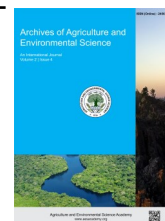This content is available online at AESA

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ORIGINAL RESEARCH ARTICLE

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Evaluation of physicochemical parameters in wastewater from Muhammad Ayuba dam in Kazaure, Jigawa state, Nigeria

S.O. Oladeji [iD]

Polymer Technology Department, Hussaini Adamu Federal Polytechnic, Kazaure, Jigawa State, NIGERIA
E-mail: saheedilori75@gmail.com

ABSTRACT

Evaluation of physicochemical parameters namely alkalinity, biological oxygen demand (BOD), chemical oxygen demand (COD), conductivity, dissolved oxygen (DO), hardness, pH and total dissolved solids (TDS) in the wastewater samples collected from Muhammad Ayuba dam in Kazaure, Nigeria. The study was conducted during harmattan season for a period of three months from November, 2019 – January, 2020. All the parameters were analysed using conventional methods. The results showed their concentrations were in the range of 1.00 – 1.50 mg/L for alkalinity, 3.00 – 3.45 mg/L for BOD, 12.45 – 24.00 mg/L for COD, 745 – 1200 μS/cm for conductivity, 5.50 – 6.30 mg/L for DO, 1.82 – 2.45 mg/L for hardness, 7.20 – 7.90 for pH and 410 – 440 mg/L for TDS. The concentrations of these parameters in the wastewater were observed less than World Health Organization (WHO) tolerance limits with exception of electrical conductivity that was above 1000 μS/cm after four weeks of investigation. This study revealed gradual build-up of various ions in the dam water due to the mixing of contaminated wastewater from the adjacent community. Therefore, the periodical monitoring of different physicochemical parameters of the dam water should put in place as to evaluate their environmental impacts and possible potential risks.

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INTRODUCTION

Dams have been considered as uncontaminated but this water source is under threat from pollution as a result of human life style manifested by the low level of hygiene practised by the developing nation or leaching from solid rocks, industrial and agricultural practices (Ikem *et al.*, 2002). Ascertaining the quality of water consumed, there are physical and chemical properties that must be tested as to know its level of purity or extent of pollution (Kumar *et al.*, 2016). Among these parameters are; alkalinity, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), electrical conductivity, hardness, pH, Total Dissolved Solid (TDS), turbidity and Total Suspended Solid (TSS). Alkalinity is an important measurement in the analysis of certain industrial wastes and seawater (Kumar *et al.*, 2018). It is a measure of the ability of a

given sample of water or effluent to neutralize strong acids to an arbitrarily designated pH or an indicator end point (US-EPA, 2007). Alkalinity in natural water is caused by three major classes of materials; hydroxides (strong bases), carbonates and hydrogen carbonate (salts of weak acids but of strong bases). In all forms of effluents, alkalinity is due to the presence of salts of weak acids such as ethanoic, propanoic, succinic, formic, carbonic and/or the presence of ammonia and hydroxides (Ademoroti, 1996). Biochemical Oxygen Demand (BOD) is the amount of oxygen required by microorganisms for stabilizing biologically decomposable organic matter (carbonaceous) in water under aerobic conditions. The test is used to determine the pollution load of dam, lake and wastewater, the degree of pollution and the efficiency of wastewater treatment methods. BOD can be taken as a measure of the concentration of organic matter present in any kind of water. The greater the decomposable

matter present, the greater the oxygen demand and the greater the BOD value (Ademoroti, 1996). The purpose of this test is to determine the potential of wastewater and other water to deplete the oxygen levels of receiving waters (Brake, 2007). Chemical Oxygen Demand (COD) is a measure of the amount of oxygen required for complete oxidation of organic matter present in a sample of water, wastewater or effluent to carbon (IV) oxide and water (AHDEL, 2004). COD is a rapidly measured parameter to determine the pollution strength of domestic and industrial waste. The chemical oxygen demand is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant (APHA, 1998). For samples from a specific source, COD can be related empirically to BOD, organic carbon or organic matter. Electrical conductivity of portable waters is mainly due to dissolve mineral matter. Free carbon (IV) oxide and ammonia also impart conductivity but their effect is negligible except in water of very low salinity. The electrical conductivity of industrial wastewaters, treatment plant effluents and polluted waters is due to the presence of ionic solutes. The magnitude of the conductivity is a useful indication of the total concentration of the ionic solutes (Sharma *et al.*, 2004). Solutions of most inorganic acids, bases and salts are relatively good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly, if at all (Chapman, 1997).

