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Toxicological assessment of groundwater containing high levels of iron against fresh water fish (Clarias gariepinus)

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Abstract: Water is very essential to aquatic ecosystem. Groundwater is the recommended water source for aquaculture systems. Unfortunately, groundwater from Bayelsa State is characterized by high level of iron and acidic pH; which has become a major challenge to catfish farming. In order to assess the suitability of the water for aquaculture purpose, untreated groundwater samples were collected from 7 domestic boreholes and analyzed for physicochemical parameters and total iron. Furthermore their toxicological values were assessed in a 96hour static non-renewal test. The iron level of the groundwater ranges from 5.119 - 11.131mg/l, with a corresponding pH in the range of 3.97-6.40. At 96hrs exposure, groundwater from BH4 induced 85% mortality for 20-day old fingerlings, 65% for 40 day-old fingerlings and 55% 60 day old fingerlings. The least amongst all toxicants screened (BH7) caused 35, 25 and 10% mortalities for 20, 40 and 60-day old fingerlings respectively. The positive control was lethal in less than 24 hours while the negative control was not lethal throughout the duration of the experiment. Based on the findings of this research it is recommended that groundwater of Bayelsa State should be properly treated prior to their use for aquaculture as well as constant monitoring of the physicochemical parameters of pond water.

Keywords: Iron, *ClariasGariepinus*, Toxicity, Groundwater, Suffocation, Acclimation, Fingerlings

1. Introduction

Fish farming has become a major practice in both rural and urban areas of Bayelsa State, as a result of fish depletion in the natural rivers [1,2]. Raising fish in homestead pond for commercial and subsistence purposes has become a common practice [1,3,4]. Fish has been an essential source of protein as its consumption in Bayelsa State is often preferred in most delicacies compared to other sources of animal protein [1]. In addition, fish farming has become a major source of employment in Nigeria economy [5]. Fish farming occupies a unique position in the Nigerian economy, employing about 70% of its labour force [5-7]. It is the commonest source of protein all over the world [4,5,8,9], accounting for an estimated 50% protein intake [5].

In Bayelsa state, the aquaculture industry has been challenged by inappropriate management practices by farmers [1,3,4], which has become the basic predisposing factor to diseases [1,3,4].Tucker [10] recommended underground water as the most preferred source of water for aquaculture. Although, Bayelsa state is endowed with groundwater from shallow aquifer which remains their major source of water for aquaculture and domestic purpose [10,11]. On the other hand, the suitability of this water is impaired by heavy metals of which iron ranks the highest [11-14]. It has been established in literature that heavy metals are a major contaminant of groundwater used for aquaculture [10,15]. In Bayelsa State it is estimated that about 24.63% of fish death is caused by non-infectious diseases of which heavy metal poisoning due to iron ranks highest [4].

Furthermore, in Bayelsa state, iron is the most abundant heavy metal in both surface and groundwater [11]. The soluble iron II oxide in water becomes insoluble iron III oxide when the water is exposed to air forming a red or brown pigment [10,16]. Iron has the ability to deplete dissolved oxygen and can cause sub lethal stress or suffocation. In terms of ranking, iron happens to be the fourth most abundant element in the earth and second most abundant metal in the earth's crystal rocks and varieties of minerals in some food [16,17].

Iron may bea beneficial element to fish in a trace amount; however it becomes toxic to fish health in excess. The inorganic characteristic of iron in water is linked to low pH and high acidity which is lethal to aquatic life, especially fish [11]. Smith and Sykora [18] reported that low pH and partial pressure of oxygen consequently oxidizes ferrous iron (Fe^{2+}) to ferric (Fe^{3+}) forms of iron, these forms of iron are insoluble and forms thick sludge.

The toxicity of iron to aquatic life is well documented in literature [10,16,19]. Tucker [10] reported that solid precipitates of iron oxide are toxic and may coat the gills of fry, which interferes with respiration, causing non-infectious disease [4]. The high iron content in Bayelsa groundwater is one of the major causes of fingerling mortality [1,4]. In this study, we investigate the acute toxicity of different sources of groundwater from shallow aquifer against *C. gariepinus* in a static non-renewal test.

2. Sample Collection and Analysis

Three age groups of catfish fingerlings (20days, 40days and 60days) belonging to the genus *C. gariepinus* with no history of disease were purchased and transported to the laboratory in plastic cans equipped with aeration facilities. The fish was carefully dispensed into a 49 X 28 X 24cm aerated aquarium and was allowed time to acclimatize as described by Ezeonyejiaku*et al*., [20].

Groundwater was randomly collected from seven boreholes (BH1-BH7) in Bayelsa state. The depth of the boreholes ranged from 40–60 ft. The samples were collected on the 17th of January, 2014. The raw groundwater i.e. untreated ground water, were analyzed using standard analytical methods [21,22].

