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Variation in water quality indices of sachet water brands consumed in Kaduna State: consumers' perceptions

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ABSTRACT

The purpose of this study was to evaluate the quality of selected sachet water brands consumed in Kaduna South Local Government Area (LGA). Twenty sachet water samples were collected from the ten most popular brands consumed by residents. The American Public Health Organization (APHA) and the American Society for Testing and Materials (ASTM) standard procedures were used to analyse 18 water quality indicators. The findings were compared to water quality criteria established by the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organisation (WHO). The results of the studies show that, of the eighteen (18) water quality parameters tested, only pH exceeded the allowable limit in portable water as recommended by NSDQW and WHO. Since pH has no substantial detrimental influence on human health, the water brands are safe to drink. However, the recent epidemic of waterborne infections in area is not linked to the use of sachet water from brands that have NAFDAC, manufacturing, and expiration dates. It is thus advised that further research be conducted in the study area to analyse the quality of sachet water brands that are not NAFDAC-approved, as well as manufacturing and expiration dates.

Keywords: contamination, NSDWQ, sachet water, water quality, waterborne diseases, WHO

1. INTRODUCTION

Water is life when it is pure and free of toxins. One of the biggest challenges confronting the global society is the shortage of portable water (Afangideh and Udokpoh, 2021). In a report by United Nations (UN), there is more contaminated water than portable water in the world water system (Bahago et al., 2019). Water contaminated with certain chemicals can have serious impacts on humans, animals, and even plants (Utsev & Ekwule, 2020; Gandhi & Sirisha, 2021; Afangideh & Udokpoh, 2022). Risks associated with contaminated water include a high death rate, a low quality of life, and low productivity, all of which have raised severe concerns (Orji et al., 2006). These hazards are posed by water-borne illnesses connected to polluted water (Ikpesu & Ariyo, 2021). Humans can contract ailments including dysentery, cholera, diarrhoea, polio, typhoid, and

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others by drinking polluted water (Ifeanyi et al., 2006). In a society where these diseases are prevalent, residents would spend more on receiving treatment, resulting in a high cost for health care delivery. Waterborne diseases remain one of the world's most serious public health issues. Unhygienic practises and the usage of unclean water contribute to the high prevalence of diarrhoea in children and babies (Omalu et al., 2010; Tortora et al., 2002).

Access to potable water in Nigeria is severely hampered by cost, availability, proximity, and other variables, implying that customers are forced to accept what they can afford or what is available. Water thought to be pure by manufacturers and customers (often known as sachet water) is the most readily available source of drinkable water for most Nigerians. In different places of the world, different ways are used to meet the need for freshwater resources (Uduma, 2014). Any commercially processed water that is produced, packaged, and disseminated for sale that is meant for human consumption is referred to as sachet water (Denloye, 2004). Water filled in individual units of 50 or 60 centilitre polyethylene sachets of high density is widely used in Nigeria (Omoniyi and Abu, 2012). Water packaging into polythene bags (as a form of water distribution) has gained a reputation for ingenuity that has spread beyond Nigeria to other developing countries (Omole et al., 2015). This breakthrough, which was developed in direct response to Nigerians' unique potable water requirements, is known as 'pure water' in local dialect (Babatunde and Biala, 2010). A variety of issues, including climatic, economic, and quality concerns, spurred the emergence of sachet water in Nigeria in the early nineties. (Edoga et al., 2008). Although sachet water started in Nigeria, it has now spread to other West African nations such as Niger, Benin, Ghana, Cameroon, Togo, Côte d'Ivoire, and Burkina Faso (Stoler et al., 2012). Conversely, water in sachets is widely available and inexpensive, although there are worries about its quality (Omalu et al., 2010; Kumpel et al., 2017). The product has been considered as a low-cost, widely available option to supplying safe water, eventually permitting contributions from local organisations in the drive to achieve the Millennium Development Goals (MDGs) water objective (MacArthur and Darkwa, 2013).

