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Research article

Toxicity Assessment Of Challawa Industrial Effluent On African Catfish (*Clarias gariepinus*, Burchell, 1822) In Kano, Nigeria

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ABSTRACT
Industrial effluents contaminate water bodies and harm aquatic biota. In this study, industrial effluent was collected from Challawa Industrial Area, Kano State and analyzed for physicochemical conditions, heavy metals concentrations and impact on the survival of juveniles of *Clarias gariepinus* under standard laboratory conditions, using Completely Randomized Designed (CRD) with three treatments (0.00ml/L, 5ml/L and 10ml/L) in three replicates. Test fish with a mean weight of 183.2g and a mean length of 24.1cm were purchased from Kano State Ministry of Agriculture and Mineral Resources, Department of Fishery and Aquaculture, Fisheries Unit and acclimated in 100L tank for 14 days. The test fish exhibited abnormal respiratory action, opercular movement, body movement and mucus secretion with increase in the concentrations of the effluent. The mean values of DO (2.59±0.05mg/L), temperature (29.0±0.10°C) and pH (10.28±0.00) varied slightly between the control and the effluent. The mean values for Turbidity, Total alkalinity, TDS, Electrical conductivity and Chloride were beyond FAO/WHO (2018) recommended limit with exception of temperature. Heavy metals concentration in the effluent was: Pb > Cu > Fe > Zn > Cd > Mn > Cr and decreased in gill and liver tissues (Fe > Zn > Cu > Mn > Pb > Cr > Cd). In conclusion, exposure to varying concentrations of the effluents caused toxicity signs, death and considerable damage to tissues of *C. gariepinus* during the study period. The study recommends that regulatory bodies should adopt holistic approach on aquatic pollution abatement, due to its negative impact to non-target organisms.

Keywords: African catfish, Challawa Industrial effluent, Heavy metals, physicochemical conditions, Toxicity

INTRODUCTION

Contamination of aquatic ecosystem with industrial effluents have become a source of concern not only because of their threats to aquatic biota but also due to public health implications of such pollutants (Reddy, 2018). Human activities including industrialization and agricultural practices contribute immensely in no small measure to the degradation and pollution of the environment, which adversely affects the quality of many water bodies (Jamila and Sule, 2020). The aquatic environment is a sink of toxic contaminants, which find their way to the water bodies through industrial, domestic and agricultural activities; these toxic chemicals disturb the integrity of the aquatic environment and adversely affect aquatic animals (Rabiu *et al*., 2018). The contamination of water from rivers or land by industrial effluent could cause a pronounced health and environmental hazard as reported by Javed and Usmani (2014). Abattoir wastes have been reported to contain a large amount of suspended solids, organic matter and other contaminants (Sani *et al*., 2020). Aquatic ecosystem contamination is considered among the important environmental problems. In Nigeria, one of the serious aspects of environmental problems is water pollution especially in places with many industrial activities taking place (Ali *et al.*, 2018).

Wastewater containing heavy metals are produced by many manufacturing processes and find their way into the aquatic environments (Shawai *et al*., 2018). Fishes and other organisms (humans inclusive) in their habitats come across many challenges including extinction as a result of exposure to such polluted water. Fish could accumulate some toxic compounds in their body because they are at the top of food chain (El-Moselhy *et al*., 2014).

Discharge of industrial effluents from Lagos and Abeokuta into Ogun River was reported to result in high faecal coliform count in all the sampling sites (Jaji *et al.*, 2007). Similarly, discharge of untreated water from Challawa and Sharada industries into Challawa River was identified as the major factor responsible for its contamination, which can lead to various diseases such as skin diseases due to high chromium content from tannery industries (Dan'Azumi and Bichi, 2010). It was also reported that in the tannery industry, the production of 1 ton of hides per day requires water consumption of 50m3. This quantity of water is equal to the daily water consumption of 250 urban people (Kaul *et al*., 2005).

Increase in human population, industrialization, agriculture and increasing anthropogenic activities have contributed significantly to aquatic pollution in Nigeria (Ahmad *et al*., 2018). Chemical pollution as a result of untreated effluent discharges and inadequate waste management and disposal appears to be the major sources of aquatic pollution in developing countries (Ahmad *et al*., 2018). A large number of chemical pollutants, due to their persistency in the environment and accumulation over time have been reported to impair water quality, making it unsuitable for aquatic life, domestic, recreation and industrial purposes (Alimba *et al*., 2015).

Studies on the effects of effluents on well-being of fish fauna in aquatic environment have been on the increase. Ibrahim (2009) reported that various substances released from Challawa industrial areas enter the aquatic ecosystems and produce alterations in survivability of aquatic biota. These pollutants can be essential at a very low concentration and at higher levels have the ability to override their importance thereby resulting in many adverse health effects that include damage to the liver, renal failure and sometimes death. This study was carried out to determine the effect of Challawa Industrial effluents on African catfish (*Clarias gariepinus*), which appears to be scanty in literature.

