Assessment of Physicochemical and Microbiological Quality of Table Water Sold in School Campuses of the University of Port Harcourt, Nigeria

Stephenson Danagogo Lawson[1*], Abiye Anthony Ibiene[2], Victoria Amadi[2], Stella Ogbonnie Enyinnaya[1], Lasbry Chidi Nnodim[2] and Gift Atumatuchukwu Uzah[2]

[1]*Department of Medical Microbiology and Parasitology, Faculty of Basic Clinical Sciences, Rivers State University, Port Harcourt, Rivers State, Nigeria.*
[2]*Department of Microbiology, Faculty of Science, University of Port Harcourt, Rivers State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Author SDL designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AAI, VA, SOE, LCN and GAU managed the analyses of the study. Author GAU managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Water is the elixir of life which is essential for proper metabolic processes to take place. The quest for cheap and readily available source of potable water has led to the emergence of sachet and bottle water which the sale and consumption continue to grow astronomically and rapidly in most countries of the world. This study was aimed at assessing the microbial and physicochemical water quality of table water sold on School campuses. Standard microbiological procedures were used to isolate and identify various microbial genera associated with the water samples using morphological, microscopic and biochemical characterization method. The bacterial genera identified were *Escherichia sp., Streptococcus sp., Micrococcus sp., Vibrio cholera., Staphylococcus sp.* and

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Corresponding author: E-mail: stephensonlawson@yahoo.com;

Bacillus sp. with Choba campus having the highest microbial contamination of packaged water. However, the results of the physicochemical properties from this study were all below the WHO recommended limits. The temperature and pH ranged between 26-27°C and 6.98-7.08, respectively. The values of the electrical conductivity ranged from 0.080 to 0.150 μs/cm; turbidity ranged between 0.40-1.40 NTU; chloride ranged between 1.187-2.103 mg/l, nitrate was within the range of 0.01 to 0.14 mg/l; BOD ranged from 0.02-0.04 mg/l, COD was between 0.00-0.08 mg/l and the total soluble solids were between the ranges of 0.04-0.10 mg/l. Therefore, this study suggests the improvement of water-borne disease preventive and control measures, and monitoring of water quality by the regulatory agencies to ensure good manufacturing practices by the water bottling companies which will result in reduction of health hazards associated with water borne diseases.

1. INTRODUCTION

Water is a vital substance for the survival of all lives [1]. It is one of the indispensable resources needed for the continued existence of all living things including man [2]. It is also one of the most important and most abundant substances on earth, vital to any organism's survival [3]. Water is one of the most important needs of all forms of life and is unavoidable in man's daily life, constituting a sizeable percentage of man's daily food intake because human bodies do not have reserve supply [4].

Water is termed potable when it is safe for cooking, drinking, and domestic use which contains less than 1000 ml per litre of dissolved solids, and does not contain chemical substances and microorganisms in amounts that could cause hazard to health. It should be clear, without disagreeable taste, colour or odour, therefore fit for human and animal consumption. It is water that has been treated, cleaned or filtered to meet established drinking standards [5,6]. It can be sourced from surface water such as river, streams or the ground water such as spring, well and borehole [5]. Water quality is the physical, chemical, radiological and biological characteristics of water in relation to the requirements of human and animal need [7].

Access to safe drinking water is important to health and development [8], but because of its inadequacy and government's inability to provide enough, a number of small scale water producing industries are packaging and marketing factory filled sachet drinking water. These are small nylon sachets containing 0.5L of water which are electrically heated and sealed at both ends [9]. The sale and consumption of packaged water continue to grow astronomically and rapidly in most countries of the world. The quest for cheap and readily available source of potable water has led to the emergence of sachet water [4] which is a locally sourced low cost alternative drinking water scheme providing sustainable access to safe water in rural and semi urban settings of developing nations [10,11]. This is thought to be cheaper and more affordable than bottled water and also safer, more hygienic and better than hand filled, hand tied packaged polythene bag water initially popularly sold [12,13]. Consequently sachet water has gradually become the most consumed liquid for both the rich and poor. Current trends however unfortunately suggest that sachet water could be a route of transmission of enteric pathogens which raises issues of the problem of its purity and health concern [14,13,6]. Many major brands of bottled water use tap water as their water source, but may put it through additional treatment steps. The FDA has set specific definitions for different water source types, such as "spring water and other sources". The FDA standards for bottled water and the EPA standards for municipal (tap) drinking water are similar but not identical [15]. Municipal plants are generally subject to much more frequent testing and inspection and must report test results to the public. Water bottlers may be able to use ozonation or ultraviolet light, since they use sealed containers for distribution, and so they can avoid an after taste from chlorine treatment. On the other hand, ozonation by products and plastic bottles themselves may adversely affect the taste of bottled water. Much attention is being paid in the recent news to the economic, energy, and environmental costs of making bottles, withdrawing water from the environment, bottling the water, transporting it, advertising it, and recycling or disposing of bottles [15].

