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Buffering Efficiency of Phytoplankton on Acidic Borehole Water for Fish Production in Port Harcourt, Nigeria

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Abstract

Low water pH has been a major problem affecting growth and profitability of aquaculture in Port Harcourt, Rivers State, Nigeria. In recent times, organic agriculture is being advocated for safe and healthy food thus alternative buffer agent is necessary to combat this challenge in order to boost fish production. Based on this, a study was conductedat the Aquaculture Centre of the Department of Fisheries and Aquatic Environment, Rivers State University, Port Harcourt, Nigeria, to determine buffering efficiency of phytoplankton on pH and other water quality parameters. Fifteen (15), 18-litre shaded plastic tanks (3/4- filled, pH 4.48) of three replicates per treatment of 0litre (T0), 1 litre (T1), 2 litres (T2), 3 litres (T3) and 4 litres (T4) of green water containing phytoplankton were used. These tanks were screened with plastic net to keep off mosquitoes and other unwanted objects throughout the study. Dissolved oxygen, pH, temperature, total dissolved solids, electrical conductivity, alkalinity and ammonium of water were measured once daily (morning) for 25 days using standard methods. Phytoplankton were analysed microscopically and its density was calculated following standard method. Data were subjected to analysis of variance and descriptive statistics using Microsoft Excel.Some photosynthetic species in families of Chlorophyceae, Cyanophyceae, Eugleneophyceae, Pyrrophyceae and Xanthophyceaewere observed. These might be responsible for the recorded pH values. pH values ranged between 4.76 (T0) and 6.10 (T4) within five days though not within the acceptable range (6.0-9.0) for fish production except T4. This study therefore recommends the use of at least 4 litres of green water containing phytoplankton as organic source of buffer for treatment of 14 litres of acidic water for minimum of five days for aquaculture.It is free of cost and safe for fish production and human consumption.
Keywords: Organic aquaculture; Organic buffer; Phytoplankton; Potency; pH; Evaluation.

1. Introduction

Organic aquaculture is one of the most relevant areas for organic food production [1]. Organic aquaculture can be described as a system of production that can sustains the health status of aquatic ecosystem [2]. The growing importance of aquaculture sector has increasing responsibility and accountability to produce safe and healthy products to sustain economic feasibility, environmental integrity and social responsibility [3]. Perdikaris and Paschos [4], noted aquatic products from organic production are becoming more and more accessible to consumers. Aquatic and terrestrial plant have been recognised as materials used for biotechnology [5]. United Nations [6], reported it as any technological application that uses biological systems, living organisms, or derivatives thereof to make or modify products or processes for specific use. Thus, concerted effort on production of organic products is made to reduce or completely abandon the use of chemical from synthetic origin [7].

Water pH is a critical water quality parameter for aquaculture. Therefore, water quality is one of the most important factors in fish production (hatchery operation and management, nursery, grow-out and brood stock management). Deterioration in the quality of water increases stress on the captive animals, reduces their growth, makes them vulnerable to disease and cause heavy mortality which is tie to the acidity or alkalinity of the culture water. Based on this, understanding the physico -chemical indices of water quality determines the success of any aquaculture venture [8]. Generally, the pH of ground water (borehole) in Port Harcourt city, Nigeria is acidic [8]. The quality of water, to a large extent determines the success or failure of an aquaculture operation. Managing water quality is important but expensive [9]. This has been a major constraint affecting the growth and profitability of aqua-culturists in Port Harcourt, Nigeria. The acceptable range for fish culture is normally between pH 6.5 and 9.0 [10].

Aqua-farmers pay much attention on the colour of pond water and the promotion of phytoplankton in pond water. The colour of pond water usually indicates the predominant phytoplankton species [11]. The cycling of biological mineral nutrients in water is initiated by the sun's heat and light, transform the inorganic matter and carbonic acid in solution into organic matter, in the form of vegetable tissues consisting of a variety of

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phytoplankton [12], phytoplankton populations enrich the systems with oxygen through photosynthesis during day light hours and lowers other nutrients in the water. It decreases temperature loss in winter and stabilizes water temperature [13].

The use of lime such as quick, slaked and agricultural lime has been the conventional method of buffering water and increasing its pH [14, 15]. The use of plant and animal materials as buffering agents in aquaculture have been reported by some authors such as Davies, *et al.* [16]; Davies, *et al.* [17] and that utilized plantain plant (*Musa acuminata*) and rock (*Thais coronata*) shells respectively, as organic buffers to improve the pH of water in the culture media. Also, Davies and Ansa [3], Davies, *et al.* [18]; Davies and Ogidiaka [19] equally used oyster, bloody cockle and periwinkle shells respectively as organic buffers to increase the pH of water in Niger Delta areas Nigeria. Hence, the study aimed to assess the efficiency of different volumes of green water containing phytoplankton as organic buffering agent on acidic borehole water in Port Harcourt, Rivers State, Nigeria.

2. Materials and Methods

2.1. Study Area

The study was carried out at Aquaculture Centre in the Department of Fisheries and Aquatic Environment, Faculty of Agriculture, Rivers State University, Port Harcourt, Rivers State, Nigeria. The duration of the experiment was for a period of four weeks (28 days).

