Acute Toxicity of NPK 15:15:15 Fertilizer on the Fingerlings of *Heterobranchus bidorsalis*

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Abstract

The toxicity of NPK (15.15.15) fertilizer on *Heterobranchus bidorsalis* fingerlings (mean total length, 6.98 ± 0.30 cm; mean body weight 2.04 ± 0.35 g) was investigated. The fingerlings were exposed to increasing concentrations of NPK (0.00 g/l, 2.50 g/l, 3.13 g/l, 3.75 g/l, 4.38 g/l, 5.00 g/l, 5.63 g/l and 6.25 g/l) fertilizer in the static renewal bioassay for 96 h. Exposed fish showed initial stress responses such as erratic swimming, restlessness, loss of balance, frequent attempts at jumping out of the tank and quietness. Water quality examinations showed a decrease in the dissolved oxygen content and increase in total hardness and alkalinity as the concentration of fertilizer was increased. The 96 h LC_{50}, associated confidence limits and safe concentrations for the fertilizer were (1.09, 0.29-3.86, and 0.11 g/l, respectively. Mortality rates were concentration-dependent and death rate in the highest concentrations were significantly higher ($P < 0.05$) than the others. Mortality rate was influenced by both concentration and time. The findings show that NPK fertilizer could be classified as toxic to *H. bidorsalis* fingerlings at certain concentrations.

Introduction

The major environmental issues of present time are the growing concern about water quality suitable for use by man and animals (Calamari & Naeve, 1994). The daily activities of humans in one way or the other affect the aquatic environment negatively. These activities, which include the discharge into streams and river systems of various pollutants, such as agricultural fertilizers of different types, pesticides, insecticides and industrial effluents, pollute the water bodies and alter ecological balance (Osibanjo, 2002). Pollutants in their effects influence the quality of these water bodies which is of high importance in the aquatic ecosystem balance and, consequently, affect the survival of aquatic organisms inhabiting such environments (Odiete, 1999). It is a known fact that water quality conditions are constantly being threatened by pollution. The rivers and coastal water bodies are presently exposed to increasing quantities and concentrations of both natural as well as anthropogenically derived contaminants (Ezeka, 2004). Environmental concern about intensive agricultural practices and excessive or inappropriate use of chemical fertilizers calls for some global action among environmentally conscious individuals and other stakeholders (Nychas, 1990).

A fertilizer is any material, organic or inorganic, natural or synthetic, that supplies plants with the necessary nutrients for growth and optimum yield (Addiscott *et al.*, 1991) or a substance added to water to increase the production of natural fish food organisms (Nwadukwe, 1995). Inorganic (or chemical) fertilizers are fertilizers mined from mineral deposits with little processing for example,

lime, potash, or phosphate rock or industrially manufactured through chemical processes, for example NPK and Urea (Amadi, 1991). Inorganic fertilizers vary in appearance depending on the process of manufacture. The particles can be of many different sizes and shapes (crystals, pellets, granules or dust) and the fertilizer grades can include straight fertilizers (containing one nutrient element only), compound fertilizers (containing two or more nutrients usually combined in a homogeneous mixture by chemical interaction) and fertilizer blends (formed by physically blending mineral fertilizers to obtain desired nutrient rates (Alexander, 1996).

Fertilizers are carried through surface run-off from cultivated agricultural farm lands and they enter into the aquatic environment in either soluble or particulate forms and, consequently, deliver soluble phosphorus, nitrogen and carbon for uptake and growth of plants (Cooke, 1975). Fertilizer analysis can be categorized into organic and inorganic chemical varieties (Ball, 1949). The use of chemical fertilizers in agricultural production is highly indispensable and is widely acceptable by an ever increasing number of farmers, not because fertilizers help condition the fragmented and nutrient-depleted soil for further production and boost soil resistance to erosion, but also that it encourages vegetal cover (Almazan & Boyd, 1978). However, the increasing application of fertilizers has threatened the human environment and aquatic ecosystems with deleterious consequences (Enger & Smith, 1991). These harmful effects if unchecked can negate to quite some extent the benefits derived from increasing usage of fertilizer (Maxwell, 1973).

