Water Quality at Wastewater Discharge Site, Treatment Plant and Distribution Systems

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ORIGINAL RESEARCH

Abstract— Effluent from wastewater treatment plant may be acceptable, however, changes can occur as it travels through distribution systems. This research is aimed at determining the quality of the wastewater sourced from Awba Dam. It also determines the efficacy of the raw water treatment, and its reticulation process. The raw was treated using different unit operations such as sedimentation, Filtration, Coagulation and Chlorination. The treated water was conveyed using pipe distribution system to different storage facility. Water samples were collected at 2 weeks interval using standard procedures of APHA and EPA. Most of the physico-chemical parameters meet International Standards except for Cl,$^-$ Ca^{2+}, $Mg^{2+}$and Na^+ with data ranging from 11.4- 18.1mg/1 for Cl^-, 62-68mg/1 for Ca^{2+}, 6.5-7.8mg,1 for Mg^{2+} and 215-350mg/1 for Na^+ at 6 sampling points. The treatment process used was not effective in the reduction of BOD_5 and Total Aerobic Count of isolated organisms (*Bacillusspp*, *Pseudomonas*) with data ranging from 0.3-1mg/1 for BOD_5 and 1.5×10^3- 2.1×10^5 cfus/ml for Total Aerobic Count. Recommends such as usage of effective treatment methods, disinfection of storage tanks, flushing of lines in the vicinity of break, application of disinfectant and removal of ageing pipes were highlighted.

Keywords— Wastewater, treatment, distribution systems, Awba dam

1 INTRODUCTION

Water is a transparent, colorless and odorless liquid. Of all natural resources, water is of paramount importance in every aspect of life. It is an important resource needed for the sustenance of human life (Ugrina and Milojkovic, 2024). It is undoubtedly an invaluable resource because it is readily available either as polluted or unpolluted. Polluted water is usually generated from various domestic, agricultural, medical and industrial activities. Inadequate functional wastewater treatment plant has also led to a poor supply of portable water for human consumption. Therefore, proper wastewater management is essential in ensuring availability of potable water for consumption, proper hygiene and sanitation. The falls within the purview of Goal 6 in the Sustainable Development Goals (SDGs). Water is a major factor that will influence the state and activities of an environment. Unfortunately, its distribution is not even globally (Bhealerao, 1988; Linsley *et al* 1992; Ugrina and Milojkovic, 2024). In other to achieve the SDG 6, wastewater treatment and reuse becomes undoubtable imperative (UN, 2015). Wastewater treatment is pivotal in achieving responsible water resource management. As global population increases the burden of urbanization grows geometrically leaving the need for effective wastewater treatment increasingly imperative (Silva, 2023). Wastewater effluent reuse from municipal treatment plants is gaining grounds as an alternative sustainable water supply (Akpor and Muchie, 2011).

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Section B- AGRICULTURAL ENGINEERING & RELATED SCIENCES
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Innovations in wastewater treatment has significantly transformed from the process from crude methods to advanced and efficient technologies (Rizzo *et al*., 2019; Onyinyechukwu, 2023). Developing countries face challenges applying these technologies as a result of deficits in finance, infrastructure, regulatory and policy frameworks (Tan and Taeihagh, 2020). Partnerships, training, and specific investments are possible avenues for solving challenges that will be encountered when unlocking the potentials of these treatment process (Sharma *et al*., 2023).

Water in its appropriate quality and quantity is fundamental for the world to experience socio-economic growth. World Water Development in 2009 revealed that by 2030, almost half of the world's population will experience water stress (Pl, 2010). It is becoming hard to access new potable water supply due to high cost and changes with the environment (Earl *et al*., 1988). Pollution is gotten from the word pollare, a Latin word which means defile. Pollution is defined by Environmental Agency of Japan (1987) as an unwanted transformation of the characteristics (physical, biological and chemical) of the environment that will affect life negatively. This has been modified by the Canadian Council of Resource and Water management (1997) which defined pollution as the degradation of the quality of an environment that adversely affects its usage. Pollution can be undesirable and also detrimental to heath in various ways leading to serious cost implications (Adamson, 1971). Pathways for the entry of contaminant into distribution lines according to Sangodoyin, (1993) include survival of treatment process by microorganisms, groundwater contaminations, contaminations from repairs and installations. Depending on the age and condition of the distribution system, wall reaction accounts for most of the losses of disinfectant residual (Hallam *et al.*, 2002). The three systematic processes involved in wastewater treatment are primary which is physico-chemical in nature, secondary which involves biological treatment, and an advanced physical–chemical treatment regarded as the tertiary treatment. The main aim of wastewater treatment process is meeting legal standards for effluent discharge into nearby water bodies or for possible reuse. However, achieving the required water quality is challenging due to emerging contaminants (Ugrina and Milojkovic, 2024). Thus, treated wastewater has numerous benefits which includes; domestic, agricultural and industrial purposes (Zarei, 2020). In previous study, Maremane *et al.* (2024), focused on the quality of wastewater and a suitable model for wastewater recovery. The objectives of this research was to determine the quality of the wastewater sourced from Awba Dam. The research is also aimed at determining the efficacy of the raw water treatment process, and the reliability of the reticulation process.