Many years of government negligence and insufficient investment in public infrastructures has rendered Nigeria's public drinking water supply unreliable (Dada, 2009). The government's unwillingness to guarantee the delivery of drinkable water for its citizens, a teeming population of more than 140 million people, has contributed to regular Nigerians' widespread reliance on sachet water (Omole et al., 2015). Because of the substantial price difference comparing sachet water and bottle-filled water (Omoniyi and Abu 2012), sachet water is considered as clean and inexpensive by a broad range of consumers (Babatunde and Biala, 2010; Stoler et al., 2012). When sachet water was launched into the Nigerian market, the Federal Government of Nigeria entrusted the sector's regulation to the National Agency for Food and Drug Administration Control (NAFDAC) (Babatunde and Biala, 2010). To accomplish this, NAFDAC established a number of conditions and quality requirements prior to the establishment of sachet water factories (Akunyili, 2003). NAFDAC's development of quality criteria improved public trust in the product, as did demand for the product (Akunyili, 2003: Babatunde and Biala, 2010). Because of the alarming prevalence of dissemination by various sachet water business operators, NAFDAC seems unable to keep up with regulatory obligations throughout the years (Dada, 2009; Omoniyi and Abu, 2012). As the public's desire for sachet water continues to rise, so does the revenue stream from sales (Mojekeh and Eze, 2011). NAFDAC's failure to regulate the sale of sachet water has resulted in the unlawful establishment of factories that produce low-quality sachet water, which is widely available in Nigerian marketplaces (Longe et al., 2012).

Moreover, sachet water production in Nigeria confronts various issues that tend to compromise "quality," failing to satisfy the aim of supplying cheaper potable water to the majority of Nigerians (Obiri-Danso et al., 2003; Dodoo et al., 2006; Addo et al., 2009; Stoler et al., 2012). While affordability and convenience are major considerations, the popularity of sachet water has been mostly driven by municipal water systems' inability to offer consistent quantities of tap water (Stoler et al., 2013). As a result, sachet water has proven to be an appropriate solution for tumbling water scarcity, especially among low-income households (Nyarko et al., 2008).

However, compromises in NAFDAC regulations have caused a decline in the quality of sachet water, which has a detrimental impact on customers. Furthermore, numerous published studies (Akinyemi et al., 2011; Abua et al., 2012; Ackah et al., 2012; Manizan et al., 2011; Fisher et al., 2015; Addo et al., 2016) on the poor quality of sachet water on the market have caused consumers to doubt the product. In Kaduna State, Nigeria, a recent outbreak of waterborne infections (cholera, typhoid fever, and diarrhoea) has been linked to portable water sources, with sachet water being one of the most prevalent source in the area. Therefore, it is against these worries that the authors seek to assess the quality of sachet water brands consumed in Kaduna South LGA, Kaduna State, Nigeria. The brands assessed were those that strictly adhered to operating standards and conditions recommended by regulatory agencies.

The following specific objectives were drawn out in achieving the above aim.

- To analyse the physicochemical and bacteriological parameters of selected sachet water brands sold in Kaduna South LGA.
- To compare these parameters of selected sachet water brands in the study area with NSDWQ and WHO standards.
- To compare the physicochemical and bacteriological parameters among the brands sold in the study area.

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2. METHODOLOGY

This study used a qualitative, quantitative, and descriptive research approach to provide extensive information on the quality and consumers' perception of sachet water consumed in the research area (Robson, 2002; Jupp, 2006). The descriptive research responds to the following questions: who, what, where, when, and how (Saunders et al., 2009).

2.1. Description of study area

Kaduna South is situated on latitude 10°27′42″ N and longitude 07°25′37″ E, at an altitude of 550-700 metres. It shares boundaries with three local government areas: Kaduna North LGA to the north, Chikun LGA the south and Igabi LGA to the northwest, respectively. Its headquarters is in the town of Makera. According to the 2006 population census, Kaduna South had 402,731 people with land area 59km². Based on the 3% growth rate of the 2006 census, population growth was projected to be about 543,600 by 2016. The Kaduna South water treatment facility, which was built in 1927, is unable to fulfil the rising population's needs. For at least 5 years, the water taps have remained dry, with wells and boreholes providing alternatives, as well as purchased water from water vendors for household and commercial usage (Musa et al., 2009). Due to the lack of both quantity and quality of public water supplies, the town has become increasingly dependant on sachet water for consumption.

2.2. Sample of population

The target demographic was made up of individuals from all of Kaduna South LGA's political wards. Because urban wards are believed to drink more sachet water than rural wards, the population size was not evenly distributed among the wards. Consumers of not less than one of the sachet water brands, sachet water as being the most prevalent source of portable water, and individuals/relatives of those afflicted by the disease epidemic were the criteria used to choose the respondents.

The population of this research consisted of 500 respondents from rural and urban areas, cutting across the 12 political wards. Using the statistical formula below, a corrected sample of the population was calculated.