MATERIALS AND METHODS

Study Site

The study site was ’Yan Danko Village in Kumbotso local government area of Kano State, where raw industrial effluent, primarily from food, textile and tannery industries is mixed up with the Challawa River water.

Effluent Collection

The industrial effluent discharged into River Challawa, Kano State was collected in August, 2017, within the stretch of thirty (30) meters away from the point of discharged (N 11º52.745', E 008º28.473') into the River Challawa, close to Challawa River at ’Yan Danko Village in the direction of flow. Grab samples of effluent produced by the industries was collected using 25L jerry cans washed with water and then rinsed with the effluent (Tolulope *et al*., 2019).

Source of Fishes Used in the Experiment

Thirty four (34) post-juvenile catfish (C. *gariepinus*) in total, with a mean weight of 183.2g and a mean length of 24.1cm were purchased from Kano State Ministry of Agriculture and Mineral Resources, Department of Fishery and Aquaculture, Fisheries Unit, and were transported to Department of Biological Sciences, Bayero University, Kano. The fish were kept in a 200-liter plastic tank that was regularly refilled with dechlorinated water. They were acclimated for two weeks (14 days) in a semi-static 28°C environment in a laboratory setting. A 2mm pelletized meal (42% crude protein) made by Vital Fish Feed Nigeria Plc. was given to them twice daily at 5% of their body weight. Feeding was stopped 24 hours before the toxicity test. The study was conducted at the Department of Biological Sciences, Bayero University, Kano following

OECD (2013) recommended technique in 40L plastic containers. The experimental and control groups of *C. gariepinus* were exposed to 3-level of exposure to the variable concentrations of the effluent in a completely randomized design (CRD). By combining effluent with distilled water. Two test solutions (5ml/L and 10ml/L) were prepared, and 0.00ml/L containing normal borehole water, served as control.

Acute Toxicity Experimentation

The protocol outlined by the OECD (2013) was used to calculate the definitive concentration for the range-finding test on the effluent. An acute toxicity test was carried out to determine the 96-hour LC_{50} of the effluent. The test was run for 12, 24, 48, 72, and 96 hours in triplicate. To get the LC_{50} values, data on mortality from effluent exposure was collected at 24-hour intervals.

Exposure regimes

The fish were exposed by adding a known concentration of effluent based on the different effluent groups (5ml/L and 10ml/L) to the containers. These concentrations were developed based on range finding tests described by OECD (2013). They received the following treatment schedule:

Group I: Control (no exposure to effluent).

Group II: 5ml effluent per litre.
Group II: 10ml effluent per litre.

Observation of Behavioral Responses

After exposure of the fishes to the various concentrations of the effluent for thirty (30) minutes, the fish behaviors, including respiratory action swimming, air gulping, loss of reflex and mucous secretion were monitored as adopted by Rakesh and Kumar (2019). When there was no discernible movement or no reaction to light poking, fish are considered to be dead. Following the procedure used by Saiyadi *et al*. (2022), the water samples were promptly evaluated for Colour, pH, Total Dissolved Solids (TDS), Dissolved Oxygen (DO) and Electrical conductivity using a multifunction water testing kit (Model no. EZ-9909-SP).

Digestion of Fish and Water Sample

A total of 100ml water samples were poured into a 250ml beaker. After adding 10ml of HNO_3 and heating it to 100°C, the samples were allowed to evaporate to roughly 50ml before another 5ml of HNO_3 was added and heated continuously until it reached a final volume of 15ml. The digested samples were filtered and given a final volume of 20 ml after dilution with 5 ml of distilled water. According to the methodology used by Saiyadi *et al*. (2022), concentrations of Cadmium, Chromium, Nickel, Manganese, Iron, Zinc and Lead were examined in the water at the Centre for Dryland Agriculture (CDA) Laboratory, Bayero University, Kano, using Microwave Plasma Atomic Spectroscopy (MP-AES).

The fish samples were dissected using the procedure adopted by Ahmad *et al*. (2018). Gills and liver were removed and oven dried at temperature of 105°C until it reached a constant weight. Each organ was grinded into powdery form and kept in the desiccator prior to digestion. The powdered samples were homogenized and subjected to digestion using concentrated nitric acid and hydrogen peroxide (1:1) v/v as adopted by Samson (2015). The powder samples (2g) were added into 250ml round bottom flask and 10ml each of HNO_3 and H_2O_2 were added and the content of the flask was allowed to undergo digestion. The content of the flask was heated on a heating mantle to a temperature of 130°C till dissolution inside a fume hood reduced to 4ml. The digested samples was allowed to cool and filtered into conical flask. The filtered sample was transferred to a 50ml volumetric flask and de-ionized water was used to further dilute the sample to 50ml in the volumetric flask.

