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Assessment of the growth performance and haematological indices of *Clarias gariepinus* fingerlings exposed to soap effluent

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Abstract

Background: Various substances released from modern complex human societies which enter the aquatic ecosystems produce alterations in survivability of aquatic biota. This study assesses the consequence of exposure to industrial effluents containing potentially hazardous constituents, especially soap industrial waste effluent, relative to fish physiology, growth and survival, particularly food fish such as *Clarias gariepinus*. Five hundred (500) fingerlings of *C. gariepinus* (15.65 ± 0.02 g) randomly stocked at 50 fish per tank in duplicates were exposed to varying concentration (0, 0.32, 0.66, 1.31 and 2.63%) of homogenous effluent sample and fed Durante® floating feed at 5% of the body weight in two instalments per day for 180 days. The growth performance and feed utilization data were generated to determine the growth performance indices. The haematological parameters of the fish were also determined following routine methods of fish haematology.

Result: Generally, fish in the control had significantly ($p < 0.05$) better growth performance indices compared with the exposed fish. It was also observed that most of the significant increase or decrease observed in the growth performance was concentration dependent. Increase in HES concentration which significantly increases ($p < 0.05$) WBC count of the experimental fish was observed to decrease ($p < 0.05$) the HGB level of the fish. Significantly higher ($p < 0.05$) levels of RBC ($3.02 \pm 0.03 \times 10^6$/μL) and HCT (36.70 ± 1.68%) were recorded in the control fish. However, all the exposed fish had significantly higher ($p < 0.05$) levels of platelet count compared with the control.

Conclusion: This study concluded that exposure to concentrations of soap effluent induced stress, inhibited growth and altered the haematological indices of the exposed fish. Uncontrolled discharge of soap effluent into receiving water bodies, apart from affecting the wellbeing of an important freshwater food fish, there is every probability of possible accumulation of the chemical/toxic additives of the soap effluent which could have serious implications considering the man as the major and final recipient of these toxic bioaccumulated chemicals via the food chain and the environment.

Keywords: *Clarias gariepinus*, Sub-lethal, Haematological indices, Growth performance, Soap effluent

Background

Over the years, aquatic pollution has been a major environmental concern globally. Increase in human population, civilization, industrialization and increasing anthropogenic activities have contributed greatly to aquatic pollution in developing countries (Siyanbola et al., 2011). Chemical pollution as a result of untreated

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effluent discharges and inadequate waste management and disposal appears to be the major sources of aquatic pollution in developing countries (Ekiye & Zeijao, 2010; Olayinka & Alo, 2004). Earlier studies have shown that less than 10% of industries in developing countries treat their effluents before being released into the nearby streams or rivers (Adewoye et al, 2010; Essoka & Umaru, 2006).

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 (Agrawal et al., 2010; Ahmed & Tanko, 2000; Olayinka & Alo, 2004; Siyanbola et al., 2011; Taiwo et al., 2012; Wakawa et al., 2008).

Studies on the effects of pollutant and/or effluents on well-being of fish fauna in aquatic environment have been on the increase. Adewoye et al. (2010) reported that various substances released from modern complex human societies which enter the aquatic ecosystems produce alterations in survivability of aquatic biota. Range of alterations related to physiological abnormalities in fish living in polluted rivers/lagoons which are recipients of high discharges of effluent from industries were reported by Vethaak et al. (2002), Olayinka and Alo (2004) and Siyanbola et al. (2011). Several authors also reported that mixtures of chemicals interact synergistically in an additive manner to induce effects on the reproductive physiology of fish at lower concentrations than when they act individually (Brian et al., 2007; Thorpe et al., 2001, 2003). Agrawal et al. (2010) reported that the impact of the toxicants could be well understood by analysing either blood or serum of the fish, because blood is a pathophysiological reflector of whole body.

However, in Nigeria, government established various environmental protection and regulatory agencies in an attempt to provide a pollution-free environment, but in spite of these efforts, the pollution problem remains unabated.

It is therefore essential to undertake studies to document the consequence of exposure to industrial effluents containing potentially hazardous constituents, especially soap industrial waste effluent, relative to fish physiology, growth and survival, particularly food fish such as *Clarias gariepinus*, hence this study.

