Quality Assessment of Selected Sachet Water Brands Marketed in Owo, Akure and Ondo Areas of Ondo State, Nigeria

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ABSTRACT

Sachet water in Nigeria, popularly called pure water is the most ubiquitous commercially packaged water in the country. As a result, they are cheaper and vended in several locations such as motor parks, markets, hospitals road sides, outskirt of schools and streets. Given the threat of potential health risk, there is therefore need to periodically ascertain its water safety qualities (physical, chemical and microbial) to protect public health. This study focuses on ascertaining the quality of selected Sachet water brands in 3 major areas of Ondo State namely Akure, Owo and Ondo metropolis. Sampling 100 retail outlets to inquire about the top 5 most consumed sachet water brands from each area which were subjected to analysis. The results showed that the sachet water samples had good aesthetic value as all the brands of sachet water evaluated met the recommended WHO standard for appearance, colour, odour and turbidity. Thirteen of the sachet water samples had pH values between 6.5 - 7.6 which met the limit described by WHO while the other three samples had pH value below 6.5 and did not fall within WHO drinking water standard. Other physico-chemical characteristics of all the brands of water evaluated such as electrical conductivity, total dissolved solid, chloride, magnesium, calcium and Nitrate were within the acceptable limits recommended by WHO for quality drinking water except for their chemical oxygen demand properties which was >10mg/L described by WHO. Two samples had values higher than the recommended 100mg/L for total alkalinity. The concentration of metals; Pb, As, Cr and Mn was not detected in all the water samples, however, Zn, Fe, Cd and Cu were found in some samples in values slightly higher than the value described by WHO for quality water in all the 3 locations. Results of the microbiological analyses further shows that all the brands of water had zero MPN/100mL count for coliforms except for only three brands with values higher than the 0 MPN/100 mL maximum limits recommended by WHO. Only two brands of the sachet water samples had value (113CFU/mL) above the 102 CFU/mL described by WHO for aerobic mesophilic count. This study suggests that maximum and effective treatment technique/method should be adopted by the water manufacturing industries to reduce or totally eradicate water-borne diseases.

KEYWORDS: *Sachet Water; Ondo State; Water Quality; Physical properties; Chemical Properties; Microbiological Properties.*

1. Introduction

Man's dependence on water cannot be over-stressed, as it remains a matchless natural resource needed for the upkeep of metabolic activity in the human body. Its use is also extended to agricultural production, industrial production as well as domestic use (Akoteyon *et al.*, 2011**;** Nwankwoala and Nwagbogwu, 2012; Subramani *et al.*, 2012). However, the availability of water for these different purposes has been a major concern throughout the world especially in developing countries, where water resources are poorly managed. In developing countries, the portability and availability of drinking water is a far cry from world accepted standard. For instance, (WHO/UNICEF, 2004) reasonable access to quality water means at least 20 liters/person/day accessibility within 1 km to individual homes. This is however far from reality as about one-sixth of human population on earth does not have access to safe drinking water (Amoo and Akinbode, 2005). Also, report by WHO (2004), indicates about 1.1 billion individuals do not have access to improved water supply in 2002 and about 2.3 billion people suffer from water-borne disease.

Thus, the need for safe and accessible drinking water becomes a priority for the global world. Most urban-rural communities in the developing countries of the Sub-Saharan Africa have access to surface waters (rivers, streams, and lakes among others) which is the most available sources of water used for domestic purposes. Water from these sources is often contaminated by domestic, agricultural, and industrial activities and likely to cause water related diseases (Ojekunle, 2000; Ayeni *et al.*, 2009; Dimowo, 2013). Depending on the source of water and level of unhealthy anthropogenic activities, biological contaminants such as bacteria, virus, protozoa; chemical contaminants such as heavy metal, pesticide residue, organic matter etc. varies in composition. Today, research reveals that polluted water kills more people than cancer, AIDS, wars, terrorism or accidents. It is therefore pertinent that the water meant for human consumption be free of disease-causing agents and toxic chemicals, which are capable of posing threat to human health (Hughes and Koplan, 2005; Prasanna and Reddy, 2009).