The presence of microorganisms and heavy metals in water sources constitute one of the major contaminant. Improper waste disposal and Industrial activities such as mining, agricultural,

manufacturing and oil exploration activities are sources of heavy metals and pathogenic organisms that contaminate water sources. Also natural factors, domestic and commercial practices which generate waste could also contaminate water sources with heavy metals [16,17]. Water has always been associated with diseases. The first reported case of polluted drinking water was that of Broad street water pump, London after which many other cases have been reported in different parts of the world [2]. It threateneds the population's existence causing diseases such as cholera, gastroenteritis, hepatitis, typhoid fever, shigellosis and giardiasis. It could also result in symptoms such as bacillary diarrhoea. WHO estimates that 88% of diarrhoea cases is caused by unsafe water [18,19]. Mortalities due to water associated diseases and symptoms now exceed 5 million people per year [20]. Therefore, this work sets to investigate the microbiological and physicochemical quality of table water consumed on school campuses, the implication to public health as well as to seek and suggest ways in which such produced water could be more wholesome and fit for consumption.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study was carried out in the three campuses of University of Port Harcourt, all in Obio-Akpor Local Government Area of Rivers State, Nigeria which covers an area of 260 km^2.Obio-Akpor is bounded by Port Harcourt (local government area) to the South, Oyigbo to the East, Ikwerre to the North, and Emohua to the West. It is located between latitudes 4°45'N and 4°60'N and longitudes 6°50'E and 8°00'E. University of Port Harcourt has a total area of 461 ha divided into Choba, Delta and Abuja park (campus) by three public roads and is located at coordinates 4°52′30″ and 4°55′00″N, 6°54′40″ and 6°55′49″E.

2.2 Sample Collection

A total of six table water samples were purposively sampled aseptically from shops in the three campuses of the University of Port Harcourt (Abuja, Delta and Choba campuses) and taken immediately to the microbiology laboratory for microbial testing. The samples consisted of threebottle water and threesachet water sources. Purposive sampling was used based on other available water sources around the University of Port Harcourt campuses. The

samples were first coded as B and S based on the type of table water representing Bottle or Sachet, and the second coding of 1, 2 and 3 represented the campuses as in Abuja, Choba and Delta respectively. Each Sample was approximately 1litre. The sampling was done during the month of August, 2019.

2.3 Physicochemical Analysis

The physicochemical parameters of the water samples were carried out in accordance with the method of APHA [21].

2.3.1 Temperature and pH

The temperature of water samples was taken immediately on site using a thermometer calibrated in degree Celsius while the pH was determined using a pH meter (model HI 98130 Hanna).

2.3.2 Electrical conductivity

The electrical conductivity of the water samples was measured using a digital conductivity meter model NATOP PB5 (London, UK). Standardization of the meter was performed using 0.1N KCl at 25°C.

2.3.3 Turbidity

The turbidity of the water samples was measured using a digital turbidity meter (2100AN HARCH Model). A clean deionized water was used to standardize the turbidity meter before introducing the test samples. The turbidity reading of each water sample was then recorded.

2.3.4 Total suspended solids

The total suspended solids in the water samples were determined by simple calculation shown below:
Total suspended solids = Total solids – Total dissolved solids

2.3.5 Chloride

This test was performed to determine the total chlorine content of the water sample using the HACH Test Kit Model CN66/66F/66T). A colour viewing tube was filled to the 5 mL mark with the water sample. Also, another viewing tube was filled to the 5-mL mark with the water sample. Then, clippers were used to open one DPD Total chlorine reagent powder pillow, and the content was emptied inside the water sample. It was

gently swirled to achieve a homogenous solution, allowed to stand for three minutes and the results were recorded.