Methods

Soap effluent collection

Raw whole unfiltered soap effluent samples were obtained fresh from the discharge point of a soap manufacturing company in Osogbo, Osun State, Nigeria. Effluent samples were collected into clean air-tight plastic kegs of 25 L and transported to the Hydrobiology Laboratory, Department of Zoology, Obafemi Awolowo University, Ile-Ife, for the necessary physico-chemical analysis and static bioassay tests as described by Reish and Oshida (1986) and OECD (2002).

Fish collection and acclimatization

Seven hundred (700) 6-week-old juvenile of *Clarias gariepinus* (7.65 ± 0.02 g) obtained from BOS Integrated Bioresources Farm, Ile-Ife, Osun State, Nigeria, were transported to the Fish Culture Laboratory, Department of Zoology, Obafemi Awolowo University, Ile-Ife. The fish was acclimatized for two weeks in holding aquaria and fed Durante® floating feed at 5% of the body weight in two instalments per day.

Range finding test and 96-h LC_{50}

The range finding test followed standard procedures for bioassay with slight modification as described by Reish and Oshida (1986) and Obuotor (2004). The acute toxicity of the effluent on the experimental fish was determined by exposing 10 juveniles of the test fish each in 5 L of holding aquaria containing a range of concentrations (1, 2, 3, 4, 5, 6 and 7%) of whole unfiltered homogenous effluent sample (HES) in replicates for 24–48 h, and the fish were subsequently observed for mortality. Result obtained from the acute toxicity test was used to carry out a 96-h LC_{50} test to determine the concentration of soap effluent that will affect 50% of the fish population. The procedure for the 96-h static bioassay was similar to those of the range finding test with the test concentrations made by appropriate dilutions with distilled water. Twenty (20) fingerlings were randomly distributed into 40.32 L of each test concentrations in two replicates in regular glass aquaria of 70 L capacity. The experimental set-up was observed for 96 h, and the number of dead fish (fish with no opercula movement) was recorded. Toxicity range value was then estimated from the probit analysis and Spearman–Karber method of estimating mortality results (USEPA, 1997; Carter and Hauler, 2000).

Experimental design for sub-lethal exposure

Homogenous effluent sample (HES) preparation

At the end of the 96-h exposure period, results were analysed based on the percentage mortality. Median lethal concentration (LC_{50}) of the soap effluent which is considered useful, precise, important and biologically significant to evaluate the potential toxic effect and dose–response for quantal (mortality) response of a test organism to a chemical was measured using Trimmed Spearman–Karber method (USEPA, 1997). Nominal fractions (1/2, 1/4, 1/8, 1/16) of the LC_{50} value (5.25%) which gave HES concentrations of 2.626, 1.313, 0.656 and 0.323%, respectively, and denoted as Treatment A

(Control), Treatment B (0.32%), Treatment C (0.66%), Treatment D (1.31%) and Treatment E (2.63%) were used for a static/renewal bioassay for a period of 180 days.

Sub-lethal exposure of *Clarias gariepinus* to HES

Fish fingerlings were randomly selected and carefully exposure to varying concentrations (0.32, 0.66, 1.31 and 2.63%) of HES and the control (0%) in duplicate at fifty (50) fish per tank (glass aquaria of 70 L capacity) for 180 days. During the period of the exposure, the fishes were fed Durante® floating feed at 5% of the body weight in two instalments per day. The exposure concentrations were renewed every 72-h with fresh effluent mixture to maintain the requisite concentrations in the experimental culture. During the exposure period, water quality parameters, wet weights and standard lengths of fishes were recorded.

Water quality parameter determination

The temperature, pH, conductivity and dissolved oxygen (DO) of the exposed treatments and control were determined daily in situ using portable device while other water quality parameters of both the treatment and control tanks were determined every three days using the standard method for chemical analysis of water and waste water (APHA, 1995; OECD, 2002; Reish & Oshida, 1986).

Fish growth performance indices

Specimens of fish cultured in each HES exposure concentration were selected, and the total length and body weight of fish were measured fortnightly. The total length and body weight were measured with a standard measuring board and an Ohaun Compact digital weighing balance (Mettler Instrument). Data collection started from the first day of fish stocking in the exposure aquarium and ended after 180 days. From the weight data collected, the quantity of feed offered, the growth performance and feed utilization data were generated to determine the growth performance indices as shown in Table 1.

