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Effects of Abattoir Effluent on Growth Performance of *Clarias gariepinus* (Burchell, 1822)

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Abstract

This study investigated the acute and sub-chronic toxicological effects of untreated abattoir effluent on juvenile *Clarias gariepinus* (African catfish), with the aim of assessing its impact on fish behavior, survival, growth performance, and bioaccumulation of heavy metals. Effluent samples were collected from the discharge point of Alubarika abattoir, located in Ile-Ife, Osun State, Nigeria. Standard analytical methods were used to determine parameters such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), electrical conductivity, total dissolved solids (TDS), and concentrations of heavy metals (Cd, Pb, Fe, Cu and Zn). Acute toxicity testing was carried out by exposing juvenile *C. gariepinus* to six concentrations (0%, 12.5%, 25%, 50%, 75%, and 100%) of the effluent over 96 hours to determine LC_{50}. Sub-chronic tests were conducted over 30 days using lower concentrations (0%, 2.5%, 5%, 7.5%, and 10%) to assess growth, behavior, feed utilization, and metal accumulation in fish tissues (gill, muscle, liver, and gastrointestinal tract). The results revealed that the effluent had BOD (6350 mg/L), electrical conductivity (3321 µS/cm), TDS (2220 mg/L), and heavy metal concentrations exceeding both NESREA and WHO standards. Behavioural stress responses such as erratic swimming, surfacing, and discolouration were observed in fish exposed to concentrations 50% and above. Mortality rates increased with concentration, with 100% mortality recorded in 50%, 75%, and 100% treatments within 48 hours and 96-hour LC_{50} of 35.4 mg/L. In the sub-chronic phase, fish exhibited varying growth responses. Weekly measurements showed that while all groups experienced some level of growth, the highest mean weight gain (116.27 ± 2.50 g) was observed in the 7.5% treatment, whereas the lowest performance occurred in the 2.5% group. Specific growth rate (SGR), daily feed intake (DFI), and percentage weight gain (PWG) varied inconsistently across treatments. Heavy metal accumulation showed a dose-dependent increase, with the highest concentrations of Cd, Pb, Fe, Cu, and Zn found in fish exposed to the 10% effluent, particularly in the gills and gastrointestinal tract. The study concluded that untreated abattoir effluent significantly degrades water quality, induces acute toxicity, alters growth dynamics, and promotes bioaccumulation of toxic metals in *C. gariepinus*. There is an urgent need for abattoir waste treatment and effective regulatory enforcement to mitigate environmental pollution and ensure the safety of aquatic food sources.

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Keywords: Abattoir effluent, *Clarias gariepinus*, Acute toxicity, Heavy metal bioaccumulation, Fish growth performance

1. Introduction

Water is indispensable for life and ecosystem health (Abasi *et al.*, 2024; FAO, 2025). Contaminated water, whether from polluted rivers or untreated wastewater, poses serious risks to human health and aquatic ecosystems (Abasi *et al.*, 2024; FAO, 2025). In Nigeria and other developing countries, urban expansion and intensive agriculture have degraded water quality. Recent reviews highlight that industrial and farming activities (including agrochemical runoff and sewage) have increasingly polluted surface and groundwater in Nigeria (Isukuru *et al.*, 2024).

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For example, a recent field study found water near abattoirs in Jos, Nigeria exceeded WHO contamination limits, with untreated slaughterhouse waste directly entering water sources (Ibimode *et al.*, 2024). Abattoirs (slaughterhouses) are important for meat production but generate large volumes of organic waste. Operations such as slaughtering and butchering produce blood, fat, internal organs, manure, hair, urine, and other animal residues (Abasi *et al.*, 2024). These wastes are often mixed with cleaning detergents and simply discharged. The disposal of untreated abattoir effluent into nearby streams and soils causes severe pollution: it adds nutrients and pathogens, depletes oxygen, and alters the water chemistry (Abasi *et al.*, 2024). Studies report that abattoir wastewater dramatically raises BOD, COD, suspended solids and nutrients downstream of discharge points, far exceeding regulatory limits (Asibor *et al.*, 2020; Abasi *et al.*, 2024). For example, one study of a Nigerian river found that abattoir effluent caused up to a 192% rise in biochemical oxygen demand downstream, and the effluent did not meet national discharge standards (Asibor *et al.*, 2020). Likewise, the high blood and urine content in slaughterhouse effluent makes receiving waters extremely turbid (Abasi *et al.*, 2024), which can suffocate aquatic life and clog irrigation systems. In short, untreated abattoir waste significantly degrades water quality and endangers aquatic organisms (Asibor *et al.*, 2020; Abasi *et al.*, 2024).

Agricultural inputs compound this pollution. Animal feed is often grown in monocultures with heavy pesticide and fertilizer use, which adds toxic chemicals and nitrates to runoff (FAO, 2025). Livestock are also routinely given antibiotics; about 75% of these drugs are excreted unchanged and enter manure and wastewater (Xu, 2022). When such manure and carcass processing waste enter water bodies, they introduce antibiotics and resistant bacteria into the aquatic environment (Xu, 2022; FAO, 2025). In Nigeria, traditional slaughtering methods may even involve burning animal skins with waste tyres or petroleum products, releasing additional pollutants into the surrounding soil and water (Maduforoh, 2024). All these contaminants can bioaccumulate: many fish absorb heavy metals, antibiotics, and other toxins from their environment over time (Opasola *et al.*, 2019; Phaenark *et al.*, 2024).

The African catfish *Clarias gariepinus* is widely farmed and consumed in Nigeria, and it has traits that make it a useful bioindicator of water pollution. This hardy freshwater fish is omnivorous and bottom-dwelling, feeding on both living and dead animal matter (Opasola *et al.*, 2019). It can breathe atmospheric air and tolerate low-oxygen conditions (Opasola *et al.*, 2019), enabling it to survive in polluted or hypoxic waters. Critically, *C. gariepinus* readily accumulates contaminants in its tissues; studies show it can concentrate heavy metals and other pollutants from polluted rivers (Opasola *et al.*, 2019; Abalaka *et al.*, 2020). Thus monitoring the health and biochemistry of *C. gariepinus* provides insight into the impact of effluent on aquatic ecosystems.

In many Nigerian communities, abattoirs are sited adjacent to rivers or streams that receive their wastewater. This effluent – rich in blood, fat, meat scraps, manure, detergents, and more – flows untreated into the aquatic environment. Such unmanaged discharge elevates nutrient loads and chemical oxygen demand in the water, leading to oxygen depletion and toxic conditions for fish. The buildup of these pollutants can impair growth, behaviour, and physiology of cultivated fish such as *C. gariepinus*, yet there is limited data on these effects for Nigerian abattoir effluent. Therefore, it is essential to assess how untreated slaughterhouse wastewater influences water chemistry and the health of local fish populations. This study evaluated the toxicity of untreated abattoir effluent using juvenile *C. gariepinus* as a biological indicator. Specifically, the study assessed key physical and chemical parameters of the abattoir wastewater (such as pH, dissolved oxygen, BOD, nutrients) at the point of discharge; observed the growth, behaviour, and survival of *C. gariepinus* exposed to graded concentrations of the effluent; determined the 96-hour median lethal concentration (LC_{50}) and the bioaccumulation of Heavy Metals by *C. gariepinus* (African Catfish) exposed to graded concentrations of the effluent.

