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DEVELOPMENT AND PERFORMANCE EVALUATION OF A PROTOTYPE AQUAPONICS SYSTEM (PAS) FOR THE TREATMENT OF WASTEWATER

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ABSTRACT

Aquaponics (AP) is one of the newest integrated sustainable food production systems (especially in Nigeria). It is a system in which aquatic animals can be reared and integrated with organically grow plants for food consumption. In this study, wastewater generated in the aquaculture component is passed into the hydroponics component to grow some plants without soil being employed in the system. The system was constructed at National Water Resources Institute (NWRI) workshop using locally available materials. Lettuce and mints plants were used as natural bio-filter to treat the wastewater from the aquaculture component after which the treated water was returned into the aquaculture section for the development of the aquatic animals (fish). Samples of wastewater from the aquaculture and the treated water from hydroponics components were taken and analyzed at the NWRI water quality laboratory. Phosphate in wastewater ranges from 5.2 – 8.2 mg/l, while the in the treated water it ranges from 3.1 – 5.5 mg/l; Nitrate in wastewater ranges from 3.8 – 9.4 mg/l and in the treated it ranges from 2.5 – 6.8 mg/l; chloride in wastewater ranges from 13.25 – 43.25 mg/l and that of the treated water ranges from 12.22 – 34.24 mg/l. The results showed that the system had performed effectively in the removal of contaminants from the water used in the aquaculture component of the system when compared with the desirable water quality for fish ponds. It has also shown that the plants i.e. lettuce and mints used, were good absorber of contaminants from the wastewater.

KEYWORDS: *Aquaculture, aquaponics, fish, hydroponics, lettuce and mints plants, wastewater*

INTRODUCTION

Aquaponics is a bio-integrated system serving as a technique for food production that combines aquaculture and hydroponics in a symbiotic manner (Panigrahi *et al.,* 2016; Hochman *et al.,* 2018). Aquaculture is the farming of aquatic plants, sea foods and animals in the process of which water is cleaned and recycled in a closed-loop system (Timmons and Ebeling, 2007; Palma and Viegas, 2020). Aquaculture is defined as the "farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants (Tacon, 2003; Wakchaure *et al.,* 2015). Farming implies some sort of intervention in growing of crops and rearing of animals to enhance agricultural production, such as regular stocking, feeding, and protection from predators (Menezes *et al.,* 2017).

Aquaculture has become the fastest growing sector of the world's food economy, increasing by more than 10 % per year and currently accounts for more than 30 % of all fish consumed (Ahmed and Thompson, 2019). Aquaculture has had the potential to bring sustainable practice that can supplement the production of sea foods and significantly contribute to feeding the world's growing population, just as it happened with the green revolution of agriculture in Nigeria in the last century.

Aquaponics combines raising sea food (like fish) in tanks (recirculating aquaculture) with soilless plant culture (hydroponics). In aquaponics, the nutrient-rich water from fish raising system (fish tank) provides a natural fertilizer for the plants, which helps to purify the water ready for recycling into the fish raising system (Jephi *et al.,* 2017). This process can be carried out year round as an indoor farming system anywhere to provide fresh natural food free of pesticides, herbicides and chemical fertilizers (easy and safe) (Nelson and Pade, 2019). Aquaponics system is a promising technology in the integration of fish and plant production; wastewater from fish raising system (fish tank) which is rich in nutrients is used for plant growth, while the plants are used as biofilters for water regeneration (Delaide *et al.,* 2017).

Food production is becoming slower than necessary due to shorter period of rainfall with less amount of water combined with late commencement and early cessation of rainfall and less availability of water from dam reservoirs for irrigation (Davis and Hirji, 2014). A revolutionary system of food production is needed in order to meet up with food supply for the teaming population (Pawlak and Kołodziejczak, 2020).

Another problem facing the world in general and most of the countries in particular is the inadequate food supply causing health, economic and social problems. The current farming system is unsustainable and not producing the needed amount of food required as the population grows and climate change becomes more of a reality. A radical transformation of the farming system is required for which innovative new solutions like aquaponics is required. Reuse of the nutrients released by fish to grow crops is the primary goal of aquaponics.

Thus, aquaponics system enables efficient use of resources, reduction in risk of total crop failure, additional sources of food, extra income and reduction of operation costs for farmers than fish culture alone. This also will vastly increase food production and to supplement both rain fed and irrigation food production in order to aid fast food production with less water and no soil. Therefore, it is against this background that this research was undertaken to design and construct aquaponics system to treat aquaculture wastewater using plant as natural bio-filter, improve water quality of both effluent water of the system and evaluate the aquaponics system operation.

2.0 MATERIALS AND METHODS

2.1 Materials

Materials employed include pipes for grow bed, plastic water tank, water samplers (bottles), and water quality reagents for the analysis of water samples. The equipment for titration includes burette, conical flasks, beaker, submersible water pump, crusher retort stand and distilled water.

2.2 Methods

The following flow diagram (Fig. 1) shows the general procedures taken to carry out the design and operation of the aquaponics system.