2.3.6 Nitrate

An aliquot of nitrate solution (containing 15.0-135.0 µg L^{-1}) was placed in a conical flask fitted with a ground glass stopper. The pH was adjusted to ca. 9.0 with 2.0 mL of the buffer solution. The solution was diluted to 250 mL with water, and 4.0 mL of 1.0×10^{-3} M PPP was added. The solution was mixed well and was allowed to rest for 5 min; later 5.0 mL of a 20% naphthalene solution in acetone was added with continuous shaking. The formed solid mass, consisting of naphthalene and the metal complex was separated by filtration on a glass filter. The residue was washed with water and then dried in the fold of filter glass. The solid mass was dissolved in DMF and came up to volume with the same solvent in 5.0 mL volumetric flask. The absorbance of the complex was measured at 328.0 nm.

2.3.7 Biological oxygen demand (BOD)

This test was performed using Winkler's method. Manganese (II) salt, iodide (I^-) and hydroxide (OH^-) ions were added in excess to the samples causing a white precipitate of $Mn(OH)_2$ to form. The precipitate formed was oxidized by the dissolved oxygen in the water sample which turn into a brown manganese precipitate and hydrochloric acid was added to acidify the solution. The brown precipitate was then converted from iodide ion (I^-) to iodine. The amount of dissolved oxygen was directly proportional to the titration of iodine with a thiosulphate solution. Three hundred millilitre (300 ml) BOD bottles were filled with water samples respectively. Two millilitre (2 ml) of manganese sulphate and 2 ml of alkali-iodide-azide solution was added by inserting a pipette just below the surface of the liquid. The bottles were stoppered to avoid air being introduced, then the content of the bottles were properly mixed by inverting them several times. The bottles were left to stand for 3 min. The presence of oxygen was indicated by the formation of brownish-orange precipitate. Two millilitres (2 ml) of H_2SO_4 was added to the samples, then properly mixed again and inverted to dissolve the precipitate. Two hundred and one millilitre (201 ml) of the samples was measured into a clean 250 ml conical flask and titrated against sodium thiosulphate solution ($Na_2S2O_3.5H_2O$) using the starch indicator until the solution turned colourless. BOD measurement requires taking two samples at each site. One set of the BOD bottles were tested immediately for dissolved oxygen, and the second is incubated in the dark at 20 C for 5 days and then tested for the amount of dissolved oxygen remaining. The difference in oxygen levels between the first test and the second test, in milligrams per litre (mg/L), is the amount of BOD.

2.3.8 Chemical oxygen demand (COD)

The COD measurement was performed according to the standard methods using reflux digestion and $K_2Cr_2O_7$ titration, that is described in the International Standards ISO 6060-1989 and ISO 15705-2002. The excess $K_2Cr_2O_7$ is titrated against ferrous ammonium sulphate solutionusing ferroin as an indicator, and the oxidation of the sample was performed by the open reflux procedure.

2.4 MICROBIOLOGICAL ANALYSIS

2.4.1 Isolation

A 0.1ml serially diluted water samples were each inoculated onto the following media to determine the total heterotrophic bacterial and fungal counts, total coliform, Salmonella-Shigella and vibrio counts: Nutrient Agar, MacConkey agar, Eosin methylene blue agar, Salmonella- Shigella agar, Thiosulphate-citrate-bile salt-sucrose agar, and Potato Dextrose agar. Isolation was performed by spread plate technique and the cultures were incubated at 37^oC for 24hrs and 3-5 days for fungi. A Pure culture of the isolates was obtained using the same culture media and the morphology was analysed to identity the bacterial and fungal genera.

2.4.2 Identification and Characterization

The bacterial and fungal isolates were identified microscopically, macroscopically and biochemically, and characterized using colonial, morphological and biochemical identification methods. The biochemical parameters include the following tests: citrate, oxidase, catalase, MR-VP, indole, TSIA, and sugar fermentation.

2.5 Statistical Analysis

Data collected were subjected to simple inferential statistical analysis to determine the frequency and percentage of occurrence of microbial species on the water samples using Microsoft Excel Software.

