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Research Article
Portable Water Analysis from Different Factories Within Port Harcourt Metropolis, Rivers State, Nigeria

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Abstract

Background and Objectives: This study was carried out to compare the effects of different potable water treatment options from four different bottle water factories within Port Harcourt metropolis, Rivers state, Nigeria. **Materials and Methods:** Standard methods of APHA were used to assess the water treatment process steps within these factories. These were taken in the following sequence: (1) Sand and granular activated carbon (GAC) filtration, (2) Reverse osmosis, (3) Ozone disinfection and (4) UV disinfection (finished product). **Results:** The pH of the finished products across the four factories ranged from 5.15 -7.90 with Kent water having the lowest pH which did not meet WHO standard. The electrical conductivity had values between16.85-124.80 μS cm^{-1}, total dissolved solids values ranged from 9.01-66.14 mg L^{-1}. The total suspended solids and turbidity values ranged between <1.00 and <0.01 mg L^{-1}, the total alkalinity ranged between 3.40-32.00 mg L^{-1} and across the four water factories, respectively. Total hardness had values between 8.00-23.00 mg L^{-1}. Anions and Sulphate values ranged between 1.04 and 5.49, Nitrate was <0.02 across the factories. Chloride ranged from 3.33-15.50, Phosphate ranged between <0.001 and 2.89, calcium ranged from 1.98-4.50 while magnesium values were between 0.81 and 2.2. Heavy metals such as iron as well as other heavy metals like Cd, Cr, Hg, Pb and Mn were all <0.001. **Conclusion:** The four water factories all gave adequate treatment to the groundwater except for Kent table water whose pH value was below the expected limit but other parameters are within WHO standard. There is therefore; the need to consistently monitor and proper education on adequate treatment of potable water from these sources for safety and portability by regulatory bodies.

Key words: Physical, chemical, parameter, groundwater, water treatment

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Water is one of the basic necessities of life and good drinking water is of paramount importance to health. Good quality drinking water must be wholesome and palatable for consumption devoid of diseases and infection without any adverse effect on health[1,2]. The availability of a reliable and clean supply of water is one of the most important determinants of our health. Historically, improvements in human health have been related to improvements in our water supply system i.e., source protection, water treatment, operation and maintenance, quality monitoring from source to tap[3]. In Nigeria, most of the populace depends on groundwater as a major source of potable water, this is because of its availability throughout the year. In Rivers state, Port Harcourt is a fast growing area faced with increasing demand for water resources due to high population growth rate, rapid expansion and industrialization. Because of the level of eutrophication in the rivers and creeks, the entire population depends on groundwater sources for their domestic and industrial needs[4]. Several contaminants inhabit groundwater quality as a result of the activities, practices and treatments leading to alterations in the quality and parameters that will affect their physico-chemical characteristics[5-7]. A number of groundwater quality investigations have been carried out though these are usually on local scales and consider a limited number of chemical constituents[8]. The chemical, physical and bacterial characteristics of groundwater determine its usefulness for various purposes. Soluble minerals and salts are normally found in groundwater; these occur in association with geological materials at higher concentrations relative to surface water[9]. Chemical analysis of groundwater includes the determination of the concentrations of inorganic constituent. The analysis also includes measurement of pH and specific electrical conductance, temperature, colour, turbidity, odour and taste. Different potable water factories employ different methods in the treatment of groundwater. This investigation compares the various water treatment processes carried out within factories to ascertain the best option for groundwater sources.

MATERIALS AND METHODS

Kent table water, Rivoli table water (Choba Road), Fressi table water (Rumuokwuta) and Elioha table water in Emuoha (all in Rivers state) are the water factories selected for this study. The permission of the factory managers and quality control managers enabled us collect bottle water samples for the study.

