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Toxicity assessment of Nile Tilapia fingerlings (*Oreochromis niloticus*) exposed to effluents from male hostel of Delta State University, Abraka, Nigeria

E. O. Ayoola [a,*], V. N. Enwemiwe [b], H. O. Erhenhi [b], C. C. Obi [c], A. A. Adebowale [d], E. Esiwo [b], J. A. Onokpasa [b], R. B. Ikomi [b]

[a] *Department of Environmental Management and Toxicology, College of Environmental Resources Management, Federal University of Agriculture, Abeokuta. P.M.B. 2240. Ogun State. Nigeria*
[b] *Department of Animal and Environmental Biology, Faculty of Science, Delta State University, Abraka, Nigeria*
[c] *Department of Biology, Faculty of Science, Delta State University of Science and Technology, Ozoro, Nigeria*
[d] *Department of Nutrition and Dietetics, College of Food Science and Human Ecology, Federal University of Agriculture, Abeokuta. P.M.B. 2240. Ogun State. Nigeria*

Abstract

Studies on aquatic pollution are crucial for maintaining environmental health. This study assessed the toxicity of effluents from the male hostel site II at Delta State University (DELSU) on Oreochromis niloticus fingerlings. Behavioral responses and mortality rates were observed as toxicity indicators. The physicochemical characteristics of the raw effluent were evaluated and compared with standard methods. In a 96-hour static bioassay, 20 fingerlings were exposed to varying effluent concentrations: 0%, 20%, 40%, 60%, 80%, and 100%, with the experiment triplicated. Analysis showed pH (5.6), temperature (26.1 °C), TDS (304 mg/L), dissolved oxygen (5.7 mg/L), chlorine (5.55 mg/L), ammonia (0.21 mg/L), and hardness (0.79 mg/L). Water analysis over 12-96 hours ranged for pH (5.45-5.62), temperature (22.50-26.30 °C), TDS (61.50-237.50 mg/L), DO (4.45-6.00 mg/L), chlorine (0.84-3.98 mg/L), ammonia (0.14-0.37 mg/L), and hardness (6.52-31.93 mg/L), with no statistically significant differences (p¿0.05). Behavioral responses included air gulping, irregular swimming, and lack of reflex. Mortality depended on effluent concentration, with no deaths at 0%-80% but 80% mortality at 100%. Lethal times for 50% and 95% mortality at 100% concentration were 48.6 and 102.8 hours, respectively. Diluting or treating wastewater before release is necessary to prevent fish mortality in the wild.

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1. Introduction

Water pollution is a pervasive environmental issue that arises from many human activities and threatens the overall health and quality of water bodies, such as lakes, rivers, seas, and groundwater [1]. Contamination in aquatic ecosystems harms the creatures

*Corresponding Author Tel. No.: +234-816-079-8164.
Email address: ayoolaebenezeroluwaseun@gmail.com (E. O. Ayoola)

and plant life residing in these environments, often resulting in notable ecological disturbances at both the individual and community levels. Water pollution sometimes originates from the releasing of contaminants into bodies of water, either directly or indirectly, without sufficient treatment to decrease their harmful components [2]. Toxicity is a crucial notion within the realm of water pollution, referring to the degree to which a substance can cause harm to organisms [3]. The detrimental effects can be observed in several creatures, including animals, microorganisms, and plants. Therefore, evaluating acute toxicity is a crucial initial screening process for thoroughly assessing the hazardous characteristics of different substances [4]. According to the United States Environmental Protection Agency, effluent refers to wastewater originating from treatment plants, sewers, or industrial outfalls, regardless of whether it has undergone treatment or remains untreated [5]. Effluents are consistently acknowledged as a significant contributor to water pollution, including sewage emissions from treatment facilities and wastewater discharge from industrial establishments [6].