2.0 MATERIALS AND METHODS

The study is located 8km (5miles) from the centre of Ibadan in southwestern region of Nigeria. It spans an area of 12.24km^2.The study site is characterized by gently undulating relief having elevations ranging between 180m and about 230m. The mean annual rainfall ranges between 788m and 1884m while the mean monthly temperature is 26.6^{0}c. The investigation was done over a 5 month period. Six (6) sampling sites were selected based on considerations such as water source i.e Awba Dam to understand the original level of contaminant present, the treated water to assess the efficiency of the treatment process used, and 4 points of usage to ascertain the extend of recontamination with the distribution system. Awba Dam is a small man-made wastewater reservoir located within latitude 7^0 26' to 7^0 28' North and longitude 3^0 35' and 3^0 54' East having a 6 ha surface area and an average depth of 5.5m. The artificial lake has an altitude above sea level of 185m. The dam is surrounded by vegetation with aquatic microphytes such as pistiastratiotes, Canna indics, Nymphae lotus, Banhima sp. On it edges. The reservoir has fish fauna which includes Hetrotisniloticus, Barbuscallipterus, Clariasgaripinus, Tillapiazillii, Hemichromisfasciatus, Oreochromisniloticus, Sarotherodongalileus, Channaobscura and Alesteslongipinnis (Akin-Oriola, 2002).

3.0 COLLECTION OF SAMPLES

250ml sterile sampling bottles fitted with aluminum foil were used for collection of samples. Six different points A to F where Point B is 300m from Point A, Point C is 300m from Point B, Point D is 300m from Point C, Point E is 300m from Point D, and Point F is 300m from Point E were designed study points. Point A is the Awba dam site, Point B is the location of the treatment plant. Point C to F are locations where residents collect the treated water for domestic purposes. The same number of samples was collected in dark bottles to avoid the penetration of light which may alter the results during test for BOD. The collected samples were carefully transported to the laboratory within 45mins.

3.1 DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS

The concentration of the various metal ions was determined using the Atomic Absorption Spectrometer in which adequate solution of the metallic ions were prepared. The concentration was measured in mgl^{-1}. The concentration of Nitrate and phosphate were determined using the colorimetry method where its nutrient enrichment ability was used as criteria in its determination. The concentration of sulphate was determined using gravimetry and colorimetry method. Where possible, reduction to H_2S, corrotion and toxicity potential used as criteria. The pH value was determined using a pH meter (Henna S358236) which was well calibrated using a buffer solutions. The turbidity of the sample was determined using the Nephelometric method which compares light intensity dispersed with the aid of a standard reference suspension. The conductivity of sample was determined using a conductivity cell. Total Suspended Solids (TSS) was obtained using Gravimetric method. lodometric method was used to determine Biochemical Oxygen Demand (BOD_5). Chemical Oxygen Demand (COD) was calculated by applying the open reflux method and involves the application of potassium dichromate, (APHA, 2017).

3.2 DETERMINATION OF MICROBIOLOGICAL PARAMETERS

The microbiological parameters are total coliform and total aerobic count. The total coliform total aerobic counts were determined using the Membrane Filter Method (EPA, 2005).

3.3 STATISTICAL ANALYSES

The data was based on a completely book design and a one way ANOVA was performed on all parameters measured. The correlation between parameters measured was reported for all treatments.