Samples and sampling technique: The factory's treatment processes were monitored and about 16 bottle water samples were collected for the study using sterile containers of about 500 mL. Raw water from borehole, water after pre-treatment i.e., sand and granular activated carbon filtration and finished product i.e., water after reverse osmosis, disinfection with ozone and ultraviolet (Uv) light were the bottle water samples selected for the study. The water treatment process steps were taken in the following sequence: (1) Sand and granular activated carbon (GAC) filtration, (2) Reverse osmosis, (3) Ozone disinfection and (4) UV disinfection (finished product). The pH and total dissolved solids content of the samples were immediately measured on the spot using the pH and TDS meters in the factory. The samples were transported in an ice-packed cooler to the microbiology laboratory at the University of Port Harcourt for immediate analysis.

Physico-chemical analysis

Determination of physico-chemical parameters and heavy metals: The standard method for the examination of water and waste water[10] was adopted for the study.

Nitrate determination: Measurements of nitrate content was carried out with the Lamotte smart-3-spectrophotometer using the cadmium reduction method. About 25 mL of the sample was poured into the sample cell and nitrate reagent powder added. After 5 min, the concentration of nitrate was taken at a wavelength of 400 nm.

Sulphate determination: The sulphate content of the water samples were determined by the turbidimetric method. Sulphate ion was precipitated in an acid medium with barium chloride to form barium sulphate crystals of uniform sizes. Light absorbance of the barium sulphate suspension was measured by spectrophotometer at 450 nm.

Calcium determination: Calcium hardness was determined by EDTA titrimetric method. About 25 mL of the sample was diluted to 50 mL with distilled water added 1.0 mL NaOH and 2 g of indicator mixture. The mixture was titrated against the EDTA with a colour change from pink-purple.

Phosphate determination: Total phosphate is determined by the ascorbic acid method in a reaction in which ammonium molybdate and potassium antimonyl tartrate reacts in an acid medium with orthophosphate to form a heteropoly acid phosphomolybdic acid. This is intensely reduced to a coloured blue molybdenum by ascorbic acid. The colour intensity is measured with a spectrophotometer at 690 nm.

Alkalinity determination: Alkalinity concentration was determined by titrimetric method. To about 10 mL of the water sample was added 3 drops of bromocresol green indicator and was titrated against 0.01 N solution of tetraoxosulphate (VI) acid. The titre value was used to calculate the alkalinity concentration in mg L^{-1} using the relationship:

$$\text{Total alkalinity (mg L}^{-1}) = \frac{V \times N \times 1000}{\text{Vol. of sample}}$$

Where:

V = Titre value

N = Normality of tetraoxosulphate (VI) acid

1000 = Constant

Turbidity determination: This was carried out on the same day using Horiba U-53 multi-parameter water quality meter.

Total suspended solids: This was determined by filtering about 100 mL of the sample through a dried and pre-weighed Millipore filter paper using a vacuum filtration apparatus. The filter paper was then dried at 105°C to constant weight. The difference in weight of the filter paper represents the total suspended solids.

Chloride determination: The chloride content of the samples was determined using the Mohr's method. This is based on the reaction of silver with chloride ion using potassium chromate as indicator. The reaction results in the precipitation of silver chloride quantitatively before a red colour of silver chromate is formed.

Total hardness determination: Total hardness was determined by measuring 10 mL of the buffer solution added to 10 mL of the water sample. About 2 drops of Erichrome indicator was added and the sample titrated against EDTA (ethylene diamine tetraacetic acid) with a colour change from red to blue:

$$\text{Total hardness (mg L}^{-1}) = \frac{\text{Titre value} \times 0.4 \times 2.5 \times 1000}{\text{Vol. of sample}}$$

pH determination: A pH meter was used to check the pH of the water samples. The pH meter was calibrated in the laboratory using buffer solution and subsequently standardized. Hydrogen ion concentrations were carried out using an automatic digital pH meter (Model Mettle Delta-340, England).