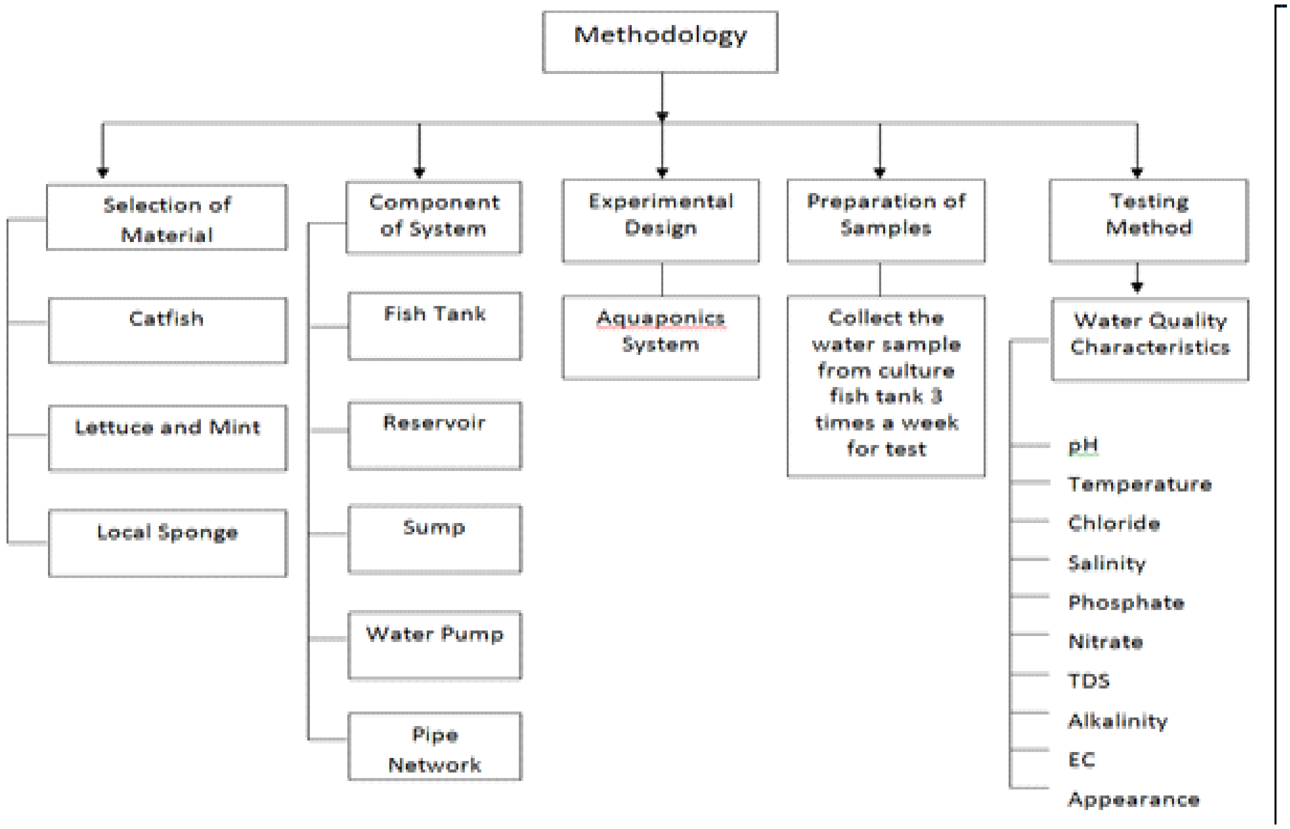

Figure 1: The process flow diagram showing the steps taken to run the system

2.3 Selection of Materials

2.3.1 Catfish (Clarias Gariepinus)

This species has drawn attention because of its biological attributes that include resistance to diseases, faster growth rate and can be stocked at high density. They are one of the most known and cultivated fish in Nigeria. Catfish (clarias gariepinus) with average initial weight of 0.18 kg was obtained from a Fish Farm in Mando, Kaduna State and transported to NWRI Demonstration farm and stocked in 50 litres plastic tank for acclimatization for 6 days. During the acclimatization, the fish were fed with commercial feed (blue crown) thrice a day at 9:00 am, 2:00 pm and 6:00 pm. The body weight was measured before the commencement of the experiment.

2.3.2 Lettuce and Mint

Nursery lettuce and mint plant with initial height of 4 cm were obtained from NWRI Entrepreneurship Farm Mando, Kaduna, which were transplanted into the 12 blue and red colored plastic re-useable growing cups, with a perforated base that held the plants in the NFT pipe (Figs 2 & 3). The perforated base ensures capillary action to draw water in and a way, out for the growing roots.

2.3.3 Local Sponge

Local sponge (luffer) plants are supported within holes in the pipe by perforated cups and roots supported with a growth media (local sponge). It was cut into circular sections to fit into the cups (Figs 2 & 3).

2.3.4 Centrifugal Submersible Pump

This pump is the main electrical unit that pushes the water. It is used to pump water from the sump tank back to the fish tank. The pump used here has the following ratings; 230VAC; Power: 15 Watts; Output: 800 L/hr.

2.3.5 The Aquaponics System Components Design

2.3.5.1 The Fish Tank

A transparent plastic 50 L tank was used to develop the fish representing the tank and another one was used where wastewater from the fish tank is directly discharged into this tank and at a controlled rate and the water flows continuously into the hydroponics system (Fig. 5).

