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Water Quality Assessment of Coca-Cola Wastewater Reservoir in Maiduguri Borno State Nigeria

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Abstract: *Assessment of monthly variation of some water quality parameters in coca cola wastewater reservoir was conducted fortnightly from July to December 2013. The range of parameter observed for the period of the study were Temperature (22±0.47^{o}C to 28±1.25C^o), Conductivity (4.0±0.22 to 5.4±0.37µc/cm), Hydrogen ion (pH) (6.97±0.03 to 7.54±0.33), Dissolved Oxygen (9.9±1.42 to 14.5±1.31mg/l), Alkalinity (9.33±0.46 to 9.86±0.37), Nitrogen (0.84±0.06 to 1.04±0.12mg/l), Ammonia (0.42±0.09 to 0.67±0.00mg/l) and Phosphorus (0.37 to 0.74mg/l) were all significantly different ($p<0.05$), while Transparency (11.0±0.82 to 17.5±0.36cm) and Free Carbon dioxide (6.3±0.40 to 6.8±0.57mg/l) were not significantly different ($p>0.05$) within the monthly variables. Variability within the stations shows Temperature, Conductivity, Hydrogen ion (pH), Free Carbon dioxide, Ammonia and Phosphorus not significantly different ($p>0.05$), while Transparency and Alkalinity were significantly different ($p<0.05$). Temperature, Hydrogen ion (pH), Free Carbon dioxide, Dissolved Oxygen, Conductivity, Alkalinity, Nitrogen and Phosphorus justify the suitability of the wastewater reservoir for fish production, while others such as Transparency and Ammonia do not.*

Key words: *Physicochemical parameters, Coca cola, Wastewater reservoir*

I. Introduction

In Nigeria, reservoirs are put to many uses, which include sources of water for irrigation, drinking by both human and domestic animals and aquaculture amongst others. Examples of these reservoirs are the Lughu reservoir in Michika and the Kiri reservoir in Shalleng both in Adamawa state northeasthern Nigeria. The coca-cola plant wastewater reservoir in Maiduguri is unique from these two in the sense that this reservoir was constructed and designs to collect wastewater from the coca-cola production plant due to its location in a land lock area, which was later put to use for aquaculture.

Wastewater aquaculture as a possible means of water renovation, environmental protection and food production have all along been practiced in some countries and is receiving serious attention in feature planning in some arid countries (Gaigher 1983).

The problems related to management of wastewater is due to extensive industrialization, increase population density and high urbanized societies (McCaseland et-al.,2008). Fish and other aquatic organisms performance (status) is directly affected by water quality or (Physicochemical) properties of water body in which they live (Moody and Folorunsho, 2006).

The general acceptance is that wastewater use in agriculture is justified on agronomic and economic grounds, although care must be taken to minimize adverse health and environmental impacts (Sowers, 2009; Rietveld et-al.,2009). Furthermore wastewater reuse is increasingly becoming important for supplementing drinking water needs in some countries around the world. The option of reuse of wastewater is becoming necessary as a result of increased climatic change, thus leading to draught and water scarcity, and the fact that wastewater effluent discharge regulations have become stricter leading to a better water quality (Rietveld et al., 2009).

Studies of water quality parameters are therefore important to determine the extent of deterioration most especially in the reuse of wastewater so as to monitor the likely danger to aquatic organisms (Peter and Acholonu, 2008). Abubakar (2006), also stated that studying the physicochemical properties of water body helps to protect and maintain the aquatic ecosystems and other resources from the water bodies. Thus the need for proper consistent assessment of water quality and potentials of wastewater and natural reservoirs for proper management.

II. Materials And Method

Study area: Maiduguri is the capital of Borno State and is located between latitude 10^{o}09'and 13^{o}44' N and longitude 11^{o}36' and 14^{o}38' E. Most part of the state lies within the sahelian climate zone classified under the tropical continental climate with rainfall of 250 – 1000mm. the temperature regime of the state is relatively more constant than that of rainfall pattern. The hottest months of the year are March, April, and May with mean temperature of 29.5, 32.8, and 34.5^{o}C respectively (Aminu, and Omoyeni, 2001).The plant and reservoir constructed in 1978 are located at Pompomari industrial area and the reservoir covers an estimated area of about 43,200sq meter with an approximate depth of about 6 meters.

