IBOM MEDICAL JOURNAL
Vol.18 No.1 | January - April, 2025 | Pages 187 - 195
www.ibommedicaljournal.org

Quality assessment of packaged water brands in a university teaching hospital in southern Nigeria

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Abstract

Background: Every year, globally, high rates of morbidity and mortality from waterborne diseases are reported due to non-compliant packaged water that fails to meet recommended safety standards. While studies have assessed the quality of drinking water in communities, researches on water quality in healthcare facilities are scarce. Healthcare facilities must ensure safe drinking water sources, to prevent complicating patient illnesses or prolonged hospital stay.
Objective: This study aimed at determining the conformity of bottled and sachet water brands available in the University of Uyo Teaching Hospital to both national and international guidelines for drinking water quality.
Methodology: This was a facility based descriptive cross-sectional study involving the physicochemical and biological analysis of 10 randomly selected packaged water (5sachet and 5 bottled water) brands. Results of analysis were compared with values in WHO Guidelines and the Nigerian Industrial Standards for Drinking Water Quality.
Results: Physical analysis of the water samples revealed no abnormalities. Electrical conductivity, total dissolved solids and magnesium hardness were increased in both bottled and sachet water brands. 60% of the sachet water samples showed evidence of gross bacterial contamination (>50cfu/ml) while 20% of the bottled water samples were grossly contaminated.
Conclusion: Sachet water brands failed to meet minimum standards in most of the parameters assessed. In contrast, bottled water brands were found to be of relatively safer quality. Bottled and sachet water brands sold in the healthcare facilities should undergo regular quality analyses to ensure patient safety.

Keywords: drinking water, sachet and bottled water, UUTH, Uyo.

Introduction

Water is a key component of the human body, comprising about 60% of the total body weight in an average 70kg man (~42 litres)[1]. Access to clean and safe water is a basic human right and is essential for life[2]. Lack of access to water that is safe for human consumption is of significant public health importance. Safely managed drinking water which is “drinking water from an improved water source that is located on premises, available when needed, and free from faecal and priority chemical contamination”, is a key indicator of Sustainable Development Goal Target 6.1[2].
Water quality refers to the physical, chemical and biological properties of water which determines its suitability for human consumption[3]. It is assessed by using indicators which are referenced against local and international standards. These can be physical, chemical, or biologic indicators[4]. In Nigeria, water quality is assessed using Nigerian Standards for Drinking Water Quality (NSDWQ)[5] and the World Health Organization Drinking Water Guidelines[6].

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DOI: 10.61386/imj.v18i1.607

The inability of the government to provide safe drinking water to communities in Nigeria has led to a tremendous increase in the production of cheap and readily available packaged water (sachet and bottled water)[7,8]. The National Agency for Food and Drug Administration and Control (NAFDAC) is primarily responsible for enforcing quality standards on the production of packaged water[9]. Sachet water, locally known as "pure water", refers to drinking water that is purified, packaged and then sold in clear polyethylene bags. Sizes are conventionally maintained between 250ml-500ml. Bottled water undergoes a treatment process as described by NAFDAC but is packaged and sold in sealed plastic containers in net volumes ranging from 50cl-100cl[9]. Bottled water is generally considered by most to be less contaminated than sachet water[10]. Although it would be difficult to completely eliminate 100% of contaminants from drinking water, it is the duty of regulatory agencies to ensure that drinking water is safe for consumption and contamination is kept within acceptable limits.

Studies have shown however, that most brands of packaged water sold in Nigeria fail to meet minimum safety standards. For instance, a study carried out in 2017 on 100 sachet water brands in Uyo metropolis, showed that all samples had high levels of bacterial contamination when referenced against WHO standards[11]. An analysis of the physicochemical and biological properties of bottled and sachet water sold in 9 communities in Abia State, Nigeria, showed that 4 brands contained lead in amounts that exceeded the maximum permissible limits[12]. In Minna, North Central Nigeria, 15 samples made up of five sachet water brands were found be grossly contaminated with faecal coliform bacteria and their physico-chemical properties were below WHO Standards[13]. These results may be due to the fact that sachet and bottled water companies are largely unregulated with several of them operating illegally[14,15].

