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Water Quality Contamination and Mortality of African Mud Catfish (*Clarias gariepinus;* Burchell, 1822) Fingerlings Exposed to Paint Effluents

Bassey Esio Otong[1], Akaninyene Paul Joseph[1*] and Finian Tobias Okoro[2]

[1]*Department of Zoology and Environmental Biology, Faculty of Biological Sciences, University of Calabar, Calabar, Nigeria.*
[2]*Department of Environmental Pollution and Control, Faculty of Marine Environmental Management, Nigerian Maritime University, Okerenkoko, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author APJ designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BEO managed the analyses of the study. Author FTO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The toxicological effects of paint effluents on *Clarias gariepinus* fingerlings and its aquarium water was studied. Ten fingerlings were used in each aquarium and exposed to 4 different concentrations of the effluent along with the control group. The fingerlings were exposed to 0%, 85%, 90%, 95% and 100% concentration of the effluent in a triplicate experiment. A total of 150 *C. gariepinus* fingerlings with a mean weight of 1.92 ± 0.34 g were used throughout the study. The physico-chemical parameters of the culture water varied with an increase in paint effluent concentration. Temperature, pH and conductivity increased with increasing concentration of effluent in most cases, while DO decrease with increase in effluent concentration. The mortality data trend of fingerlings exposed to the toxicant was concentration dependent. The 96 hours LC_{50} value with 95% confidence limit of *C. gariepinus* exposed to the effluent was 39.81% ± 12.68, and was

**Corresponding author: E-mail: joseph.akan@yahoo.com;*

significant with a determination coefficient (r^2) of 0.95 at P<0.05. The high LC_{50} value for the fingerlings exposed to the paint effluent showed that the effluent is less toxic, but still caused mortality to the fingerlings at increased concentration. Although the paint effluents are less toxic, it was still able to alter the physico-chemical parameters of the culture water as well as cause mortality to fingerlings. As a result, the study emphasizes that paint industries should treat their effluents properly, reduce the microbial and chemical load before discharging into the environment. Also, the Government should enforce laws and regulations prohibiting indiscriminate discharge of untreated effluents by industries into drainage channels and any water body, because failure to enforce these laws could lead to the mortality of biological organisms, pollute organisms in surrounding water by altering the physico-chemical parameters and cause harmful diseases to humans that consume the resources from this polluted aquatic environment.

Keywords: Water quality; contamination; toxicity; paint effluents; Clarias gariepinus; fingerlings.

1. INTRODUCTION

Clarias gariepinus (African sharp tooth catfish) belongs to the Clariidae family. They are also described as air-breathing catfishes. It is a large eel-like fish with a white belly and dark gray or black colour at the back. It can grow and attain a maximum weight of 60 kg (130Ib) and total length of 1.7 m (5 ft 7In). Their bodies are slender, flat bony headed, posses a broad and terminal mouth with four pairs of barbells. Their pectoral fins have spines and also posses gill arches with its breathing organs. *Clarias gariepinus* feeds on dead and living animal matter. They are the most cultured fish species in Nigeria, because of their high resistance to disease and adverse environmental conditions [1].

In Nigeria, paint production utilizes large volume of water without adequate wastewater treatment plant [2]. Hence, large quantities of both hazardous and non-hazardous wastes are inherently released to the environment, thus causing health-related problems, ecological imbalance and bioaccumulation in aquatic organisms. Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It can originate from a combination of domestic, industrial, commercial or agricultural activities, surface runoff or storm water and sewer inflow or infiltration [3]. Increase in volume, diversity of solid waste and sewage generation has led to euthrophication of water bodies, destruction of fisheries, decrease in the aesthetic and recreational values of water resources [4] leading to water pollution.

Water pollution is the contamination of water bodies such as lakes, rivers, oceans and groundwater by human activities. It occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful constituents [5]. Discharge of untreated waste can cause bacteria or viral contamination of fisheries and shell fish beds, thus resulting in high risk to public health [6]. Nutrients in sewage such as nitrogen and phosphorus promote excessive algal blooms, which depletes oxygen in the water, leading to fish kills and destruction of other aquatic life. Rivers are used as site for the disposal of refuse, human sewage, municipal and domestic waste waters from kitchens, abattoirs and industries. Streams and rivers running through areas of significant human influence such as farms, cities and industrial locations are therefore prone to pollution, especially in Nigeria where environmental protection regulations are not strictly enforced [7].

