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Heavy metals in effluents from Bodija abattoir, and their effects on organisms in Oshunkaye Stream, Ibadan, Nigeria

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The size of grain and analysis of heavy metals in sediments, waste, and benthic organisms from the Oshunkaye stream due to heavy effluent from the Bodija abattoir are investigated with samples taken from six different sampling points. The mean size analysis in all six sampling points is sand, very rough grain, and rough grain particle sizes between Phi -2.0 to 1.0. The skew values of the sediment size in the samples showed mostly coarse skewed and strongly coarse skewed between -1.0 and 1.0. The highest levels of heavy metals were predominantly found at sampling points 1, 4, and 6. Point 1 is located at the point of discharge of abattoir waste, while points 4 and 6 are situated downstream after the discharge. In contrast, the lowest levels were recorded at points 2 and 3, which are located upstream, before the discharge of abattoir waste. This indicates that waste from the Bodija abattoir negatively impacts the physical, chemical, and biological parameters of the Oshunkaye stream, thereby posing a health risk to individuals living in the surrounding area.

Key words: Heavy metals, benthic organism, Bodija abattoir waste, Oshunkaye Stream.

INTRODUCTION

Slaughtering livestock for human consumption promotes health and economic stability for both producers and consumers (Ng et al., 2022). It also raises several public health, environmental health, and natural resources issues, such as water pollution, solid waste generation, high strength of effluent discharge, food contamination, nutrient runoff, human disease risk, and diminishing biodiversity resulting from large quantities of waste generated during slaughtering and processing activities. (Omole and Ogbiye, 2013; Daramola and Olowoporoku, 2017; Ng et al., 2022). Blood, meat tissue fat, manure, and urine are usually discharged into streams and rivers

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during abattoir processing (Aleksić et al., 2020). Blood, followed by fats, are the highest pollution load components of abattoir effluents that enter the stream (Ng et al., 2022). Aquatic life can also be endangered as a result of abattoir effluent, which reduces the oxygen in water (Dada et al., 2020). While abattoir waste can be beneficial for some crops, it can also lead to water quality impairment (Omole and Ogbiye, 2013; Ng et al., 2022). Studies by Dada et al. (2020) showed that abattoir waste entering streams significantly increases levels of nitrogen, phosphorus, biochemical oxygen demand, and other nutrients, contributing to water pollution. Additionally, wells near abattoirs can become contaminated by effluent, posing health risks to butchers and other well users (Dada et al., 2020; Ng et al., 2022). Ajanaku et al. (2018) reported that abattoirs' waste management issues have been underestimated or completely neglected in Nigeria. This negligence results from a lack of comprehensive regulations and adequate or sometimes wrong information on the nature, extent, characteristics, and current implications of abattoir waste in Nigeria. In many of Nigeria's abattoirs, there is a huge heap of animals quite close to the area where animals are slaughtered which can serve as breeding grounds for disease vectors (Magaji and Chup, 2012). These effluents are generally channeled directly into the drainage and usually end up draining into river bodies or seeping underground to cause water pollution (Omole and Ogbiye, 2013; Daramola and Olowoporoku, 2017).

Benthic macro-invertebrates, including various species from phyla such as annelids, coelenterates, molluscs, arthropods, and chordates, play a crucial role in nutrient circulation and recirculation within aquatic ecosystems (Campbell et al., 2009). These organisms serve as valuable bio-indicators, offering a more accurate and long-term understanding of changing aquatic conditions compared to chemical and microbiological data, which often reflect only short-term fluctuations (Campbell et al., 2009; Ng et al., 2022). Research by Campbell et al. (2009) showed that the use of benthic macro-invertebrates is the most widely adopted biological method for assessing freshwater bodies impacted by domestic and industrial wastewater. Their composition, abundance, and distribution are influenced by water quality, with variations often reflecting differences in local environmental conditions (Ng et al., 2022). Grain size analysis helps to determine the distribution of different grain sizes within a sediment or rock sample. Grain size analysis is a key factor in understanding sediment dynamics and their role in pollution distribution and environmental monitoring. It helps in tracing contaminants, as fine-grained sediments tend to trap pollutants like heavy metals.

This research was carried out to assess the effects of heavy metals from Bodija abattoir on organisms in the Oshunkaye stream in Ibadan, Nigeria.

MATERIALS AND METHODS

Study area

Bodija abattoir is the largest abattoir in Oyo State and is located beside Bodija International Market in the Ibadan North Local Government area of Oyo State, Nigeria. It was established in 1974, with an average daily slaughter of 350-400 cattle, 150-200 goats, and 50-100 pigs, it is the primary abattoir serving Ibadan and its surrounding areas. The facility includes a meat shop, a cold room, a demonstration slaughter room, a lairage, a control post, and an open-roof slaughtering house for public use.

The slaughterhouse is situated on a slope, and its wastewater is drained over a short course that ends abruptly along the gradient, allowing the waste to flow down the slope into the Oshunkaye stream. Solid waste, meanwhile, accumulates in the abattoir area, forming a large mass. In addition to abattoir waste, domestic wastewater, and fecal waste are also discharged into the stream. According to Abiola (2021), animals slaughtered at Bodija Abattoir account for 65.95% of all animals slaughtered in Oyo State. Figure 1 shows the location of the sampling points in the study area. Table 1 shows the coordinates of the sampling sites.

Sample collection

First, sediments were collected from each sampling point using a Van Veen grab, placed into well-labeled plastic bags, and transported to the laboratory. Then the abattoir waste samples were collected in a metal container, and transferred into labeled polythene bags for transport to the laboratory. Finally, samples for benthic organism analysis were also collected with the use of Van Veen grab, with the sediment samples from each point placed into labeled plastic bags and transported to the laboratory. Sampling was conducted for seven months, from December 2011 to June 2012.

Analysis of the laboratory samples

Sorting and pooling of samples

The analysis was carried out in three batches which are as follows:

1) Batch 1 comprised abattoir wastes from Bodija abattoir.
2) Batch 2 comprised soil samples from the Oshunkaye stream.
3) Batch 3 comprised *Eristalis* species from the Oshunkaye stream.