Required sample size

$$n_r = \frac{z^2pq}{d^2} \quad (1)$$

Where: n_r = required sample size

Z, from the gradation curve is the standard normal deviation set with an approximate 90% confidence level = 1.845

P = proportion of the population having a given characteristic. For this case, it is taken to be 45% because most of the respondents are not doing the same task and as such their responses may not likely conform.

q = proportion of the population not having a given characteristic; q = 1-p =1 -0.45 = 0.55= 55%

d = degree of precision or confidence level = ±5%

Therefore, $n_r = \frac{1.845^2 x0.45x0.55}{0.05^2} = 336.998$

Minimum sample size = **337**

Since this proportion is less than 5% of the expected population of 543,600 (Kaduna South LGA), the small population adjustment factor is discarded.

2.3. Sample collection

There are 26 brands of sachet water available in Kaduna South LGA, all of which have been registered by NAFDAC. Ten (10) of the most popular brands were identified and selected from among the 26 brands based on consumers and distributors patronage. A total of 20 samples were gathered directly from manufacturers using random stratified sampling, two from each of the 10 brands of sachet water. The collecting was done in a way that it was evenly distributed among the Kaduna South LGA's political wards.

Following collection, samples were labelled and transferred to the lab in ice packs for physicochemical and bacteriological analyses. The sachet water brands' NAFDAC registration number, manufacture and expiry dates were also examined. Before piercing with a sterile needle and syringe, the water in each sachet was properly mixed and a portion of the sachet wiped with

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cotton wool soaked in ethanol. To comply with some producers' anonymity agreements, brand names are replaced with sample numbers.

2.3.1. Sample handling and preservations

To ensure data quality, proper sample handling and storage is essential. To avoid contamination from hand contact, the samples were obtained and stored in a sterile cooler. If accurate and representative results are to be obtained from the sampling procedures, proper sample preservation is important. To minimise sample degradation, all samples were stored on ice in the dark and analyses were started as soon as possible upon collection.

2.4. Laboratory analysis

A total of 18 water quality indicators were examined using standard procedures recommended by the American Public Health Association (APHA) and the American Society for Testing and Materials (ASTM). pH, temperature, turbidity, conductivity, total dissolved solids (TDS), total hardness (TH), free carbon dioxide (FCD), chloride, nitrate, iron, calcium, carbonate alkalinity, total alkalinity, and bicarbonate alkalinity are the parameters considered. Other tests include general bacteria count, faecal coliform, and coliform MPN. The results of all the parameters were compared to the recommendations of the NSDWQ (2007) and the WHO (2011).

Within six hours of collecting the water samples, the physicochemical analysis was completed. A calibrated Crison pH metre Basic C20 and thermometer were used to determine the pH and temperature of each water sample as soon as it arrived at the laboratory. A DR/2000 spectrophotometer was used to determine the turbidity of the samples (Hach Company, Loveland, Colorado, USA). This is a multifunctional spectrophotometer that has been set up to detect turbidity at a wavelength of 750 nm. The TDS of the water samples were determined using a calibrated Crison conductivity metre Basic C30. The argentometric method was used to determine the chloride content. The sample was titrated using a standard solution of silver nitrate and potassium dichromate as the indicator under neutral circumstances. SPADNS colorimetric approach was used to quantify the level of fluoride ions in each sample (APHA, 2005). The EDTA titrimetric procedure was used to evaluate magnesium, total hardness, and calcium (APHA, 2005). A calibrated DR/2000 spectrophotometer (Hach Company, Loveland, Colorado, USA) set to the wavelength of 450 nm was used to determine sulphate ions. Using a DR/2000 spectrophotometer (Hach Company, Loveland, Colorado, USA), the ions nitrate and phosphate were measured spectrophotometrically.

The Multiple Tube Fermentation /MPN method was utilised for water bacteriological analysis. In this approach, 100 mL of water was collected from each sachet and sterilised into bottles of double strength MacConkey broth, which included an upturned Durhams tube for gas collection and monitoring. This was cultured aerobically at 35°C for 18 to 24 hours. This was the preliminary test for total coliform. After 37°C incubation, the number of bottles in which lactose fermented with acid and gas production occurred was counted. Lactose ferment and acid development were confirmed by a change in the colour of MacConkey broth from purple to yellow, while gas production was indicated by the displacement of broth in the durhams tube with a bubble. In the confirmatory test for faecal coliform, a loopful of broth from the positive tubes in the preliminary test was transferred into elevated coliform broth and incubated at 44.5°C for 24 hours. After 24 hours, the tube's gas production was positive. There was no gas production in any of the tubes after incubation at 44.5°C, while streaking a loopful of the broth on Mac Conkey plate and incubating at 35°C for 18 to 24 hours yielded no growth. Using probability tables, the most likely number of coliforms in the 100 mL water sample was determined. Positive presumptive test tubes were grown on MacConkey plate and aerobically incubated at 35°C for 18 to 24 hours. The isolates were subsequently identified by colonial morphology, gramme stain, motility, and biochemical tests.

