir Wastewater

Contamination Factor of Heavy Metals in Water Samples

Regarding the contamination factor of water (Table 1), Lead (Pb) has a CF of 185, suggesting a substantial level of contamination. Cadmium (Cd) is of particular concern, with CF values of 216.67, indicating extreme pollution. Similarly, chromium (Cr) and arsenic (As) exhibit high contamination levels, with CF values ranging from 64 to 77 and 96 to 115, respectively, indicating potential environmental risks associated with these toxic metals in environmental

media, which contribute to ecological imbalance. Zinc (Zn) and copper (Cu) show moderate contamination, with CFs of 98.5 to 106 and 2.125 to 2.55, respectively, indicating a notable but less critical level of pollution. Nickel (Ni) shows moderate contamination, with CFs of 21.43 and 25.71. On the other hand, iron (Fe) exhibits CFs of 31 and 36.4, indicating higher contamination compared to its background value, while manganese (Mn) shows no significant contamination, with CFs of 6.45 and 7.2. Overall, these water samples reveal high contamination levels for many metals, especially cadmium, arsenic, and lead, which are contained in animal intestines, the detergent (alkylbenzene sulfonate) used in the cleaning of abattoirs, and the equipment used in the dressing of carcasses (Ahmed & Al-Mahmood, 2023; Ovuru *et al*., 2024; Gufe *et al*., 2025).

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) for heavy metals in the soil samples (Table 2) varies across samples, indicating differing levels of environmental pollution. Lead (Pb) shows no contamination, with CF values of 0.145, reflecting no contamination. Also, Cadmium (Cd) with CFs of 0.465 was below the background value. Chromium (Cr) also shows low contamination, with CF values of 0.037for. Zinc (Zn) demonstrates significantly low contamination with CFs of 0.375. These findings agree with those of Ali *et al.* (2024). Moreover, Copper (Cu) exhibits low contamination, with CFs of 0.345, indicating a relatively low level of pollution, which is lower than that of cadmium or zinc. Thus, the soil shows no contamination levels for heavy metals like lead, cadmium, and zinc, highlighting that concerns for soil health do not have any significant effect on plant and animal life and this is

possible because most of the parameters are present in the wastewater, which is channelled directly 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 because high Lead (Pb) contamination factor, with CF values of 180 for Source A and 210 for Source B, indicating notable pollution. Similarly, Cadmium (Cd) had an extremely high CF value of 216.67, pointing to severe contamination. Additionally, chromium (Cr) and arsenic (As) show considerable 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 levels of contamination, 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, which is a threat to the environment and a possible health risk. These results align with similar studies reporting high to moderate PLI levels in water samples in an abattoir (Woolhouse *et al*., 2015; Ogunlade *et al*., 2021).

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 contamination, as measured by the pollution load index of soil (see Table 4). Findings indicate 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) shows no severe contamination, with CF values of 0.04, while Zinc (Zn) also exhibits lower contamination in both sources, with CFs of 0.37. Similarly, Copper (Cu) shows no significant contamination 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 the values in both abattoirs were less than the value or standard set by the WHO. This highlights that no environmental health risks are posed by heavy metals, such as cadmium, lead, and zinc, in either source, particularly in the soil, thus aligning with a previous study (Zainab *et al*., 2023).

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 reveals varying levels of ecological risk across different 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) exhibit 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) exhibit 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 are factors contributing 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).

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

Abduljaleel, S. A., Shuhaimi-Othman, M., & Babji, A. (2012). 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, 5(6), 441-451.

Agboola, O. E. (2024). *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)).

Ahmed, A. H., & Al-Mahmood, O. A. (2023). Food safety programs that should be implemented in slaughterhouses. *Journal of Applied Veterinary Sciences*, *8*(2), 80-88.

Alhazmi, H. A., Alnami, A. M., Arishi, M. A., Alameer, R. K., Al Bratty, M., Rehman, Z. U., et al. (2018). 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, 86(1), 1.

Amukali, O., Bariweni, P. A., & Imaitor-Uku, E. E. (2018). 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, 3(4), 23–33.

Ayeku, P. O., Ajibare, A. O., & Ogungbile, P. O. (2025). Health Risk Assessment and Potential Ecological Risk of Trace Metals of Ogunpa River, Oyo State, Nigeria. *Advances in Environmental Health Sciences and Toxicology*, *1*(2).

Baquedano, F. G., Zereyesus, Y. A., Valdes, C., & Ajewole, K. (2021). International food security assessment 2021-31.

Birtukan, A., & Gebregziabher, B. (2014). 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, 2(10), 32-36.

Bustillo-Lecompte, C., & Mehrvar, M. (2017). Slaughterhouse wastewater: Treatment, management and resource recovery. In R. Farooq & Z. Ahmad (Eds.), Physico-Chemical Wastewater Treatment and Resource Recovery.

Çelik, U., & Oehlenschläger, J. (2007). High contents of cadmium, lead, zinc and copper in popular fishery products sold in Turkish supermarkets. Food Control, 18(3), 258-261.

Dogan, Y., Ugulu, I., & Durkan, N. (2013). Wild edible plants sold in the local markets of Izmir, Turkey. Pakistan Journal of Botany, 45(S1), 177-184.