The scope of this study is limited to the anthropogenic activities occurring within Delta State University Boys Hostel, primarily located on-site II of Abraka, is often known as Abraka Hall. The release of wastewater from multiple sources, such as bathrooms, kitchens, laundry facilities, and toilets, occurs through a drainage system, ultimately leading to the river Ethiope. This discharge is observed as sewage effluent. The release has significant consequences for the water body, resulting in pollution and harming aquatic organisms. The discharge emanating from the male students' residence at Delta State University (DELSU), known as Abraka Hall, mainly enters the adjacent marine ecosystem, specifically the River Ethiope, and carries pollutants, contributing to water contamination in this area. The uncontrolled discharge of waste into water bodies leads to environmental contamination, resulting in detrimental changes to the Earth's ecosystem's physical, chemical, and biological aspects. This interference with natural ecological processes has negative consequences [7]. Considering the location of pollution within the aquatic system, it can be firmly established that the unselective discharge of waste leads to the occurrence of marine pollution, resulting in the contamination of natural water bodies due to the combination of chemical, physical, and biological pollutants that have widespread effects throughout the biosphere. A wide range of waterborne contaminants, including oil, industrial effluents, and residential and agricultural waste, all contribute to the deterioration of aquatic ecosystems. These pollutants pose a significant threat to the survival of various marine creatures.

The Ethiope River, which flows through heavily populated regions in Delta State, Nigeria, including Umuaja, Umutu, Obiaruku, Eku, Aghalokpe, and Sapele, holds significant importance within the local environment. The area in question is essential because of its abundant and varied freshwater fauna and flora. Additionally, it is a central location for engaging in leisure pursuits. Physicochemical parameters refer to a range of inherent properties that characterize a substance or water body. These features include, but are not limited to, pH, temperature, total dissolved solids, dissolved oxygen, ammonia, chloride, and others [8]. The combination of these criteria determines the distinct attributes of a water body. It significantly impacts the occurrence and behaviour of microorganisms and macroorganisms while greatly influencing water quality. The importance of acute toxicity testing using *Oreochromis Niloticus* (Tilapia fish) fingerlings arises from its usefulness in assessing the potential environmental impact of a particular xenobiotic substance. Acute toxicity assessments are succinct evaluations that aim to measure the effects of harmful substances on Tilapia fish for a limited duration of their lifespan [9]. In brief, the contamination of water, resulting from various anthropogenic activities, presents a pervasive hazard to aquatic ecosystems, leading to adverse consequences for species and vegetation. The pollution of *Oreochromis Niloticus* fingerlings in this study results from the discharge of contaminants into water bodies without sufficient treatment. The sewage effluent from the DELSU boys' dormitory (Abraka Hall), which enters the River Ethiope directly, is an example of the extent of pollution. The pollution that ensues leads to a series of ecological repercussions, marked by adverse alterations in the physical, chemical, and biological constituents, ultimately resulting in the degradation of aquatic ecosystems. Therefore, it is imperative to closely observe and mitigate the pollution levels of the Ethiope River and its consequences on *Oreochromis Niloticus*, specifically in the DELSU boys' dormitory neighbourhood, to preserve the integrity of this crucial ecological system.

2. Materials and methods

2.1. Research setting

The research area comprises the drainage system of the boys' hostel at DELSU, specifically situated at Site II within the confines of Delta State University, Abraka campus. The effluent examined consists of wastewater from several sources, including bathroom facilities, kitchens, laundry areas, and toilets.

2.2. Collection and preservation of effluent

The effluent samples were carefully collected using 25-litre containers and then carried to the Department of Animal and Environmental Biology's animal house. The Tilapia fish samples above were stored in a refrigeration unit set at 4 °C, following the guidelines provided by the United States Environmental Protection Agency [10].

2.3. Physicochemical analysis of the effluent

The laboratory environment was utilized to evaluate the physicochemical characteristics of the effluent. The parameters that were tested included Dissolved Oxygen (mgl^{-1}), pH, Total Dissolved Solids (mgl^{-1}), Temperature (°C), and Ammonia (mgl^{-1}), Chloride (mgl^{-1}), and Total Hardness (mgl^{-1}). The analysis was conducted following the recommendations set forth by the United States Environmental Protection Agency (USEPA) in 2002, using standard methods.