3. RESULTS AND DISCUSSION

Figure 1 shows the demographics of respondents. The high number of female respondents observed (55 percent) is attributed to the fact that the surveys were distributed in residential areas where women were often present during contact time. The population size was dominated by respondents aged 31 to 40 years. In terms of marital status, single respondents were far ahead of married respondents. However, this is because respondents in Nigeria between the ages of 31 and 40 are either married or live independently in their apartments.

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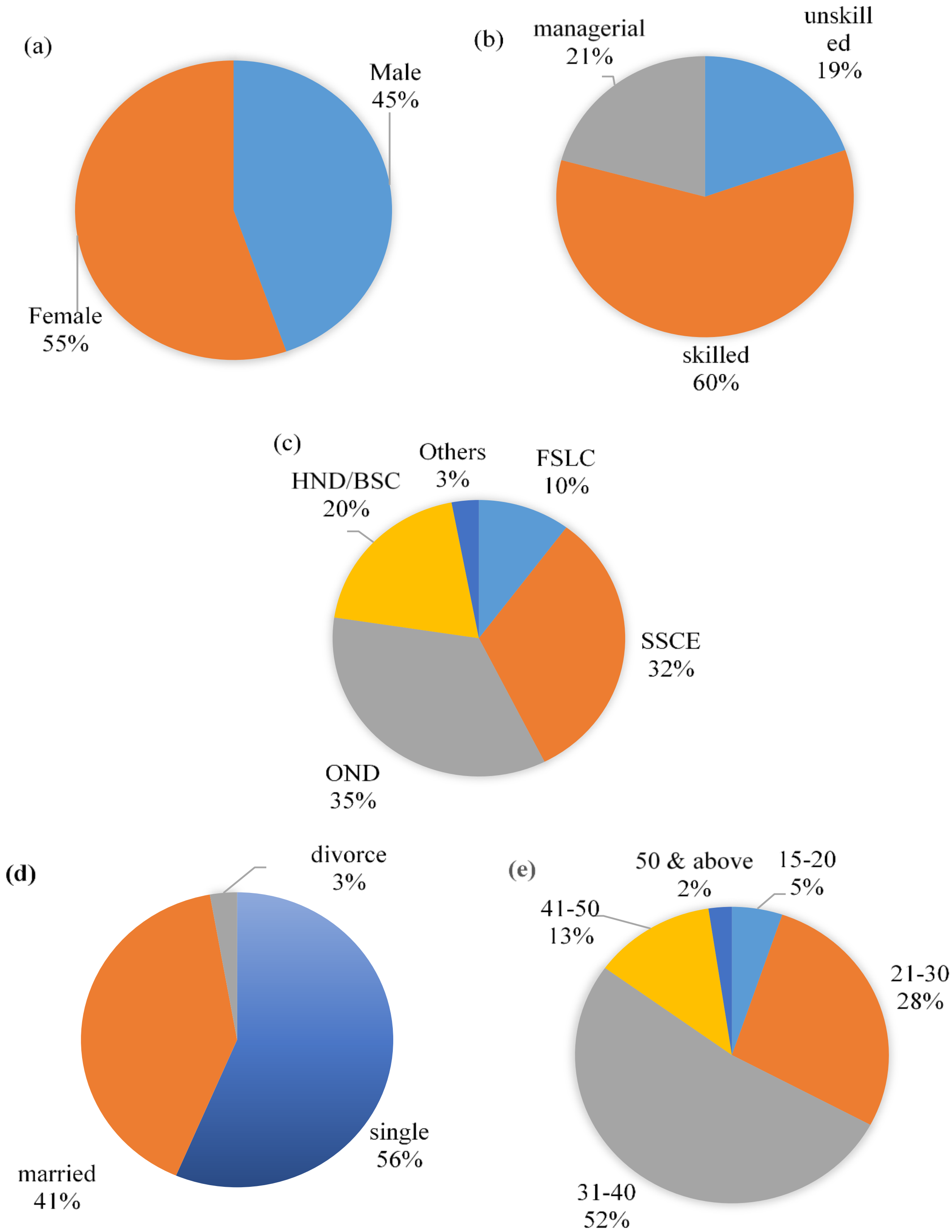

Figure 1: Respondents Demographics

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Table 1 displays respondents' views on the status of packet water consumption in Kaduna South LGA. The results show that respondents patronise sachet water, showing the government's inability to provide portable water to its residents, as reported by Dada (2009). According to the survey, they consume it on a daily basis, with the majority of them consuming between 5 and 8 sachets each day. They go on to say that they use this source as drinking water since it is inexpensive and readily available. This shows that the vast majority of respondents are sceptical of its quality and are hesitant to consume it. This might be related to some producers' poor production practises, which may jeopardise the product's quality. (Stoler et al., 2012). In accordance with the recent outbreak of waterborne diseases in the study area, survey results reveal that typhoid fever, diarrhoea, and cholera are common types of waterborne diseases that are either directly linked to the respondents or their close relatives.