Conductivity/total dissolved solids determination: A JENWAY conductivity meter (Model, 4010) was used to check the electrical conductivity of the water samples. The conductivity meter was calibrated in the laboratory using standard conductivity solutions and subsequently standardized. Electrical conductivity can be effectively converted to total dissolved solid by the following relationship:

$$\text{TDS (mg L}^{-1}) = \text{EC } (\mu\text{S cm}^{-1} \text{ at } 25°\text{C}) \times 0.6$$

where, TDS is total dissolved salt or solid and EC is electrical conductivity.

Heavy metal concentrations (lead, iron, mercury, cadmium, chromium, magnesium, sodium, potassium and manganese) were detected with Biotech. Eng. Mgt. Co., Ltd., (Model Phoenix, 986, UK), -AA-8390 atomic absorption spectrophotometer (AAS). Mercury was analyzed by cold vapour method (APHA 3112-B) while the remaining metals were analyzed by direct air-acetylene flame method (APHA 3111-B).

RESULTS

The physico-chemical analysis of water samples from the water factories are represented. Figure 1-12 shows the effect of each treatment step on different physico-chemical parameters.

Effect of Kent table water treatment: The effect of Kent treatment processes from the raw water to finished products on pH, total alkalinity and total hardness, conductivity, TDS, calcium and sulphate, chloride and sodium were presented in Fig. 1-3. The treatment steps start from raw water through sand and carbon filtration, reverse osmosis and ozone/Uv treatment. The pH, total alkalinity and total hardness were measured in the raw water and water after each treatment stage. The pH and total hardness of the bottle water ranged from 4.77-4.96 and 6.00-8.60. These values did not show much variation across the treatment stages. There was a decrease in

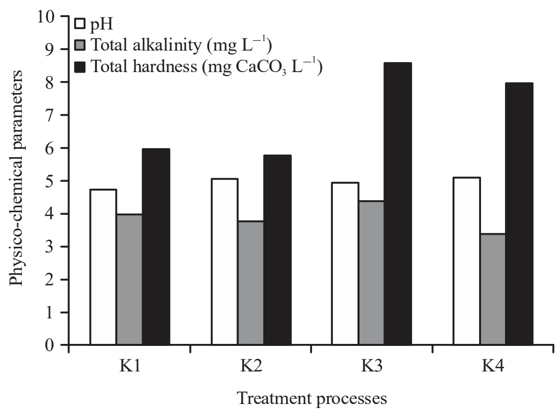

Fig. 1: Effect of Kent treatment processes on pH, total alkalinity and total hardness
K1:Raw water, K2: Water after sand and carbon filtration, K3: Water after reverse osmosis treatment, K4: Water after treatment with ozone and ultraviolet light

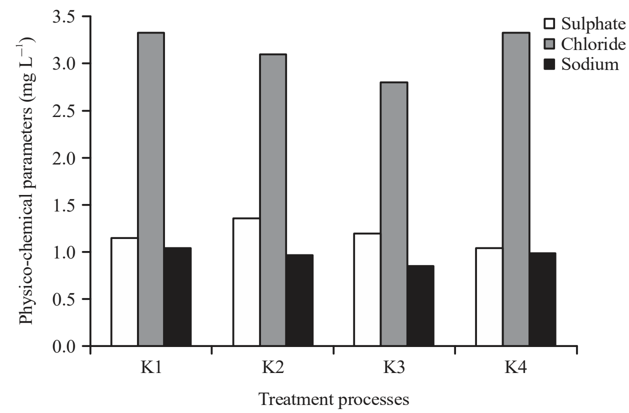

Fig. 3: Effect of Kent water treatment processes on sulphate, chloride and sodium
K1:Raw water, K2: Water after sand and carbon filtration, K3: Water after reverse osmosis treatment, K4: Water after treatment with ozone and ultraviolet light