Each sample was treated separately and analyzed for manganese, iron, copper, zinc, chromium, cadmium, lead, and nickel.

Sediment analysis and grain size analysis

In the laboratory, the sediment samples and abattoir waste intended for heavy metal analysis were spread on plastic trays for air drying and were then sieved through a 0.5 mm sieve to extract fine particles, following the method described by Salomons and Forstner (1980). The fine sediments were then packed into covered, labeled plastic containers for storage.

The grain size analysis for the sediments began by spreading the sediment on a clean plastic sheet and allowing it to dry at room temperature. To expedite the drying process, clumps of sediment were broken into smaller pieces. Once dry, the sediment sample was ground using a mortar and pestle. A 100 g portion was then manually sieved for 15 min using a series of sieves with mesh sizes of 12.75, 3.18, 2.0, and 0.25 mm, and a pan. Once all the soil samples were sorted and separated by size, they were transferred

Table 1. Coordinates of the sampling sites

Point	Co-ordinate	Elevation
1	N07.43794 E003.91813	213
2	N07.43737 E003.91856	218
3	N07.43587 E003.71935	223
4	N07.43.878 E003.91723	215
5	N07.43989 E003.91722	211
6	N07.44087 E003.91707	208

into Petri dishes and weighed on an electronic scale to the nearest two decimal points. The weight of each soil sample size was then calculated as a percentage of the total soil sample. These weight values were used to construct an ordinate arithmetic graph.

The x-axis represents the phi value, while the y-axis represents the cumulative percentage scale ranging from 0 to 100%. The cumulative curve was used to determine specific phi values at 5, 16, 25, 50, 75, 84, and 95%.

Several statistical parameters, including graphic mean, sorting, and skewness, were derived from the sieve analysis of the samples. Cumulative weight percentages were plotted against their corresponding phi values on probability log paper for each sample. From these plots, percentiles at 5, 16, 25, 50, 75, 84, and $\phi 95$ were extracted. These percentiles were then used to calculate the mean, median, skewness, and sorting, following the formula proposed by Folk and Ward (1957):

1) Graphic mean: Graphic mean was used to determine the overall size of the sediments:

$$Mean = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

2) Sorting: it is a measure of the standard deviation or spread of grain size distribution. It is a crucial parameter because it indicates how effectively the depositional medium separates grains of different sizes:

$$Sorting = \frac{\phi 84 - \phi 16}{4}$$

3) Skewness: it measures the symmetry of sediment distribution and reflects the characteristics of the depositional process:

$$Skew\ (S) = \frac{\phi 84 + \phi 16 - 2(\phi 50)}{2(\phi 84 - \phi 16)} + \frac{\phi 95 + \phi 5 - 2(\phi 50)}{2(\phi 95 - \phi 5)}$$

Heavy metal determination

Samples were digested to dissolve the metals for subsequent analysis by atomic absorption spectrophotometry (AAS). The digestion followed the HNO_3 procedure as modified by Anderson (1974) and Middleton et al. (1973). Collected samples were air-dried to remove excess moisture and then sieved using a 0.5 mm sieve. The sieved samples were thoroughly mixed to create an analytical sample.

A 1 g portion of the sieved sediment was weighed and transferred to a 100 ml tall-form beaker. Next, 20 ml of 1:1 HNO_3 (Analar grade) was added using a measuring cylinder, and the mixture was gently boiled on a hot plate until the nitric acid volume reduced to about 5 ml. Afterward, 20 ml of deionized water was added, and the mixture was boiled again until the volume was reduced to approximately 10 ml. The suspension was then cooled and filtered through the Whatman No. 540 filter paper, with the beaker and filter paper rinsed with small portions of deionized water to obtain a final volume of about 25 ml. The filtrate was transferred to a 50 ml graduated flask and diluted to the mark with deionized water.

The prepared sample was then taken to the laboratory of the Department of Agronomy, Faculty of Agricultural Science, University of Ibadan, Oyo State, Nigeria, for analysis by AAS.

Analysis of benthos

The benthic organism was identified in the laboratory by extraction using a sieve of 0.5 mm mesh size. The benthic sample was transferred into a plastic bath in which the sieve containing the sediment samples was swirled to facilitate the extraction of the benthic organisms. The extracted benthic organisms were stored and labeled in sampling bottles and preserved by freezing. Identification of the different organisms was done using identification guides (Pennak, 1953; WHO, 1978).

Each sample was dried to a constant weight by gently heating it in an oven and then crushed by grinding. The samples were