Physicochemical parameters such as hardness, dissolved oxygen, pH, temperature and heavy metals were analysed. Whereas dissolved oxygen and hardness were measured using portable field kit Extech 407510A and Liuhui UHT003 respectively, temperature and pH were measured using portable field kits Hanna instruments HI9813. Furthermore, the iron levels of the groundwater samples were analysed using Perkin Elmer 5100PC AA Spectrometer Atomic Absorption Spectrophotometer.

2.1. Experimental Set Up

Three age groups (20, 40 and 60-day old fry) of infection free and laboratory acclimatized *C. gariepinus*were used for the experiment in a staticnon-renewal test. A minimum of20 fingerlings per test aquarium were placed in the toxicant (i.e. untreated high iron containing groundwater) and observed daily for mortality. Mortality was assessed in percentage (%). Iron-free de-chlorinated groundwater as well as distilled water was used as negative control. Whereas de-chlorinated water amended with copper sulphate was used as positive control.

2.2. Statistical Analysis

The acute toxic effect of the iron water on *C. gariepinus* was evaluated statistically using Microsoft Excel 2013.

3. Results and Discussion

The general physicochemical parameters and heavy metal (iron) analysis of the toxicant i.e. raw untreated groundwater is presented in Tables 1. The toxicological assessments results on the three categories of fish screened based on their age groups (20, 40 and 60days old) is presented in Figures 1-3. The toxicants (BH1-BH7) had temperatures and iron in the range of 25.7-29.3°C and 5.119-11.131 mg/L respectively, and acidic with pH in the range of 3.97-6.40. The groundwater samples had hardness in the range of 467-241mg/L and DO in the range of 2.98-6.08mg/L.

Generally the high level of iron with a corresponding low pH is characteristic of groundwater in the Niger Delta Region [11]. The high level of iron in the groundwater which makes it unfit for domestic and aquaculture purpose. Ohimain et al., [11] reported high level of iron and a corresponding low pH in untreated Bayelsa groundwater in the range of 5.32-9.96mg/l and 4.39-517 respectively, while other authors had similar findings, for pH, these authors reported the following; 3.84 - 7.72with a mean of 6.17 [12], 6.40-7.23 mean 6.54 [13], 5.27-7.00 mean 6.02 [23], 6.40-7.23 mean 6.54 [24], 5.20-7.20 [25], and 3.84-7.72 [26].

Table 1. *General physicochemical parameters and Iron level of the untreated groundwater samples.*

Sample codes	Coordinates	AquiferDepth	Temperature (^{0}C)	Total iron (mg/l)	pH	Hardness (mg/l)	DO(mg/l)
BH1	4°56□056□□ N6°20□026□□E	60Ft	27.2 ± 0.03	9.988 ± 0.20	4.58 ± 0.31	456 ± 0.40	3.51 ± 0.17
BH2	5°05□045□□N 6°15□007□□E	55Ft	26.5 ± 0.02	5.935 ± 0.41	6.10 ± 0.01	279 ± 0.32	5.40 ± 0.33
BH3	5°50□045□□N 6°15□005□□E	50Ft	27.1 ± 0.01	9.843 ± 0.33	5.08 ± 0.20	411 ± 0.38	4.01 ± 0.20
BH4	5°58□048□□N 6°15□005□□E	60Ft	28.9 ± 0.03	11.131 ±0.40	3.97 ± 0.20	467 ± 0.31	2.98 ± 0.40
BH5	4°57□055□□N 6°21□023□□E	50Ft	25.7 ± 0.03	8.417 ± 0.32	5.37 ± 0.17	362 ± 0.37	4.61 ± 0.38
BH6	4°15□005□□N 6°04□008□□E	45Ft	27.1 ± 0.04	7.816 ± 0.44	5.69± 0.33	344 ± 0.48	4.98 ± 0.22

Sample codes	Coordinates	AquiferDepth	Temperature (^{0}C)	Total iron (mg/l)	pH	Hardness (mg/l)	DO(mg/l)
BH7	4^o15□005□□N 6^o04□008□□E	40Ft	29.3 ± 0.03	5.119 ± 0.38	6.40 ± 0.32	241 ± 0.40	6.08 ± 0.44
++Control			27.9 ± 0.04	N/A	4.03 ± 0.02	511 ± 0.03	3.03 ± 0.03
--Control			27.0 ± 0.38	<0.001	7.70 ± 0.04	220 ± 0.04	6.4 ± 0.07

N/A: Means Not applicable, ++ Control: Positive control was copper sulphate, - -Control: Negative control.

