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Growth Responses of *Oreochromis niloticus* Exposed to Sub-lethal Concentrations of Industrial Effluent from Agbara Environs of Ologe lagoon, Lagos, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The present study is on the toxicity of sub-lethal concentrations of industrial effluents (IE) on the growth responses of *Oreochromis niloticus* (fingerlings and juveniles) from the Agbara environs of Ologe Lagoon, Lagos state, Nigeria.
Study Design: The culture system was a static renewable bioassay and was carried out in the fisheries laboratory of the Lagos State University, Ojo-Lagos, Nigeria. The fish were cultured in varying concentrations of industrial effluents: 0% (control), 5%, 15%, 25%, and 35%. Trials were carried out in triplicates for twelve (12) weeks.
Methodology: Weekly physico-chemical parameters: temperature (^{0}C), pH, conductivity (ms/cm) and dissolved oxygen (DO in mg/l) were measured in each treatment tank. Length (cm) and weight

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(g) data were obtained and used to calculate various growth parameters: mean weight gain (MWG), percentage weight gain (PWG), daily weight gain (DWG), specific growth rate (SGR) and survival.
Results: The physico-chemical parameters showed that the pH of the culture water for *O. niloticus* fingerlings ranged from 7.57 – 7.97 and 7.86 – 7.97 for juveniles. DO results ranged from 2.89 - 4.72 mg/l for fingerlings and 4.54 - 7.68mg/l for juveniles. There were significant differences (P<0.05) in the DO values among the culture water. The DO values decreased with increase in effluent concentration for all treatments. The mean conductivity values obtained ranged from 0.51 – 0.53 ms/cm and 0.35 – 0.42 ms/cm for fingerlings and juveniles respectively. The temperature was stable throughout the study period; it ranged from 27.9 – 28.12^{0}C and 23.94 – 27.14^{0}C respectively. There was progressive increase in length and weight of fish during the culture period. The fish placed in the control had the highest increase in both weight and length, while fish in 35% had the least. MWG ranged from 5.15 – 8.8 and 4.48 – 15.2, DWG is from 0.14 – 0.19 and 0.52 – 0.64, PWG varied from 42.53 – 54.17 and 10.36 – 28.38, SGR ranged from 0.69 – 0.93 and 0.13 – 0.39 for fingerlings and juveniles respectively.
Conclusion: This study had shown that the industrial effluents from study site affected the health status of the test organisms, the water quality parameters (especially oxygen content), and impaired the growth of both the fingerlings and juveniles of *O. niloticus* when exposure continued for a long period of time.

Keywords: Toxicity; industrial effluents; Oreochromis niloticus; growth; Ologe lagoon.

1. INTRODUCTION

In urban areas, the indiscriminate disposal of industrial effluents and other wastes may contribute to the poor quality of the water. The industry is the source of pollution, accounting for almost fifty percent (50%) of the pollutants present in the biosphere [1,2]. Pollutants given off by various industries and factories are often considered to be one of the prime factors contributing to air and water pollution. In Nigeria, especially Lagos being the commercial and industrial hub of the country, industrial waste water (effluents) and heavy-metals are key environmental toxins contaminating the fresh and brackish water systems, due to their constant and relentless existence [3].

To evaluate the health status of the aquatic organisms, fish are commonly used [4] in contrast to water or sediment as fish accumulate metals more and take up these in their body organs too [5]. Effluents have various components of xenobiotics, which may include: zinc, copper, iron, lead, cobalt, and nickel amongst others. Zinc is an important toxicant to fish [6]: disruptions of gill tissue, hypoxia, iron regulation and disturbance of acid-base balance occur due to zinc pollution [7]. In the cellular structure, nickel somehow plays its role for morphological conversion and chromosomal anomalies. Lead is recognized for amending the haematological system by holding back the activities of several enzymes which take part in heme biosynthesis [8]. Iron is the most vital element for haemoglobin and myoglobin development in fish as well as it also plays a fundamental role for the growth of aquatic organisms. Unfortunately, increased industrial effluent pollutes the natural ecosystem and it enhances the momentous contamination stage [9]. The sub-lethal exposure of industrial effluents not only affects the survival of the fish, but also reduces growth [10].