During the processing of basic industrial raw materials to finished goods, various harmful wastes, effluents and other toxic by-products are generated alongside the desired products. These toxic materials, if discharged untreated into the environment are capable of interfering with the components as well as affecting man and other living components of the ecosystem. Effluent is generally considered to cause water pollution, such as the outflow from a sewage treatment plant facility or the waste water discharge from industrial facilities [8].

In Africa, coastal water bodies are mainly polluted by run-off and industrial discharge [9]. The discharge of industrial effluents had led to alterations in the quality and ecology of receiving water bodies [10]. These have resulted in challenges to water resource managers, aquatic ecologists and hydrobiologists in developing countries like Nigeria. The contaminants under greatest regulatory scrutiny in paint wastewater streams are total suspended solids (TSS), and to a somewhat lesser extent, heavy metals, biological oxygen demand (BOD) and (COD) chemical oxygen demand [11]. Fishes found in rivers/lagoons receiving high discharges of effluent from industries, do have a range of alterations related to physiological abnormalities [12]. These effects have been attributed to various estrogenic chemicals known to be present within treated or/and untreated industrial effluents. Indeed, extensive laboratory-based studies have confirmed that chemicals contained in industrial effluents can induce many effects seen in effluent exposed fish [13]. Furthermore, it has been shown that exposure to industrial effluents can inhibit the reproduction of fish [14].

The study was aimed at evaluating the culture water contamination and acute toxicity of paint effluent on the survival of *C. gariepinus* (African Catfish) fingerlings.

2. MATERIALS AND METHODS

2.1 Study Area

The Paint Manufacturing Company is located at Amika Utuk lane, Esin Ufot Efut Clan, Calabar South Local Government Area, Cross River State, South east Nigeria. It is geographically located between latitude 4° 56' 46.875" N and longitude 8° 20' 05.877" E (Fig. 1) at an altitude of 30.0 meters. Uwanse lane links up with other major streets in Calabar South like Goldie, Uwanse, Mount Zion Street etc. The area is located in the sub-equatorial belt and is characterized by the wet and dry seasons. The wet season begins in April and ends in September with a peak in June and July, while the dry season starts from October and ends in March [15]. Its topography is basically plain except a few sloppy terrain which ends in a ravine. The area has functional drainage system which collates rain water into a bigger drainage channel that finally empty into the river. However, it is always flooded each time it rains heavily due to blockage in the drainage channels. The vegetation is, however, affected by activities like agriculture, construction and urbanization. Apart from the wind system, other climatic parameters such as mean annual rainfall and temperature, global radiation reflections coefficient to mention a few also influence the study area [16].