3. RESULTS

The results of the physicochemical properties of the water samples analysed are shown in Table 1. The data indicate that the tested parameters were below the WHO limit and there was no significant difference in the temperature and pH of the different samples. The temperature and pH range between 26-27°C and 6.98-7.08, respectively. The values of the electrical conductivity ranged from 0.080 to 0.150 µs/cm; turbidity ranged between 0.40-1.40 NTU; chloride ranged between 1.187-2.103 mg/l, nitrate was within the range of 0.01 to 0.14 mg/l; BOD ranged from 0.02-0.04mg/l, COD was between 0.00-0.08 mg/l and the total soluble solids were between the ranges of 0.04-0.10mg/l.

Total coliforms are also known as Indicator organisms; stating that their presence indicates the presence of other disease causing organisms in the water body. The faecal coliform count in the table water sampled ranged from < 2 to 7 cfu/100ml as shown in Table 2. The result indicated that all the six samples collected were within the permissible limit in comparison to WHO and USEPA standard for drinking water which is 10 cfu/ml. However, there was high coliform count in S3.

The test result of the total heterotrophic bacterial count shown in Table 3 indicated that the water samples from Choba Campus S3 and B3 had the highest bacterial load. Also, there was no growth from Salmonella-shigella agar in all the campuses while there was bacterial growth using TCBS in Choba campus which indicated the presence of *Vibrio cholera.* The morphological and biochemical characterization of the bacterial isolates are shown in Table 4 with a total of nineteen isolates while morphological characterisation of fungal isolates are shown in Table 5 with a total of sixteen isolates respectively. From the biochemical tests of the bacterial isolates, Gram negative rods were ten, Gram positive cocci were five and Gram positive bacilli were four. The Identification of the isolated colonies was carried out and a total of 6 bacterial genera were identified using Bergey's manual of Bacteriology.

The results of frequency of occurrence for both bacteria and fungi isolates are shown in Fig. 1 and 2 respectively. The result in Fig. 1. indicates that *Escherichia coli* has the highest occurrence and *Staphylococcus sp.* the least, while in Fig. 2 *Aspergillus sp.* appeared to have the highest occurrence and *Fusariumsp* having the least frequency occurrence.

Table 1. Physicochemical properties of the water samples

	ABUJA		DELTA		CHOBA		
	Bottle water1	Sachet water1	Bottle water2	Sachet water2	Bottle water3	Sachet water3	WHO standard
Temperature (°C)	26.8	26.9	26.8	27.0	26.8	26.9	Ambient
pH	6.98	7.01	6.93	7.08	7.00	7.03	6.5-8.5
Conductivity(µs/cm)	0.130	0.150	0.080	0.120	0.150	0.150	1200
Turbidity(NTU)	0.40	0.80	0.40	1.40	0.60	1.20	5
Nitrate(mg/l)	0.01	0.01	0.01	0.13	0.14	0.13	50
Chloride(mg/l)	1.930	1.932	1.187	2.103	2.103	2.103	10
BOD(mg/l)	0.02	0.02	0.02	0.04	0.04	0.04	
COD(mg/l)	0.01	0.00	0.01	0.06	0.06	0.08	2
TSS(mg/l)	0.04	0.08	0.04	0.10	0.06	0.08	500

NTU=Nephelometric turbidity unit WHO, (2002)

Table 2. MPN reading of faecal coliform

	Number of positive tubes			
Sample	10ml	1ml	0.1ml	MPN/100ml
Bottle water 1	0	0	0	<2
Bottle water 2	0	1	0	2
Bottle water 3	0	0	1	2
Sachet water 1	0	2	0	4
Sachet water 2	1	0	0	2
Sachet water 3	2	1	0	7

Table 3. Log (cfu/ml) of the total heterotrophic bacterial count, fungal count, salmonella shigella agar count and vibrio count