2.3.5.2 The Sump

A transparent plastic 50 L tank was used where the treated water enters and is pumped back to the fish tanks. The tanks used have the same dimensions (Fig 5).

2.3.5.3 The Pipe Network

Four inches polyvinyl chloride (PVC) pipe of 1.46 m length per roll was used for the construction which was perforated at every 0.15 m where the grow bed float on top of the nutrient rich solution (See Figs. 2 & 3).

Figure 2: Three (3) weeks old mint plant at different stages of development in the hydroponics system in the PVC pipe

2.4 The System Design and Set-up

The design of the aquaponics system was based on the NFT (Nutrient Film Technique) system (Fig 4). It consists of one fish rearing tank of about 50 liters, a clarifier filter tank, and plant

Figure 3: Full grown stage at about 1 month old at different stages of development in the hydroponics system in the PVC pipe

growth bed unit. The used water was discharged into a reservoir beneath the fish tank. The system operated continuously with a known density of fish biomass to maintain stable bacterial populations. Catfish were stocked in the rearing tanks of 50 liters, whereas water depth was 40 liters. Three fish of about equal sizes were stocked and cultured for 1 month, the mean mass of stocked fish ranged from 0.1 g to 0.2 g. They were always fed two times daily with a pellet at a mean rate of 3 % of body weight per day. Water from the fish tank flows by gravity to the system at a flow rate of 1.9 l/h and works for 24 hour delivering water to a perforated 0.1016 m plastic pipe. The nutrient-rich water circulated through the long pipe at a depth of about 0.0508 m, while the grow bed float on top. Plants are supported within holes in the pipe by perforated cups and roots were supported with a growth media (local sponge). The plant roots hang down in the nutrient-rich, oxygenated water, where they absorb large amounts of oxygen and nutrients which contribute to rapid growth conditions and submerged in water. Water flows through pipe, and then it returns to the sump tank again and is then pumped back to the fish tank

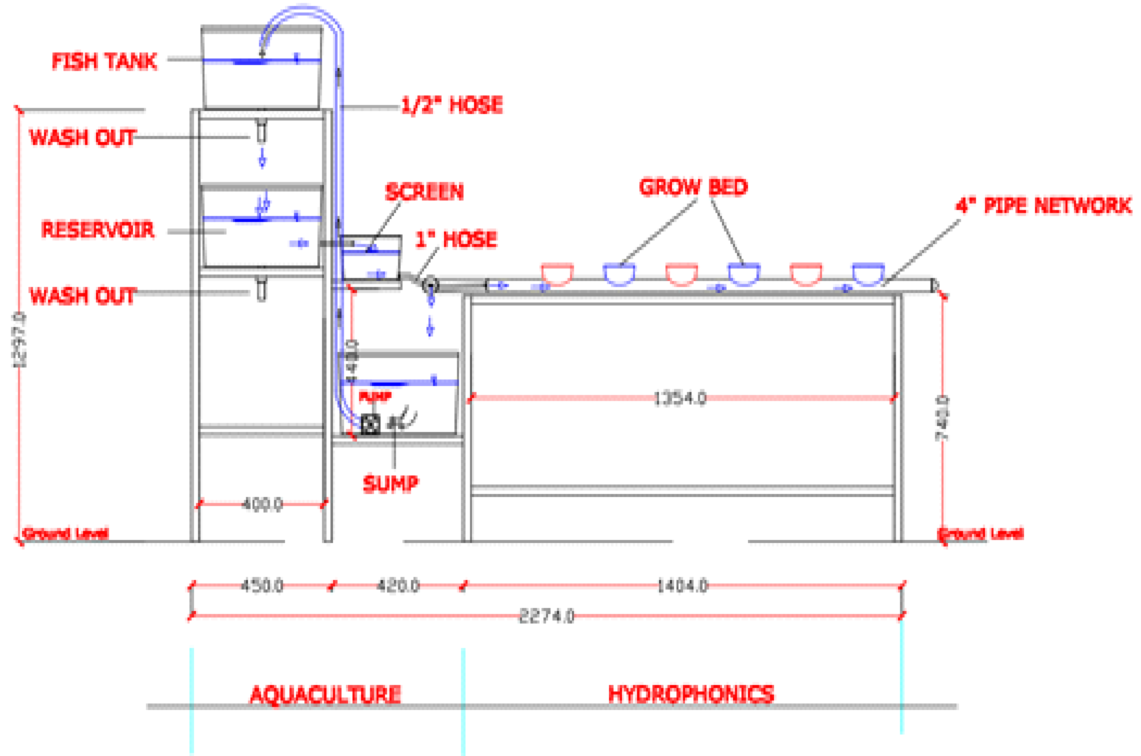

Figure 4: The Nutrient Film Aquaponics System Layout Diagram

Figure 5: The Constructed Aquaponics System

2.4.1 Water Flow and Filtration

In the NFT unit described in this technology, water flows by gravity from the fish tank and then to the reservoir, through the mechanical filter, and into the bio-filter and then to the sump. From the sump, the water is pumped back directly, thus completing the cycle. The flow rate of the water entering each pipe network is relatively low. Generally, the system has 24 hours of retention time. Retention time is a similar concept to turnover rate and refers to the amount of time it takes to replace all the water in a container (Somerville *et al.,* 2014). In this system, water flows by gravity from the fish tank straight into the network of pipe, passing through a very simple mesh screen. Water is then returned to a sump and pumped back to the fish tanks. The fish waste is broken down by nitrifying and mineralizing bacteria living on the plant root surface and the pipe walls (Fig 5). Two types of filters were constructed using these techniques: first, a physical trap to catch the solid wastes, and then secondly, a biological filter for nitrification. The water passes through a mesh screen to trap any solids and then reaches the bio-filter. With insufficient filtration, the NFT units would clog, become anoxic and exhibit poor growing conditions for plants and fish alike (Fig 5).