2.4. Fish collection and acclimatization

A procurement of Three hundred and sixty (360) fingerlings of *Oreochromis niloticus* was made from Pdexter Farm in Ughelli, Delta State. These fingerlings were characterized by an average length of 3.58 ± 0.35cm and weight of 0.78 ± 0.4 g. The *Oreochromis niloticus* fingerlings were subjected to a 14-day acclimatization phase, following the standards for acclimatizing freshwater organisms [11]. The Tilapia fish were fed daily, and any uneaten food was promptly removed. Additionally, the water in the tank was replaced every three days to ensure the fish's overall health and welfare.

2.5. Determination of range and assessment of acute toxicity

After acclimatization, a preliminary test was conducted to determine the range of concentrations for the subsequent assessment of acute toxicity. The 96-hour LC50 value of the effluent was measured using a static bioassay in a laboratory following the protocols established by the Organization for Economic Co-operation and Development (OECD) in 2014. Plastic aquaria with dimensions of 24 x 47 x 33 cm were employed. A total of twenty fish specimens were subjected to a randomized exposure to five distinct concentrations of effluent, namely 20%, 40%, 60%, 80%, and 100%. Each concentration was tested in triplicate, and a control group with a concentration of 0% was included. The fish underwent a fasting period lasting 24 hours before the commencement of the experiment, during which mortalities were documented at regular 12-hour intervals. According to OECD [12], fish are deemed dead if they display no discernible signs of movement or responses when stimulated at the caudal peduncle. The present study investigates the behavioural responses of fish when exposed to effluent from the DELSU male Hostel (Abraka Hall). During the 96-hour acute toxicity test, the exposed fish exhibited behavioural abnormalities. The observed behaviours encompassed ingesting air, diminished reflex responses, and irregular swimming movements.

2.6. Data analysis

The statistical presentation of the results obtained from assessing physicochemical parameters during the bioassay was Mean ± SD. The Probit method was utilized to determine the effluent's LT_{50} and LT_{95}, and data analysis was conducted using SPSS Version 23.

3. Results and discussion

3.1. Physicochemical parameters of raw effluent

Physicochemical parameters of the raw effluent obtained from DELSU male hostel (Abraka hall) site II are shown in Table 1 in comparison with the Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO) standards permissible for wastewater released into the environment. The pH value obtained for wastewater discharge into the aquatic environment was below the limit acceptable by FEPA and WHO, and it is acidic. The value received from Total Dissolved Solid (TDS) was within the acceptable limit for FEPA and WHO. Moreover, the value obtained for Dissolved Oxygen was within the permissible limit. The value received for chloride does not conform to the acceptable limit by either FEPA or WHO, as it was far below the proper limit. The ammonia value of the raw effluent was within the limit acceptable by the FEPA and WHO for wastewater discharge into aquatic environments.

3.2. Physicochemical parameters with concentrations

The physicochemical parameters of the different effluent concentrations throughout the 96-hour exposure period is shown in Tables 1 - 5. Hydrogen ion concentration across the concentrations with time was stable and range from 5.45 to 5.62. Temperature decreased from 12 to 96 hours of fingerling exposure. Temperature was within the tolerable limits for fingerling survival (22.50 to 26.30 °C). The total dissolved solids (TDS) in the water was within the range of 61.50 to 237.50 mgl^{-1}. Dissolved oxygen (DO) decreased from 12 to 96 hours of fingerling exposure. DO ranged from 4.45 to 6.00 mgl^{-1}. Chlorine, ammonia and hardness increased slightly from 12 to 96 hours of fingerling exposure. They ranged from 0.84 to 3.98 mgl^{-1}, 0.14 to 0.37 mgl^{-1}, and 6.52 to 31.93 mgl^{-1} respectively. The differences between and within the concentrations were not statistically significant ($p>0.05$).

3.3. Behavioural responses of oreochromis niloticus fingerlings

The behavioural responses shown by the fingerings of Oreochromis niloticus after exposure to various concentrations of effluent during the 96-hour is illustrated in Table 6. These behavioural responses included air gulping, loss of reflex, and erratic swimming. Normal behaviour was observed in the control group. Between 12 to 24 hours of exposure, all behavior changes were recorded in fingerlings exposed to 100% of the effluence. Loss of reflex, and erratic swimming were recorded in fingerlings exposed to 20% to 80% of the effluent. Between 36 to 48 hours of exposure, no behavioural changes was observed. However, the 100% effluent caused the expression of all the behavioural changes. From 60 to 96 hours of exposure, no behavioural changes was observed in all concentrations.