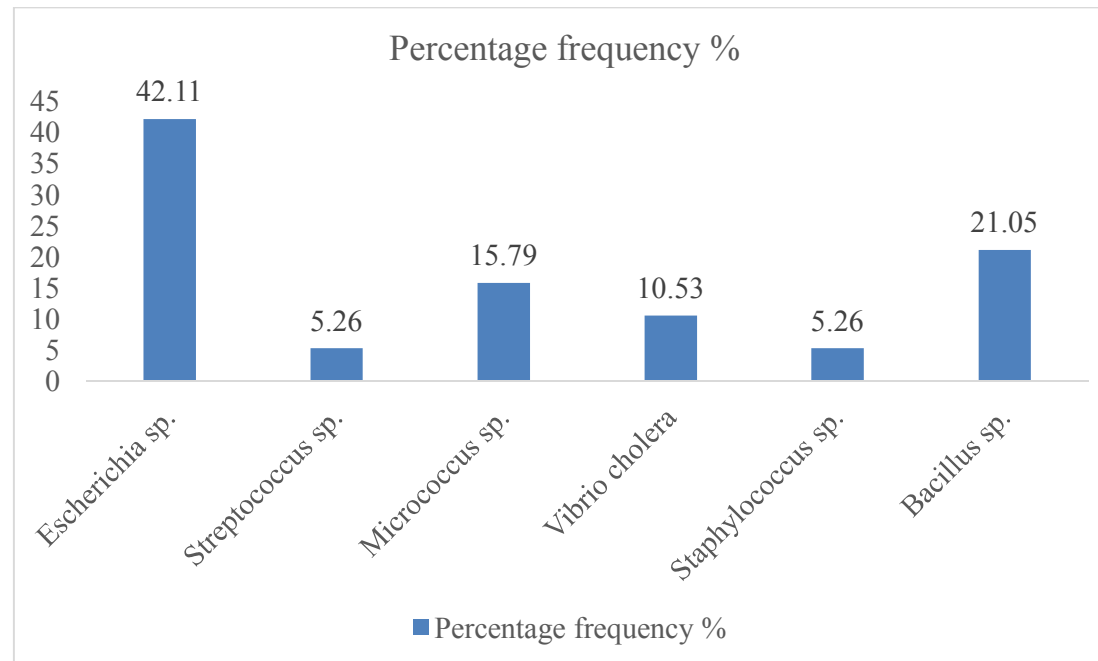| Sample code	THBC		THFC		*Shigella sp.* and *Salmonella sp.*		*Vibrio cholera* count on TCBS	
	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2
B1	3.53	3.46	3.69	3.49	-	-	-	-
B2	3.59	3.49	3.43	3.41	-	-	-	-
B3	3.61	3.51	3.52	3.45	-	-	2.49	2.46
S1	3.69	3.53	3.49	3.65	-	-	-	-
S2	3.71	3.62	3.39	3.56	-	-	-	-
S3	4.08	4.13	3.84	3.76	-	-	2.53	2.61

Fig. 1. Percentage occurrence of bacteria isolates

Table 4. Cultural morphological and biochemical characteristics of bacterial isolates

S/N	MORPHOLOGICAL CHARACTERISTICS								BIOCHEMICAL CHARACTERISTICS								Probable Organism
	ISOLATE	SHAPE	ELEVATION	APPEARANCE	OPACITY	MARGIN	COLOUR	SIZE	GRAM	CAT	COAG	OXID	MOT	LAC	MAN	IND	
1	B1(1)	Circular	Urbanite	Smooth	Opaque	Entire	Yellow	1mm	+	+	-	+	+	+	+	-	*Micrococcus sp*
2	B1(2)	Circular	Raised	Shinning	Translucent	Entire	Cream	2mm	-	+	-	-	+	-	+	+	*Escherichia sp*
3	B1(3)	Circular	Convex	Shinning	Opaque	Entire	Cream	3mm	-	+	-	-	+	-	+	+	*Escherichia sp*
4	B2(1)	Circular	Convex	Smooth	Opaque	Entire	Cream	2mm	-	+	-	-	+	-	+	+	*Escherichia sp*
5	B2(2)	Circular	Convex	Shinning	Opaque	Entire	Cream	1mm	-	+	-	-	+	-	+	+	*Escherichia sp*
6	B2(3)	Circular	Convex	Smooth	Transparent	Entire	Cream	0.5mm	+	-	-	-	-	+	+	-	*Streptococcus sp*
7	B3(TCBS)1	Circular	Flat	Smooth	Opaque	Serrated	Yellow	2mm	-	+	-	+	+	+	+	+	*Vibrocholerae*
8	B3(NA)1	Circular	Raised	Shinning	Opaque	Entire	Golden	3mm	+	+	+	+	-	+	+	-	*Staphylococcus sp*
9	B3(NA)2	Circular	Convex	Smooth	Opaque	Entire	Yellow	1mm	+	+	-	+	+	+	+	-	*Micrococcus sp*
10	B3(NA)3	Circular	Convex	Smooth	Opaque	Entire	Cream	2mm	-	+	-	-	+	-	+	+	*Escherichia sp*
11	S1(1)	Irregular	Convex	Dull	Opaque	Entire	Cream	Large	+	+	-	+	+	-	+	-	*Bacillus sp*
12	S1(2)	Circular	Convex	Smooth	Opaque	Entire	Cream	3mm	-	+	-	-	+	-	+	+	*Escherichia sp*
13	S1(3)	Circular	Convex	Dull	Opaque	Entire	Cream	1mm	+	+	-	+	+	-	+	-	*Bacillus sp*
14	S2(1)	Irregular	Convex	Dull	Opaque	Irregular	Cream	Large	+	+	-	+	+	-	+	-	*Bacillus sp*
15	S2(2)	Circular	Convex	Dull	Opaque	Entire	Cream	3mm	+	+	-	+	+	-	+	-	*Bacillus sp*
16	S2(3)	Circular	Convex	Shinning	Opaque	Entire	Yellow	1mm	+	+	-	+	+	+	+	-	*Micrococcus sp*
17	S3(NA)1	Circular	Raised	Smooth	Opaque	Entire	Cream	1mm	-	+	-	-	+	-	+	+	*Escherichia sp*
18	S3(NA)2	Circular	Raised	Smooth	Opaque	Entire	Cream	1mm	-	+	-	-	+	-	+	+	*Escherichia sp*
19	S3(TCBS)1	Circular	Flat	Smooth	Opaque	Serrated	Yellow	2mm	-	+	-	+	+	+	+	+	*Vibrocholerae*

