Journal of ENVIRONMENTAL Treatment Techniques

J. Environ. Treat. Tech.
ISSN: 2309-1185

Journal weblink: http://www.jett.dormaj.com

Toxicity of Detergent Containing Linear Alkyl benzene Sulphonate on Some Commonly Cultured Fish Species in the Niger Delta

Enemuadia Oyoroko* and Emmanuel N. Ogamba

Environmental Toxicology Research Unit, Department of Biological Sciences, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria

Received: 29/05/2017 Accepted: 29/06/2017 Published: 30/06/2017

Abstract

This study evaluated the toxicity of detergent containing linear alkyl benzene sulphonate against some commonly reared freshwater fish (*Clarias gariepinus*, *Heterobranchus bidorsalis* and *Heteroclarias*) in the Niger Delta. The fish species were allowed to acclimatize in separate aquaria for 3 days in the laboratory. The range finding test was carried out at three different concentrations. From the range finding test result, the main experimental set-up was carried out at 0, 50, 100, 150, 200 and 250ppm of the detergent in a renewed bioassay. Results showed that the mortality rate increased as the exposure time and concentration of the toxicants increased. The LC50 values for *Heterobranchus bidorsalis*, *Clarias gariepinus* and *Heteroclarias* were 91.67ppm, 183.3ppm and 41.67ppm. The apparent differences among the LC50 values of the various species could be associated to age, size and species type’s composition. Due to the toxicity associated to the detergent, caution should be exercised in the use and discharge of effluents of detergents containing linear alkyl benzene sulphonate into the aquatic ecosystem.

Keywords: Detergent, fisheries, Toxicant, Toxicity

1 Introduction

Environmental degradation is among the problems affecting environmental sustainability [1–3]. As such, several anthropogenic activities lead to environmental pollution including air, soil and water. Typically, pollutants are substances that are injurious to the ecosystem or environment [4]. In most countries of the world, pollutants emanate from agricultural and industrial sectors. The effects of pollutant have a short, medium and long term impact on the environment which could be direct or indirect depending on the exposure rate/dose. Various pollutants of the environment (including those present in soil, air and water) are deposits of matter, gases, acids, droplets, metals, fluorides, agrochemicals, organic substances, photo chemicals, oxidant solid wastes, detergents, radioactive wastes and noise [4]. In many cases wastes ends up in the aquatic ecosystem. On air, they could also find their way to the soil or water during precipitation/rainfall.

Pollutants have detrimental effects on the aquatic environment [5]. Pollutants are from several anthropogenic activities of human including surfactant used for production of detergents. Surfactants are very toxic to the aquatic organisms [6]. Furthermore, detergents affect both chemical and biological characteristics of receiving water bodies [7] and the associated biota. Topale et al. [8] reported that detergent concentrations exceeding 5 ppm could kill eggs of fish and destroy breeding ability of aquatic organisms such as fisheries.

Detergents are produced with surfactant compounds [6]. Surfactants are a diverse group of chemicals used by several for the production of several products and as input for cleaning up contaminant from the environment. For instance, they are used for the production of soap, shaving creams, fabric softeners, paint, leather and textile items, pesticides, defoliants, antiseptics, disinfectants [7, 9, 10]. Furthermore, they are active ingredient for the remediation of crude oil contaminated environment. Typically, some of the major surfactants that are used in detergent production include linear benzene sulphonate, alkyl sulphates, alkyl ethoxysulphates, ethoxylates, alkyl phenol ethoxylates, cetyltrimehtyl ammonium bromide [7, 9, 11].

Like surfactants, detergents are recalcitrant to degradation [12]. As such they can remain in the aquatic ecosystem for a long period of time [8, 12]. Consequently, detergents enter the food web through uptake by vegetation, phytoplankton, fishes and zooplankton [12]. Fishes absorb substances in their environment through skin or gills [8]. Thus, detergents can accumulate in tissues and organs of fishes [13]. Fishes have been used to assess effects of contamination in the aquatic ecosystem especially pesticides [14–23]. This suggests that fishes are good biosensors and bio-indicators of aquatic ecosystem [12]. For instance, Chandanshive [13] reported that Mystus montanus, a fresh water fish is highly sensitive to two commonly used household detergent powders (Surf and Nirma). Typically, aquatic toxicology is a study of toxic

Corresponding author: Enemuadia Oyoroko, Environmental Toxicology Research Unit, Department of Biological Sciences, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria, E-mail; eoyoroko@gmail.com.

materials found in the aquatic ecosystem and how they affect life in the environment including mortality [8].