Contamination of water can also arise from industrial and agricultural processes, especially when the waste products are disposed into water bodies which may serve as drinking water sources. Ground water contains some naturally occurring chemical constituents like arsenic and fluoride which can pose health risks if elevated. Chemicals used in water treatment and supply such as fluoride and lead can also contaminate drinking water[16].

WHO estimates that as at 2020, up to 2 billion people worldwide do not have access to safe drinking water sources[16]. This is worrisome as lack of access to clean and safe drinking water poses significant health risks. In 2020, 323,320 cases of cholera and 857 deaths were notified from 27 countries[17]. These deaths are largely preventable, especially if access to "safely managed drinking water"[2] is improved. In addition, health expenditure due to illness from unsafe water constitutes a significant economic burden in terms of financial costs as well as loss of work hours by caregivers or the patients themselves. For instance, a study done in the United States in 2021 revealed that emergency room admissions and deaths due to infectious waterborne illnesses incurred US $3.33 billion in direct healthcare costs[18]. Forty six percent of interviewed households surveyed in Indonesia during and after a diarrhoeal illness faced catastrophic expenditure from the costs of treatment[19]. A study in Burundi, East Africa showed that the average total cost for an episode of diarrhoea was US $109.0, while clinic visits and hospital admission costs per episode of diarrhoea were $59.87 and $292, respectively[20]. In Umuahia, South-Eastern Nigeria, a 2021 study estimated that the average cost of diarrhoea (in-patient and loss in productivity) was USD83.8 (N39,000)[21].

Access to safe water sources for drinking is especially important in healthcare facilities. Globally, 15% of patients develop an infection during a hospital stay, and the greatest burden of these infections is in low and middle income countries[16]. Hence, measures must be taken to ensure that a patient's existing illness is not complicated by drinking from unsafe packaged water sources, or that they do not develop waterborne diseases during admission or hospital visits which may lead to death in severe cases.

The dearth of studies on quality of drinking water in health facilities prompted the conduct of this study. Therefore, this study assessed the physical, chemical and biological properties of samples of sachet and bottled water sold in the University of Uyo Teaching Hospital, Uyo, Akwa Ibom State, Nigeria

Materials and Methods.

Study Area and Design.

This facility based cross-sectional study was carried out in the University of Uyo Teaching

Hospital, a tertiary healthcare institution in Uyo, Akwa Ibom state, South-South Nigeria, from December 2023 to January 2024. It is a five hundred (500) bed capacity hospital and has a total of 25 departments which consists of 21 clinical departments, 4 non-clinical departments, as well as several support units[22]. A section of the hospital known as a “mammy market” contains kiosks and stalls allocated to food vendors, provision stores and business centres, which serve the hospital and its environs. Consumables including bottled and sachet water are sold in this area. Environmental Health Officers, who monitor environmental health issues in the hospital, conduct regular inspections of the market in order to maintain strict hygienic standards.

The public health laboratory of the University of Uyo, located in the University of Uyo Teaching Hospital, is a centre for undergraduate and postgraduate training and research in Community Medicine and public health. The laboratory is run by trained laboratory scientists employed by the university with oversight provided by consultant public health physicians from the Department of Community Medicine, University of Uyo. In addition to its primary functions, the laboratory regularly carries out periodic medical examinations on food vendors and analysis of food and water sources found in the hospital, in order to ensure their safety for human consumption. Physical and biological analysis of the water samples used in this study were carried out here.

Chemical analysis of the water samples was conducted at the Akwa Ibom Water Board Company limited central laboratory quality control unit located in Uyo, Akwa Ibom State. The company is primarily responsible for the supply of potable water to urban and semi-urban communities within the state[23].