Ologe lagoon is used for fishery, waste disposal, sand mining and transportation. As with other lagoons within the Lagos lagoon complex (Fig. 1), it is also regarded as the 'large septic tank' in the region. The main anthropogenic pressure on Ologe lagoon is from the adjacent Agbara industrial estate, where over 20 factories belonging to food and beverages, pharmaceutical, breweries, metal finishing industries, chemical and pulp and paper companies presently occupy the industrial area. The effluents of these industries are discharged in the lagoon all year round, with their immediate impacts on the ecology of the lagoon system [11]. The lagoon in this case study is one of the major sources of fish to the inhabitants of Lagos, Nigeria. Local and indigenous fish species are caught in Ologe lagoon. The concern about the ecological consequences of the discharge of effluents from the adjacent Agbara Industrial Estate on the environment (Fig. 1) as well as the aquatic lives has been widespread in recent years. The quality and safety of fish and fisheries products of this area is critical and needs to be monitored.

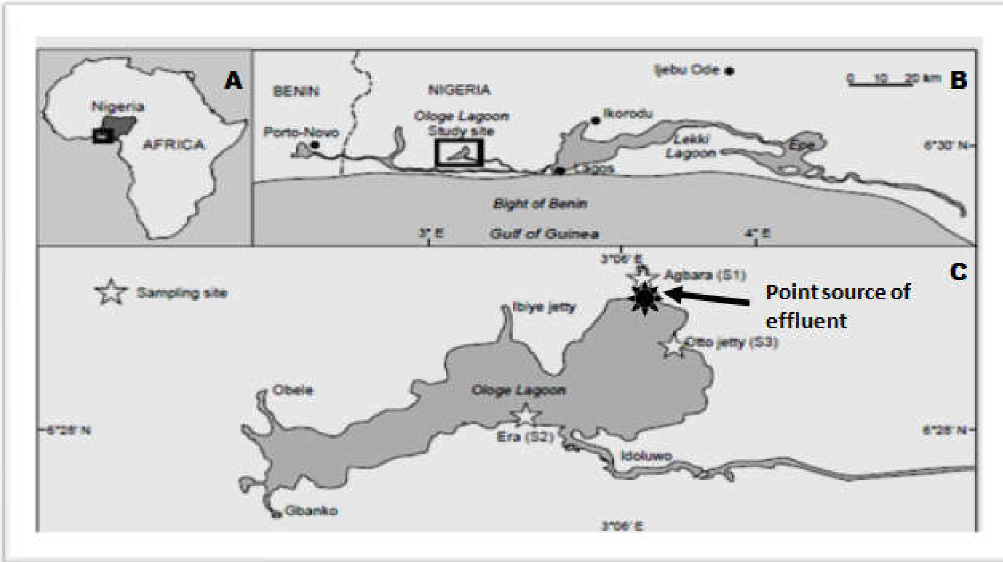

Fig. 1. Showing the location of Ologe lagoon (C) in the Lagos lagoon complex (B) and Agbara industrial environs.

Source: [11]

1.1 Objectives

The specific objectives of this research are to determine the sub-lethal effects of industrial effluent from Agbara environs of Ologe lagoon, Lagos state, Nigeria on water quality parameters of the culture medium and growth characteristics of two life stages of *O. niloticus* (fingerlings and juveniles). Growth trials were done in twelve weeks for each life stage in a static renewable bioassay in the laboratory, where test organisms was cultured in varying industrial effluent concentrations of 35%, 25%, 15%, 5% and 0% (control) in triplicates to obtain weekly water quality parameters: temperature (^{0}C), pH, conductivity (ppm) and dissolved oxygen (mg/l) and to determine length (cm) and weight (g) data weekly, which is used in calculating growth parameters: Mean Weight Gain (MWG), Percentage Weight Gain (%WG), Daily Weight Gain (DWG), Specific Growth Rate (SGR) and the fish survival (%). This study is based on the prior research on the acute toxicity of industrial effluents from the same study location on early life stages of *Oreochromis niloticus* [11].