The amount of oxygen found by determination in a sample of wastewater at the time of collection is the dissolved oxygen (DO). The method of measurement is carried out by the use of Winkler's titration or by the electrometric method using oxygen-detecting electrode. The Winkler's method is very labour intensive, titrants need to be re-standardized monthly and reagent preparation is complicated and subject to error (APHA, 1998). Use of a dissolved oxygen probe is a much quicker and easier way to measure the dissolved oxygen of a sample. The iodometric or Winkler's method is a titrimetric procedure based on the oxidizing property of DO while the membrane electrode procedure is based on the rate of diffusion of molecular oxygen across a membrane. The hardness of water was initially understood to be a measure of the capacity of the water to precipitate soap. The precipitation of soap is chiefly due to the presence of calcium and magnesium ions in water. Precipitate of soap may also be due to other polyvalent metal ions such as aluminium, iron, manganese, zinc and of course hydrogen ions (ATSDR, 2009). Natural waters contain calcium and magnesium only in significant concentrations, so the hardness of such water is defined as a characteristic of water which represents the total concentration of just the calcium and magnesium ions expressed as calcium carbonate. Polluted or wastewaters may contain all the metallic ions mentioned above in significant concentrations. In calculating the hardness of this kind of water, all the metallic ions producing the hardness should be mentioned (APHA, 1998). The value of hardness may range from zero to hundreds of milligrams per litre in terms of calcium carbonate depending upon the source of the water.

pH is the term used to express the intensity of the acid or alkaline of a solution. The pH value can be defined as the logarithm to base ten of the reciprocal of the concentration or pH value is equal to the logarithm of the hydrogen-ion concentration with negative sign. Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically, every phase of water supply and wastewater treatment e.g. acid-base neutralization, water softening, precipitation, coagulation, disinfection and corrosion control, is pH-dependent (APHA, 1998). At a given temperature, the intensity of the acidic or basic character of a solution is indicated by pH or hydrogen ion activity (Metcalf and Peck, 1993). The pH value of a highly dilute solution is approximately the same as the negative common logarithm of the hydrogen ion concentration. Natural waters usually have pH values in the range of 4 to 9, and most are slightly basic because of the presence of bicarbonates and carbonates of the alkali and alkaline earth metals (APHA, 1998). Total Dissolved Solids (TDS) is the term applied to the material residue left in the vessel after evaporation of the sample and its subsequent drying in an oven at a temperature of 103-105 °C. Solids refer to matter suspended or dissolved in water or wastewater. Waters with high dissolved solids generally are of inferior palatability and may induce an unfavourable physiological reaction in the transient consumer (WHO, 2006). For these reasons, a limit of 500 mg dissolved solids per litre is desirable for drinking waters. Highly mineralized waters also are unsuitable for many industrial applications. Water that is high in suspended solids may be esthetical unsatisfactory for such purposes as bathing (SON, 2007). Total solids analysis is important in the control of biological and physical wastewater treatment process and for assessing compliance with regulatory agency wastewater effluent limitations (APHA, 1998).

Long term use of polluted water for cultivation of crops result in the accumulation of ions in agricultural soils, affecting microbial activities as well as their transfer to various crops under cultivation with level of contamination that exceed permissible level. The anthropogenic activities aimed at enhancing food production may also facilitate accumulation of undesirable substances in plants and affect the quality of soil and water resources adversely (Olorunsola *et al.*, 2011). Due to proximity of sampling site to the Kazaure community, there is a need to evaluate the level of contamination in the dam. This study is aimed at ascertaining the extent at which physicochemical parameters in wastewater from Muhammad Ayuba dam in Kazaure accumulate.

