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Physicochemical Characteristics of Selected Sachet and Bottled Water in Abraka, Delta State

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ABSTRACT

Some physicochemical properties of five brands of sachet and five brands of bottled water sold/produced in Abraka; Ethiope East Local Government Area of Delta State was investigated. Amounts of heavy in the water samples were also determined. The results were compared with World Health Organization (WHO) standards and Nigerian Standard for Drinking Water Quality (NSDWQ) respectively. Seventy percent of the samples had pH levels below the minimum level of 6.50 recommended by WHO and NSDWQ, suggesting that the water samples are acidic. The slight acidity of the water samples may not be unconnected to impurities from poor treatment techniques. Results for other physicochemical parameters: EC (78.60 ± 34.06 µs/cm), TDS (42.80 ± 18.46mg/l), Temperature (30.02 ± 0.46 ^{O}C), Cl^- (16.88 ± 7.01mg/l), NO_3^- (0.12 ± 0.05mg/l), NO_2^- (<0.001mg/l), TH(10.60 ± 7.09mg/l), Cu(0.05 ± 0.00mg/l), Fe(0.34 ± 0.19mg/l), Zn(0.11 ± 0.02mg/l) and Mn (0.03 ± 0.00mg/l) for sachet water samples; EC (99.60 ± 76.18 µs/cm), TDS (54.20 ± 41.84mg/l), Temperature (29.96 ± 0.21 ^{O}C), Cl^- (20.85 ± 17.44mg/l), NO_3^- (0.12 ± 0.03mg/l), NO_2^- (0.01 ± 0.01mg/l), TH(15.00 ± 16.36mg/l), Cu(0.04 ± 0.01mg/l), Fe(0.20 ± 0.15mg/l), Zn(0.11 ± 0.03mg/l) and Mn (0.09 ± 0.01mg/l) for bottled water samples; were within permissible limits, indicating that the water samples are good enough for human consumption.

Keywords: Sachet water, Bottled water, Physicochemical characteristics, Potable, Abraka

1.0. Introduction

Water is very crucial for the sustenance of lives (Gangil *et al.*, 2013; Thliza *et al.*, 2015). Virtually all processes of life in the atmosphere, lithosphere or hydrosphere require water (Aroh *et al.*, 2013). Water is an essential part of human diet and is required for maintaining personal hygiene, for drinking, domestic, industrial and agricultural uses (Isikwue and Chikezie, 2014; Thliza *et al.*, 2015). In many developing countries, availability of potable water is a perennial challenge and has become a matter of concern to families and communities (Maduka *et al.*, 2014). Studies have shown a gross inadequacy of access to potable water amongst the world's population (Akinde *et al.*, 2011; Oyelude and Ahenkorah, 2011).

In Nigeria, the situation is worrisome. Several studies have corroborated the inadequacy of the country's potable water supply. (Gbadegesin and Olorunfemi, 2007; Aderibigbe *et al.*, 2008; Maconachie, 2008; Adamu, 2009; Omalu *et al.*, 2011).This has occasioned an increase in water related illnesses that has continued to be one of the foremost health burdens worldwide (Onifade and Ilori, 2008; Omalu *et al*., 2011). According to Akunyili (2003), the Government's persistent inability to provide the required quality and quantity of water for the growing population contributed in no small measure to the proliferation of the so-called 'pure water' companies in Nigeria. The proliferation of sachet and bottled drinking water products brings to fore the argument as to whether they are hygienically produced, especially when the poor sanitary conditions in most urban and rural areas of Nigeria coupled with irregular and insufficient monitoring of sachet and bottled water producers by regulating agencies is taken into cognizance (Adekunle *et al*., 2004).

Akpoborie and Ehwarimo (2012) analyzed a variety of common packaged water products in Warri. The potability of the water samples was determined by investigating coliform count, selected physical and chemical properties as well as presence of heavy metals like cadmium, chromium and lead. Sachet and bottled water samples were procured from street vendors, wholesale shops and production plants. The results showed that pH ranged from 7.1 to 8.2; Total dissolved solids (TDS) was between 2.26 to 89.6mg/l; Turbidity: 0.45 to 2.55 NTU; Calcium: 0.11 to 1.21mg/l; Magnesium: 0.03 to 0.31mg/l; Sulphate: 0 to 1.21mg/l; chloride: 0.5 to 3.1mg/l; nitrate: 0.2 to 0.25mg/l. The cadmium level in three brands of the water samples ranged from 0.001 to 0.002mg/l. Lead concentrations ranged from 0.001 to 0.003mg/l and chromium levels ranged from 0.001 to 0.002mg/l. The parameters analysed were well below regulatory guidelines. However, the authors observed a significantly small amount of TDS in the water samples.