Keys: (+)-Positive; (-)-Negative; (CAT)-Catalase; (COAG)-Coagulase; (OXI)-Oxidase; (MOT)-Motility; (LAC)-Lactose; (MAN)- Mannitol; (IND)- Indole

Table 5. Macroscopic and microscopic identification of the fungi isolates

| S/N	ISOLATES	MACROSCOPY	MICROSCOPY	PROBABLE FUNGI
1	B1(org.1)	Greenish velvety surface with white rough reverse side.	Septate hyphae with simple conidiosphores. The phialides are having brush-like clusters.	*Penicillin sp.*
2	B1(org.2)	Black-brownish powdery surfaced mycelia with cracks.	Septate hyaline with cornidia like a mop-head.	*Aspergillusniger*
3	B1(org.3)	White-cream convex colony	Budding cells	*Saccharomyces sp*
4	B2(org.1)	Black-brownish powdery surfaced mycelia with cracks.	Septate hyaline with cornidia like a mop-head.	*Aspergilussp*
5	B2(org.2)	Greenish velvety surface with white rough reverse side.	Septate hyphae with simple conidiosphores. The phialides are having brush-like clusters.	*Penicillin sp*
6	B2(org.3)	Whitish-pinkish cotton-like surface with white smooth reverse.	Hyaline septate, conidiophores, phialides are produced from tshe branched cornidia.	*Fusariumsp*
7	B3(org.1)	White-cream convex colony	Budding cells	*Saccharomyces sp*
8	B3(org.2)	Greenish velvety surface with white rough reverse side.	Septate hyphae with simple conidiosphores. The phialides are having brush-like clusters.	*Penicillin sp.*
9	S3(org.1)	Whitish-pinkish cotton-like surface with white smooth reverse.	Hyaline septate, conidiophores, phialides are produced from tshe branched cornidia.	*Fusariumsp*
10	S3(org.2)	Greenish-yellow velvety surface with whitish edge. It has smooth yellow and cracked transverse.	Septate, hyphae with cornidia are long with spherical vesicles at the apex.	*Aspergillusflavus*
11	S3(org.3)	Greenish velvety surface with white rough reverse side.	Septate hyphae with simple conidiosphores. The phialides are having brush-like clusters.	*Penicillin sp.*
12	S3(org.4)	Black-brownish powdery surfaced mycelia with cracks.	Septate hyaline with cornidia like a mop-head.	*Aspergillusniger*
13	S1(org.1)	White-cream convex colony	Budding cells	*Saccharomyces sp*
14	S1(org.2)	Black-brownish powdery surfaced mycelia with cracks.	Septate hyaline with cornidia like a mop-head.	*Aspergillusniger*
15	S2(org.1)	Greenish velvety surface with white rough reverse side.	Septate hyphae with simple conidiosphores. The phialides are having brush-like clusters.	*Penicillin sp.*