The study was conducted through assessment of monthly variation of some water quality parameters in the wastewater reservoir from July to December 2013. Wastewater samples were collected fortnight at 08:00Hrs local time at a depth of 30cm below the water surface. Wastewater samples were collected at three different points (Station 1, 2 and 3) which the reservoir is divided into for the purpose of this study. Station 1 is the area of discharge, station 2 is the area covered by macrophytes and station 3 is the open water were fishing activity takes place. Wastewater samples were collected in triplicate for the analysis.

Determination of physico-chemical parameters: Wastewater samples were collected in labeled and fixed sampling bottles of 100ml. Water temperature, Conductivity, pH and Transparency reading were taken directly at the sampling sites. Temperature was measured (in situ) Mercury bulb thermometer (Glaswekwer Tien Model), Conductivity was measured using conductivity meter (Model: PHYTE 65667:00), Transparency were determined by 20cm diameter Secchi disc, suspended by graduated cable as described by Stirling (1985). Measurement were taken around 12:00 hours for best results. pH were measured using pH meter (Model: Hanna Instrument Model No H18915ATC).

Alkalinity was determined as described by Stirling (1985), Free carbon dioxide and Total dissolved oxygen were determined as described by Saxena (1990), Total Nitrogen and Total Ammonia were determined as described by Phillips (1985) while Total Phosphorus was determined as described by AOAC (1990). All statistical analysis was performed using spps software. Water quality parameters data were subjected to one-way ANOVA for comparism.

III. Results And Discussion

The Physico-chemical parameters of the three sampling stations are summarized in Table 1. The monthly mean variation for temperature ranged from 28 ± 1.25^{o} C in July to 22 ± 0.47^{o}C in December (Table1). The variation in monthly mean water temperature compares favourably with the range of 17 – 28.5 ^{o} C reported by Haruna (1992) in Jakara Lake Kano and 19 – 27^{o}C reported by Jidauna and Abubakar (2008). The differences in variability of stations were not significant ($p>0.05$). This variation might be as a result of seasons of the year in which the lowest mean temperature was recorded during the harmattan season (October to February), which also coincide with the highest dissolved oxygen (DO) concentration of 14.5mg/l. Abubakar (2006) reported that cold water hold more dissolved oxygen (DO) than warm water. The highest temperature recorded in July might be due to waste discharge from production, use of organic bait by fishermen and accumulation of fish metabolites (e.g Ammonia). Suspended particles absorbed more heat (APHA,2002). The result also observed a positive correlation between temperature and ammonia.

The recorded monthly mean transparency value ranged from11.0 ± 0.82cm in November to 17.5 ± 0.36cm in October (Table 1). However, the value falls within 8.6 – 17.8cm as reported by Jidauna and Abubakar (2008) in Lughu reservoir. The difference in variability in both sites and months were not significant ($p>0.05$). The variation observed might be because there is variation among daily and monthly discharge of wastewater from the plant, activities of fishermen around the reservoir (use of organic bait) that gave rise to water colouration (Green) as a result of algal bloom. Though water transparency was low and fluctuates throughout the period, the lowest transparency recorded at station 2 and in the month of November, might be due to algal bloom arising from the discharge of organic waste, the activities of the fishermen around the reservoir of using chaff mixed with clay as organic bait and excreta from animals that visit the reservoir for drinking water. Horner et al., (1994) states that the released of suspended solids into receiving water body can have a number of direct and indirect environmental effects.