An investigation into the potability of sachet water available to residents of Kano metropolitan area was carried out by Ezeugwunne *et al.* (2009). The concentrations of metals (Zn, Pb, Fe, and Cu), conductivity, dissolved solids and hardness were within the World Health Organization's (WHO) permissible limits. However, some of the pH values were above the WHO permissible limits. Adekunle *et al.* (2004) assessed the socio-economic and health implications sachet water in Ibadan Nigeria. The authors reported that the physical parameters were within the WHO limits for drinking water quality, except for pH. Some chemical properties studied were also within the WHO limits. However, aluminum, fluoride and cyanide concentrations in the water samples were not within the WHO limits.

Sachet and bottled water are regulated as food products in Nigeria by the National Agency for Food and Drug Administration and Control (NAFDAC). The agency relies on WHO and NSDWQ standards for the product regulation, registration and certification. Packaged water is relatively affordable and convenient to carry and has increasingly become popular. However, many local manufacturers of sachet and bottled water do not adhere strictly to NAFDAC guidelines. This undermines the safety of such water for human consumption. The need to investigate the quality of packaged water therefore becomes imperative. The objective of this study is to investigate the quality of packaged water produced or sold in Abraka town.

2.0. Methodology

2.1. Description of study area

Abraka is a sprawling University town situated between latitude 5°45'and 5°50' N and longitude 6° and 6°15'E.It is unevenly lowland with a gradient that slopes gently towards the River Ethiope. It is a collection of a number of linear communities in Ethiope East Local Government Area of Delta State, Nigeria. It is majorly populated by students, civil servants, farmers and small scale business owners, because it hosts the three sites of the Abraka campus of the Delta State University and a large market respectively.