Table 1: Physicochemical parameters of raw effluent from DELSU male hostel (Abraka hall).

Parameters	Raw Effluent	FEPA [13]	WHO [13]
Hydrogen ion concentration (pH)	5.60 ± 0.01	6.0 - 9.0	6.5 - 9.2
Temperature (°C)	26.1 ± 0.14	NP	NP
Total Dissolved Solids (mgl^{-1})	304.00 ± 1.41	2000	250- 500
Dissolved Oxygen (mgl^{-1})	5.70 ± 0.14	5	5
Chlorine [Cl^- (mgl^{-1})]	5.55 ± 0.01	100	250
Ammonia [NH_3 (mgl^{-1})]	0.21 ± 0.01	0.1 - 0.6	0.2
Hardness (as $CaCO_3$) (mgl^{-1})	0.79 ± 0.01	NP	NP

Note: NP means not provided

Table 2: Physicochemical parameters of the different effluent concentrations from 12-24 hours.

Parameters	Concentrations (%)					
	0	20	40	60	80	100
pH	5.47 ±0.08	5.53 ± 0.04	5.57 ± 0.02	5.60 ± 0.04	5.61 ± 0.01	5.62±0.00
Temp (° C)	25.3 ± 0.57	25.10 ± 0.28	24.85 ± 0.21	24.85 ± 0.07	24.90 ± 0.00	2.49±0.00
TDS (mgl^{-1})	62.00 ± 9.90	90.5 ± 0.71	126.00 ± 0.00	158.50 ± 0.71	191.5 ± 0.71	223.50±0.71
DO (mgl^{-1})	5.60 ± 0.14	6.00 ± 0.14	5.45 ± 0.07	5.15 ± 0.07	5.00 ± 0.14	4.50±0.14
Cl^- (mgl^{-1})	1.32 ± 0.00	2.21 ± 0.00	1.33 ± 0.00	3.32 ± 0.00	3.98 ± 0.00	3.36 ± 0.00
NH_3 (mgl^{-1})	0.18 ± 0.00	0.25 ± 0.00	0.20 ± 0.00	0.25 ± 0.00	0.14 ± 0.00	0.26 ±0.01
Hardness (mgl^{-1})	6.52 ± 0.02	7.79 ± 0.01	20.38 ± 0.03	11.41 ± 0.01	31.61 ± 0.01	15.01 ±0.01
p-value	0.671	0.770	0.571	0.540	0.430	0.461

Note: values are Mean (±SD)

Table 3: Physicochemical parameters of the different effluent concentrations from 36 – 48 hours.

Parameters	Concentrations (%)					
	0	20	40	60	80	100
pH	5.48 ± 0.13	5.54 ± 0.03	5.56 ± 0.02	5.58 ± 0.02	5.61 ± 0.01	5.60 ± 0.00
Temp (°C)	24.05 ± 0.21	23.90 ± 0.00	23.80 ± 0.14	23.75 ± 0.07	23.80 ± 0.00	23.80 ± 0.14
TDS (mgl^{-1})	63.00 ± 9.90	92.50 ± 0.71	127.50 ± 2.12	161.00 ± 1.41	195.50 ± 0.71	228.50 ± 0.71
DO (mgl^{-1})	5.55 ± 0.07	5.70 ±0.14	5.15 ± 0.07	4.95 ±0.07	4.70 ± 0.14	4.45 ± 0.07
Cl^- (mgl^{-1})	2.12 ±0.01	1.91 ± 0.00	1.88 ± 0.14	3.25 ±0.00	2.94 ±0.00	3.31 ± 0.00
NH_3 (mgl^{-1})	0.19 ± 0.00	0.32 ± 0.00	0.18 ± 0.00	0.27 ± 0.00	0.14 ± 0.00	0.27 ± 0.00
Hardness (mgl^{-1})	6.52 ± 0.05	7.73 ± 0.01	20.49 ± 0.03	12.23 ± 0.01	30.53 ± 0.03	15. 21 ± 0.01
p-value	0.711	0.777	0.574	0.540	0.441	0.461