16	S2(org.2)	Black-brownish powdery surfaced mycelia with cracks.	Septate hyaline with cornidia like a mop-head.	*Aspergillusniger*
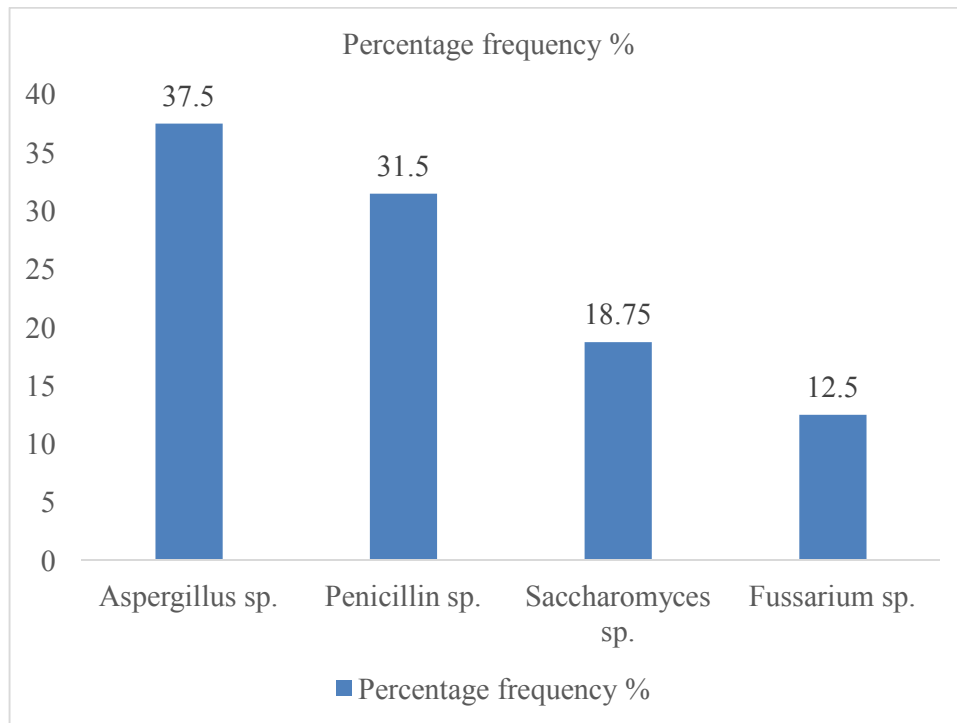
Fig. 2. Percentage occurrence of Fungal Isolates

4. DISCUSSION

Water is an important natural resource on earth due to its vitality. It is essential for the growth of all living organisms, ecological system, human health, and food production. Portable water has been an answer to the question of whether there is safe drinking water. The University of Port Harcourt has an industrious environment with diverse distribution of manufactured products including table water.

The temperature of the studied six water samples were in the range (26.0-27.0) which is higher than the value reported by Milkiyas et al. [22] and Patil et al. [23].Increase in temperature affects the rate of proliferation of microorganisms and it also controls the rate at which chemical reactions occurs, the reduction in solubility of gases, amplifications of tastes and colours of water [24].

The pH is a measure of the acidic or alkaline nature of a solution [25] (Asamoah-Boateng, 2009). The water samples collected from University of Port Harcourt showed pH values ranging from 6.00-7.02. which meets the permissible standard established by USEPA [10] and WHO [19,26]. Milkiyas et al. [22] and Patil et al. [23] reported pH range of 6.5-8.0 in drinking water. Ezekwe et al. [27] also reported a circum-neutral pH of 6.3-7.3 in run downstream. These reports are in agreement with the findings from this study. pH is a significant factor that impacts many biological and chemical processes. It is a water quality assessment parameter which is very important in evaluating water supply and treatment [28]. It has been established that high alkalinity of water is responsible for swelling of hair fibres as well as gastrointestinal irritation [29].

Turbidity is caused by suspending organic/ inorganic materials. Solid particles suspended in water absorb or reflect light causing the water to appear cloudy [27]. According to WHO standard, the turbidity limit of drinking water must be 5.0 NTU. The value found in present study for both the bottle and sachet water were within the prescribed limit (i.e. 0.40-1.40) which is different from those reported by Milkiyas et al. [22].