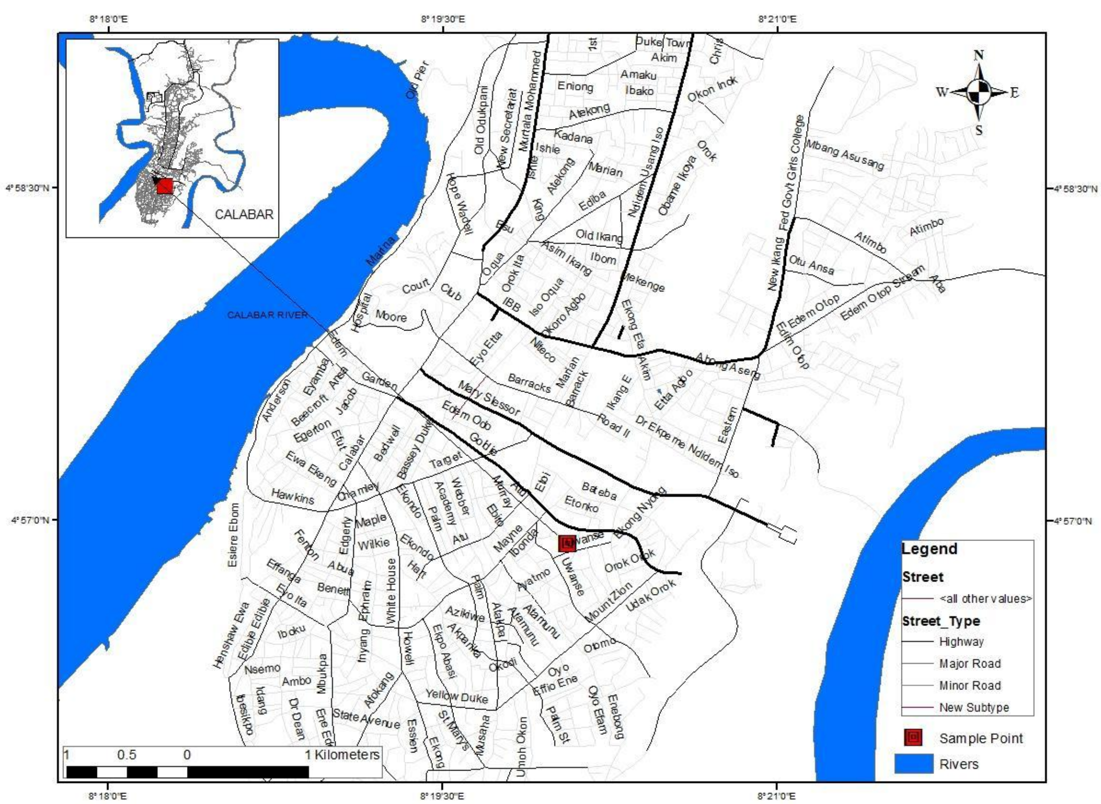

Fig. 1. Map of Calabar showing the location of the paint effluent

2.2 Collection and Acclimation of Test Organism

One hundred and fifty fingerlings of *Clarias gariepinus* were randomly selected and transported from the University of Calabar fish farm using two uncovered rubber buckets along with its habitat water between the hours of 8:00am and 9:00am. The fishes were visibly free of any deformities, lesions or disease. *Clarias gariepinus* used had a mean weight of 1.92 ± 0.34 g.

In the laboratory, the test organism was kept in a tank measuring 60 X 30 X 30 cm^3, filled with borehole water and continually aerated for a minimum of 14 days to allow them to acclimate to prevailing laboratory conditions. During the acclimation, the fingerlings were fed with Coppens feed at 5% of their body weight twice a day, and the culture water was changed daily to avoid accumulation of toxic waste metabolites and food particles.

2.3 Characterization of Paint Effluents

The paint effluents were analysed and its physico-chemical parameters determined. Dissolved Oxygen was measured using dissolved Oxygen (DO) meter (DO-5509 model) in mg/L, Hydrogen ion (pH) concentration was determined using a pocket sized pH meter (pH-1 model). A thermometer was used to measure temperature in degree Celsius. Electrical Conductivity was measured with the aid of Hannah conductivity meter (BM-211 model) to the nearest µs/cm. Also, the effluents were analysed using UV/VIS Spectrophotometer (HACH 5000) for levels of heavy metal.

2.4 Range Finding

Feeding was discontinued 48 hours to the time of commencement of the experiment. Range finding was carried out for 4 days to determine the definitive concentrations range. Ten fingerlings were put into each aquarium, then exposed to 4 widely spaced toxicant concentrations along with a control (borehole water), making it five concentrations. The fingerlings were exposed to the effluent for 96 hours [16].

2.5 Test Procedure

Fifteen glass aquaria of dimensions 60 X 30 X 30 cm^3 were used for the actual experiment. Ten fingerlings were randomly stocked in 4 aquaria containing 1 litre of culture water (borehole water) with the control as the fifth. Static non-renewal test method was used, meaning that the test organism maintained the same solution, same concentration, throughout the prescribed time interval. The fingerlings were exposed to 0%, 85%, 90%, 95% and 100% concentration of the paint effluent in a triplicate experiment. A total of 150 *C. gariepinus* fingerlings with a mean weight of 1.92 ± 0.34 g were used throughout the study. The mortality and general behaviour of fish were also observed after 24, 48, 72 and 96 hours of exposure. Fingerlings were considered dead when they cannot move any longer, even when touched with a glass rod. Dead fingerlings were removed immediately and then its mortality recorded.

Four water quality parameters were measured and recorded after 24, 48, 72 and 96 hours of contamination of culture water with the paint effluents using a pH meter (pH-1 model), Hannah conductivity meter (BM-211 model) to the nearest µs/cm., Dissolve Oxygen (DO) meter (DO-5509 model) to the nearest mg/L and Thermometer to the nearest °C for pH, conductivity, DO and temperature respectively.

2.6 Data Analysis

The mortality data obtained was subjected to Probit transformation. Regression analysis was also performed and the LC_{50} value was computed using Predictive Analytical Software (PASW). The 95% confidence interval was computed and the slope of the regression line was tested using chi-square. Analysis of variance (ANOVA) was also used to test for the significance of the difference in the physico-chemical parameters between each treatment group for each exposure duration at 0.05 level of significance and at their relevant degree of freedom. Descriptive statistics (mean and standard deviation) was used on the physico-chemical parameters data of the culture water obtained. Graph was plotted using Microsoft excel (MSE) version 2013.