Among the fish resources found in the Niger Delta, are species such as *Heterobranchus bidorsalis* and *Clarias gariepinus* [14, 20, 21, 24, 25]. In the Niger Delta this two different fish families (*Clarias* and *Heterobranchus*) are also crossed and reared in household using earthen and concrete ponds and are called hybrid fish. During the maintenance of the pond (concrete pond), detergents are used to wash the surfaces. Drains and/or remains of detergent could induce toxicity especially in juveniles. Therefore, this study aimed to investigate the mortality rate of Juvenile *Heterobranchus bidorsalis*, *Clarias gariepinus* and *Heteroclarias* exposed to detergent containing linear alkyl benzene sulphonate.

2 Materials and Methods

2.1 Source of Fish, Transportation and Acclimation

One hundred and eighty healthy juvenile Heterobranchus bidorsalis, Clarias gariepinus with mean length 10.00cm and 9cm respectively were purchased from a private fish farm in Ozoro, Delta state. Furthermore, 180 healthy juvenile hybrid (Heteroclarias) with mean length of 3.0cm were obtained from private fish farm in Ughelli, Delta state. The fish samples were transported in 20 liter rubber cans with their natural water and cans covered with fishing net to the laboratory at Niger Delta University were they were allowed to acclimatize in a 80 liter circular rubber aquaria for 3 days. A renewal bioassay was carried out where test water, and sub-lethal concentrations of toxicant were renewed daily. Fishes were daily fed with coupen fish diet (fish meal) at 5% body weight at 11:00 hours [26]. Fishes adapted to laboratory conditions with <1% death recorded. This process was discontinued 24hours before the commencement of the range finding trial.

2.2 Range Finding Test (Trial Test)

A static renewal bioassay procedure was employed in this experiment. During the process, the test toxicant (detergent containing linear alkyl benzene sulphonate) and test solution (water) were renewed daily including their feed which was served at an interval of 12 hours. During this process, the fishes were removed and replaced in the test solutions in the original containers. A range finding test (trial test) was carried out using the toxicant in the following concentration (1000ppm, 800ppm, 600ppm and 400ppm) for 2 days, to determine a safe sub-lethal concentration for the main experimental run [26].

2.3 Main Experiment

Based on the findings of range finding test, the main experiment was carried out using the same procedure described for the trial test using lower concentrations of the toxicant for a period of 3 days at 12 hour interval. During the period (every 12 hours interval) virtual number of dead fishes was recorded. The details of the main experimental setup are presented in Table 1. There were six treatment levels with ten fishes. Each treatment contained different trade mark (i.e. different product) of detergent containing linear alkyl benzene sulphonate. Borehole water was used as diluents and control. The experiment lasted for 3 days or 72 hours.

2.4 Mortality determination

The fishes were confirmed dead when they did not respond to repeated prodding of their anal fins. The mortality was recorded after exposure. Mortality rate was calculated as follows;

$$\text{Mortality rate} = \frac{\text{Number of dead fish}}{\text{Total number of fish exposed to the detergent}} \times 100$$

2.5 In-situ water quality Analysis

The in-situ water quality parameters measurement was carried out using portable meters. All parameters were analyzed according to the manufacturer's instructions. Turbidity and pH were analyzed using turbidity meter (Extech Model TB400) and pH meter (Extech DO700; a multipurpose meter) respectively. Also salinity, temperature, total dissolved solid and conductivity were analyzed using multipurpose meter (Extech EC400).

2.6 Statistical Analysis

Statistical package for social sciences version 20 (IBM) was used for the statistical analysis. Mortality data was expressed as mean ± standard error. Tukey Honestly Significance Difference test statistics was used to show source of the observed differences. The LC50 was estimated based on the method previously used by Bassey et al. [27], Ohimain et al. [28, 29], Angaye et al. [30 – 35], Chandanshive [13]. Thus, the corresponding concentration of the detergent that induces 50% mortality in the fishes.