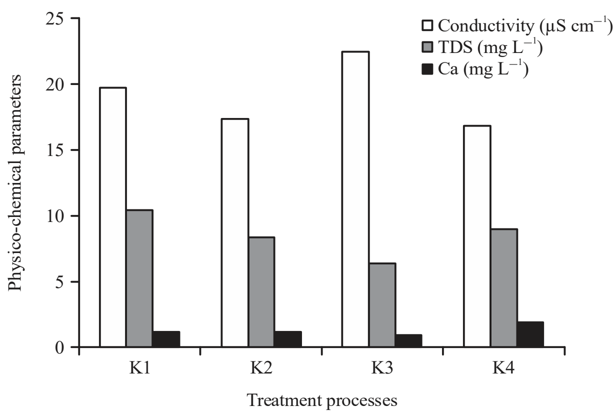

Fig. 2: Effect of Kent water treatment processes on conductivity, TDS and calcium
K1:Raw water, K2: Water after sand and carbon filtration, K3: Water after reverse osmosis treatment, K4: Water after treatment with ozone and ultraviolet light

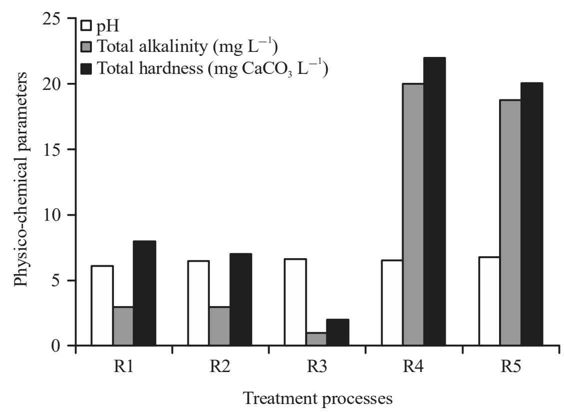

Fig. 4: Effect of Rivoli water treatment processes on pH, total alkalinity and total hardness
R1: Raw water, R2: Water after sand and carbon filtration, R3: Water after reverse osmosis treatment, R4: Water after treatment with ozone, R5: Water after treatment with ultraviolet light

the values of these parameters after sand and carbon filtration and subsequently increased after treatment with ozone. The pH of the water was increases with the addition of calcite (calcium carbonate) after passage through reverse osmosis just before treatment with ozone. The water is passed through some micro-filters before the final treatment with ultraviolet rays hence the reduction in the values of these parameters after treatments. In Fig. 2, the TDS and calcium contents decreased from the raw water after passage through sand and carbon and reverse osmosis. There was an increase after the finished product. The conductivity of the water sample increased after reverse osmosis treatment and decreased slightly after treatment with ozone and ultraviolet rays. These changes reflect the calcium carbonate dozed into the water after reverse osmosis treatment and microfiltration of the bottle water during ozonation and ultraviolet treatment. Figure 3 depicts the values of sulphate, sodium and chloride in the raw water and after it has been subjected to a purification process. The values showed minimal variation across each treatment steps but the chloride content of the water increased after treatment with ozone showing a possibility of added chlorine though the residual chlorine content was not measured. Kent water recorded the lowest values for pH, total hardness, total alkalinity, conductivity, TDS, sodium and calcium compared to the other 3 factories.

Effect of Rivoli water treatment: The effects of Rivoli treatment processes on pH, total alkalinity, total hardness,

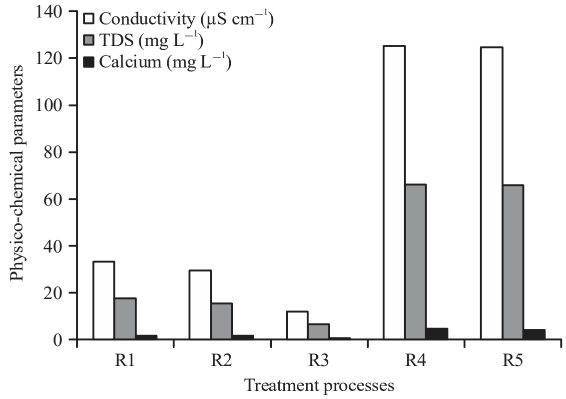

Fig. 5: Effect of Rivoli water treatment processes on conductivity, total dissolved solids and calcium

