International Journal of Environmental Chemistry
2025, Vol. 9, No. 2, pp. 72-89
https://doi.org/10.11648/j.ijec.20250902.15

Research Article

Assessment of the Quality of Sachet (Packaged) Water Consumed in Kono District, Sierra Leone

Sahr Emmanuel Lebbie[1, *], David Conteh[1], Sahr Gbeinda[2], Fatmata Gegbe[3]

[1]Chemistry Department, Njala University, Moyamba, Sierra Leone
[2]Public Health Department, University of Makeni, Makeni, Sierra Leone
[3]Nursing Department, Njala University, Bo, Sierra Leone

Abstract

A significant priority in developing countries, including Sierra Leone, is access to clean and safe drinking water, which is largely unavailable. Packaged water, often sold in sachets, is increasingly filling this gap, particularly in urban areas. However, public health concerns persist due to a lack of stringent regulations and monitoring to ensure compliance with water quality standards. This study evaluated the physical, chemical, and biological quality of sachet drinking water from five companies in Kono District, Sierra Leone. Standard laboratory analyses were performed on water samples, and consumer perceptions were gathered via questionnaires. While the physical and chemical properties of the sachet water brands generally complied with Sierra Leone Ministry of Water Resources (MWR-SL) and World Health Organization (WHO) standards, bacteriological quality, specifically aerobic plate counts, exceeded these standards in most samples. Only Good Family Pure Water company met all MWR-SL and WHO permissible standards. Consumer preference analysis revealed Good Family Pure Water was favored by 54.5% of respondents, followed by Janneh Spring Water (15%), Diamond Pure Water (12%), Hali Fresh Water (10.5%), and Nimi Hills Spring Water (8%). Good Family Pure Water also ranked highest in perceived quality, aligning with laboratory results. The study recommended that sachet water companies in Sierra Leone adhere strictly to hygiene standards to prevent product contamination, ensuring public safety and a healthier population, thereby reducing the need for resource allocation towards disease control.

Keywords

Water Quality, Physico-Chemical Property, Sachet Water Company, WHO Standard, Drinking Water, Perception Survey, Kono District

1. Introduction

One of the main priorities of people living in developing countries is that of obtaining clean and safe drinking water. In Asia and Africa, most people in rural areas depend on ground and surface water for sustenance [17]. Eight hundred and forty four (844) million people, just 1 in 10 of the global population in 2015 were still living without access even to basic drinking water services [23], only 71% were using safely managed drinking water service [23], and sadly 58% of 159 million people who were still collecting drinking water directly from surface water lived in sub-Saharan Africa [24] and the situa-

*Corresponding author: sahremmanuellebbie17@gmail.com (Sahr Emmanuel Lebbie)

Received: 6 September 2025; **Accepted:** 16 September 2025; **Published:** 9 October 2025

tion is still the same 1 in 3 people do not have access to safe drinking water [32]. Also, it is estimated that 1.2 billion people around the world or one fifth of world's population lack access to safe water either because of unavailability or inadequacy [16, 21, 3, 2]. This could probably be due to increase in human and animal population [10]. Water as a vital nutrient, our organs need it for their normal functioning and to keep the water balance in our body [11]. On average, Water accounts 60% of the body weight for an adult human being [9]. The average water intake of 2 liters per day for adults is needed as commonly used by the World Health Organization and regulators in computing drinking water guidelines and standards [29].

Sierra Leone Water Company is charged with the responsibility of providing potable water for urban cities within the country, since half of the population in the country don't have access to safe drinking water. According to Sierra Leone Water Company on average, only 35% of rural residence have access to safe drinking water [32]. The source of water used to produce sachet/packaged water is mainly obtained from wells, ground water, spring and pipe-borne water. There is high probability of contamination of these sources by leachate, waste disposal and surface runoff. Before sachet water industry was introduced.

In Kono district, eastern Sierra Leone. Before 2002, the hand tie packaged water had been the major means of acquiring water potable drinking water, since most people consider it potable and clean. Although the process was very easy to perform where the producer usually fetched water from bore holes, streams, or hand pump and filtered using white linen cloth and the polythene plastic, air pumped through the mouth into the polythene bag which forces the polythene to open, and water poured into and tied using both hands. This method is considered very unhygienic and could be a mode of transmission of diseases such as cholera and typhoid. Since the implementation of sachet water by Grafton Water Company in Sierra Leone between the years of 2005–2006 [17], that enhances and upgraded the quality and standards of drinking water in Kono district. These developments and improvement have attracted a lot of entrepreneurs to embark on the production of sachet/packaged water. Packaged water is mainly bottled, and sachet water is rapidly growing as a major source of drinking water in the Kono district. The introduction of packaged or sachet water to consumers was to provide safe, hygienic, and affordable instant drinking water to the public [1]. Due to the growing demand in market for sachet water, this has attracted a lot of suppliers.

A comprehensive mapping exercise was carried out in 2012 by the Ministry of Energy and Water Resources [12] in Kono district, the report states that, some 930 functional water sources were recorded and 305 sources were in need of repair and, the report further indicated that most of the water sources available during the time of the research were contaminated, and not potable for drinking. This situation forced the people of Koidu community to seek for an alternative means of acquiring clean and potable water Moreover, the health and safety of consumers of sachet drinking water in Kono district is a public health concern. The limited access to certified water quality data makes the industry questionable to consumers as to quality control and assurance and the increase in demand for sachet/packaged water has also been attributed to changes in fashion towards the consumption of designing water, increased concerns about the safety of municipal water and an increased influx of people into major urban areas with a dire need for good drinking water. It is perceived to be safe and clean by most people. However, most of these sachet water producers have no hygienic knowledge and are producing these sachet water in an unhygienic environment with little or no monitoring mechanism. and don't work with the recommendation guidelines set by WHO [30]. Each year 1.8 million people die from diarrhoea diseases, and 90% of these deaths are of children under five [35]. Many drinking water contaminants including various chemicals, physical, microbiological and radiological are known to be hazardous to health [28, 4]. It is important that the water meant for human consumption be free of disease-causing germs and toxic chemicals that pose a threat to public health [22].

Sierra Leone, like many others developing countries still struggles to provide safe and potable water for its urban population, which Kono district, is no exception, During the dry season most of the boreholes, and local wells dried up leaving the inhabitant of that community in water stress. Most people had to look for alternative means of acquiring water, either by using swamp water or water from the rivers for both drinking and other domestic work. Most people were relieved when sachet water was introduced into the commercial market of Kono district. However, recent study has indicated that most of the sachet water produced in Kono district doesn't march with the WHO recommended guidelines set out. The need for potable water is of great public health significance because of waterborne infections. It is also reported that some unscrupulous producers just bag and seal pipe-borne or well water without any form of treatment [14, 6]. Several studies on the microbial quality of bottled and sachet/packaged water have reported violations of international quality standards [15]. Rutz D. [20] reported that sachet water vending machines may not be free of microorganisms, because bacteria like *Streptococcus faecalis*, have been isolated from sachet water producing machines. Current trends, however, unfortunately, suggest that sachet/packaged water could be a route of transmission of enteric pathogens which raises issues of the problem of its purity and health concern [15, 10, 8, 5]. This brings us to the question of whether these sachet waters are therefore well treated and handled with WHO standards and guidelines for drinking water quality [25, 26, 33, 34]. The World Health Organization estimated that up to 80% of all sickness and diseases in the world are caused by inadequate sanitation, polluted water or unavailability of water [27].

This research therefore, examines the physicochemical and bacteriological parameters of sachet water produced in Kono district and the specific objectives of this research are as follows; To determine the physical and chemical characteristics (physicochemical parameter) of some sachet drinking water, to identify the microbiological quantity of some selected sachet water brands sold in Kono and the perception survey of the consumers of the selected brands of sachet water in the Kono district municipality.

2. Data and Method

2.1. Study Area

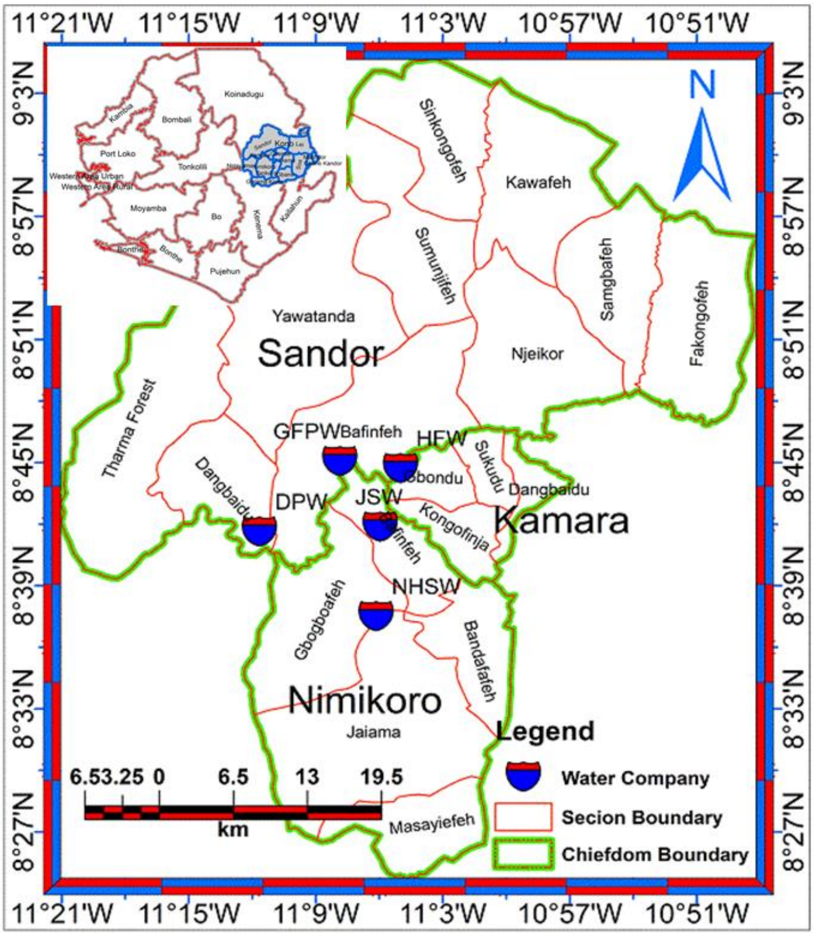


Figure 1. *A map of Sierra Leone (inset) depicting Kono District and its chiefdoms in grey and then a map of the study area (main plate) depicting the chiefdoms covered (green boundary), the sections in the chiefdoms (red boundary) and the locations of the sachet water companies (red-blue badge-like shapes).*

Kono District shared by fourteen chiefdoms; in the eastern region of Sierra Leone and approximately 360 km east of Freetown the capital city. The chiefdoms lie between two physical regions. A ridge of plateaux dominates the landscape in this northeastern section of the chiefdom called Tankoro. Diamond mining takes place in Koidu city within the main city centre in Tankoro which lies at Latitudes 8°56′03″ North, Longitude 11°12′07″ West. These places which previously offered viable sites for residents and dwellings are now being actively mined using the open cast and underground mining method and thereby destroying their potential for residential development. The Tankoro chiefdom carries the grater area of the mining operation. The temperature ranges from 17℃ in the Harmattan season over 40℃ during the dries. Rainfalls over 2500 mm per annum spreading over eight months. The inhabitants of this area were initially upland farmers and to lesser extent permanent crops such as oil palm, coffee, and cocoa are grown as well. The people also practice also three religions, namely, Christianity, Islam and African tradition religions. According to the recent survey by statistical services and projections from the 2015 population and housing census, the population of the study area is 500,342 [19].