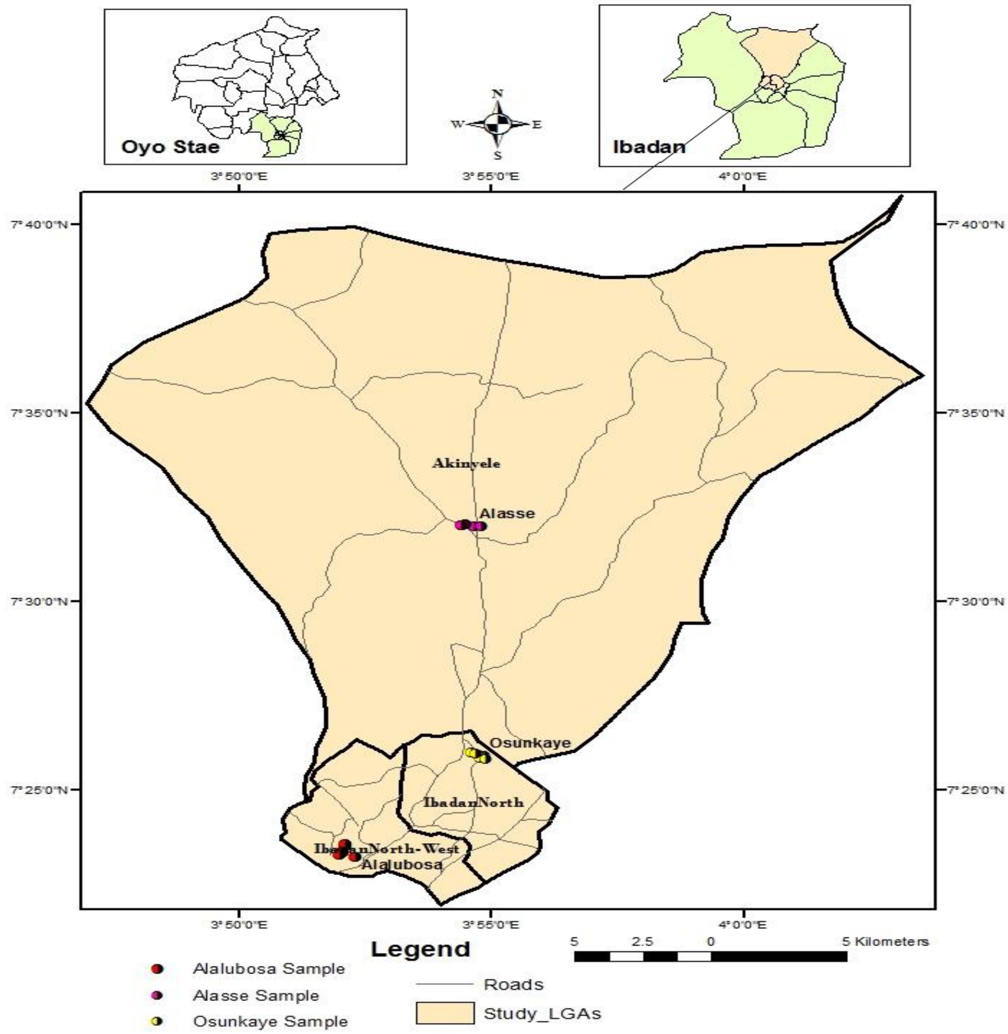

Figure 1. Map showing the location of the sampling points in the study area.

digested with HNO_3 using the method modified from Anderson (1974) and Middleton et al. (1973). The digested samples were then sent to the Department of Agronomy, Faculty of Agricultural Science, University of Ibadan, Oyo State, Nigeria. The benthic organisms were analyzed for heavy metals using Atomic Absorption Spectrophotometry (AAS).

RESULTS

Grain size analysis (graphic mean, sorting, and skewness)

The results of the grain size analysis are shown in Table 2 and Figures 2 to 7. The mean phi values of the samples range from -1.179 to 0.4, indicating a range from sand to rough grain. Sorting phi values range from 0.60 to 1.40, suggesting that the sediments are poorly to moderately well sorted. The skewness phi values range from -1.22 to 0.144, indicating a range from fine skewed to strongly coarse skewed.

Heavy metal analysis in sediments and raw waste

The summary of heavy metal concentrations in the sediment from Oshunkaye streams is shown in Table 3, while the summary of heavy metal concentrations in the raw waste from Bodija abattoir is shown in Table 4.

In the Oshunkaye stream, Manganese concentration recorded during the study period for abattoir waste was between 119-620 mg/g while the concentration ranges between 5.66 and 307 mg/g in sediments (Figure 8). Iron concentration recorded during the study for abattoir waste was between 500.4 and 10817.25 mg/g while the concentration ranges between 187.5 and 28725.75 mg/g in sediments (Figure 9). Copper concentration recorded

Table 2. Sediment grain size distribution

Station	Mean		Skew		Sorting	
	Phi	Interpretation	Phi	Interpretation	Phi	Interpretation
Sampling Point 1	0.4	rough grain	-0.071	near-symmetrical	0.6	Moderately well sorted
Sampling Point 2	0.2	rough grain	-1.22	strongly coarse skewed	1.4	Poorly sorted
Sampling Point 3	-0.567	very rough grain	-0.252	coarse skewed	1.125	Poorly sorted
Sampling Point 4	0.267	rough grain	-0.164	coarse skewed	0.625	Moderately well sorted
Sampling Point 5	-1.179	Sand	0.091	near-symmetrical	1	Poorly sorted
Sampling Point 6	-0.633	very rough grain	-0.280	coarse skewed	1.125	Poorly sorted

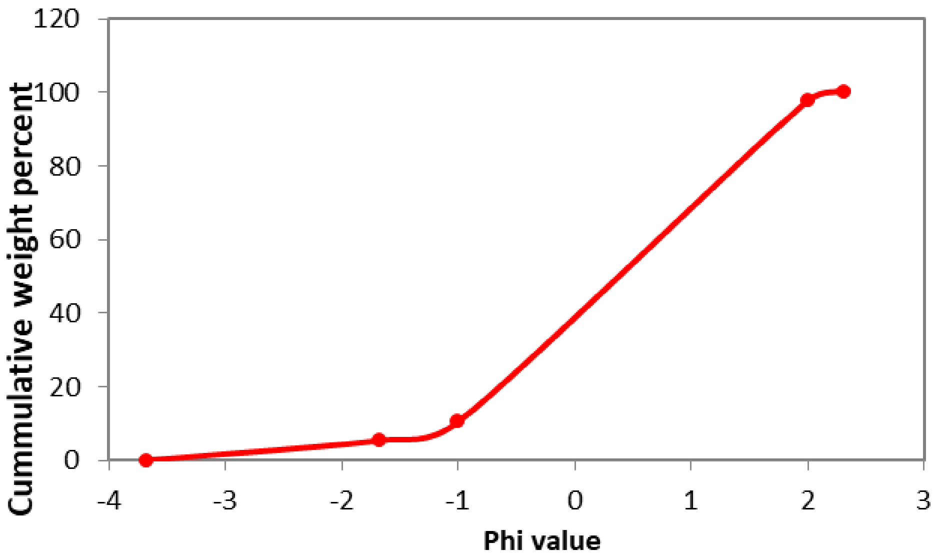

Figure 2. Sediment grain size graph for sampling point 1.