R1: Raw water, R2: Water after sand and carbon filtration, R3: Water after reverse osmosis treatment, R4: Water after treatment with ozone, R5: Water after treatment with ultraviolet light

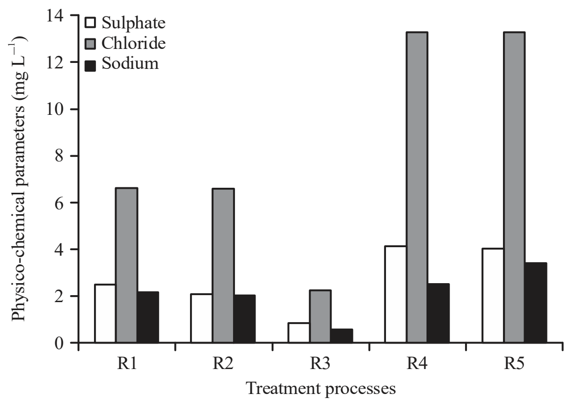

Fig. 6: Effect of Rivoli water treatment processes on sulphate, chloride and sodium

R1: Raw water, R2: Water after sand and carbon filtration, R3: Water after reverse osmosis treatment, R4: Water after treatment with ozone, R5: Water after treatment with ultraviolet light

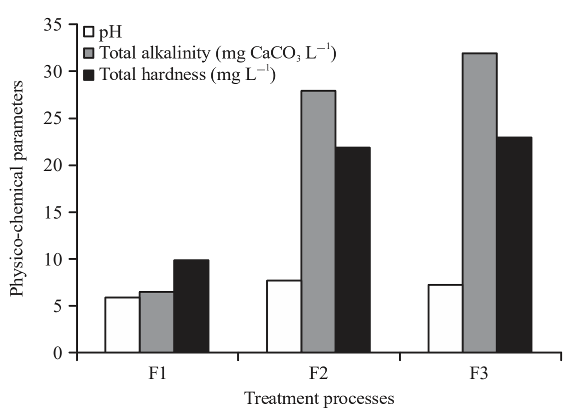

Fig. 7: Effect of Fressi water treatment processes on pH, total alkalinity and total hardness

F1: Raw water, F2: Water after sand and carbon filtration, F3: Water after ozone/ultraviolet treatment

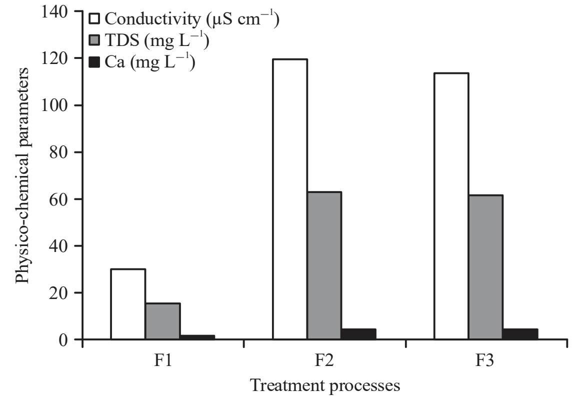

Fig. 8: Effect of Fressi water treatment processes on conductivity, TDS and calcium

F1: Raw water, F2: Water after sand and carbon filtration, F3: Water after ozone/ultraviolet treatment