3. RESULTS

3.1 Heavy Metals Characterization of Paint Effluents

The summary of the heavy metals levels of the paint effluent is shown in Table 1. After laboratory analyses, the paint effluents were found to contain various heavy metals ranging from zinc, copper, iron, cadmium, sodium, potassium, chromium, lead, arsenic, mercury, bitumen, and selenium. The result shows that the concentration of zinc (Zn^{2+}) (0.98 ± 0.01 mg/L) complied with WHO maximum permissible level of 15.0 mg/L. The concentration of copper (Cu^{2+}) in the effluents was high with 2.52 ± 0.12 mg/L compared with the standard approved by WHO which is 1.00 mg/L. Iron (Fe^{2+}) had amazingly high concentration of 7.01 ± 1.28 mg/L when compared with the WHO standard of 1.00 mg/L. Cadmium (Cd^{+}) concentration in the analyzed effluents was 1.50 ± 0.02 mg/L, which is quite high considering the 0.001 mg/L maximum permissible level of WHO. Sodium (Na+) and potassium (K+) had relatively low concentrations of 4.50 ± 1.86 mg/L and 3.00 ± 1.22 mg/L which are within WHO permissible limit of 200 respectively. A high 5.66 ± 2.10 mg/L value was recorded for chromium (Cr^{3+}) in the effluents sample when compared to 0.05 mg/L being the recommended WHO standard. Arsenic and lead concentration value of 0.51 ± 0.01 mg/L and 0.07 ± 0.01 mg/L respectively were higher than the 0.01 mg/L accepted by WHO. Furthermore, mercury (Hg^{2+}) and selenium (Se^{2+}) concentrations of 0.92 ± 0.02 mg/L and 3.11 ± 1.08 mg/L were above WHO permissible limit of 0.001 and 0.01 respectively (Table 1).

Table 1. Heavy metals concentration of paint effluents

Metal ions	Concentration	WHO limit
Zn^{2+}	0.98 ± 0.01	15.0
Cu^{2+}	2.52 ± 0.12	1.0
Fe^{2+}	7.01 ± 1.28	1.0
Cd^{+}	1.50 ± 0.02	0.01
Na^{+}	4.50 ± 1.86	200
K^{+}	3.00 ± 1.22	200
Cr^{3+}	5.66 ± 2.10	0.05
Pb^{2+}	0.07 ± 0.01	0.01
Hg^{2+}	0.92 ± 0.02	0.001
As^{3+}	0.51 ± 0.01	0.01
Bi^{3+}	2.50 ± 0.19	-
Se^{2+}	3.11 ± 1.08	0.01

3.2 Physico-chemical Parameters of Paint Effluent

The summary of the physico-chemical parameters of the paint effluent is shown in Table 2. The pH of the effluent sample was 6.35 ± 2.38 which is within the WHO permissible limit of 6.5 – 8.5, while the Biological Oxygen demand (BOD_5) value of 190.00 ± 12.62 mg/L was above the 30 mg/L acceptable limit. The Temperature of the effluent samples was 28.00 ± 5.21°C, which is within the 20 – 32°C WHO acceptable limit. Total dissolve solid concentration was 2.42 ± 1.02 mg/L, which complied with WHO Permissible limit of 500 mg/L. Electrical conductivity (EC) and Total suspended solid (TSS) values were 238 ± 16.52 µs/cm and 7.50 ± 2.11 mg/L respectively, which were within WHO permissible limit (Table 2).

3.3 Physico-chemical Parameters of Culture Water

The summary of the alterations in the physico-chemical parameters of water contaminated with different concentrations of paint effluents during 96 hours test period is shown in Table 3. The control had the values for temperature, conductivity, pH and dissolved oxygen (DO) as 28.300 ±0.020°C, 69.690 ± 0.438 µs/cm, 7.010 ± 0.218 and 6.555 ± 0.005 mg/L respectively (Table 3).

After 96 hours of contamination of water with 85% of the paint effluents, the values of 28.500 ±0.015°C were recorded for temperature, 72.300 ± 1.083 µs/cm for conductivity, 7.050 ± 1.283 for pH and 6.435 ± 0.003 mg/L for dissolved oxygen (DO). The water contaminated with 90% concentration of paint effluents after 96 hours had the values of 29.000 ± 1.050°C for temperature, 73.500 ± 0.707 µs/cm for conductivity, 7.500 ± 1.582 for pH and 6.375 ± 0.001 mg/L for dissolved oxygen (DO). The water contaminated with 95% concentration of paint effluents after 96 hours had the values of 29.030 ±0.001°C, 73.800 ± 1.021 µs/cm, 7.900 ± 2.651 and 6.365 ± 0.005 mg/L for temperature, conductivity, pH and dissolved oxygen (DO) respectively. The water contaminated with 100% concentration of paint effluent after 96 hours had the values of 29.500 ± 1.625°C for temperature, 85.625 ± 2.360 µs/cm for conductivity, 8.040 ± 0.014 for pH and 4.415 ± 0.558 mg/L for dissolved oxygen (DO) (Table 3). The lowest value of water temperature after 96 hours was observed in the control aquarium (28.300±0.020°C), while the highest value of water temperature was observed in the 100% paint effluent aquarium (29.500±1.625°C) (Table 3).