Fulton's condition factor (Kf)

The study of the condition of fish is usually based on the analysis of length–weight data and other indices to evaluate the fitness of fish populations. The condition of the fish at the end of the experiment was determined by measuring the total length and weight of the fish. The condition factor was calculated as:

$$K_f = \frac{100W_f}{L_3}$$

where L = mean total length of fish (cm); W_f = mean final weight (g).

Collection of blood and haematological analysis

Blood from the caudal blood vessel of six (6) *Clarias gariepinus* in each treatment was collected using 5-ml sterile plastic syringe fitted with 0.8 × 40 mm hypodermic needle. 2 ml of the blood was collected and introduced into ethylene diamine tetra-acetic acid bottles (EDTA) to avoid coagulation for haematological examination. After sampling, fish were placed in separate tanks of freshwater for necessary recovery.

The routine method of fish haematology designed by Blaxhall and Daisley (1973) was employed. The RBC count (RBC × 10^6 µl) was determined by counting the erythrocyte from 5 small squares of Neubaner haemocytometer using Vulpian dilution solution. The haematocrit (PCV, %) was determined by duplicate using heparinized capillary tubes centrifuged for 4 min at 13,000 rpm in a micro haematocrit centrifuge. The photometrical cyanohaemoglobin method was used for determining

Table 1 Growth performance and feed utilization indices

Parameter	Formula	References
1. Mean weight gain (MWG) (g)	Wf-Wi	Pitcher and Hart (1982)
2. Relative growth rate (RGR) (g/fish/day)	MWG × 100/Wi	Davies and Ezenwa (2010)
3. Daily weight gain (DWG) (g)	MWG/D	Pitcher and Hart (1982)
4. Total feed intake (TFI) (g)	TWF/Nc	Abdel-Hakim et al. (2008)
5. Daily feed intake (DFI) (g)	TFI/D	Abdel-Hakim et al. (2008)
6. Specific growth rate (SGR) (%/d)	Log Wf—Log Wi × 100/D	Brown (1957)
7. Food conversion ratio (FCR)	TFI/MWG	Burel et al. (2000)
8. Protein intake (PI) (g)	Diet protein content x DFI	Sveier et al. (2000)
9. Protein efficiency ratio (PER)	MWG/PI	Wilson (1989)
10. Survival (%)	Nf × 100/Ni	Deyab et al. (2009)

Wf, final weight of the fish; Wi, initial weight of the fish; D, rearing period; Nf, final number of fish at the end of the experiment; Ni, initial number of fish at the beginning of the experiment; TWF, total weight of feed fed; Nc, number of fish currently exposed; MWG, mean weight gain; TFI, total feed intake; DFI, daily feed intake

the haemoglobin concentration (Hb, g/dl) using standard formula by Svobodova (2001). The white blood cell count (WBC) was evaluated according to the routine clinical methods (Wintrobe, 1978).

Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH) and Mean Corpuscular Haemoglobin Concentration (MCHC) were calculated from the data obtained for RBC, Hb and PCV using standard formula by Torts et al. (1988).

Data analysis

Mortality of fish during acute exposure period (quantal response) was analysed using the Spearman Karber and Arithmetic Graphic method in which results were expressed as Mean ± SEM. Data generated on the physico-chemical parameters of the culture media, growth performance and haematological parameters of the fish specimens were each subjected to one-way ANOVA to test for significant differences in the means of parameters across the exposure gradients, respectively, using Statistical Package for Social Sciences 18.0 (SPSS Inc. USA). Differences in means which were considered significant at $p < 0.05$ levels were separated using Duncan multiple range test (Duncan, 1955).

Animal care

All the fish at the end of the experiment were anesthetized, thermally killed and incinerated.

Results

Toxicity

Upon fish exposure, mortality at acute exposure time of 24 h was recorded in both 6.0 and 7.0% HES concentration. Increased mortality was recorded after 48 h and at the end of the 96-h exposure period. The percentage mortality recorded in 5.0, 6.0 and 7.0% HES was 30, 80 and 100%, respectively. The LC_{50} which was determined using Trimmed Spearman–Karber method was 5.25% with lower and upper confidence limit of 4.93 and 5.60%, respectively (Fig. 1).

Physico-chemical quality of the culture media

The mean physico-chemical parameters of the culture media over a period of 180 days are shown in Table 2. Generally, among the analysed parameters, the conductivity and TDS levels were higher compared to other analysed parameters in the culture media (Table 2). Significantly ($p < 0.05$) highest levels of pH, conductivity, alkalinity, total dissolved solids and calcium were observed in the treatment with highest concentration of HES (Table 2).