Table 1: Status of sachet water consumption

Sachet Water Consumption		
S/N	**ITEMS**	**RESPONDENTS**
1	Yes	500
2	No	0
Frequency of sachet water consumption		
3	Daily	500
4	Weekly	0
5	monthly	0
Daily frequency of sachet water consumption		
6	1 – 4 sachets	188
7	5 – 8 sachets	209
8	9 – 12 sachets	103
Reasons for sachet water consumption		
9	Quality/hygienic	91
10	Affordable	246
12	Availability	163
Skeptical sachet water quality		
13	Yes	289
14	No	211
Prevalent waterborne diseases in the area		
15	Cholera	112
16	Typhoid fever	202
17	Diarrhea	186

Table 2 shows the results of laboratory analyses (physicochemical and bacteriological) on all the sachet water brands. The pH of all the samples tested in the study area ranged from 4.1 to 6.78, signifying acidic or neutrality. The findings differ significantly from those of a similar study done by Joshua et al. (2019) in Kaduna State's Sabon Gari LGA. Their pH levels varied from 7.45 to 8.39, indicating a neutral pH. The pH of the sachet water measured by Uduma (2014) in Kano city, on the other hand, ranged from 4.2 to 8.5, indicating acidic, neutral, and slightly alkaline conditions. The sachet water samples had ionic conductivity ranging from 73.6 to 94.4s/cm. The sachet water samples' TDS distribution was skewed toward a high frequency of low concentration. The total hardness of the samples ranged from 10 to 122.2mg/l. These findings contradict Uduma's investigation (2014). His samples had greater conductivity, TDS, and total hardness values and concentrations than the present study. Laboratory studies of all sachet water samples indicate increased chloride contents (18.99 – 57.98 mg/l), iron (0.01 – 0.18 mg/l), calcium (6 – 40 mg/l), and sulphate (3 – 13 mg/l). Yusuf et al. (2015) reported higher concentrations of chloride and calcium in sachet water samples in Zaria, Kaduna State, than the levels observed in this research. The bacteriological investigation confirms that there is no sign of Faecal coliform or MPN coliform in any of the samples. The concentration of General bacteria count, on the other hand, was recorded in all samples and ranged between 2/ml and 4/ml. Bahago et al. (2019) discovered a significant concentration of Faecal coliform (32-78/100 CFU) in all of the samples they tested in a similar study conducted in Kaduna metropolis.

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Table 2: Results of physiochemical and bacteriological analysis

S/N	Samples/ Parameters	Units	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	Sample G	Sample H	Sample I	Sample J	NSDWQ/ WHO limits
1	pH	-	5.5	6.8	6.7	6.7	5.7	5.7	4.1	4.1	6	5.8	6.5-8.5
2	Temperature	^{o}C	25	25	25	25	25	25	25	25	25	25	12-25
3	Turbidity	NTU	3.16	2.8	3.9	3.22	2.18	2.9	3	3.18	2.86	2.72	0-5
4	Conductivity @ 25 ^{o}C	µ/cm	84.9	79.2	85	77.3	73.6	68.1	94.4	88.6	93.1	84.8	1000
5	TDS	mgL^{-1}	44.57	41.68	44.73	40.68	38.73	35.84	49.68	46.43	49	44.66	500
6	TH $CaCO_3$	mgL^{-1}	48	122.22	30	40	20	10	10	12	16	16	150
7	FCD	mgL^{-1}	32	34	28	20	20	30	30	30	20	28	-
8	Chloride	mgL^{-1}	31.99	27.99	34.99	27.99	57.98	28.99	32.99	22.99	27.99	18.99	250
9	Nitrate	mgL^{-1}	0	0	0	0	0	0	0	0	0	0	50
10	Iron	mgL^{-1}	0.03	0.01	0.04	0.02	0.08	0.05	0.18	0.04	0.05	0.02	0.3
11	Calcium	mgL^{-1}	30	40	28	14	18	6	8	16	14	18	10-200
12	Carbonate Alkalinity	mgL^{-1}	0	0	0	0	0	0	0	0	0	0	-
13	Sulphate	mgL^{-1}	5	5	8	3	13	0	5	7	5	3	-
14	Total Alkalinity	mgL^{-1}	12	12	26	16	14	10	12	24	16	16	-
15	Bicarbonate Alkalinity	mgL^{-1}	12	120	26	16	14	10	12	24	16	12	-
16	General bacteria count		3	2	3	4	3	4	3	4	2	3	500/ml
17	Faecal coliform	1/100 CFU	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0
18	MPN of coliform	MPN/ 100ml	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0