Thirty litres (30 L) of green water rich with phytoplankton was sourced from Roone Fish Farm, Abuloma, Port Harcourt, Rivers State, Nigeria. The experimental design was 1x6x3 representing phytoplankton, fifteen (15) 18-litre circular plastic tanks were used for the experiment. The plastics tanks covered with plastic net were labelled T0 (control), T1, T2, T3, T4 and T5 in three replicates. The tanks were placed on indoor concrete tanks very close to the wire fence, for access to sunlight. The pH of the borehole water was measured. Each of the 18-litres plastic tanks was filled up to 14 litre mark of acidic borehole water (pH 4.48). Tanks were treated thus, 1 litre of green water containing phytoplankton for T1, 2 litres for T2,3litres for T3,4 and 5 litres for T5 in triplicates. While, for the control (T0) no water was removed and no green water was added.

2.2. Evaluation of Relevant Water Quality Parameters

Some water quality parameters namely temperature, dissolved oxygen, pH, total dissolved solids, electrical conductivity, alkalinity and ammonium were evaluated once daily in all the experimental tanks for a period of 25 days using standard methods. Measurement of these physico –chemical parameters were restricted to 28 days adopting Viveen, *et al.* [15] recommendation of minimum duration of 14 days to obtain pH 6.5 (Table 1).

TDS, EC and Temperature were measured once using EZ-1 TDS & EC meter electrode made in China,pH was taken in-situ using pHep meter (H19127) produced by Excelvan Ltd, China. While Dissolved oxygen (DO) (mg/L) was measured using Freshwater Aquaculture Testing kit (Aquacare 2000.6 Para test) by using 15 ml of the experimental water, the alkalinity (mg/L) was also measured by (Aquacare 2000.3 Para test) kit and Ammonium (mg/L) was evaluated by (Aquacare 2000.4 Para tests).

The density of phytoplankton was determined in the 30 litres of green water. A plankton net of 50µm was used to collect the phytoplankton in the 30 litres of green water collected from fish culture tank in Roone Fish Farm.

Table-1. Modified Viveen, *et al.* [15] guidelines for application of liming material in kg/hectare

pH of pond water	Heavy loamy or clay	Sandy loam	Sand
3.0-3.4	14400	9000	6300
3.1-3.4	12600	7200	5400
3.6-4.0	10800	7200	4500
4.1-4.5	9000	5400	3600
4.6-5.0	7200	5400	2700

[5]

2.3. Statistical Analysis

Data generated were subjected to analysis of variance (ANOVA), Duncan Multiple Range and descriptive statistics using Boyd [20] statistical package.

3. Results

The values of pH shown in Table 2 indicated a steady rise in the values of pH from 5.25 ±0.43 in T0 to 5.82 ±0.58 in T4.The minimum, maximum and range values of pH of treated acidic borehole water with phytoplankton are presented in Table 3. Thus, the highest range value of 2.52 was recorded in T2 and T4, while the lowest (1.42) was in T0. Also, the minimum, maximum and range values of some physico-chemical parameters of treated acidic borehole water with phytoplankton (Table 4).The comparison study of pH of acidic borehole water treated with phytoplankton and standard is presented in Table 5. All the values in all treatments were below standard value. However, the highest pH values were recorded in T4.

The initial water used in the experiment consists of only three taxonomic groups (Table 7), while the final phytoplankton population increased notably in all the treatments (Table 8).

Furthermore, the values of TDS, EC, $NH_{3,}$ and DO increased significantly in all the treatments from T0 to T4, with the highest values obtained in T_4No change was observed in NH_3, DO and ALK (Table 4). However, alkalinity increased from 0.91 in T0 to 53.60 in T4, (Table 2). For temperature, the highest range value of 5.4 was recorded in

T4, while the lowest (3.4) was in T4 (Table 4).Thus, other parameters' results indicated that temperature, DO, ALK and NH_4 were comparative to the standard values, while TDS and EC were not (Table 6).

3.1. The Comparison Study and Standard of Physico-Chemical Parameters of Acidic Borehole Water Treated with Phytoplankton

The values of pH in acidic water treated with phytoplankton varied among the treatment, higher values of pH were recorded in treatment T4 in all the experimental days (Figure 1).Temperature are presented in (Figure 2), the values were within the same range in the treatments. TDS is presented in (Figure 3), the values were higher in all treatments across the experimental period while EC increased consistently in all treatments with increasing experimental period (Figure 4). Lower values of NH_4 were observed at earlier experimental period, while from Day 11to day 25 higher values were recorded in all the treatments (Figure 5). Thus, the values for DO are presented in Figure 6, but higher values of DO were observed as the experimental period increased. Alkalinity values were very high from Day 15 to 25, compared to Day 1 to 10 (Figure 7).