However, while pH, conductivity and total dissolved oxygen levels of culture media increase with increasing concentration of HES, the temperature ($p > 0.05$) and the dissolved oxygen ($p < 0.05$) level of the culture media decreased with increasing HES concentration (Table 2).

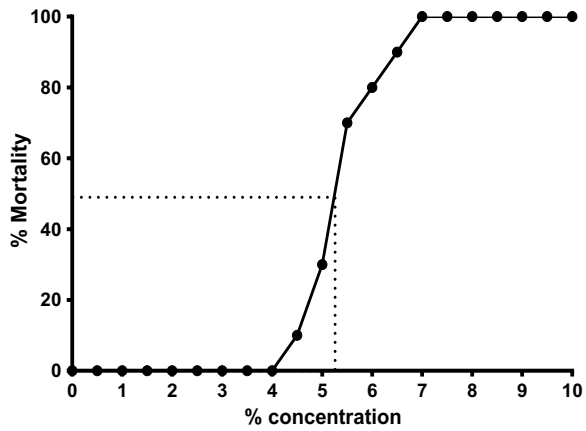

Fig. 1 96-h LC_{50} value for *Clarias gariepinus* fingerlings exposed to varying concentrations of the soap effluent during the period of study

The analysis of the biogenic ions in the culture media revealed that calcium was the only biogenic ion whose level was not significant ($p > 0.05$) across the treatments, although the level was higher ($p < 0.05$) compared to other analysed biogenic ions (Table 2).

Growth performance indices

The mean weight gain by fish exposed to different concentrations of Homogenous Effluent Sample (HES) during fortnight weight readings is shown in Fig. 2. As shown in the figure, the fish exposed to various HES concentration and control had a consistent growth pattern until the 8th week of the experiment when they began to show inconsistent pattern in weight gain. The fish in the control, however, showed a consistency and highest mean weight gain during the fortnight weighing throughout the period of study while the fish exposed to 2.63% HES had the least weight gain from the 12th week of the experiment (Fig. 2). The rate of growth was at the peak between the 20th and 24th week of exposure (Fig. 2).

The result of the growth performance of the fish exposed to varying concentrations of HES is shown in Table 3. The indices of growth are calculated as daily weight gain (DWG), mean weight gain (MWG), relative growth rate (RGR) and specific growth rate (SGR). The daily weight gain and mean weight gain of the experimental fish were observed to significantly decrease ($p < 0.05$) with increasing concentration of HES (Table 3). The relative growth of the fish which was highest in Treatment C (1569.16 ± 12.89) and lowest in Treatment E (1070 ± 38.59) significantly varied ($p < 0.05$) across the

Table 2 Comparative means* (± SE) of physico-chemical parameters in the culture system during the exposure period