The lowest value of electrical conductivity after 96 hours was observed in the control aquarium (69.690 ± 0.438 µs/cm), while the highest value of water conductivity was observed in the 100% paint effluent aquarium (85.625 ± 2.360 µs/cm).

Table 2. Physico-chemical parameters of paint effluent

Parameter	Sample Conc.	WHO Limit
pH	6.35 ± 2.38	6.5 – 8.5
Biochemical oxygen demand (mg/L)	190.00 ± 12.62	30
Total dissolved solid (mg/L)	2.42 ± 1.02	500
Electrical conductivity (µs/cm)	238.00 ± 16.52	900
Temperature (°C)	28.00 ± 5.21	20 - 32
Total suspended solid (mg/L)	7.50 ± 2.11	30

Table 3. A 96 hours alterations in the physico-chemical parameters of water contaminated with different concentrations of paint effluent

Physico-chemical parameters	Paint effluent concentrations					
	0% (Control)	85%	90%	95%	100%	WHO Limit
Temperature (°C)	28.300 ± 0.020[a]	28.500 ± 0.015[b]	29.000 ± 1.050[c]	29.030 ± 0.001[d]	29.500 ± 1.625[e]	20 - 32
Conductivity (µs/cm)	69.690 ± 0.438 [a]	72.300 ± 1.083 [b]	73.500 ± 0.707 [c]	73.800 ± 1.021 [d]	85.625 ± 2.360 [e]	900
pH	7.010 ± 0.218 [a]	7.050 ± 1.283 [b]	7.500 ± 1.582 [c]	7.900 ± 2.651 [d]	8.040 ± 0.014 [e]	6.5 – 8.5
DO (mg/L)	6.555 ± 0.005 [a]	6.435 ± 0.003 [b]	6.375 ± 0.001 [c]	6.365 ± 0.005 [d]	4.415 ± 0.558 [e]	>6

Values are in mean ± Standard deviation
Values with different superscript are significantly different at P<0.05

The lowest value of water pH after 96 hours was observed in the control aquarium (7.010 ± 0.218), while the highest value of water pH was observed in the 100% aquarium (8.040 ± 0.014). The lowest DO value after 96 hours was observed in the 100% paint effluent aquarium (4.415 ± 0.558 mg/L), while the highest value of DO was observed in the control aquarium (0%) (6.555 ± 0.005 mg/L) (Table 3). Statistically, the values of temperature, conductivity, pH and DO in water varied significantly between the water contaminated with different concentrations of paint effluents at $P<0.05$ (Table 3).

Temperature, conductivity and pH of water contaminated with the paint effluents increased with increase in the concentration of effluents added to the culture water in each aquarium. The water DO decreased with increase in the concentration of the effluent introduced into each aquarium (Table 3). The water temperature, electrical conductivity and pH of the water contaminated with 0%, 85%, 90%, 95% and 100% effluents after 96 hours were all within the WHO acceptable limits. The level of dissolved oxygen was above WHO permissible limits for the 100% effluents group, but the 0%, 85%, 90% and 95% effluents group were all within the WHO acceptable limits (Table 3).

3.4 Mortality Profile of *C. gariepinus* Fingerlings Exposed to Paint Effluents

The summary of the survival and mortality profile of *Clarias gariepinus* fingerlings exposed to different concentrations of paint effluent is shown in Table 4. The *C. gariepinus* fingerlings exposed to 0% (control) concentration of paint effluent had 10 survivors and with a 100% survival rate. No fingerlings mortality was recorded in the control group, having a 0% mortality. The 85% effluent concentration recorded 8 survivors and with 80% survival rate. Fingerlings mortality of 2 was recorded for the 85% effluent group, having a 20% mortality. The 90% effluent concentration recorded 6 survivors (60% survivor). Fingerlings mortality of 4 was recorded for the 90% effluent group (40% mortality). The 90% effluent concentration recorded 6 survivors (60% fingerlings), while mortality of 4 was recorded for the 90% effluent group (40% fingerlings mortality). The 95% effluent concentration recorded 1 survivor (10% fingerlings survivor). Fingerlings mortality of 9 was recorded for the 95% effluent group (90% fingerlings mortality), while no survivor was observed for the 100% paint effluent group (0% survivor). Fingerlings mortality of 10 was recorded for the 100% group (100% mortality) (Table 4).