3. Results and Discussion

The in-situ water quality parameters of the diluent are presented in Table 2. The mean turbidity, pH, conductivity, salinity, temperature and total dissolved solid were 0.42±0.06 NTU, 7.02±0.05, 32.30±0.06 µS/cm, 16.13±0.09ppm, 28.97±0.26 ºC and 22.77±0.15mg/l respectively. The pH and temperature reported in this study is within the values previously reported to support fish life. For instance, pH 6.5 – 9.0 has been recommended to support fish life [36 – 38]. Bhatnagar and Devi [39] presented a stricter value of 7.0 – 8.5. Furthermore, the total dissolved solid, salinity and conductivity of the water was within the drinking water standard previously reported by Standard Organization of Nigeria [40]. As such, the water quality parameters may not have effect on the mortality of the fishes during the experiment.

Table 1: Experiment setup of juvenile fish exposed to some common detergent containing linear alkyl benzene sulphonate

Concentration of toxicant into the water g/l	Quantity of water (liters) further added	Final volume of water (liters)	Final Concentration, mg/l or ppm
1	3	4	250
0.8	3.2	4	200
0.6	3.4	4	150
0.4	3.6	4	100
0.2	3.8	4	50
0.0	0.0	4	0

Table 2: In-situ water quality parameters of the water used for the bioassay

Parameters	N	Minimum	Maximum	Mean ± Standard error
Total dissolved soli, mg/l	3	22.50	23.00	22.77±0.15
Temperature, ºC	3	28.50	29.40	28.97±0.26
Salinity, ppm	3	16.00	16.30	16.13±0.09
Conductivity, µS/cm	3	32.20	32.40	32.30±0.06
pH	3	6.93	7.09	7.02±0.05
Turbidity, NTU	3	0.34	0.54	0.42±0.06

Table 3 and 4 present the effect of time and concentration respectively on the mortality rate of some freshwater fish exposed to detergent containing linear alkyl benzene sulfonate. The mortality rate for Heterobranchus bidorsalis was 26.67% at 12 hours, 61.67% at 48 hours and 76.67% at 72 hours, significant differences ($p < 0.05$) among the various time intervals (Table 3). However, it was observed that no significant variation ($p>0.05$) existed between 24 and 36 hours and between 60 and 72 hours (Table 3).

Each data is expressed as mean± standard error (n=18); Different letters along the column indicate significant variation ($P< 0.05$) according to Tukey Honestly Significance Difference Test statistics Based on concentration, at 0.00ppm, 150ppm and 250ppm mortality was 0.00, 57.14% and 60.95% respectively. There was no significance variation ($P>0.05$) among the various concentration apart from 0 and 50ppm that was significantly different ($p < 0.05$) (Table 4). The mortality level increased as the concentration and time interval increased based on the number of replicate for each factor. Basically there was significant interaction between the concentration and time. For Clarias gariepinus, the mortality rate at 0, 24 and 72 hours were 0.00, 38.33 and 69.44%. There was significant difference ($P<0.05$) among the various time intervals. Furthermore, at 36 and 48 hours and between 60 and 72 hours, there was no significant variation ($P>0.05$) (Table 3). Based on concentration, at 0.00ppm, 150ppm and 250ppm mortality was 0.00, 47.62% and 63.33% respectively. Basically, there was significant variation ($P<0.05$) among the various concentrations apart from 50ppm and 100ppm and between 200ppm and 250ppm there was no significant difference ($P>0.05$) (Table 4).

For the hybrid, the mortality rate at 0, 36 and 72 hours were 0.00, 66.67 and 83.33%. Basically, there was significance difference ($P<0.05$) among the various time intervals (Table 3). Furthermore, at 24, 36 and 48 hours and between 48, 60 and 72 hours, there was no significant variation ($P > 0.05$) (Table 3). Based on concentration, at 0.00ppm, 150ppm and 250ppm mortality was 0.00, 73.33% and 83.81% respectively. Basically, there was significant variation ($P<0.05$) among the various concentrations. But no significant variation ($P>0.05$) between 50ppm and 100ppm and between 150, 200ppm and 250ppm. The mortality level increased as the concentration and time interval increased based on the number of replicates for each factor. Typically, there was significant interaction between the concentration and time.