Fertilizers and pesticides are often associated with pollution problems because they could be toxic to fish and other aquatic organisms over a range of concentrations under varied environmental conditions (Rand, 1995). The concern about pesticides has always been present because of their chemical nature, whereas that of fertilizer use has appeared only relatively recently mainly because of the measurable effects of nitrate groundwater pollution and increase of nitrate in drinking water, which pose serious health problems to the consumer and the public in general (Kolenbrader, 1981). Other problems include contamination of aquatic environment by heavy metals such as cadmium, through run-off containing phosphate fertilizers (Shaivon *et al.*, 1995) and nutrient enrichment, leading to eutrophication and deterioration of water quality (Kofoed, 1981). The objective of this study is, therefore, to determine the acute toxicity, i.e. lethal concentrations (LC_{50}) and effects of NPK fertilizer on *H. bidorsalis* fingerlings.

Materials and methods

Description of test organism

The species, *Heterobranchus bidorsalis* belong to the family clariidae and is one of the most widely cultured catfish in Nigeria (Marioghae, 1991). They have the ability to grow on a wide range of artificial and natural foods, with good feed conversion efficiency. They are hardy and tolerant to low dissolved oxygen and other adverse culture conditions. They are dark to brownish olive (sometimes with blotches) with flattened head, and strongly granulated as well as depressed body. There have typically four pairs of barbels, usually grey and white at their bases, with wide mouth and upper lip reddish. *H. bidorsalis* has smooth and scale-less skin as well as accessory breathing organs on the

head and can survive out of water for a long time. Like *Clarias*, they can walk out from the pond if the conditions are unfavourable (Teugels *et al.*, 1998; Huisman & Richter, 1997; Haylor, 1993). They are important species with a high market value, rapid growth, and are propagated in Africa (mainly South Africa and Nigeria), parts of Europe and Asia (Teugels, 1984; Viveen *et al.*, 1985). They are most commonly used as experimental fish (Robert, 1988; Clay, 1989; Okaeme, 1989).

Source of experimental fish

Five hundred fingerlings of *H. bidorsalis* were obtained from Premier Fisheries Ltd., Akai Ubium, Nsit Ubium Local Government Area, Akwa Ibom State. They were transported in a 50-litre jerry-can by car to the Department of Fisheries and Aquaculture hatchery, University of Uyo. The mean body weight (g) and total length (cm) of the species were 2.04 ± 0.35 and 6.98 ± 0.29, respectively.

Acclimation

The fish were acclimated for 14 days, in groups of 50 fish per plastic container in 30 litres of dechlorinated tap water. The containers were aerated (Hannah Product Model 292B) during this period, while the water was renewed daily to discard faecal

Fig. 1. Map of Nigeria showing sampling site

material and left-over food. The species were fed twice daily with a 45% crude protein diet at 1% of their body weight (Ufodike & Onusiruika, 1990) half at 08:00 and 16:00 h GMT, respectively. During this period, dead and abnormal individuals were immediately removed. Mortality recorded during the acclimation period was less than 2% (OECD, 1992; APHA *et al.*, 2005). It was from the acclimated population that healthy individuals used as test fish in this study were carefully selected.

Preparation of test media and exploratory test

The whole experimental procedures used in the study were based on the guidelines in OECD (1992); ASTM, (2004a) and APHA *et al*., (2005). To obtain the ranges of concentrations as used in the experiment, five fish each were exposed to 4 litres of dechlorinated water containing different weights of the fertilizer. It was used for the preliminary runs for 24 h, until suitable concentration that resulted in 100% mortality was derived. The fish were not fed 24 h before and during these trials. The ranges of concentration values used in the study were determined from the 100% mortality obtained from the trials.