Worsening this situation, treated drinking water in Nigeria (popularly sold in sachet and bottled water) (Yusuf *et al.*, 2015) are not spared from these contaminations. The production of these water requires two important raw materials; water source (which is usually borehole) and the packaging materials usually nylon and PET bottles. And are popularly referred to as "pure water" and "ragolis water" respectively by the general public. This water products, although commercially treated, packaged and distributed for sale to the public, are unsafe (Denloye, 2004). They are often sold in car parks, road sides, markets and various supermarkets and drink stores. However, there are number of reported cases of typhoid, diarrhea and other water borne diseases arising from consumption of sachet water (Ogamba, 2004). Water-borne diseases such as cholera, typhoid fever and hepatitis have been reported, some of which had led to acute health conditions and even death. The integrity of these sachet waters is therefore doubtful and many report abounds of how most vendors do not adhere to national regulations (NAFDAC) on sachet waters hygiene and production before sales to the public (Oladipo *et al.*, 2009). This has however raised the concern for public health workers, governmental agencies and concerned individual (Oladipo *et al.*, 2009) within the Country. Everyday more cases of water-borne disease is also being constantly reported and treated and the more the growing concerns about its purity (Oladipo *et al.*, 2009).

Following the public concerns raised as a result of the poor qualities of drinking water in Ondo state, Nigeria, in light of the increasing number of people in the urban and suburban part of the state tending to consume more of sachet "pure water" as it was seen to be the best treated water they can access for drinking. As a result, this research seeks to assess the drinking water quality and characteristics of sachet water manufactured in Ondo state with case studies of Akure, Owo and Ondo town. These will be done by assessing the physical, physicochemical, heavy metal composition and microbiological properties of sachet water for human consumption within Ondo state.

2. Materials and Methods

2.1 Description of Study Area(s)

Ondo state is located in southwestern part of Nigeria located within coordinate 7^0 10'N 5^0E / 7.167^0 N 5.083^0 E. This study was carried out on 15 different sachet water brands in three major local governments in Ondo State. The three major area (location) studied includes; Owo, Akure and Ondo town. Owo is located about 45 kilometers east of Akure, the Ondo State capital and lies on latitude 7°15' North of the Equator and longitude 5°35' East of Greenwich Meridian. It is placed about 348 metres above sea level and has a population of 276,574 people (2006 census). Akure lies on latitude $7^0 15'$ North of the Equator and on longitude $5^0 11'$ East of the Greenwich meridian. Akure is the capital of Ondo state (largest city) with a population of about 484,798 people according to National Population Census of 2006 and it stands at the altitude of about 353 meters above the sea level. Ondo Town is the third most populated local government in Ondo State and is located southwest from Akure about 47.8Km away and lies in latitude $7^0 15'$ North of the equator and longitude $4^0 50'$ East of the Greenwich meridian. It is situated 263metres above sea level with a population of 358,430 people (2006 census).