4.0 RESULT AND DISSUSSION

4.1 WATER QUALITY PARAMETERS FROM SITE TO POINT OF USAGE

Figure 1 shows the total solids content over the period of 3 months with samples taken after every weeks. The total solid is highest in the water sample from the Awba dam but is reduced to about half of its original value after undergoing treatment. There is no significant change point C but increased significantly at points D, E and F. Taste and appearance are usually affected by solids in drinking water.

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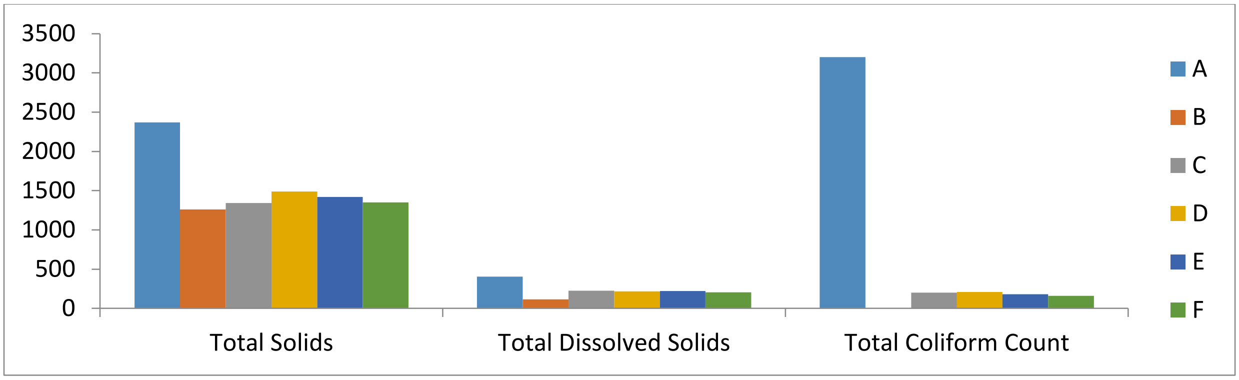

Figure 1: Total solids (mg/l), total dissolved solids (mg/l) and total coliform (cfus/ml) from point A to F

Presence of solids could be attributed to contamination from various sources like surface runoff, ingress or waste water. One way ANOVA test confirms a significant difference in parameters between point A and F at 0.05 level of significance. The total dissolved solid is highest at Awba dam compared to other locations. The dissolved solid reduced by 72% after treatment but increases by 95% at point C. it shows no significant difference in parameters between point A and F at 0.05 level of significance. According to Meride and Ayenew, (2016), high TDS affects people with existing kidney diseases. *Aeromonas* and *pseudomonas*spp are gram negative pathogens that are rod shape and are widespread. They can be found in feaces, soil, water and sewage and multiply easily. However, it's an important parameter for assessing the cleanliness of a water distribution system. This include deterioration in the microbiological quality, which is associated with increase in water temperature, or decreased water flow, and consequent changes in odour, turbidity and taste. The growth of the organism after treatment in the mains and storage reservoir depends on the presence of residual chlorine. Total coliform count of isolated organism was present at points A, C, D, E and highest at point A but absent after treatment.