Sampling Technique

A list of all the sachet and bottled water brands sold in the mammy market was collated. Ten water brands (5 sachet and 5 bottled) were selected from a total of 15 different brands using simple random sampling by balloting with replacement. Five packs and five bags, each of the selected bottled and sachet water brands, were purchased from vendors. Each bag of sachet water contained 20 sachets, while each pack of bottled water contained 12 bottles. Five samples were randomly selected from each brand and analysed. In order to maintain anonymity, bottled water brands were labelled B1 to B5 while sachet water brands were labelled S1 to S5.

Analysis began within 24hours of purchase.

Analysis of selected water samples

Physico-chemical Analysis

All samples were inspected for labelling information, including NAFDAC and batch numbers, as well as appearance such as leaks, broken seals, or visible sediments in the water. The presence of odour was assessed by smelling each sample. A turbidometer was used to test for turbidity. A mercury-in-glass thermometer was used to assess the temperature of the samples.

Analysis for the presence of heavy metals such as copper, zinc, aluminium and others was carried out using atomic absorption spectroscopy(AAS) as outlined in Standard Methods by American Public Health Association (APHA)[24]. Instrumental measurements for pH, electrical conductivity and total dissolved solids were done using a pH meter and HACH conductivity/TDS meter respectively[24]. Colorimetry was used to estimate the levels of ammonia, nitrite and nitrates[24]. Volumetric tests were used to assess for methyl and phenolphthalein alkalinity as well as calcium and magnesium hardness[25].

Bacteriological Analysis

Membrane filtration technique was used to assess for the presence of coliforms in the water samples using Standard Methods by APHA[24]. 100mls of each sample was filtered through a membrane with a pore size of 0.45 nm. Each membrane was carefully transferred to separate MacConkey agar plates and incubated at 37°C for 24 hours. After incubation, the plates were examined using a handheld lens for the presence of growth and colour changes. Colonies were counted and results expressed as cfu/ml[26]. Biochemical tests such as Indole, Oxidase, Citrate tests and Gram staining were done to identify E.coli, an indicator organism for the presence of faecal coliforms[24,27,28,29].

Quality Control

During biological analysis, the media, membrane filtration unit and membrane were sterilized in an autoclave to eliminate any form of contamination. The temperature of the incubator was set at 37°C and the plates were examined after 24 hours of incubation. During chemical analysis of the samples, test equipments like pH meter, COND/TDS (Conductivity/total dissolved solids) metre were calibrated with PH standard 4 and 7, along with COND/TDS calibration reagents, before use. Incoming samples were used to rinse the probe before analyzing the samples. A weighing balance with a precision of 0.0000 decimal places was used to measure reagents and the exact amounts measured were noted for standard preparation. Fresh standards were prepared for acidity or bicarbonate ($HC0_3$) testing. American Public Health Association (APHA) methods as outlined in Standard Operating Procedures (SOPs) were applied to the analysis.

Statistical Analysis

Data analysis was done using Stata statistical software version 15.0. Measured parameters of the selected water samples were compared with WHO and NSDWQ standards.

Ethical Consideration

Ethical approval for this study was obtained from the Ethics and Research Committee of the University of Uyo Teaching Hospital, Uyo, Akwa Ibom State.