Parameters	Homogenous effluent concentrations (%)				
	0%	0.32%	0.66%	1.31%	2.63%
pH	6.64 ± 0.05^{a}	6.69 ± 0.07^{a}	6.73 ± 0.07^{a}	6.79 ± 0.07^{a}	7.02 ± 0.06^{b}
Temperature (℃)	26.57 ± 0.35^{a}	26.51 ± 0.26^{a}	26.49 ± 0.29^{a}	26.47 ± 0.35^{a}	26.43 ± 0.31^{a}
Conductivity (µs/cm)	222.33 ± 17.30^{a}	231.01 ± 17.38^{a}	239.51 ± 17.96^{a}	248.82 ± 17.95^{a}	260.79 ± 19.14^{b}
Dissolved oxygen (DO)	4.90 ± 0.73^{b}	4.43 ± 0.66^{b}	4.00 ± 0.64^{b}	3.43 ± 0.59^{a}	3.11 ± 0.59^{a}
Chemical oxygen demand (COD) (mg/L)	13.08 ± 2.72^{a}	18.90 ± 3.37^{b}	17.46 ± 3.10^{b}	17.85 ± 2.15^{b}	21.56 ± 3.73^{c}
Alkalinity ($CaCO_3$ mg/L)	54.67 ± 9.51^{a}	53.50 ± 9.49^{a}	65.17 ± 13.70^{b}	65.00 ± 13.39^{b}	87.83 ± 13.16^{c}
Acidity ($CaCO_3$ mg/L)	16.50 ± 3.45^{a}	23.76 ± 6.76^{b}	21.84 ± 6.26^{b}	21.01 ± 5.85^{b}	30.18 ± 9.22^{c}
Total dissolved solids (TDS) (mg/L)	126.33 ± 10.64^{a}	131.59 ± 11.45^{b}	135.95 ± 10.64^{b}	141.30 ± 10.63^{c}	146.42 ± 11.74^{c}
Chloride (mg/L)	12.36 ± 2.04^{b}	12.23 ± 1.13^{b}	10.88 ± 1.89^{a}	10.87 ± 1.89^{a}	12.89 ± 1.98^{b}
Calcium (mg/L)	24.25 ± 1.54^{a}	22.70 ± 1.49^{a}	23.58 ± 1.31^{a}	25.65 ± 1.42^{a}	25.72 ± 2.09^{a}
Magnesium (mg/L)	10.59 ± 0.45^{a}	10.12 ± 0.19^{a}	12.45 ± 1.20^{c}	10.39 ± 0.33^{a}	11.15 ± 1.26^{b}
Phosphate (mg/L)	0.07 ± 002^{a}	0.46 ± 0.13^{c}	0.39 ± 0.05^{c}	0.26 ± 0.04^{b}	0.34 ± 0.12^{c}
Sulphate (mg/L)	0.19 ± 0.03^{a}	0.39 ± 0.05^{b}	0.27 ± 0.01^{b}	0.36 ± 0.06^{b}	0.37 ± 0.08^{b}
Nitrate (mg/L)	0.27 ± 0.08^{a}	0.57 ± 0.15^{b}	1.05 ± 0.45^{c}	0.60 ± 0.17^{b}	0.51 ± 0.17^{b}

*Column mean values for each parameter with different superscripts are significantly different at $p < 0.05$

The * is a note to the usable of the superscript

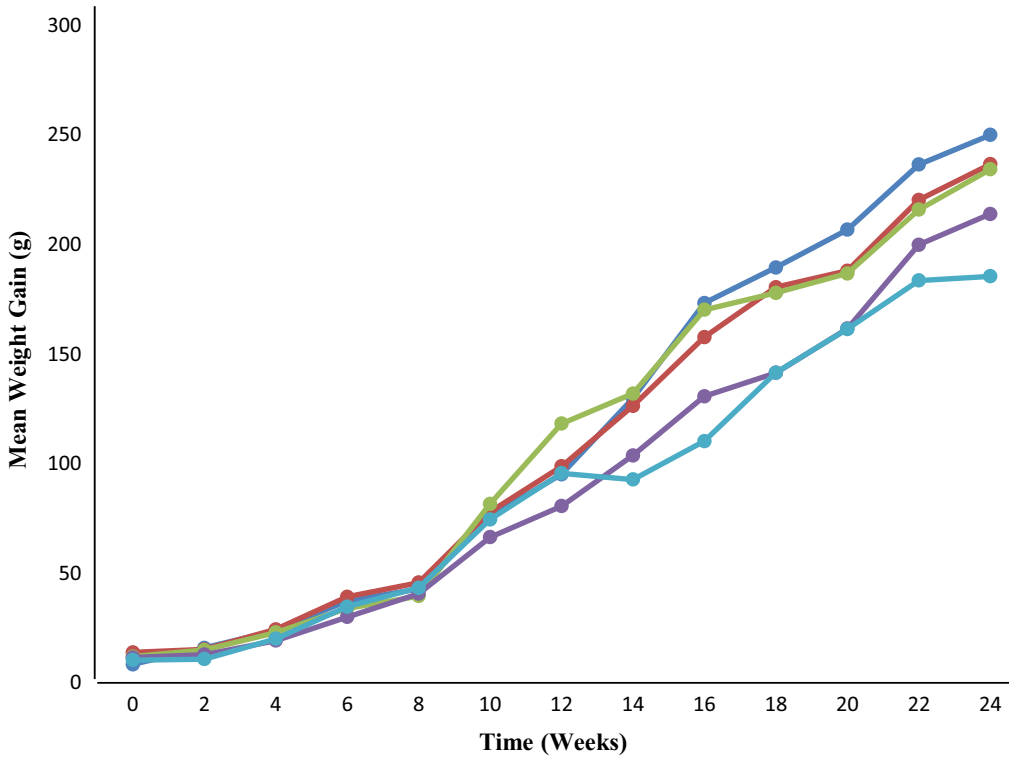

Fig. 2 Mean weight gain in *Clarias gariepinus* fingerlings during the HES exposure period. —0%, —0.33%, —0.66%, —1.31%, —2.63%