Determination of Bio-Accumulation Factor (BAF)

Bioaccumulation Factor (BAF) was calculated using the protocol described by Vaseem and Banerjee (2013):

$$BAF = \frac{Cf}{Cw}$$

where, Cf is concentration of metal in fish tissue (mg/Kg) and Cw is metal concentration in water (mg/L).

Statistical Analyses

Probit Analysis was used to calculate the experimental fish's mortality profile (LC_{50}) using SPSS version 20.0. After a one-way analysis of variance (ANOVA) was conducted to determine the effect of various effluent concentrations on the experimental fish (*C. gariepinus*), the means were compared using the LSD test at a probability level of 5%.

RESULTS AND DISCUSSION

Physicochemical and Heavy Metals Parameters

Table 1 presents the mean values of water physicochemical parameters for the control and treatment groups before exposure to varying effluent concentrations. Eight parameters were determined before the treatment. These are Temperature, pH, turbidity, Alkalinity, EC, TDS, DO and Chloride respectively. The mean values of the parameters varied between the control and the effluent during the exposure period, with considerable changes in turbidity, alkalinity, TDS, EC and Chloride. The mean values recorded were beyond the FAO/WHO (2018) recommended range with exception of temperature.

Table 1: Mean ±SD Values of Physicochemical Parameters of Industrial Effluent Obtained from Challawa Industrial Area, Kano State, Nigeria

Water quality parameters	Control	Effluent	Standard limits
Temperature (°C)	28.51±0.11	29.0±0.10	<30.0**
pH	6.50±0.00	10.28±0.00	6.5-8.5*
Turbidity (NTU)	4.50±0.10	60.0±0.10	<25 NTU**
Total Alkalinity (mg/l)	150.0±0.11	1035.0±0.32	
Electrical conductivity (µS/cm)	131.0±0.32	3990.0±0.06	<1000 µ/Scm*
Total dissolved solid (TDS) (mg/l)	161.0±0.54	8230±0.03	<500mg/L**
Dissolved oxygen (DO) (mg/l)	5.20±0.19	2.59±0.05	5.0-9.0mg/L*
Chloride (Cl^{-1}) (mg/l)	60.0±0.11	359±0.32	<250mg/L**

Keys: Control = borehole water, Effluent, * = FAO/WHO (2018), ** = WHO (2011)

Toxicity Symptoms

Toxicity signs in response to varied concentration levels of the effluent were observed in the test as well as in the control group. Immediately the fish were introduced into varying concentrations of the effluent (0.00mg/L, 5ml/L, 10ml/L), normal respiratory action, normal body movement, normal opercular movement and no mucus secretion were examined in the control and lowest concentrations. This pattern persisted for 96hr exposure period. The different toxicity symptoms shown by the test animals are presented in Table 2.

Table 2: Behavioral Changes Observed by *Clarias gariepinus* during 96hr Exposure to Varying Effluent Concentrations

Exposure time (hr)	Concentration (ml/L v/v)	Respiratory action	Body movement	Mucus secretion	Opercular movement
	0.00	-	-	-	+++
12	5.00	-	-	+	+
	10.0	++	+	++	++
48	0.00	-	-	-	-
	5.00	-	+	+	+
	10.0	+++	++	++	-
72	0.00	-	-	-	-
	5.00	+	+	-	+
	10.0	++	++	-	-
96	0.00	+	-	-	-
	5.00	+	+	-	-
	10.0	++	+	+	-

Keys: None = -, Mild = +, Moderate = ++, Strong = +++

Behavioral Changes Recorded in Clarias gariepinus During Acute Exposure to Industrial Effluent

Table 3 presents the fish survival and cumulative mortality profile on exposure to various test concentrations of the effluent.

Table 3: Cumulative Mortality Profile of *Clarias gariepinus* Exposed to Varying Concentrations of Industrial Effluent

Exposed conc. (ml/L, v/v)	No. of fish exposed	No. of live fish at different duration (hrs.) 24	48	72	96	% survival	% mortality
0.00	10	10	10	10	10	100	00
5.00	10	10	09	09	09	90	10
10.00	10	09	08	07	07	70	30

Among the heavy metal concentrations in the fish tissue, Cu had the highest mean concentration (4.484mg/L) while Cr (0.990mg/L) had the least. The heavy metal concentrations in the fish decreased in the following order: Cu > Pb > Cd & Mn > Zn > Fe > Cr.