Table 3: Effect of time on the mortality rate (%) of some freshwater fish exposed to detergent containing linear alkyl benzene sulphonate

TIME	*Heterobranchus bidorsalis*	*Claris gariepinus*	Hybrid (*Heteroclarias*)
0,hours	0.00±3.15a	0.00±2.84a	0.00±3.52a
12,hours	26.67±3.15b	22.78±2.84b	52.22±3.52b
24,hours	39.44±3.15bc	38.33±2.84c	62.78±3.52bc
36,hours	46.67±3.15c	41.11±2.84cd	66.67±3.52bc
48,hours	61.67±3.15d	51.11±2.84d	74.44±3.52cd
60,hours	71.67±3.15de	65.00±2.84e	82.78±3.52d
72,hours	76.67±3.15e	69.44±2.84e	83.33±3.52d

Table 4: Effect of concentration on the mortality rate (%) of some freshwater fish against detergent containing linear alkyl benzene sulphonate

Concentration	*Heterobranchus bidorsalis*	*Claris gariepinus*	Hybrid
0,ppm	0.00±2.91a	0.00±2.63a	0.00±3.26a
50,ppm	45.24±2.91b	37.14±2.63b	60.48±3.26b
100,ppm	51.43±2.91bc	43.33±2.63b	64.29±3.26b
150,ppm	57.14±2.91bc	47.62±2.63bc	73.33±3.26bc
200,ppm	60.95±2.91c	55.24±2.63cd	80.00±3.26c
250,ppm	61.91±2.91c	63.33±2.63d	83.81±3.26c

Each data is expressed as mean± standard error (n=21); Different letters along the column indicate significant variation ($P<0.05$) according to Tukey Honestly Significance Difference Test statistics

Detergent molecules can be easily absorbed from surrounding water through gills and/or intestinal epithelium, if it is found in the food, it can be easily absorbed by intestinal epithelium and circulated to other parts of the body [41]. As such detergents can be accumulated in tissues and released into the blood stream [42]. Due to the ability of fish to absorb detergent into their blood stream, it could lead to alteration in histology, histopathology, haematology, electrolytes, metabolites and enzymatic parameters of the fish. The alteration in these parameters could lead to death of the fishes. Detergents typically have toxic effects and produce osmo-regulatory imbalances in aquatic organisms especially fisheries (shelled and fin fish) when the concentrations exceed the metabolic demand [43]. Detergent molecules can enter and solubilize the lipid content of cell membrane of living things [13].

The concentration of the detergent that could cause 50% mortality among the different fish is presented in Figure 1. Clarias gariepinus have higher LC50 values. This could be connected to their ability to thrive in hash environmental condition. Ogundiran et al. [41], Ogamba et al. [24] reported that Clarias gariepinus has the ability to tolerate both well and poorly oxygenated waters. Clarias gariepinus can able to tolerate both well and poorly oxygenated waters, as such it is widely used for ecotoxicological studies. Like Clarias gariepinus, hybrid catfish (Heteroclarias), is hardy and can withstand both well-oxygenated as well as poorly oxygenated waters, hence suitable for use as a biological indicator in ecotoxicological study [43].

Typically, mortality is the effect of dysfunctioning of the various organs and tissues of the fish that were exposed to the detergent. This is because the tissues and organs play essential role in the health status of fish. In fish, the gill is a prime organ for gaseous exchange and performs several other physiological functions such as osmoregulation and excretion [44]. Alteration could lead to dysfunctioning of the various roles of the gills.

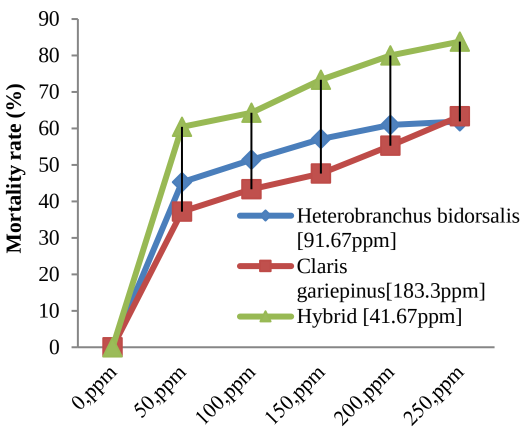

Figure 1: Concentration-Mortality rate response bioassay of detergent containing linear alkyl benzene sulphonate against some common fish species

The median concentration that induces 50% mortality in this study is higher than the concentration previously reported in literature. For instance, Ogundiran et al. [43] reported LC50 values of 0.0166 mg/L and 0.0038 mg/L for lethal and sublethal tests respectively for juvenile Clarias gariepinus exposed to detergent effluents containing linear alkylbenzene sulfonates. Ndome et al. [41] reported median lethal concentrations (LC50) values of omo and Ariel in the range of between 33.03–35.19 ppm (mean 34.11 ppm) and 37.43–39.79 ppm (mean 36.66ppm) respectively for fingerlings of Clarias gariepinus, Heterobranchus longifilis and hybrid (Heteroclarias) in a 96 hour bioassay. Variation in the LC50 values may be associated with age/size of the fish, fish species and concentration of the detergent.