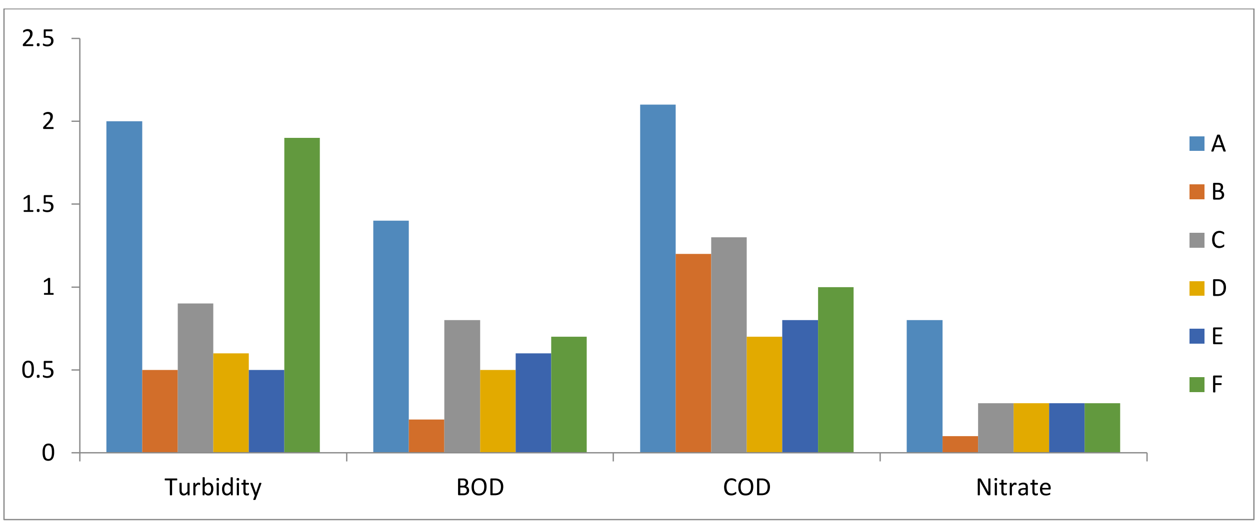

Figure 2: Turbidity (mg/l), BOD (cfus/ml), COD (mg/l) and nitrate (mg/l) from point A to F

Figure 2 shows the variation of turbidity of the samples. The turbidity value is highest at pints A and F. the turbidity is reduced by 75% after treatment and increase by 60% at point C. The turbidity of point A and F shows no significant difference. Turbidity is not necessarily related with presence of faecal material, however, increase in turbidity is usually accompanied with increasing pathogen number which include cysts or oocytes. Presence of BOD_5 shows the contamination of the water by organic matter. The treatment method used was not effective. The BOD_5 is highest at point A which is the raw water.

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After treatment it is reduced by 79%. The BOD_5 increased by 167% at point C, 50% at points D and E, about 150% at point F. Biological treatment is ideal treating raw water high in organic load. An increase in the level of organic matter after treatment shows the potential of heterotrophic bacteria regrowth. One way ANOVA test confirms a significant difference in parameters between point A and F at 0.05 level of significance. The values of COD of same sample collected at different time vary significantly. The COD is highest at point A but reduced slightly during the first 6 weeks after treatment and reduced significantly by 90% during the last weeks. The COD at point C shows no significant change but reduced by 48% at points D and E and by 16% at point F. COD increased by 250% at point C, with no significant change at points E and F. The one way ANOVA test confirms a significant difference in parameters between points A and F at 0.05 level of significance. The concentration of nitrate ion is highest at point A which is the raw water. It reduced by about 87% after treatment and increased by about 50% at points C, D, E and F. Water samples with high nitrate levels is unsafe for drinking. This can induce "blue baby" syndrome (methaemoglobinaemia) in infants. Nitrate on its own is not directly toxic but becomes a health hazard when converted to nitrite. Nitrite reacts with the red blood cell (hemoglobin) causing "blue baby" syndrome. According to Mandilonga *et al*., (2022), present of nitrate could be linked to recontamination with agricultural waste. One way ANOVA test confirms a significant difference in parameters between points A and F at 0.05 level of significance.

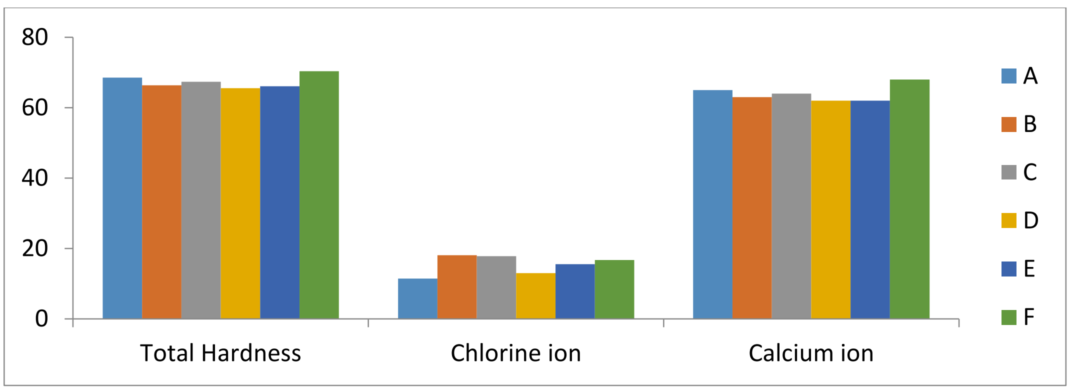

Figure 3: Total hardness (mg/l), chlorine ion (mg/l) and calcium ion (mg/l) from point A to F