Note: values are Mean (±SD)

3.4. Acute toxicity test

The mortality rate of Oreochromis niloticus exposed to different concentrations (0 to 100%) of effluent collected from the DELSU boy's hostel (Abraka hall) over a 96-hour is shown in Table 7. During the experimental period, no mortality was recorded in the control group or the 20%, 40%, 60%, and 80% effluent concentrations. Mortality occurs in the highest concentration of effluent (100%). Sixteen (16) fishes died when exposed to the 100% effluents. This amounts to 80% of the exposed fishes.

3.5. Probit model

The analysis of the fingerlings population that died after exposure to 100% effluents for 96 hours is shown in Figure 1. Lethal time analysis was recorded. However, it will take 48.6 hours for 50% of the fingerling population to die in the 100% effluent. It will equally take 102.8 hours for 95% of the fingerlings to die in the exposure.

Table 4: Physicochemical parameters of the different effluent concentrations from 60 –72 hours.

Parameters	Concentrations (%)					
	0	20	40	60	80	100
pH	5.45 ± 0.00	5.51 ± 0.03	5.53 ± 0.01	5.59 ± 0.01	5.60 ± 0.02	5.59 ± 0.00
Temp (°C)	23.00 ± 0.14	22.55 ± 0.07	22.50 ± 0.14	22.65 ± 0.07	22.65 ±0.07	22.70 ± 0.14
TDS (mgl^{-1})	61.50 ± 6.36	94.50 ± 0.71	128.00 ± 0.71	163.00 ± 0.00	198.00 ± 1.41	232.50 ± 2.12
DO (mgl^{-1})	5.80 ± 0.00	5.65 ± 0.07	5.85 ±0.07	5.10 ±0.00	4.85 ± 0.07	4.55 ± 0.07
Cl^- (mgl^{-1})	1.58 ±0.00	1.37 ± 0.00	2.62 ±0.00	2.25 ±0.00	3.44 ± 0.00	3.22 ± 0.00
NH_3 (mgl^{-1})	0.18 ± 0.00	0.34 ± 0.00	0.17 ± 0.00	0.26 ± 0.00	0.15 ± 0.00	0.27 ± 0.00
Hardness (mgl^{-1})	6.70 ± 0.01	7.82 ± 0.01	21.80 ± 0.01	13.43 ± 0.02	31.26 ± 0.01	15.86 ± 0.01
p-value	0.651	0.758	0.550	0.529	0.429	0.452

Note: values are Mean (±SD)

Table 5: Physicochemical parameters of the different effluent concentrations from 84–96 hours.

Parameters	Concentrations (%)					
	0	20	40	60	80	100
pH	5.49 ± 0.09	5.49 ± 0.04	5.55 ± 0.04	5.59 ± 0.01	5.60 ± 0.02	5.60 ± 0.03
Temp (°C)	26.30 ± 1.27	25.80 ± 0.71	25.55 ± 0.35	25.40 ± 0.14	25.35 ± 0.07	25.35 ± 0.07
TDS (mgl^{-1})	65.50 ± 9.19	96.00 ± 0.00	128.50 ± 3.54	164.00 ± 0.00	199.50 ± 2.12	237.50 ± 2.12
DO (mgl^{-1})	5.90 ± 0.00	5.75 ± 0.07	5.75 ±0.21	5.40 ± 0.00	4.65 ± 0.64	4.85 ± 0.07
Cl^- (mgl^{-1})	1.85 ± 0.00	0.84 ± 0.00	3.46 ± 0.00	2.18 ± 0.00	3.95 ± 0.00	3.17 ±0.00
NH_3 (mgl^{-1})	0.19 ± 0.00	0.37 ± 0.00	0.15 ± 0.00	0.24 ± 0.00	0.16 ± 0.00	0.27 ± 0.01
Hardness (mgl^{-1})	6.75 ± 0.02	7.92 ± 0.01	21.89 ± 0.02	14.63 ± 0.04	31.93 ± 0.03	16.04 ± 0.04
p-value	0.734	0.789	0.572	0.543	0.442	0.462