4 Conclusion

Most human activities in the environment are major cause of pollution, thereby affecting the associated biota. Detergent is commonly used for washing and cleaning processes and the water may drain into aquatic ecosystem. Sometimes washing of household item are carried out in the surface water including stream, river, creek and creeklets using detergents and or other soap containing surfactants. This study investigated the toxicity of detergent containing linear alkyl benzene sulphonate against some commonly reared freshwater fish in the Niger Delta. The study found that the detergent could induce mortality in juvenile species of Clarias gariepinus, Heterobranchus bidorsalis and hybrid (Heteroclarias). As such, caution should be exercised in the use of detergents close to aquatic ecosystem.

Acknowledgements

This publication is based on part of Master of Science project work of the lead author (Enemuadia Oyoroko) supervised by the second author (Dr. E.N. Ogamba) at the Niger Delta University, Nigeria.

References

1. Izah, S.C.; Angaye, T.C.N.; Ohimain, E.I. Environmental Impacts of Oil palm processing in Nigeria. *Biotechnol. Res.* 2016, 2(3), 132-141
2. Ogamba, E.N.; Izah, S.C.; Omonibo, E. Bioaccumulation of hydrocarbon, heavy metals and minerals in Tympanotonus fuscatus from coastal region of Bayelsa state, Nigeria. *Inter. J. Hydrol. Res.* 2016, 1, 1-7.
3. Izah, S.C.; Angaye, T.C.N. Heavy metal concentration in fishes from surface water in Nigeria: Potential sources of pollutants and mitigation measures. Sky J. Biochem. Res. 2016, 5(4), 31-47
4. Priya, R.; Loganathan, S.; Ganapathi, N.; Narendiran, N.T. Estimation of protein in the detergent induced toxicity fish, Catla catla. *J. Global Biosci.* 2014, 3(1), 314-320.
5. Hedayati, A.; Salati, A.P. Acute toxicity test of detergent powder in silver carp (Hypophthalmicthys molitrix), common carp (Cyprinus carpio), goldfish (Carassius auratus) and roach (Rutilus rutilus caspicus). *Iranian J. Aqu Ani. Health,* 2015, 2(1), 11-16
6. Ivanković, T.; Hrenović, J. Surfactants in the environment. *Arh. Hig. Rada. Toksikol*., 2010, 61, 95-110.
7. Chandanshive, N.E. Studies on Toxicity of Detergents to Mystus montanus and Change in behaviour of Fish. *Res. J. Ani. Veter. Fishery Sci.* 2013, 1(9), 14-19.
8. Topale, P.S.; Ghaware, A.U.; Jadhao, R.G. Effect of Detergent Tide on Paratelphusa Jacquemontiil (Rathbun) Freshwater Crab from Vidarbha Region. *Inter. Res. J. Sci. Eng.* 2013, 1 (1), 10-12.
9. Singh, R.P.; Swarrop, D.; Annie K. Surfactants and their toxicity to aquatic animals. *Ecotoxicol. Environ. Monit*. 1999, 11(2), 117-121.
10. Lewis, M.A. Chronic and sublethal toxicities of surfactants to aquatic animals: a review and risk assessment. *War. Res.*, 1991, 25(1), 101-113.
11. Chandanshive, N.E. Studies on the consequence of detergents on reserved glycogen in muscles and liver of Mystus montanus. *Inter. Res. J. Nat. Appl. Sci.* 2015, 2(6), 156 – 168