2. Materials and Methods

2.1. Study Area

Abattoir effluent used in this toxicity test was collected from the discharge point of Alubarika abattoir, Ile-Ife, Osun State, Nigeria. The abattoir is situated at Oke Ogbo road, Ilode, Ile-Ife and it lies within latitude 7º28'55.1"N and longitude 4º34' 18.5"E (Figure 1). It is in close proximity to the bank of Owena River and has existed for about two decades with an average daily kill of 3-4 cows (as obtained from a pilot study). Among the facilities within the premises are slaughter slabs, furnished with water taps, borehole and a drainage system. The effluent sample was collected using plastic kegs fortnightly for the period of four (4) weeks and it was used immediately after each collection.

2.2. Abattoir Effluent Analysis

This was aimed to give a background idea about the properties or condition of the abattoir effluent prior to the experiment. It majorly focused on the physiochemical and accumulation of heavy metals.

2.2.1. Physical and Chemical Properties of Abattoir Effluent

Analysis of physicochemical properties of the effluent was carried out following standard methods described by Ademoroti (1996) and APHA (2005). The dissolved oxygen was fixed on site with wrinkler A ($MnSO_4$) and wrinkler B (KI/NaOH), and the content was determined by titrating with sodium-thiosulphate after the addition of concentrated H_2SO_4 using starch indicator. Sample incubation was done for 5 days at 20°C in a Biochemical Oxygen Demand (BOD) bottle. The BOD_5 was calculated after the incubation periods i.e. five days as described by Ademoroti (1996). The pH and temperature readings of the effluent were taken at the point of collection on site. Concentrations of five (5) selected heavy metals (Cadmium (Cd), Zinc (Zn), Copper (Cu), Iron (Fe) and Lead (Pb)] were measured in the experimental effluent based on previous studies (Dahunsi *et al*., 2011; Agboola and Fawole, 2014; Obasi *et al*., 2014). The abattoir effluent was digested as follows: 100 ml of the sample was transferred into a beaker and 5 ml aqua regia (HNO_3 and HCl in ratio 1:3) was added. The beaker with the content was placed on a hot plate and evaporated down to about 20 ml. The beaker was cooled and another 5 ml aqua regia was added. The beaker was then covered with watch glass and returned to the hot plate. The heating continued until the solution appeared light colored and clear. The beaker wall and watch glass were washed with distilled water and the sample was filtered to remove any insoluble materials that could clog the atomizer. Determination of heavy metals in the abattoir effluent was done using PG 990 Atomic Absorption Spectrophotometer at the Centre for Energy Research and Development (CERD), OAU, Ile - Ife

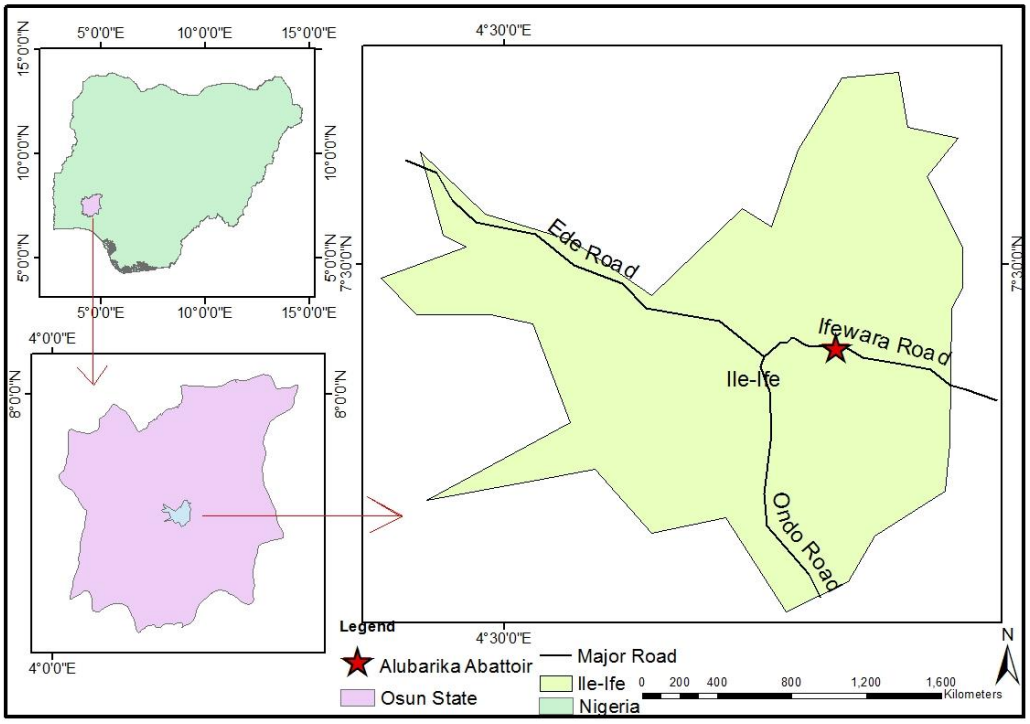


Figure 1: Map of Sampling Point Location (Location of Sampling: Latitude 7º28'55.1"N and Longitude 4º34' 18.5"E (Alubarika abattoir) Oke Ogbo Road, Ilode, Ile-Ife, Osun State, Nigeria.)

2.3. Toxicity Testing

Two hundred and fifty (250) post-juvenile African catfish (*Clarias gariepinus*) having mean weight 41.30 ± 0.96 g and mean length 20.10 ± 0.80 cm were sourced from the hatchery unit of Osin Farm Limited, Yakoyo, Ife-North, Local Government, Osun State, Nigeria. The fishes were transported in a ventilated and aerated plastic container covered with mesh net to prevent them from jumping out. This research was carried out at the culture room of the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife.

2.3.1. Acclimatization of Fish

The test fish were held in plastic stock tanks containing borehole water for two weeks to allow them acclimatize to the new environment. The water was renewed once in every 48 hrs to avoid accumulation of waste material which could

become toxic to the fishes (ASTM, 1990). The fishes were fed twice a day during acclimatization with Durante vital fish feed (5% of their body weight) (Odiete, 1999; Eleyele et al., 2017). Feeding was discontinued twenty four hours prior to the commencement of the treatments.