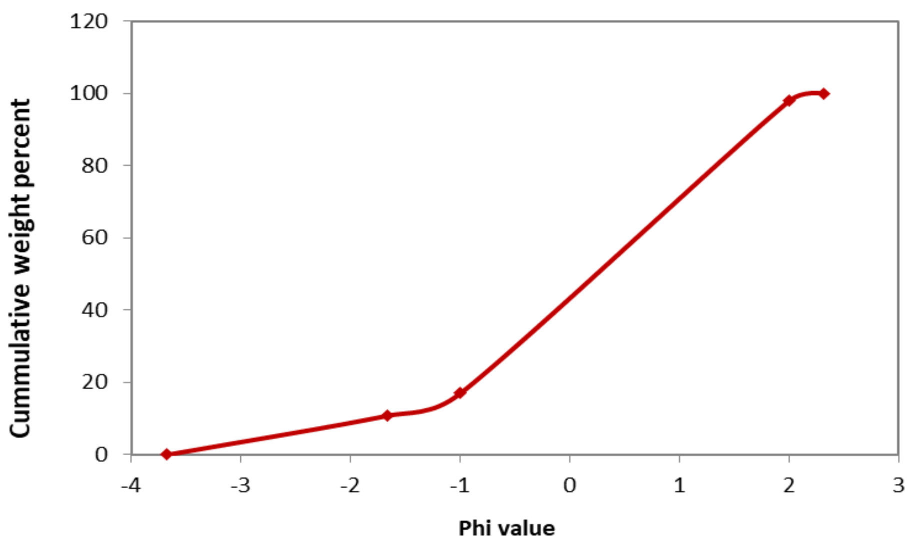

Figure 3. Sediment grain size graph for sampling point 2.

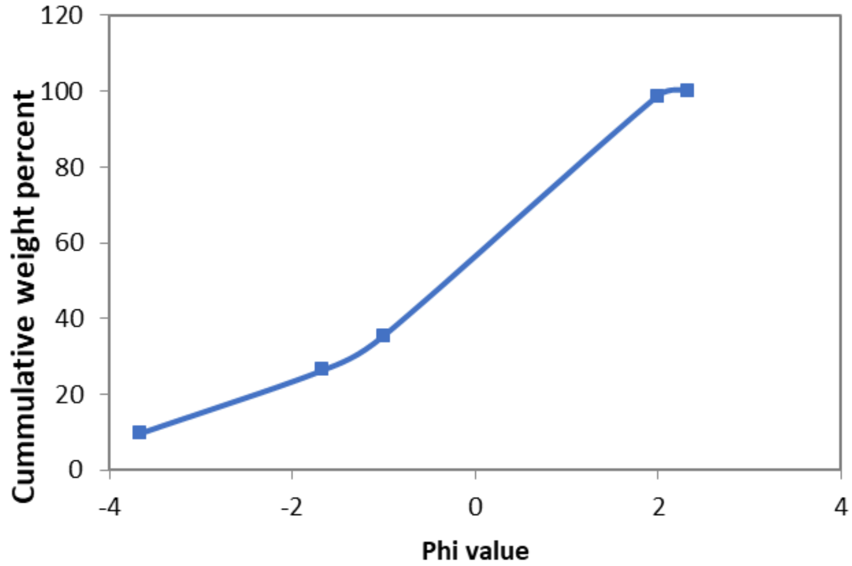

Figure 4. Sediment grain size graph for sampling point 3.

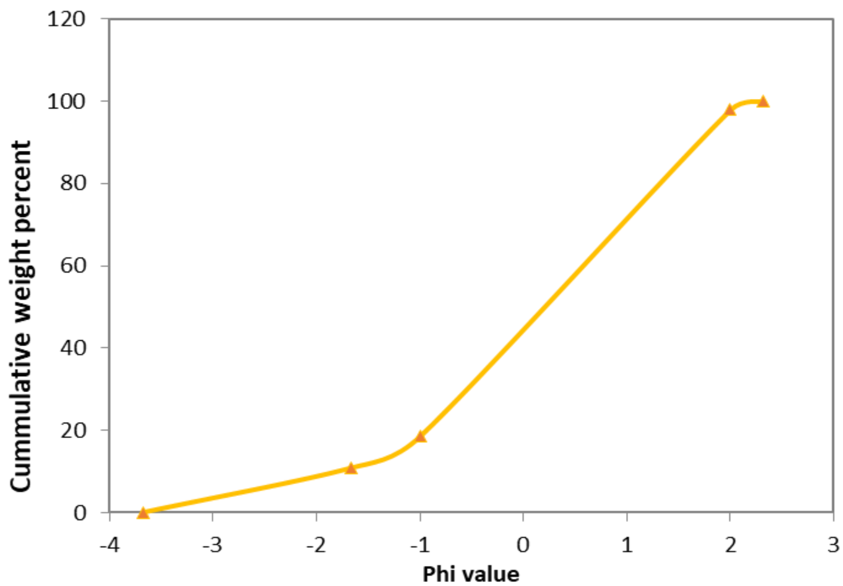

Figure 5. Sediment grain size graph for sampling point 4.

during the study period for abattoir waste was between 3.9 and 20.7 mg/g while the concentration ranges between 0.2 and 37.6 mg/g in sediments (Figure 10). Zinc concentration recorded during the study for abattoir waste was between 28.63 and 119.5 mg/g while the concentration ranges between 5.15 and 297.35 mg/g in sediments (Figure 11). Chromium concentration recorded during the study for abattoir waste was between 0 and 8.15 mg/g while the concentration ranges between 0 and 61.63 mg/g in sediments (Figure 12). Lead concentration recorded during the study for abattoir waste was between 0 and 56.75 mg/g while the concentration ranges between 0 and 95 mg/g in sediments (Figure 13).

Cadmium and Nickel were not detected in the stream and the abattoir waste.