Kono district is the largest diamond producer in Sierra

Leone, gold and alluvial diamond mining are important economic activities of the residents. Although agriculture has not been the main source of livelihood of the majority (less than 30% rely on farming) [7], in some areas rice, cassava, corn, and beans are grown and small groups of residents grow coffee, cacao and palm oil. The diamond mining industry has attracted many people from other parts of the country to settle down in Kono, making the district a cosmopolitan one. Diamonds were first discovered in the area during the 1930s, residents work as employees for the large foreign owned mining companies. 12% of the population are in poorest category and 30% fall into the medium poor category [7]. Gini coefficient [17] is 0.27 which is on the lower side (scale from 0–1).

2.2. Research Design

This study aims to identify all sachet water that is produced in Kono District. And, to assess the quality of the most popular brands of sachet water consumed by people living within the Kono district municipality through physical, chemical and microbiological characteristic of the selected five most popular brands sachet water. Thus, a design to tender quality control measures should be adopted to achieve quality standards of sachet (packaged) water.

2.3. Sampling and Sampling Method

The five brands of packaged water with the rate of consumption were collected within the study area at retailers' point and consumers' household. Three (3) sachet water were extracted from each bundle of the five brands of packaged water and placed in a cooler with an iceberg and then transported directly from Kono district to the Freetown and then the laboratory (Sierra Leone Standards Bureau) for analysis. The samples in the cooler were iced because we want to maintain a specific required temperature. These samples were then subjected to chemical, physical and bacteriological analyses.

Table 1. Selected Sachet Water companies in Kono District.

Sample or Brand Name	Volume (ml)
Good Family Pure Water	250
Hali Fresh Water	250
Diamond Pure Water	250
Nimi Hills Spring Water	250
Janneh Spring Water	250

2.4. Personal and Focused Group Discussion

A one-to-one personal interview was conducted using a well-structured questionnaire to obtain very accurate and vital information about the selected brands of sachet water. These interviews helped the Researcher to know more about the water regarding their views and ideas and enhance the entire processes to be successful. Moreover, cross sections of people were engaged in serious and long discussions in relation to the selected brands of sachet water especially in the production site and other small groups. Different respondents contribute their views in terms of taste, odor colour and even the price at which they purchase these brands of water. This method really helped the Researcher and made work much easier.

2.5. Data Analysis

A total number of 11 parameters including both the physiochemical and biological parameters; [pH, Turbidity, TDS, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), and Electrical Conductivity (EC)] whilst the biological parameters are; Coliform Bacteria, Total Coliform Bacteria, Faecal Coliform Bacteria and Non-Faecal Coliform Bacteria] have been analyzed from each one of the 5 samples in a triplicate, which means that a total number of 165 laboratory tests were undertaken. The pH, TDS, Turbidity and EC values were read directly from the appropriate kits/equipment, while others by undertaking titration (Ca^{2+} and Mg^{2+}) and the biological parameters [Coliform Bacteria, Total Coliform Bacteria, Faecal Coliform Bacteria and Non-Faecal Coliform Bacteria] were kept for 18–24 hours before analysis were done on them. Only the average of replications of tests for a single parameter has been considered for comparison whereas all results have been used in statistical analysis for further interpretation. Laboratory test results have been compared among brands and WHO drinking water quality standards, the statistical analysis was undertaken to test the significance of the analyzed treatments.

The conductivity was determined by using the Digital Conductivity Meter in the Laboratory. The meter was first calibrated by setting the temperature knob at 25 ℃, and the function knob was turned to check and adjust the display value to 1.00 by turning the screw at the back of the instrument. The probe was then dipped into a 0.1 M potassium chloride (KCl) solution, and the reading was adjusted to 1.408 with the cell constant knob. The function knob was then turned to conduct and the value displayed was recorded. 10 ml of each sample was poured into a clean beaker. The probe was dipped into each sample one after the other. After it was removed from one sample it was rinsed with distilled water and then wiped thoroughly with tissue before it was dipped into another sample. The fixed or steady value displayed on the screen has been recorded as the conductivity value. The process was repeated three times for each sample to ensure accuracy and consistency.

Turbidity was determined in the Laboratory using the HACH 2100Q turbidimeter measured in Nephelometer turbidity unit (NTU). The instrument was calibrated first using standards such as 20, 60, 80, 100 and 10 (verification standards) respectively. After calibration, a portion of each sample is poured into their specific labelled clean oiled turbidity vial after the sample had been shaken several times. The turbidity vial was filled to the white line, gently inverted several times and then placed into the turbidimeter. The final readings were obtained after 60 seconds, and the average reading was obtained. This process was repeated three times to ensure accuracy and consistency.

The Total dissolved solids were determined using the Conductivity/TDS meter. A probe was inserted into the sample to determine. About 10 ml of water sample was poured into a clean glass beaker. The probe was then immersed into the sample and stirred to ensure uniform mixture. The value obtained from the reading is recorded in mg/L. This process is repeated about three times for accuracy.

A digital pH meter was used to determine the pH of water samples. The pH meter is first calibrated (verified) to ensure that it is in good working condition. About 10 ml of water sample was poured into a clean glass beaker and the probe inserted in it. The selector of the pH meter was switched on the pH value was read and recorded instantly. The procedure was repeated twice for all other samples, and the probe was rinsed with distilled water after each experiment for all the samples.

Total Hardness, 100 ml of the water sample was poured into a 250 ml conical flask. Two drops of Erichrome black T-indicator were added. The content in the conical flask was titrated against a standard EDTA solution (0.02 M) until the contents of the flask changed from wine-red to blue at the end point. Titration was repeated until a consistent titre was obtained. The value of the average titre was recorded.

Total Hardness (TH) in milligrams per litre as $CaCO_3$ is given by the formula

$$\mathrm{TH} = \frac{A\ X\ B \times 1000}{mL} \tag{1}$$

where A = Ml EDTA used, and B = mg $CaCO_3$ which is equivalent to 1 mL EDTA titrant.

Calcium Hardness, 100ml of the water sample was poured into a 250 ml conical flask. Then 2 ml aqueous NaOH was added to the contents of the flask, followed by the addition of about 0.05M murexide indicator. The content in the conical flask was titrated against 0.02 M EDTA to the end point which is indicated by pink colouration. Titration was repeated until a consistent titre was obtained.

Calcium Hardness (CaH) in milligrams per litre as $CaCO_3$ is given by the formula

$$\mathrm{CaH} = \frac{Ve \times 1000}{Vs} \tag{2}$$

where Ve is volume of EDTA solution used for analysis; Vs is volume of sample used for analysis

The magnesium hardness of a sample was calculated as the difference between the total harness and calcium hardness values obtained from analysis of the sample since we know that the total hardness in water is due to the presence of Ca^{2+} and Mg^{2+} ions in water therefore the magnesium hardness in water can be determined from the difference between the total hardness and calcium hardness.

Magnesium hardness (MgH) in millimetres per litres is given by the formula

$$\mathrm{MgH} = TH - CaH \tag{3}$$

where TH is total hardness; and CaH is calcium hardness.

Faecal/Total coliform, the membrane filter technique was used to investigate the bacteriological status of samples collected. Growth absorbent pads were dispensed with pad dispenser into twelve (12) sterile petri-dishes and labelled 'FC' (from 1–5) for faecal Coliforms testing and TC (from 1–5) for Total Coliforms test. Two sterile petri-dishes were set as blanks for both faecal and total Coliforms. The pads were saturated or soaked with Membrane Lauryl Sulphate Broth (MLSB). Forceps were sterilized using a flame and allowed to cool, after which, methanol was smeared on them. Using these forceps, sterile membrane filters were placed onto the bronze membrane support and covered with the filtration funnel. 10 ml of water sample was poured into the filter funnel and a hand vacuum pump connected to the filtration unit base was pumped to suck the water sample through the membrane. Sterile forceps were used to remove the membrane filter from the bronze membrane support after the water has been filtered. The membrane filter was then placed on the pad in the petri-dish which had been saturated or soaked with the MLSB media.

This was repeated for the various water samples. The lids for the petri-dish were replaced immediately. The membrane filter was placed on top of the soaked pads, and the petri-dishes were placed in a petri-dish rack. When the last sample had been processed, a resuscitation period of about 30 minutes was observed before incubating. For the incubation of faecal Coliforms, a temperature of 44℃ was selected on the incubator and 37℃ for that of total Coliforms. The racks were placed into the incubator for 24 hours for observation and counting of colonies. Yellow colonies indicated that faecal Coliforms were present and pink colonies indicated total Coliforms. Counting was done with the aid of a hand lens and the estimated bacteria present per 100 ml of water and calculated was done as shown below:

The bacterial colonies were then counted using magnifying lens or colony counter when necessary and expressed as numbers per 100mls of water.

$$TCC = \frac{NC \times VW}{100} \tag{4}$$

where TCC is total coliform count; VC is number of colonies; and VW is volume of water.

The non-faecal Coliforms growth was calculated by using the formula below.

$$NFC = TCG - FCG \tag{5}$$

where NFC is non-faecal coliform; TCG total coliform growth; and FCG is faecal coliform growth.