Table 3: Chemical characteristics of selected sachet water brands

Parameter	Unit	S1	S2	S3	S4	S5	Mean	WHO	NSDWQ
pH	_	7.42	7.9	7.51	7.52	8.2	7.71	6.5 - 8.5	6.5 - 8.5
Electrical Conductivity	us/cm	1814	1023	1046	1674	1046	1320.6	-	1000
Total Dissolved Solid (TDS)	mg/L	832	464	473	766	473	601.6	-	500
Fe	mg/L	BD	BD	BD	BD	BD	-	-	0.3
Mn	mg/L	BD	BD	BD	BD	BD	-	0.1 - 0.2	0.2
NO_3	mg/L	0.68	0.92	1.28	0.98	1.36	-	50	50
NO_2	mg/L	BD	BD	0.03	BD	0	-	0.3	0.2
NH_3	mg/L	BD	BD	BD	BD	BD	-	-	0
PO_4	mg/L	BD	BD	BD	BD	BD	-	-	3.5
SiO_2	mg/L	0	0	0	BD	BD	0	-	17
SO_4	mg/L	0	0	0	BD	BD	0	-	100
Al^{3+}	mg/L	BD	BD	BD	BD	BD	-	0.2 or less	0.2
Cu	mg/L	0	BD	0	BD	BD	0	2	1
Zn	mg/L	BD	BD	BD	BD	BD	0	< 600	500
Cl	mg/L	0	0	0	BD	BD	0	< 250	250
Total Hardness	mg/L	76	90	74	90	74	80.8	100-300	150
Calcium hardness	mg/L	66	62	64	60	64	63.2	-	75
Magnesium hardness	mg/L	10	32	10	30	10	18.4	-	0.2
Acidity	mg/L	0.84	0.8	0.72	0.48	0.4	0.65	-	4.5 - 8.2
Total alkalinity	mg/L	54	52.8	46.8	54	57.6	53.04	-	100 - 200
Methyl alkalinity	mg/L	54	52.8	46.8	54	57.6	53.04	-	100 - 200
Phenolphthalein alkalinity	mg/L	0	0	0	0	0	0	-	0

Key- BD: Below Detectable

Results

The results of the physical, chemical and biological properties of the selected bottled and sachet water samples are hereby presented. Standard values as provided by WHO and NSDWQ are also represented.

Table 1: Labelling information on selected water samples

Samples	Type	Batch Number	NAFDAC Number	Nutritional Information
B1	Bottled	Provided	Provided	N/A
B2	Bottled	Provided	Provided	N/A
B3	Bottled	Provided	Provided	N/A
B4	Bottled	Provided	Provided	N/A
B5	Bottled	Provided	Provided	N/A
S1	Sachet	N/A	Provided	N/A
S2	Sachet	N/A	Provided	N/A
S3	Sachet	N/A	Provided	N/A
S4	Sachet	N/A	Provided	N/A
S5	Sachet	N/A	Provided	N/A

Key - N/A: not available

Table 2: Physical characteristics of bottled and sachet water brands

Parameter	B1	B2	B3	B4	B5	S1	S2	S3	S4	S5	WHO	NSDWQ
Appearance	C	C	C	C	C	C	C	C	C	C	-	-
Colour (TCU)	5	5	5	5	4	5	5	5	5	4	15	15
Odour	U	U	U	U	U	U	U	U	U	U	-	U
Turbidity (NTU)	1.08	1.05	0.98	1.17	1.78	0.93	0.79	1.09	1.34	1.61	4	5
Temperature (°C)	29.3	29.5	29.7	29.3	29.7	29.3	28.9	29.1	29.3	29.1	-	Ambient
Taste	U	U	U	U	U	U	U	U	U	U		

KEY- C: clear U: unobjectionable TCU: true colour unit NTU: nephelometric turbidity unit

Nutritional information was not displayed on the packages of all analysed samples. Batch numbers were seen on all bottled water brands but not seen on any of the sachet water bags.(*Table 1*)

Samples taken from all ten brands had a clear appearance, with no objectionable taste or odour .Values for colour were far below the maximum permissible limit of 15TCU. The mean temperatures of bottled and sachet water samples were 29.5°C and 29.1°C respectively.(*Table 2*)

Tables 3 and 4 show the parameters routinely assessed in the chemical analysis of drinking water, with values obtained for sachet and bottled water samples compared with reference values.