Heavy metal analysis in organism

A summary of heavy metal concentration in organisms

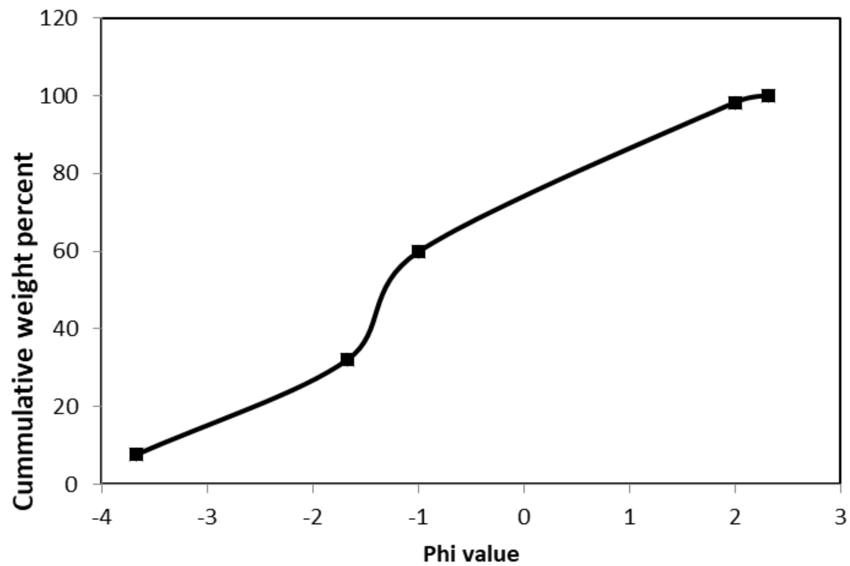

Figure 6. Sediment grain size graph for sampling point 5.

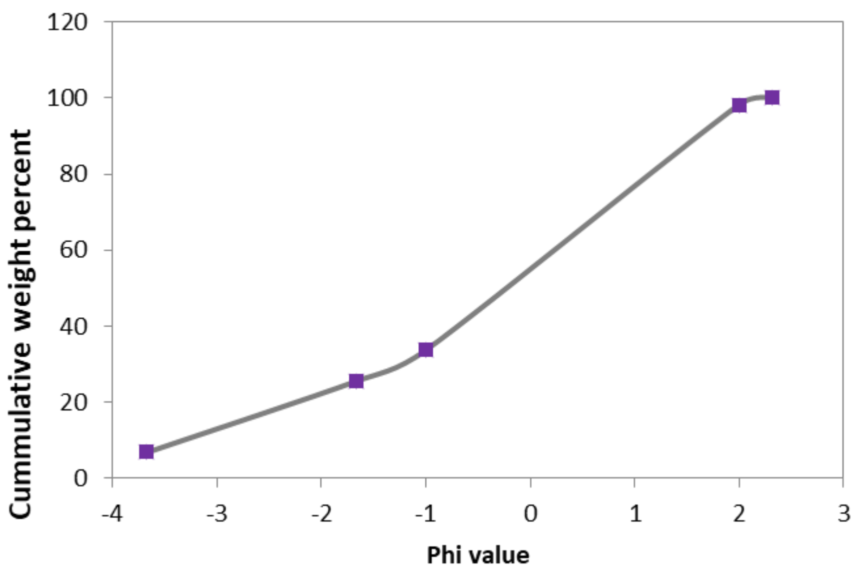

Figure 7. Sediment grain size graph for sampling point 6.

from the Oshunkaye stream is shown in Table 5. The checklist of benthic organisms is shown in Table 6. Figure 14 shows the metal concentration in *Eristalis* spp. during the sampling period, while Figure 15 shows the relative abundance of benthic organism classes throughout the study period.

DISCUSSION

The Oshunkaye stream exhibited very low diversity, with only one species recorded during the sampling period. This may be because the stream was dry throughout the sampling period. The stream contained only abattoir wastewater and domestic wastewater. Similar findings were reported by Adetunde et al. (2019) and Amoo et al. (2023), who noted that slaughterhouse effluents, regardless of their disposal location, are significant pollutants of groundwater and can impact the diversity of aquatic organisms.

The grain size parameters considered in this study include mean particle size, sorting, and skewness,

Table 3. Summary of metals in sediments from Oshunkaye stream receiving the abattoir waste

Metals	Oshunkaye stream (mg/g)	NESREA Standards (1000 mg/L (1 mg/g)
Manganese	79.01± 8.35 5.66-307	0.04
Iron	6493.15± 777.91 187.5-28725.75	0.0005
Copper	8.76± 1.01 0.2-37.6	0.00001
Zinc	65.76± 7.68 5.15-297.35	0.0002
Chromium	6.82± 1.39 0-61.63	0.0005
Cadmium	ND	0.00001
Lead	13.73 ± 2.31 0-95	0.0001
Nickel	ND	0.0001

ND: Not detected.

Table 4. Summary of metals in raw waste from Bodija abattoir

Metals	Abattoir raw waste (mg/g)	NESREA Standards (1000mg/L (1mg/g)
Manganese	222.89± 171.98 119-620	0.04
Iron	4576.49± 4283.75 500.4-10817.25	0.0005
Copper	12.89±6.24 3.9-20.7	0.00001
Zinc	66.24±31.11 28.63-119.5	0.0002
Chromium	3.44±3.13 0-8.15	0.0005
Cadmium (Cd mg/g)	ND	0.00001
Lead (Pb mg/g)	22.59±21.31 0-56.75	0.0001
Nickel (Ni mg/g)	ND	0.0001

ND: Not detected.