MATERIALS AND METHODS

Sampling

Wastewater samples from Muhammad Ayuba dam in Kazaure were obtained for period of three-months (November, 2019 – January, 2020) on weekly basis at point of inlet into the river at five designated points along the dam channels (Figure 1). Sampling period covered the harmattan season in northern, Nigeria. Samples were collected using composite sampling
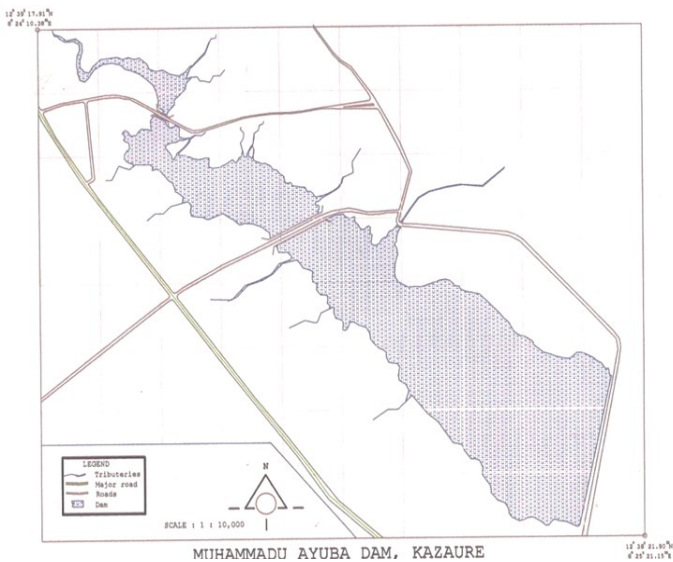
Figure 1. *Muhammad Ayuba dam, Kazaure (Source: Digital from Satellite Image, 2020).*

technique in a polyethylene plastic container that were previously cleaned by washing in non-ionic detergent, rinsed with tap water and soaked in 0.1M HNO_3 for one day and finally rinsed with deionized water before usage (Ademoroti, 1996). During sampling, two separate wastewater samples were collected inside 1000 cm^3 capacity bottles from each of the designated sampling points; the first sample bottle for the determination of physicochemical parameters while second sample was meant for BOD determination. Sample bottles were rinsed with sampled water three times and then filled to the brim at one-meter depth below the sampling points. They were labelled, stored in ice-blocked coolers and transported to the laboratory. Sampled bottles were stored in the refrigerator at about 4 °C prior to the analysis (APHA, 1998).

Determination of alkalinity

HACH Model CO150 meter was used to measure the alkalinity of the samples from Muhammad Ayuba dam. The mode key was pressed until a unit of part per thousand (ppt) displayed. The probe of the meter was inserted into the sample solutions. The tip was immersed and probe was agitated vertically. The measurement was recorded after stabilization.

In measuring the alkalinity of water, the concentration of salt dissolved in the water was considered. Meter is usually kept in gentle motion through the water column while readings were taken. Allow several minutes for the meter to stabilize before another reading (US-EPA, 2001). These are the classes of salinity used for water: Fresh water - less than 5, Brackish water - from 5 to 25 ‰ Saline water - from 25 to 36, Super-saline (or hyper-saline) water - greater than 36 (more saline than seawater) (US-EPA, 2001**).**

Determination of Biochemical Oxygen Demand (BOD)

BODTrak Test Procedure was adopted in the determination of Biological Oxygen Demand (BOD). The method consists of filling the samples in airtight bottles of a specified size and incubating them at specified temperature (typically 20 °C) for 5 days. Using a clean graduated cylinder, sample water was poured into a BODTrak sample bottles. For optimum bacterial growth, BOD nutrient pillow was added to each bottle. Stopcock grease was applied to the seal lip of each bottle and to the top of each seal cup to make it airtight. The seal cap was placed in the neck of each bottle and analysed as described by Ademoroti (1996).