The PH of sachet water samples were within acceptable limits with a pH range of 7.42 to 8.2. All of the sachet water samples showed no evidence of heavy metal toxicity. However, electrical conductivity was significantly elevated above the standard limit of 1000us/cm in 100% of the samples analysed. Three (60%) of the samples contained increased amounts of total dissolved solids (>500mg//L). Magnesium hardness was far above the accepted value of 0.2mg/L in samples S1-S5. (*Table 3*)

The pH of the bottled water samples

Table 4: Chemical characteristics of selected bottled water brands

Parameter	Unit	B1	B2	B3	B4	B5	Mean	WHO	NSDWQ
pH	-	6.52	7.62	6.46	6.77	6.51	6.8	6.5 - 8.5	6.5 - 8.5
Electrical Conductivity	us/cm	334	91.5	1992	2050	2130	1319.5	-	1000
Total Dissolved Solids (TDS)	mg/L	146.3	38.7	909	946	975	603	-	500
Fe	mg/L	BD	BD	BD	BD	B.D	-	-	0.3
Mn	mg/L	BD	BD	BD	BD	BD	-	0.1- 0.2	0.2
NO_3	mg/L	0.48	0.46	0.58	0.5	0.16	0.44	50	50
NO_2	mg/L	BD	0	BD	BD	BD	0	0.3	0.2
NH_3	mg/L	BD	BD	BD	BD	BD	-	-	0
PO_4	mg/L	BD	BD	BD	BD	BD	-	-	3.5
SiO_2	mg/L	BD	BD	BD	BD	BD	-	-	17
SO_4	mg/L	0	BD	BD	BD	BD	0	-	100
Al	mg/L	BD	BD	BD	BD	BD	-	0.2 or <	0.2
Cu	mg/L	0	BD	BD	BD	BD	-	2	1
Zn	mg/L	BD	BD	BD	BD	BD	-	< 600	500
Calcium hardness	mg/L	70	66	70	64	60	66.0	-	75
Magnesium hardness	mg/L	BD	4	BD	6	BD	2.0	-	0.2
Acidity	mg/L	0.48	0.6	0.8	0.52	0.52	0.58	-	4.5 - 8.2
Total alkalinity	mg/L	50.4	48	56.4	64	54	54.56	-	100-200
Methyl alkalinity	mg/L	50.4	78	56.4	64	54	60.56	-	100-200
Phenolphthalein alkalinity	mg/L	0	0	0	0	0	0	-	0

Key- BD: Below Detectable

Table 5: Summary of biologic properties of sachet and bottled water samples.

PARAMETER	B1	B2	B3	B4	B5	S1	S2	S3	S4	S5	WHO	NSDWQ
Total Coliforms (cfu/ml)	35	8	44	3	>50	6	>50	>50	>50	5	*	10
Lactase	+	+	+	+	+	-	+	+	+	-	-	-
Indole Test	IN+	IN+	IN+	IN+	IN+	IN+	IN+	IN+	IN+	IN+	-	-
Oxidase Test	OX-	OX-	OX-	OX-	OX-	OX-	OX-	OX-	OX-	OX-	-	-
Citrate Test	CI-	CI-	CI+	CI-	CI -	CI+	CI+	CI+	CI+	CI+		
Gram Staining	G-	G-	G-	G-	G-	G-	G-	G-	G-	G-	-	-

KEY: IN+ Indole Positive; OX- Oxidase Negative; G- Gram Negative; CI+ Citrate Positive; CI- Citrate negative

ranged from slightly acidic to mildly alkaline (6.5 to 7.6) and were within the reference values (6.5 to 8.5). Samples B3, B4 and B5 had markedly elevated results for electrical conductivity (>1000us/cm). Three (60%) of the samples contained an increased amount of total dissolved solids, much higher than the permissible value of 500mg/L. All of the heavy metals tested for were below detectable limits. Magnesium hardness was increased in 2 of the samples (B2 and B4). (*Table 4*)

All the brands tested (B1-B5, S1-S5) showed varying degrees of bacterial contamination as demonstrated in Table 5. Of the five bottled and 5 sachet water brands analysed, two (40%) brands respectively had coliform counts below the maximum allowable limit of 10 cfu/ml. Sachet water brands exhibited high coliform counts. Gross bacterial contamination (>50 cfu/ml) was more prevalent in sachet water (60%) when compared with bottled water (20%).