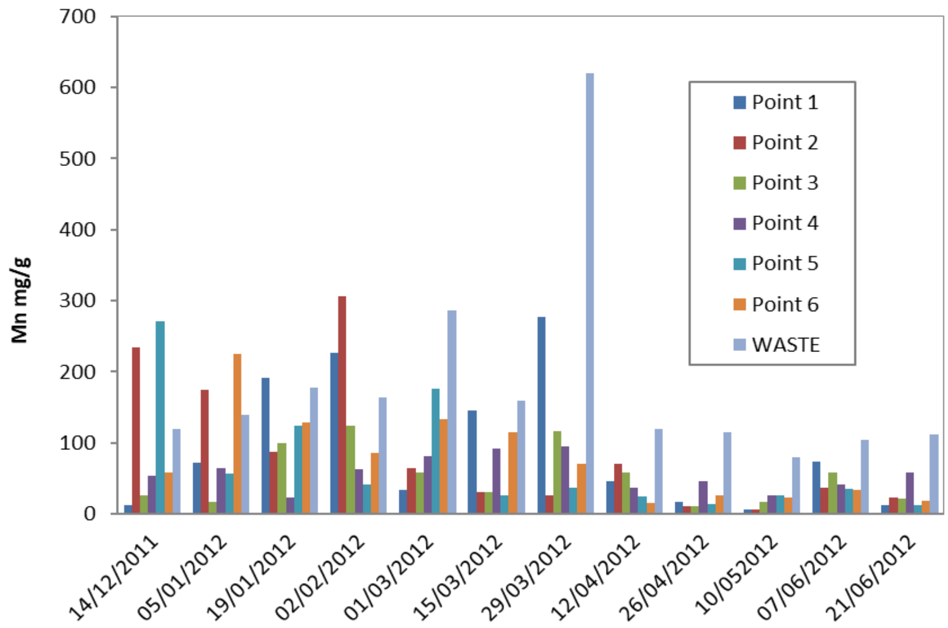

Figure 8. Manganese concentration in sediments and waste during the sampling period.

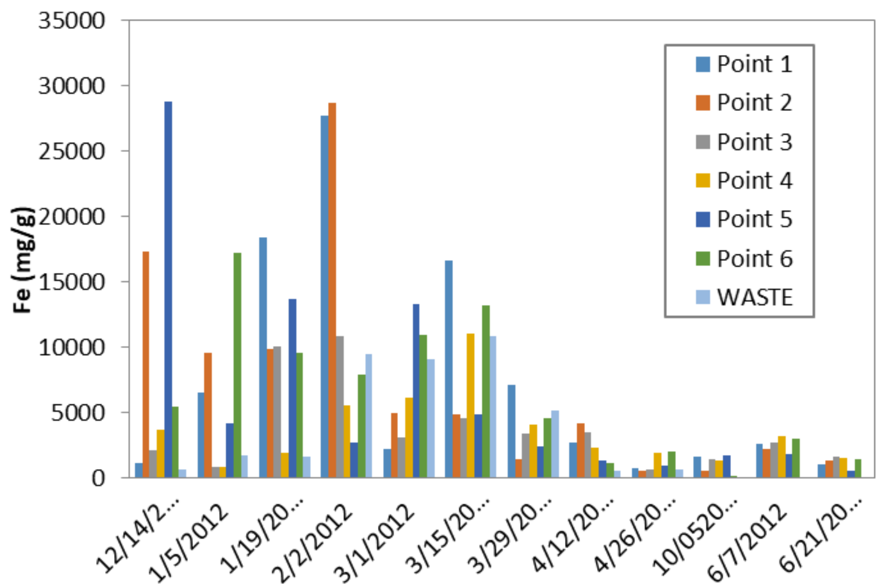

Figure 9. Iron concentration in sediments and waste during the sampling period.

providing insight into sediment transport and pollutant retention. The mean particle size reflects the balance between the weight force and flow force required to initiate water movement, this is significant because sediment grain size influences how contaminants are transported and deposited. Areas dominated by coarser grains (sand, very rough grain, and rough grains, Phi-2 to 1.0), as observed across all sampling stations, indicate high-energy environments where sediments are frequently resuspended and pollutants are less likely to accumulate. Conversely, finer sediments in low-energy environments tend to trap contaminants such as heavy metals and organic pollutants.

The skewness value of the sediment samples, ranging

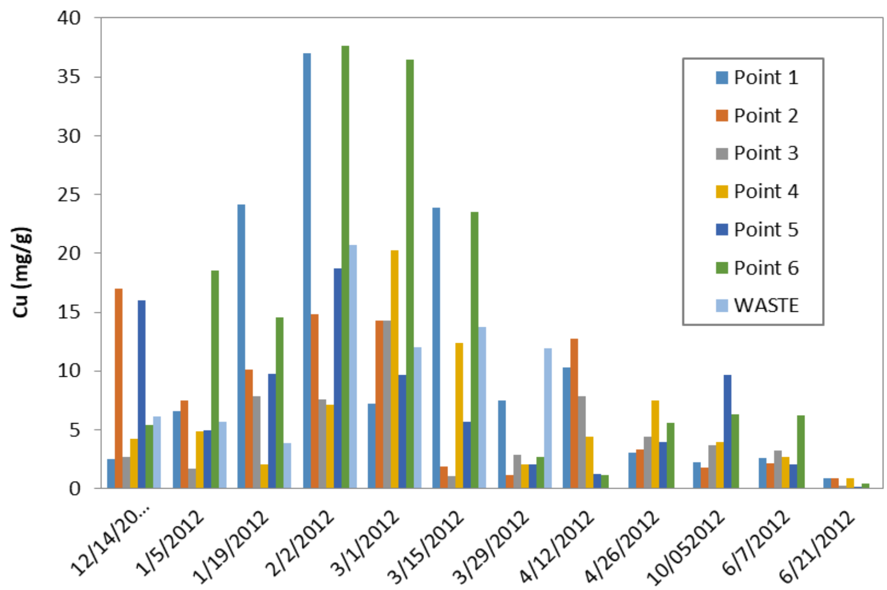

Figure 10. Copper concentration in sediments and waste during the sampling period.