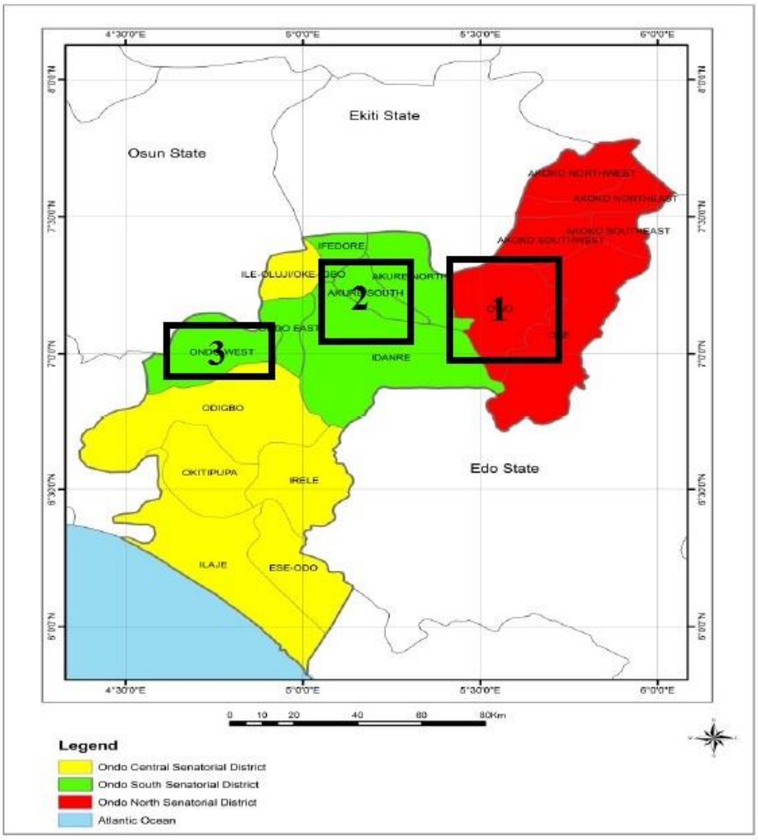

Figure 1: Map of Ondo state Showing Study Areas 1(Owo), 2 (Akure) and 3 (Ondo)
Source: Ondo State Ministry of Housing and Urban Development, Akure (2015)

2.2 Sample Collection

A total of 15 sachet water brands were sampled with 5 from each of the three locations (Owo, Akure, Ondo). Each of the brands was selected based on a survey of 100 randomly selected retailers from each study area. From this survey, the first five (5) most patronized sachet water products were selected for study from each area. The samples were analyzed for their physical, chemical (including heavy metals) and microbiological properties. Samples for metal analysis were preserved with few drops of HNO_3 likewise samples for microbiological analysis were collected in a sterile autoclave bottle (temperature between 0-10^{0}C).

Table 1: Sample Code and Name

Akure		Owo		Ondo	
Sample Code	**Brand Name**	**Sample Code**	**Brand Name**	**Sample Code**	**Brand Name**
A1	Glazzy Water	**B1**	Oyin water	**C1**	Hotis water
A2	Omitab Water	**B2**	Rugipo water	**C2**	B.mor water
A3	Fearon Water	**B3**	Ibiloye water	**C3**	Fade-olu water
A4	DPC Water	**B4**	Prayer water	**C4**	First value water
A5	Amuye Water	**B5**	Adreeb water	**C5**	Datisam water

2.3 Physical and Chemical Analysis of Samples

The physicochemical examination of the water samples were completed within six hours of sample collection. The pH of each water sample was determined immediately after receiving the sample at the laboratory using a calibrated handheld pH meter (Techmel and Techmel USA). The colour and turbidity of each sample was measured with a digital spectrophotometer. A calibrated conductivity meter was employed for the determination of the Conductivity of the water samples. Other chemical analyses of the samples such as TDS, Total Alkalinity, Total Hardness, Chloride, COD, Calcium, Magnesium, and Nitrate were done using methods specified in APHA (2005).

2.4 Digestion of Sample and Heavy Metal Analysis

All glass apparatus used were rinsed with dilute acid (10% HCl) and washed many times with distilled-deionized water to ensure no metal contaminants were introduced. 100ml of water sample was measured into a clean 250mL conical flask and 10mL of the concentrated nitric acid was added. The mixture was boiled slowly and then evaporated to the lowest possible volume (about 25mL) on a hot plate placed in the fume cupboard. The remaining volume of solution after heating was filtered into a 100 mL standard flask and made up to the mark with distilled water. The concentrations (in *mg/L*) of eights metals Zn, Pb, Fe, Cd, Cr, Mn, As and Cu were determined in the samples by atomic absorption spectrophotometry, AAS (Buck Scientific Model 210VGP).