3. Results and Discussions

Table 2. *Values of physicochemical and biological parameters from five-brands of sachet water.*

No	Parameter	Unit	DPW	HFW	JSW	NHSW	GFPW	WHO Standards
1	pH	---	7.3	7.0	7.0	7.7	7.1	6.5–8.5
2	Conductivity	µS/cm	59.8	31.4	51.3	28.2	28.7	< 450
3	Turbidity	NTU	0.41	0.19	1.48	0.46	0.32	< 5.0
4	Calcium hardness	mg/L	12.0	4.0	8.0	8.0	8.0	< 250
5	Magnesium hardness	mg/L	8.0	4.0	8.0	6.0	4.0	< 250
6	Total Dissolved Solids	mg/L	48.5	24.9	41.1	22.7	22.9	1000.0
7	Total hardness	mg/L	20.0	8.0	16.0	14.0	12.0	500.0
8	Aerobic plate count at 37 ℃	cfu/ml	1.0×10^3	9.1×10^2	8.3×10^2	9.7×10^2	1.5×10	20 (max)
9	Aerobic plate count at 22 ℃	cfu/ml	5.3×10^2	2.0×10	1.4×10^2	4.7×10^2	1.6×10	100 (max)
10	Coliform count at 37 ℃	cfu/ml	<1	< 1	<1	<1	< 1	00.0 (not detected)
11	E. coli count at 44 ℃	cfu/ml	<1	< 1	<1	<1	< 1	00.0 (not detected)

Also note Good Family Pure Water (GFPW), Nimi Hills Spring Water (NHSW), Diamond Pure Water (DPW), Hali Fresh Water (HFW) and Janneh Spring Water (JSW).

3.1. Physicochemical Parameters

pH Value

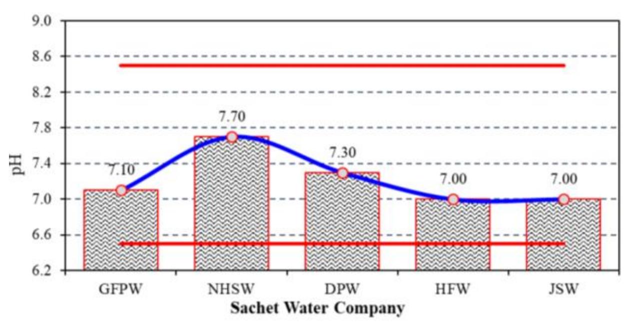


Figure 2. *Plot of measured pH of water samples collected.*

Figure 2 above, the pH values for all the five brands of sachet drinking water fall within the WHO standards (6.5–8.5) of drinking water which indicate that there is no corrosive characteristics in the five brands of sachet water. Majority of the brands provide similar value of pH and although all the brands of sachet water produced in Kono District do not provide pH content label on the sachet, all brands are within WHO permissible guideline limit hence, all brands had satisfactory quality in terms of pH.

Conductivity Value

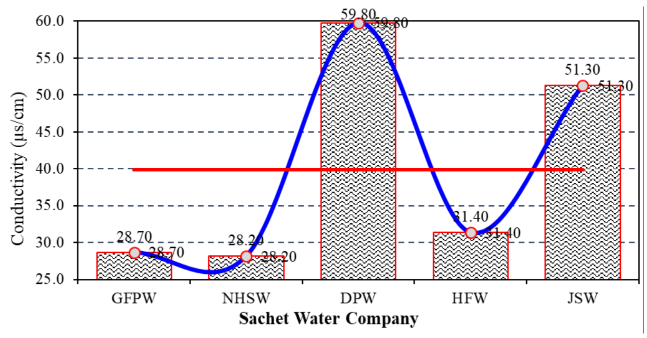


Figure 3. *Plot of measured Conductivity of water samples.*

Figure 3 above, the Electrical Conductivity measurements found in laboratory ranged 28.2–59 µS/cm. It is directly related to the concentration of salts dissolved in water and the Total Dissolved Solids (TDS) as well and it serves as a good indicator to determine the ionic strength of water sample. Hence, Electrical Conductivity measured for all the brand of sachet drinking water are far within the standard set by the WHO which is <450.0 µs/cm with Diamond Pure Water and Janneh Spring Water having the highest Electrical Conductivity values which were 59.8 µS/cm and 51.3 µS/cm, respectively. All the sachet drinking water companies do not provide the EC value on the sachet, but all brands are within

WHO permissible guideline limit hence, all brands had satisfactory quality in terms of Electrical Conductivity (EC).

Turbidity Value

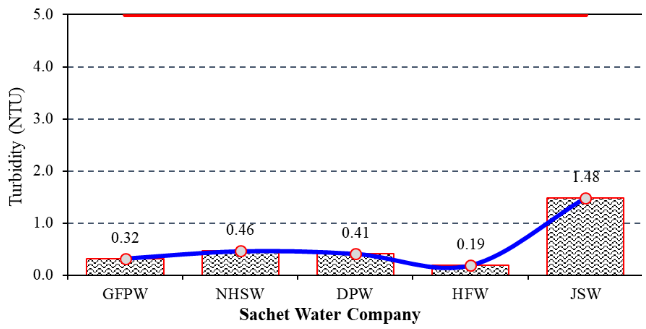


Figure 4. *Plot of measured Turbidity of water samples.*

Figure 4 above, the turbidity values found from the laboratory analysis ranged 0.19–1.48 NTU for all brands. All turbidity values read were within the WHO permissible limit of 5.0 NTU (max). Therefore, this indicates that all these brands of sachet drinking water could have gone through series of filtration or efficient filters during production to get rid of suspended clay particle, trace elements and suspended solids. Excessive turbidity is often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria which represent health concern. Although it does not necessarily adversely affect human health, it can protect microorganisms from disinfection effects, can stimulate bacterial growth, and indicate problems with treatment processes [35]. Therefore, the brands of sachet drinking water have proven from the laboratory analysis conducted less turbidity which result in less microorganisms such as parasite and bacterial which are sometime associated with high level turbidity which consequently leads to diarrhoea and typhoid.

The brands of sachet drinking water didn't provide turbidity content on label. Even though, all brands were within the WHO guideline limit. Hence, all brands had satisfactory quality in terms of turbidity.

Total Dissolved Solid Value

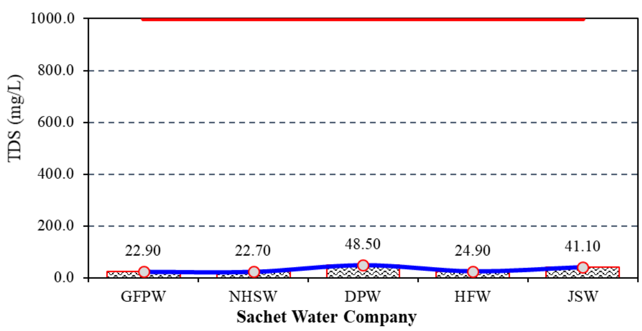


Figure 5. *Plot of measured Total Dissolved Solids (TDS) of water.*

Figure 5 above, Total dissolved solids (TDS) results ranged between 22.7 mg/L to 48.5 mg/L. The diversity in TDS was attributed to natural sources of water and/or manufacture, this indicated that all the brands of sachet drinking water contained varied concentrations of dissolved mineral elements for the mineral nutrition of consumers. The Diamond Pure Water has the highest (48.5 mg/L) followed by Janneh Spring Water (41.1 mg/L) and the least is Nimi Hills Spring Water (22.7 mg/L) followed by Good Family Pure Water (22.9 mg/L). The highest TDS in Diamond Pure Water and Janneh Spring Water may be due to the fact that it is a natural mineral water coming from a natural spring hence many minerals as its chemical composition was not altered and Lowest TDS content in Nimi Hills Spring Water, Good Family Pure Water and Hali Fresh Water can also be assigned to the automated processes of purification and filtration which is undertaken before packaging that lower the content of minerals. Lower TDS means softer drinking water. However, water with extremely low concentrations of TDS may also be unacceptable to some consumers because of its flat insipid taste and make it not advisable to people with high nutrient diet. Even though WHO did not provide any limit for TDS content in its fourth edition (which is the latest) of guidelines for drinking water quality, our results were evaluated based on the third edition WHO recommendation limit of 1000 mg/l and all TDS values for all brands fall within the standard value. Hence, all brands had good quality water in terms of TDS.

Total Hardness Value

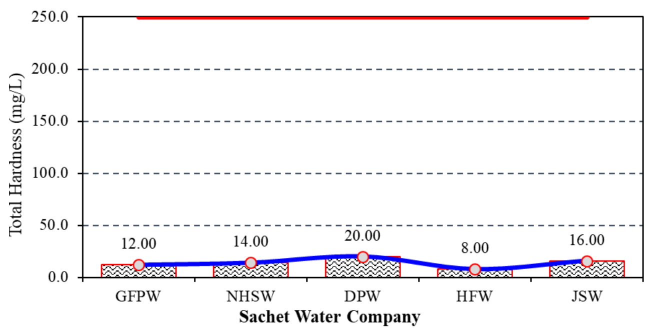


Figure 6. *Plot of measured Total Hardness (TH) of water samples.*

Figure 6 above, the laboratory analysis of brands of sachet drinking water, its show a clear indication that the results fall within the WHO standards or permissible guidelines limits set by the WHO which is <500 mg/L in which Diamond Pure Water has the highest (20.0 mg/L) followed by Janneh Spring Water (16.0 mg/L) and Hali Fresh water has the least (8.0 mg/L) followed by Good Family Pure Water (12.0 mg/L). Total hardness is a measurement of the mineral content in a water sample that is irreversible by boiling and therefore total hardness can be equivalent to the total calcium and magnesium hardness.

Hard water is not a health risk but is a nuisance because of the mineral build up on plumbing fixtures and poor soap and detergent performance. Since hard water contains essential minerals, it is sometimes the preferred drinking water, not only because of the benefits, but also the flavor. Also, calcium hardness like potassium plays a crucial role in several biological functions in human's body. Calcium is very important especially for children as it supports bone and tooth growth, muscle contraction, and the transmission of nerve impulse. Its deficiency results in structure deformation for children and increased risk of fracture for adults. At higher concentration it becomes one of the responsible water hardness that leads to Total Hardness and has been suspected to have a link with cardiovascular problems like blood pressure, growth retardation, and cancer. Magnesium salts are important contributors to the total hardness of water which breaks down when heated, forming scale in boilers. Chemical softening, reverse osmosis, electro dialysis, or ion exchange reduces the magnesium and associated hardness to acceptable levels [18]. Moreover, too much or too low concentrations of magnesium in human body both cause health struggles but still the quality of our water is good as the laboratory results didn't exceed the standard limit. Food diet is the main source of magnesium content in the body and medicine can supply more magnesium if needed. Its concentration in drinking water is just a small supplement. The brands of sachet drinking water didn't provide Total Hardness content on label. Even though, all brands fall within the WHO guidelines limit. Hence, all brands had satisfactory quality in terms of total hardness.