Table 2 further compares the water quality indicators of sachets marketed in Kauna South LGA to those of national (NSDWQ) and international (WHO) agencies. The pH range of the sachet samples was greater (4.1 – 6.8). The pH values of 70% of the brands marketed in the region were not within the WHO and NSDWQ permissible limits for drinking water. The results of the investigation also reveal that the sulphate levels in all ten sachet water brands tested were within the permissible limits set by both standards. Interestingly, the concentrations of the remaining 16 water quality indicators in all the brands analysed were in line with the standard values recommended by WHO and NSDWQ for temperature, turbidity, conductivity, TDS, total hardness, free carbon dioxide, chloride, nitrate, nitrate, iron, calcium, Carbonate Alkalinity, Total Alkalinity, Bicarbonate Alkalinity, General bacteria count, Faecal coliform, and MPN of coliform. Microorganisms or pathogens in water are responsible for waterborne disease. According to laboratory data, the concentrations of microorganisms in all water samples were zero, indicating that there was no sign of waterborne disease pathogens. The relevance of this conclusion is that the manufacturers of these brands of water acquire raw water from reliable sources and adhere to government-mandated criteria.

Figures 2A–2M provide a comparison of sachet water quality across different brands. The results show that there is variation across the brands in all 18 water quality measures. There was no discernible pattern to the variation.