Experimental design and procedures

The experiment is a completely randomized design. Each of the treatment levels had two replicates (Akindele, 2004; Ogbeibu, 2005). Exposure concentrations of the fertilizer were 0.00 g/l, (control) 2.50 g/l, 3.13 g/l, 3.75 g/l, 4.38 g/l, 5.00 g/l, 5.63 g/l, 6.25 g/l. Sixteen plastic containers of dimension 0.002 m^3 were randomly labeled and each filled with dechlorinated tap water to 8 litres mark for each treatment. The different concentrations were prepared by dissolving directly different weights of the fertilizers in the 8 litres of dechlorinated tap water, to obtain the desired concentration (APHA *et al.*, 2005). The solution was stirred with a glass rod to obtain a homogenous mixture. Within an hour, the containers were randomly stocked with 10 fish each using a scoop net. The test fish were not fed 24 h prior to the test (experiment) and during the 96 h exposure period. Test solution in each tank was drained completely each morning and the fish removed carefully with a scoopnet and kept in a 30 litre plastic container. Fresh solutions were prepared and the fish were carefully put back. Test solutions were renewed daily.

Water quality parameters

Temperature, dissolved oxygen, *p*H, alkalinity and total hardness of the control and various test media were determined at 24, 48, 72 and 96 h intervals during the experimental period (ASTM, 2004a; APHA et al., 2005).

Temperature. The temperature was monitored with mercury in-glass thermometer (Cole-Parmer Model 90201-10). The thermometer was inserted into the test water and the corresponding readings were taken and recorded.

Dissolved oxygen. The dissolved oxygen content was assessed by Winkler's method (ASTM, 2004a). The procedures involved filling oxygen bottles (125 ml) with water samples from each tank and fixing immediately with 2 ml of manganous sulphate and 2 ml of potassium iodine solution. A brown precipitate was formed. 2 ml of concentrated sulphuric acid solution was added to the bottle and shaken to further dissolve the precipitate. 10 ml of this solution was pipetted into a 25 ml conical flask and

titrated with sodium thiosulphate solution (0.25 N) using starch as an indicator until a colourless endpoint was reached. The *p*H was determined with a digital *p*H meter (Hannah product Portugal, Model HA 989).

Alkalinity. The procedure involved the collection of water samples from each tank in Stoppard bottles. 25 ml of the sample was pipetted into a conical flask. Five drops of methyl red indicator and bromocresol green were added and titrated with standard HCl acid (0.01 N) from a 10 ml burette. Continuous shaking ensued a color change from blue to pale pink. The endpoint of *p*H was read with a *p*H meter.

Total hardness. The procedure involved the collection of 25 ml of water samples from each tank into a 100 ml conical flask. 1 ml of diluted buffer solution of borax was added and a measure of solochrome black indicator added also, with constant shaking. This was then titrated with 1.00 g of disodium salt of ethylene diamine-tetra acetic acid (EDTA) solution, from a 2-ml *burette* until the wine red colour changed sharply to blue.

Data collection

Water quality parameters were determined at fixed intervals of 24, 46, 72 and 96 h, respectively. Mortality of the fish species in each tank was observed and recorded at fixed intervals of 24, 48, 72 and 96 h, respectively. Dead fish were removed immediately to prevent polluting the test media. A fish was considered dead when there was lack of movement and reaction to gentle prodding with a glass rod. Other unusual signs of stress were equally monitored, such as uncoordinated and irregular swimming pattern, vertical erection, overturning, restlessness, jumping out of the tank and gasping for air.

Data analysis

Each set of results obtained from these experiments was analyzed in completely randomized design (CRD) at 5% probability level, then the Student's t-test was used to test for significant difference ($P < 0.05$) in the treatments (Irwin, 1953; Finney, 1978,1979; Akindele, 2004; Ogbeibu, 2005). Analysis of the lethal concentration (LC_{50}) values for the 24, 48, 72 and 96 h with associated confidence intervals for the various concentrations of the NPK fertilizer were determined by Probit Analysis using Statistical Package for the Social Sciences (SPSS) Data Editor version 10.0 (Finney, 1978; 1979; Stephan, 1977). Safe concentrations at the various time intervals were obtained by multiplying the lethal concentration (LC_{50}) value by a factor of 0.1 or dividing by a factor of 10 (Irwin, 1953; Finney, 1978; 1979).