Figure 3 shows the variation between Total hardness of samples. There was no significant change in the total hardness of the sample taken from various points. Hard water neutralizes soap lathering, blocks the free flow of water in pipes and drastically impede boiler efficiency due to scale formation. Therefore, as hardness rises its effect increases but according to Meride and Ayenew, (2016), calcium also helps in strengthening the bone and reduces cardiovascular diseases. One way ANOVA test confirms a significant difference in parameters between point A and F at 0.05 level of significance. The concentration of chlorine ion is lowest at point A but highest at point B. The concentration at C and F shows little change but was reduced by 28% and 8% respectively for point D and E. One way ANOVA test confirms a significant difference in parameters between point A and F at 0.05 level of significance. There is no significant change from points A to F. Total hardness rich in calcium are beneficial and very palatable. One way ANOVA test confirms a significant difference in parameters between points A and F at 0.05 level of significance.

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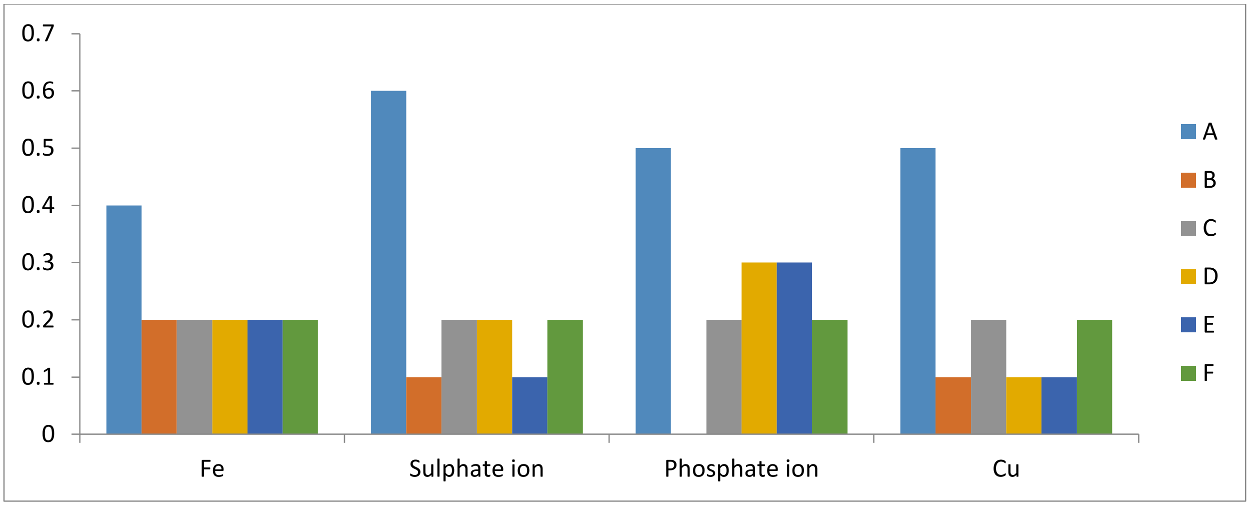

Figure 4: Iron (mg/l), sulphate ion (mg/l), phosphate ion (mg/l) and Cu (mg/l) from point A to F

Figure 4 shows the concentration of Fe^{2+} ion was highest at point A but was reduced by 33% after undergoing treatment. The concentration of Fe^{2+} at points C, E and F shows no significant change when compared with the concentration after treatment but reduces by about 50% at point D. Drinking water rich in iron may pose different health challenges but the effect might not be significant due to its quantity. According to Mandilonga *et al*., (2022), consumption of Iron can cause hypertension and blood vessel blockage. However, there exist problems of aesthetics where soluble ferrous (Fe^{2+}) iron is oxidized to insoluble ferric (Fe^{3+}), resulting in changes in colour or turbidity. One way ANOVA test confirms a significant difference in parameters between point A and F at 0.05 level of significance. The concentration of sulphate ion is highest at point A which is the waste water and reduces by about 84% after treatment and remains unchanged at point E but increased by 50% at point D. An increase of between 40-50% was observed between point C and F. Polluted waters with zero oxygen level, sulphide is formed from sulphate resulting in noxious odours. Concrete sewer pipes are attacked by sulphates in water flowing through. One way ANOVA test confirms a significant difference in parameters between point A and F at 0.05 level of significance. Phosphate ion is the highest at point A but there is a total removal of the phosphate ion after treatment. Traces of similar concentration of phosphate ion were noticed at points C, D, E and F as can be observed between point A and F at 0.05 level of significance. The concentration of Copper ion is highest at point A and reduces by about 80% after treatment. The concentration of copper ion shows no significant change at points C, D E but increases by about 50% at a point F. Corrosion is caused by contamination of water with copper from the plumbing material. Exposure to water contaminated with copper in excess leads to gastrointestinal distress, kidney or liver damage. Astringent tastes in galvanized tanks are caused levels of copper above 1 mg/l. The variation of sulphate ion in samples. One way ANOVA test confirms a significant difference in parameters between point A and F at 0.05 level of significance.