2.5 Microbiological Analysis

The total coliform was estimated according to the method described by Chatterjee *et al*., (2007) using the 5-tube most probable number method. Other microbiological properties were conducted by multiple tube fermentation tests described in APHA (2005) and Manish and Abhishek, (2016).

3. Results And Discussion

3.1 Physical Properties

The quality of water is first judged by it physical properties, which further determines its acceptability by consumers for direct consumption (Adekunle, *et al*., 2007). Physical or Organoleptic properties like appearance, colour, odour and turbidity are often used in water purification plants to give a firsthand examination of its aesthetic and approximated degree of contamination. From literature, water safe for drinking is expected to be clear, colourless and odourless. These physical parameters are however subjective and dependent on appropriate human sense organ (FSSAI, 2015). Table 2 gives a detailed description of the physical (organoleptic) properties of the sachet water brands. However, alteration to this parameter signifies contamination by external matters present in it. The results of physical properties for all the sachet water samples evaluated met the recommended WHO standards for quality drinking water for appearance, colour, odour and turbidity. This showed that the water sample has good aesthetic value.

Table 2: Result of Physical Properties

	Appearance	Colour (TCU)	Odour	Turbidity (NTU)
WHO	CLR	CLS	ODL	5
A1	CLR	CLS	ODL	ND
A2	CLR	CLS	ODL	ND
A3	CLR	CLS	ODL	ND
A4	CLR	CLS	ODL	ND
A5	CLR	CLS	ODL	ND
B1	CLR	CLS	ODL	ND
B2	CLR	CLS	ODL	ND
B3	CLR	CLS	ODL	ND
B4	CLR	CLS	ODL	ND
B5	CLR	CLS	ODL	ND
C1	CLR	CLS	ODL	ND
C2	CLR	CLS	ODL	ND
C3	CLR	CLS	ODL	ND
C4	CLR	CLS	ODL	ND
C5	CLR	CLS	ODL	ND

† Key: A1 – C5 (Different Samples); CLS (Colourless); CLR (Clear); ODL (Odourless): ND (Not Detected): TCU (True Colour Unit): NTU (Nephelometric Turbidity Units); WHO 2006

3.2 Physico-Chemical Properties

The pH for sample water can change depending amount dissolved gases such as carbon dioxide, hydrogen sulphide and ammonia, as well as inorganic matter dissolved in it. Pure water should have a pH of 7.0. However, this is far from reality due to impurities and ability of water to dissolve matter and organic salt around it. Natural water can be either slightly acidic or slightly alkaline (Alexander *et al.*, 2019). From the result in Table 3, all the samples analyzed has values within the recommended limit (6.5-8.5) described by the WHO standard for quality drinking water except for samples A5 (6.40), C3 (6.20) and C5 (6.20) which has pH values slightly below the recommended limit and there is a slight significant difference in the means of the samples between and within study areas i.e. $p>0.05$. More generally, the pH values reported for Owo, Akure and Ondo lies between 6.60 – 7.60, 6.40 – 7.60 and 6.20 – 7.00 respectively. This implies that the underground soil in the study areas specifically Ondo is slightly acidic and as such the packaging and/or the treatment process may alter the water pH slightly. Their acidic nature may be due to poor sanitation and domestic effluent discharge that percolates into the ground of the area. They are also likely to be associated with the erosion of loamy and clayey soils from cultivated fields that increase the concentration of ions.

Conductivity is a faster and reliable method of controlling and monitoring water treatment. It gives the idea about ionisable materials in water (Alexander *et al.*, 2019). It affects all aspects of water treatment and suitability of specific application (Ogundipe, 2015). The result in Table 3 reveals that all the analyzed sachet water brands possesses EC values ranging from 60.8µmho/cm to 353.0µmho/cm which is within the acceptable limit of 1000µmho/cm described in the manual for quality drinking water by WHO. There is a huge significant difference in the means of the samples between and within study areas i.e. $p>0.05$. However, literature has it that long term consumption of treated sample water with EC > 40µmho/cm can lead to high probability of fracture in children, pregnancy disorder, diuresis and increased tooth decay (Guler 2007).