2.4.2 Planting in a NFT Unit

This method involves suspending plants in pipes, with their roots hanging down into the water. The pipe has the total of 12 holes drilled to fit the perforated cups used for supporting each plant. The amount and location of the holes are dictated by the vegetable type and the distance desired between the plants, where smaller plants can be spaced more closely. Seedlings were used and once these seedlings were big enough to handle, they were transferred into perforated cups and fixed into the pipe unit. The remaining space in the net cup was filled with hydroponic media (local sponge) to support the seedling (Fig 5).

2.4.3 Pumping to the Fish Tank and Final Checks

The submersible pump is placed at the bottom of the sump. Water is pumped from there into the fish tank. It is connected to a hose of 1.3 m length and diameter of 0.2 mm allowing water to flow to the fish tank. Once all parts of the system were integrated, the fish tank was filled, both filters and NFT pipes with water and pump was operated to check for any leaks in the system. The leaks that appeared were fixed immediately by tightening the plumbing connections; reapplying thread tape to the fittings; and finally making sure all valves are in their proper positions.

2.5 Treatment Process and Recycling

The aquaculture wastewater flows into the hydroponics unit where plant uses the nutrient from fish waste as fertilizer by absorbing them through their root. While the fish benefit from plant nutrient uptake capability to improve water quality. The treated water is re-circulated to the fish tank and plants grow beds via a pipe system.

3.0 WATER SAMPLING AND DATA ANALYSIS

Samples for water quality analysis were collected in both the influent and effluent of the growth bed and the rearing tank. The samples for both were collected using sampling bottles 3 times a week to test the change in nutrients concentrations. The physical and chemical parameters were measured for the period of a period of one month.

3.1 Temperature and pH Value Measurements

Temperature was measured using a clean dry beaker to get the sample to appropriate quantity. The conductivity electrode was rinsed with distilled water, then with the sample under test. The electrode was dipped into the sample, on it, set the instrument's mode to temperature following the method of Bartram and Ballance (1996). The pH Value was analysed using Wagtech WE30200 pH meter after the methods of Cheng and Zhu (2005) and Toledo (2007).

3.2 Phosphate

For every 100 mL of each prepared non-turbid and colourless water sample, a drop (0.05 mL) phenolphthalein indicator was added. Thereafter 2 drops of 2 M H_2SO_4 were added to form pink colour formed and 4 mL molybdate reagent and 0.5 mL (10 drops) stannous chloride reagent were added with thorough mixing at room temperature. The solutions were allowed to stand for 11 minutes. The samples were then analyzed spectrophotometrically using at λ_{max} 690 nm (Gavat *et al.,* 2019).

3.3 Nitrate

This was determined using the reduction method and the nitrite obtained was determined through the reaction by sulphanilic acid in the presence of N-(1-naphathyl)-ethyline diamine to get a reddish dye, with detection limit of the method being 0 - 20 mg/L.

3.4 Chloride

This was determined by complexometric titration of 100 mL sample using 0.141 mol dm^{-3} silver nitrate ($AgNO_3$) in the presence of 1 mL Potassium Chromate (K_2Cr_4), at pH of 7 - 8. At the endpoint, titration colour changed from yellow to pink-yellow and the chloride concentration was computed by the formulae below:

$$\text{Chloride (Cl)} \left(\frac{m}{Ll}\right) = \frac{(A+B)*N*35450}{\text{Vol (ml) sample}} \quad \ldots (1)$$

Where A = Sample titre value, and B = Blank titre value and N = 0.0141.

3.5 Salinity

Salinity was determined by multiplying the concentration of chloride by salinity factor (1.65). Using the relationship below:

$$\text{Salinity as NaCl (mg/L)} = mgL\ Chloride\ x\ 1.65 \quad \ldots\ldots\ldots\ldots (2)$$

3.6 Alkalinity

This was measured by titration of 100 mL sample using 0.01 mol dm^{-3} of H_2SO_4 phenolphthalein indicator, methyl orange indicator and pH meter at the end of 4.5 and the amount was calculated using the relationship below:

$$\text{Mg/L Total Alkalinity} = \frac{\text{Titre x 1000}}{\text{Volume of sample used}} \quad \ldots\ldots\ldots (3)$$

3.7 Total Dissolved Solids (TDS)

TDS refers to total dissolved solids which are small enough to survive filtration through a filter with two micrometer pore. This parameter was measured in the sample by using Wagtech WE30120 TDS meter (Rhoades, 1996; Hubert and Wolkersdorfer, 2015).