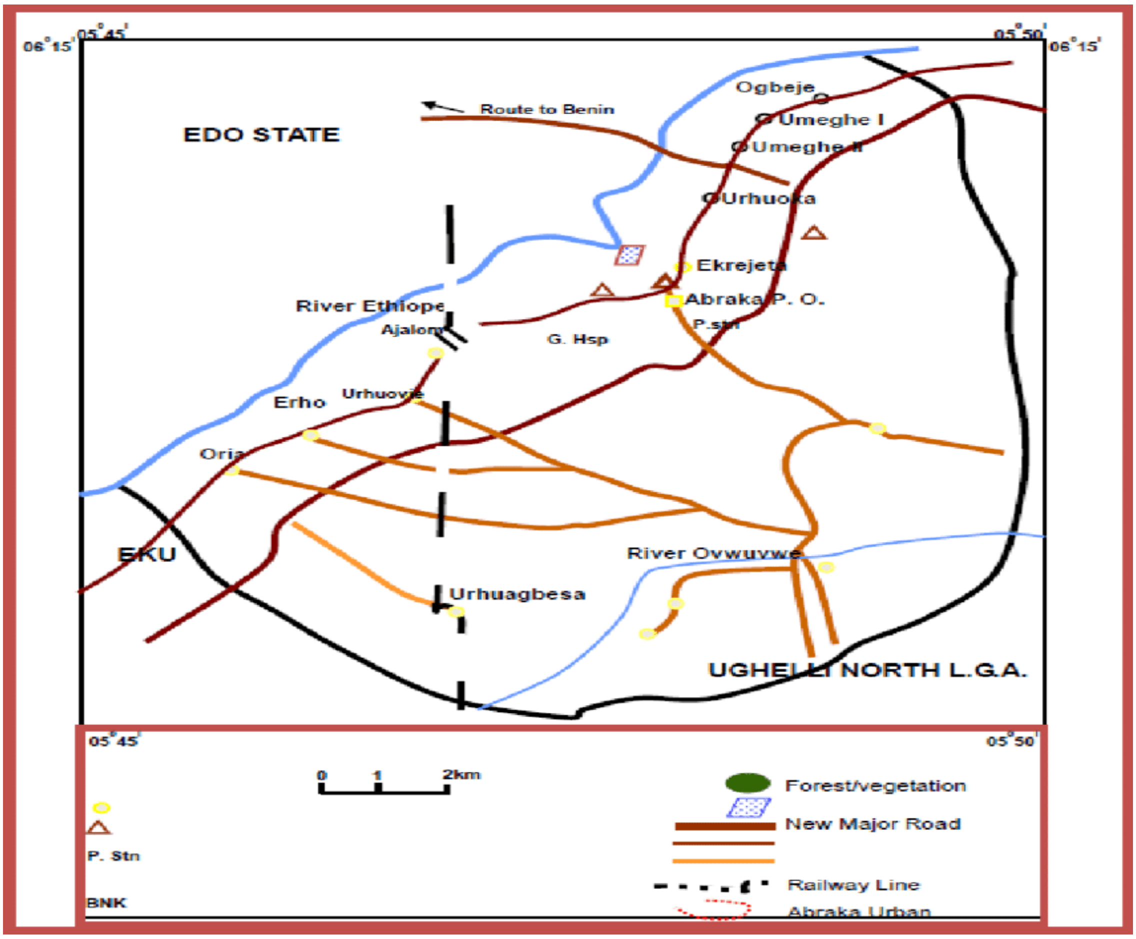

Figure 1: Map of Abraka showing its several linear settlements

Source:https://www.researchgate.net/figure/Map-of-Abraka-Ethiope-East-LGA-Delta-State-Nigeria

2.2. Collection/preservation of samples

Ten (10) different bottled and sachet water brands were procured at random on the 12th of March, 2020 from the different communities that constitute Abraka town. Particular attention was on popular brand names commonly consumed in Abraka. Five (5) samples of each brand were purchased to obtain a composite sample of each satchet and bottled water brand. To protect the identity of each brand, they were labelled sample A to J. Samples A to E are sachet water, while F to J are bottled water samples. The samples were stored in the refrigerator at 4 ^{O}C prior analyses.

2.3. Methods

2.3.1. pH and Temperature

The pH of each water sample was determined with a pH meter as described in standard methods (APHA 4500-H^+ Electrometric, 2017). The temperature of each water sample was measured with a digital thermometer (APHA 2550B Electrometric, 2017). About 200ml of water sample was measured into a conical flask. The thermometer was lowered into the sample until the mercury bulb was sufficiently covered by the sample and the temperature was read and recorded.

2.3.2. Conductivity and turbidity

The conductivity of each sample was determined using digital conductivity meter (APHA 2510B Electrometric, 2017). The turbidity was determined by the nephelometric method with the aid of a laboratory nephelometer (APHA 2130B Nephelometric, 2017).

2.3.3. Total Dissolved Solids

Total Dissolved Solids (TDS) was determined with TDS meter. The electrode was rinsed with deionised water followed by the water sample. The rinsed electrode was allowed to stabilize in the sample for 1 minute after which the TDS value was read directly inmg/l (APHA 2540C Gravimetric, 2017).

2.3.4. Colour

Colour was determined by the method reported in the work of Dinrifo *et al.* (2010). A Lovibond visual colour comparator (APHA 2120B Visual) was used. Ten tubes of Lovibond visual colour comparator were filled with each water sample and the eleventh tube was filled with distilled water as standard control. The tubes were placed in the comparator and aligned by rotating the disc until a nearest colour match was observed. Total Hardness (TH) was determined by the EDTA titrimetric method using Eriochrome black T as indicator. The titration was done at pH = 10 (APHA 2340C Titrimetric, 2017).

2.3.5. Chloride, nitrate and nitrite concentrations

Chloride content was determined by Argentometric/Titrimetric method (APHA 4500-Cl-B Titrimetric, 2017). Nitrate (NO_3^-) and nitrite (NO_2^-) contents were determined by colorimetric method using a potable UV-visible spectrophotometer (Searchtech Instrument, 752N model, India) (APHA 4500E Colorimetric, 2017) and (APHA 4500-NO_2 Colorimetric, 2017) respectively.

2.3.6. Heavy metals

Heavy metals such as copper (Cu), lead (Pb), iron (Fe), zinc (Zn), manganese (Mn) were determined by Flame Atomic Absorption Spectrophotometry (FAAS) using acetylene/air with Atomic Absorption Spectrophotometer, Varian Spetra AA 600 model (USA) (APHA 3111B FAAS, 2017). Arsenic (As) was determined using AAS-Hydride method (APHA 3111B AAS-Hydride, 2017).