2.3.2. Range Finding Test

After acclimatization, a preliminary investigation (range finding test) was carried out prior to the commencement of the definitive test (Solbe, 1995; Eleyele et al., 2017). The following concentrations 0, 12.5, 25, 50, 75 and 100% were used. Ten fully acclimatized fish with mean weight 52.37 ± 1.99 g and mean length 21.20 ± 0.89 cm were exposed to each concentration of the effluent (in duplicates). Twelve (12) stock tanks of 40 Litres containing the six treatments (10 L) in duplicates were used for the toxicity test. The range finding test was carried out for 96 hrs (4 days).

2.3.3. Acute Toxicity Evaluation

Sixty (60) post juvenile African catfish (*Clarias gariepinus*) were used for the acute toxicity assay. Based on the result obtained from the range finding test, an acute toxicity test was carried out for 96 hrs. Twelve (12) stock tanks of 40 Litres containing the six treatments (10 L) in duplicates were used for the toxicity test. Five (5) samples of *Clarias gariepinus* were introduced into each tank of water containing the different concentrations (0, 12.5, 25, 50, 75 and 100%) of the abattoir effluent (as deem suitable from the range test) (Eleyele et al., 2017). During the 96-hr test, dead fish was promptly removed from the experimental tanks. Mortalities were recorded at intervals of 12 hrs and at the end of 96 hrs. The total number of death (mortality) after 96 hrs; the percentage mortality at 96 hrs and median lethal concentration (LC_{50}) were also determined. The 96-hr LC_{50} (concentration that killed 50% of the test organisms) was determined from the graph of percentage mortality against concentration.

2.3.4. Sub-Chronic Evaluation

Fifty (50) post juvenile African catfish (*Clarias gariepinus*) were used for the sub-chronic toxicity assay. Based on the LC_{50} results obtained from the acute toxicity test, a sub-chronic investigation was carried out. Five (5) samples of *Clarias gariepinus* each were introduced into different stock tanks of water containing the different graded concentrations (0, 2.5, 5, 7.5 and 10%) of the abattoir effluent in duplicates. The entire exposure period was 30 days, the media was changed every 48 hrs and this permitted the monitoring of the behavioral responses growth parameters and mortality of the test fish to the different concentrations of the abattoir effluent.

2.4. Assessment of the Culture Media

The pH, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), acidity, alkalinity and conductivity from each experimental tank were determined at the end of the 30 days sub-chronic evaluation according to standard procedures described (Ademoroti, 1996).

2.5. Fish Growth Performance Evaluation

A balance was used to take the weights of the experimental fish (in grams). Data collection started on the first day of stocking and ended on the thirtieth day. The fishes were weighed at the end of every week for each treatment throughout the experimental period. From the data collected, the growth performance and the feed utilization data were generated (Eleyele et al., 2017).

2.6. Digestion of Sample and Heavy Metal Analysis

The fish specimens were dissected to remove the organelles (muscle, gill, liver and gastrointestinal tract) for heavy metal analysis. One (1g) each of the separate specimen was placed in a test tube of 5 ml aqua regia (HNO_3 and HCl in ratio 1:3) and the tubes were covered with cotton wool and left on the bench overnight. The cotton wool was removed the following day, the tubes were boiled in water bath for 1 hr. The tubes were removed from the bath and allowed to cool and diluted to 15 ml with distilled water. The beaker was cooled and another 5 ml aqua regia was added. The beaker was then covered with watch glass and returned to the hot plate. The heating continued until the solution appeared light colored and clear according to the method of APHA (2005). The sample was filtered to remove any insoluble materials that could clog the atomizer. Determination of heavy metals in the abattoir effluent was done using PG 990 Atomic Absorption Spectrophotometer at the Centre for Energy Research and Development (CERD), OAU, Ile - Ife.

2.7. Statistical Analysis

Statistical analysis of data obtained was done using SPSS 26 package. The values obtained were analyzed using one-way ANOVA at $p<0.05$ different level of significance.

3. Results

3.1. *Physical and Chemical Properties of the Abattoir Effluent*

The results of physical and chemical analysis of the abattoir effluent compared with NESREA and WHO standards is presented in Table 1. The physical and chemical characteristics of the effluent were compared with national (National Environmental Standard and Regulations Enforcement Agency) and international (WHO) standards and guideline for effluent discharges for aquaculture. There were variations between the results and the standard effluent discharges. The effluent was characterized by extremely high biochemical oxygen demand 6350 mg/L which was above NESREA standard of 50 mg/L. Meanwhile, the result of dissolve oxygen was 0 mg/L while the alkalinity was 16 mg/L. This was below NESREA and WHO standards which were 45 and 20-300 mg/L respectively. The effluent had 2220 mg/L of total dissolved oxygen which was extremely higher than that of NESREA standard 500 mg/L.

The results of heavy metals concentrations in the abattoir effluents compared with national and international standard respectively. There were variations between the concentration of heavy metals of the abattoir effluent and the known standards. Cadmium (0.052 m/L) and Lead (0.021 m/L) were found to be higher than the WHO standard (0.002 m/L) and (0.015 m/L) respectively. Also, iron (1.248 mg/L) was higher than national (NESREA) standard (1 m/L) (Table 1).

Table 1: Physical and Chemical Parameters of Abattoir Effluent

Parameter	Effluent	NESREA Limit (2009)	WHO Limit (2009)
DO (mg/L)	0	-	-
BOD (mg/L)	6350	50	-
Alkalinity (mg/L)	16	45	20-300
Acidity (mg/L)	22	-	-
Conductivity (µs/cm)	3321	-	20-1500
pH	7.4	6-9	6.5-9
Temperature (ºC)	27.8	-	-
TDS (mg/L)	2220	500	-
Heavy Metal (mg/L)			
Cadmium	0.052	-	0.002
Lead	0.021	0.05	0.015
Iron	1.248	1	0.03
Zinc	0.148	0.5	1.5
Copper	0.28	-	0.5

NESREA- National Environmental Standards and Regulations Enforcement Agency; WHO-World Health Organization; DO- Dissolved Oxygen; BOD- Biochemical Oxygen Demand; TDS- Total Dissolve Solids

3.2. *Physical and Chemical Properties of the Culture Media*

The mean concentrations of the heavy metals in the culture media increased with the concentration of abattoir effluents (0, 25, 5, 7.5, 10, and 100%) and were all significantly different with $p<0.0001$ at $p<0.05$ (Table 2).

3.3. *Fish Observable Physical Response to Abattoir Effluent*

The observable physical responses of the fish at different concentrations of abattoir effluents in the water are presented in Table 3. This was evaluated under different parameters. There were no significant changes in all the parameters measured at introduction of 0, 12.5, and 25% abattoir effluents. Changes in behavior were slight, moderate and extreme at 50, 75 and 100% treatment respectively. Frequent surfacing, discoloration, loss of reflexes and erratic swimming started at 50% with slight responses while moderate and extreme responses were recorded at 75 and 100% concentration respectively. Extreme lethargy was equally observed at 50, 75 and 100% treatment respectively.