2. MATERIALS AND METHODS

2.1 Study Area

Lagos, being the economic and industrial hub of Nigeria, is located in the south-western part of the country within the latitudes 6º 23´ N and 6º 41´ N and longitudes 2º 42´ E and 3º 42´ E on the west coast of Africa. The state is flanged from the north and east by Ogun State, in the south by Republic of Benin and the Atlantic Ocean/Gulf of Guinea (Fig. 1). The total landmass of the State is about 3,345km^2, which is just about 0.4% of the total land area of Nigeria. It is the geographically smallest; but highly populated state in the country with an estimated population of about 10 million inhabitants which is about 10% of the total population of Nigeria, Africa's most populous country. Lagoons are ecologically and economically important aquatic ecosystems in South-western Nigeria. They provide natural food resources, rich in protein which includes an array of fish and fisheries. They are also important in water transportation, energy generation, exploitation and exploration of some mineral resources including sand [11]. Lagoons also inadvertently serve as sinks for the disposal of domestic, municipal and industrial wastes in the region. Ologe lagoon is one of the nine lagoons in South-western Nigeria. It is presumably the smallest of the lagoons with a surface area of 9.4km2. The climate is of the equatorial type with two peak rainy periods which are generally during May-July and September-October. Ologe Lagoon is bounded by heavy industry including plastic, pharmaceutical, glass, paper and pulp among several. Partially and largely untreated discharges from these sources end up in the water body via Otto (Fig. 1) which when coupled with the foulings attributable to the satellite communities cause significant levels of pollution.

2.2 Sub-lethal Bioassay

30 rectangular glass tanks (length 80cm x breadth 40cm x height 40cm) were constructed for the experiment. 15 tanks were used for each stage having five concentrations each in triplicate. Two sizes of *O. niloticus* were used (fingerlings and juveniles). A total of 300 fingerlings and 300 juveniles of *O. niloticus;* was collected from a reputable farm in Badagry and acclimatized for 4 weeks in the Laboratory. Industrial effluent was collected from a identified point source on the Ologe lagoon (Fig. 1) over-night in 25 litre containers and later mixed with water for the bioassay in the required amount to obtain the different test concentrations. The effluent was used within one month after which fresh effluent was collected according to [12]. Static renewable bioassay was conducted with three replicates per concentration treatment (Control 0%, 5%, 15%, 25% and 35%) as shown in Fig. 2. The control experiment contained 100% dilution water (volume of water in each tank was 20 liters). Each aquarium contained 20 fish samples. Exposure lasted for 12 weeks, per species during which freshly prepared test solution was made weekly as the water is changed and tanks were cleaned. The fish were fed with COPPENS feed at 4% body weight twice daily (Table 1). Water quality parameters of the test tanks were monitored weekly using standard methods [13]. The water quality parameters were: temperature (ºC), conductivity (ms/cm), pH and dissolved oxygen (DO in mg/l).

Table 1. Proximate composition of experimental diets (Coppens 0.8 - 1.2mm)

Ingredients	Values
Crude Protein	56%
Crude Fat	15%
Crude Fibre	0.4%
Ash	10.9%
Vitamin A	22.5 IU/kg
Vitamin D3	2.5 IU/kg
Vitamin E	200 mg/kg
Vitamin C	300 mg/kg
Phosphorus	1.8
Calcium	2.6
Sodium	0.7

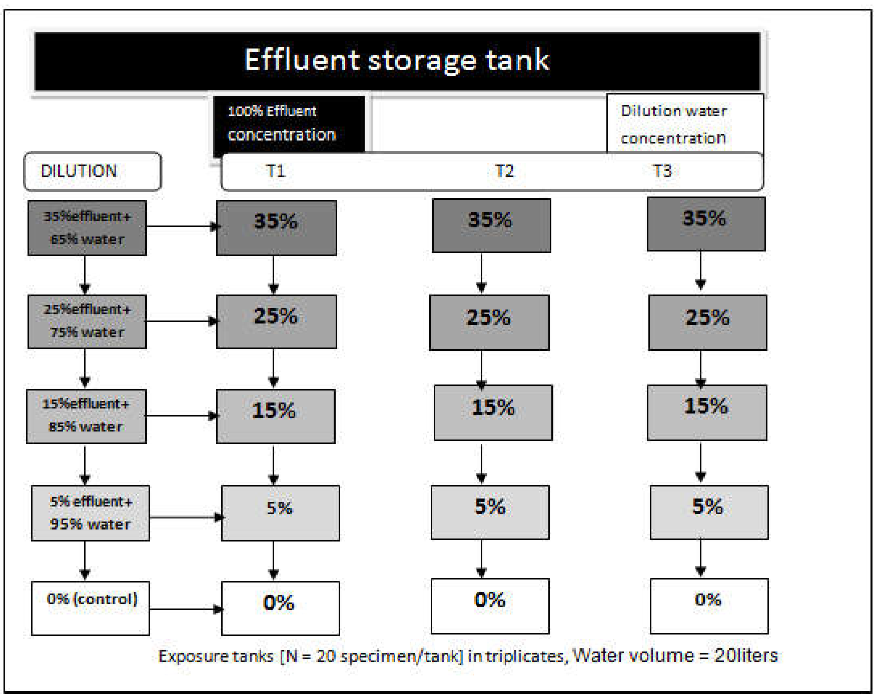

Fig. 2. Experimental set-up for static renewable bioassay with three replicates per concentration treatment