Results

Physico-chemical parameters

The result of the physico-chemical parameters of the experimental media for the fertilizers showed that there was a significant reduction in the mean values of dissolved oxygen. Conversely, alkalinity and total hardness values increased as the fertilizer concentrations were increased, compared to the control group ($P < 0.05$). However, there was no significant difference between the various mean values of temperature and *p*H ($P > 0.05$) (Table 1).

General behavioural changes

Behavioural changes occurred in the fish treated with NPK fertilizer at different concentrations. The abnormal behaviours

TABLE 1

Mean water quality parameters during 96 h exposure of H. bidorsalis *fingerlings to acute concentrations of NPK fertilizer, mean ± SD (n = 40, 2 replicates per treatment level)*

Fertilizer Concentration (g/l) Parameters	0.00	2.50	3.13	3.75	4.38	5.00	5.63	6.25
Temperature (°C)	27.56 ± 0.41	27.38 ± 0.16	27.47 ± 0.34	27.39 ± 0.34	27.36 ± 0.29	27.38 ± 0.29	27.31 ± 0.33	27.42 ± 0.35
Dissolved oxygen(mg/l)	7.00 ± 0.006	6.46 ± 0.39	5.16 ± 0.14	4.27 ± 0.37	3.08 ± 0.11	2.26 ± 0.38	2.24 ± 0.34	2.05 ± 0.08
Total hardness	28.31 ± 0.37	31.08 ± 0.75	31.58 ± 0.50	32.57 ± 0.08	33.51 ± 0.35	34.42 ± 0.42	35.88 ± 0.73	36.34 ± 0.79
*p*H	6.06 ± 0.13	6.35 ± 0.13	6.19 ± 0.12	6.15 ± 0.12	6.17 ± 0.15	6.13 ± 0.12	6.15 ± 0.12	6.21 ± 0.16
Alkalinity (mg/l)	30.6 ± 0.24	35.45 ± 0.49	40.72 ± 0.57	45.53 ± 0.39	53.63 ± 0.21	57.6 6± 0.70	61.29 ± 0.92	68.79 ± 1.11

observed in fish exposed to concentrations of NPK fertilizers were characterized by restlessness, gulping of air and erratic swimming before death. These behavioural changes showed by the exposed fish in response to the effect of the toxicant was more pronounced in tanks containing higher concentrations, but decreased with increase in time of exposure, though there was gradual reduction also at higher concentrations. There were no obvious changes in fish behaviour in the lower concentrations less than 3.13 g/l for the first 24 h of exposure. However, fish in the control group of the treatment did not exhibit any abnormal behaviour.

Mean mortality of fingerlings exposed to NPK fertilizer for 96 h

The mean mortality (Fig. 2) of the fingerlings exposed to various concentrations of NPK fertilizer indicated that the different concentrations caused significant ($P < 0.05$) but variable death rate in the exposed fish. Mortality rate was concentration-dependent, with highest concentrations having death rates significantly higher than the others. No mortality was recorded in the control groups of the fish. The lethal effect of NPK fertilizer on the fingerlings expressed as LC_{50} for 24, 48, 72 and 96 h and their associated 95% confidence limits (Table 2), showed that the range of values between the 24 h LC_{50}; 7.48 g/l and 96 h LC_{50}; 1.09 g/l of the toxicant was wide. A safe concentration at LC_{50}; 0.75 g/l for 24 h and 0.11 g/l for 96 h was very low. The LC_{50} values of the concentrations decreased with increase in time of exposure from 24–96 h. At 24 h, the LC_{50} values were greater than the 96 h LC_{50-} values.