2.3.7. Statistical analysis

Data analysis was done by independent samples t-test using Statistical Package for Social Sciences (SPSS) version 20 Software. At a significant level (p – value) of 0.05; differences between the means of the two sets of data for each parameter were considered not significant at $p > 0.05$.

3.0. Results and Discussion

Tables 1 and 2 show the physical and chemical properties of the sachet and bottled water samples determined in this study. A comparison of the average values of physicochemical parameters and heavy metals concentration of the water samples with international and national guidelines for drinking water is presented on Table 3. Samples A to E are sachet water samples while samples F to J are bottled water samples.

The pH values of the sachet water samples ranged from 4.11 – 6.65, while that of the bottled water ranged from 5.17 – 7.77. There is a significant deviation in the pH values of most of the water samples from acceptable standards as can be observed in Figure 1. Only samples E, F and I had values within the acceptable limit. The pH values of the other water samples were below acceptable limits. This is similar to the observations of Oyelude and Ahenkorah (2012). At a degree of freedom (df) equal to 8 and a p-value of 0.116, there was no significant difference between the pH values obtained for the sachet and bottled water samples. The pH of water affects transformation processes of the various forms of nutrients and metals. Extreme pH values poses health risks to humans.

Table1: Physicochemical properties of the sachet water samples

Parameter	Sachet water samples				
	A	B	C	D	E
pH @ 25 (°C)	6.40	4.57	4.50	4.11	6.65
EC (µs/cm)	20	88	91	109	85
TDS (mg/l)	11	48	50	59	46
Turbidity (NTU)	<0.1	<0.1	<0.1	<0.1	<0.1
Temp. (°C)	30.10	30.20	29.80	29.90	30.10
Colour (Pt-Co)	<1	<1	<1	<1	<1
Cl^- (mg/l)	6.00	17.90	20.24	24.85	15.39
NO_3^- (mg/l)	0.10	0.09	0.07	0.21	0.12
NO_2^- (mg/l)	<0.001	<0.001	<0.001	<0.001	0.080
TH(mg/l)	6.00	7.00	10.00	7.00	23.00
Cu(mg/l)	0.05	ND	ND	ND	ND
Pb(mg/l)	ND	ND	ND	ND	ND
Fe(mg/l)	0.20	ND	ND	ND	0.47
Zn(mg/l)	0.09	0.12	0.14	0.11	0.09
Mn (mg/l)	ND	ND	ND	ND	0.03
As (mg/l)	ND	ND	ND	ND	ND

ND = Not Detected

Table2: Physicochemical properties of the bottled water samples

Parameter	Bottled water samples				
	F	G	H	I	J
pH @ 25 (°C)	7.21	5.17	5.93	7.77	6.33
EC (µs/cm)	142	36	83	209	28
TDS (mg/l)	78	19	45	114	15
Turbidity (NTU)	<0.1	<0.1	<0.1	<0.1	<0.1
Temp. (°C)	30.10	29.70	29.80	30.20	30.00
Colour (Pt-Co)	<1	<1	<1	<1	<1
Cl^- (mg/l)	28.04	8.10	14.12	47.99	6.00
NO_3^- (mg/l)	0.14	0.15	0.09	0.15	0.08
NO_2^- (mg/l)	<0.001	<0.001	0.009	0.018	<0.001
TH(mg/l)	44.00	5.00	8.00	11.0	7.0
Cu(mg/l)	0.05	ND	0.03	ND	ND
Pb(mg/l)	ND	ND	ND	ND	ND
Fe(mg/l)	0.01	ND	0.24	0.37	0.18
Zn(mg/l)	0.09	0.11	0.15	0.06	0.13
Mn (mg/l)	ND	ND	0.10	0.08	ND
As (mg/l)	ND	ND	ND	ND	ND

ND = Not Detected

Table3: Comparison of physicochemical properties of the water samples with National and International Guidelines