The bacteria isolated from all ten samples were found to be indole positive (IN+), oxidase negative (OX-), and gram negative (G-) organisms. Lactase was detected in all bottled water samples and 60% of sachet water samples with only S1 and S3 testing negative. Sixty percent of the total samples (S1-S5, B3) contained citrate positive bacteria (CI+), while 40% (B1, B2, B4, B5) were citrate negative (CI-). (*Table 5*)

Discussion

The National Agency for Food and Drug Administration and Control (NAFDAC) requires all pre-packaged water produced in Nigeria to carry specific labelling information including registration number, batch number, net content, nutritional information and others[30]. Food labels provide at a glance information which influence a consumer's decision to purchase a product[31]. Unique identifiers such as batch number are useful in cases where a product may need to be recalled if it is found to be unfit for consumers[10]. All of the sachet water samples in this study failed to provide batch numbers which may indicate issues with quality control. NAFDAC registration numbers are only issued to manufacturers that have passed inspections carried out by the agency. Hence, unregistered products should be considered as fake or unsanitary. When such products are discovered, it is the duty of regulatory authorities to cease their production immediately[14].

The results of the physical analysis of the water samples were compared with WHO and Nigerian Industrial Standards for Drinking Water Quality. Although standard values are not provided for temperature, the growth of pathogenic organisms such as E. coli could be facilitated by temperatures ranging from 20°C- 45°C[32]. The average temperatures of both types of packaged water used in this study fell within this range. A 2017 study which assessed the quality of packaged water sold in Ibadan, Nigeria also recorded elevated temperatures in the samples[33]. Colour in water may result from coloured organic matter associated with humus soil or the presence of metals such as iron[6]. The absence of colour in the analysed samples indicates that such contaminants were not detected.

Taste, odour and appearance comprise the acceptability aspects or aesthetics of water[6]. Since consumers have no way of objectively assessing the quality of their drinking water themselves, the perception of its safety is mainly judged by what is detectable to their senses[34]. For instance, a study in USA found that consumers were more likely to choose bottled water as their primary drinking water source when they perceived that tap water was unsafe[35]. Similar perceptions were shared by Ghanaian respondents who found water free of colour, taste, and odour to be more appealing[36]. A cross-sectional analysis of ten sachet water brands sold in the University of Nigeria, Nsukka Campus, Enugu State, showed that four samples had a chlorinous, rancid taste[37]. Taste and odour in water could arise from various sources, including the presence of foreign organic matter or even changes in pH[3,38].

Turbidity is a measure of the clarity of water and is determined by the amount of suspended particles it contains[39]. The low turbidity of the samples aligns with their clarity and colourlessness, indicating the absence of particulate matter.

The pH is an important parameter in the chemical analysis of drinking water. It is a measure of acidity or alkalinity of a substance and can directly impact the taste of water, especially during treatment[38]. At levels below 6.5, water develops a bitter taste, while levels above 8.5 produce a sour, baking-soda-like taste[38]. Some studies suggest that alkaline water may be useful in the treatment of acid reflux disease and osteoporosis in post-menopausal women[40,41].

Conductivity is a measure of the amount of electric current that can pass through water and is directly influenced by the number of charged ions that are present. These ions are formed when salts of minerals like calcium and magnesium or inorganic compounds like sulphides or chlorides, dissolve in water[42]. Changes in electrical conductivity could be an early indicator of water pollution[42]. For instance, in areas with industrial effluent discharge into water sources, the conductivity rises due to increased levels of nitrite, phosphate or chloride ions[42]. The elevated conductivity levels observed in the analysed samples may indicate pollution of the water sources used in production.