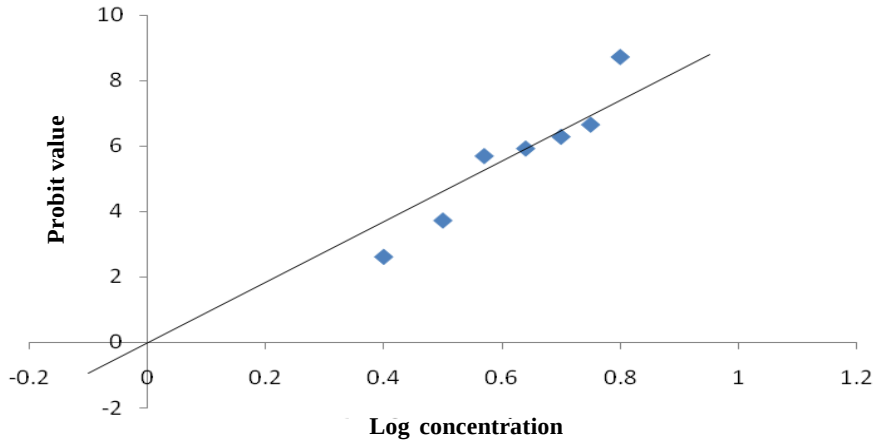

Fig. 2. Mortality rate of *H. bidorsalis* exposed to different concentrations of NPK fertilizers for 96 h

TABLE 2
24, 48, 72 and 96h LC_{50} values, associated confidence limits and safe concentrations of NPK fertilizers to H. bidorsalis

Time (h)	*LC_{50} (g/l)*	*Confidence limits (g/l)*		*Safe conc. (g/l)*
		Lower	*Upper*	
24	7.48	9.64	15.86	0.75
48	5.65	7.23	9.65	0.57
72	3.88	2.96	4.79	0.39
96	1.09	0.29	3.86	0.11

Discussion

Water quality parameters

The water quality parameters of the experimental media for NPK and urea fertilizers showed that there was a significant reduction in the mean values of dissolved oxygen content, while, conversely, alkalinity and total hardness values increased as the fertilizer concentrations were increased ($P < 0.05$), compared to those of their control groups. There was no significant difference between the various mean values of temperature and *p*H ($P > 0.05$) as both were within the suggested tolerance ranges for warm water fish species (Boyd, 1979; Mackereth, 1963; Adeniji & Ovie, 1989). This result agrees with the work of Ofojekwu *et al.* (2008a); Ofojekwu *et al.* (2008b) and Ufodike & Onusiriuka (1990), who exposed *Tilapia zilli* and *Clarias gariepinus* fingerlings, respectively to acute concentrations of inorganic fertilizers; NPK, urea, calcium hydroxide ($Ca(OH)_2$, potassium phosphate ($Na_3PO_4.12H_2O$) and sodium nitrate ($NaNO_3$), and reported no significant difference between the various mean values of temperature and *p*H ($P > 0.05$). The affected parameters may have contributed significantly to the observed behaviours and mortality of the test fish species exposed to the fertilizer concentrations. The increase in alkalinity and total hardness may imply an increased toxicity with the raised values of physico-chemical parameters (Table 1).

The toxicity of a chemical in water depends largely on the concentration and the physico-chemical properties of the medium. Svobodova *et al.*, (1993), Sprague (1969, 1970) and Klussmann *et al.* (1969) stated that the piscicidal activity of chemicals vary

with temperature, *p*H and other environmental factors. Osekita (2003) also documented that the toxicity of a pollutant to fish usually increases with the physico-chemical properties of the medium which may be due to an increased uptake of toxin to added environmental stress, e.g. reduced oxygen solubility (Ananthakrishman & Kutty, 1974). The recorded mean values for temperature and *p*H in the fertilizer test media were within the tolerance range for this tropical species, and may not have contributed to the toxicity of the fertilizer on the behaviours and mortality of the exposed fishes.

General behavioural responses and lethal concentrations of the toxicants to the exposed fish species

Behavioural responses of fish to most toxicants and differences in reaction times have been observed to be due to the effect of the chemical, their concentrations, species, size and specific environmental conditions (FAO, 1984). The behavioural responses reported for the test fishes in this study are similar to those reported by other authors for clarrids under various stress conditions (Onusiriuka & Ufodike, 1994, 1998, 2000; Ufodike & Onusiriuka, 1990, 1992; Avoajah & Oti, 1997; Auta *et al.*, 2004; Nwanna *et al*., 2000).