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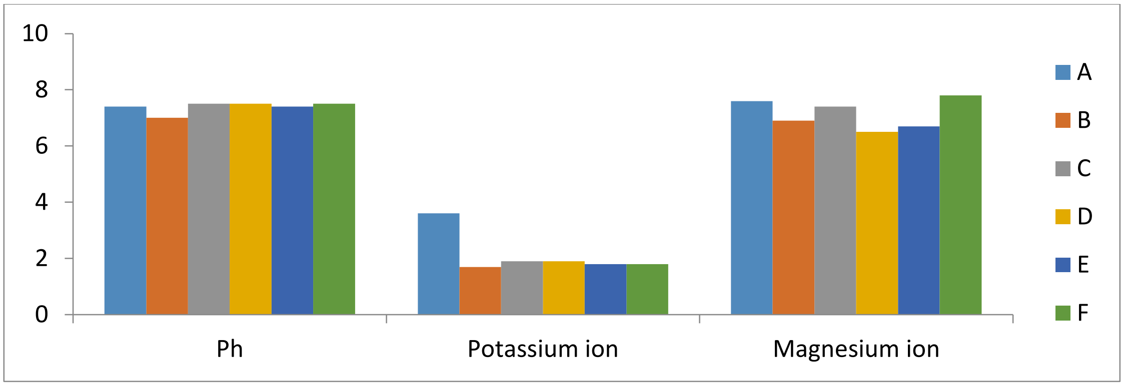

Figure 5: pH, potassium ion (mg/l) and magnesium ion (mg/l) from point A to F

Figure 5 shows the variation of pH of over a period of 3 months. The pH value shows no significant change at the individual points. The pH value reduced slightly after treatment but increased at point C to F. Solubility of nutrients like phosphate and nitrites increases as pH reduces. Low pH encourages the corrosion of pipes. One ANOVA test confirms a significant difference in parameters between point A and F at 0.05 level of significance. The concentration of potassium ion is the highest at a point A which is the raw water sample; it reduces by about 53% after treatment. Potassium ion shows no significant change at point C, D, E and F. Potassium is usually fixed in soil and it's a major constituent in fertilizer formulations hardly leaches out. There are no implications of toxicity. One way ANOVA test confirms a significant difference in parameters between point A and F at 0.05 level of significance. The Magnesium ion concentration shows no significant change at points A, B, C and F but reduces slightly at points D and E. One way ANOVA test confirms difference in parameters between point A and F at 0.05 level of significance.