3.2. Bacteriological Parameter Value

Aerobic plate count Value

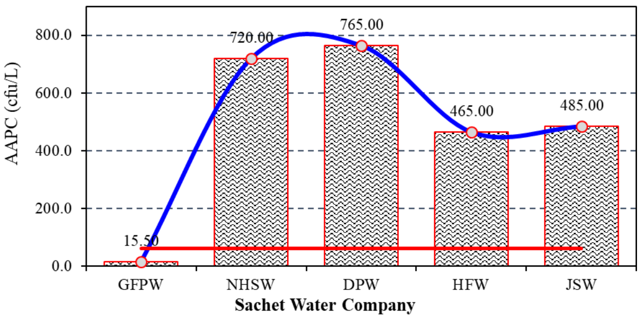


Figure 7. *Plot of measured Average of the Aerobic plate count at 37 ℃ and at 22 ℃ of water samples.*

Figure 7 above, the results from the laboratory for both Aerobic plate count at 37 ℃ and at 22 ℃ for the brands of sachet drinking water are far above the WHO permissible limit or standards and the Average of the Aerobic plate count at 37 ℃ and at 22 ℃ Result are far above the WHO permissible limits or standards. In other words, they are above specification limits when analyzed using Enumeration of Total Coliforms method. Good family Pure water is the only sachet water that is within the WHO permissible limit or standard with an average value of 15.50 cfu/ml for Aerobic plate count at 37 ℃ and at 22 ℃ and all other brands of sachet water are off specification limit of WHO standard for water quality. Therefore, both Aerobic plates count at 37 ℃ and at 22 ℃ for the brands of sachet drinking water produced in Kono District, Good Family Pure Water is the only sachet water that is within the WHO permissible limit and had satisfactory quality in terms of Aerobic plate count at 37 ℃ and at 22 ℃ respectively. And from the result Hali Fresh Water is within the WHO permissible limit for Aerobic plate count at 22 ℃.

The reason why Good Family Pure Water is the only sachet water that is within the WHO permissible limit and had satisfactory quality in terms of Aerobic plate count at 37 ℃ and at 22 ℃ respectively and also the average, is as a result of the following purification methods; Ultraviolet (UV) light, Chlorination and other sanitation-based health risks measures. The average Aerobic plate count at 37 ℃ and at 22 ℃ (Total Coliform) are indicator organisms, and their presence in treated water can be used to determine if water treatment processes were adequate to destroy bacterial pathogens. It is possible for water containing Aerobic plate count at 37 ℃ and at 22 ℃ (Total Coliform) to be free of human pathogens; however, it is unlikely that a water sample would contain pathogenic bacteria and test negative for total coliform bacteria.

Notwithstanding, almost all the four brands of sachet water produced in Kono District were positive for Aerobic plate count at 37 ℃ and at 22 ℃ (Total Coliform) contamination except for Good Family Pure Water. Based on the laboratory analysis and observations, the reasons why Aerobic plate count at 37 ℃ and at 22 ℃ (Total Coliform) becomes positive (that is, off specification limit) in the sachet water samples for the four samples of sachet drinking water might be the following reasons; lack of proper maintenance on treatment units such as carbon filters, sediment filters, water softeners; plumbing repairing or additions without system disinfection; seasonal system can have total coliform introduced during draining, start-up or anytime drained water lines are not properly closed or capped in the fall; when dead ends in the plumbing system allow water to become stagnant and sediment to accumulate creating conditions favourable for bacterial growth. That is, they are created when plumbing fixtures are removed or taken out of service and the associated water lines are left in place. Dead ends can also exist on water feed lines to fire and lawn sprinkler systems, boilers and heat exchangers [11]. Nevertheless, the presence of Aerobic plate count at 37 ℃ and at 22 ℃ (Total Coliform) by itself does not imply an imminent health risk but does indicate the need for an analysis of all water system facilities and their operations to determine how these organisms entered the water system and to curtailed it.

Coliform Value at 37 ℃

Table 3. *Table listing values of Coliforms present in sachet water at 37℃.*

Brand	Coliform Count at 37℃ (cfu/ml)
Good Family Pure Water	<1
Janneh Spring Water	<1
Diamond Pure Water	<1
Hali Fresh Water	<1
Nimi Hills Spring Water	<1
WHO Standard	00.0

Table 3 above, the results of laboratory analysis show that the brands of sachet water are within the specification limit of WHO permissible limit which is 00.0 cfu/ml for Coliforms at 37℃ when the enumeration of total coliform method was used (also note that; <1 = absence of growth for liquid sample).

A significant amount of coliform is released in the waste produced by animals which is one of the primary sources of coliform. This is a serious problem in water near cattle feedlots, hog farms, dairies, and barnyards that have poor animal keeping practice and waste is not properly contained. Also, high number of sediments is often related to high concentrations of pathogenic bacteria. The bacteria can attach to sediment particles. Bacteria grow faster at higher temperatures; the growth rate slows drastically at very low temperatures. Bacteria occur naturally in the intestinal tracts of humans and animals and in the soil. Although Coliforms bacteria normally do not cause illnesses, they should not be present in drinking water. Hence, all brands are of satisfactory quality in terms of Coliforms at 37℃.

E. coli at 44℃

Table 4. *Table listing values of E. coli present in sachet water at 44℃.*

Brand	E. coli Count at 44℃ (cfu/ml)
Good Family Pure Water	<1
Janneh Spring Water	<1
Diamond Pure Water	<1
Hali Fresh Water	<1
Nimi Hills Spring Water	<1
WHO Standard	00.0

Table 4 above, the results of laboratory analysis that shows the brands of sachet water are within the specification of WHO standards which is 00.0 cfu/ml for E. coli at 44℃ when the Enumeration of total coliform test method was used (also note that; <1 = absence of growth for liquid sample).

Faecal coliform, and E. coli bacteria whose presences in water indicate that it might be contaminated with human or animal wastes. Diseases-causing microbes (pathogens) in these wastes can cause diarrhoea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems. One study conducted in Nigeria, Nwachukwu and Emeruem [13], reported that bacteria isolate from sachet water were even in some cases resistant to eight common antibiotics, this gives an indication of the public health issues that could be attributed to bacterial contamination of sachet water. E. coli are also indicator organisms and can be used to determine whether drinking water has been exposed to a source of faecal contamination such that there could be pathogenic organisms present. The drinking water guidelines set forth by WHO dictate that there should be no detectable E. coli per 100mL of water intended for drinking, including packaged or bottled water [31]. Despite the added expense and level of trust that consumers have, the sachet drinking water in the study sites demonstrated coliform and E. coli contamination levels that may pose a substantial health risk to consumers. Therefore, all brands are of satisfactory quality in terms of E. coli at 44℃.

3.3. WHO and Sachet Water Parameter Values

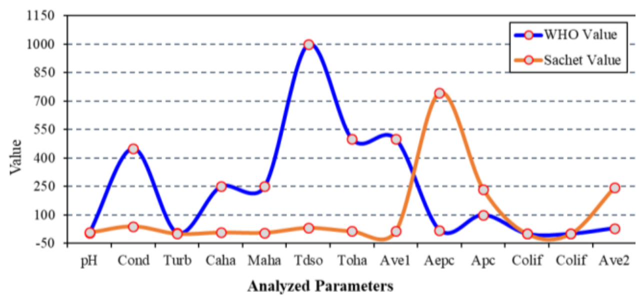


Figure 8. *Plot of parameters values and WHO permissible values including the averages.*

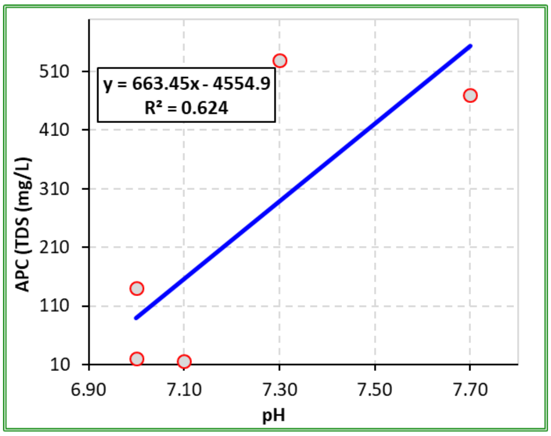
Figure 8 above, the results of laboratory analysis of all parameters including both physicochemical and bacteriological parameters versus WHO permissible limit shows that all the physicochemical parameters are within the WHO permissible limit for the five brands of sachet water and for the bacteriological parameters, the Aerobic plate counts at 22℃ and at 37℃ are far off the WHO permissible limits or standards while the E. coli at 44℃ and Coliforms at 37℃ fall within the specification of WHO standards. Notwithstanding, a total number of eleven (11) parameters including both physicochemical and biological parameters were analyzed and ten (10) of which fell within the WHO permissible limit hence, all the five brands of sachet drinking water had satisfactory quality in terms of the physicochemical parameters.

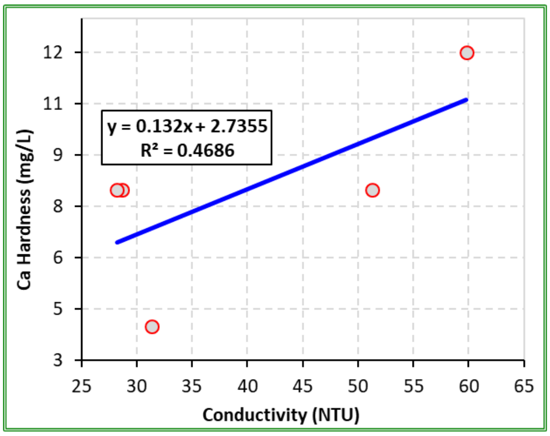
3.4. Measured Property Correlativity

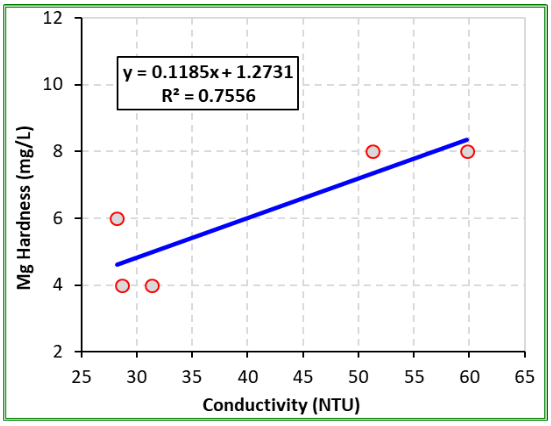
Table 5. A table of correlation shows the correlations among every pair of water quality parameters measured.