3.5 A 96 hours Probit Transformation

The summary of the probit transformation mortality data for *C. gariepinus* exposed to different concentration of paint effluent is shown in Table 5. The mortality data trend of fingerlings exposed to the effluent was concentration dependent (Table 4). The fingerlings of *C. gariepinus* showed signs of stress, erratic behaviour and gasping for air when exposed to different concentrations of effluents, due to respiratory impairment.

The regression equation for the probit transformation of *Clarias gariepinus* fingerlings exposed to different concentration of effluent was $y = 32.888X - 1.7072$ (Table 6) and was significant at $P<0.05$, yielding a determination coefficient (r^2) of 0.95 (Table 6), chi-square value of 1.196 (Table 7) and a 96 hours LC_{50} with 95% confidence limit values of 39.81% ± 12.681 (Fig. 2) (Table 8). The lower and upper limit values were 59.32 and 84.68 respectively (Table 8).

Table 4. A 96 Hours survival and mortality profile of *Clarias gariepinus* fingerlings exposed to different concentrations of paint effluent

Effluent concentration (%)	Survival	% Survival	Mortality	% Mortality
0	10	100	0	0
85	8	80	2	20
90	6	60	4	40
95	1	10	9	90
100	0	0	10	100

Table 5. A 96 Hours Probit transformation of mortality data of *Clarias gariepinus* fingerlings exposed to different concentrations of paint effluents

Conc (%)	Log Conc (x)	N	R	P	M_R	Y	R_P	*P*
0	0.00	10	0	0.00	0	0.00	0.00	0.00
85	1.929	10	2	0.20	20	1.340	0.660	0.134
90	1.954	10	4	0.40	40	5.289	-1.289	0.529
95	1.978	10	9	0.90	90	8.827	0.173	0.883
100	2.000	10	10	1.00	100	9.877	0.123	0.988

n = Number of fish fingerling tested at each concentration, r = Number of fish fingerling responding, p = Response rate, r/n, M_R = Mortality rate, Y = Expected probit from visual regression line, R_P = Residual probit, P = Probability

Table 6. Results of regression analysis of 96 Hrs Log Concentration–probit relationship of *Clarias gariepinus* fingerlings exposed to different concentrations of paint effluent

Conc. (Log Unit)	Response rate, p	Equation	Co-efficient of determination, r^2	Significant level, α
0.00	0.00			
1.929	0.20			
1.954	0.40	Y = 32.888X – 1.7072	0.95	0.05 (S)
1.978	0.90			
2.000	1.00			