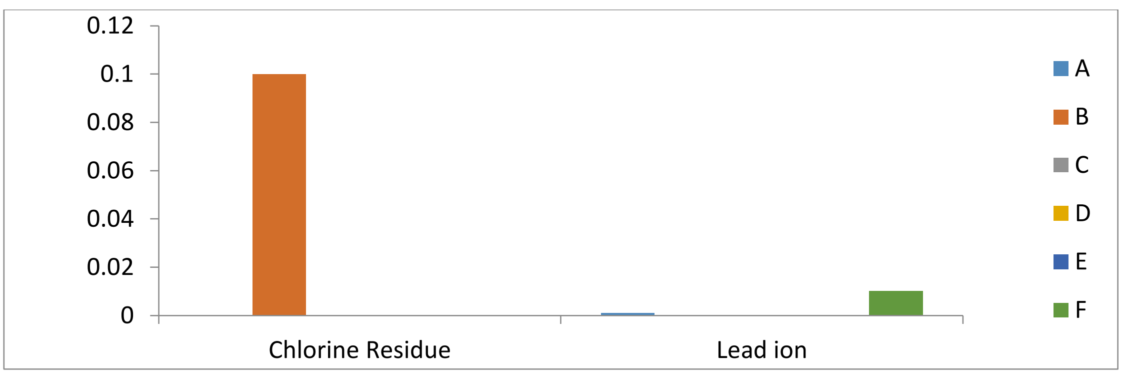

Figure 6: Chlorine residue (mg/l) and lead ion (mg/l) from point A to F

Figure 6 show the results and chart of chlorine residues of samples at different points. Chlorine residue can only be found at point B which is the treated water. Water distributed with no chlorine residues makes recontamination by microorganism possible. Chlorination of water which had been polluted severely affects odour and taste which could be from trace organic compounds emanating from decomposing algal growths giving rise to problems in taste and odour, rendering the water unsafe for drinking. Organic (humic) colouring matter react with chlorine to produce byproducts like trihalomethanes, which are undesirable. One way ANOVA test confirms a significant difference in parameters between points A and F at 0.05 level of significance. Lead ion can only be noticed significantly at point A which is the raw water but traces of it was found occasionally at point F. Lead can affect human health adversely. This could be by interfering with the red blood cell chemistry. It also

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impedes physical and mental development of infants, and increases blood pressure of adults. Lead has the potential to cause cancer from a lifetime exposure. One way ANOVA test confirms a significant difference in parameters between points A and F at 0.05 level of significance.

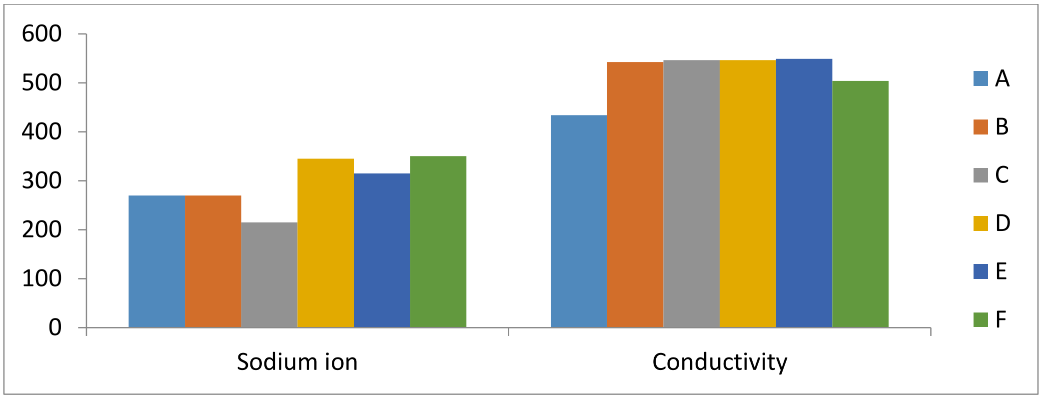

Figure 7: Sodium ion (mg/l) and conductivity (mg/l) from point A to F

Figure 7 indicates that sodium ion concentration is high at points D, E and F but shows no significant change after treatment. It is observed to be lowest at point C. The major intake of sodium is through common salt which is an important dietary requirement. Excessive consumption could lead to hypertension. The variation of sodium ion concentration of samples. One way ANOVA test confirms a significant difference in parameters between points A to F at 0.05 level of significance. The conductivity of samples is lowest at point A but increases significantly at point B which is the treated water. There is no significant change observed in the conductivity at points C, D, E and F. Conductivity of water relates to the possibility of conducting electric current due to its ionic content. Conductivity to water analyst is of little interest but it indicates the range of dissolved solids present. Conductivity mainly reflects the mineral content. One way ANOVA test confirms a significant difference in parameters between points A and F at 0.05 level of significance.