3.4. *Toxicity Test*

Table 4 shows acute mortality responses at different level of treatments. During the 96 hrs, acute toxicity test, fish mortality was recorded in each tank except for the 12.5% and the control tank. Range finding test was carried out for 96 hrs, initially fishes in the 100%, 75% and 50% treatment tank in all treatment were swimming to the surface of the water

at intervals to obtain oxygen (erratic movement). After 24 hrs, a change in skin coloration of the fish was also observed in the 50, 75 and 100% treatment tank and at the end of 96 hrs, 100% mortality was recorded. No mortality was recorded for the fish 0, 12.5 and 25% treatment tanks.

There was no mortality recorded in all concentrations at 36 hrs after stocking but twenty percent mortality was recorded at 48 hrs in 12.5% concentration. At the same 48 hrs, hundred percent mortalities each were recorded in concentration 50, 75 and 100% respectively. Table 4 shows the arithmetic table of percentage mortality against concentration. However, the mortality rate per hour of exposure shows that there were no incidence of mortality from the control to the 2.5% but mortality became more pronounced at 50, 75 and 100% during the 96 hrs experimentation. The arithmetic graph of percentage mortality against concentration for the acute evaluation is shown in figure 2. At the time of termination of the experiment (96^{th} hr), it was only the fishes in the control (0%), lower concentrations of abattoir effluent (12.5% and of 25%) tanks that were alive while total mortality was recorded in higher concentrations (50, 75 and 100%) of abattoir effluent.

Table 2: Concentration of Heavy Metals in the Culture Media

Concentration (mg/L)	Cd	Pb	Fe	Zn	Cu
0%	0.014±0.001	0.005±0.000	0.238±0.003	0.094±0.001	0.146±0.003
2.5%	0.016±0.001	0.006±0.000	0.298±0.002	0.103±0.001	0.169±0.005
5%	0.023±0.000	0.007±0.000	0.306±0.001	0.122±0.002	0.202±0.003
7.5%	0.027±0.000	0.008±0.000	0.328±0.002	0.132±0.002	0.211±0.003
10%	0.032±0.000	0.011±0.000	0.458±0.002	0.141±0.003	0.230±0.004
100%	0.052±0.001	0.021±0.000	1.248±0.001	0.148±0.007	0.280±0.006
F-value	**1.152**	**1.785**	**3.677**	**2.379**	**4.306**
p-value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

Values are significantly different at ($p<0.05$) Values are mean ± SEM

Table 3: Behavioral Responses of *Clarias gariepinus* to Different Concentrations (%) of the Abattoir Effluent

Parameters	0%	12.5%	25%	50%	75%	100%
Change in behaviour	-	-	-	+	++	+++
Frequent surfacing	-	-	-	+	++	+++
Decolouration	-	-	-	+	+++	+++
Loss of reflexes	-	-	-	+	+++	+++
Gill movement	-	-	-	+	++	+++
Erratic movement	-	-	-	++	+++	+++
Lethargy	-	-	-	+++	+++	+++

- : no response; +: slight response; ++: moderate response; +++: extreme response

Table 4: Acute Mortality Rate and Time of Death of *Clarias gariepinus* Exposed to Varied Concentration of Abattoir Effluent

Concentration %	12 hrs	24 hrs	36 hrs	48 hrs	72 hrs	96 hrs	Total Mortality	% Mortality
Control (0%)	0	0	0	0	0	0	0	0
12.5%	0	0	0	0	0	0	0	0
25%	0	0	0	0	0	0	0	0
50%	0	0	0	7	1	2	10	100
75%	0	0	0	10	-	-	10	100
100%	0	0	0	10	-	-	10	100

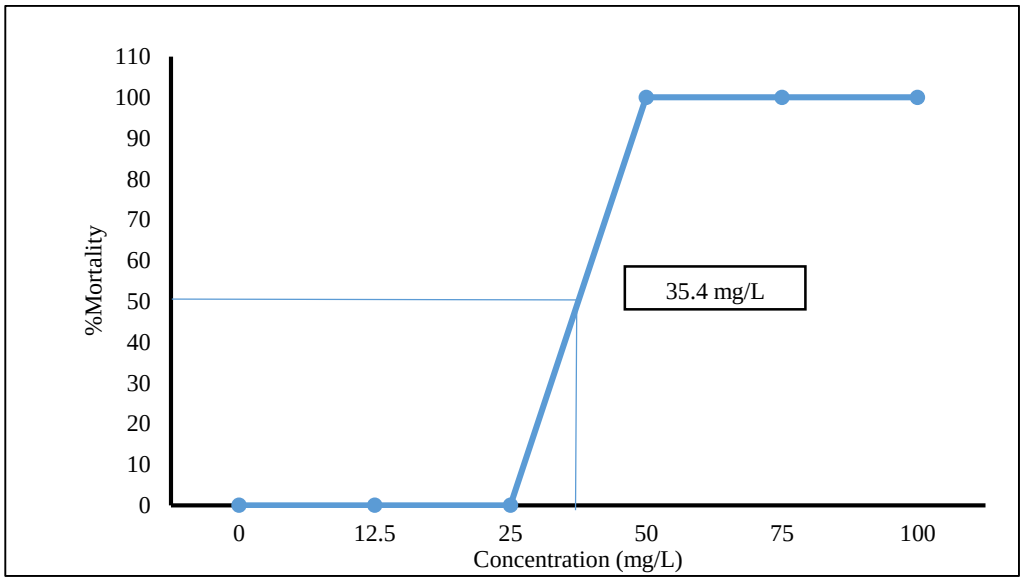


Figure 2: Median Lethal Toxicity of Abattoir Effluent on *C. gariepinus*

From the graph, it was observed that the LC_{50} was 35.4 mg/l. This means that fifty percent of the test organisms would have been killed at this concentration (Figure 2). During the sub-chronic toxicity testing, fish behavior in all the tanks was normal throughout the 30 days experiment, however, but on a few occasions, lethargy and vertical, swimming were noticed usually prior to water change. No mortality was recorded.

3.5. Fish Growth Performance and Nutrient Utilization in Sub-chronic Evaluation

Table 5 shows growth performance weekly summary which displays the mean body weight gain of C. *gariepinus* exposed to varying concentrations of abattoir effluent. The lowest mean weight 49.67±2.00 mg/L (week 0) was recorded in the treatment with 10% concentration of abattoir effluent while the highest mean weight gain 116.27±2.50 mg/L (week 4) was found in the treatment 7.5% concentration effluent. The least growth performance was in 2.5% concentration of the abattoir effluent. Fish growth, mean weight gain and nutrient utilization were at increase in each percentage concentration of the effluent as the number of the weeks increased from 0-4.

In figure 3, the total feed intake (TFI) was lowest in the fish exposed to 2.5% and highest in that of 7.5% concentration of effluent. Comparative analysis has shown that specific growth rate was smallest at concentration 5% and highest at 2.5% abattoir effluent. Daily feed intake (DFI) was lowest in the control and highest at 5% treatment tanks. The daily weight gain (DWG) and percentage weight gain (PWG) were lowest at 5% and highest at 2.5% effluent concentration (Figure 4). In like manner, the mean weight gain (MWG) was lowest at 5% and highest at 2.5% effluent concentration (Figure 5).