3.8 Electrical Conductivity (EC)

Electrical Conductivity (EC) was measured with conductivity meter (in S/cm) using the Wagtech WE30120 conductivity meter by lowering the probe into the water samples in a plastic beaker and stirred while it was allowed to stand before measurement was taken (Hubert and Wolkersdorfer, 2015).

Table 1: Desirable Water Quality for Catfish Ponds

Parameter	Range	Reference
Ph	6.5 – 9.0	Ekubo and Abowei, 2011
Temperature	26 – 32°C	Santhosh and Singh, 2007
Phosphate	0.01– 3 mg/l	Bhatnagar and Devi, 2013
Nitrate	0 – 20 ppm	Meck, 1996
Chloride	> 6 mg/l	Stone and Thomforde, 2004
Salinity	< 10,000 mg/l	Stone and Thomforde, 2004
Alkalinity	50 – 300 mg/l	Mayer, 2012; Mikkola, (Ed.) (2016).
Total Dissolved Solid (TDS)	< 500 mg/l	Boyd, 1998
Electrical Conductivity	30 – 5,000 uS/cm	Stone and Thomforde, 2004

Table 2: Water Quality Parameters of Aquaculture Wastewater and Treated Water

Parameters	Date	25/10/19	28/10/19	30/10/19	01/11/19	04/11/19	08/11/19	12/11/19	13/11/19	15/11/19	18/11/19	20/11/19	22/11/19
pH	Waste	6	5.6	6.10	5.5	5.7	5.5	5.7	6.4	6.6	6.5	6.2	6.4
	Treated	6.8	6.5	6.9	6.3	6.5	6.3	6.5	7.2	7.5	7.6	7.5	7.8
Phosphate	Waste	7.4	7.6	8.2	7.8	6.8	5.8	5.76	5.8	5.75	5.6	5.62	5.2
	Treated	5	5.3	5.5	5.5	4.2	3.8	3.2	3.15	3.1	3.4	3.5	3.4
Nitrate	Waste	3.8	4.2	6.2	7.6	8.6	8.8	9.2	9.44	9.3	8.2	8.5	8.3
	Treated	2.5	2.8	4.8	6.8	5.6	5.9	4.6	4.2	3.5	4	5.5	5
Chloride	Waste	30.9	35.74	43.24	29.7	13.25	19.2	19.7	19	21.24	20.74	17.24	17
	Treated	28	34.24	23.24	26.7	12.25	12.22	13.01	13.2	13.75	17.74	15.25	14.3
Salinity	Waste	50.99	58.97	71.34	49	21.86	31.68	32.51	31.35	35.05	34.23	28.45	27.2
	Treated	46.2	56.46	38.35	44.19	20.21	20.13	21.47	21.8	22.68	29.28	25.15	24
Alkalinity	Waste	128	200	190	150	103	97	148	141	150	120	118	116
	Treated	120	146	131	99	88	82	102	92	108	103	100	98
TDS	Waste	125	132	140	142	140	141	142	141	141	136	139	137
	Treated	89	94	103	101	100	99	98	96	102	98	100	102
EC	Waste	247	264	278	280	279	281	280	279	280	269	272	274
	Treated	178	190	204	200	201	182	191	196	201	200	201	205
Temp.	Waste	27	26.3	26.4	26.2	27.9	26.7	27.2	27.6	27.3	28.3	27.6	27.2
	Treated	26.2	26.1	25.9	26	27.6	26.4	26	26.2	27.3	27	27.4	26.4

4.0 Discussion of Results

The main concern of the aquaponics system is the removal of metabolic waste products from the fishery. Nitrate was used as fertilizer and phosphate used for the plant development. From the results of the analysis of the physicochemical parameters generally indicated that there were differences between the raw aquaculture wastewater and the treated water (Table 1). The values of physicochemical parameters measured in the raw aquaculture wastewater were higher than the values observed in the treated water except that of pH and temperatures of the observations in the wastewater were lower. These differences could be explained by the ability of plant in removing nutrients and other related pollutants in aquaculture wastewater. This is an indication that pollutants and nutrients in aquaculture wastewater are biodegradable. The results also show that plants have the ability to treat wastewater generated by fishery making it suitable for reuse.

4.1 The pH values

As shown in Table 2, the pH values of the aquaculture wastewater ranged from 5.5 to 6.6, in which the values are considered not normal and ideal for the system, since the pH value of below 6.5 leads to sluggish growth of fishes. The values of the treated water ranged from (6.3 - 7.6), which is desirable for fish production. At the beginning of the experiment, normal pH was observed, however, a slight decrease to 6.3 in the treated water was observed due to the addition of fresh water with a pH value of 6.7 after a week of observation. It rose again till it reached a value of 7.8 and the wastewater to 6.4. Fish has an average blood pH of 7.4, and generally pH between 7.0 and 8.5 is more optimum and conducive to fish life and for biological productivity. Fish can become stressed in water with a pH ranging from 4.0 to 6.5 and 9.0 to 11.0 and death is almost certain at a pH of less than 4.0 or greater than 11.0 (Ekubo and Abowei, 2011). Ideally, an aquaculture pond should have a pH between 6.5 and 9 (Bhatnagar *et al*., 2004; Ekubo and Abowei, 2011). Therefore, the pH values observed in the system are within the optimum range for plant and fish production (See Table 1).