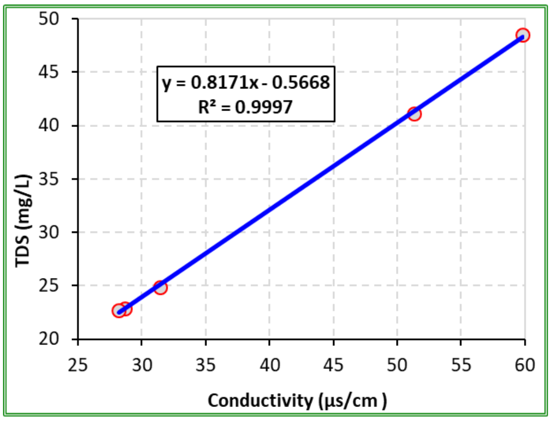
r	pH	Cond	Turb	Caha	Maha	Tdso	Toha	Aepc	Apc	Brpo
pH	1.00									
Cond	-0.19	1.00								
Turb	-0.25	0.48	1.00							
Caha	0.36	0.68	0.15	1.00						
Maha	0.17	0.87	0.67	0.71	1.00					
Tdso	-0.18	1.00	0.47	0.70	0.87	1.00				
Toha	0.30	0.82	0.39	0.95	0.89	0. 83	1.00			
Aepc	0.33	-0.01	0.15	0.08	0.55	0.42	0.29	1.00		
Apc	0.79	0.43	-0.04	0.73	0.64	0.45	0.75	0.60	1.00	.
Brpo	-0.11	-0.48	-0.35	0.03	-0.58	-0.47	-0.24	-0.96	-0.41	1.00

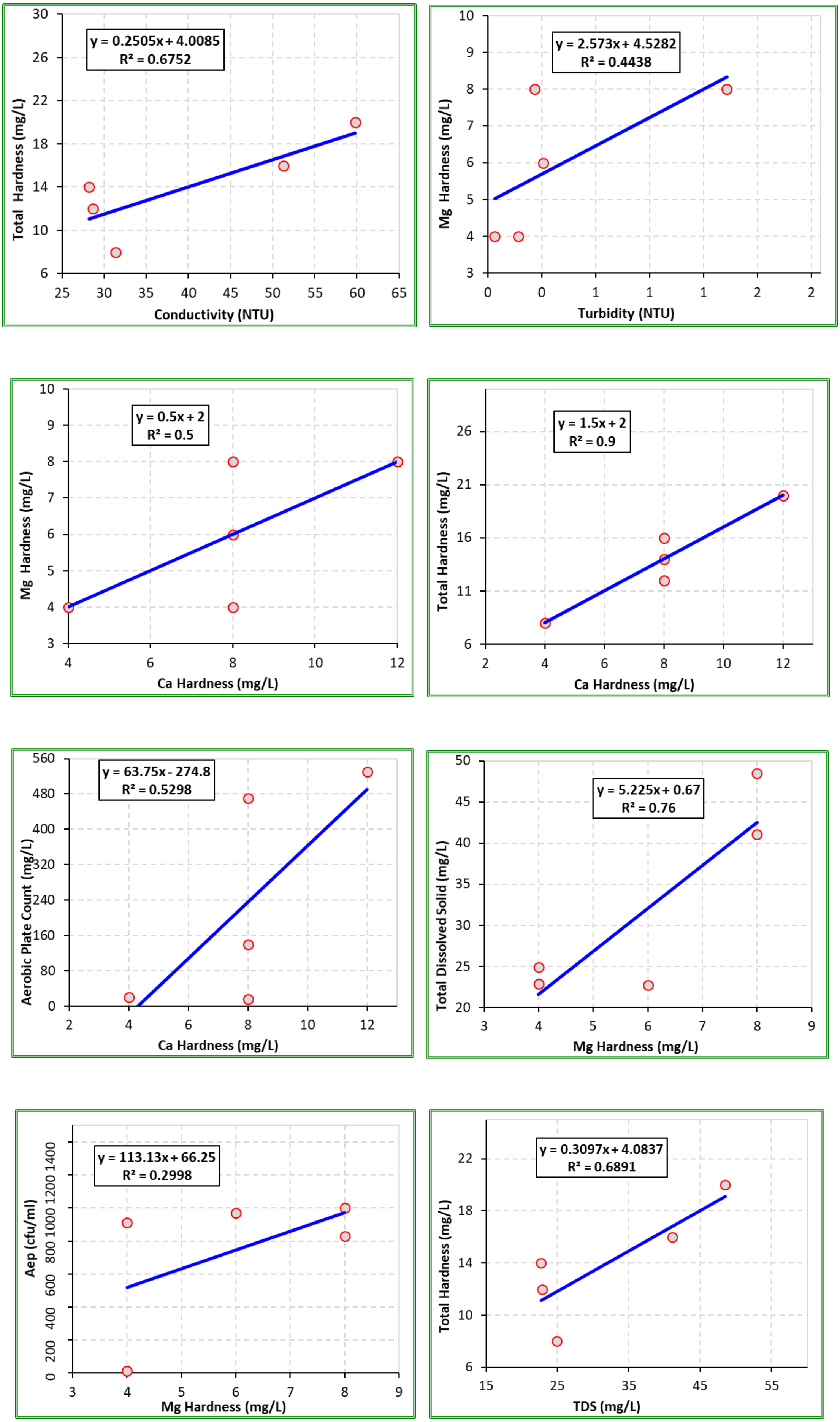
Note that the parameters were also correlated against sachet water product popularity (Prpo). Also note that r = Spearman's correlation coefficient, Cond = conductivity, Turb = turbidity, Caha = calcium hardness, Maha = magnesium hardness, Tdso = total dissolved solids, Toha = total hardness, Aepc = aerobic plate count at 37 ℃, Apc aerobic plate count at 22 ℃.

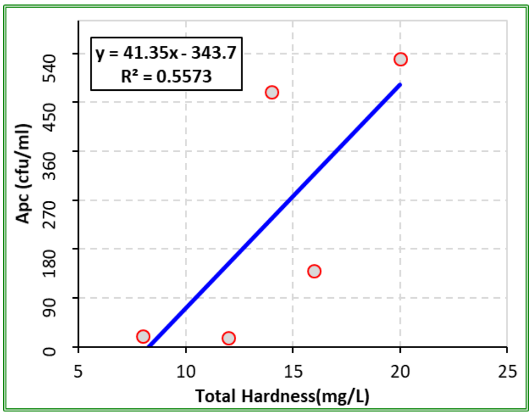









y = 0.2505x + 4.0085
R² = 0.6752
Total Hardness (mg/L)
Conductivity (NTU)
y = 2.573x + 4.5282
R² = 0.4438
Mg Hardness (mg/L)
Turbidity (NTU)
y = 0.5x + 2
R² = 0.5
Mg Hardness (mg/L)
Ca Hardness (mg/L)
y = 1.5x + 2
R² = 0.9
Total Hardness (mg/L)
Ca Hardness (mg/L)
y = 63.75x - 274.8
R² = 0.5298
Aerobic Plate Count (mg/L)
Ca Hardness (mg/L)
y = 5.225x + 0.67
R² = 0.76
Total Dissolved Solid (mg/L)
Mg Hardness (mg/L)
y = 113.13x + 66.25
R² = 0.2998
Aep (cfu/ml)
Mg Hardness (mg/L)
y = 0.3097x + 4.0837
R² = 0.6891
Total Hardness (mg/L)
TDS (mg/L)



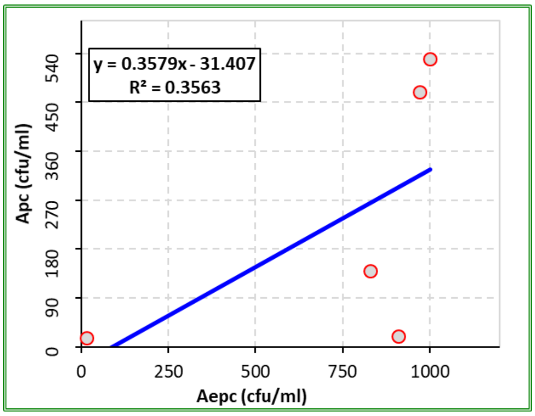


Figure 9. *Figures of correlativity showing correlations among every pair of the water quality parameters measured.*

Note that the parameters were also correlated against sachet water product popularity (Prpo). Also note that *r* = Spearman's correlation coefficient, conductivity, turbidity, calcium hardness, magnesium hardness, total dissolved solids, total hardness, aerobic plate count at 37 ℃, aerobic plate count at 22 ℃.

From Figure 9, the correlation coefficient between pH and Aerobic plate count at 22 ℃ is 0.79 which implies a stronger or high correlation between the two parameters. Majority of the brands of sachet water provide similar value of pH which are within the WHO permissible limits while the Aerobic plate count at 22 ℃ are far above the WHO permissible limit. Hence, it is true that the correlation between Aerobic plate count at 22 ℃ and pH is a positive correlation as the alkaline concentration increases so the growth of Aerobic plate count at 22 ℃ also increases.

The correlation coefficient between Calcium Hardness and Conductivity is 0.68 which implies the correlation between Calcium Hardness and Conductivity is moderate and from the analysis it is evident that the concentration of Calcium Hardness in the brands of sachet drinking water has been found minimal in all brands and all of them fall within the WHO standard of permissible limit. Moreover, Electrical Conductivity is directly related to the concentration of salts dissolved in water and the Total Dissolved Solids (TDS) as well and it serves as a good indicator to determine the ionic strength of water sample.