Table 5: Fish Growth Performance and Nutrient Utilization in Sub-Chronic Evaluation (unit in grams)

Abattoir Conc. (mg/L)	Week 0	Week 1	Week 2	Week 3	Week 4
0%	52.10±5.62	59.57±6.35	81.90±2.56	94.25±3.32	107.08±9.10
2.5%	50.02±32.66	57.65±8.22	73.53±7.14	88.97±5.07	93.33±7.17
5%	68.93±3.39	80.97±7.26	96.75±7.61	105.12±9.37	110.50±2.50
7.5%	63.12±1.26	75.78±1.36	89.53±5.86	103.21±9.16	116.27±2.50
10%	49.67±2.00	59.06±2.01	86.58±15.10	99.21±16.96	113.71±13.56

Values are mean ± standard Error of mean

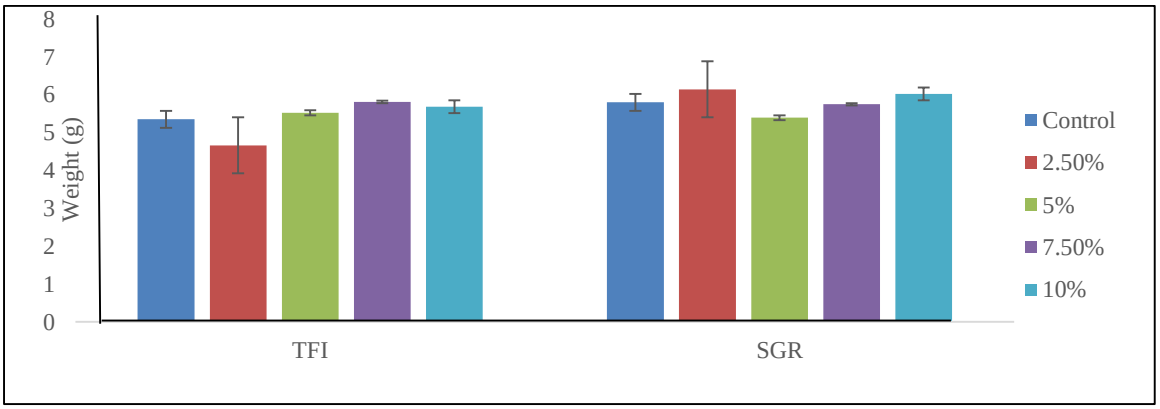


Figure 3: Total Feed Intake (TFI) and Specific Growth Rate (SGR) of *C. gariepinus* Exposed to Varying Concentration of Abattoir Effluent

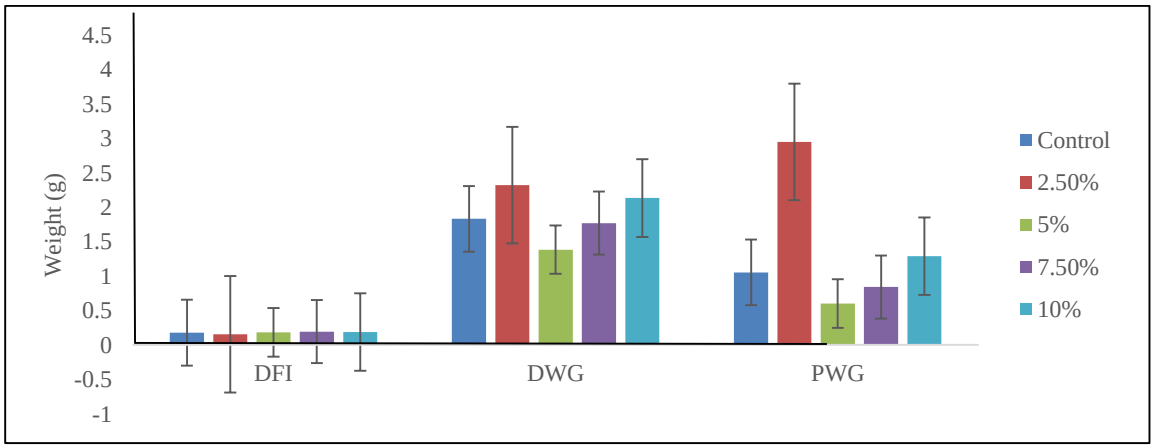


Figure 4: Daily Feed Intake (DFI), Daily Weight Gain (DWG) and Percentage Weight Gain (PWG) of *C. gariepinus* Exposed to Varying Concentration of Abattoir Effluent

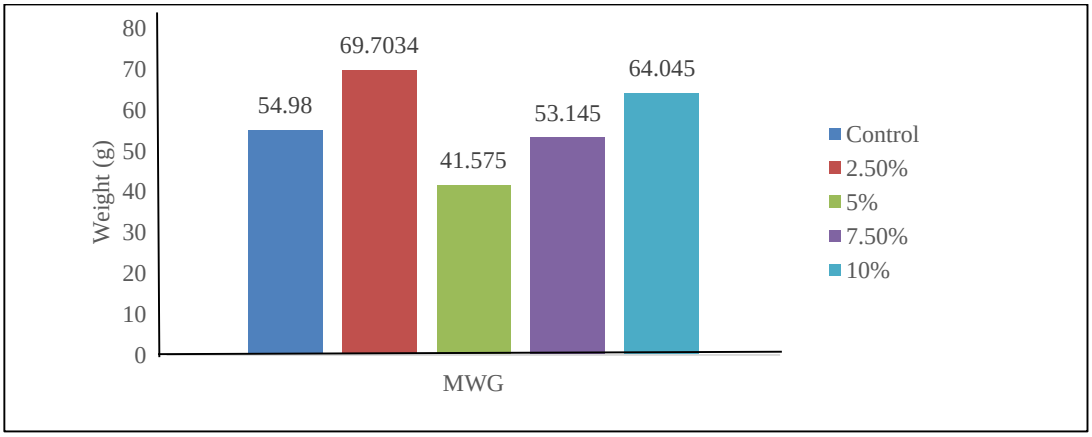


Figure 5:Mean Weight Gain (MWG) Parameter Indices of *C. gariepinus* Exposed to Varying Concentrations of Abattoir Effluent