4.2 The Electrical Conductivity (EC)

The EC value of waste and treated water and their variation throughout the experiment is shown in Figure 6. The EC of the wastewater in the aquaponics system ranged between 247 and 281 µS/cm and that of the treated water between 178 and 205 µS/cm (Table 2). These values are within the ideal range for agricultural production particularly for lettuce development (Table 1). After about 10 days, with increase in plant growth, the EC values for the treated water also decreased. This increase in growth requires high amounts of nutrients, which finally leads to the low observations in the EC. The result shows that the more plant develops, the higher the absorption of nutrients from the water thereby treating the water. In the fourth week, the lettuce plant was attacked by birds, and this led to the death of three (3) plants within the week. This unexpected decrease in the number of plants attributed to the decrease in the rate of absorption of the nutrient in the water and thus led to the slight increase in the EC values as shown in Figure 6. As fish differ in their ability to maintain osmotic pressure, the optimum conductivity for fish production differs from one species to another. Stone and Thomforde (2004) recommended the desirable range of 100 - 2,000 mS/cm and acceptable range of 30 - 5,000 mS/cm for pond fish culture (Table 1).

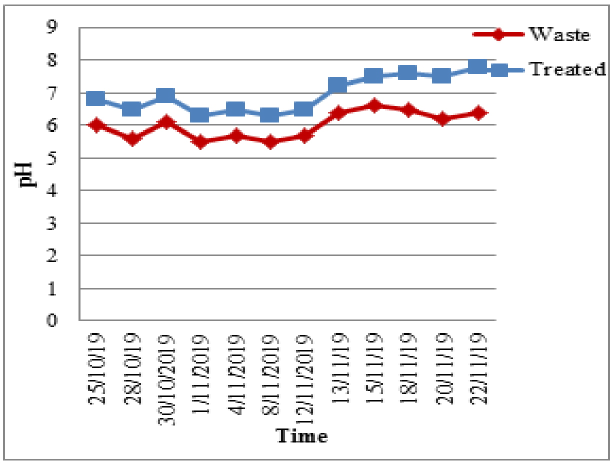

Figure 5: pH value of both wastewater and treated water during the period of measurement

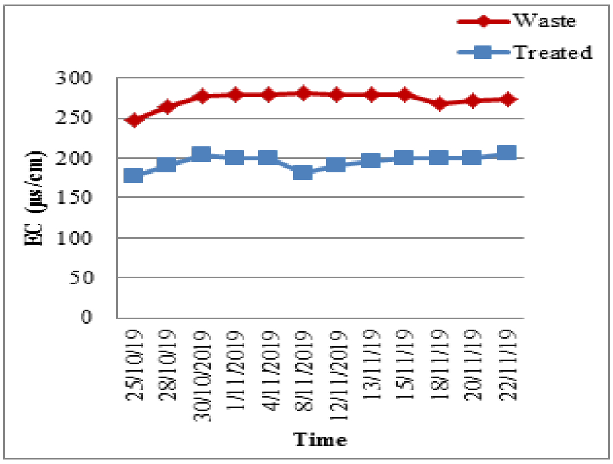

Figure 6: Electrical Conductivity (EC) values of the wastewater and treated water.

4.3 The Total Dissolved Solids (TDS)

Figure 7 Shows the TDS values of waste and treated water and their variation throughout the experiment. In fact, this parameter is important in determining the availability of nutrients for plants. As shown in Table 2, the TDS of the wastewater in the aquaponics system ranged between 125 and 142 ppm and that of the treated water ranged between 89 and 103 ppm. These values are within the ideal range for lettuce growth. There was low absorption of nutrient by the plants in the first week of the experiment, but with the increase in plants growth in the subsequent days accounting for high absorption of nutrients from the water. The TDS values for the treated water decreased and later remained almost stable. In the fourth week, the lettuce plant was attacked by birds which led to the death of 3 plants within a week. This sudden decrease in the number of plants was attributed to the decrease in the rate of absorption of nutrient in the water.

4.4 The Nitrate values

The values obtained from the water quality analysis for the aquaculture wastewater ranged between 3.8 and 9.44 mg/L and that of the treated water ranged between 2.5 and 6.8 mg/L as shown in Table 2. With time, the nitrate concentration in the wastewater began to rise as the fish are beginning to acclimatize with their new environment. Also, the abstraction of nutrient by plants at the early stage was low but began to rise as plants starts to blossom. In the fourth week of the experiment, it was observed that the treatment rate began to decrease as a result of the loss in the number of plants. The result shows that the growth of the plants and quantity of plants planted have effect on the treatment of the wastewater. Meck (1996) recommended that nitrate concentration from 0 to 200 ppm is acceptable in a fish pond. According to Stone and Thomforde (2004) nitrate is relatively nontoxic to fish and do not cause any health hazard except at exceedingly high levels (above 90 mg/L).