Determination of Chemical Oxygen Demand (COD)

0.4 g of $HgSO_4$ was placed in reflux-flask and 20 cm^3 of wastewater sample was added with about 20 cm^3 of deionized water. A few drops of sulphamic acid (NH_2SO_3H) was added to remove nitrate and nitrite present in the wastewater sample. 10 cm^3 of 1M $k_2Cr_2O_7$ solution and several glass beads previously dried at 600 °C for 1 hour then added. 30 cm^3 of a mixture of Ag_2SO_4 and H_2SO_4 solutions were slowly and gently added in swirling manner. Reflux flask was then connected to the condenser. Blank sample was prepared in the same way and mixtures were refluxed for 2 hours. After completion of reaction, it was cooled; the condenser was washed with deionized water into Erlenmeyer flask and diluted to 150 cm^3. It was then cooled at room temperature and the excess dichromate was titrated with 0.5M $FeSO_4(NH_4)_2SO_4.6H_2O$ (FAS) using ferroin as the indicator (Ademoroti, 1996).

Calculation:

$$COD\ (mg/L)\frac{(V_b - V_a)\ X\ M\ X\ 16000}{Amount\ of\ sample\ (cm^3)}$$

Where V_b= amount of FAS used for blank; V_a= amount of FAS used for sample; M = Molarity of FAS

Conductivity measurement

Conductivity was measured by dipping the conductivity meter into the individual samples and the readings were recorded after normal stabilization of the meter value shown as µS/cm.

Determination of Dissolved Oxygen (DO)

Dissolved Oxygen (DO) was determined on field when sampling by using Membrane-Type Dissolved Oxygen Meter. Meter was switched on and its electrode was connected and dipped into an area where there is continually flowed of the water and allowed to be in the stationary position for 2 minutes before reading was taken on the screen of the meter (US-EPA, 2007).

Determination of total hardness

Total hardness was measured using Calmagite calometric method. Hardness was measured by mixing 199 cm^3 of the wastewater sample with 1.0 cm^3 of calcium and magnesium indicator solution using 1.0 cm^3 measuring dropper. The mixture was inverted several times to mix. Then 1.0 cm^3 of alkali solution for calcium [Ca(OH)$_2$] and magnesium [Mg(OH)$_2$] were added and inverted several times to mix. The samples were them analysed as described by APHA (1998).

Determination of pH

pH was measured using the HANNA pH 210 Microprocessor pH meter. The pH meter was calibrated using the following procedures. Three (3) pH buffers were prepared (4.0, 6.0 and 7.0). The pH electrode was dipped into each of the three buffers prepared and calibration solutions save. The actual pH of the samples was recorded after a stabilized reading was noted on pH meter.

Determination of Total Dissolve Solids (TDS)

50 cm^3 of wastewater samples were placed into pre-weighed dishes and evaporated to dryness at $103 \degree C$ on a steam bath. The evaporated samples were dried in an oven for 1 hour at $105 \degree C$ and cooled in desiccators and record for constant weights. The difference in the weights of Total Solids (W_1) and Total Suspended Solids (W_2) expressed in the same unit gives Total Dissolved Solids (TDS).

Calculation:

$$\text{Total Dissolved Solids} \quad \frac{(W_1 - W_2)}{\text{Sample volume (cm}^3)} X \, 1000$$

W_1 = Weight of total solids + dish; W_2 = Weight of total suspended solids.

RESULTS AND DISCUSSION

The results of physicochemical parameters in wastewater from Muhammad Ayuba dam in Kazaure were presented in bar charts. Figure 2 shows alkalinity levels in wastewater from Muhammad dam in Kazaure. The concentrations determined were in range of 1.00 – 1.50 mg/L. Highest level of 1.50 mg/L were obtained in week 3 and 12 followed by 1.30 mg/L recorded in week 2 and this was closely followed by 1.25 mg/L in week 5 while the least level of 1.00 mg/L was noticed in week 4. Low alkalinity in wastewater during sampling could be attributed to low deposition of carbonate and hydroxide from discharged wastewater into the dam. This low level could also be traced to sampling period (harmattan season) as suggested by Oladeji and Saeed (2018). This could cause decrease in Dissolved Oxygen (DO) in water due to reduction in the intermolecular space available for oxygen according to Goldman and Home (1983). WHO
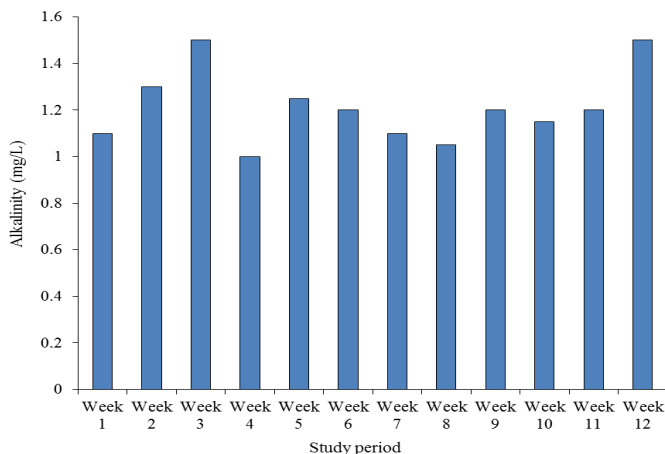
(1985) recommends 600 mg/L as maximum level for alkalinity in water indicating this wastewater is not contaminated with alkaline. Akubugwo *et al.* (2012) reported 209.67 – 335.00 mg/L and Yasmeen *et al.* (2010) reported 570 mg/L as alkalinity levels in wastewater which was higher than this study concentration.