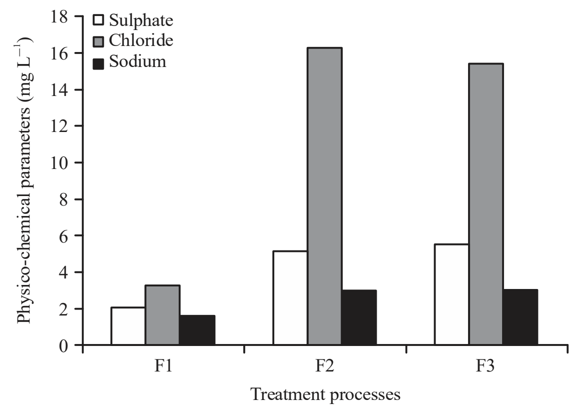

Fig. 9: Effect of Fressi water treatment processes on sulphate, chloride and sodium

F1: Raw water, F2: Water after sand and carbon filtration, F3: Water after ozone/ultraviolet treatment

conductivity, TDS, calcium and sulphate, chloride, sodium, respectively from the raw water to finished products (Fig. 4-6). The pH did not show much variation from raw water to finished products however, the values obtained for the finished product is within the expected range (6.5-8.5). The total hardness and total alkalinity reduced from raw water through reverse osmosis but showed appreciable increase after treatment with ozone and ultraviolet rays. Treatment with reverse osmosis greatly reduced the amount of solutes in the water. According to the quality control personnel, calcium carbonate is dozed into the water after passing through reverse osmosis (i.e., before treatment with ozone). The increase in the values obtained for total hardness and total alkalinity reflects the amount of calcium carbonate dozed into the water after reverse osmosis. Conductivity, TDS and calcium contents decreased after reverse osmosis and

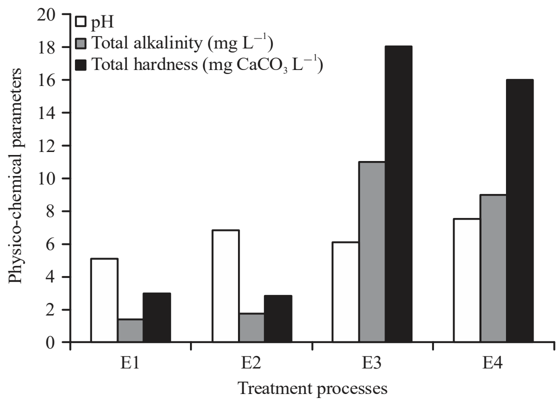

Fig. 10: Effect of Elioha water treatment processes on pH, alkalinity and total hardness
E1: Raw water, E2: Water after sand and carbon filtration, E3: Water after reverse osmosis treatment, E4: Water after treatment with ozone/ultraviolet light

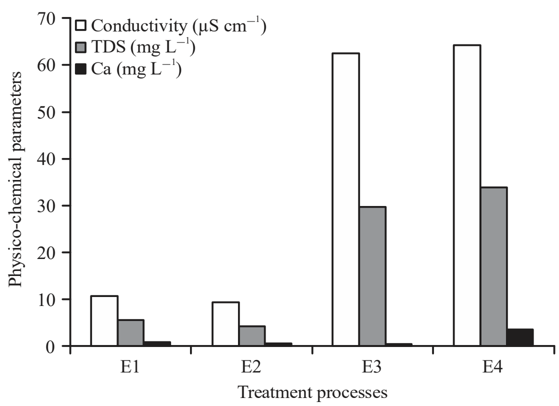

Fig. 11: Effect of Elioha water treatment processes on conductivity, TDS and calcium
E1: Raw water, E2: Water after sand and carbon filtration, E3: Water after reverse osmosis treatment, E4: Water after treatment with ozone/ultraviolet light

increased tremendously after treatment with ozone. However, there was a slight decrease after treatment with UV light due to further microfiltration of the water samples. Rivoli table water recorded the highest values for conductivity, TDS, calcium and sodium when compared with other 3 factories. The values ranged from 11.81-125.10, 6.61-66.30, 0.39-4.5 and 0.5-3.46, respectively. Despite these observed changes, the values obtained are still within the expected ranges.