Table-2. Mean values (± SD) of physico-chemical parameters of treated acidic borehole water with phytoplankton

Treat ment	pH	Temp (°C)	TDS (mg/L)	EC (µS/cm)	NH_3(mg/L)	DO (mg/L)	ALK (mg/L)
T0	5.25± 0.43[a]	28.96± 0.66[a]	67.36± 4.81[a]	154.68 ±13.01[a]	0.19 ±0.11[a]	6.08 ±1.24[a]	0.91 ±7.85[a]
T1	5.48± 0.38[b]	28.64 ±0.38[a]	71.03± 6.88 [b]	158.24± 13.92[a]	0.19 ±0.11[a]	6.24 ±1.22[a]	38.08± 3.98 [b]
T2	5.57± 0.41[b]	28.55 ±0.87[a]	72.88 ±6.65[b]	163.32 ±14.61[b]	0.20 ±0.10[a]	6.19 ±1.14[a]	43.40 ±2.77 [c]
T3	5.61± 0.47[b]	28.32 ±0.83[a]	75.07 ±5.75 [b]	167.23 ±13.76[b]	0.21 ±0.09[a]	6.37 ±1.19[a]	45.40 ±1.55 [c]
T4	5.82 ±0.58[b]	28.40 ±0.59[a]	75.96 ±5.49[b]	169.97 ±14.36[b]	0.21 ±0.09[a]	7.01 ±1.43[b]	53.60 ±7.19 [c]

Means within the same column with different superscript are significantly different ($P<0.05$)

pH-Hydrogen ion concentration, Temp- Temperature, TDS- Total dissolved solid, EC- Electronic conductivity, NH3- Ammonia, DO-Dissolved oxygen, , ALK-Alkalinity

Table-3. Minimum, maximum and range of pH values of treated acidic borehole water with phytoplankton

Treatment	Minimum	Maximum	Range value
T0	4.48	5.9	1.42
T1	4.48	6.01	1.53
T2	4.48	7.00	2.52
T3	4.48	6.90	2.42
T4	4.48	7.00	2.52

Table-4. Minimum, Maximum and range of some physico-parameters of treated acidic borehole water with phytoplankton

Trt	Minimum values of Parameters						Maximum values of Parameters						Range values of Parameters					
	Temp	TDS	EC	NH_3	DO	ALK	Temp	TDS	EC	NH_3	DO	ALK	Temp	TDS	EC	NH_3	DO	ALK
T0	26.4	60	140	0.00	4.50	0	30.1	85	185	0.25	9.00	68	3.7	25	45	0.25	4.5	68
T1	24.7	61	141	0.00	4.50	0	30.1	94	203	0.25	9.00	68	5.4	33	62	0.25	4.5	68
T2	24.8	60	141	0.00	4.50	0	29.8	99	211	0.25	9.00	68	5.0	39	70	0.25	4.5	68
T3	24.8	63	141	0.00	4.50	0	29.6	99	210	0.25	9.00	68	4.8	36	69	0.25	4.5	68
T4	26.2	60	141	0.00	4.50	0	29.6	82	211	0.25	9.00	68	3.4	22	70	0.25	4.5	68

Temp- Temperature, TDS- Total dissolved solid, EC- Electronic conductivity, NH3- Ammonia, DO- Dissolved oxygen, , ALK-Alkalinity

Table-5. Mean pH values of treated acidic borehole water with phytoplankton and standard

Treatment	The study	Standard
T0	5.25	6.5-9.0 [21] 6.0-9.0 [22]
T1	5.48	
T2	5.57	
T3	5.61	
T4	5.82	

Table-6. Comparison study of some physico-chemical parameters of treated acidic borehole water with phytoplankton

Trt	Temp		TDS		EC		NH_4		D0		ALK	
	The study Min - Max	**Standard**	**The study Min - Max**	**Standard**	**The study Min – Max**	**Standard**	**The study Min – Max**	**Standard**	**The study Min - Max**	**Standard**	**The study Min - Max**	**Standard**
T0	26.4 – 30.1	(McNeely *et al*., 1979) 0 - 40 ºC [20]	60 - 85	≥500mg/L [23]	140 – 185	340-700 (µS/cm) [23]	0.00 – 0.25	0.25 [23]	4.50 - 9.00	5.0 & above [20] 19	0 - 68	75 – 200 (mg/L) [12]
T1	24.7 – 30.1		61 - 94		141 – 203		0.00 – 0.25		4.50 – 9.00		0 – 68	
T2	24.8 – 29.8		60 - 99		141 – 211		0.00 – 0.25		4.50 – 9.00		0 – 68	
T3	24.8 – 29.6		63 - 99		141 – 210		0.00 – 0.25		4.50 – 9.00		0 – 68	
T4	26.2 – 29.6		60 – 82		141 – 211		0.00 – 0.25		4.50 – 9.00		0 - 68	

Temp- Temperature, TDS- Total dissolved solid, EC- Electronic conductivity, NH3- Ammonia, DO- Dissolved oxygen, ALK-Alkalinity

Table-7. Initial phytoplankton assemblage in the culture tanks

Green water sample	Taxonomic group	Species	No of individual	Density (org/ml)
Initial	Euglenophyta	*Phacus pleuronectes*	1	116.55
	Cyanophyta	*Rhapidiopsis mediterranae*	1	116.55
	Chlorophyta	*Closterium dianae*	1	116.55