Biochemical Oxygen Demand (BOD) levels in wastewater collected along Muhammad Ayuba dam is presented in Figure 3. The concentrations determined were in the range of 3.00 – 3.45 mg/L. Highest level was found in week 3 (3.45 mg/L) followed by 3.30 mg/L in week 12 while the least concentration of 3.00 mg/L was obtained in weeks 4 and 8. High levels of BOD during sampling could be attributed to the use of chemicals, which were organic or inorganic that are oxygen demand in nature as noticed by Akan *et al.*, (2008). This could also be traced to excessive application of chemicals like herbicides, fungicides, pesticides and fertilizers as BOD is known as measure of the oxygen required by microorganisms while breaking down organic matters. WHO (1985) recommends 50 mg/L as maximum allowable limit for BOD in wastewater before it could be discharged into the steam indicating wastewaters from these sampling sites are not polluted with BOD. Akubugwo *et al.* (2012) reported 2.48 – 20.74 mg/L and Yasmeen *et al.* (2010) reported 362 mg/L as BOD in wastewater which were higher than concentration obtained in this study.

Figure 4 presents Chemical Oxygen Demand (COD) levels in wastewater from Muhammad Ayuba dam. The concentrations determined were in the range of 12.45 – 24.00 mg/L. Week 9 (24.00 mg/L) showed highest level followed by 23.15 mg/L in week 10 and this was closely followed by 23.10 mg/L in week 12. High level of COD during sampling indicates excessive application of chemicals like herbicides, fungicides, pesticides, manure and fertilizers to nourish the soils as observed by Akan *et al.*, (2008) and Oladeji (2017). Results obtained in this study was lower than maximum allowable limits for COD in wastewater before it could be discharged into the stream (1000 mg/L) as set by World Health Organization (WHO, 1985). Akubugwo *et al.* (2012) reported 2.48 – 112.00 mg/L, Yasmeen *et al.* (2010) reported 130 – 170 mg/L and Akan *et al.* (2008) also reported 512.45 – 698.11 mg/L as COD in wastewater which were higher than this study concentration.
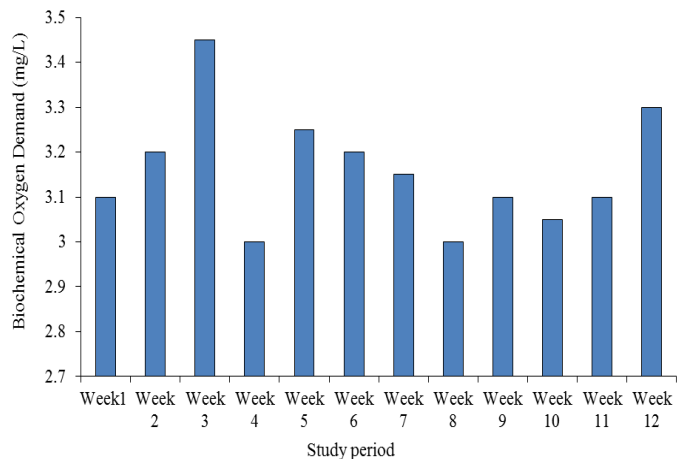