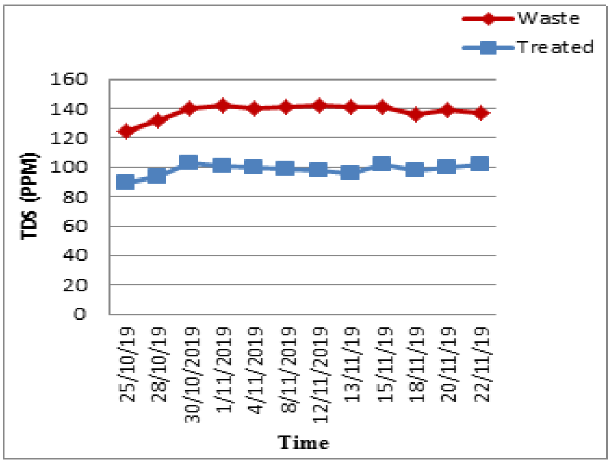

Figure 7: TDS values of the waste and treated water throughout the experiment in the aquaponics system

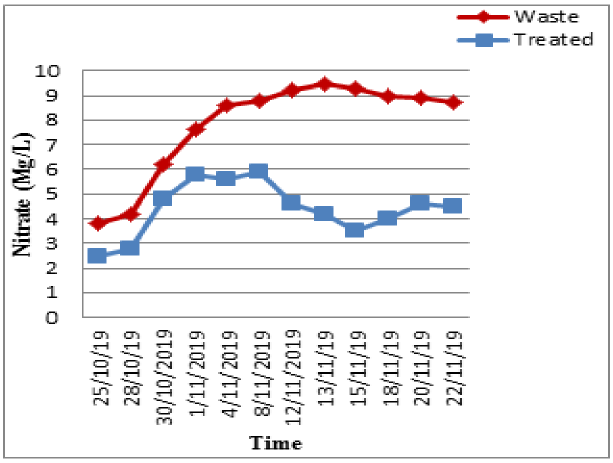

Figure 8: Nitrate values of the wastewater and the treated water throughout the experiment in the aquaponics system

4.5 The Phosphate

The phosphate content in the wastewater ranged between 5.6 and 7.8 mg/l and that of the treated water between 3.1 and 5.8 mg/l as shown in Table 2. The phosphate concentration at the early stage of the analysis increased as a result of uneaten feed by the fish. This resulted to serious deterioration of the water quality in the system. After a week of observation, the quantity of water in the fish tank decreased and more water was added, which led to a sudden decrease in the phosphate concentration.

4.6 The Temperature values

For the African catfish an acceptable temperature range is between 26 ºC and 32 ºC. The temperature of the wastewater ranged between 26.2 and 28.3 ºC and that of the treated water between 25.9 and 27.6 ºC (See Table 2). The temperature throughout the period of the experiment was within the permissible limit

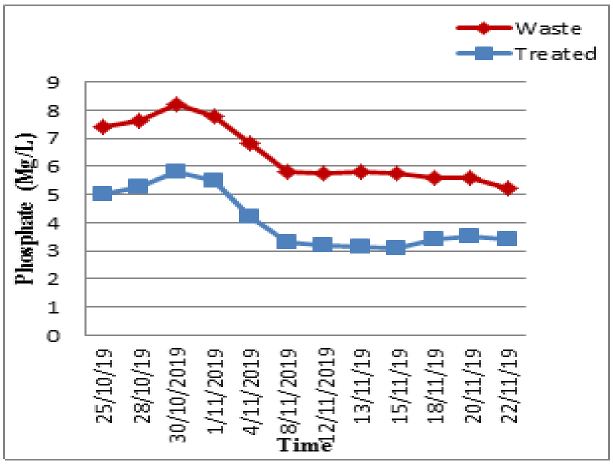

Figure 9: Phosphate values of the waste and treated water throughout the experiment in the aquaponics system

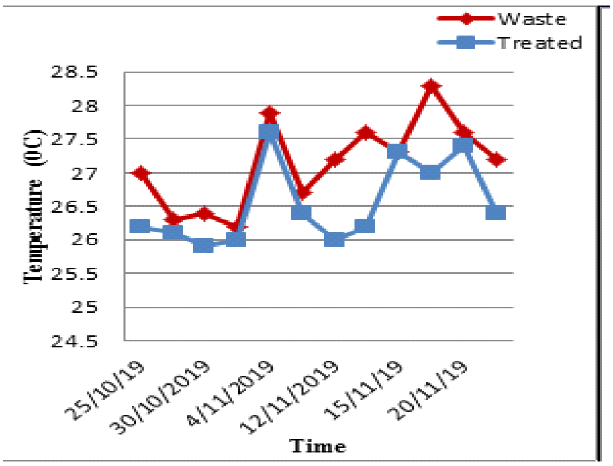

Figure 10: Recorded temperature values of the waste and treated water during the experiment in the aquaponics system

4.7 The Alkalinity values

According to Santhosh and Singh (2007) the ideal value for fish culture is 50 – 300 mg/L. The alkalinity values of the wastewater in the aquaponics system ranged between 97 and 200 mg/L, while the value of the treated water ranged from 82 – 146 mg/L (Table 2). So, the range of alkalinity in both the waste and treated water were within the permissible ranges as shown in Table 1.

4.8 Chlorides values

According to Stone and Thomforde (2004) the desirable limit of chlorides for commercial catfish production is above 60 mg/L. As shown in Table 2, the chloride values of the wastewater in the aquaponics system ranged between 13.25 and 43.24 mg/L, while the value of the treated water ranged from 12.22 to 34.24 mg/L. Chloride concentration below 70 is generally safe for all plants and above 70 sensitive plants show sign of injury. Therefore, the concentration of chloride in the system was alright for both the fish and the plants growth.