12. Spirita, S.V.; Kanagapan, M.; Sam, M.D.S.; Avila V. R. Studies on the toxicity of Alkylbenzene sulphonate to Zebra fish, Danio rerio Hamilton. *J. Entomol. Zool. Studies*, 2015, 3 (1), 204-207
13. Chandanshive, N.E. Effects of different Concentrations of Detergents on Dissolved Oxygen Consumption in fresh water fish Mystus montanus. *Inter. Res. J. Environ. Sci.* 2014, 3(8): 1- 5.
14. Inyang, I.R.; Seiyaboh, E.I.; Job, U.B. Condition Factor, Organosomatic Indices and behavioural Abnormalities of *Clarias gariepinus* exposed to Lambda Cyhalothrin. *Greener J. Life Sci.* 2017, 4 (1), 001-005.
15. Inyang, I.R.; Okon, N.C.; Izah, S.C. Effect of glyphosate on some enzymes and electrolytes in Heterobranchus bidosalis (a common African catfish). *Biotechnol. Res.* 2016, *2*(4), 161-165
16. Inyang, I.R.; Obidiozo, O.Z.; Izah, S.C. Effects of Lambda cyhalothrin in protein and Albumin content in the kidney and liver of Parpohiocephalus obscurus. *EC Pharmacol. Toxicol.* 2016, 2(3): 148-153
17. Inyang, I.R.; Akio, K.; Izah, S.C. Effect of dimethoate on some selected metabolites in the brain, liver and muscle of *Clarias lazera. Sky J. Biochem. Res.* 2016, *5*(4), 63-68
18. Inyang, I.R.; Thomas, S.; Izah, S.C. Activities of electrolytes in kidney and liver of *Clarias gariepinus* exposed to fluazifop-p-butyl. *J. Biotechnol. Res.* 2016, 2(9): 68 – 72.
19. Inyang, I.R.; Thomas, S.; Izah, S.C. Evaluation of Activities of Transferases and Phosphatase in Plasma and Organs of *Clarias gariepinus* Exposed to Fluazifop-p-Butyl. *J. Environ. Treat. Techniq.* 2016, 4(3), 94-97
20. Inyang, I.R.; Akio, K.; Izah, S.C. Effect of dimethoate on lactate dehydrogenase, creatinine kinase and amylase in *Clarias lazera. Biotechnol. Res.* 2016, *2*(4), 155- 160.
21. Inyang, I.R.; Ollor, A.O.; Izah, S.C. Effect of Diazinon on Organosomatic Indices and Behavioural Responses of *Clarias gariepinus* (a Common Niger Delta Wetland Fish). *Greener J. Biol. Sci*. 2017, 7(2): 15 – 19.
22. Inyang, I.R.; Izah, S.C.; Johnson, D.T.; Ejomarie, O.A. Effects of Lambda cyhalothrin on some electrolytes and metabolites in organs of Parpohiocephalus obscurus. *Biotechnol. Res.* 2017, 3(1): 6-10.
23. Inyang, I.R.; Ajimmy, R.; Izah, S.C. Organosomatic index and behavioral response of *Heterobranchus bidorsalis* exposed to rhonasate 360sl containing glyphosate (isopropylamine salt glycine). *ASIO J Microbiol, Food Sci. Biotechnol. Innov.* 2017, 3(1): 6 – 14.
24. Ohimain, E.I.; Inyang, I.R.; Osai, G.U. The Effects of Raffia Palm Mesocarp on Haematological Parameters of *Clarias gariepinus*, a Common Niger Delta Wetland Fish. *Ann. Res. Rev. Biol*. 2015, 8(1), 1-7
25. Ogamba, E.N.; Izah, S.C.; Isimayemiema, F. Bioaccumulation of heavy metals in the gill and liver of a common Niger Delta wetland fish, Clarias garepinus. *Bri. J. Appl. Res.* 2016, 1(1), 17 – 20.
26. Oyoroko, E.; Ogamba, E.N. Effects of detergent containing linear alkyl benzene sulphonate on behavioural response of Heterobranchus bidorsalis, *Clarias gariepinus* and *Heteroclarias*. *Biotechnol. Res*. in press.
27. Bassey, S.E.; Ohimain, E.I.; Angaye, T.C.N. The Molluscicidal Activities of Methanolic and Aqueous Extracts of Jatropha curcas leaves against Bulinus globosus and Bulinus rholfsi, Vectors of Urinary Schistosomiasis. *J. Parasitol.* 2013, 103, 115 - 122.
28. Ohimain E.I.; Angaye, T.C.N.; Bassey, S.E. Comparative larvicidal activities of the leaves, bark, stem and root of Jatropha curcas (Euphorbiaceae) against malaria vector Anopheles gambiae. *Sky J. Biochem. Res*. 2014, 3(3): 029 - 032.