The monthly mean variation for conductivity ranged from 5.4 ± 0.37μs/cm in November to 4.0 ± 0.22μs/cm in July (Table1). There is gradual increase in wastewater reservoir monthly conductivity from September to November, this might be because of discharge wastewater from the plant that contains high concentration of salts and this variation was markedly significant statistically ($p<0.05$) and not significantly different within stations ($p<0.05$). The conductivity value falls below the recommended ranged of 10μs/cm to 100μs/cm (ACTFR, 2002). Stirling (1985) states that very acidic pH < 4.5 or alkaline pH >10 water have appreciable high conductivity values. The observed slight change in the values of electrical conductivity might be due to the discharged wastewater used for cleaning and washing of bottles in the plant, constant use of detergent around the reservoir and influx of ground water from the surrounding environment that house the abandoned Borno state soda ash plant and M&W pump industries. ACTFR (2002) reported that increase effect of ground water generally increase conductivity of fresh surface water. With corresponding slightly gradual increase in conductivity values, this study observed negative relationship between conductivity and temperature values in the reservoir which does not agree with ACTFR (2002), reported that with increase temperature, conductivity in water rises due to evapoconcentration effect (i.e high temperature leads to water evaporation and increase in concentration of ions in water). Abubakar (2006) also reported higher value of conductivity with increase in temperature, which do not agree with this study which might be as a result of the rainy season and discharge of wastewater from the plant on daily bases. The highest conductivity mean value recorded in November might be attributed to high concentration of suspended matter associated with discharge from the plant, mixed of chaff and clay soil by the fishermen around the reservoir as bait and possibly the wind action in the arid zone that can deposit large amount of particles into the reservoir.

Hydrogen ion (pH) is an important parameter in many ecological studies because of a strong relationship between pH and physiology of most aquatic organisms (Abubakar, 2006). The monthly mean variation for pH ranged from 7.54 ± 0.33 in December to 6.97 ± 0.03 in July (Table1), this variation from neutral to slightly septic condition indicates the presence of microbes due to availability of organic waste in the reservoir. This variation was markedly significant statistically ($p<0.05$) and not significantly difference within station ($p<0.05$). The recorded value falls within the recommended range of 6 to 9 in most tropical natural waters (ACTFR, 2002), which is also suitable for fish production (Adeniji and Ovie, 1990) values outside the range stress the physical systems of most aquatic organisms and reduced reproduction. Abubakar (2006) also reported that low pH allows toxic elements and compound to become mobile and available for uptake by plants and animals. However, the constant pH value recorded in all the sites may be attributed to the non-significant difference in temperature values in all the sites.

The monthly mean variation for dissolved oxygen ranged from 14.5 ± 1.31mg/l in the month of December to 9.9 ± 1.42mg/l in the month of July(Table1) and the variation was markedly significant statistically ($p<0.05$) and not significant within stations ($p<0.05$). The observed range of 9.90-14.50mg/l in this study is less than13.86-17.26mg/l reported by Jidauna and Abubakar (2008) in Lughu reservoir Michika. EIFACT/T19 (1973) reported that DO value of 5.0mg/l is satisfactory for most species of aquatic life. Absalom et al., (2002) reported that high dissolved oxygen values during wet season might be due to the prevailing wind action. Oxygen enters water through diffusion and photosynthesis. However, Anonymous (1972) reported that in a well-oxygenated water, nutrient element form a bond with sediments that prevents their recycling-locked in nutrients. DO shows a negative correlation with temperature, the lowest value of DO observed in station 1 may be due to high influx of suspended organic waste discharge from the plant and the activities of fishermen using chaff mixed with clay soil as organic bait for fishing in the reservoir. Ufodike and Garba (1992) reported that decrease in water transparency reduces production of natural food in the water. APHA (2002) reported that low transparency increase water temperature because suspended particles absorbed more heat this in turn reduced the concentration of dissolved oxygen.

The study observed decreases in monthly mean of free CO_2 6.7 ± 0.12mg/l in July and August to 6.3 ± 0.40mg/l in October and November, which might be because of photosynthetic activities by phytoplankton's. The monthly mean variation for free carbondioxide ranged from 6.8 ± 0.57mg/l in December to 6.3 ± 0.40mg/l in October and November (Table1) and this variation was markedly not significant statistically within the months and stations ($p>0.05$). The observed ranged (6.3 to 6.7) falls slightly below the observed ranged 6.0 to 7.9mg/l reported by Jidauna and Abubakar (2008) in Lughu Reservior Michika. The value falls within the recommended safety limit of 10mg/l as reported by Haruna (2003). The high values of free carbondioxide observed may be due to low alkalinity (Soft water) nature of the reservoir. Saxena (1990) reported that high alkaline (hard water) water bodies are characterized by negative values of free carbondioxide. Haruna (2003) reported that high concentration of carbondioxide in water can cause ceasation of feeding and eventual death of fish. Absalom et al., (2002) also reported that high free CO_2 in water indicate low photosynthetic activities.