2.3 Evaluation of Growth Parameters

Growth performances were estimated using the following formulae:

1 Weight Gain = Final mean weight gain of fish – initial mean weight gain of fish.
2 Daily Weight Gain = Final mean weight /Period (84 days).
3 Percentage (%) Weight Gain = (X-Y) x 100 / X.
Where: X = final weight, Y = initial weight.
4 Specific Weight Gain (SWG) = 100 ($\log_e$ Final weight - $\log_e$ Initial weight) / Period (84 days).

2.4 Statistical Analysis

Data for water quality parameters were reported as mean ± SD (standard deviation). The significant differences among the treatments are tested using SPSS version 16.0 analysis of variance (ANOVA) test. All growth data were subjected to one-way analysis of variance (ANOVA) test and the significance difference between means was determined by Least significant difference (LSD) range test (at P<0.05).

3. RESULTS

3.1 Some Water Quality Parameters during the Sub-lethal Bioassay Studies

The results of the water quality parameters of the industrial effluent treated tanks for *Oreochromis niloticus* fingerlings and juveniles are presented in Tables 2 and 3. The mean pH varied from 7.57 - 7.89 for fingerlings. While in the Juveniles treated tanks, it varied from 7.86 - 7.97. However, the differences among concentrations was not significant at P>0.05. The mean temperature value varied from 27.90 ^{0}C - 28.12 ^{0}C for the fingerlings and 23.94^{0}C - 27.21 ^{o}C for juveniles. The temperature values did not differ significantly in the different concentrations for the fingerlings stage, but the differences at the juvenile stage was significant at 95% confidence limit (P<0.05) amongst the different concentrations. The highest mean conductivity values ranged from 208.54±1.59 - 265±18.99ppm for fingerlings and juveniles respectively. There were no significant differences among various concentrations for the fingerlings, but was different significantly amongst the two life stages. The lowest conductivity values were recorded in the control (0%) in both age groups. While, the highest values were obtained from 5% and 25% treatment tanks, throughout the period of the experiment/exposure (12 weeks each).

There was a concentration dependent decrease in the DO values. The DO values decrease from 4.72mg/l (obtained in the Control treated tanks) to 2.89mg/l (obtained in the 35% tanks) for fingerlings and from 7.68mg/l in the control tanks to 4.54 mg/l obtained from the 35% tanks of the juveniles. The decrease was not significant among the triplicate, but was significant (P<0.05) in the different concentration and these was consistent even in the two life stages. There were considerable reductions in the mean DO values consistent with increase in concentrations, with the control tank having the highest. This implies that the effluent is mainly an oxygen limiting toxicant and this condition is detrimental to survival, physiology and metabolic activities of the test organisms.

Table 2. Some water quality parameters of medium during 12 weeks of sub-lethal bioassay of effluents to *O. niloticus* fingerlings

Dilution (%)	Water quality parameters			
	pH	Temperature (^{o}C)	Dissolved oxygen (mg/l)	Conductivity (ms/cm)
0	7.89±0.66^a	27.97±0.35^a	4.72±1.75^a	0.52±19.38^a
5	7.79±0.09^a	28.01±0.35^a	4.70±1.12^a	0.53±18.99^a
15	7.58±0.12^a	27.90±0.35^a	3.06±1.01^b	0.53±21.97^a
25	7.57±0.11^b	28.01±0.36^a	2.72±0.78^c	0.51±18.73^a
35	7.70±0.5^a	28.12±0.16^a	2.89±2.17^c	0.52±8.76^a

Note: Values in each column with similar superscripts are not significantly different (at P>0.05)

Table 3. Some water quality parameters of medium during 12 weeks of sub-lethal exposure of effluents to *O. niloticus* Juveniles

Dilution (%)	Water quality parameters			
	pH	Temperature (^oC)	Dissolved Oxygen (mg/l)	Conductivity (ms/cm)
0	7.97±0.02 [a]	27.14±0.03[a]	7.68±0.08 [a]	0.35±9.54 [a]
5	7.89±0.02 [a]	27.21±0.07 [a]	6.77±0.11 [b]	0.38±7.21 [b]
15	7.91±0.01 [a]	26.35±0.83 [a]	6.20±0.08 [c]	0.39±7.70 [b]
25	7.91±0.02 [a]	25.57±1.67 [b]	5.49±0.11 [c]	0.42±1.59 [b]
35	7.86±0.03 [a]	23.94±2.19 [c]	4.54±0.07 [d]	0.41±16.72 [b]