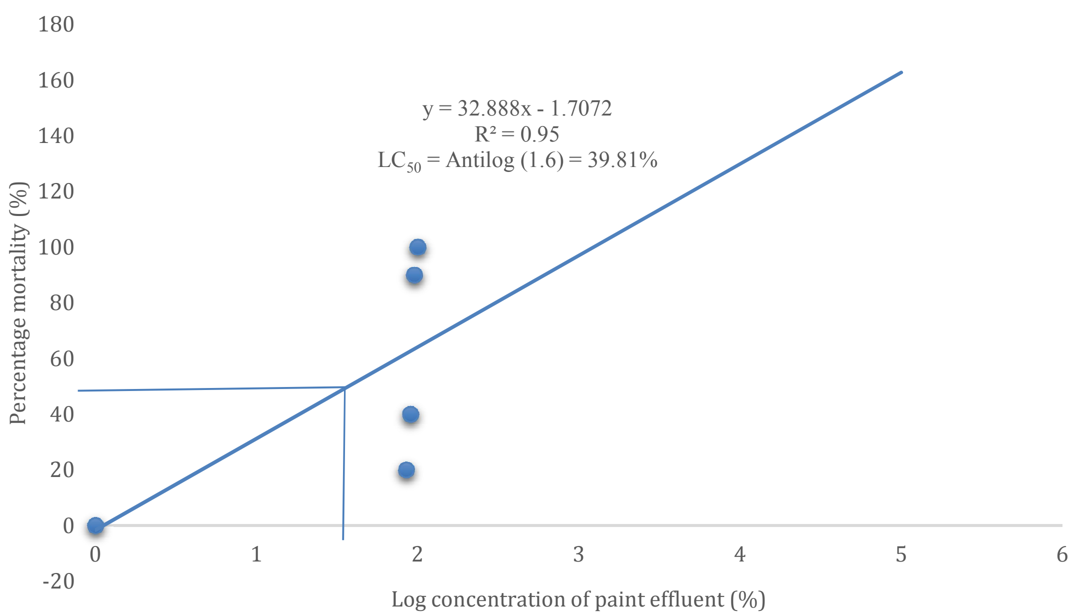

Fig. 2. Probit transformation graph of *Clarias gariepinus* fingerlings exposed to different Concentrations of effluents

Table 7. Chi-square tests of *Clarias gariepinus* fingerlings exposed to different concentrations of paint effluents

	Chi square	df[a]	Sig.
PROBIT Pearson Goodness-of-Fit Test	1.195	2	0.05[a]

Table 8. LC_{50} with 95% confidence limits of *Clarias gariepinus* fingerlings exposed to concentrations of paint effluents

LC_{50} with ± 95%CL	Confidence limits	
	Lower	Upper
39.81% ± 12.681	59.32	84.68

4. DISCUSSION

Coastal water bodies in Africa are mainly polluted by run-off and industrial discharge [9]. Nutrients in sewage such as nitrogen and phosphorus promote excessive algal blooms, which depletes oxygen in the water and leads to fish kills and destruction of other aquatic life. In areas where industrial waste effluents are discharged into surface waters, there is general reduction in the quality of such water and its ability to support aquatic life is equally reduced [8].

The present study revealed variations and increase in the physico-chemical parameters of contaminated water with an increase in the concentration of the paint effluent except for DO which decreased with increase in the effluent concentration, this corroborated with the reports of Adeboyejo et al. [17] who also reported alterations in the physico-chemical parameters of water while studying the acute toxic effect of industrial effluents from Agbara Industrial environs of Ologe lagoon for 96hours, and the findings of [18] who reported alterations in the studied water physico-chemical parameters while studying the acute toxicity of copper (11) tetraoxosulphate on Cat fish fingerlings. The gradual reduction in the physico-chemical parameters of water with an increase in the concentration of the effluent observed in the present study corroborated with the findings of [18]. The reduction in the dissolved oxygen and increase in water pH with effluent concentration increase could be due to the increase in the micro-organisms and microbial activities in the culture water, which correspondingly increases the oxygen demand of the microbes. Also, the increase in the conductivity of culture water with increased effluent concentration could be due to the increased chemical ions associated with the paint effluent. In general, temperature, conductivity, pH values were higher and the DO level was lower in the aquarium contaminated with the highest concentration of the effluent (100% paint effluent concentration) than in the control aquarium. Similar observations were reported by Adeboyejo et al. [17], who were studying the acute toxicity of industrial effluents from Agbara environs of Ologe lagoon on early life stages of *C. gariepinus*. Statistically, the physico-chemical parameters varied significantly across the different culture water group contaminated with different concentrations of the effluent at $P<0.05$, and this was contrary to the report of Adeboyejo et al. [17] who reported insignificant alterations in the physico-chemical parameters except for dissolved oxygen.

The mean water temperature and dissolved oxygen of culture water contaminated with 100% paint effluents were higher than that reported by Adeboyejo et al. [17]. The variation between the two findings could be due to the difference in the toxicants, length of formation of the effluents and differences in composition of the test toxicant. All the physico-chemical parameters of water were within the WHO acceptable limits except the dissolved oxygen for the 100% effluent group which was above the permissible limit. This made the water contaminated and unconducive for the fingerlings thereby causing mortality. Even as most of the water parameters (pH, temperature, and conductivity) were within the WHO acceptable standard after 96 hours of contamination with paint effluents, there is a high tendency of a chronic contamination of the water over a long period of time, leading to its pollution. Apart from the alteration of the water and fingerlings mortality, the fish (biological organisms) could accumulate the toxicants from the paint effluents into their tissues, which are consumed by humans, leading to lots of health challenges.