Monthly mean total alkalinity ranged from 9.33 ± 0.46mg/l in December to 9.86 ± 0.37mg/l in September, which is less than 9.1 to 28.3mg/l reported by Abubakar (2006) in Lake Geriyo. There was significant difference in variability ($p<0.05$) between the months and sites. The high productivity of water should have alkalinity over 100mg/l (Saxena, 1990). Low total alkalinity values increase the toxicity of heavy metals ions, such as copper and zinc to fish and invertebrates (Stirling, 1985). Saxena (1990) reported that increase in pH values of water with high alkalinity (hard water) ranged from 8.5 upward. Stirling (1985) reported alkalinity tends to be positively related to water hardness and hence pH buffering capacity. This study also observed a gradual increase in monthly mean of total alkalinity of the reservoir as the wet season progresses and decreases as harmattan progresses. ACTFR (2002) reported that the alkalinity buffering capacity in natural fresh water system is due mainly to presence of bicarbonate leached from the soils in rainwater runs off. The highest value of total alkalinity recorded in September and at station 1 may be due to the leaching effect of bicarbonate from the soils as rainwater influx into the reservoir from the surrounding farmlands and the presence of chemicals from the discharge wastewater uses in cleaning the bottles. The result also observed a positive correlation between alkalinity and phosphorus.

The monthly mean variation for nitrogen ranged from 1.04 ± 0.12mg/l in November to 0.84 ± 0.06mg/l in July (Table1) and this variation was markedly significant statistically ($p<0.05$) and not significance within stations ($p>0.05$). The observed mean total nitrogen shows an increase in the first three months then fluctuates in the last three months this might be as a result of influx of runoff from the surrounding farms with organic and synthetic fertilizers. The observed range is lower than 0.68-2.19 reported by Jidauna and Abubakar (2008) in Lughu reservoir Michika. The values of nitrogen recorded in the reservoir were less than the danger limit of 10mg/l. Abubakar (2006) reported that excess total nitrogen at higher concentration of 10mg/l or higher can cause low level of dissolved oxygen and become toxic to warm blooded animals under certain conditions. In the environment, ammonia is oxidized to nitrate creating and oxygen demand and low DO in surface water (Kuroso,2001; Sabalowsky, 1999). Similarly, nitrogen in the form of ammonia is toxic to fish and exerts an oxygen demand on receiving water nitrifiers (CDC, 2002). The low concentration of total nitrogen recorded at the reservoir might be due to high concentration of DO recorded throughout the period of the study. However, Saxena (1990) reported that domestic and industrial effluents and agricultural run offs are major sources of nitrogen in water.

The monthly mean variation of ammonia ranged from 0.67 ± 0.00mg/l in October to 0.42 ± 0.09mg/l in December (Table1). Ammonia is an important nutrient of phytoplankton, it is also the major end product of protein catabolism excreted by aquatic animals (Stirling, 1985). Ammonia in water is released as an end product of decomposition of organic matter and also an excretory product of some aquatic animals (Saxena, 1990). The monthly mean total ammonia variations observed in this study is lower than 0.34mg/l to 0.67mg/l reported by Jidauna and Abubakar (2008) in Lughu reservoir Michika. The values observed are higher than the recommended 0.025mg/l by Alabaster and Lloyd (1982). There was no significant difference observed between the variability ($p>0.05$) at both stations and month. Khanna and Singh (2003) reported that growth rate of fish slows down if ammonia is present in higher concentration. Haruna (2003) also reported that high ammonia levels cause poor growth, increase susceptibility to disease and eventual death. The highest concentration of ammonia recorded in station 1 and station 3 in the month of October might be due to decomposition of organic materials from the discharge wastewater, influx of organic matter from the surrounding farms and plants that are found within the stations. Stirling and Philips (1990) reported that ammonia could originate where farm water supply is polluted with sewage, silage or other organic rich water.