Total Dissolved Solid (TDS) is a measure of the total amount of dissolved substances in the water sample. According to Olusiji and Adeyinka, (2011), high levels of TDS can lead to gastro-intestinal irritation and stains to fabric. Drinking water containing TDS levels above 500mg/L usually has a disagreeably strong taste (Apau *et al*., 2014) and generally indicates hard water, which can cause scale buildup in pipes, valves and filters (Nsiah and Boakye, 2015). As seen in Table 3, the TDS (Total Dissolved Solid) obtained for the analyzed samples ranges from (42.0 – 247.0 mg/L) which are within the WHO reference standards. However, there is a huge significant difference between and within the means of samples in the study areas i.e. $p>0.05$.

Alkalinity is a measure of the acid-neutralizing capacity of water. In most natural waters, it is due to the presence of carbonate (CO_3^-), bicarbonate (HCO_3^-), and hydroxyl (OH^-) anions. However, borates, phosphates, silicates, and other bases also contribute to alkalinity if present (Wilson, 2010). The result obtained for all the sample are within the WHO acceptable limit except for sample A3 and B5 with values (128.8 mg/L) and (114.5 mg/L) respectively which are slightly above the recommended limit (100 mg/L). The high TA values observed in B5 may be due to deposits or contamination during treatment. However, the values observed in samples from Akure are between 86.5 – 128.8 mg/L which may be due to the basic nature of the soil in the area. There is no significant difference in the means of the samples between and within the study areas i.e. $p<0.05$.

Total hardness which measure the concentration of multivalent metallic cations (majorly Ca^{2+}, Mg^{2+}) in water; can serve as source of dietary Calcium and Magnesium to the body (Alexander *et al*., 2019). As indicated in Table 3. Sample A3 has the highest TH value (122 mg/L) which is above the recommended limit prescribed by WHO and correlates well with the high value (247mg/L) observed in TDS of the sample which is could cause clogging in pipes and rusting for plants. However, all other samples have values which are within the 100mg/L recommended by WHO. There is no significant difference in the means of the samples between and within the study areas i.e. $p<0.05$.

Chlorides are found naturally in the environment, but elevated levels of chloride can also be associated with septic system effluent, storm water runoff, brine water, cleaning solutions, and other industrial solutions (Mandal *et al* ,2011; WHO, 2006). Increase in chloride concentration in conventional water treatment plant is due to the amount of free chloride after chlorination. The result shown in Table 3 depicts that the values (14 – 56 mg/L) obtained in all the samples met the requirement of 100mg/L described by WHO for chloride concentration in drinking water. However, Nitrate was not detected in all the sample except for B3, B4, C1 and C3 whose values are also within the 50 mg/L described by WHO for Nitrate concentration in drinking water. The presence of nitrates in a water sample could be due to inorganic fertilizers, plants and animal decomposition and wastes which may have percolated the soils over time (Ademoroti, 1996). The low values of nitrate and chloride as shown in Table 3 could be due to the fact that soluble particles that are chemical in nature could be well distributed in the body of the water and possibly interact with the water molecules in a form that storage for one week may not have significantly affected the concentration in the body of water. However, no significant difference was observed in the means of the samples between and within the study areas i.e. $p<0.05$.

The values obtained for magnesium for all the samples analyzed ranged from 3.2 mg/L to 12.8 mg/L which are within the limit (30mg/L) described by WHO for quality drinking water. A slight significant difference was observed in the means of the samples between and within the study areas i.e. $p<0.05$. However, high concentrations of Mg can cause consumer unacceptability when used in productions.