Figure 2. *Mean concentration of alkalinity in wastewater along Muhammad Ayuba dam in Kazaure, Nigeria.*

Figure 3. *Mean concentration of biochemical oxygen demand in wastewater along Muhammad Ayuba dam in Kazaure, Nigeria.*
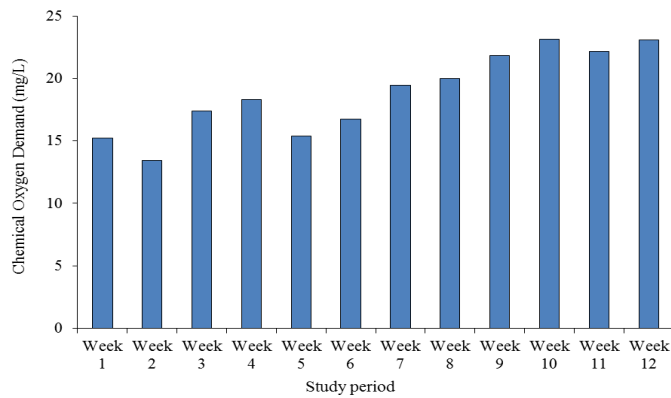
Figure 4. *Mean concentration of chemical oxygen demand in wastewater along Muhammad Ayuba dam in Kazaure, Nigeria.*
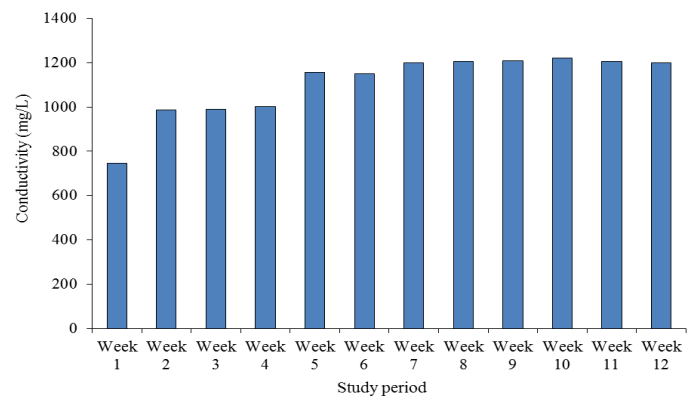

Figure 5. *Mean conductivity in wastewater along Muhammad Ayuba dam in Kazaure, Nigeria.*

Figure 5 presents conductivity levels in wastewater collected along Muhammad Ayuba dam. The conductivity in the range of 745 – 1220 µS/cm was obtained. Highest level was observed in week 10 (1220 µS/cm) followed by 1210 µS/cm in the weeks 9 and 12 and this was closely followed by 1205 µS/cm obtained in week 8 whereas the least conductivity of 745 µS/cm was recorded in week 1. High conductivity could be as a result of excessive use of inorganic chemicals causing elevated levels in wastewater as suggested by Adepelumi *et al*. (2001). WHO recommends 1000 µS/cm as tolerance limits for conductivity in wastewater before it could be discharged through channels into the stream indicating the sampling site conductivity exceeds the limit from week 4 up to 12 weeks of investigation. Earlier, Yasmeen *et al*. (2010) reported 1959 µS/cm and Akan *et al*. (2008) reported 1021.17 – 1534.21 µS/cm as conductivity level in wastewater which was similar to this study values.

 Figure 6 shows Dissolved Oxygen (DO) levels in wastewater from Muhammad Ayuba dam. The concentrations determined were in the range of 5.50 – 6.30 mg/L. Highest level (6.30 mg/L) was found in week 6 followed by 6.25 mg/L in week 5 and this was closely followed by 6.20 mg/L in weeks 7 and 12 whereas the least concentration of 5.50 mg/L was noticed in week 1. Other weeks with high DO were; week 10 (6.10 mg/L) and week 2 (6.00 mg/L) High level of DO noticed is an indication of aquatic life sustenance as WHO stipulates 5 mg/L as adequate limit for aquatic organisms whereas concentration below this level could adversely affect aquatic life. Even, concentration below 2 mg/L may lead to death for most fishes as suggested Chapman (1997). Elevated levels of DO recorded could be attributed to precipitation of nutrients associated with organic matters brought in by domestic and fertilizer application as suggested by Yasmeen *et al*. (2010). High concentration in DO observed could be traced to heavy application of chemicals as dissolved oxygen is a measure of the degree of pollution by organic matters. WHO (1985) sets 9.20 mg/L as maximum limit for DO in wastewater indicating this site is less in dissolved oxygen with International standards limit. Yasmeen *et al*. (2010) reported 6.60 mg/L and Akan *et al*. (2008) reported 6.22 – 8.43 mg/L as Do in wastewater which were similar to results obtained in this study.