The monthly mean variation of phosphorus ranged from 0.74 ± 0.08mg/l in September and October to 0.37 ± 0.04mg/l in November (Table1) and this variation was markedly significant statistically ($p<0.05$) and not significantly difference within stations ($p>0.05$). Phosphorus is one of the most important elements that can limit the growth of autotrophs productivity in a system (Saxena, 1990). Phosphorus generally occurs in very low concentration within the natural environment and is rapidly taken up by plants (ACTFR, 2002). The monthly mean range of 0.37-0.74mg/l is higher than 0.14-0.58mg/l reported by Jidauna and Abubakar (2008) in Lughu reservoir Michika. When phosphorus input to water is higher than that which a population of living organism can assimilate, the problem of excess phosphorus content occur (Rybicki, 1997). When in excess they contribute to eutrophication which leads to algal blooms and plant growth in streams, ponds, lakes, reservoirs, and estuaries along shorelines (EPA, 2000; Eynard et al,2000). The highest value of phosphorus recorded at station 2 and in the months of September and October may be due to sediment of organic waste as most of station 2 is covered by macrophytes, washing of cars around the reservoir discharge from the plant and influx of rain run offs from the surrounding farms. (ACTFR, 2002) reported that artificial source of phosphorus includes fertilizers, detergents, wastewater, industrial effluent and animals excretes amongst other.

IV. Conclusion And Recommendation

Although this reservoir was constructed for the collection of wastewater generated from the production activities in the coca cola company, the result of the physicochemical parameters obtained during the period of this study justify its utilization for continuously use in fish production. All human activities with negative impact around the wastewater reservoir be regulated.

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Table1: Physicochemical Parameters of Wastewater Reservoir

	July	August	September	October	November	December	SEM/P value
Temperature (°C)	28 ± 1.25^{a}	24 ± 0.47^{b}	26 ± 0.94^{a}	27 ± 0.8^{a}	25 ± 0.47^{b}	22 ± 0.47^{c}	0.8819 ****
Alkalinity (mg/l)	9.52 ± 0.21^{ab}	9.58 ± 0.08^{ab}	9.86 ± 0.37^{a}	9.58 ± 0.04^{ab}	9.42 ± 0.20^{ab}	9.33 ± 0.46^{b}	4.303*
Conductivity (µs/cm)	4.0 ± 0.22^{c}	4.7 ± 0.24^{b}	4.5 ± 0.12^{b}	5.3 ± 0.12^{a}	5.4 ± 0.37^{a}	5.2 ± 014^{a}	0.223234 ****
Transparency (cm)	15.0±1.83	13.7±0.26	14.8±0.28	17.5±0.36	11.0±0.82	12.3±1.89	0.92835 NS
pH	6.97 ± 0.03^{b}	7.31 ± 0.08^{a}	7.26 ± 0.11^{b}	7.48 ± 0.14^{a}	7.34 ± 0.161^{a}	7.54 ± 0.33^{a}	0.081758 ****
Carbon dioxide (mg/l)	6.70 ± 0.12^{a}	6.70 ± 0.43^{a}	6.50 ± 0.40^{a}	6.30 ± 0.40^{a}	6.30 ± 0.33^{a}	6.80 ± 0.57^{a}	0.088506 NS
Dissolved Oxygen (mg/l)	9.90 ± 1.42^{b}	13.5 ± 1.02^{a}	13.0 ± 1.56^{a}	12.4±1.84	13.3 ± 1.1^{a}	14.5 ± 1.31^{a}	0.638575 ****
Nitrogen (mg/l)	0.84 ± 0.06^{b}	0.99 ± 0.18^{ab}	1.01 ± 0.06^{ab}	0.88 ± 0.06^{ab}	1.04 ± 0.12^{a}	0.88 ± 0.04^{ab}	0.033961*
Phosphorus (mg/l)	0.70 ± 0.03^{a}	0.67 ± 0.09^{a}	0.74 ± 0.08^{a}	0.74 ± 0.02^{a}	0.37 ± 0.04^{b}	0.46 ± 0.04^{b}	0.064687****
Ammonia (mg/l)	0.60 ± 0.11^{a}	0.61 ± 0.09^{a}	0.50 ± 0.04^{a}	0.67 ± 0.00^{a}	0.49 ± 0.09^{a}	0.42 ± 0.09^{a}	0.038072 NS

All data on the same row with different superscript are significantly different ($p<0.05$).