The correlation coefficient between Calcium Hardness and Conductivity is 0.87 which implies a strong or high correlation between Calcium Hardness and Conductivity. Moreover, Magnesium salts are important contributors to the hardness of water which breaks down when heated, forming scales in boilers which also increases the conductivity concentration and Chemical softening, reverse osmosis, electro dialysis, or ion exchange reduces the magnesium and associate hardness to acceptable levels [18]. Hence, it is evident that the correlation between Calcium Hardness and Conductivity is positive and strong.

The correlation coefficient between Total Dissolved Solid (TDS) and Conductivity is 1.00 which implies a very strong or very high correlation between the two parameters and it is also referred to as a perfect correlation which means as the Total Dissolved Solid (TDS) increases so also the conductivity and it is also evident that the treatment process for both of the parameters are almost the same and therefore show a very high coefficient of determination value (R^2 = 0.9997). However, all the brands of sachet drinking water fall within the WHO permissible limits for both Total Dissolved Solid (TDS) and Conductivity.

The correlation coefficient between Total Hardness and Conductivity is 0.82 which implies a stronger or high correlation between the two parameters. Total hardness is a measurement of the mineral content in a water sample that is irreversible by boiling and therefore total hardness can be equivalent to the total calcium and magnesium hardness and this shows a positive correlation to that of conductivity that is, as the hardness of water increases due to impurities so also the conductivity which show a positive and strong correlation.

The correlation coefficient between Magnesium Hardness and Turbidity is 0.67 which implies a moderate correlation between the two parameters. It is also evident that the treatment process for magnesium hardness is quite different from turbidity and therefore shows a low coefficient determination value (R^2 = 0.4438). Nevertheless, from the laboratory analysis the different brands of sachet drinking water analyzed for magnesium fall within the guidelines of WHO permissible limit and for turbidity.

The correlation coefficient between Magnesium Hardness and Calcium Hardness is 0.71 which implies a strong or high correlation between the two parameters which shows a correlation determination value of R^2 = 0.5 and it is also obvious that the treatment processes for both parameters must be similar. The two parameters cause hardness of water and Hard water is not a health risk but is a nuisance because of the mineral build up on plumbing fixtures and poor soap and detergent performance. Nevertheless, both parameters fall within the WHO standards or permissible guidelines limits for all the brands of sachet drinking water.

The correlation coefficient between Magnesium Hardness and Calcium Hardness is 0.93 which implies a very strong or very high correlation between the two parameters and has a correlation determination value of R^2 = 0.9 and it is also evident that as the concentration of calcium increases so also the total hardness increases which indicates a positive correlation and both parameters must have similar treatment processes. However, Total hardness is a measurement of the mineral content in a water sample that is irreversible by boiling and therefore total hardness can be equivalent to the total calcium and magnesium hardness in water.

The correlation coefficient between Magnesium Hardness and Aerobic plate count at 22 ℃ (APC) is 0.73 which implies a strong or high correlation between the two parameters and has a correlation of determination value of R^2 = 0.5298. Aerobic plate count at 22 ℃ (Total Coliform) are indicator organisms, and their presence in treated water can be used to determine if water treatment processes were adequate to destroy bacterial pathogens whereas, calcium are indicator of water hardness and from the laboratory analysis both parameters are correlated that is, as the concentration of calcium hardness increases so also the increase of Aerobic plate count at 22 ℃.

The correlation coefficient between Total Dissolved Solid and Magnesium Hardness is 0.87 which implies a strong or high correlation between the two parameters and has a correlation of determination value of R^2 = 0.76. TDS may be due to the natural mineral water coming from a natural spring which may be true for the calcium also and from the correlation analysis they may have similar treatment process. And, from the laboratory analysis both parameters are within WHO permissible limit for the sachet drinking water.

The correlation coefficient between Aerobic plate count at 37 ℃ and Mg Hardness is 0.55 which implies moderate correlation between the two parameters and has a low correlation of determination value of R^2 = 0.2998. It is evident that the two parameters are not that correlated like the others. From the laboratory analysis it shows that the different brands of sachet drinking water analyzed for magnesium fall within the guidelines of WHO permissible limit wherein for Aerobic plate count at 37 ℃ do not fall within but rather far below the WHO permissible limit except for GFPW.

The correlation coefficient between Total Hardness and TDS is 0.83 which implies a strong or high correlation between the two parameters and has a correlation of determination value of R^2 = 0.6891. It is also obvious that as the concentration of Total hardness increases so also the concentration of TDS increases. The Total Hardness can be equal to the total calcium and magnesium hardness which causes the impurity of the water and the diversity in TDS was attributed to natural sources of water and/or manufacturers and from the laboratory analysis it shows that all the brands of sachet drinking water contained varied concentrations of dissolved mineral elements. Nevertheless, both the parameters fall within the WHO permissible limit for sachet drinking water. Hence, all brands had satisfactory quality in terms of Total Hardness and TDS.

Figure 9 above, the correlation coefficient between Aerobic plate count at 22 ℃ (APC) and Total Hardness is 0.75 which implies a strong or high correlation between the two parameters and has a correlation of determination value of R^2 = 0.5573. It is evident that the relationship between Aerobic plate count at 22 ℃ (APC) and Total Hardness is not perfect. However, hard water is not a health risk but is a nuisance because of the mineral build up on plumbing fixtures and poor soap and detergent performance wherein Aerobic plate count at 22 ℃ (APC) is a health risk to the consumers and the correlation coefficient between Apc at 22 ℃ and Aepc at 37 ℃ is 0.60 which implies a moderate correlation between the parameter at two different temperature and have a correlation of determination value of R^2 = 0.3563. From the correlation analysis it is evident that the relationship between the parameters at two different temperatures is not strong because of the temperature difference. Both parameters (Total coliforms) are indicator organisms, and their presence in treated water can be used to determine if water treatment processes were adequate to destroy bacterial pathogens. And from the laboratory analysis, all the sachet drinking water do not meet the WHO permissible guideline limit except for GFPW which fall within the WHO permissible standard.

3.5. Results from Questionnaire

This section analysed the rate of consumption of sachet water and the type of brand of sachet water with the highest sales. It shows how consumers became aware of sachet water; point of purchase and the specific brand they would prefer to buy.

Water Consumption Rate

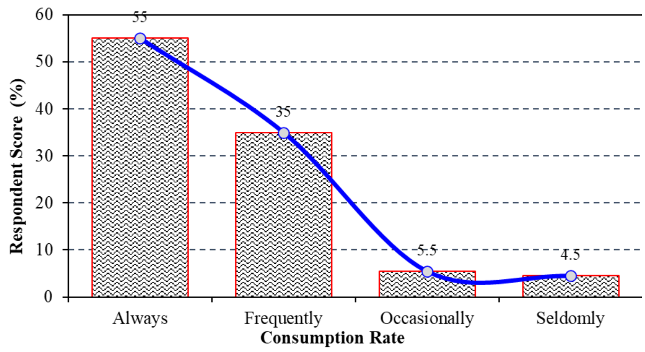


Figure 10. *Plot of the rate of consumption of sachet water.*

Note that ALW = always, FRE = frequently, OCC = occasionally, SED = seldomly.

Figure 10 above shows that 110 (55%) of the respondent drink sachet water always, 70 (35%) drink frequently, 11 (5.5%) of the respondent drink sachet water occasionally and 9 (4.5%) are uncertain of their usage of this sachet water. It is evident that people within the study area do always and frequently consume sachet water since they have the highest percentage.

Source of Information

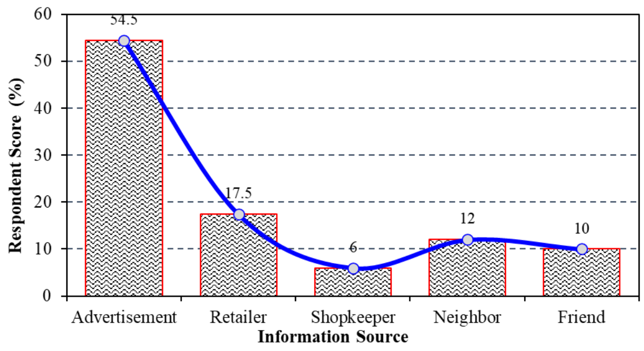


Figure 11. *Plot of source of information of respondents about existence of sachet water.*

Figure 11 indicates 109 (54.5%) of the respondents said that they got the information through advertisements, 35 (17.5%) through retailers, 12 (6%) through shopkeepers, 24 (12%) through Neighbors and 20 (10%) through friends and relatives. The high percentage in advertisement indicates that these water producing companies are involved in showcasing their goods to the public in the form of advertisement.

Consumption Time

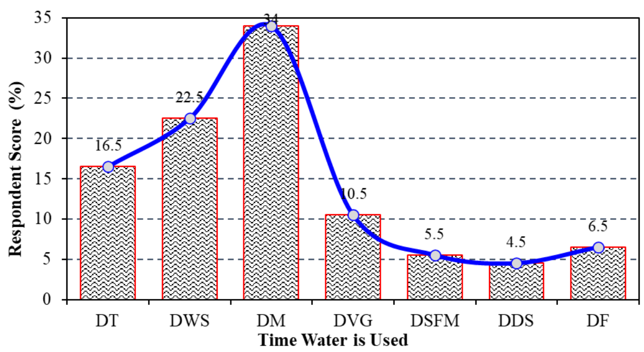


Figure 12. *Plot of time sachet water is consumed.*

Note that DT = during shortage of drinking water, DWS = during shortage of water, MT = during breakfast, lunch or dinner, DVG = during visits of guests, DSFM = during sickness of family members, DDS = during dry season, DF = during functions.

Figure 12 above shows that 33 (16.5%) of the respondents do consume sachet water during travel, 45 (22.5%) during shortage of drinking water, 68 (34%) at breakfast, lunch or dinner and 21 (10.5%) during visit of guests, 11 (5.5%) during sickness of close relatives, 9 (4.5%) during dry seasons and 13 (6.5%) during functions. Sachet water is mostly consumed at breakfast, lunch or dinner within the study area since it carries the highest percentage recorded in the table above. And moreover, people normally consumed this sachet water during shortage of drinking water since it carries the second highest record in the study area.