Effect of Fressi table water treatment: Reverse osmosis treatment was absent in the Fressi water treatment processes. The effects of Fressi water treatments on pH, total alkalinity, total hardness, conductivity, TDS, calcium and sulphate, chloride and sodium, respectively (Fig. 7-9). The conductivity,

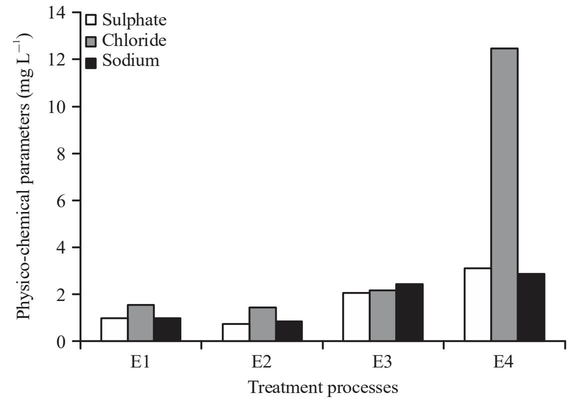

Fig. 12: Effect of Elioha water treatment processes on sulphate, chloride and sodium
E1: Raw water, E2: Water after sand and carbon filtration, E3: Water after reverse osmosis treatment, E4: Water after treatment with ozone/ultraviolet light

TDS and sodium, chloride contents increased after treatment with sand and carbon filtration and decreased slightly after ozone/ultraviolet ray treatment, respectively. While the total alkalinity, total hardness and sulphate, increased appreciably throughout the treatment processes. The factory uses sodium hypochlorite solution to wash their PET bottles before filling with the finished product. This practice might have been responsible for the visible increase in sodium and chloride content of the water samples. Calcium carbonate might also have been dozed into the water even though the quality control manager did not admit to introducing any chemical during the water treatment. Fressi table water recorded the highest values in total hardness, total alkalinity, sulphate and chloride compared to the other 3 factories. However, these values are still within the expected range.

Effect of Elioha water treatment: The treatment processes on pH, total alkalinity, total hardness, conductivity, TDS, calcium and sulphate, chloride, sodium, respectively from the raw water to finished products from Elioha water are represented in Fig. 10-12. These parameters were measured in the raw water and water after each treatment stage through sand and carbon filtration, reverse osmosis and Ozone/Ultraviolet treatment. The pH was ranged from 5.10-7.54. pH did not show much variation from raw water to finished products however, the value obtained for the finished product is within the expected range (6.5-8.5). The total hardness and total alkalinity increased after passage through sand and carbon and reverse osmosis and decreased slightly after treatment with ozone/ultraviolet. Treatment with reverse osmosis greatly reduces the amount of solutes in the water. According to the quality control personnel, calcium carbonate is dozed into the water after passing through reverse osmosis (i.e., before treatment with ozone. In Fig. 11, conductivity and TDS contents increased all through the treatments steps. Calcium recorded the highest value in the finished product. In Fig. 12, the sulphate and chloride showed increased values throughout the treatment steps. For the sodium, its content decreased in the finished product. However, the slight decrease in some these parameters after treatment with ozone/UV light is due to further microfiltration of the water samples. Despite these observed changes, the values obtained are still within the expected ranges.