Parameter	Sachet Water Mean ± SD	Bottled Water Mean ± SD	WHO	NSDWQ
pH @ 25 (°C)	5.25 ± 1.18	6.48 ± 1.03	6.50-8.50	6.50-8.50
EC (µs/cm)	78.60 ± 34.06	99.60 ± 76.18	NG	1000.00
TDS (mg/l)	42.80 ± 18.46	54.20 ± 41.84	1000.00	500.00
Turbidity (NTU)	<0.1	<0.1	0.2	5
Temp. (°C)	30.02 ± 0.46	29.96 ± 0.21	Ambient	Ambient
Colour (Pt-Co)	<1	<1	15	15
Cl^- (mg/l)	16.88 ± 7.01	20.85 ± 17.44	250.00	250.00
NO_3^- (mg/l)	0.12 ± 0.05	0.12 ± 0.03	50.00	50.00
NO_2^- (mg/l)	<0.001	0.01 ± 0.01	3.00	0.20
TH(mg/l)	10.60 ± 7.09	15.00 ± 16.36	500.00	150.00
Cu(mg/l)	0.05 ± 0.00	0.04 ± 0.01	2.00	1.00
Pb(mg/l)	ND	ND	0.01	0.01
Fe(mg/l)	0.34 ± 0.19	0.20 ± 0.15	1.00	0.30
Zn(mg/l)	0.11 ± 0.02	0.11 ± 0.03	5.00	3.00
Mn (mg/l)	0.03 ± 0.00	0.09 ± 0.01	0.40	0.20
As (mg/l)	ND	ND	0.01	0.01

WHO = World Health Organization (2017), Guideline for drinking water quality, 4th edition
NSDWQ = Nigerian Standard for Drinking Water Quality
NG = No Guideline
ND = Not Detected

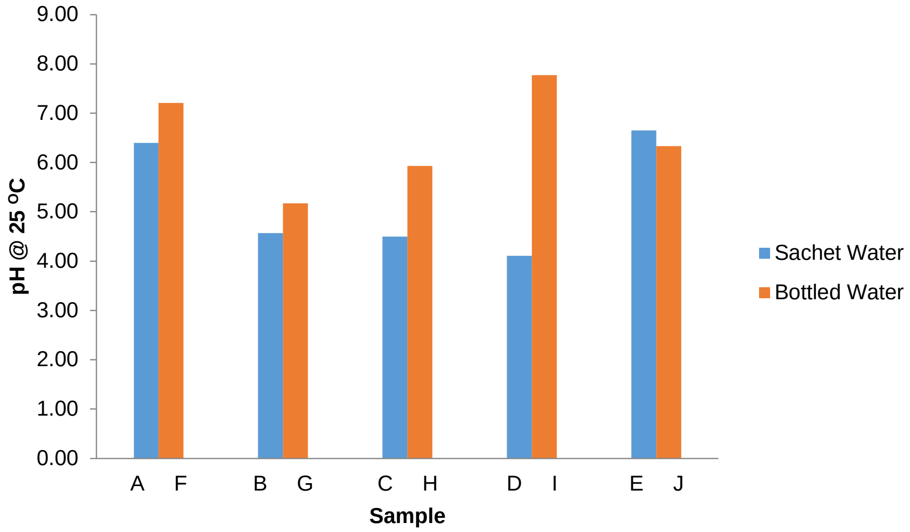

Figure 1: pH of Water Samples

Electrical conductivity (EC) of the sachet water samples ranged from 20.00 to 109.00µscm^{-1}; while that of bottled water samples ranged from 28.00 to 209.00µscm^{-1}. At a df of 8 and a p-value of 0.589, there was no significant difference between the EC values obtained for the sachet and bottled water samples. The EC values were far below the maximum of 1000µscm^{-1} recommended for drinking water by NSDWQ. According to Nwidu *et al*. (2008) low EC values indicate the presence of minimal amount of dissolved salts (mineral elements such as calcium, magnesium and fluoride) in water. The long term drinking of packaged water with EC value that is lower than 40µscm^{-1} constitute a number of health risks such as higher probability of fracture in children, pregnancy disorder (preeclampsia), diuresis, premature or low baby weight at birth and increased tooth decay (Guler and Alpalsan, 2009).

TDS of the bottled water samples ranged from 15.0 – 114.0mg/l; that of the sachet water samples was 11.0 – 59.0mg/l. At a df of 8 and a p-value of 0.592, there was no significant difference between the TDS values obtained for the sachet and bottled water samples. However, TDS of all the water samples was observed to be within the WHO and NSDWQ standards of 1000mg/l and 500mg/l respectively. TDS above the WHO upper limit of 1000mg/l affect the taste of drinking water negatively, making it unacceptable for drinking purpose. In the same vein, a very low level of TDS gives water a flat taste, this for many people is undesirable.

The salinity of the water samples was within the limit recommended for potable water. The Turbidity of drinking water is purely dependent on presence of particulate matter. Turbidity has effects on taste, odour and colour of water (Ndinwa *et al.,* 2012). The turbidity of all the sachet and bottled water samples was less than 0.1 NTU. This is within the 0.2 NTU recommended standard of WHO.