Table 3 Growth performance* indices in *Clarias gariepinus* fingerlings exposed to homogenous effluent samples (HES)

Concentration of homogenous effluent samples (% HES)	Initial mean weight (g)	Final mean weight (g)	Daily weight gain (DWG) (g)	Mean weight gain (MWG) (g)	Relative growth rate (RGR) (g/days)	Specific growth rate (SGR)	Survival (%)
A	$16.01^{b} \pm 0.40$	$250.03^{a} \pm 5.77$	$1.30^{b} \pm 0.03$	$234.02^{c} \pm 3.17$	$1461.71^{c} \pm 40.43$	$0.66^{b} \pm 0.01$	67
B	$15.31^{b} \pm 0.05$	$236.69^{a} \pm 7.46$	$1.23^{b} \pm 0.04$	$221.38^{bc} \pm 17.14$	$1445.98^{c} \pm 50.42$	$0.66^{b} \pm 0.02$	64
C	$14.04^{a} \pm 0.82$	$234.35^{a} \pm 18.36$	$1.22^{b} \pm 0.09$	$220.31^{bc} \pm 17.55$	$1569.16^{d} \pm 12.89$	$0.68^{b} \pm 0.01$	63
D	$16.89^{b} \pm 0.03$	$213.97^{a} \pm 17.76$	$1.12^{a} \pm 0.09$	$197.08^{ab} \pm 17.78$	$1166.84^{b} \pm 16.97$	$0.61^{a} \pm 0.03$	62
E	$15.85^{b} \pm 1.21$	$185.56^{b} \pm 20.84$	$0.97^{a} \pm 0.09$	$169.71^{a} \pm 17.16$	$1070.73^{a} \pm 38.59$	$0.59^{a} \pm 0.04$	55

A—control; B—0.32%; C—0.66%; D—1.31%; E—2.63%

*Values with different superscripts within the same column are significantly different at $p < 0.05$

treatments. The SGR of the fish in treatments with higher concentration of HES (1.31 and 2.63%) were significantly lower ($p < 0.05$) compared to the other treatments (Table 3).

All the treatment groups had mortality recorded which was highest in fish exposed to 2.63% HES (45%) and lowest in the control treatment (33%) (Table 3).

Feed utilization indices

The feed utilization indices of *Claris gariepinus* fingerlings exposed to different concentration of homogenous effluent samples are shown in Table 4. The daily feed intake ($p > 0.05$), total feed intake ($p < 0.05$) and total feed weight ($p < 0.05$) of the fish decrease with increasing concentration of HES (Table 4). However, fish in the control tank had the best FCR which was not significant ($p < 0.05$) compared to the exposed fish up to 1.31% HES concentration (Table 4). Although the PI of the fish in various treatments was not significantly different ($p < 0.05$), PER indices showed that control fish and fish in treatment B had significantly higher protein efficiency ratio compared to fish in other treatments (Table 4).

Fulton's condition factor (Kf)

The condition factor of the fish after exposure to various treatments at the end of 180 days was 0.87, 0.83, 0.81, 0.77 and 0.73 for the control group, 0.32, 0.66, 1.31 and 2.66% HES concentration, respectively. The result showed that the Kf of the exposed fish specimens decreases with increasing HES concentration.

Haematological analyses

Haematological characterization of *Clarias gariepinus* on exposure to different HES concentration after the period of study for 180 days is shown in Table 5. Increase in HES concentration which significantly increases ($p < 0.05$) WBC count of the experimental fish was observed to decrease ($p < 0.05$) the HGB level of the fish. Significantly higher ($p < 0.05$) levels of RBC ($3.02 \pm 0.03 \times 10^{6}$/µL) and HCT ($36.70 \pm 1.68\%$) were recorded in the control fish (Table 5). However, the MCV, MCH and MCHC levels which were not significant across the treatment were highest in the fish exposed to treatment E, C and B, respectively (Table 5). All the exposed fish had significantly higher ($p < 0.05$) levels of platelet count compared with the control (Table 5).