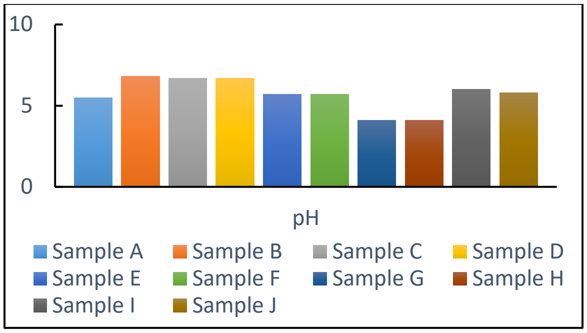

Figure 2A: comparison of pH

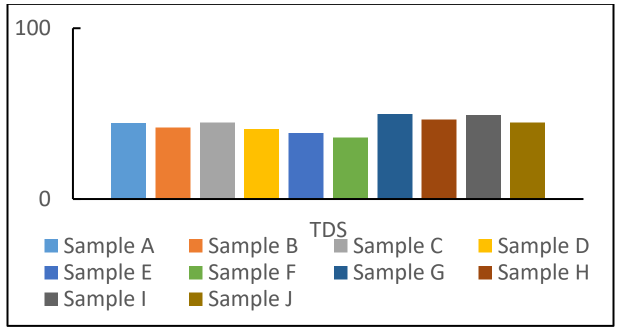

Figure 2B: comparison of TDS

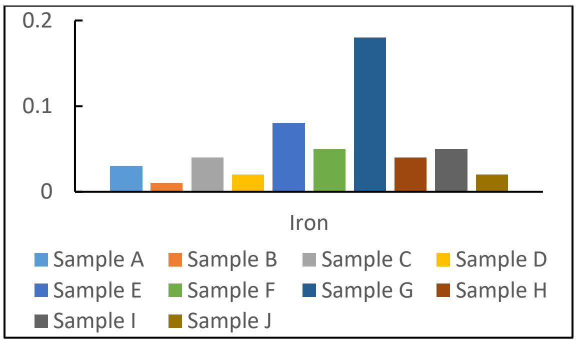

Figure 2C: comparison of Iron

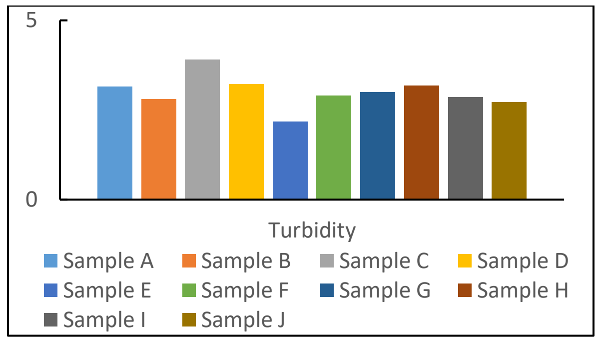

Figure 2D: comparison of Turbidity

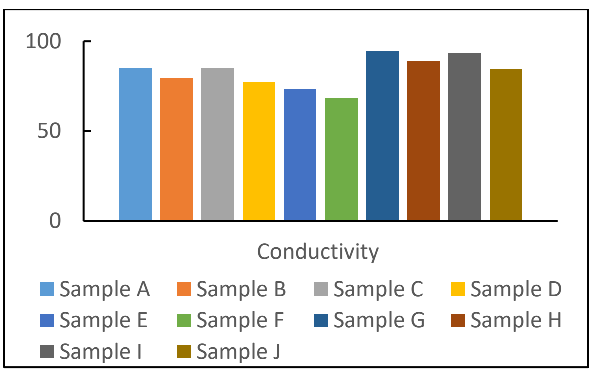

Figure 2E: comparison of conductivity

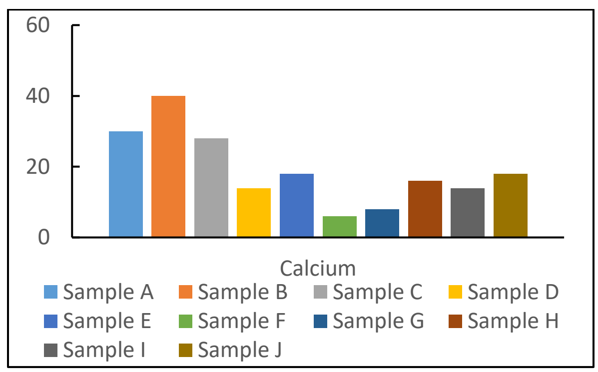

Figure 2F: comparison of calcium

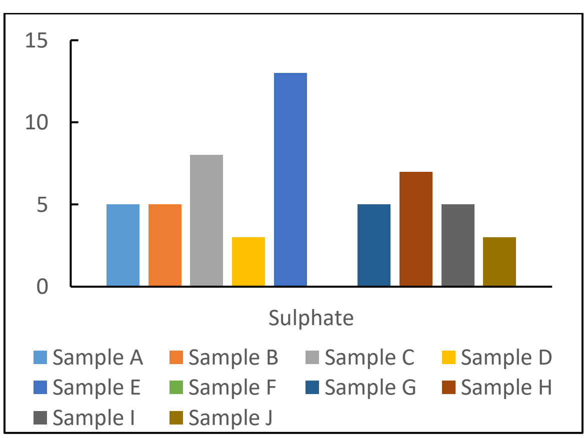

Figure 2G: comparison of Sulphate

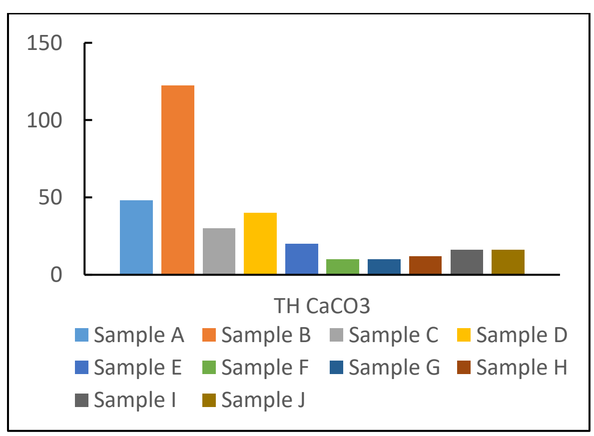

Figure 2H: comparison of $CaCO_3$

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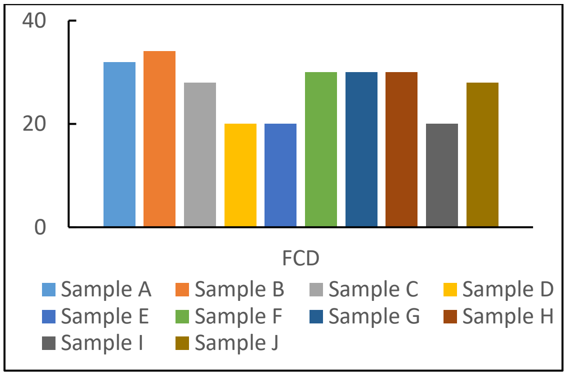