Popular Water Brand

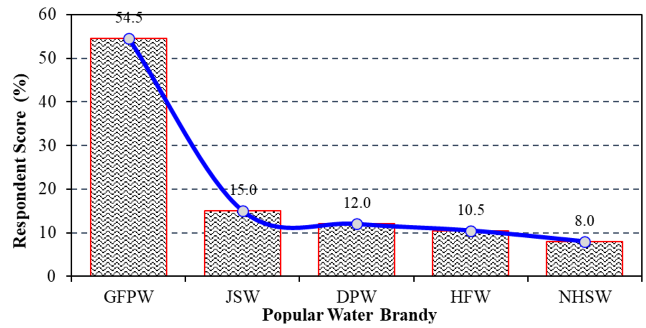


Figure 13. *Plot of popular brands of sachet water used in the study area.*

Note: GFPW = Good Family Pure Water; JSW = Janneh Spring Water; DPW = Diamond Pure Water; HFW = Hali Fresh Water; NHSW = Nimi Hills Spring Water.

Figure 13 above shows that 109 (54.5%) preferred Good Family Pure Water, 30 (15%) preferred Janneh Spring Water, 24 (12%) preferred Diamond Pure Water, 21 (10.5%) preferred Hali Fresh Water and 16 (8%) preferred Nimi Hills Spring Water. However, from the table above, it is evident that people preferred Good Family Pure Water followed by Janneh Spring Water, Diamond Pure Water, Hali Fresh Water and Nimi Hills Spring Water in the study area.

Reason for Water Use

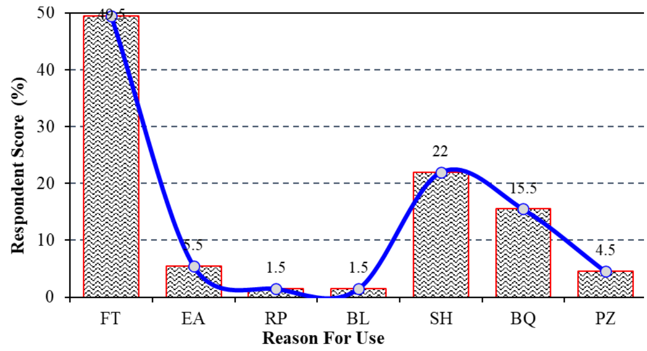


Figure 14. *Plot of the reasons for purchasing sachet water for drinking in the study area.*

Note that FT = taste of water, EA = easy availability, RP = reasonable price, BL = brand loyalty, SH = health safety, BQ = better quality, PZ = due to its packaged size.

Figure 14 above shows that 99 (49.5%) of the respondents said the purchase the water because of the taste, 11 (5.5%) said due its easy availability, 3 (1.5%) because of its reasonable price, 3 (1.5%) preferred its brand loyalty, 44 (22%) said because of its health safety, 31 (15.5%) due to its better quality and 9 (4.5%) due to its packaged size. The result clearly shows that a greater number of people purchased sachet water because of its health and safety, due to its better quality, taste and only a few purchased because of brand loyalty, easy availability, packaged size and reasonable price.

3.6. Consumer Satisfaction

This section deals with the satisfaction of consumers with the different brands of packaged water in terms of high dissatisfaction, dissatisfaction, moderation, satisfaction and high satisfaction. These are some aspects considered in terms of consumer satisfaction towards packaged water; taste, product design, quality of product and trustworthy source.

Sachet Water Taste and Package Design

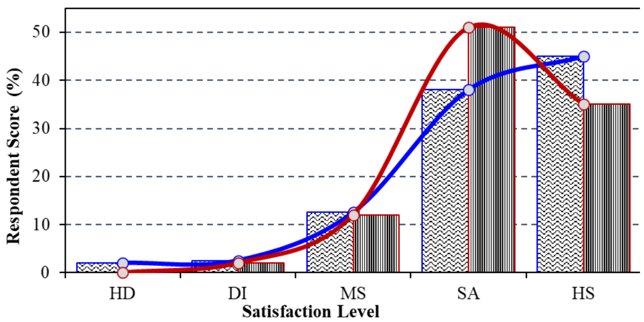


Figure 15. *Plot of taste of sachet water and package design of sachet water collected.*

Note: HD = highly dissatisfaction; DI = dissatisfaction; MS = moderate satisfaction; SA = satisfaction; HS = highly satisfaction; Red plot = taste of sachet water and blue plot = package design.

Figure 15 above shows the general perception of the taste of sachet water by consumers within the study area. It is clearly seen that 76 (38%) have great satisfaction towards sachet water, 90 (45%) high satisfaction, 25 (12.5%) moderate and only a few have dissatisfaction, which is about 5 (2.5%) and 4 (2%) have high dissatisfaction. The results above clearly show the consumers have high satisfaction in the taste of the sachet water produced in Kono district, and this is very important with regards health, safety and portability. Moreover, From the Figure 15 above, it is seen that 102 (51%) of the respondents were satisfied with the product design, 70 (35%) were highly satisfied with the product design, 24 (12%) had moderate preference towards the product design, and only a small number of people had dissatisfaction which is about 4 (2%) and none of respondents had high dissatisfaction in the products design. The data analyzed signposts that a greater number of people within the study area favored the way in which the product were designed more, especially the sachet.

4. Conclusions

Sachet water is essential in providing potable and quality water for the people of Kono District, and its immediate surroundings. The selected brands of sachet water have gone through laboratory analysis for both the physicochemical and bacteriological parameters. The research revealed that the brands of sachet drinking water produced in Kono District were in line with MWS, SL and WHO permissible standards for both the physical and chemical parameters except for the bacteriological parameters which are above the WHO and MWR, SL standards. Even though the Good Family Pure Water met all the MWR, SL and WHO permissible standards.

For the bacteriological analysis, three of the sachet water sample (Nimi Hills Spring Water, Diamond Pure Water and Janneh Spring Water) were assessed to be positive (off specification limit) for both Aerobic plate count at 37 ℃, and Aerobic plate count at 22 ℃, and Hali Fresh Water was found to be positive for Aerobic plate count at 37 ℃ with the exception of the Good Family Pure Water which met all the MWR, SL and WHO permissible standards for physicochemical and bacteriological parameters. These bacteriological parameters have pathogens in them which are disease causing agents.

From the questionnaire, it shows that 109 (54.5%) preferred Good Family Pure Water, 30 (15%) preferred Janneh Spring Water, 24 (12%) preferred Diamond Pure Water, 21 (10.5%) preferred Hali Fresh Water and 16 (8%) preferred Nimi Hills Spring Water. However, from the people's perception, it is evident that people preferred Good Family Pure Water followed by Janneh Spring Water, Diamond Pure Water, Hali Fresh Water and Nimi Hills Spring Water in the study area.

Even though few discrepancies were observed from the laboratory analysis for the bacteriological parameters, it is not a big deal as the difference from the MWR, SL and WHO permissible limit is very negligible. The research, therefore, concluded that sachet drinking water produced in Kono city is safe and suitable for drinking purpose in terms of physical and chemical quality except for bacteriological parameters (Aerobic plate count at 37 ℃, and Aerobic plate count at 22 ℃). Nevertheless, out of the five brands of sachet water, Good Family Pure Water is safe and suitable for drinking purpose as it meets all the physicochemical and bacteriological parameter standards set by MWR, SL and WHO. Hence, other research is still needed to assess the radiological quality of those sachet water produced in Kono District.

The author therefore, recommended that, the regulatory authorities of water resources in the ministry of water resources management should undertake routine checks of licensed sachet water seller, the producers of these sachet water companies should be properly guided on the need to keep their premises neat to prevent contamination of the sachet water, government should set up a quality control monitoring team to be regularly checking this production sites through the ministry of water resources to enhance the heath and sanitation and also the safety of the entire public, regulatory authorities should educate these water producing bodies on the effects of bacteriological parameters in water, well-trained personnel in terms of water quality should be employed in each of the company for a hygiene and health safety of this sachet water and finally further research should be done within the study area and with the same brands of sachet water to determine the reason(s) for the high bacteriological (Aerobic plate count at 37 ℃, and Aerobic plate count at 22 ℃) values.

Abbreviations

APC	Aerobic Plate Count
Ca	Calcium
$CaCO_3$	Calcium Carbonate
CaH	Calcium Hardness
DPW	Diamond Pure Water
EC	Electrical Conductivity
EDTA	Ethylenediaminetetraactic Acid
FCG	Faecal Coliform Growth
GFPW	Good Family Pure Water
HFW	Hali Fresh Water
JSW	Janneh Spring Water
KCl	Potassium Chloride
Mg	Magnesium
MgH	Magnesium Hardness
MLSB	Membrane Lauryl Sulphate Broth
MWR	Ministry of Water Resources
NC	Number of Colonies
NFC	Non-Faecal Coliforms
NHSW	Nimi Hills Spring Water
NTU	Nephelometer Turbidity Unit
pH	Potential of Hydrogen
TC	Total Coliforms
TCC	Total Coliform Count
TDS	Total Dissolved Solid
TH	Total Hardness
UV	Ultraviolet
VW	Volume of Water
WHO	World Health Organization

Author Contributions

Sahr Emmanuel Lebbie: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft

David Conteh: Funding acquisition, Resources, Supervision

Sahr Gbeinda: Supervision, Validation, Writing – review & editing, Resources

Fatmata Gegbe: Funding acquisition, Resources, Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Addo, K. K., Mensah, G. I., Bonsu, C. and Akyeh, M. L. (2009): Bacteriological Quality of Sachet Water Produced and Sold in Teshie-Nungua Suburbs of Accra, Ghana. African Journal of Food, Agriculture and Nutrition Development 9, 1-12.

[2] Adebayo, A. K., Adedebiyi, A. A., Oladapo, O. O., et al. (2009): Characterisation of Heart Failurewith Normal Ejection Fraction in a Tertiary Hospital in Nigeria. BMR Cardiovascular Disorders, 9, 52.

[3] Akinde S. B., Nwachukwu M. I., Ogamba A. S., (2011): Storage effects on the quality of sachet water produced within port harcourt metropolis, Nigeria. *Jordan J. Biol. Sci.*. 2011; 4(3): 157-164.

[4] Aturamu Adeyinka O., Ojo Adebayo O, Adebayo Olajide F, Akinyemi Segun A (2012): palynostratigraphic analysis of the agbada formation (well) offshore, eastern Niger-delta basin, Nigeria. Vol. 3, No. 5, pp. 19-31, December 2015.