Table-8. Final Phytoplankton assemblage in the culture tanks

Treatment	Taxonomic group	Species	No of individual	Density (org/ml)
T0	Cyanophyta	*Dactylococcopsis sp*	1	116.55
	Cyanophyta	*Eyngbya hieronynusii*	4	29.14
	Cyanophyta	*Phormidium mucicola*	2	57.94
	Cyanophyta	*P. valderiae*	2	57.94
	Bacciliarophyta	*Nitzschia closterium*	1	116.55
	Bacciliarophyta	*N. sigma*	1	116.55
T1	Chlorophyta	*Schroderia setigera*	2	57.94
	Cyanophyta	*Rhaphidiopsis mediterranea*	3	38.85
	Cyanophyta	*R. mediteirranea*	1	116.55
	Chlorophyta	*Closterium gracile*	6	19.43
	Pyrrophyta	*Nephroselmis reflexa*	1	116.55
	Bacciliarophyta	*Cryptomium obvovata*	1	116.55
	Chlorophyta	*Ankistrodemus falcatus*	2	57.94
	Chlorophyta	*Synedra ulna*	2	57.94
	Chlorophyta	*Closterium juncidum*	4	29.14
	Chlorophyta	*C. dianae*	2	57.94
	Xanthophyta	*Melosira ambigua*	1	57.94
T2	Chlorophyta	*Aphanizomenon flos-aquae*	1	116.55
	Euglenophyta	*Coelastrums phaericum*	1	116.55
	Bacciliarophyta	*Synedra ulna*	2	57.94
	Chlorophyta	*Gonatozygon aculeatun*	2	57.94
	Chlorophyta	*Closterium parvulum*	1	116.55
	Chlorophyta	*C. intermedium*	1	116.55
	Chlorophyta	*C. dianae*	1	116.55
	Chrysophyta	*Dinobryon marssoni*	1	116.55
T3	Chlorophyta	*Tetrablepharis multifilis*	1	116.55
	Xanthophyta	*Tribonema viride*	1	116.55
	Pyrrophyta	*Epithemia turgid*	1	116.55
	Cyanophyta	*Rhaphidiosis mediterranea*	1	116.55
	Chlorophyta	*Treubariumtri appendiculats*	1	116.55
	Chlorophyta	*Closterium intermedium*	1	116.55
	Xanthophyta	*Tribonema viride*	1	116.55
	Euglenophyta	*Euglena gracilis*	1	116.55
	Cyanophyta	*Aphanizomenon flos-aquae*	1	116.55
	Cyanophyta	*Gloeetrichia calnuli*	1	116.55
	Cyanophyta	*Anabaenopsis arnolddii*	1	116.55
T4	Chlorophyta	*Ankistrodesmus falcatus*	1	116.55
	Chlorophyta	*Closterium intermedium*	6	19.43
	Chlorophyta	*Pleurotaenium coronatum*	1	116.55