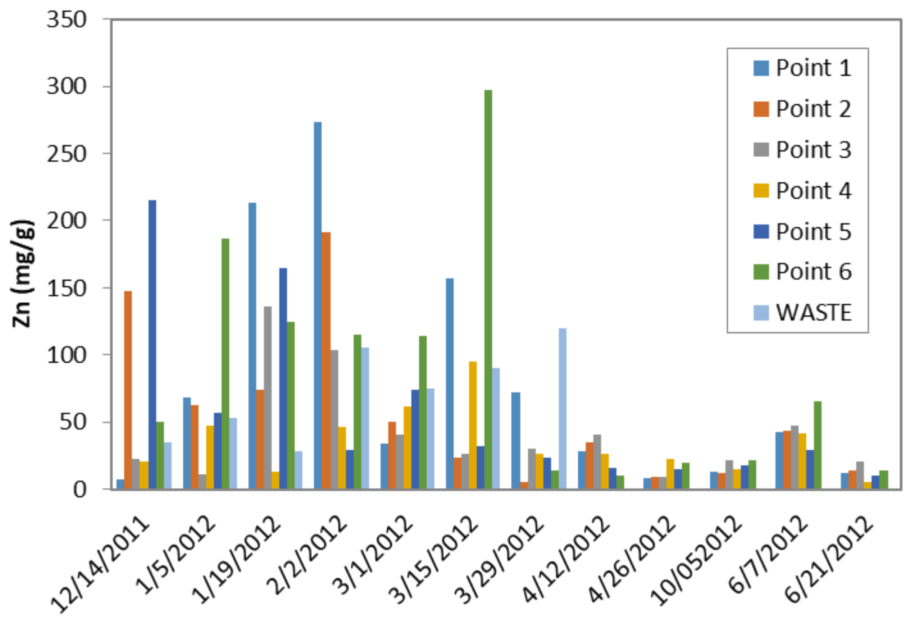

Figure 11. Zinc concentration in sediments and waste during the sampling period.

from -0.1 to -1.0 suggests a predominance of coarse skewed and strongly coarse skewed distributions. This indicates that finer-grained sediments, which typically act as pollutant sinks, are not present in significant quantities at these sampling sites. As a result, pollutants in this environment are more likely to be transported from the abattoir effluent and domestic waste that is directly discharged into the water. The uniformity of coarse-grained sediments across all sampling stations suggests that these areas are less susceptible to long-term pollution accumulation.

The summary of trace metals in the sediments and abattoir waste from the Oshunkaye stream shows the following trends: The highest concentration of iron (Fe)

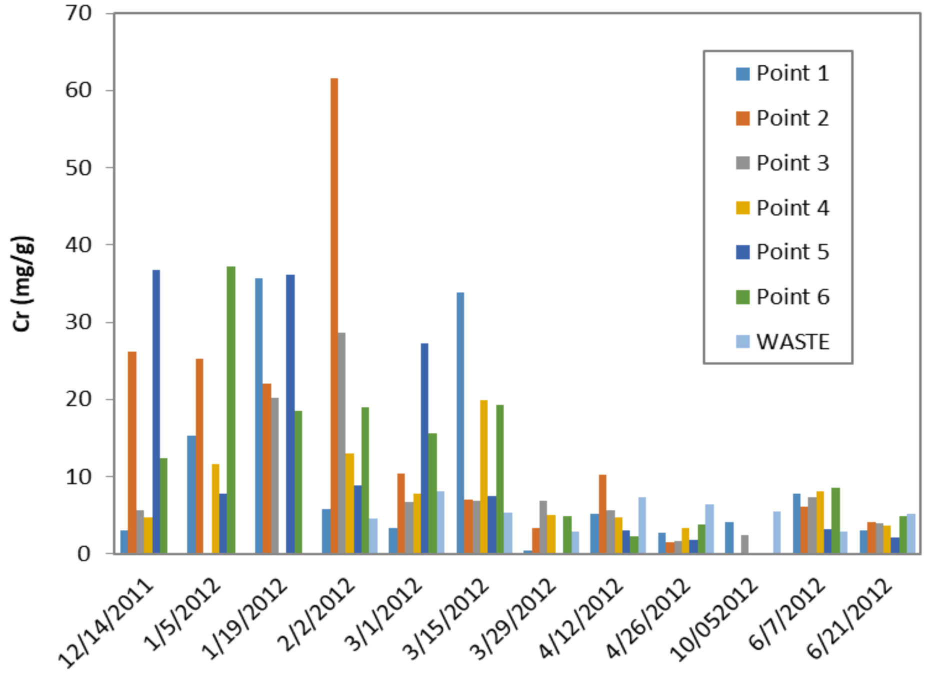

Figure 12. Chromium concentration in sediments and waste during the sampling period.

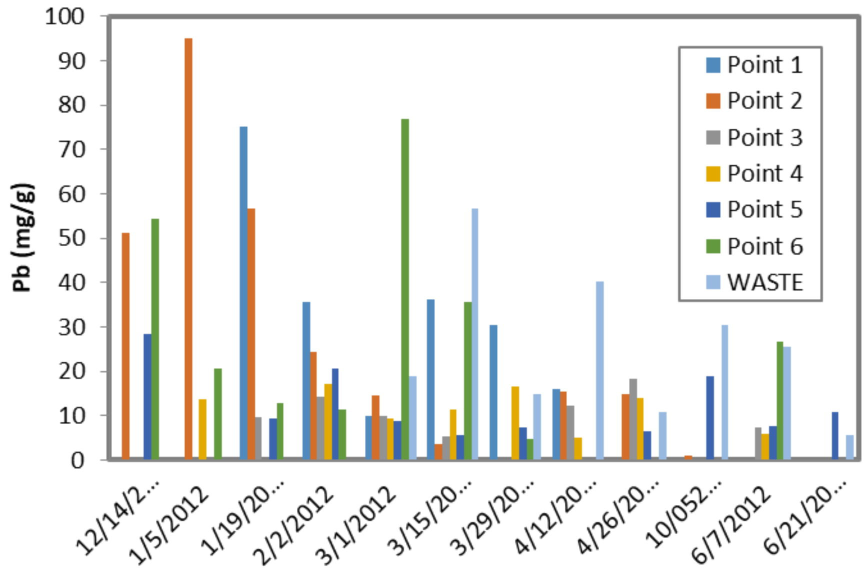

Figure 13. Lead concentration in sediments and waste during the sampling period.