Note: values are Mean (±SD)

4. Discussion

The physicochemical examination of raw effluent collected from DELSU male hostel (Abraka hall) site II revealed notable findings (Table 1). Ref. [14] measured the acute cytotoxic effect of petroleum refinery effluent on *Oreochromis niloticus* fingerlings and found a pH of 6.9. The decreased pH in this study reveals a more acidic and potentially hazardous environment for aquatic life. The total dissolved solids (TDS) in the raw effluent, with a mean value of 304 mg^{-1}, went below the allowable level specified by FEPA (2000 $(mg/l)^{-1}$) but stayed within the acceptable range defined by WHO (250 - 500 mgl^{-1}). This TDS level was significantly lower than what Ref. [15] reported, who discovered a much higher TDS value of 12023.6 mgl^{-1} in wastewater effluent from Mumbai's Taloja industrial district.

The mild TDS level in this investigation shows a considerably reduced deposition of organic molecules in the raw effluent. Dissolved oxygen (DO) values in the raw effluent were recorded at 5.7 mg^{-1}, which exceeded both FEPA and WHO regulations (5.0 mgl^{-1}) [16]. This somewhat enhanced DO concentration could be attributable to significantly higher organic matter in the effluent. The DO level indicates a slightly more oxygenated atmosphere in the present investigation. The chloride ion content in the raw effluent was significantly low, with a mean value of 5.55 mg^{-1}, well below the WHO minimum of 250 mg^{-1}. The low chloride content can be attributed to the absence of numerous chloride sources, such as chloride-contaminated sediments, sewage, and industrial discharges, in the effluent. Chloride in water can promote electrical conductivity and metal corrosion, but its absence in the present investigation mitigates these effects. The ammonia concentration in the raw effluent was detected at 0.2 mgl^{-1}, within the permitted limits of WHO and FEPA (0.2 and 0.1 - 0.6, respectively). This low ammonia level implies a limited presence of nitrogenous waste in the effluent.

Behavioural reactions of *Oreochromis niloticus* fingerlings subjected to varied effluent concentrations exhibited aberrant behaviours such as air gulping, irregular swimming, lack of reflex, and final mortality. Similar behavioural reactions have been recorded in other research of involving exposure of fishes to different toxicants [17]. These behaviour modifications are determined by chemical composition, concentration, species, size, and specific environmental conditions.

Table 6: Behavioural responses of *Oreochromis niloticus* fingerlings exposed to different concentrations of effluent.

Conc (%)	Air Gulping	Loss of Reflex	Erratic Swimming
12 - 24 hours			
0	-	-	-
20	-	+	+
40	-	+	+
60	-	+	+
80	-	+	+
100	+	+	+
36 - 48 hours			
0	-	-	-
20	-	-	-
40	-	-	-
60	-	-	-
80	-	-	-
100	+	+	+
60 - 96 hours			
0	-	-	-
20	-	-	-
40	-	-	-
60	-	-	-
80	-	-	-
100	-	-	-