Note: Values in each column with similar superscripts are not significantly different (at P>0.05)

3.2 Growth Performance of *Oreochromis niloticus* Fingerlings Exposed to Sub-lethal Concentration of Industrial Effluent for 12 weeks

Weekly changes in length (cm) and weight (g) of *O. niloticus* fingerlings exposed to different dilution of industrial effluents are presented in Figs. 3 and 4, while the results of the growth parameters are shown in Table 4. From the cumulative mean weight and length increase, it was shown that the fish in the control had the highest mean weight gain (MWG) – 8.8±0.1 and 35% concentration had the lowest (5.15±0.1). The percentage weight gain (PWG) ranged from 42.53 - 54.17 from 0% to 35% effluent concentrations respectively. However, survival was 100% throughout the bioassay in this group. The specific growth rate (SGR) ranged from 0.66 (25%) to 0.93 in the control. Differences observed in the weight analysis over the weeks which was significant (at p<0.05) between control and higher concentrations. There was progressive increase in weight (g) with increase in weeks, but reduced when compared to increase in effluent concentrations.

3.3 Growth Performance of *Oreochromis niloticus* Juveniles Exposed to Sub-lethal Concentration of Industrial Effluent for 12 Weeks

Table 5 showed a concentration dependent decrease in mean weight gain with the fish in the

Table 4. Analysis of growth performance of *O. niloticus fingerlings* exposed to Sub-lethal concentrations of industrial effluents in Ologe lagoon

Growth parameters	Concentration (%)				
	0	5	15	25	35
Initial mean weight (g)	7.45±0.2[a]	7.52±0.1 [a]	6.86±0.8 [a]	6.62±0.6 [a]	6.8±0.2 [a]
Final mean weight (g)	16.3±0.2 [a]	14.5±0.2 [b]	13.54±0.5 [b]	12.26±0.2 [c]	11.72±0.1 [c]
Mean weight gain (g)	8.8±0.1 [a]	6.98±0.2 [b]	6.14±0.9 [b]	5.22±0.3 [c]	5.15±0.1 [c]
Daily weight gain (g)	0.19±0.0 [a]	0.17±0.0 [b]	0.16±0.0 [c]	0.14±0.0 [d]	0.14±0.0 [d]
Percentage weight gain	54.17±0.9 [a]	48.11±1.0 [a]	44.96±5.6 [b]	42.53±2.6 [b]	43.9±0.8 [b]
Specific Growth rate(g)	0.93±0.0 [a]	0.78±0.0 [a]	0.72±0.1 [b]	0.66±0.0 [b]	0.69±0.0 [b]
Survival (%)	100	100	100	100	100

Note: Values in each row with similar superscripts are not significantly different (at P>0.05)

Table 5. Analysis of growth performance of *O. niloticus* Juveniles exposed to Sub-lethal concentrations of industrial effluents for 12 weeks

Growth parameters	Concentration (%)				
	0	5	15	25	35
Initial mean weight (g)	38.26±0.3[a]	36.99±0.4 [b]	35.41±0.1 [c]	36.64±0.4 [b]	38.66±0.1 [c]
Final mean weight (g)	53.46±1.2 [a]	49.07±0.2 [b]	46.82±1.1 [bc]	45.04±0.2 [c]	43.16±0.5 [c]
Mean weight gain (g)	15.2±0.1 [a]	12.07±0.6 [b]	11.41±1.9 [c]	8.4±0.5 [d]	4.48±1.0 [e]
Daily weight gain (g)	0.64±0.0 [a]	0.58±0.0 [b]	0.55±0.0 [c]	0.54±0.3 [cd]	0.52±0.0 [d]
Percentage weight gain	28.38±0.9 [a]	24.61±0.7 [b]	24.28±1.8 [c]	18.66±0.7 [d]	10.36±1.3 [e]
Specific Growth Rate(g)	0.39±0.0 [a]	0.33±0.0 [b]	0.33±0.0 [b]	0.26±0.0 [c]	0.13±0.0 [d]
Survival (%)	100	100	100	100	100

Note: Values in each row with similar superscripts are not significantly different (at P>0.05) control tanks having the highest Specific Growth Rate (0.39±0.01), while the highest concentration (35%) had the lowest specific growth rate (SGR) of 0.13±0.01. the specific growth rate was lower in the juveniles when compared with the fingerlings (0.93±0.01). While specific growth rate in the control significantly differed from higher concentrations ($p<0.05$), the 5% and 15% did not show any difference; such as observed in 25% and 35% concentrations. Figs. 5 and 6 shows the decrease in weight and length gained as the concentration increased. From the graphs it could be observed growth was lower in the other concentrations excluding the control where growth rate was high.