was recorded at sampling point 1 in February, with the lowest at sampling point 3. The highest concentration of manganese (Mn) was found in raw abattoir waste in March, while the lowest was at sampling point 2 in May. Copper (Cu) peaked at sampling point 6 in February, with the lowest concentration at sampling point 3 in June. The highest concentration of zinc (Zn) was recorded at sampling point 6 in April and the lowest at sampling point 2 in May. The concentration of Chromium and Lead was low in all the sampling points. Cadmium (Cd) and Nickel (Ni) were not detected at any of the sampling points or in the raw abattoir waste during the study period. Magaji

Table 5. The monthly mean concentration of metals in Benthic macro-invertebrates from the Oshunkaye stream

Metals	*Eristalis* spp. from Oshunkaye stream (mg/g)
Manganese	5.13±0.375 4.75-5.5
Iron	152.13±9.63 142.5-161.75
Copper	3.01±0.04 2.96-3.05
Zinc	28.41±0.96 27.45-29.375
Chromium	ND
Cadmium	ND
Lead	ND
Nickel	ND

ND: Not detected.

Table 6. Checklist of benthic organisms

Species	Abundance					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
Eristalis spp.	+	-	-	+	+	+

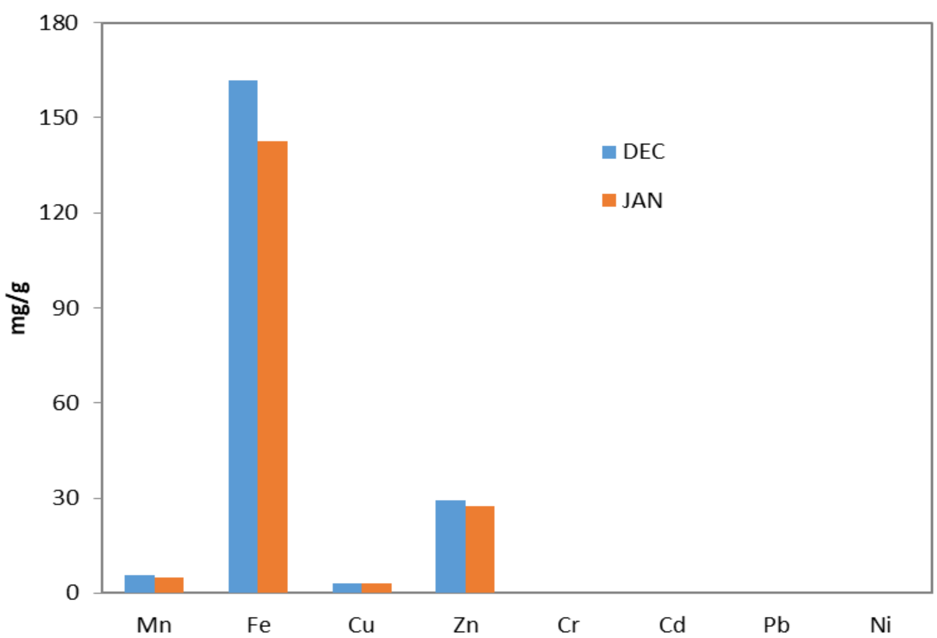

Figure 14. Metal concentration in the organism (*Eristalis spp.)* during the sampling period.

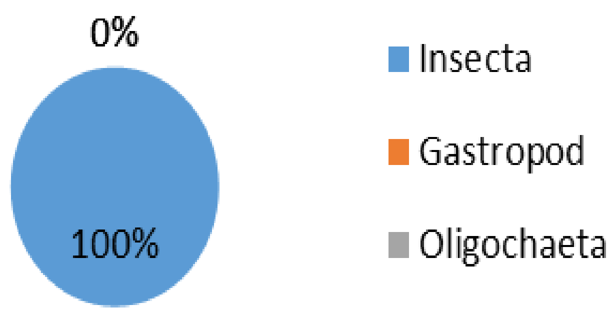

Figure 15. Relative abundance of classes of benthic organisms during the study period.

and Chup (2012) reported that Cadmium, Copper, Zinc, Nickel, and Aluminium are below the FEPA recommended limits. However, it was further reported that Iron and Lead are above the FEPA acceptable limits.

The highest concentrations of all metals across the sampling stations were primarily found at sampling point 1, as well as at points 4 and 6, which are located at and just downstream of the abattoir waste discharge point, respectively.

The lowest level of all the metals in the sampling was recorded in sampling points 2 and 3, which are the sampling points before the discharge of abattoir waste. This indicates that the wastewater from the abattoir harms the stream.

The level of all the metal concentrations recorded during the study period in all the sampling highly exceeds the acceptable limit recommended by NESREA (2011). In contrast, Adetunde et al. (2019) reported that the physical characteristics of the stream water samples in Bolgatanga municipality in Ghana-West are within tolerable limits. However, microbiological exceeds the limits. It was also reported that the solid and liquid wastes generated at the abattoir polluted the stream water, with the physical and microbiological qualities of the effluent exceeding EPA-Ghana standards. The discharge of abattoir waste into streams in Bolgatanga was found to harm the microbiological quality of the water, particularly mid-stream, making it unsuitable for human consumption.

A total of 28 benthic individuals were collected and identified into 1 species, 1 phyla, and 1 class. Insecta was the only class that was present with a percentage composition of (100%). This could be attributed to the high level of tolerance of the class Insecta in the polluted environment. Adeyemi and Adeyemo (2007) reported that there is no straightforward solution to the waste disposal problem at the Bodija abattoir. The issue is complex, involving both health and environmental concerns. They suggested that policy options should focus on finding a socially acceptable, economically viable, and environmentally sustainable strategy to mitigate the predominantly negative impacts on human well-being, biodiversity, and its habitat.

Conclusion

The analysis of heavy metals in the sediments, waste, and benthic organisms of the Oshunkaye stream reveals that abattoir effluents and domestic waste discharged into the stream negatively affect its physical, chemical, and biological parameters, ultimately impacting the health of nearby residents. The stream's ability to purify itself is further compromised by the increased toxic stress from these discharges. The concentrations of iron, copper, zinc, manganese, chromium, and lead were found to be above the maximum permissible limits.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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