3.6. Bioaccumulation of Heavy Metals (Cadmium, Lead, Iron, Copper and Zinc) in the Tissues of *Clarias gariepinus.*

The bioaccumulation of heavy metals in the muscles, GIT and gill *C. gariepinus* exposed to varying concentration of abattoir effluent is shown in Figures 6 -10. The results show that the lowest concentrations (at 0.016, 0.020 and 0.245 mg/L) of cadmium (Cd) in muscle, GIT and gill were found in control; while the highest Cd concentration (0.153±0.180 mg/L) was found in GIT at 7.5% concentration (Figure 6). A progressive increase in accumulation of lead (Pb) in the muscle of *C. gariepinus* at different concentration of abattoir effluent i.e. from control, 2.5, 5, 7.5 and 10% (0.008, 0.009, 0.009, 0.010 and 0.011 mg/L) respectively; the lowest accumulation (0.005 mg/L) of lead in GIT was however recorded in 2.5 % concentration of abattoir effluent while the highest (0.008 mg/L) was found in the 10% concentration (Figure 7). There was a direct proportional accumulation of iron in the GIT of the fish with increase in the concentration of abattoir treatment effluents (0-10%); consequently, the lowest value was recorded in the control (0.18 mg/L) while the highest value was at 10% concentration (0.52 mg/L). There was a steady increase in the accumulation of iron in gill of the fish at concentration 2.5% (0.31 mg/L) till concentration 10% (0.65 mg/L) (Figure 8). A direct proportional relationship of accumulation of zinc and copper in the muscle of the fish with the increase in the concentration of abattoir treatment effluents (0-10%) was observed (Figures 9,10). The least accumulation (0.18 mg/L) of zinc was in the control while the highest (0.57 mg/L) was in 10%; though with different values, this trend is also similar to accumulation of zinc in the GIT and gill respectively (Figure 9).

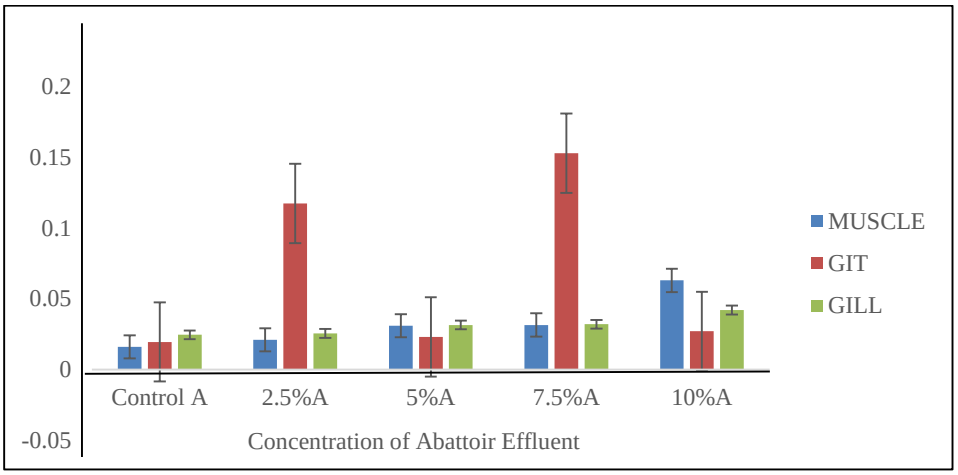


Figure 6: Cadmium Accumulation in the Muscle, GIT and Gill of *Clarias gariepinus* Exposed to Abattoir Effluent

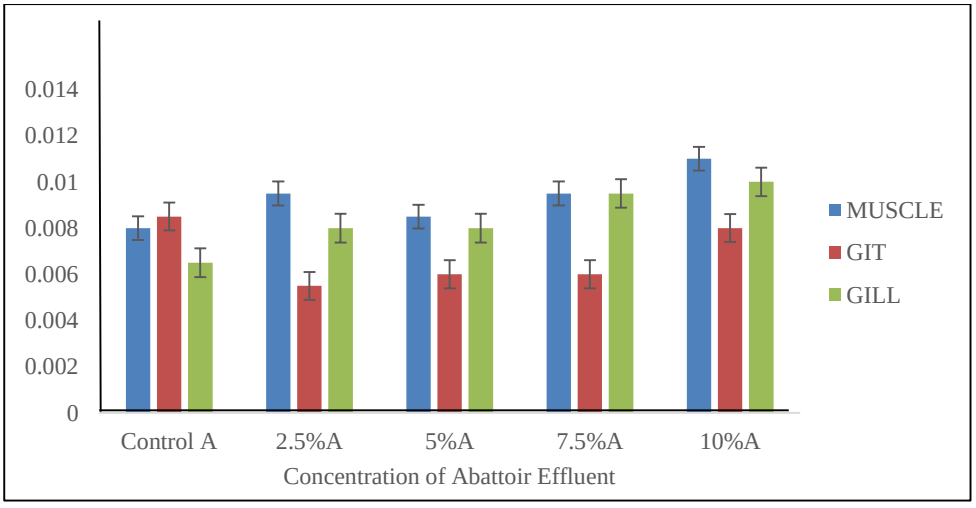


Figure 7: Lead Accumulation in the Muscle, GIT and Gill of *Clarias gariepinus* Exposed to Abattoir Effluent

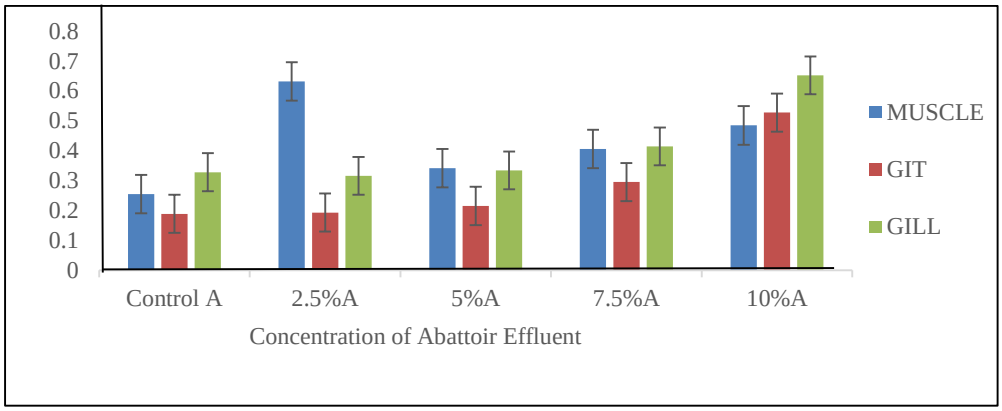


Figure 8: Iron Accumulation in the Muscle, GIT and Gill of *Clarias gariepinus* Exposed to Abattoir Effluent