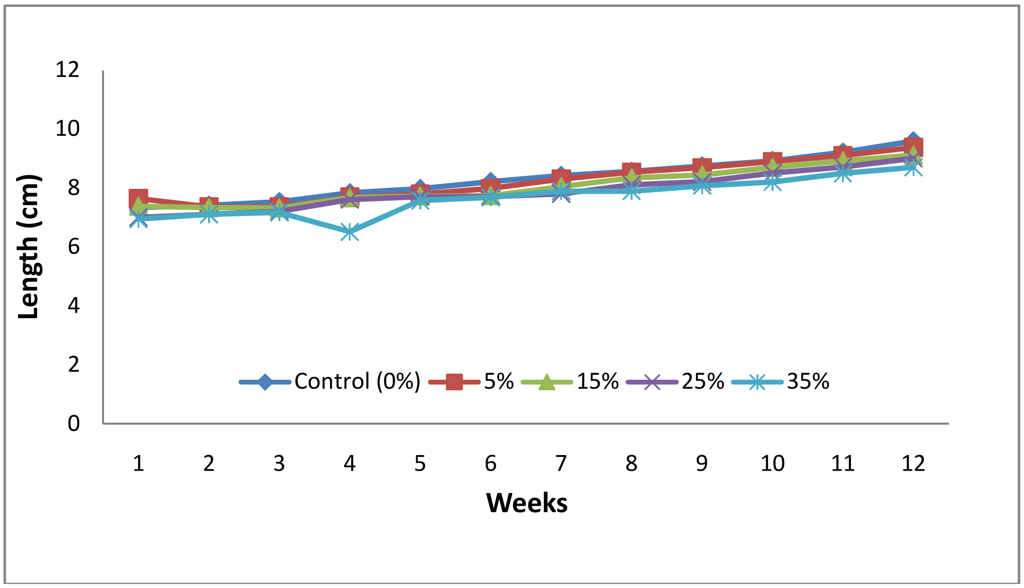

Fig. 3. Weekly changes in Length (cm) of *O. niloticus* fingerlings exposed to various concentrations of industrial effluents for 12 weeks

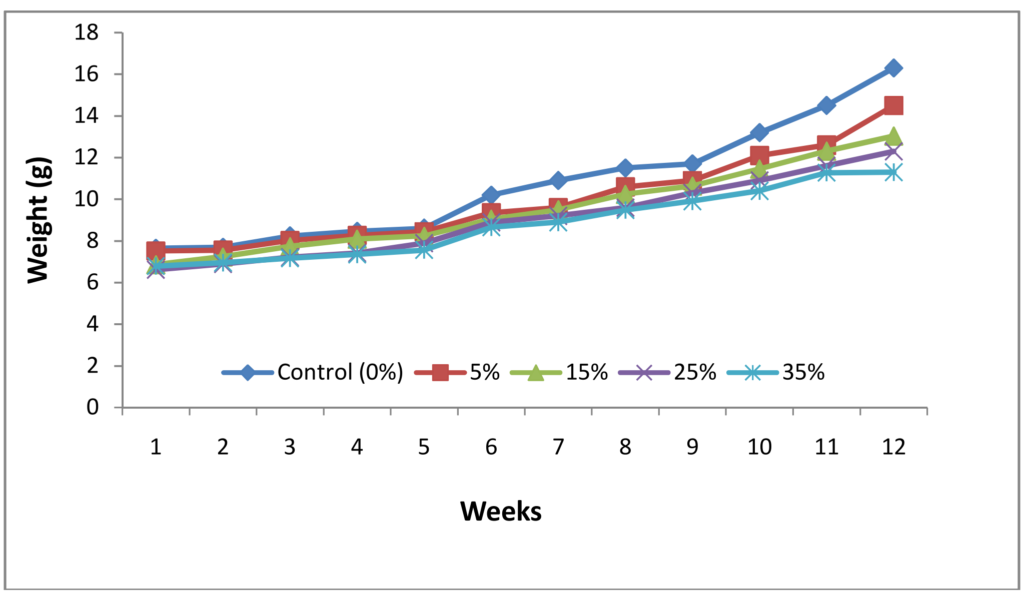

Fig. 4. Weekly changes in Weight (g) of *O. niloticus* fingerlings exposed to various concentrations of industrial effluents for 12 weeks