Table 4 Feed utilization* indices in *Clarias gariepinus* fingerlings exposed to homogenous effluent samples

Concentration of homogenous effluent samples (% HES) treatment	Daily feed intake (g)	Total feed intake (g)	Total weight of feed (g)	Feed conversion ratio	Protein intake	Protein efficiency ratio
A	$0.034^{a} \pm 0.002$	$6.12^{b} \pm 0.24$	$363.68^{a} \pm 5.57$	$0.026^{a} \pm 0.01$	$3.128^{a} \pm 0.07$	$74.82^{b} \pm 0.02$
B	$0.033^{a} \pm 0.001$	$5.91^{a} \pm 0.31$	$342.12^{a} \pm 1.44$	$0.027^{ab} \pm 0.005$	$2.950^{a} \pm 0.07$	$75.04^{b} \pm 0.73$
C	$0.033^{a} \pm 0.005$	$5.88^{a} \pm 0.93$	$332.56^{a} \pm 8.61$	$0.027^{ab} \pm 0.005$	$3.040^{a} \pm 0.34$	$72.47^{a} \pm 2.45$
D	$0.031^{a} \pm 0.01$	$5.62^{a} \pm 2.36$	$292.72^{b} \pm 42.84$	$0.029^{ab} \pm 0.007$	$2.903^{a} \pm 0.61$	$67.89^{a} \pm 8.85$
E	$0.029^{a} \pm 0.01$	$5.29^{a} \pm 1.76$	$254.99^{b} \pm 19.73$	$0.031^{b} \pm 0.001$	$2.903^{a} \pm 0.43$	$58.46^{a} \pm 14.63$

A—control; B—0.32%; C—0.66%; D—1.31%; E—2.63%

*Values with different superscripts within the same column are significantly different at $p < 0.05$

Table 5 Haematologiacal characterization of the *Clarias gariepinus* on exposure to soap effluent concentrations

Treatment	WBC (10^3/μL)	RBC (106/μL)	HGB (g/dL)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)	PLT (10^3/μL)
A	43.45 ± 2.20^a	3.02 ± 0.03^b	11.50 ± 0.23^c	36.70 ± 1.68^b	112.40 ± 12.06^a	39.60 ± 3.12^a	35.15 ± 3.52^a	35.50 ± 0.33^a
B	52.84 ± 3.60^b	2.68 ± 0.11^a	11.30 ± 0.18^c	30.60 ± 2.12^a	111.30 ± 13.16^a	38.85 ± 3.64^a	36.40 ± 0.14^a	40.50 ± 3.42^b
C	56.28 ± 1.57^b	2.55 ± 0.17^a	10.96 ± 0.14^b	31.01 ± 1.72^a	118.20 ± 8.26^a	40.50 ± 0.79^a	36.20 ± 0.22^a	43.50 ± 3.10^b
D	58.36 ± 2.26^b	2.15 ± 0.16^a	10.43 ± 0.28^b	30.15 ± 1.89^a	117.32 ± 7.66^a	38.80 ± 0.19^a	34.35 ± 0.33^a	65.00 ± 7.24^c
E	66.75 ± 2.31^c	2.30 ± 0.09^a	8.40 ± 0.09^a	28.25 ± 1.87^a	122.40 ± 16.19^a	39.30 ± 2.18^a	31.20 ± 0.61^a	40.00 ± 2.99^b

A—control; B—0.32%; C—0.66%; D—1.31%; E—2.63%

*Values with different superscripts within the same column are significantly different at $p < 0.05$

Discussion

The 96-h LC_{50} which is used to rate acute toxicity of different toxicants in exposed organisms is known to vary for different toxicants and their concentrations (Samabaswa & Roa, 1985; Cagauan et al., 2004; Ayotunde et al., 2010; Mahmoudvand et al., 2011). LC_{50} value recorded in this study was moderately toxic (2.0–10.99 ml/L) as reported by Kulkarni et al. (2016) and was within the range of 5.40 and 5.80 mg/l reported by Ettah et al. (2017) in a study on toxicity of two liquid soaps on Mud catfish.

Relatively high mortality recorded in test fish exposed to HES treatments test D and E during sub-lethal toxicity could be due to possible disease contagion observed, probably as a result of the deleterious nature of some compounds in the soap effluent which lower the fish immune-suppression system and increased disease susceptibility in the fishes (Couch & John, 1978). Environmental toxicity in fish and even at small concentration has been reported by Hussain et al. (2010) to have negative effect on fish survival rates.