The Chemical Oxygen demand for all the sachet water brands studied in all the three areas are observed to be above WHO standard of 10mg/L except for some few cases of A1, A4, A5, C3 and C4 in which COD was not detected. As a result of high value of COD, samples from the 3 studied areas might have a lower shelf life as there are more chemicals in sample competing for oxygen (Oko *et al.,* 2015).

Table 3: Result of Physico-Chemical Analysis

	pH	EC (µmho/cm)	TDS (mg/L)	TA (mg/L)	TH (mg/L)	Chloride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Nitrate (mg/L)	COD (mg/L)
WHO	6.5-8.5	1.0×10^3	500	100	100	100	75	30	50	10
A1	6.80	143.1	100.1	90.9	84.6	46	20.8	12.8	ND	ND
A2	7.40	136.5	95.4	98.2	66.1	45	21.6	4.8	ND	48
A3	7.60	353.0	247.0	128.8	122.0	56	30.4	18.4	ND	64
A4	7.20	152.3	106.8	86.5	82.0	34	29.6	3.2	ND	ND
A5	6.40	143.9	89.4	90.6	78.0	32	20.8	12.8	ND	ND
B1	6.80	107.4	75.2	28.8	30.4	34	7.2	4.8	ND	42
B2	6.80	167.4	117.2	86.3	68.2	31	16.8	10.4	ND	64
B3	6.60	170.6	119.3	44.8	58.7	30	14.4	8.8	0.12	32
B4	7.60	123.8	86.4	66.4	40.9	31	8.8	7.2	0.08	64
B5	7.60	169.1	118.3	114.5	40.0	14	12.8	3.2	ND	64
C1	7.00	173.0	121.6	82.1	52.2	32	11.2	9.68	0.05	96
C2	7.00	119.3	83.3	52.3	34.1	32	11.2	2.48	ND	160
C3	6.20	286.5	200.2	66.4	86.4	43	24.8	9.64	0.12	ND
C4	6.80	89.5	62.1	36.9	30.7	29	7.2	4.87	ND	ND
C5	6.20	60.8	42.0	26.0	26.3	28	ND	10.41	ND	128

† Key: A1 – C5 (Different Samples); ND (Not Detected); EC (Electrical Conductivity); TDS (Total Dissolved Solids); TA (Total Alkalinity); TH (Total Hardness); COD (Chemical Oxygen Demand); WHO 2006.

3.3 Heavy Metal Properties

For this study, four (4) essential micronutrient nutrients (Mn, Fe, Cu and Zn) with significant nutritional value (Alexander *et al.*, 2019) was studied alongside four (4) toxic heavy metals (As, Cr, Pb and Cd). Large dose of these metals is known to have adverse contribute to the taste of water and further lead to acute or chronic health condition (Ibrahim *et al.*, 2015).

As shown in Table 4, metals such as manganese, chromium, arsenic and lead were not detected in all the sachet water brands across all the three areas of study, which further indicate that the water samples in those areas are free from heavy metal contamination capable of causing chronic health challenges. Significantly the Cadmium concentration (0.036 – 0.199 mg/L) for all water brands in Akure is alarming exceeding the 0.003 mg/L allowance limit described WHO for quality drinking water and as a result, consumers in Akure are exposed to chronic health risk from cadmium toxicity. However, cadmium was not detected in water brands from Ondo and Owo except for B5 (0.111 mg/L) which could pose danger to consumers as a result of health risk due to cadmium toxicity.