The temperature of sachet water samples ranged from 29.80 - 30.20°C; the bottled water samples had a temperature range of 29.80 - 30.20°C. At a df of 8 and a p-value of 0.626, there was no significant difference between the temperature values obtained for the sachet and bottled water samples. Variation in temperature for packaged potable water is probably due to increased hours of exposure to sunlight during the day and improper storage of water. High temperature reduces the amount of dissolved oxygen in water, (Sawyer *et al.,* 2000). The temperatures of the water samples were within the standard guidelines for drinking water.

Chloride ions concentration in the water samples varied from 6.00 – 47.99mg/l for bottled water, with sample I having the highest concentration, while the range for sachet water was 6.00 – 24.85mg/l as shown in Figure 2. At a df of 8 and a p-value of 0.649, there was no significant difference between the Chloride ion concentrations obtained for the sachet and bottled water samples. The values were however, within the WHO maximum permissible concentration of 250mg/l desirable for drinking water. This limit is primarily based on taste considerations. However, intake of water containing higher concentrations of chloride, have not been widely reported to have adverse health effect on humans (Ndinwa *et al.,* 2012). Higher levels of chloride ions in drinking water can become very evident in the taste of water. The values observed in this study were higher than 0.31- 3.03mg/l reported for sachet water analysis in Warri and Abraka, Nigeria (Ndinwa *et al.,* 2012).

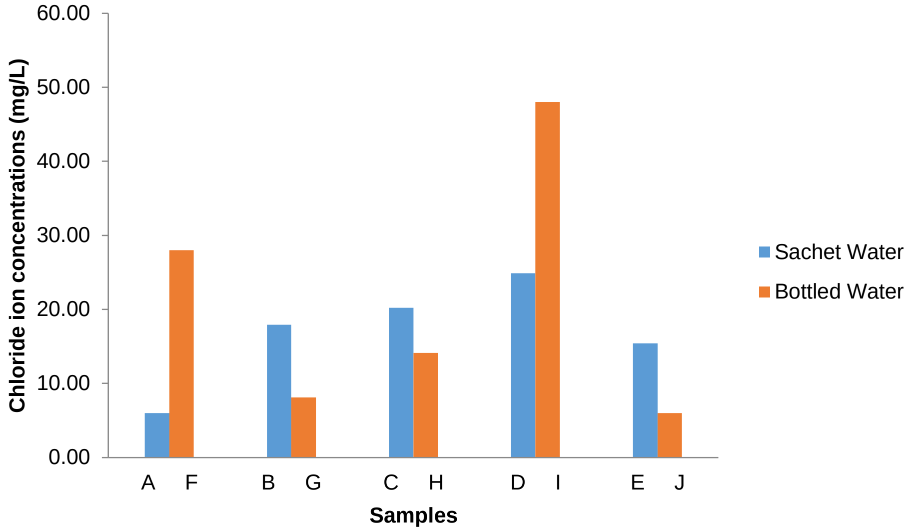

Figure 2: Chloride ion concentrations in the water samples

The range of nitrate ion levels in the water samples was 0.07 - 0.21mg/l for sachet water and 0.08 - 0.15mg/l for bottled water. At a df of 8 and a p-value of 0.893, there was no significant difference between the nitrate ion levels obtained for the sachet and bottled water samples. The results showed nitrate content to be relatively lower than the WHO and NSDWQ permissible limit of 50mg/l. Excessive amounts of nitrate ions can cause water quality problems, as well as contribute to the illness known as methemoglobinemia in infants (Zhang, 2007).

The concentration of nitrite ions in sachet water ranged from less than 0.001 to 0.08mg/l. The concentration is in compliance with the 3.0mg/l maximum standard (WHO, 2017). The bottled water samples had a nitrite concentration range of less than 0.001 to 0.02mg/l. There was no significant difference in the nitrite ion levels for sachet and bottled water.

The distribution pattern of heavy metals concentrations in the study as observed on Table 3 is: Fe > Zn > Mn > Cu > Pb> Ar for sachet water and Fe > Zn > Cu > Mn > Pb > Ar for bottled water respectively. Copper occur naturally in water in only minute quantity (few micrograms per litre) in drinking water (Saleh *et al.,* 2001). In all the water samples investigated, only three sample A (sachet water) with samples F and H (bottled water) contained this trace element at concentrations 0.05, 0.05 and 0.03mg/l respectively. Copper was not detected in 70% of the samples. They were all within the 2.0mg/l standard for drinking water (WHO, 2017). Higher level of copper is not desirable in drinking water as it could causes gastrointestinal disorder (SON, 2007).