Growth performance indices are one of the important criteria used in measuring fish responses to environmental stress. Better growth performance indices were recorded in the control group than in the fish exposed to varying HES concentrations. Lawee and Imgbian (2017) reported such growth depensation in *Clarias gariepinus* fingerings exposed to sublethal concentrations of Bentazon pesticide. The reduced growth could also be due to a reduced oxygen carrying capacity of blood leading to inefficient utilization of assimilated food or inhibitions of the activities of certain enzymes of the metabolic pathways (Lawee & Imgbian, 2017). Metabolic activities and excretion of toxicants are known to be on the increase in fishes at different exposure concentrations. Such increase requires more energy for homeostatic maintenance than for storage, which ultimately leads to growth depensation (Gbem et al., 2003). In fish, condition factor (Kf) is a reflection of physiological state in relation to well-being. The fish in the control group had a fairly better condition than those in the HES exposed group. In both groups, the Kf is lower than 1.0. The relatively poor condition factor recorded in exposed fish may be attributed to physiological stress due to the fish eco-physiology impacted by the physical and chemical conditions of the test media. Similar result was earlier reported by Nwabueze and Ekelenu (2011).

Effective monitoring of the status of fish exposed to various types of toxicity in the aquatic environment requires haematological parameters evaluation such as red blood cell count, haematocrit and haemoglobin concentration (Garcia et al., 2016; Khalid et al., 2016).

The HES introduction into the fish tanks induced a mean decrease in haematocrit, haemoglobin and red blood cells count across the exposure concentrations. The results obtained were in good congruence with Benajee et al. (2003) who reported a decrease in major blood parameters [red blood cells (RBC) and haemoglobin (Hb)] in the fish, *Channa puntatus* on exposure to Rayon industrial effluents. The observed reduction in the haematological parameters with increasing HES concentration in this study could be due to toxic effect such as destruction of erythrocytes or inhibition or erythrocyte production or haemodilution, haemophilia, injury of the gills and osmoregulation (Saravanan et al., 2011).

Significant increase in white blood cells (WBC) in *Clarias gariepinus* juveniles exposed to various concentrations of HES during the period of study was observed across board. This increase recorded could be attributed to increased production of leucocytes in the haematopoietic tissue of the kidney and perhaps the spleen in response to fish immunity (Joshi et al., 2000; Omoniyi et al., 2002; Ayoola, 2011). Lymphocytes which are the most numerous cells, comprising predominantly the leucocytes, function in the production of antibodies and chemical substances serving as defensives against infection (Golovina, 1996; Joshi et al., 2000). The presence of the high white blood cells in the fish during the period of study is indicative of a phagocytic action against disease and a depleted immunological status due to toxic exposure to various HES concentrations.

Conclusion

Based on the data and evidence recorded in this study, the effluent from soap making industry could be inimical to the growth and survival of *Clarias gariepinus* as well as quite toxic as revealed in some haematological indices indicating physiological stress caused by effluent exposure.

Abbreviations

HES: Homogenous effluent sample; DFI: Daily feed intake; DWG: Daily weight gain; MWG: Mean weight gain; BWG: Percentage body weight gain; TFI: Total feed intake; FCR: Feed conversion ratio; SGR: Specific growth rate; PI: Protein efficiency ratio; SR: Fish survival rate; Kf: Fulton's condition factor; EDTA: Ethylene-diamine-tetra-acetic; RBC: Red blood cell; WBC: White blood cell; Hb: Haemoglobin concentration; HCT: Haematocrit; PCV: Packed cell volume; MCH: Mean corpuscular haemoglobin; MCV: Mean corpuscular volume; MCMH: Mean corpuscular haemoglobin concentration; ANOVA: Analysis of variance; TDS: Total dissolved solid; DO: Dissolved oxygen; COD: Chemical oxygen demand; LC_{50}: Lethal concentration at which half of the organism died.

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Authors' contributions

AS carried out the research work and analysed the data. HA assisted in the experimental design and supervision of the experiment. He also drafts the manuscript. OP and BM assisted in the practical section, sample collection and analysis of data. VF conceived the idea, designed the study and proof read the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

Data are available on request.

Declarations

Ethics approval and consent to participate

The protocol and procedures employed in this study for the animal used were ethically reviewed and approved by Health Research Ethics Committee, Institute of Public Health, Obafemi Awolowo University, Ile-Ife, Nigeria. The procedures also complied with directive 2010/63/EU of the European Parliament and of the Council on the protection of animals.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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