In Nigeria, paint production utilizes large volume of water without adequate wastewater treatment plan. Hence, large quantities of both hazardous and non-hazardous wastes are inherently released to the environment, thus causing health related problems, ecological imbalance and bio-accumulations in aquatic organisms [3]. Increase in volume and diversity of effluent generation causes eutrophication of water bodies, destruction of fisheries, and decrease in the aesthetic and recreational values of water resources, leading to water pollution [4]. Water pollution affects organisms and plants that lives in these water bodies and in almost all cases, the effect is damaging not only to the individual species and populations, but also to the natural biological communities [5]. Fishes living in rivers/lagoons receiving high discharges of effluent from industries, experience physiological abnormalities, due to estrogenic chemicals known to be present within treated or/and untreated industrial effluents [12]. The presence of environmental stress such as low dissolved oxygen, high temperature and high ammonia reduces the ability of organisms to maintain its internal environment (i.e. metabolism, catabolism) [19]. Fish growth depends on water quality to boost its production and physicochemical parameters are known to affect the biotic components of an aquatic environment in various ways [20].

The toxicity of effluents on *C. gariepinus* fingerlings in the present study was concentration dependent, and this corroborated with the findings of Adeboyejo et al. [17]. The fingerlings of *C. gariepinus* exposed to different concentrations of the effluents showed abnormal behaviours and appearance like; repeated darting movement within an hour of introduction, darkening in the eye and on the skin, spiral swimming and death, erratic swimming, loss of balance due to impaired metabolism and nervous disorder due to respiratory impairment, and this was similar to the findings of several authors [21,22,23].

In the present study, 100% mortality of *C. gariepinus* fingerlings was observed in the group exposed to 100% paint effluent after 96 hours, which differed from the report of several authors [24,25] who reported 45% and 18.5% mortality respectively for 100% exposure to different landfill leachates. This denotes that the paint effluents are less toxic than the compared land fill effluents. The differences in the mortality of the test fingerlings for the different studies could be due to the difference in composition of the toxicant, length of formation of toxicants, fish species and age of fingerlings. Also, the difference could be due to the fact that the response of fish to variety of metal and organic pollutants are transient and are dependent on species, enzymes and contaminants [26].

The 96 hours LC_{50} with 95% confidence limit for *C. gariepinus* exposed to different concentrations of the paint effluents was 39.81% ± 12.681, and this high value indicates that the paint effluents used for the study is less toxic. The 96 hours LC_{50} value observed in this study was higher than that reported by Adeboyejo et al. [17] (LC_{50} of 34.03%) who were studying the acute toxicity of industrial effluents from Agbara environs of Ologe Lagoon on early life stages of *C. gariepinus*; [27] (LC_{50} of 9.50%) who were studying the toxicity and behavioural changes in *Rasbora daniconius* exposed to lethal concentration of paper mill effluents and [28] (LC_{50} of 6%) who were studying the toxic effect of paper and pulp mill effluents on different parameters of bioenergetics in the fingerlings of *Oreochromis anossambicus*. The discrepancies in the 96 hours LC_{50} value of the different study could be due to the difference in composition of the toxicant, the difference intoxicant, duration of effluent existence, fish species and age of fingerlings used. The difference could also be due to the fact that the response of fish to variety of metal and organic pollutants are transient and are dependent on species, enzymes and contaminants [26]. The higher LC_{50} value observed for the present study denotes that the paint effluents are less toxic than leachates and other effluents which have been compared in this study. Despite the low toxicity of the paint effluent, it still led to the mortality of the fingerlings and are also capable of causing bacteria or viral contamination of fisheries and shell fish beds, thus resulting in high risk to public health [6].

The mortality data trend of fingerlings exposed to the effluents was concentration dependent. The fingerlings of *C. gariepinus* showed signs of stress, erratic behaviour and gasping for air when exposed to different concentrations of the paint effluents, due to respiratory impairment. The test toxicant was less toxic as shown by its high LC_{50} value, but was still able to kill the test fingerlings.

5. CONCLUSION

In conclusion, the paint effluents caused significant alterations in the physicochemical parameters of water compared to the control aquarium water, increasing in some cases (temperature, pH and conductivity), and reducing in some cases (DO). Also, the paint effluent raised some water parameters to undesired levels, leading to the bio-accumulation of toxicants in the fingerlings, possibly causing diseases to human who consumes them. The paint effluent was less toxic, though still toxic to fingerlings at increased concentrations. The toxicological effects of the effluents were concentration dependent. Also, it is evident that concentration of some metal contaminants such as zinc, sodium and potassium were low in the paint effluent, but the effluents were polluted with the other metals evaluated. Nevertheless, continuous discharge could cause serious toxic effects to the environment.

ETHICAL CONSIDERATION

The authors ensured that all ethical and other basic principles underlying behaviour and advancing welfare for the use of animals in research, including handling, relevant laws and regulations were considered before proceeding with the research. Permission was also received from the relevant bodies over the use of fish for this experiment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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