Other common metals like Iron, Zinc and Copper are found and can serve as dietary supplement given that they are significantly present in nutritionally significant concentration in packaging plant. Iron is found at lower concentration ranging from 0.01 mg/L to 0.04 mg/L less than the recommended 0.3mg/L described by WHO for samples A1, A5, B1, B2, and C1 but not detectable in other samples. This implies that there is no significant health risk in the samples in comparison to permissible standard used. The concentrations detected for Cu and Zn in some of the samples from the three study areas shown in Table 4 are less than 1 mg/L and 3 mg/L for copper and zinc respectively, as prescribed by WHO for quality drinking water. This implies that the samples are acceptable as they pose no risk to human health. However, water containing zinc at concentrations in excess of 3–5 mg/L may appear opalescent and develop a greasy film on boiling. Although drinking-water seldom contains zinc at concentrations above 0.1 mg/L, levels in tap water can be considerably higher because of the zinc used in older galvanized plumbing materials (Gordon *et al.*, 1996).

High concentrations of Iron, Zinc, and Copper can affect the acceptability of drinking water, and should be given adequate priority during processing (WHO, 2006). Ibrahim *et al.*, (2015) and Alexander *et al.*, (2019) reported that large doses of the aforementioned metals causes diseases such as kidney damage, liver cirrhosis, lethargy, gastrointestinal disorder, headache, sleeplessness, and leg weakness.

Table 4: Result of Heavy Metal Analysis

	Mn (mg/L)	Fe (mg/L)	Cr (mg/L)	Zn (mg/L)	Cu (mg/L)	As (mg/L)	Pb (mg/L)	Cd (mg/L)
WHO	0.5	0.3	0.05	3	1.0	0.2	0.1	0.003
A1	ND	0.01	ND	ND	ND	ND	ND	0.199
A2	ND	ND	ND	ND	ND	ND	ND	0.036
A3	ND	ND	ND	ND	0.332	ND	ND	0.052
A4	ND	ND	ND	ND	ND	ND	ND	0.128
A5	ND	0.01	ND	ND	ND	ND	ND	0.100
B1	ND	0.04	ND	0.13	0.015	ND	ND	ND
B2	ND	0.01	ND	0.218	ND	ND	ND	ND
B3	ND	ND	ND	0.157	0.011	ND	ND	ND
B4	ND	ND	ND	0.023	0.284	ND	ND	ND
B5	ND	ND	ND	0.146	0.310	ND	ND	0.111
C1	ND	0.01	ND	ND	0.424	ND	ND	ND
C2	ND	ND	ND	0.182	0.086	ND	ND	ND
C3	ND	ND	ND	0.240	0.005	ND	ND	ND
C4	ND	ND	ND	0.396	ND	ND	ND	ND
C5	ND	ND	ND	0.240	ND	ND	ND	ND

† Key: A1 – C5 (Different Samples); ND (Not Detected); WHO 2006.

3.4 Microbiological Properties

Far more dangerous is the presence of disease causing pathogens in water. High microbial load is attributed to poor sanitation in the water treatment process or ineffectiveness in the water treatment process. Consequently, WHO recommends 0 cfu/100 ml for treated water. To further assess the safety of marketed product within the three study areas and on the sachet water brands. The presence of coliform indicates the risk of water-borne diseases (Alexander *et al.*, 2019) is used. As shown in Table 5, B3 (8 MPN/100mL), C2 (6 MPN/100mL), and C4 (15 MPN/100mL) has a high most probable number and violates the 0 MNP/100mL described by WHO thus making it unfit for consumption. Hence potential risk is associated with the consumption of such treated water. Moreover, no coliform was detected in samples from Akure and some samples in Owo and Ondo. This speaks quality of the safety of this sold water product as they are exactly to the zero specification laid down by WHO. As coliform test is not a confirmed quality indicator, it is advised that company B3, C2 and C4 take decisive precaution in the treatment process to prevent further contamination of finished product and improve better in her treatment technique.

The aerobic mesophilic count is a generic term to monitor the safety, sanitary quality and organoleptic acceptability of water intended for direct consumption. Although not a quality indicator it is performed on raw water samples and treated samples to measure the count of bacterial which can aerobically survive at 25^0C-40^0C. In Table 5, the value recorded for all the sachet water brands analyzed from Akure and some of Ondo and Owo are within the standard limit of 102cfu described by WHO for quality drinking water. Only B3 and C2 samples had values (113cfu) slightly above the standard limit which make sachet water brand unsafe for consumption according to WHO, (2006) and would require constant sanitary inspection of the water source to prevent pathogenic infestation.