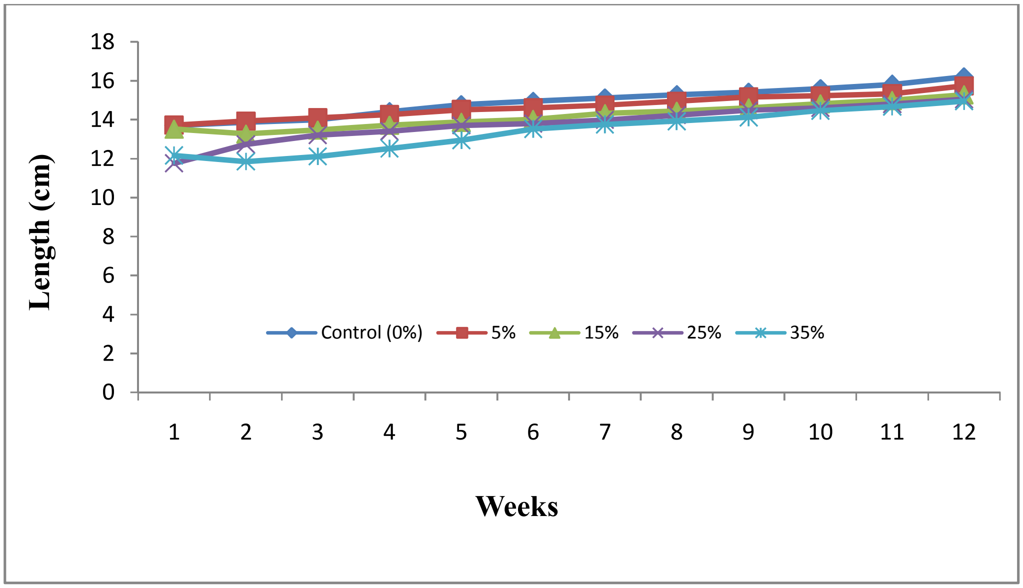

Fig. 5. Weekly changes in Length (cm) of *O. niloticus* Juveniles exposed to various concentrations of industrial effluents for 12 weeks

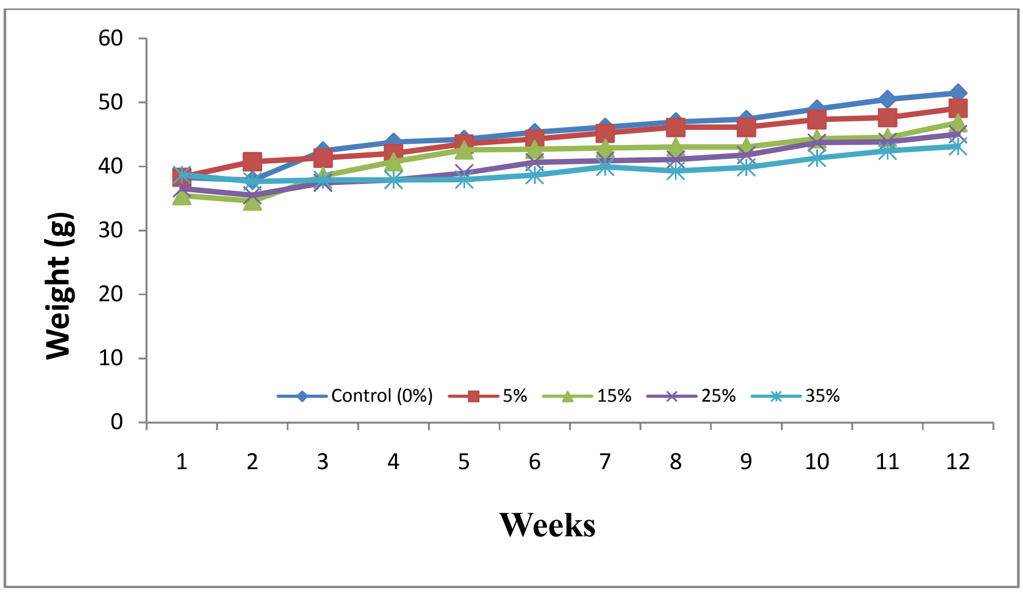

Fig. 6. Weekly changes in Weight (g) of *O. niloticus* Juveniles exposed to various concentration s of industrial effluents for 12 weeks

4. DISCUSSION

The fish growth is generally used as an amenable and a reliable end-point in chronic studies to envisage toxic influences of various biochemical and physiological processes which are more divulging to review the effects on specific processes, including: feeding, excretion, assimilation and metabolism in fish [14]. The control fish depicted significantly maximum growth in terms of average increase in weight as compared to the treated]. Moreover, the growth of Nile Tilapia (*Oreochromis niloticus*) may be adversely affected due to the exposure to effluents.