[5] Chinelo Mgbakor, G. C. Ojiegbe, Iheanyi Omezuruike Okonk, Ngozi Nma Odu, John Adeolu Alli, Jonathan Chukwudidi Nwanze and Charles Chukwuemeka Onoh. (2011): Bacteriological evaluation of some sachet water on sales in Owerri metropolis, Imo State, Malaysian Journal of Microbiology, Vol 7(4) 2011, pp. 217-225 Nigeria.

[6] Derege K, Chris, Z (2014): The African health observatory as a Platform for strengthening health information system in Sanharan Africa, vol 107(15), pp 6-9.

[7] EFSA (European Food Safety Authority), (2015): Reasoned opinion on the potential chronic and acute risk to consumers' health arising from proposed temporary EU MRLs. *EFSA Journal* 2007; 5(3): 32r, 1141 pp. https://doi.org/10.2903/j.efsa.2007.32r

[8] Isikwue, M. O. and Chikezie, A. (2014): Quality Assessment of Various Sachet Water Brands Marketed in Bauchi Metropolis of Nigeria. International Journal of Advances in Engineering and Technology, 6, 2489-2495.

[9] Je ́quier, E., & Constant, F. (2010): Water as an essential nutrient: physiological. European Journal of Clinical Nutrition, 64, 115–123.

[10] Maduka HCC, Chukwu NC, Ugwu CE, Dike CC, Okpogba AN, Ogueche PN and Maduka AA (2014): Assessment of commercial bottled table and sachet water commonly consumed in Federal University of Technology, Owerri (FUTO), Imo State, Nigeria using Microbiological indices. Journal of Dental and Medical Sciences 13: 86-89.

[11] Mihayo. I, Mkoma. S. (2012): Chemical Water Quality of Bottled Drinking Water Brands Marketed in Mwanza City, Tanzania. Research Journal of Chemical Sciences, Vol. 2(7), 21-26.

[12] Ministry of Energy & Water Resources (MoEWR) (2012): Ministry of Energy & water https://moewr.gov.so

[13] Nwachukwu, C. and Emeruem, C. M. (2007): Presence of Antibiotic-Resistant Bacteria in Sachet water Produced and Sold in the Eastern Nigeria, Research Journal of Microbiology. 2(10): 782-786.

[14] Nwosu J. N., Ogueke C. C., (2004): Evaluation of sachet water samples in Owerri Metropolis. *Nig. Food J.*. 2004; 22: 0189-7241.

[15] Oyedeji, O., Olutiola, P. O. and Moninuola, M. A. (2009): Microbiological quality of packaged drinking water brands marketed in Ibadan metropolis and Ile Ife city in South Western Nigeria. African Journal of Microbiology Research 4(1), 096-102.

[16] Oyelude, E. O. and Ahenkorah, S. (2012): Quality of Sachet Water and Bottled Water in Bolgatanga Municipality of Ghana. *Research Journal of Applied Sciences, Engineering and Technology*, 4, 1094-1098.

[17] Pujeh, et al., (2021): Assessment of the quality of hand dug well used for drinking and agricultural activities at Blama, Small-Bo Chiefdom, Eastern, Sierra Leone, Vol. 13(1), pp. 19.

[18] Putz, (2003): International standardization of water analysis. *Environ Sci & Pollut Res* 10, 183–187 (2003). https://doi.org/10.1065/espr2003.04.151

[19] Republic of Sierra Leone (2015): Population and Housing Census: Analytical Report on Population Distribution, Migration and Urbanisation in Sierra Leone. Ibrahim Mohamed Sesay, Andrew A. Karam, Jinnah J. Ngobeh. Published November 2018.

[20] Rutz D (1996). Pure water vending machines may not be so pure. CNN: Food and health. May 2.

[21] Sunday B. Akinde, Omokaro Obire (2011): situ Physico-chemical properties of the deep Atlantic oceanwater column and their implicationson heterotrophic bacterial distribution in the Gulf of Guinea. Advances in Applied Science Research. 2(6): 470 – 482.

[22] TWAS (2002): Safe drinking water, Report of the Third World Academy of Sciences, © 2002 Strada Costiera 1134014 Trieste, Italy. www.twas.org

[23] UNW-DPAC. (2015): The Human Right to Water and Sanitation, Media brief. 50014 Zaragoza, Spain, https://www.un.org/waterforlifedecade/unwdpac.shtml

[24] World Health Organization (WHO) -UNICEF-JMP. (2017): Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. Switzerland: WHO Library Cataloguing-in-Publication Data.

[25] World Health Organization (WHO), (1993): Guidelines for drinking-water quality. Vol. 2. Health criteria and other supporting information. Ch. 16. Geneva. pp. 145-15.

[26] World Health Organization (WHO), (1996): Sodium in Drinking water background document for development of WHO Guidelines for Drinking-water Quality. Geneva: WHO press.

[27] World Health Organization (WHO), (1997): Guidelines for Drinking-water Quality, FOURTH EDITION. Geneva: ISBN 9789241548151.

[28] World Health Organization (WHO), (1999): Guidelines for drinking water quality. Expert committee on International Standard for drinking water, Geneva 27, Switzerland.

[29] World Health Organization (WHO), (2005): Nutrients in Drinking Water. Geneva: WHO Library Cataloguing-in-Publication Data.

[30] World Health Organization (WHO), (2007): Guidelines for Drinking-water Quality Third Edition Incorporating the First and Second Addenda, Vol. 1, Recommendations. – 3rd ed. Geneva: WHO Press.

[31] World Health Organization (WHO), (2011): Guidelines for drinking-water quality: fourth edition incorporating the first. Geneva: WHO Library Cataloguing-in-Publication Data.

[32] World Health Organization (WHO), (2019): Retrieved from New report on inequalities in access to water, sanitation and hygiene: https://www.who.int/news-room/detail/18-06-2019-1-in-3-peopleglobally-do-not-have-access-to-safe-drinking-water--unicef-who

[33] World Health Organization. (WHO). (2001): Guidelines for Drinking water quality, Volume 1: 3rd edition, WHO Press, Switzerland.

[34] World Health Organization. (WHO). (2002): Heterotrophic Plate Count Measurement in Drinking Water Safety Management. Report of an Expert Meeting. Distribution System Indicators of Drinking Water Quality.

[35] World Health Organization. (WHO). (2004): Guidelines for Drinking water quality, Volume 1: 3rd edition, WHO Press, Switzerland.

Biography

Sahr Emmanuel Lebbie is a renowned Sierra Leonean environmentalist, an articulate and creative person with good organizational and industrial managerial skills, and competent in chemical analysis, quality control, human resource development, and administrative and research work at Njala University, Department of Chemistry. Presently, he is pursuing his PhD in environmental sciences and engineering at Harbin Institute of Technology, China. Mr. Lebbie completed his master's in environmental chemistry from Njala University in 2021 and his bachelor's degree in environmental chemistry from the same university in 2019. In addition, he holds a French Certificate from IMATT College, Freetown, in 2023, and a Generic Research Competency License Supervising

Certificate for the Postgraduate Supervision Course, Editorial Assistant and Technical Editing, APA Referencing, and Canons of Research from Njala University in 2024. Recognized for his exceptional skills and academic excellence, he was employed as a lecturer at Njala University and as an associate lecturer in the Health Sciences Department, Central University, Sierra Leone. He has participated in multiple international research collaboration projects recently, and he has published several publications in the field of environmental sciences. His contributions have significantly advanced the understanding of local ecological challenges, and he continues to mentor students, fostering a new generation of researchers. As a passionate advocate for sustainable practices, he actively engages with communities to promote awareness and action towards environmental conservation. Mr. Lebbie is dedicated to advancing environmental issues and research in Sierra Leone.

David Conteh was born and raised in Makeni City. Currently, the CEO of the International College of Makeni. He owns a BSc. Honors degree in Chemistry from Fourah Bay College, University of Sierra Leone. Conteh acquired his MSc. in Chemistry from Njala University in 2005. He worked as a laboratory analyst at the Pharmacy Board Quality Control Laboratory in 2006 and worked as a technical manager in the chemical laboratory at the Sierra Leone Standards Bureau till 2016. Has been working on environmental impact assessments as a consultant for companies. Currently pursuing a PhD in Environmental Chemistry at Njala University.

Sahr Gbeinda was born in Koidu Town, Sierra Leone. Sahr Gbeinda, a proud Sierra Leonean and member of the Kono tribe, began his journey at the Kointaya Refugee Camp as a young boy, where he started his primary education before moving to Sierra Leone to continue at the Roman Catholic Boys Primary School in Koidu, where he earned the National Primary Schools Certificate (NPSE). He then attended Saint Patrick's Boys Secondary School, where he completed his BECE and earned the Basic Education Certificate Examination Certificate. Seeking further education, he started his senior secondary school at the Koidu Secondary School and later migrated to Ghana and Liberia, where he obtained the West African Senior School Certificate Examination Certificate. His academic pursuits continued at the Zorzor Rural Teachers Training Institute/ZRTTI, where he obtained a teaching certificate. He later enrolled at Cuttington University, where he earned a BSc in Biology with Honors. Currently, he is a master's candidate in public health at the University of Makeni, Sierra Leone, and pursuing a degree in software engineering at the College of Digital Excellence/CODE and NIIT-affiliated institution. Professionally, his career started at the Christian Revival Church Association Mission Secondary School in Zorzor, Lofa County, Liberia, where he served as one of the vice principals. In health, his career started at the Zorzor Primary Health Care Center, starting from health data collector to data enterers.

Fatmata Gegbe is a dedicated healthcare professional with expertise in nursing, public health, and nursing education, currently pursuing a PhD focused on maternal and child health and healthcare leadership. Her work centers on promoting health equity, enhancing health systems, and advancing the nursing profession through research, education, and clinical practice. Her commitment to these areas has led her to collaborate with various organizations to implement innovative health programs. By integrating evidence-based practices, Fatmata aims to empower communities and improve health outcomes for vulnerable populations. She has a rich background across academic, clinical, and community health settings, with a strong commitment to developing evidence-based interventions for maternal and child health in low-resource environments. Her work integrates policy advocacy, capacity building, and alignment with the Sustainable Development Goals. As an emerging leader and scholar, she actively contributes to interdisciplinary research, health policy dialogue, and mentorship of future healthcare professionals. Her research output includes several peer-reviewed publications focused on issues such as COVID-19, mental health, maternal health, and emerging infectious diseases. Through collaborative efforts, she seeks to address health disparities and improve access to quality care for vulnerable populations.