H_2S paper strip test indicates the presents of microbes of the coliform origin capable of causing cholera and typhoid fever (Alexander *et al.*, 2019). The water safety indication of this test is shown in Table 5. All water brand samples in Akure showed no risk (NR) of pathogenic contamination (feacal coliform), and therefore consumers of product from the 5 brands in Akure are safe while the water sample for some particular brands like C2 and B3 had low risk (LR) and C4 had moderate risk (MR) as shown in the result. Sachet water brands with low and moderate risks raises a deep concern which can be potentially harmful to consumers as WHO standard stipulates no risk (NR). This can however, be treated by chlorination. Adequate waste management is a key factor in preservation of water quality. Awajiogak, (2013) reported that poor and improper waste management systems have constituted a menace to ground water.

From the results, it can be inferred that there is high efficiency in the treatment (disinfection) process by the packaging plants in Akure i.e. the treatment process for the removal of the pathogenic contamination. The existence of coliforms and bacteria in water samples after being treated may result from the absence of sophisticated treatment equipment such as UV disinfectant or reverse osmosis or inefficient or weak water treatment equipment. Hence, serious action should be taken to eliminate pathogenic contamination and make the products fit for consumption.

Table 5: Result of Microbial Analysis

	Coliforms, MPN/100mL	Aerobic Mesophilic Count (×100)	H_2S Paper Strip
WHO	0	102	--NR
A1	0	17	--NR
A2	0	21	--NR
A3	0	60	--NR
A4	0	14	--NR
A5	0	9	--NR
B1	0	11	--NR
B2	0	7	--NR
B3	8	113	+LR
B4	0	11	--NR
B5	0	11	--NR
C1	0	14	--NR
C2	6	113	+LR
C3	0	11	--NR
C4	15	15	++MR
C5	0	0	--NR

† Key: A1 – C5 (Different Samples); MR = Moderate Risk; NR= No Risk; LR= Low Risk; WHO 2006.

4. Conclusion and Recommendation

From this study it was discovered that the major contaminant of sachet water brands marketed in Akure, Owo and Ondo metropolis of Ondo State, Nigeria is due to the inconsistency in the treatment process and the level of contamination of the source water used for production. Thus measurement parameters can estimate potential serious health challenges of diarrhea, typhoid, etc. prevalent in the study areas. High values of EC (353 µmho/cm) and TDS (247 mg/L) in sample A3 confirm the presence of salts. Ca has the highest concentrations (30.4 mg/L) among the salts which resulted in high total hardness (122 mg/L) and total alkalinity (128.8 mg/L) values in the samples (A3). It is important also to note that A3 violated the WHO limits the most among the sachet water brands in the areas under study in term of their chemical property while all the brands in Akure were below the limit recommended by WHO. Water brand A1 and A4 are adjudged the best brand with respect to the parameters monitored and having met up with the standard limits described by WHO for all the parameters. But with respect to microbiological contaminants, B3 and C2 are the worst polluted and C5 is the least. The analysis reveals that sachet water brands should adequately be improved in the treatment processes. Consequently it should not be assumed that "pure or sachet water" is pure. However, more has to be done to ensure sachet water (pure water) are free from pathogen capable of causing outbreak of cholera, dysentery, diarrhea and other water borne diseases as study shows a significant level of microbial contamination in B3, C2 and C4. It is recommended that questions should be raised by the regulating authorities in Nigeria such as NAFDAC, SON and NIS about promising strategies that will improve it, so as not to push the community to regress to poorer sources which could lead to more severe conditions.

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Conflict of Interest
The authors declare that there are no conflicts of interest

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