Figure-1. Daily pH values of treated acidic borehole water with phytoplankton

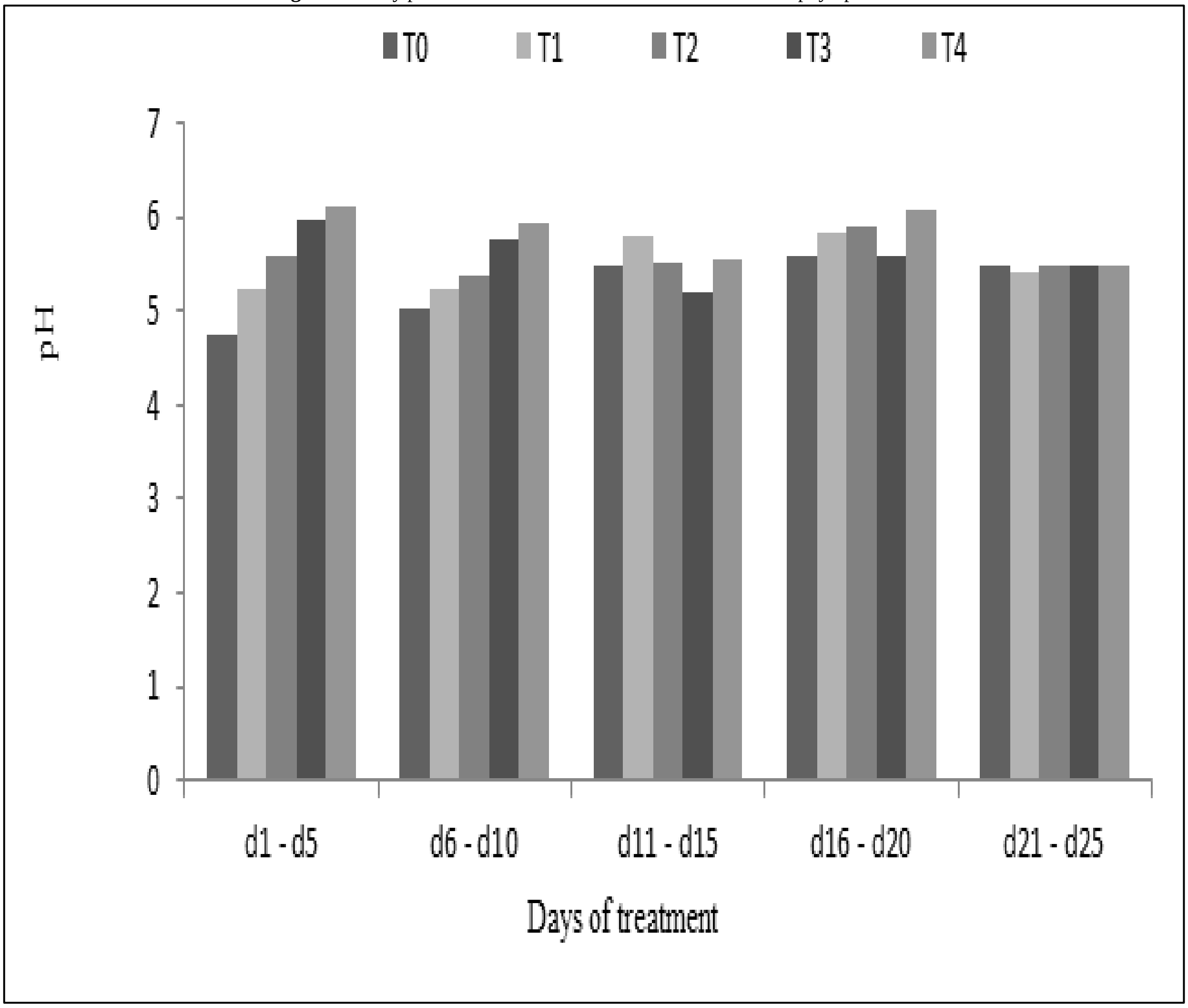


Figure-2. Daily temperature values of treated acidic borehole water with phytoplankton