Contamination of aquatic environment by industrial effluents either at lethal or sub-lethal levels constitutes additional source of stress for aquatic organisms. Sublethal concentrations of effluents/toxicants in the aquatic environment will not necessarily result in outright mortality of aquatic organisms, but will have physiological impacts when exposure is prolonged. The conclusion of [15] confirmed this when he reported that toxicants and pollutants have significant effects, which can result in several physiological disfunctions in fish. Disfunctions in the fish induces changes in the blood and growth parameters. Weight gain is known to be the most important criterion for measuring fish responses to experimental feed and a very reliable indicator of toxicity [14]. Data analysis using weight gain gives useful information concerning the growth and body physiology of the fish. During the sub-lethal exposure, a decrease in weight by the fish with increase in concentration is observed. The retardation of growth might be due to interactions of the effluent content with normal metabolism of the fish and to under- utilization of the feeds due to the toxicity of the test chemicals.

In the study, the water quality parameters measured were: temperature (^{0}C), pH, conductivity (ms/cm) and dissolved oxygen (mg/l). With the exception of dissolved oxygen, these water quality variables in triplicates showed no significant difference (p>0.05). The mean temperature for fingerlings and juveniles obtained are within range reported for tropical aquatic bodies; pH range was stable. Dissolved oxygen (DO) had a marked difference in the exposure media. The mean DO (mg/l) level in the control tank (0%) was 4.72±1.75, but dropped in the next level of treatment (5%) to 4.70±1.12 as shown in table 2, and continued to drop steadily to 3.06±1.01 in the 15% tank, and to 2.72±1.01 in the 25%. This trend was consistent throughout the study in both fingerlings and juveniles for the Nile Tilapia, which presupposes that the effluent is mainly an oxygen limiting toxicant with its evident impact on the health and growth of the fish [16]; while studying on the chronic toxicity of heavy metals, corroborated the findings in this research that increase in toxicant may decline the concentration of oxygen due to hyper-activity and subsequent excessive ammonia excretion and concluded that among the physicochemical variables, ammonia excretion in treated media exerted negative impact on fish growth.

The exposure of fish to industrial effluents from Agbara environs of Ologe lagoon, south-western Nigeria exerted significant impact on the wet weight increments of fish species, this assertion was also supported by [16]. However, the fish grown in dilution water (control) exhibited significantly better growth. It is also shown in Figs. 3, 4, 5 and 6. Effluent test treatments caused significantly (p<0.05) lesser weight gains on *Oreochromis niloticus*. Overall performance of the fish species was significantly lower under waste water (effluent) treatments. However, fingerlings of *O. niloticus* attained significantly better growth than the juveniles.

Higher growth in terms of increase in wet weight, total length, specific growth rate, daily weight gain, percentage weight, and mean weight gain was significantly attained by control fish as compared to treated fish. Dissolved oxygen in water depends upon water temperature, partial pressure of oxygen in the atmosphere and salt in water [14]. Fish wet weight increment exhibited negative and significant relationships with increase in effluent concentrations to cause changes in the growth performance of the Nile Tilapia.

5. CONCLUSION

In view of the industrial effluents from the Agbara Environs of Ologe Lagoon, the sub-lethal toxicity test carried out has shown that exposure to effluents will affect the health status of the Nile tilapia (as shown by the oxygen limiting nature of the industrial effluent) and impair growth if exposed for a long period of time. Thus, the environmental safety assessment of effluents and related products should focus primarily on the aquatic ecosystem since the ecological effects of these chemicals are detrimental to organisms. Therefore, regular monitoring of the waters containing these chemicals frequently discharged into the water body is required, for this is not only detrimental to fish but also poses health risks for humans residing around the area.

This work is relevant since there is a great concern regarding the impact of industrial effluents in aquatic environmental. The assessed parameters revealed important impairment in fish development. The understanding of sub lethal effects of aquatic contaminants is crucial for the risk assessment of chronic exposures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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