Conductivity can be affected by changes in the concentration of total dissolved solids (TDS). Total dissolved solids is the sum of all ion particles with a size less than 2 microns[42]. In our study, the TDS was elevated in the bottled water samples when compared with sachet water, suggesting increased mineral content. These minerals may have been added during the production process. An analysis of bottled water brands sold in Owerri, Imo State, Nigeria, revealed that most of the samples had elevated conductivity and dissolved solids[10]. Due to variations in the mineral composition of packaged water, it is essential for manufacturers to include nutritional information on their packaging labels[43]. However, none of the brands used in this study included such information on their packaging.

There was no evidence of heavy metal contamination in all the water brands used for this study. This finding contrasts the report from a study in Ogoja, Cross River State, Nigeria on 10 different sachet water samples which showed that the sachet water samples contained significant levels of heavy metals such as iron, lead, magnesium and aluminium[44]. Human activities such as mining and the use of fossil fuels are potential sources by which these toxic elements are introduced into the environment and eventually into water sources. Although some metals are required in trace amounts by the human body, excessive accumulation can lead to acute and chronic health complications such as hair loss, renal failure, cancers, etc[45].

Water hardness is a measure of the ability of water to react with soap i.e. the higher the water hardness, the less lather it will form with soap. Calcium and magnesium are mainly responsible for this property in water[46]. In our study, magnesium hardness was elevated in most of the brands analysed. In general, there is no demonstrable evidence of the adverse effects of water hardness on humans even though some studies have proposed a link between water hardness, cancers and cardiovascular disease[43]. The evidence is still insufficient to support these claims, hence WHO does not have a published guideline for acceptable limits of water hardness[46,47].

A key indicator of potable water is the presence or absence of pathogenic bacteria. Coliforms are generally accepted as indicator microorganisms which means that their presence in water is suggestive of contamination[26]. They belong to the family Enterobactericae, which are gram negative, facultative anaerobic/aerobic, non-spore forming, lactose fermenters. Examples of organisms in this group include E coli, Klebsiella spp, Enterobacter, etc[48]. Faecal coliforms are found in the digestive tract and are shed in faeces, hence their presence in water strongly suggests recent faecal contamination of the source[26].

In this study, sachet water samples were significantly more contaminated than bottled water. Although the national guidelines (NSDWQ 2015) allow some degree of bacterial contamination (up to 10 cfu/ml) in drinking water, WHO guidelines considers any bacterial presence to be unacceptable[6]. Similar bacterial contamination was found in sachet water samples analysed in North Central Nigeria[13]. The increased contamination observed in sachet water samples may result from unsanitary production processes[49].

Escherichia coli is the most precise indicator of faecal contamination[6]. Total coliform count can also be used but the limitation is that not all coliforms are pathogenic and hence may not be of sanitary significance[26]. All samples were Indole positive and Oxidase negative which suggests the presence of four major microorganisms namely Escherichia coli, Proteus vulgaris, Morganella morganii and Providencia spp. Citrate and lactate tests allowed further speciation of organisms that were present in each sample. Escherichia coli is a lactase fermenting, citrate negative, oxidase negative and indole positive organism[28,48]. Hence, the results of analysis strongly suggests that most of the brands were contaminated with E.coli. Morganella morganii and Providencia spp were likely present in samples S1 and S5 respectively. Drinking water that is contaminated with feacal matter is responsible for the transmission of gastrointestinal diseases such as cholera, dysentery, typhoid and poliomyelitis and is estimated to cause 485,000 diarrhoeal deaths each year[16].

Study Limitations

Analysis for the presence of some chemicals in water such as mercury, could not be done due to lack of appropriate reagents or high cost of such reagents.

Conclusion

The physical parameters of both bottled and sachet water samples met WHO and NSDWQ standards for drinking water. However, important label information, such as the mineral content, was missing on all tested brands. Both bottled and sachet water samples failed to meet minimum safety requirements in terms of biologic and chemical characteristics, with sachet water found to be less safe than bottled water. We recommend regular inspection of packaged water factories by regulatory bodies to ensure strict adherence to quality production standards. Bottled and sachet water brands sold in the healthcare facilities should undergo regular quality analyses to ensure patient safety.

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