Key: - = none, + present

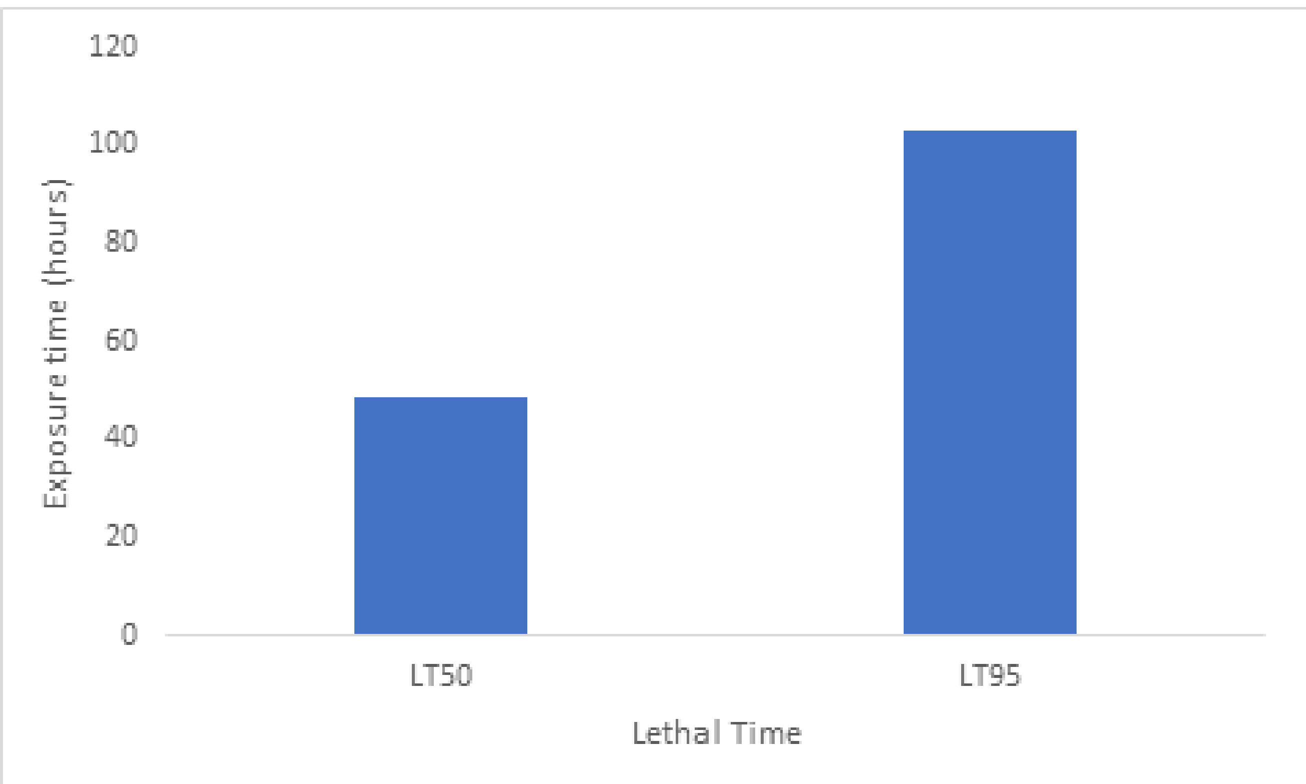

Figure 1: Lethal time of O. *niloticus* fingerlings exposed to 100% effluents.

Table 7: Mortality rate of fish.

Mortality Time (Hrs.)	Concentration of Effluent (%)					
	0	20	40	60	80	100
12	0	0	0	0	0	0
24	0	0	0	0	0	4
36	0	0	0	0	0	6
48	0	0	0	0	0	10
60	0	0	0	0	0	12
72	0	0	0	0	0	14
84	0	0	0	0	0	14
96	0	0	0	0	0	16

N= 20 fingerlings

Notably, there was no recorded death in effluent concentrations of 0%, 20%, 40%, 60%, and 100% throughout the research, with 80% mortality occurring only in the 100% concentration. The computed LC50 of 93.830% shows that the effluent, according to GESAMP criteria, is partially non-toxic. In conclusion, the physicochemical study of the raw effluent revealed its acidic character, moderate total dissolved solids, raised dissolved oxygen content, low chloride ion concentration, and acceptable ammonia levels. The behavioural reactions of *Oreochromis niloticus*fingerlings exposed to the effluent exhibited aberrant behaviours and mortality at 100% concentration. The computed LC50 implies partial non-toxicity of the effluent, underscoring the need to further assess its Ecological impact and appropriate remediation strategies.

5. Conclusion

This study indicates that the untreated wastewater collected from the boys' dormitory at DELSU caused toxicity to 80% of the fingerlings after a post treatment exposure. However, serial dilutions demonstrate non-toxicity to fingerlings with slight acute behavior changes between 12 to 48 hours of exposure. It is important to dilute or treat waste water effluents before release them into the aquatic ecosystem to avoid fish mortality in the wild.

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