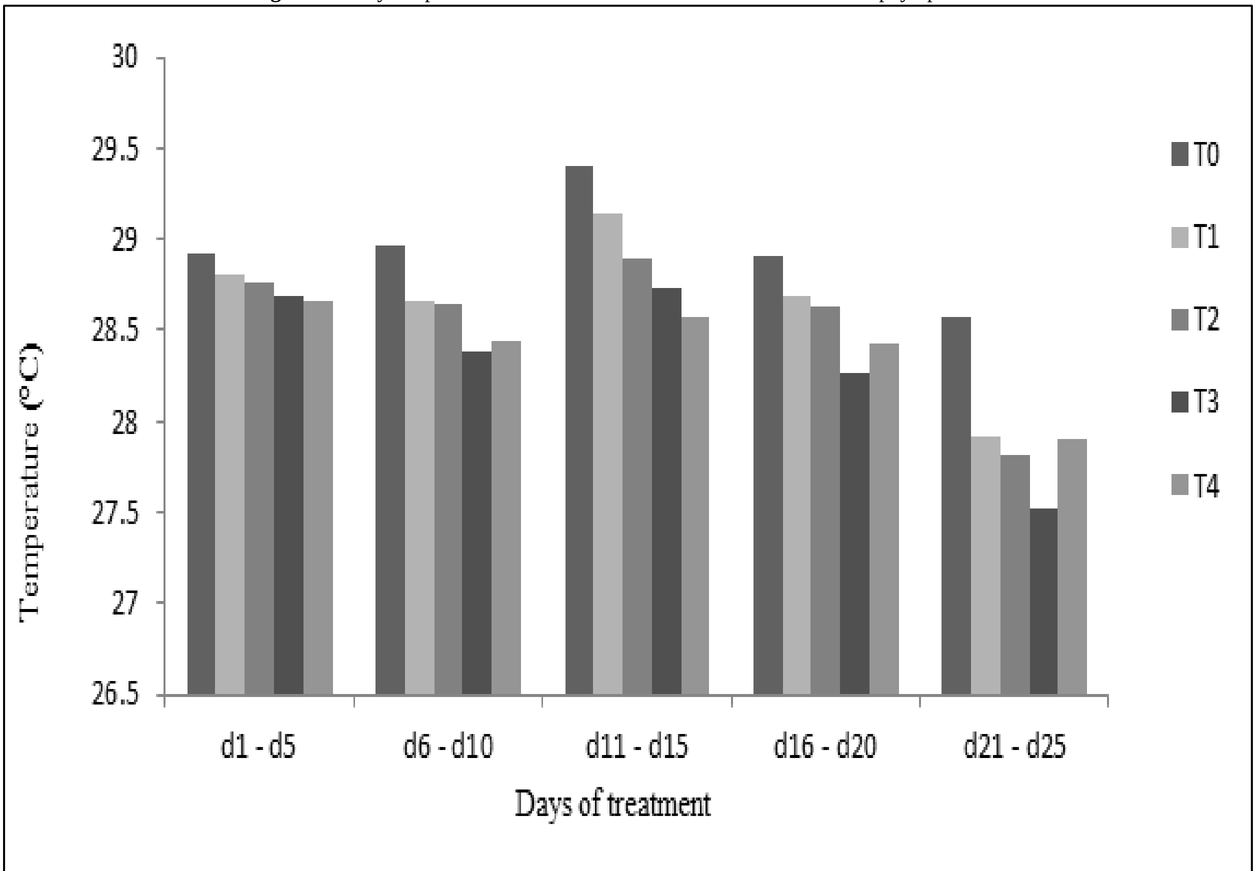


Figure-3. Daily TDS values of treated acidic borehole water with phytoplankton

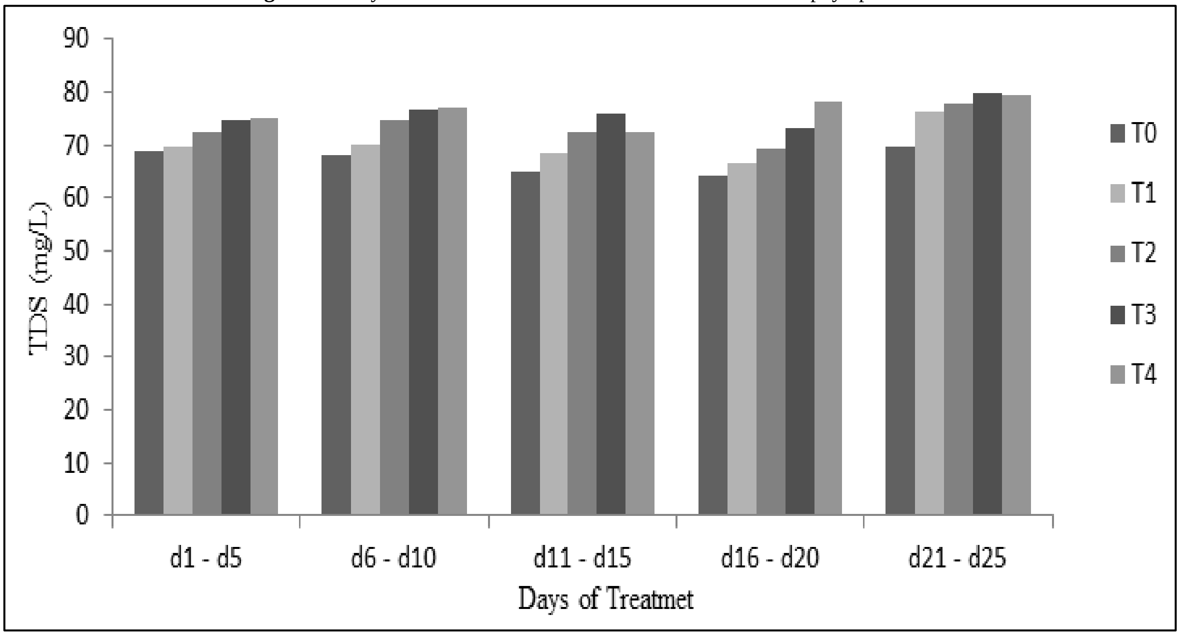


Figure-4. Daily EC values treated acidic borehole water with phytoplankton

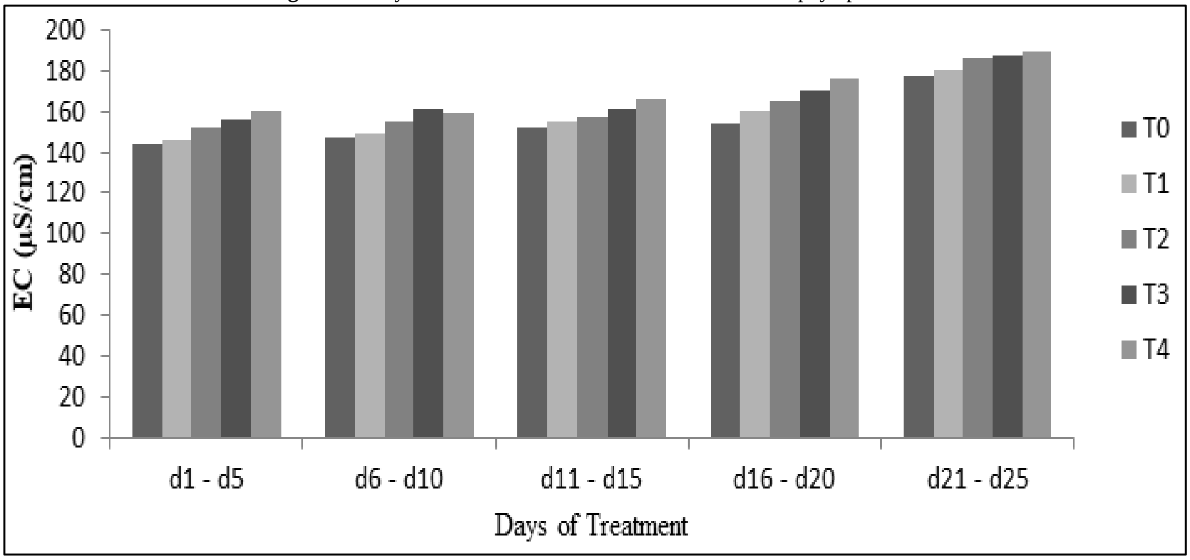