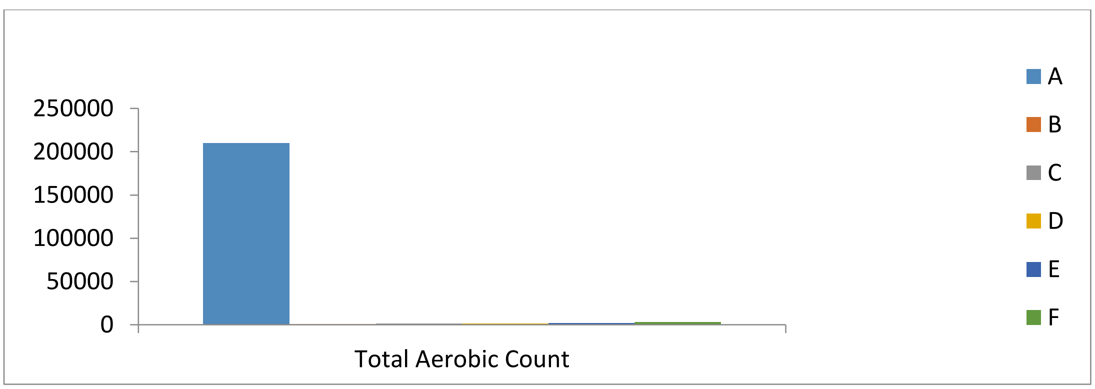

Figure 8: Total aerobic count (mm/g) from point A to F

Figure 8 shows that total aerobic count of isolated organisms occurred in all the points A was the highest. The aerobic spore formers (*Bacillus spp*) was used to access the waters bacteria content. This parameter does not represent all bacteria but they are of little sanitary significance used to assess the water treatment processes efficiency. High count may lead to spoilage of the water sample.

4.3 DISCUSSION

The significance of water quality analysis in water distribution is its evident impact upon human health. Most of the physic-chemical parameters meet

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international standards except for chloride, calcium, magnesium and sodium. Low mineral content water (Chloride, Calcium, Magnesium, and Sodium) could possess unpleasant taste and decreased thirst quenching ability which with time the consumer would adapt. Although this does not pose a health challenge, but should be considered. Thirst quenching ability of water affect the level of consumption thereby causing persons to seek alternative sources. Water with poor mineral content negatively affect the homeostasis mechanisms of the body. This is because the water used for treatment is the stream mixed a little bit of waste from the university which as a result of domestic activities. The results show that the treated water lacks enough chlorine residues which led to the recontamination of the treated water by microorganisms. The distribution system must be secure against post-treatment recontamination with the provision of adequate disinfectant. Parameters such as BOD_5 and Total Aerobic Count of isolated organisms do not meet international standards. This shows that the treatment method used (physical unit operations such as Sedimentation and Filtration, and chemical unit operation such as Coagulation and Chlorination) was not effective because a reduction in the concentration of BOD_5 and Total Aerobic Count of isolated organisms was obtained. However this result does not meet international standard and a high level of recontamination was observed during distribution to the user. The result also shows that microbiological treatment with respect to total coliform count of isolated organisms was effective at the treatment of plant but recontamination occurred during distribution and storage to the user. There are still a high number of bacteria aerobic counts after treatment. This shows that the treatment method used in the microbiological treatment of the raw water cannot be said to the effective i.e. the integrity of the distribution process is not guaranteed.

5.0 CONCLUSION

The possibility of water containing undesirable constituents led to the establishment of guidelines and regulations. Permissible limits of substances were established globally to ensure that the quality of water consumed is safe. The assessments of the physic-chemical and microbiological qualities of the water supply to the Hall of Residence have shown that standards recommended by the WHO for potable water are not met in some cases. The continual consumption of this water will definitely pose serious health threat to the user. Therefore, there is need for the usage of an effective treatment method, distribution and storage facilities. In addition, the user must be educated on the need to boil such water thoroughly before drinking.

5.1 RECOMMENDATION

The status report presented in this work indicates that poor treatment methods, loss of integrity of the distribution and storage facilities have caused gross contamination of water supplied to the Hall of Residence. As part of the millennium development goals of providing portable water to the citizens of Nigeria, the University is advised to embark on the following plan;

I. Effective chemical and microbiological treatment method should be used in the treatment of the raw water.
II. Keep contaminated or poorly treated water out of the distribution system
III. Residual disinfection will provide protection against recontamination thus chlorine residue of at least 0.5mg/l in the treated water should be released to the distribution system.
IV. Disinfection of water tanks after inspection, construction, or maintenance.
V. Flush broken lines and disinfectant contaminated components.
VI. Pipes should be adequately separated from sewers.
VII. Ageing pipes should be removed and new ones installed and disinfected.

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