29. Ohimain, E.I.; Angaye, T.C.N.; Bassey, S.E.; Izah, S.C. Acaricidal activities of Hyptis suaveolens and Ocimum sanctum against African Dog Tick (Rhipicephalus sanguinneus). *Euro. J. Med. Plants,* 2015, 8(3), 149-156.
30. Angaye, T.C.N.; Oyinke, G.N.; Angaye, W.W.T.; Igbeinkutu, V.D. The Comparative Phytochemical and Bio-larvicidal Efficacy of Leaf Extracts of Gmelina arborea against Mosquito Larvae. *Inter. J. Innov. Healthcare Res*. 2017, 5(1), 1-6
31. Angaye, T.C.N.; Oyinke, G.N.; Angaye, W.W.T.; Orubina, I.A. Control of malaria and schistosomiasis vectors using express seed sap extracts of Gmelina arborea. *ASIO J. Med. Health Sci. Res.* 2017, 2(1), 1-7.
32. Angaye, T.C.N.; Bassey, S.E.; Ohimain, E.I.; Izah, S.C.; Asaigbe, P.I. Molluscicidal and synergicidal activities of the leaves of four Niger Delta Mangrove plants against Schistosomiasis vectors. *J. Environ. Treat. Techniq.* 2015, 3(1), 35 - 40.
33. Angaye, T.C.N., Bassey, S.E. and Ohimain, E.I. Biomolluscicidal Activities of Some Solvent Extracts of Jatropha Curcas Leaves against Vectors of Schistosomiasis. *Res. J. Pharmacol. Toxicol.* 2015, 1(1), 17 – 20.
34. Angaye, T.C.N., Ohimain, E.I., Zige, D.V., Didi, B. and Biobelemoye, N. Biocidal activities of Solvent extracts of *Azadirachta indica* against Some Endemic Tropical Vectorborne Diseases. *Inter. J. Trop. Dis.Health*, 2014, 4(11), 1198 - 1208.
35. Angaye, T.C.N.; Ohimain, E.I.; Siasia, E.P.; Asaigbe, P.I.; Finomo, O.A. Larvicidal activities of the leaves of Niger Delta mangrove plants against Anopheles gambiae. Sky J. Microbiol. Res. 2014, 2(7), 032 - 036.
36. Boyd, C.E. Water quality in warmwater fish ponds. Auburn University Agricultural Experiment Station, Auburn, Alabama, USA. 1979.
37. Okomoda, V.T.; Ataguba, G.A.; Ayuba, V.O. Hematological Response of *Clarias gariepinus* Fingerlings Exposed to Acute Concentrations of Sunsate®. *J. Stress Physiol. Biochem*. 2013, 9(2), 271-278.
38. Oloruntuyi, O.O.; Mulero, O.; Odukale, B. The effects of two pesticides on *Clarias gariepinus*. In: 10th Annual Conference of the Fisheries Society of Nigeria (FISON), 16-20 November 1992, Abeokuta, Nigeria, pp. 173-177. http://aquaticcommons.org/3508/1/173.pdf. Accessed June 28th, 2015.
39. Bhatnagar, A.; Devi, P. Water quality guidelines for the management of pond fish culture. *Inter. J. Environ. Sci.* 2013, 3(6), 1980 – 2009.
40. Standard organization of Nigeria (SON). Nigerian Standard for Drinking Water Quality. Nigerian industrial standard, Nigeria. 2007.
41. Ogundiran, M.A.; Fawole O.O.; Adewoye, S.O.; Ayandiran, T.A. Toxicological impact of detergent effluent on juvenile of African Catfish (*Clarias gariepinus*) (Buchell 1822). *Agric. Biol. J. North Amer.* 2010, 1(3), 330-342.

42. Jawahar, A.A.; Ayesha, M.; Kumar, M.S.A.; Chitrarasu, P. Acute toxicity of detergent to Indian major carps Catla catla and Labeo rohita. *Euro. J. Exper. Biol.* 2015, 5(1), 30-33
43. Ndome, C.B.; Mowang, D.A; Ayibaemi, T.T. Comparative acute toxicity of local detergents (Omo and Ariel) on fingerlings of the *Clarias gariepinus*♀ x Heterobranchus longifilis♂ hybrid. *Aquaculture, Aquarium, Conservation and Legislation International Journal of the Bioflux Society*, 2013, 6(4), 415 – 420.
44. Spirita, S.V., Avila, V.R. and Kanagapan, M. Alkylbenzene sulphonate, a detergent, induced toxicity on the gill of Zebrafish Danio rerio (Hamilton). *Inter. J. Fauna Biol. Studies*, 2015, 2 (4): 33-37.