Nitrates are very soluble salts obtained from Nitrogen, which can be found in drinking water. The nitrification process depends on the temperature, dissolved oxygen content and the pH of the water. The nitrate is not a direct toxicant but could cause health hazard when

converted to nitrite. According to WHO standard, the presence of nitrate in drinking water must be below 50mg/L.

Conductivity in water is influenced by the amount of dissolved salts and the temperature. This implies that at higher salt content, the conductivity will be higher. According to WHO standard for drinking water, the conductivity limit should be 1200µs/cm, and in present study all six samples were within the range (0.00-0.20µS/cm) of permissive limit which is to say they met the permissible limit.

Chloride is a major anion in water associated with sodium. High concentration of chloride may cause the water to have a salty taste. According to WHO standard, the presence of chloride in drinking water must be within 10mg/L limit. All six samples analysed were below the acceptable limit. This result is in agreement with a similar study carried out by Alex et al. [30] which reported chloride content between 3.28-34.5 mg/L in groundwater samples in a community in Rivers state. Milkiyas et al. [22], also reported chlorine concentration of 0.2 – 1.9mg/L in drinkable water. When the concentration of chloride in water exceed the WHO limit, the water is bound to have taste which is not a characteristic of pure water.
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Chemical oxygen demand is one of the most effective parameters in the control of water quality. It constitutes the amount of chemical oxidant needed to oxidize the materials present in the water. It quantifies the amount of total organic matter susceptible to chemical oxidation (biodegradable and non-biodegradable) in a liquid sample and its used to establish the level of contamination [31]. According to WHO standard, the permissible limit for drinking water is 2mg/L which the result obtained in this study is below the limit.

Total soluble solid describes solid matter dissolved in water/waste. These solids can affect the quality of water by causing unfavourable physiological reaction in the consumer. The permissible limit for drinking water according to WHO standard is 500mg/L. The six samples were below the limit (0.00-0.10). This data is different from the ones reported by Milkiyas et al. [22].A study carried out by Olubanjo et al. [32], reported that TSS of water samples from wells located in Ondo state during rainy and dry season is within the range of 0.00-8.00 mg/L and 0.0-10.00 mg/L while the values encountered in

water samples from boreholes during rainy and dry seasons is within the range of 0.00-4.00 mg/L and 0.00-6.00 mg/L, respectively. Their findings is not in agreement with ours possibly because of treatment method and anthropogenic activities in various areas. .

Following the microbiological analysis, bio chemical testing and Gram's staining, it was noted that the table water samples from the campuses were contaminated with various microorganisms which are unsafe for human consumption. *Escherichia sp.* an indicator organism which when present in water indicates a high rate of contamination and presence of other disease causing organisms in the water body like *Streptococcus sp.*, *Staphylococcus sp.*, *Micrococcus sp.*, *Bacillus sp.* and *Vibrio cholera*. The presence of fungi like *Aspergillus sp., Saccharomyces sp., Penicillin sp.*, and *Fusarium sp.*, also indicates that the water is unsafe for consumption and can result to health issues. Findings from this study is in line with the reports of Milkiyas et al. [22] and Shield et al.[33]who reported the presence of coliforms and fungi species in drinkable water samples.

5. CONCLUSION

The physicochemical analysis carried out on the table water samples collected from the different campuses of the University of Port Harcourt showed that the table water sold within the campuses can be considered potable with the facts that the water samples met the physicochemical properties permissible limit established by the World Health organisation (WHO). In contrary, the microbiological analysis showed that the table water samples were contaminated with different bacteria and fungi isolates dangerous to human health especially in the ones sold within Choba campus. The organisms identified can cause human health issues especially to students and staff within the campuses. The University of Port Harcourt has a wide distribution of different table water brands within its campuses; and it is necessary to carry out analytical work on a larger to indicate the level of contamination of the different brands of table water sold within the campuses and also identify the species of the genera isolated in the present study. The results of this analysis showed the level of contamination of the six table water samples sold within the University of Port Harcourt campuses during the month of September 2019. Therefore, this study suggests the improvement of water-borne disease

preventive and control measures, and monitoring of water quality by the regulatory agencies to ensure good manufacturing practices by the water bottling companies which will result in reduction of health hazards associated with water borne diseases.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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