Figure-5. Daily NH4 values of treated acidic borehole with phytoplankton

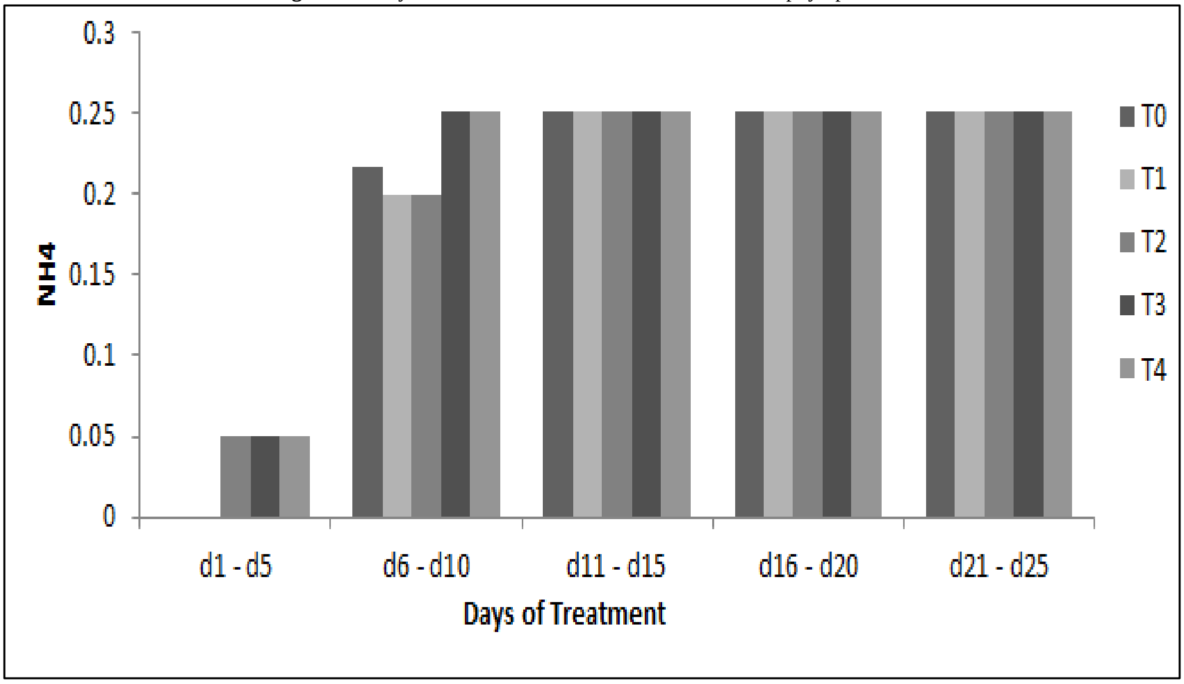


Figure-6. Daily DO values of treated acidic borehole water with phytoplankton

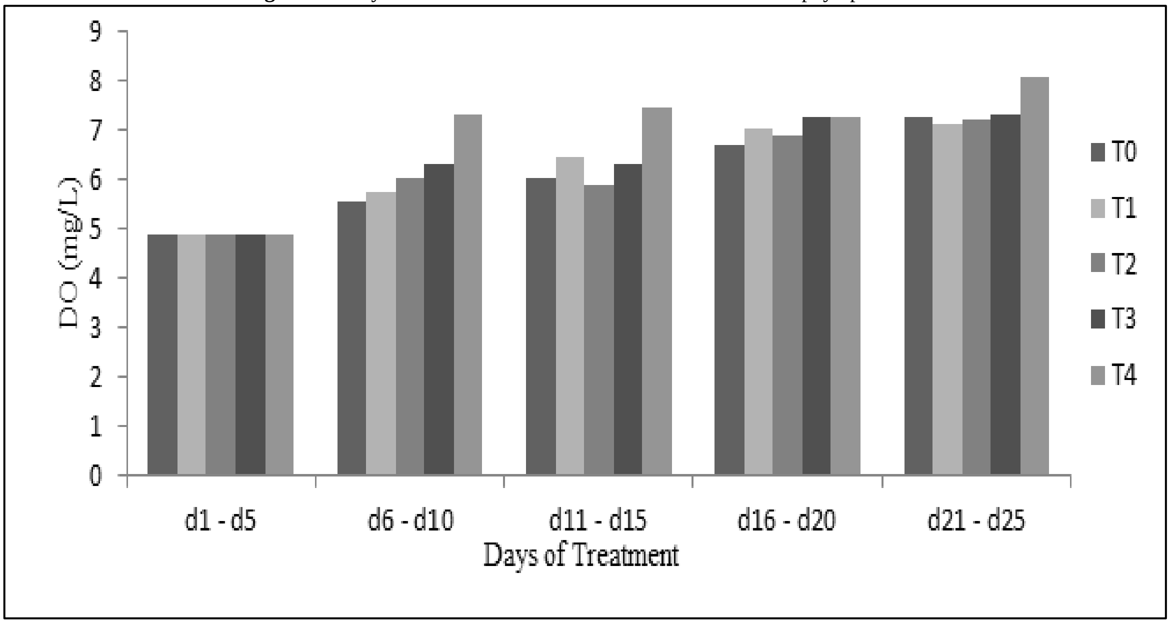
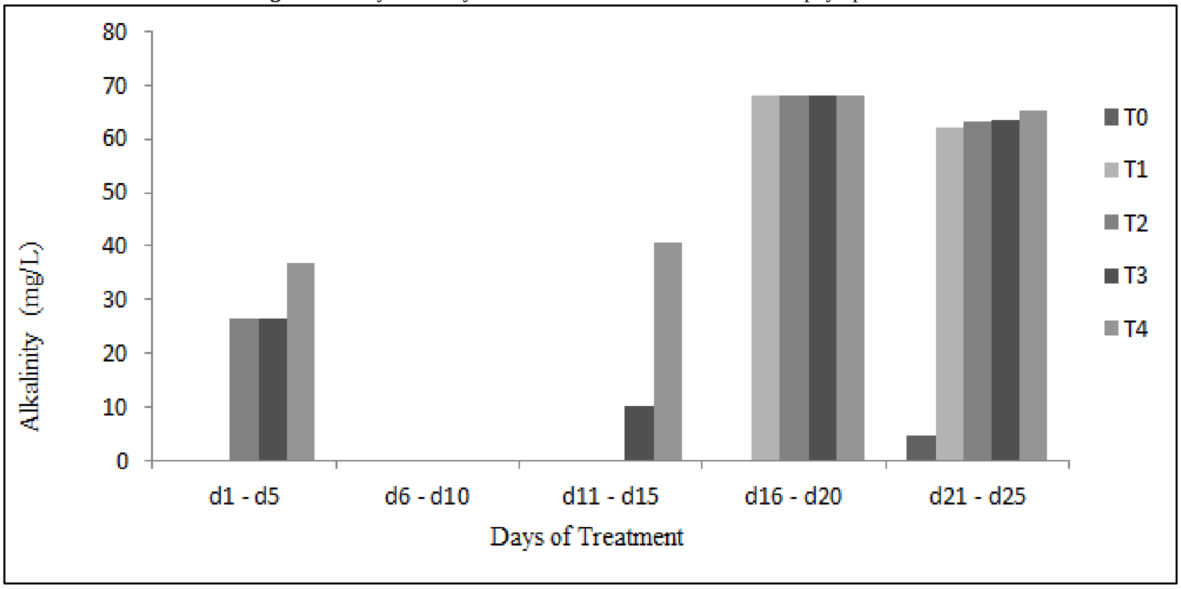