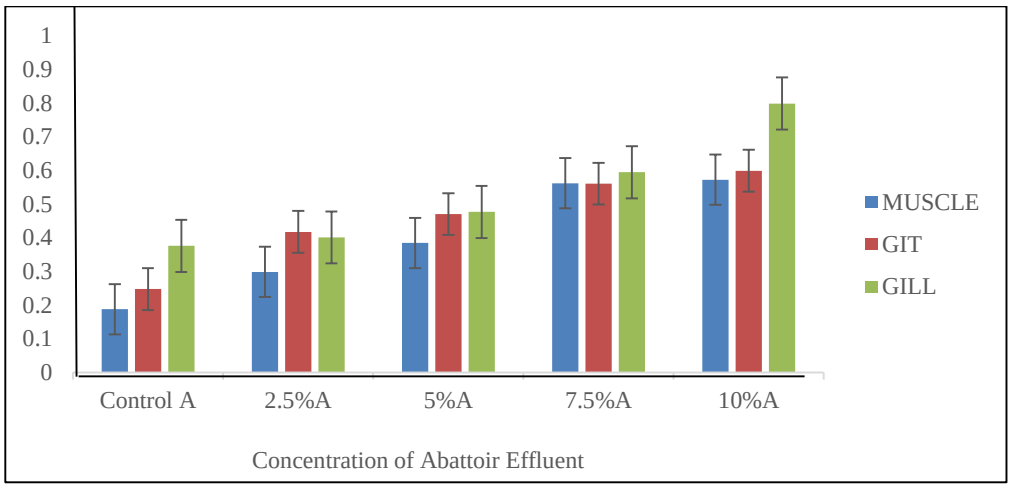


Figure 9: Zinc Accumulation in the Muscle, GIT and Gill of *Clarias gariepinus* Exposed to Abattoir Effluent

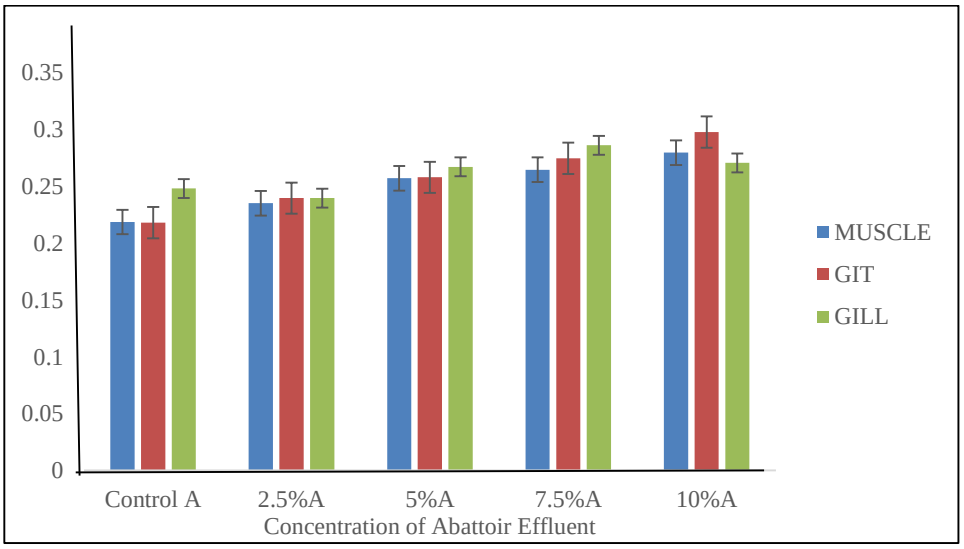


Figure 10: Copper Accumulation in the Muscle, GIT and Gill of *Clarias gariepinus* Exposed to Abattoir Effluent

4.0. Discussion

4.1. Physicochemical parameters and heavy metals of the abattoir effluents and culture media

In this study, BOD, electrical conductivity, and TDS of abattoir effluent recorded were higher than the NESREA and WHO standards; this is similar to the findings from previous studies (Sogbanmu et al., 2019; Olaniran et al., 2019; Oyeniran et al., 2021). High electrical conductivity have been associated with the presence of ions from blood, sulphates, phosphates as well as the chemicals used for treating animals (Ozturk and Yilmaz, 2019). The electrical conductivity and TDS in this study were lower than those in previous studies (Olaniran et al., 2019; Oyeniran et al., 2021); this may be due to differences in the dilution level or composition of the effluent. The BOD recorded in this study was greatly higher than 37, 39 and 95 mg/L recorded by Sogbanmu et al. (2019), Olaniran et al. (2019) and Oyeniran et al. (2021) respectively. This could be due to higher slaughter volumes in the current study site; the effluent examined may likely contained high concentrations of blood, fats, intestinal contents, and solid tissues directly from slaughtering activities. These substances are rich in biodegradable organic matter, which significantly increases oxygen demand, resulting in an exceptionally high BOD and zero DO making the water bodies receiving the abattoir effluent largely unsafe for aquatic lives and unfit for any beneficial purposes (Alabi et al., 2020; Ogbuene et al., 2020; Abasi et al., 2024). The pH of the effluent in this study remained near neutral, within both NESREA and WHO guidelines; this is generally acceptable for fish and indicates that enough hydrogen ions and buffering capacity remained to stabilize pH despite the heavy organic (microbial) load (Olaiya et al.,2016; Ugbune & Aregbor, 2024). The alkalinity recorded in this study was notably lower than NESREA and WHO guidelines which was unusual for abattoir effluent. Low alkalinity means the effluent had little capacity to resist pH swings, which could exacerbate acidity if large amounts of organic acids form which departs from the expectation that abattoir wastes are well-buffered (Asibor et al., 2020).

Accumulation of heavy metals in abattoir effluent is another key area in toxicology and water quality assessment. The concentrations of cadmium, lead, and iron were higher than the WHO and NESREA standards. The high concentration of these metals have potential of causing tissue damage and fatal toxicity in fish leading to organ damage, physiological stress and mortality in aquatic fauna; making water bodies unfit for drinking and biomagnification up the food chain (Thamke and Kodam, 2016; Sogbanmu et al., 2019). There was progressive increase in mean concentrations of heavy metals with rising abattoir effluent concentrations in the culture media. Abattoir effluent itself is known to contains high levels of heavy metals such as cadmium, lead, iron, zinc, and copper, likely originating from blood, animal tissues, cleaning agents, and equipment corrosion used during slaughtering processes. As the proportion of effluent in the culture media increased, more heavy metals were introduced, leading to a direct dose-dependent accumulation. This trend reflects the fact that abattoir effluents act as a primary source of metal contamination, and when diluted at increasing concentrations, they proportionally elevate the metal load in the medium. The statistically significant differences ($p < 0.0001$) confirm that the variation in metal concentrations across treatments was not due to random chance but rather a result of systematic increases in effluent concentration.

4.2. Fish Observable Physical Response to Abattoir Effluent

The results of the toxicity tests showed that C. gariepinus exhibited abnormal behavioral responses when the physical and chemical properties were observed to be outside the standard limits for their healthy survival. The fish exhibited abnormal observable responses with the increase in concentration of abattoir effluent. These included change in behavior, frequent surfacing and discoloration, loss of reflexes, gill movement, erratic swimming and extreme lethargy. This is an indication that the environment may be unsafe for the fish with many implications. This goes with discoveries of Adewoye (2013), Dahunsi et al. (2011) and Agboola and Fawole (2014) that fish oxidative stress causes erratic movement, vertical swimming, loss of reflex, over-secretion of mucous, opercula flaring and lethargy.