Hardness concentrations in wastewater from Muhammad Ayuba dam is presented in Figure 7. The concentrations determined were in the range of 1.82 – 2.45 mg/L. Lowest level of

1.82 mg/L was recorded in week 1 whereas highest concentration of 2.45 mg/L was observed in week 11 followed by 2.40 mg/L in both weeks 10 and 12 and this was closely followed by 2.30 mg/L in week 9. Generally, hardness levels were lower from all sampling sites when compared with WHO tolerance limit of 150 – 500 mg/L and this indicates that the levels of calcium and magnesium ions in wastewater from Muhammad Ayuba dam are insignificant. Yasmeen *et al*., (2010) reported 95 – 155 mg/L as hardness in wastewater from Industrial area which was far above the levels obtained in this present study. Figure 8 presents pH concentrations in wastewater from Muhammad Ayuba dam. The concentrations determined were in the range of 7.20 – 7.90. Highest level of 7.90 was obtained in week 8 followed by 7.80 in week 7 and this was closely followed by 7.70 in week 3 whereas lowest level of 7.20 was recorded in week 12. Alkaline nature of the wastewater could be traced to ash used in neutralizing the soil before new farming system; this might have leached into the dam as suggested by Oladeji and Saeed (2018). And Sodipo *et al*., (2012). WHO recommends pH values range from 6.00 – 9.00 as tolerance limit for wastewater to be discharged into the channels of stream and this indicates the sampling site concentrations are within the limit. Akubugwo *et al*. (2012) reported 6.43 – 7.67 and Yasmeen *et al*. (2010) reported 7.62 as pH values in wastewater which were similar to this study results but less than reported values by Akan *et al*. (2008); 8.94 – 10.34.Total Dissolved Solid (TDS) levels in wastewaters collected along Muhammad dam channels is presented in Figure 9. The concentrations determined were in the range of 410 – 440 mg/L. Highest concentration of 440 mg/L was obtained in week 8 followed by 436 mg/L in weeks 5 and this was closely followed by 435 mg/L in week 7 whereas the least levels of 410 mg/L were recorded in weeks 3, 7 and 11. High level of TDS observed during sampling could be attributed to high level of wastes discharged into Muhammad Ayuba dam from nearby houses within the Kazaure town. The results obtained for TDS is below WHO (1985) standard of 2000 mg/L for the discharged of wastewater into surface water and this indicates Muhammad Ayuba dam is not polluted with TDS. Akubugwo *et al*. (2012) reported 550.00 – 4083.33 mg/L, Yasmeen *et al*. (2010) reported 1396 mg/L and Akan *et al*. (2008) also reported 2210.21 – 2655.93 mg/L as TDS in wastewater which were higher than this study values.
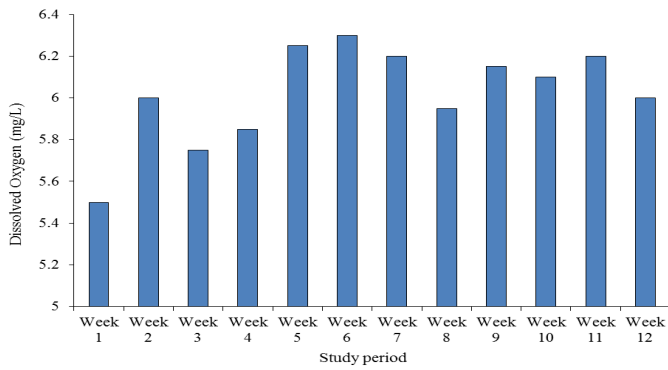
Figure 6. *Mean concentrations of dissolved oxygen in wastewater along Muhammad Ayuba dam in Kazaure, Nigeria.*
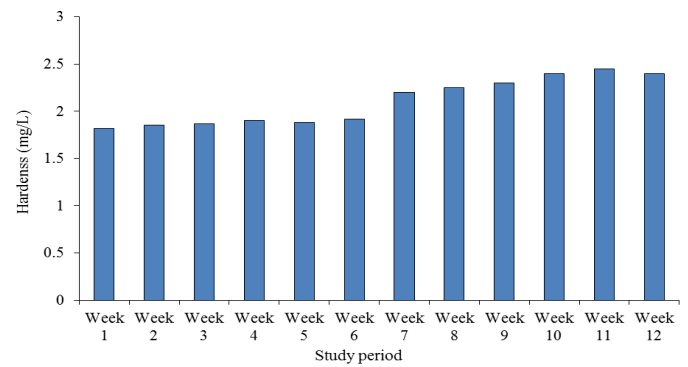