DISCUSSION

The water samples from Rivoli, Elioha and Fressi treatment processes showed pH values ranged from 5.10-7.54, while the pH of Kent table water ranged from 4.77-5.15. Thus the samples from the other three companies measured pH values within the limit[11] of 6.5-8.5. Kent table water did not measure up to standard. The pH of Kent was lowest after treatment with ozone and UV. The hydrogen ion concentration of water samples lower than 4 produces a sour taste, above 8.5 bitter tastes but the pH result of the groundwater is slightly acidic. Agbalagba *et al.*[12] reported that acidic water results in clogging of distribution pipes with high biofilm causing objectionable taste as a result of the corrosion of iron and steel materials. Such water source when used for cooking and other activities might stain clothes, rust cooking utensils and affect human health. Similar results were also reported within the Niger Delta region of Nigeria with the exception of Kent table water[13]. The WHO limit for turbidity of all the water samples is 5 NTU and the samples analyzed ranged between 0-2 NTU and falls within the WHO limit. Gyamfi *et al.*[1] reported that water turbidity is as result of the presence of particulate matter such as clay or silt, finely divided organic matter, plankton or other microscopic organisms. A reduction in water turbidity results to less cloudiness in the sample and present it as a clear transparent solution. But water samples with high turbidity harbour diverse kinds of chemicals producing undesirable tastes and odours which may be harmful to health. The total alkalinity value of the samples was below WHO limit (1.00 ± 1.00-32.00 ± 3.10 mg L^{-1}) except the Fressi table water and thus needs to be treated before production[12]. The International Standard for Drinking Water was categorized into three: soft water with a total hardness of $CaCO_3$<50 mg L^{-1}, moderately hard water between 50-150 mg L^{-1} and hard water hardness above 150 mg L^{-1}. From our investigations, all the water samples analyzed were had a total hardness greater than 50 mg L^{-1} and thus is regarded as soft water[7,14-16]. The concentration of $CaCO_3$ in the sample needs to be increased because soft water is normally associated with heart disease[12]. Sulphate values were below the permissible limit by WHO and this corresponds with the findings of Agbalagba *et al.*[12] but does not correspond with that of Nwala *et al.*[13] and Bolaji and Tse[17] within the Niger Delta region. The WHO limit for electrical conductivity (EC) showed values within the permissible limit of 1000 µS cm^{-1} signified its suitability for activities at home and in the industries. For any portable water, the total dissolve solid (TDS) values are generally below 500 mg L^{-1}, thereby falls within WHO permissible limit[12]. One of the major anions in water is chlorine, known for the maintenance of acid-base balance, ranged between (1.45 ± 0.40-16.00 ± 1.00 mg L^{-1}) but in excess may cause edema[12,13,18]. Nitrate is a very important mineral in water and when they are not present might result in methemoglobinemia (blue water body) in children and death in farm animals. From the investigations, nitrate values were very low, ranged between <0.02-0.08 mg L^{-1} and is below the WHO recommended limit[12,13] of 10.0 mg L^{-1}. The presence of Na^+, K^+, Ca^{2+} and Mg^{2+} in any water samples eliminates faecal and total coliforms as a result the sample is fit for consumption. This is because it is assumed that the microorganisms that were meant to have caused some serious diseases such as cholera, typhoid fever, botulism, leptospirosis, legionellosis, giardiasis, hepatitis A, dysentery amongst others. These microorganisms are regarded as biological pollutants and if found in water is detrimental to the health of the populace[19]. The values ranged from 0.35 to 4.50 ± 0.09 for Ca^{2+} and 0.16 to 2.36 ± 0.05 for Mg^{2+} and correspond with the report of Bolaji and Tse[17] and Agbalagba *et al.*[12]. Heavy metal concentration found within the samples was below WHO permissible limit, their absence signifies that the portability of the sample is good, acceptable, wholesome and fit for consumption.

CONCLUSION

Finished products with pH less than 6.50 should be treated to raise to an acceptable standard limit of between 6.50-8.50. This will result in routine monitoring and inspections of these factories to limit pollution and ascertain that their portability is good, fit for consumption, acceptable, wholesome and palatable. Frequent flushing of the borehole is highly recommended since acidic groundwater is aggressive and corrodes pipes, accumulates biofilms and thereby reduces the quality of water. The byproducts from these factories which are being discharged into water bodies should be treated to avoid death of plants and aquatic organisms. This study discovered that the different treatments carried out within factories significantly reduced the chemical composition of the water which might be detrimental and are beneficial for health without any side effects.

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