4.3. Toxicity Test

The acute toxicity test results in this study demonstrate a clear concentration-dependent response of fish to abattoir effluent exposure with 100% mortality observed in the higher concentration groups (50%, 75%, and 100%) by 48 hours indicating that the lethal threshold lies between 25% and 50% concentration. The pattern of mortality across concentrations reflects a typical dose-response relationship, where the severity of effects increases with the concentration of the toxicant. In the sub-chronic toxicity test, a few occasions were marked with lethargy and vertical swimming which could be traced to inadequate supply of oxygen. The median lethal concentration of the abattoir effluent to the test organisms recorded in this study is less than those reported in previous studies for the same fish species exposed to the

same effluent. Adeogun et al. (2013) and Alimba et al. (2015) reported 49.00 mg/L and 62.8 mL/L in their studies, while 126 mL/L and 154.14ml/L were reported by Olaniran et al. (2019) and Oyeniran et al (2021) respectively. The lower median lethal concentration (LC_{50}) of 35.4 mg/L recorded in this study, compared to higher values reported in previous studies, may be due to differences in the composition and pollutant load of the abattoir effluent used. Variations in environmental conditions (e.g., temperature, pH, dissolved oxygen), fish characteristics (such as age or health status), and methodological differences (including effluent preparation and experimental setup) could also have influenced the increased sensitivity of the test organisms, resulting in a lower LC_{50} value (Adeogun et al., 2013; Sogbanmu et al., 2019).

4.4. Fish Growth Performance and Nutrient Utilization in Sub-chronic Evaluation

The mean weight gain was the parameter used to assess weekly growth performance indices of *C. gariepinus* exposed to abattoir effluent for sub-lethal evaluation recorded for 30 days. The fishes in the 100% abattoir effluent concentration had the highest mean weight gain for the 4 weeks. The fish mean weight gain increased in each percentage concentration of the effluent as the number of the weeks increased from 0-4. This implied that there were yet growths despite the varying environmental conditions. The lowest total feed intake (TFI) in 2.5% of abattoir effluent treatment had corresponding effects which resulted to lowest mean weight gain or growth performance. This development may be linked to factors that influenced fish feeding habit which include feeding time of the day, season, and water quality such as temperature and dissolved oxygen levels (Eriegha and Ekokotu, 2017). This can also be as a result of environmental stressors as opined by Ayeni (2010). However, in general, the abattoir effluent was found to have no significant hindrance on the growth of the fish. Thus growth was recorded at every treatment dose. Daily feed intake (DFI) was almost equal in all concentrations but in contrary to expectation, daily weight gain (DWG) varied across the concentrations. This may be linked to the fish varying specific genetically and anatomical response to food (Eriegha and Ekokotu, 2017).

4.5. Bioaccumulation of heavy metals in the tissues of Clarias gariepinus

In the evaluation of the accumulation of heavy metals (Cadmium (Cd), Lead (Pb), Iron (Fe), Copper (Cu) and Zinc (Zn)) in the tissues of the *Clarias gariepinus* exposed to varying concentrations of abattoir effluent, the lowest concentrations of cadmium in muscle, GIT and gill were found in the control. This was connected to the fact that the control had no or little exposure to the effluents. The highest found in GIT at 10% concentration was due to high concentration of metals from the abattoir effluent. Lead had interchanging accumulations across the muscle. This may be as a result of the intermittent digestion and elimination of the metal by the fish. This further supports the finding of Ahmad et al. (2018) that, the bioaccumulation of metals in organism is dependent on the capacity of such organism to build up or eliminate the metals in the surrounding river. The lowest accumulation of Fe, Zn and Cu in the tissues was found in control concentration while the highest accumulations were in highest (10%) concentration. This implies that the accumulation of metals in the tissues of *C. gariepinus* has direct relationship with the concentration of the abattoir effluent in its surrounding. This further ascertains the report of Ahmad *et al*. (2018) that species have potentials to accumulate heavy metals to cause bioaccumulation. Consequently, Chronopoulos *et al*. (2011) argued that all the heavy metals are toxic at higher concentrations. Therefore, this can be linked to the abnormal attributes exhibited by the fish.

5.0. Conclusion

This study comprehensively evaluated the toxicological impact of untreated abattoir effluent on juvenile *Clarias gariepinus*, focusing on acute toxicity, sub-chronic growth performance, behavioral responses, and heavy metal accumulation. The physicochemical analysis revealed that the effluent was highly polluted, with values of BOD, TDS, and certain heavy metals such as cadmium, lead, and iron exceeding both NESREA and WHO permissible limits for aquatic ecosystems. The low levels of dissolved oxygen (DO) and alkalinity recorded in the effluent indicate poor water quality, which is detrimental to aquatic life and unsuitable for aquaculture practices. These results align with findings from previous studies, reinforcing the environmental threat posed by untreated abattoir discharges.

The acute toxicity assay confirmed that *C. gariepinus* is highly sensitive to abattoir effluent, with 100% mortality observed at concentrations of 50%, 75%, and 100% within 96 hours. The median lethal concentration (LC_{50}) obtained in this study suggests that the effluent was either more toxic or that the test organisms were more susceptible. The behaviours such as erratic swimming, frequent surfacing, and discolouration are observed in this study, these are early indicators of stress and physiological distress caused by toxic constituents in the effluent and highlight the immediate risk posed to fish populations in environments receiving direct effluent discharge.

In the sub-chronic exposure phase, variations in growth performance and nutrient utilization among the treatment groups were observed. While all fish exhibited some level of growth, those in lower effluent concentrations (especially 2.5% and 5%) showed reduced feed intake, lower daily weight gain, and minimal weight gain compared to those in the control and higher concentrations. Interestingly, the highest mean weight gain was recorded in the 7.5% effluent group, indicating that mild levels of organic enrichment may have had a short-term stimulatory effect on growth. However, this should not be interpreted as beneficial overall, as consistent exposure to polluted conditions can lead to long-term health and reproductive impairments.

Heavy metal analysis revealed a dose-dependent increase in the accumulation of cadmium, lead, iron, copper, and zinc in the tissues of *C. gariepinus*. The muscle, gills, gastrointestinal tract, and liver of the fish exposed to higher effluent concentrations showed significantly elevated levels of these metals. The bioaccumulation of toxic metals not only impairs fish health and survival but also poses risks to public health through potential transfer along the food chain. This finding underscores the chronic risk associated with continuous exposure to contaminated water sources and confirms the role of untreated abattoir effluent as a primary source of metal pollution in aquatic ecosystems.

Findings from this study provide compelling evidence of the ecological and toxicological risks posed by untreated abattoir effluent. From acute fish mortality to long-term accumulation of harmful substances, the effluent has far-reaching consequences for aquatic life, public health, and environmental sustainability. Based on these findings, the enforcement of strict effluent treatment regulations, periodic environmental monitoring, and the adoption of sustainable waste management practices in abattoirs are recommended. Protecting aquatic ecosystems from industrial and slaughterhouse waste is both essential for preserving biodiversity and safeguarding human livelihoods and health in communities that rely on these water resources.

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