Eze, E. J., & Phil-Eze, P. O. (2020). Abattoir effluents and population health risks. Journal of Environmental Science, Toxicology and Food Technology, 14(4), 49-52.

Gufe, C., Chari, T. A., Jambwa, P., Dinginya, L., Mahlangu, P., Marowero, S. T., ... & Machakwa, J. (2025). 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*, *11*(1), 2464419.

Hassana, A. L., & Nuradeen, L. T. (2021). Evaluation of the efficiency of constructed activated carbon for the treatment of abattoir wastewater. Science World Journal, 16(2), 172-178.

Henchion, M., Moloney, A. P., Hyland, J., et al. (2021). 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, 15, 100287.

Hwang, T. I., Ahn, T. H., Kim, E. J., Lee, J. A., Kang, M. H., Jang, Y. M., & Kim, M. H. (2011). Monitoring heavy metals in meat and meat products. *Korean Journal of Food Science and Technology*, *43*(5), 525-531.

Ja'afaru, M. I., Pola, B. J., Pukuma, M. S., & Ijabani, E. (2025). 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)*, *10*(3), 1-11.

Jolaosho, T. L., Elegbede, I. O., Ndimele, P. E., Falebita, T. E., Abolaji, O. Y., Oladipupo, I. O., ... & Isaac, O. O. (2024). 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*, *196*(2), 109.

Kirui, L., & Karugia, J. T. (2019). Economic viability of abattoirs in arid and semi-arid land (ASAL) counties of Kenya. ILRI. (link unavailable)

Massé, D. I., & Masse, L. (2000). Characterization of wastewater from hog slaughterhouses in Eastern Canada and evaluation of their in-plant wastewater treatment systems. Canadian Agricultural Engineering, 42(3), 139-146.

Mittal, G. S. (2004). Characterization of the effluent wastewater from abattoirs for land application. Food Reviews International, 20(3), 229-256.

Mohammed, A. I., Ahmed, A. A., & Dauda, T. E. (2020). Determination of levels of heavy metals and physicochemical parameters in waste water of Kasuwan Shanu abattoir, Maiduguri. Journal of Chemistry Letters, 1(2), 84-88.

Moreroa, M., & Basitere, M. (2022). The challenges and treatment of abattoir effluents: A South African perspective. *Water Practice & Technology*, *17*(12), 2598-2613.

Nandomah, S., & Tetteh, I. K. (2023). Potential ecological risk assessment of heavy metals associated with abattoir liquid waste: A narrative and systematic review. Heliyon, 9(8).

Nighat, S., Nadeem, M. S., Mahmood, T., Kayani, A. R., Mushtaq, M., & Hassan, M. (2016). Estimation of heavy metals in Indian flying fox Pteropus giganteus (Brünnich, 1782) from Punjab, Pakistan. Pakistan Journal of Zoology, 48(6).

OECD & FAO of the United Nations. (2020). OECD-FAO Agricultural Outlook 2020-2029. OECD Publishing.

Ogunlade, T. M., Babaniyi, B. R., Afolabi, F. J., & Babaniyi, G. G. (2021). Physicochemical, heavy metals and microbiological assessment of wastewater in selected abattoirs in Ekiti State, Nigeria. *J. Environ. Treat. Tech*, *9*(4), 788-795.

Olarewaju, A. J. (2014). Estimation of blast loads for studying the dynamic effects of coeffcient of friction on buried pipes by simulation. *GEOMATE Journal*, *7*(13), 1017-1024.

Osibanjo, O., & Adie, G. U. (2007). Impact of effluent from Bodija abattoir on the physicochemical parameters of Oshunkaye stream in Ibadan City, Nigeria. African Journal of Biotechnology, 6(15).

Ovuru, K. F., Izah, S. C., Ogidi, O. I., Imarhiagbe, O., & Ogwu, M. C. (2024). Slaughterhouse facilities in developing nations: Sanitation and hygiene practices, microbial contaminants and sustainable management system. *Food Science and Biotechnology*, *33*(3), 519-537.

Peña-Icart, M., Tagle, M. E. V., Alonso-Hernández, C., Hernández, J. R., Behar, M., & Alfonso, M. S. P. (2011). 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, 72(1-2), 60-66.

Singh, A., & Prasad, S. M. (2011). Reduction of heavy metal load in food chain: Technology assessment. Reviews in Environmental Science and Bio/Technology, 10(3), 199-214.

Tomlinson, D. L., Wilson, J. G., Harris, C. R., & Jeffrey, D. W. (1980). Problems in the assessment of heavy-metal levels in estuaries and the formation of a pollution index. Helgoländer Meeresuntersuchungen, 33(1), 566-575.

Wang, X., Zhang, Y., Geng, Z., Liu, Y., Guo, L., & Xiao, G. (2019). Spatial analysis of heavy metals in meat products in China during 2015–2017. Food Control, 104, 174-180.

Woolhouse, M., Ward, M., Van Bunnik, B., & Farrar, J. (2015). Antimicrobial resistance in humans, livestock and the wider environment. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1670), 20140083.

Zainab, N., Mehmood, S., Shafiq-ur-Rehman, A., Munir, A., Tanveer, Z. I., Nisa, Z. U., ... & Chaudhary, H. J. (2023). 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*, *45*(7), 5441-5466.