Besch (1975) identified four main phases in the exposure time on behavioural responses of fish to toxicants. These are the contact phase (brief period of high excitability), exertion (visible avoidance characterized by fast swimming, leaping and attempts to jump out of the toxicant), loss of equilibrium, followed by lethal (death) phase, when opercular movement and responses to tactile stimuli cease completely. Inspite of the numerous advantages of chemical fertilizers to improve fish production, they have a startling number of adverse effects on aquatic life in water bodies that receive run-off from farmlands or from excess direct application in the aquatic environment (FAO, 2000).

Results obtained from the study reveals that the 96 h LC_{50} for *H. bidorsalis* fingerlings exposed to NPK fertilizer was 1.09 g/l, with lower and upper confidence limits of 0.29–3.86 g/l, respectively. This value is at variance with the values reported by Ufodike & Onusiriuka (1990) when they exposed *C. gariepinus* to acute concentrations of some inorganic fertilizers. They reported that the 96 h LC_{50} for calcium hydroxide ($Ca(OH)_2$), NPK, sodium phosphate ($NaPO_4.12H_2O$) and sodium nitrate ($NaNO_3$) fertilizers were 33.9 mg/l, 83.6 mg/l, 748 mg/l and 1258.9 mg/l, respectively. But it closely agrees with the values reported by Ofojekwu *et al.* (2008), when they exposed *T. zilli* fingerlings to acute concentrations of NPK (15.15.15) fertilizer. Their 96 h LC_{50} was 1.05g/l. The differences between these two findings may have been as a result of the differences in fish species, sizes and levels of concentration used, as different species of organisms respond differently to the effect of a pollutant at a given time (Johnson & Finley, 1980).

Inorganic fertilizers produce intermediate products that may result in stress, fatigue, nervous disorder and death. This could be understandable as the toxicity of chemicals depend on the type, composition, technical grade of preparations and the susceptibility of the exposed organisms (Aguigwo, 2002). However, the concentrations used in this investigation relatively corresponds with the values documented by Omoregie *et al*. (2003), when they worked on the effects of

sub-lethal concentrations of NPK (15.15.15) fertilizer on growth and feed utilization by the toothed carp (*Aphyosemion gardneri)*.

At the concentrations used in this investigation, the fertilizer led to significant reduction in the dissolved oxygen and an increase in alkalinity and total hardness of the test media. The air gulping reported in the exposed fish in the study is an indication of insufficient amount of dissolved oxygen in the experimental media which may have been depleted by the fertilizer. This result is in line with the report of Warren (1977) who observed that the introduction of a toxicant into an aquatic system might decrease the dissolved oxygen content which in turn impairs respiration, thus, leading to asphyxiation. Stickney (1977) had also earlier documented that insufficient amount of dissolved oxygen is one of the contributing factors to mortality in some fish species. The darkening of the fish, air gulping and erratic swimming reported in the exposed fish to acute concentrations of NPK fertilizer is in agreement with the findings of Silva & Ranasinghe (1989), Ayuba & Ofojekwu (2002) and Ofojekwu *et al.* (2008a).

The result shows that at concentration 6.25 g/l, 100% mortality was recorded, while at concentrations of 5.63 g/l, 5.00 g/l, 4.38 g/l, 3.75 g/l, 3.13 g/l and 2.50 g/l, per cent cumulative mortality recorded were 95, 90, 80, 75, 50 and 30, respectively. No mortality was, however, recorded in the control group. This result also reveals that percentage mortality increases with increase in concentration of the toxicant as earlier documented by Omoregie & Ufodike (1991), Avoaja & Oti (1997), Omoregie (1998), Oti (2002) and Ayuba & Ofojekwu (2005). The study also reveals that concentrations above 3.13 g/l were lethally threat to the test fish within 96 h as 50% mortality was recorded.