Figure 2I: comparison of FCD

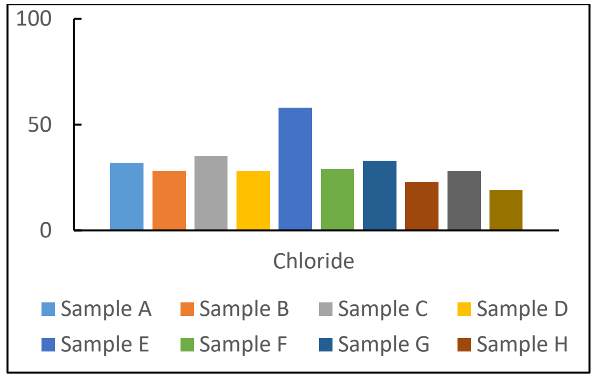

Figure 2J: comparison of chloride

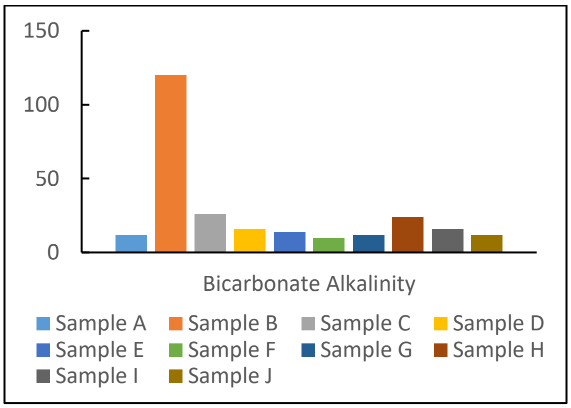

Figure 2K: comparison of bicarbonate Alkalinity

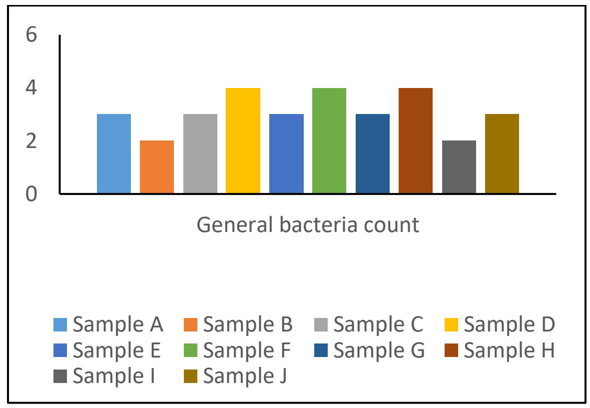

Figure 2L: comparison of general bacteria count

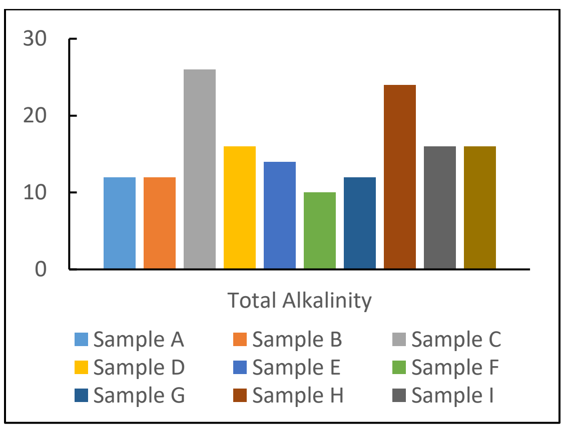

Figure 2M: comparison of total Alkalinity

4. CONCLUSION AND RECOMMENDATIONS

Epidemics of waterborne diseases can emerge as a result of widespread production and use of improperly treated or polluted packaged water. To protect public health, it is critical that accessible packaged water be properly registered and analysed on a regular basis. The results of the studies show that, of the eighteen (18) water quality indicators tested, only one (pH) was not within the permissible level in portable water, as suggested by the NSDQW and WHO. The pH readings of seven different sachet water brands marketed were not within acceptable limits. In contrast, the presence of pH concentrations beyond the NSDWQ/WHO allowed limit in certain sachet water may be hazardous to one's health. A pH value lower than the WHO maximum allowed range (6.5) reduces disinfection efficacy and may have an indirect impact on human health. Low pH concentrations in drinking water, on the other hand, are unrelated to waterborne ailments such as typhoid fever, cholera, and diarrhoea. As a result, the recent outbreak of waterborne diseases in Kaduna South LGA is not the result of drinking sachet water from brands with NAFDAC, production, and expiration dates because these brands adhere to the conditions and quality criteria established by NAFDAC for setting up

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sachet water factories. Finally, with NAFDAC's incapacity to keep up with regulatory demands owing to the increasing rate of proliferation by various sachet water business operators. Further research to assess the quality of sachet water brands without NAFDAC registration number, production dates, and expiration dates is therefore recommended.

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Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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