Figure 7. *Mean concentration of hardness in wastewater along Muhammad Ayuba dam in Kazaure, Nigeria.*
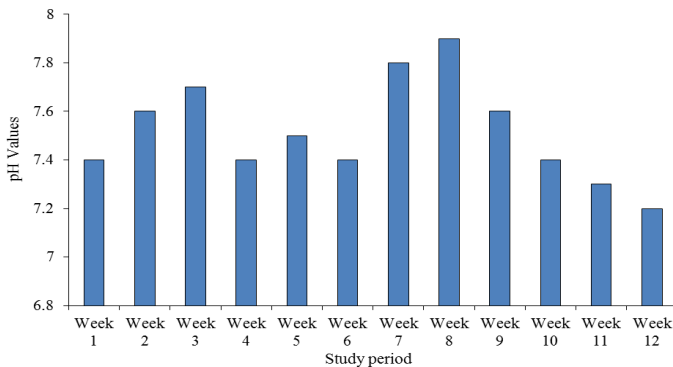

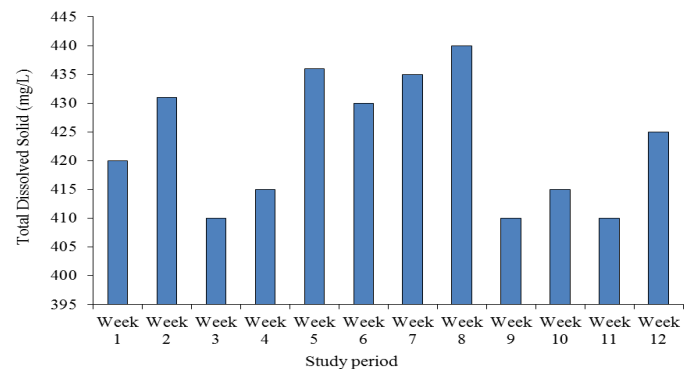**Figure 8.** *Mean pH values in wastewater along Muhammad Ayuba dam in Kazaure, Nigeria.*

Figure 9. *Mean concentrations of total dissolved solid in wastewater along Muhammad Ayuba dam in Kazaure, Nigeria.*

Conclusion

Investigation of physicochemical parameters (alkalinity, BOD, COD, conductivity, DO, hardness, pH and TDS) were determined in wastewater samples collected on harmattan season for three months (November, 2019 – January, 2020) along Muhammad Ayuba dam in Kazaure. The result indicated that alkalinity could be classified as fresh water (1 to 5 %). BOD, COD and DO levels were lower when compared with WHO standards indicating Muhammad Ayuba dam was not much infested with microorganisms. Other physicochemical parameters such as hardness, pH and TDS were also below the threshold limits set by WHO with exception of electrical conductivity that was above the limits of 1000 µS/cm after week 4 upwards. The study revealed gradual build-up of ions in the dam due to contamination from community therefore, there is a need to create comprehensive health education plan to communicate appropriate public health awareness to the farmers and community through the mass media on the implication of unhygienic environment. Periodical monitoring of physicochemical parameters along the dam should put in place as to evaluate their environmental impacts and possible potential risks.

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