Lead and Arsenic were not detected in all the samples. Iron as a trace element was not detected in about 40% of the water samples. Iron concentrations of 0.20 and 0.47mg/l were observed in sachet water samples A and E. In four brands of bottled water samples (G, H, I and J) iron levels ranged from 0.01 – 0.37mg/l. These observed values fall within the limit of 1.0mg/l stipulated by World Health Organization (WHO, 2017) for drinking water. However, the levels of iron in samples F and J were slightly above the guideline set by NSDWQ.

Manganese concentration of 0.03mg/l was detected in one sachet water sample, while concentrations of 0.10 and 0.08mg/l respectively were observed in two bottled water samples (H and I). These values are within the baseline values of 0.40 and 0.20mg/l respectively set by WHO and NSDWQ respectively. Large quantities of manganese have an effect on water taste and enhance the growth of bacteria. Large doses of manganese have also been reported to cause lethargy, irritability, headache, sleeplessness, and leg weakness, which might induce psychological symptoms like violent behavior, inexplicable laughter, impulsive acts and absent-mindedness (Saleh *et al.,* 2001).

Zinc was detected in all the water samples. Its concentration ranged from 0.09 – 0.14mg/l and 0.06 – 0.15mg/l for sachet and bottled water respectively as shown on Figure 3. At a df of 8 and a p-value of 0.916, there was no significant difference between the zinc concentration values obtained for the sachet and bottled water samples. The values obtained were within the permissible level of 5.0mg/l and 3.0mg/l recommended by WHO and NSDWQ respectively.

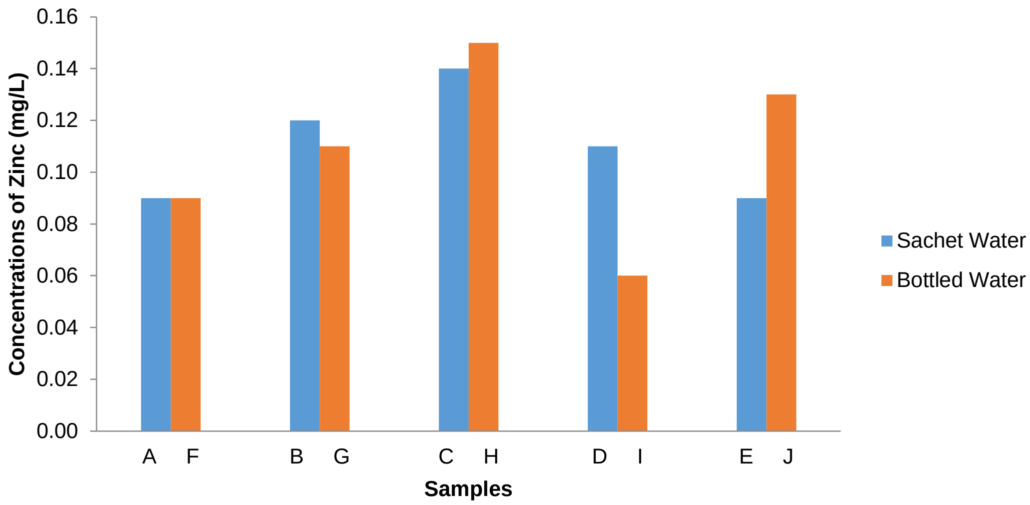

Figure 3: Zinc ion concentrations in the water samples

4.0. Conclusions

Sachet and bottled water play important roles in providing readily accessible water to the general populace; however, the quality of such water must be of paramount interest to all: producers, consumers and regulatory authorities alike. Samples of sachet and bottled water were collected from various retail outlets in Abraka and subjected to different analytical procedures to determine values of a range of physicochemical properties. The findings of this study revealed that the pH of 70% of the sachet and bottled water samples investigated was below permissible limits. The values of other parameters in the study such as: turbidity, colour, temperature, total dissolved solids, total hardness, electrical conductivity, chloride ion, nitrate ion, nitrite ion, and heavy metals such as copper, iron, zinc, and manganese were within the national and international guidelines. On the average, the sachet and bottled water samples were of good quality.

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