Figure-7. Daily alkalinity values of treated acidic borehole with phytoplankton



4. Discussion

The recorded increasing pH from Day1 to Day 25 in all treatments in the five treatments might be attributed to the very high quality of phytoplankton. The findings from this study are in consonance with Liu, *et al.* [21] in their study of treated municipal wastewater with oyster shells as biological aerated filter (BAF). The diffusion of air containing oxygen gas into the experimental water and phytoplankton oxidize oxygen could also be the reason for the increased pH in all treatments in the four treatments. Dissolved oxygen is directly proportionate to pH: DO increase as pH increased. However, this type of treatment cannot be depended upon for fish production (because it takes more time to increase the pH) especially intensive and large scale production as recommended by Viveen, *et al.* [15] suggested the use of liming materials or organic buffer agents to increase the pH. However, the observed pH values within five days were not within the acceptable range (6.0-9.0) for fish production except T4 according to UNESCO/WHO/UNEP [24].

Changes in pH influences the water quality and water chemistry and these will have a marked effect on the fish health and filter activity [24]. The pH of the water increased progressively in all the treatments with time. This could be due to the treatment materials (phytoplankton) and diffusion of air (containing oxygen) into the water. There were significant differences in the increase pH between Day 1 and Day 25 in all treatments. This is in accordance with Viveen, *et al.* [15] report that the efficiency of liming will decrease with increasing particle size of the liming material. The buffer agent of phytoplankton enhanced the buffering process as evident in the obtained results in this study. The pH of water could be increased by exposure to air (containing oxygen) but it is time dependence. Buffer agents are therefore required to facilitate the process for increased fish production especially fingerling production. Dissolved oxygen (DO) increased insignificantly as pH increased from Day 1 to Day 25 in all the treatments ($P>0.05$). Diffusion of air (containing oxygen) could possibly contribute to the increases of pH of water in all the treatments.

The recorded temperature values in all the treatments were within the acceptable range of above 20 °C [14, 25] for fish production in the tropics.High water temperature increases metabolic activities such as respiration, excretion, release of carbon dioxide, ammonia [14, 26].Temperature influences pH; it has indirect relationship with pH thus the acceptable range of temperature contributed to the buffering efficiency phytoplankton.

The recorded DO values were within the acceptable range (5 mg/L and above) for fish production according to Boyd [21]. The process of nitrification was prevented, Nitrification has a slight tendency to acidify water and remove the buffering capacity or hardness of water [24]. DO values of the experimental water increases from the beginning to the end of the experiment which could be the reason for the recorded increases in the pH with day.

The recorded maximum alkalinity values for T2 to T4 were within the permissible limit of 50 mg/L and above for many animals. Most aquaculture species can live in a broad range of alkalinity concentrations, but the desired alkalinity for many animals is 50 mg/L or higher [27]. All the treatments except T1 attained the desired alkalinity for fish at the end of the study. In addition, the desirable range of alkalinity for fish culture is between 75 and 200 mg/L $CaCO_3$ [12]. If alkalinity is low, the pH value is low thus the observed low pH in T1. Alkalinity increased with increased pH.

The recorded electronic conductivity values for T0 and T4 revealed in the increases of pH values with day in all treatments. Considering the interaction, Nwoye, *et al.* [27] noted electronic conductivity is dependent on the water pH. Therefore, drop in electronic conductivity will also affect drop the pH which is observed in treatment T_3.

5. Conclusion and Recommendation

The advocacy for organic aquaculture is gaining ground in the present world, it is therefore reasonable to consider the use of phytoplankton as organic buffer.This study therefore suggests that 4 liters of phytoplankton should be added to 4 liters of clean water for at least 25 days as alternative buffering agents for acidic water for fish production in Port Harcourt and other parts of the world with low water pH problem. The use of phytoplankton as organic buffers for safe and healthy fish production is free of cost and can be used by fish farmers for better profitability.

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