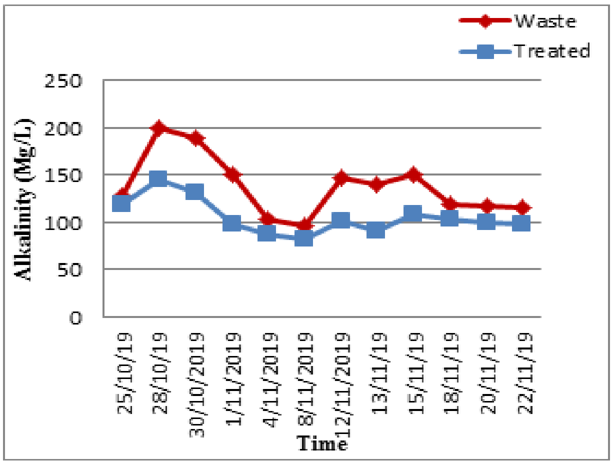

Figure 11: Alkalinity values of the waste and treated water throughout the experiment in the aquaponics system

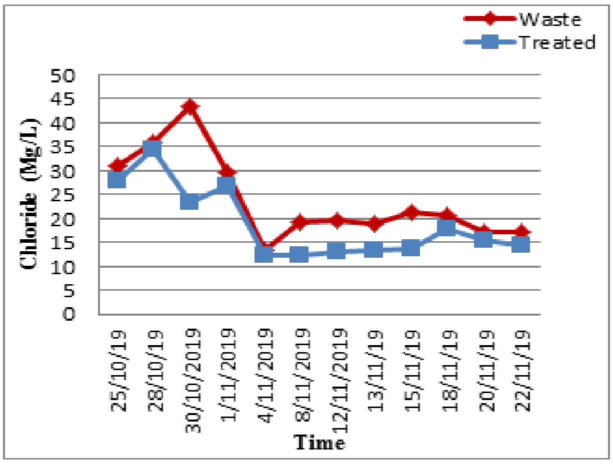

Figure 12: Shown are the Chloride values of the waste and treated water throughout the experiment in the aquaponics system.

4.9 Salinity values

According to Meck (1996), fresh and saltwater fish species generally show poor tolerance to large changes in water salinity. As shown in Table 2, the salinity values of the wastewater in aquaponics system ranged between 21.86 and 71.34 mg/L while the value of the treated water ranged from 20.21 to 56.46 mg/L. These ranges of values for salinity were in conformity with the range of values for the chloride, which was multiplied by a constant of 1.65 to derive the values for the salinity.

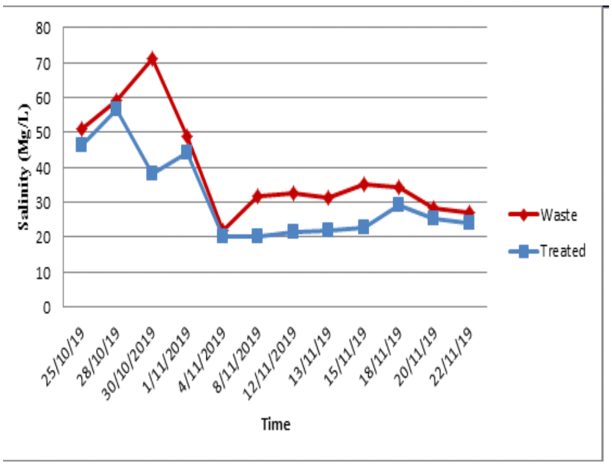

Figure 13: Shown are the salinity values of the waste and treated water throughout the experiment in the aquaponics system

CONCLUSION

It was evident from all the results obtained from the experiment that lettuce and mint plants were effective in the removal of nutrient components of wastewater discharge from catfish tank. The use of lettuce and mint plants as bio-filter was effective in reducing high phosphate, nitrate, chloride, alkalinity, salinity TDS and EC in aquaculture wastewater. The reuse of plant treated wastewater is suitable for fish culture without affecting growth performance. Under that condition the fish developed quiet well from an average initial weight of 0.18 kg to 0.25 kg. The adoption and use of aquaponics system in Nigeria can increase local fish and vegetable production. The recycling of water in the system enables the conservation of available water and non-requirement of land area/soil to grow agricultural produce.

RECOMMENDATIONS

Based on the outcome of the studies, the followings are recommended:

(i) Research efforts should investigate the long-term growth studies under different culture conditions and fish species to assess the use of other vegetables as an effective approach to sustain aquaculture development in Nigeria;

(ii) In the areas of water shortages, little water availability can be used carefully by recycling the used water from the system;

(iii) The adoption and use of aquaponics system in Nigeria can increase local fish and vegetable production;

(iv) The use of aquaponics system by individuals can aid food production and make Nigeria food self-sufficient;

(v) Using aquaponics system for crop development would enable the availability of fresh and organic crops for consumption thereby improving human health;

(vi) Adoption of aquaponics system would increase local income and thereby increase national Gross Domestic Product (GDP);

(vii) The hydroponics system being widely practiced in Nigeria should be combined with an aquaponics system in order to seize the advantage of the supplement produced from fish to be used as nutrient required for crop growth.

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