__Figure 1.__ Results of toxicological screening for 20-day old fingerling (++ positive control and – Negative control).

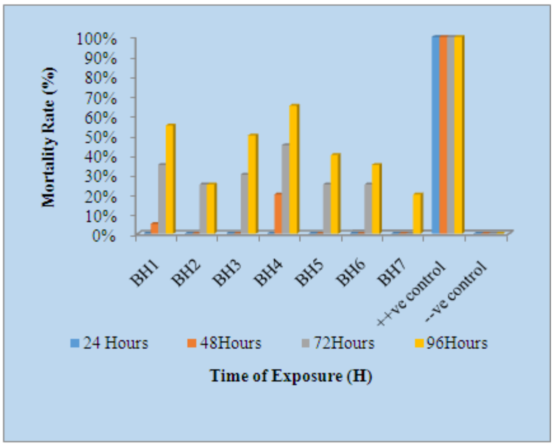

__Figure 2.__ Results of toxicological screening for 40-day old fingerling (++ positive control and – Negative control).

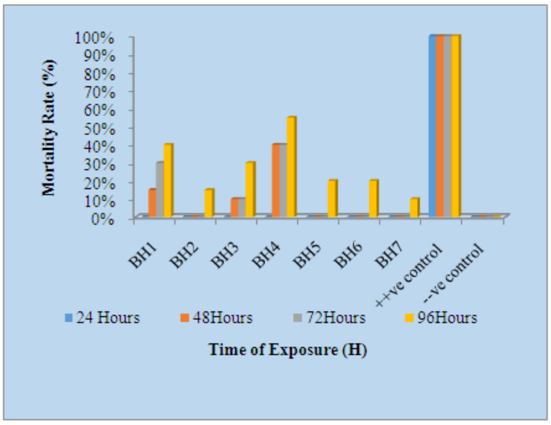

__Figure 3.__ Results of toxicological screening for 60-day old fingerling (++ positive control and – Negative control).

The results of the tested toxicants (BH1-BH7) screened against the different age groups (Figures 1-3), showed that there was a significant mortality response amongst the fingerlings screened. The 60-day fingerlings were less sensitive to the toxicant compared to the 40 and 20-day old fingerlings (Figures 1-3). At 96hrs exposure, groundwater from BH4 induced 85% mortality for 20-day old fingerlings, 65% for 40 day-old fingerlings and 55% for 60 day old fingerlings. BH4 containing the highest level of iron was the most toxic compared to BH7 having the least. While the least amongst all toxicants screened (BH7) caused 35, 25 and 10% mortalities for 20, 40 and 60-day old fingerlings respectively. The positive control was lethal in less than 24 hours while the negative control was not lethal throughout the duration of the experiment.

The result obtained during this study is comparable to what was reported by Abdullah et al., [19] who studied the acute toxicity of metals to Fish (*Labeorohita*) with results for iron having LC_{50} values of 49.75, 51.18 and 58.18 for 30, 60 and 90-day respectively. The differential toxicological activities amongst the different groundwater as well as the respective age group fish; might have been due to their physicochemical characteristics of the water [29], ages differences of the fish [19,29], and the levels of Iron in the water [11].

In our study, we observed that none of the tested toxicants screened against *C. gariepinus* induced total mortality (i.e 100% mortality) throughout the experiment (96 hour exposure).

__Figure 4.__ Picture showing sub-lethal stress influenced by iron (air bubbles in the water suggest suffocation due to limited oxygen).

Notwithstanding, sub lethal stress to the fish was also observed during the experiment as air bubbles was seen on the iron film on the surface of the water, this suggest suffocation due to limited oxygen (figure 4).

Furthermore, there are significant differences amongst species, in terms of their toxicological susceptibilities to a particular toxicant [27]. For instance,Ezeonyejiaku and

Obiakor[28] and Ezeonyejiaku et al., [20], in two different studies, using Zinc as a toxicant against *Orechromisniloticus* reported an LC_{50} value of 72.431mg/l, compared to 78.178mg/l for *C. gariepinus* in another study. Notwithstanding, the chronic/incipient effect of iron to most freshwater species is not known at the moment; as this is subject to further investigation.

4. Conclusion

Water is very essential to aquatic ecosystem. Groundwater is the recommended water for aquaculture systems, unfortunately, physicochemical and heavy metal (iron) analysis of groundwater samples from Bayelsa State reveals high level of iron and acidic pH. In this study, raw (untreated) groundwater was collected and screened against catfish fingerlings which resulted to their mortalities. This might pose a major threat to the fishing industry in the Niger Delta, as such groundwater should be properly treated prior to their usage for aquaculture and constant monitoring of physicochemical parameters of pond water should be ensured.

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