Table 4: Mean ±SD Concentrations (mg/kg) of Heavy Metals in Control and Industrial Effluent from Challawa Industrial Area, Kano State, Nigeria

Heavy metals	Effluent	Control	WHO (2011)
Cu	2.848±0.16	ND	0.05
Pb	3.463±0.11	ND	0.10
Cr	1.290±0.60	ND	0.05
Mn	2.000±0.71	ND	0.05
Cd	2.001±0.96	ND	0.01
Fe	2.450±0.33	0.32	5.00
Zn	2.350±1.05	0.98	5.00

Key: ND = Not Detected

Table 5 illustrates the variation of heavy metals concentrations in liver and gills of *C. gariepinus*.

Table 5: Heavy Metals Concentrations (mg/g) in Liver and Gills of *Clarias gariepinus* Exposed to Industrial Effluent

Metals Conc. (mg/g)	Tissues	Effluent	Control	BAF	FAO/WHO (2018)
Cr	Liver	0.02±0.10 [a]	0.03±1.01 [a]	3.21	0.05
	gills	0.59±0.01 [a]	0.01±0.00 [a]	2.76	
Cu	Liver	1.37±0.01 [ab]	0.05±0.01 [b]	4.08	2.0
	Gills	2.11±0.01 [a]	0.01±0.00 [a]	0.12	
Pb	Liver	0.34±0.01 [a]	0.03±0.01 [a]	0.35	
	Gills	0.62±0.02 [b]	0.06±0.01 [a]	1.6	0.01
Mn	liver	0.60±0.10 [a]	ND	1.6	
	gills	0.91±0.01 [a]	0.01±0.00 [ab]	2.00	0.05
Fe	Liver	3.51±0.01 [a]	0.01±0.01 [a]	1.78	0.05
	gills	8.01±0.01 [b]	0.10±0.001 [a]	3.20	
Zn	Liver	4.03±0.01 [a]	0.01±0.00 [ab]	1.84	5.0
	gills	3.02±0.01 [a]	0.02±0.01 [a]	1.15	
	Liver	0.11±0.01 [a]	0.01±0.00 [a]	0.12	
Cd	gills	0.40±0.01 [a]	0.01±0.00 [a]	1.04	0.01

Note: Mean values with different superscripts alphabets in a column differed significantly with LSD (P<0.05)

As a results of exposure to varying effluent concentrations, the mean Dissolved Oxygen decreased among the treated groups compared with control group (Table 1). The decrease in DO could either be due to change in the rate of uptake during respiration by the fish or due to oxidative breakdown of the test compounds in the effluent. The mean DO recorded after the exposure was below the recommended limit of 5.0mg/L by FAO/WHO (2018) for freshwater bodies.

Variation in the effluent temperature mirrored changes in environmental conditions, with higher temperatures linked to increased solar radiation. The recorded temperatures were unsuitable for aquatic life, supporting findings by Reddy (2018). Effluent pH fluctuations, caused by respiratory activity of experimental fish, showed alkaline levels (mean pH > 10.00), affecting fish physiology, aligning with Ibrahim *et al*. (2021). Effluent turbidity was higher than controls, indicating dissolved compounds reducing water transparency, potentially hazardous to aquatic species, similar to Sani *et al.* (2020). High turbidity was attributed to suspended materials and dissolved substances, raising TDS levels above FAO/WHO (2018) limits, altering fish metabolism. Electrical conductivity exceeded control levels, indicating high mineralization from industrial pollutants, surpassing FAO/WHO (2018) standards.

Experimental fish exposed to the effluent exhibited respiratory distress, mucus secretion, and irregular movements, indicating environmental discomfort due to dissolved chemicals, consistent with Galadima *et al*. (2011). Mucus secretion was a protective response against chemicals, as noted by Nafiu *et al*. (2022). Opercular movement initially increased, then decreased, possibly due to physiological disruption, causing hypoxia, aligning with Sani *et al*. (2020).

Effluent metal analysis showed Pb with the highest concentration (3.463mg/L) and Cr the lowest (1.290mg/L), with high Pb levels attributed to domestic waste and geological factors, consistent with Akintujoye *et al*. (2013) and Samuel *et al*. (2021). Pb levels exceeded WHO (2011) freshwater limits. Metal concentrations in fish liver and gills were above FAO/WHO (2018) standards, except Cr, with high Pb in gills linked to direct contact with contaminated water, runoff, and agrichemicals, consistent with Nafiu *et al*. (2020) and Imam *et al*. (2012).

Conclusion and Recommendations

The industrial effluent was found to be toxic to the test experimental fish at 5ml/L and above over the 96hr. exposure period. The affected fish exhibited toxicity symptoms such as respiratory challenges, abnormal body movement, mucus secretion and low rate of opercular movement that increased with exposure period and effluent concentration. Therefore, it was advised that regulatory bodies should develop comprehensive strategies for reducing aquatic pollution. Given the detrimental effects on numerous non-target organisms, strict pollution mitigation measures should also be enforced to prevent the illegal release of industrial effluent into water bodies without approppriate treatment.

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Conflicts of Interest

The authors declare no conflict of interest.

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