ANOVA showed that there was significant difference among treatment and concentration levels on mortality of the test fish for NPK fertilizer. This further signifies that the treatment effects were not equal among the different experimental units ($P < 0.05$). The mortality rate of the test fish at 3.75 g/l, which is more than 50% of the test fish, indicates that the higher the concentration, the higher the mortality rate at a given exposure time. This also clearly indicates that NPK fertilizer is harmful to *H. bidorsalis* fingerlings at acute concentrations. This confirms the findings of Nwani *et al.* (2008) and Ofojekwu *et al.* (2008 a/b) who exposed *T. zilli* fingerlings to acute concentrations of different inorganic fertilizers.

Based on the 24, 48, 72 and 96 h LC_{50} values determined from this study (Table 2), NPK fertilizer could be rated as highly toxic to *H. bidorsalis* fingerlings (Helfrich *et al.*, 1996). Thus, it would seem prudent to avoid situations where inorganic fertilizers are added intermittently to the ponds because such subsequent additions may result in total fingerling mortality, if the concentrations exceed the established LC_{50} reported in this investigation. The 96-h LC_{50} and safe concentration of the fertilizer 1.09 g/l (0.11g/l) to *H. bidorsalis* fingerlings suggest that this species is not tolerant to acute concentrations of this toxicant.

The study also establishes that with prolonged exposure to the toxicant, the fish became fatigued and stressed. Substances involved in energy generation such as protein, carbohydrates and fat, which play significant roles in body building and energy production in the fish, may be negatively affected under environmental stress (Heath, 1989).

Kormakik & Cameron (1981) and Kuma & Krisnamoorthi (1983) reported that increased utilization of protein when fish is under the influence of a pollutant leads to stress. Exposure to increasing concentrations of toxicant was observed by Umminger (1970) and Saroj (1987) to cause fatigue due to utilization of the energy substances. The energy sources may not be simultaneously used but if the principal and immediate source is depleted, the others show a proportional depletion as the metabolism of these substances are inter-linked through the common metabolic pathway-tricaboxylic acid cycle, hence, a depletion in all the components of fish tissue, leading to stress and fatigue conditions (Robert, 1988).

The stressful behaviours exhibited by the fish as established in the study, suggest that they suffered respiratory impairment, due to the effect of the toxicant on the gill and general metabolism. These behavioural responses are indications of processes leading gradually to death due to nervous disorder and insufficient oxygen supply. This result agrees with the findings of other authors, who studied the effects of inorganic fertilizers and fertilizer effluents at their acute concentrations on fish fingerlings (Oti & Chude, 1997; Ekweozor *et al.,* 2001; Bobmanuel *et al.,* 2006; Nwani *et al.,* 2008; Ofojekwu *et al.,* 2008ab).

Conclusion and recommendations

In fish farms, chemical fertilizers are often applied before stocking the pond to stimulate the production of organisms that may serve as first food for many species of fish and also increase survival and growth (Ludwig e*t al.,* 1998). Such applications may not be harmful if enough time is allowed for the degradation of these fertilizers by the micro flora. In the context of fish nursery management, it would seem prudent to avoid situations where chemical fertilizers are added intermittently to the ponds, because such subsequent additions may result in total fingerling mortality, if the concentrations exceed the established LC_{50} reported in this study.

The study clearly shows that acute concentrations of NPK fertilizer are harmful to *H. bidorsalis* fingerlings. It is, thus, recommended that the application of these fertilizers in aquatic ecosystems either in ponds, irrigations or farms should be carefully controlled or monitored, such that concentrations that are lethal to aquatic life could be avoided.

Based on the results obtained from the study, the following deductions can be drawn:

(i) Exposure to acute levels or concentrations of NPK fertilizer produced significant and adverse behavioural changes in *H. bidorsalis* fingerlings.

(ii) The tolerance range of *H. bidorsalis* fingerlings to NPK fertilizer was (0.29 –3.86 g/l), 96 h LC_{50} (1.09 g/l) and safe concentration (0.11 g/l), respectively.

There is also the need to provide further baseline data on NPK fertilizers. Such studies should be concerned with providing information on research such as the effects of sub-lethal concentrations of NPK fertilizers on the haematology, serum/plasma enzymes, metabolites, hormones and tissues of *H. bidorsalis*.

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