Original Research Article

ANTIBIOTIC SUSCEPTIBILITY PATTERN OF BACTERIA IN SACHET WATER, SOLD UYO METROPOLIS, AKWA IBOM STATE

.

ABSTRACT

Aims: This study was carried out to examine the microbiological quality of sachet drinking water sold in Uyo metropolis, Akwa Ibom State.

Study design: Sachet water was randomly sampled in Uyo Metropolis.
Place and Duration of Study: Department of Microbiology Akwa Ibom State University, Nigeria, between June 2018 and November 2018.

Methodology: Six Different brands of sachets water sold and consumed were studied for their physical and microbiological qualities. Thirty (30) sachets water from six (6) different brands were serially diluted and cultured on Nutrient agar, Eosin Methylene Blue agar, MacConkey agar and Salmonella Shigella agar, while Muller Hinton agar was used for sensitivity test. Pure isolates suspension were standardized with 0.5 McFarland turbidity standard and were subjected to antibiotics susceptibility test using Agar Diffusion method.

Results: The microbial counts ranged from 9.20×10^1 Cfu/ml to 1.77×10^2 Cfu/ml. Bacterial isolates include; *Klebsiella* sp., *Escherichia* sp., *Staphylococcus* sp., *Salmonella* sp., *Pseudomonas* sp., *Citrobacter* sp., *Bacillus* sp. All the isolates were completely susceptible to Chloramphenicol, Ampiclox, Tarvid and Peflacine. Low percentage of these isolates were resistant to Erythromycin, Gentamycin, Septrin, Ciprofloxacin, Norfloxacin, Chloramphinecol, Levofloxacin and Rifampicin but were highly resistant to Amoxil, Ceporex, Augmentin, Ampicillin, Nalidixic acid and Stretomycin. Some of the sachet water brands from bacteriological standpoints did not meet the World Health Organization Standard.

Conclusion: This study indicted sub-standard packaged waters as a vehicle of spread of antibiotic resistant pathogens, and this poses a high risk to public health. Hence, routine monitoring of producers of sachet water should been enforced.

Keywords: Sachet water, Antibiotics resistance, Public health, water standards.

1. INTRODUCTION

The safety and quality of drinking water has become a public health concern in the world. In Nigeria, high demand of safe drinking water cannot be overemphasized considering the inability of the government to provide adequate pipeborne water to the populace. Water is known to be the dwelling place for most bacteria and other microorganisms which cause a

variety of waterborne infections [1] and the World Health Organization (WHO) estimated that 1.1 billion of the world's population does not have access to safe water. In addition to this, 80% of diseases and one-third of deaths in developing countries are due to consumption or drinking of contaminated water [2]. The associated health risks from the consumption of unsafe drinking water vary throughout the world depending on the chemical or microbiological contaminants present in the environment [3]. Many of the bacteria isolated in water distribution systems are opportunistic pathogens. The presence of high numbers of opportunistic pathogens in drinking water is of concern because these microorganisms can lead to infection of certain segments of the population (newborn babies, the sick, and the elderly) [4]. According to the guideline set by the World Health Organisation, quality drinking water must not contain *Escherichia coli* or thermotolerant coliform bacteria, giardia worms, viruses, *Cryptosporidium* spp*, Legionella pneumophila, Entamoeba hystolitical* and other opportunistic pathogens such as *Clostridium* sp*ecies, Klebsiella* species and *Pseudomonas* [2]. The guideline further stated that the water should be tested against the presence of highly virulent pathogens such as *Salmonella typhi, Shigella dysenteriae* and *Vibrio cholera* that are responsible for typhoid, bacillary dysentery and cholera diseases respectively which arises due to high level of organic decay and fermentation on tropical waters. All these bacteria must not exist in water that are meant for drinking, hence, sources of water for packaged water are subjected to laboratory test by public analyst in which any of the bacteria must not be found or detected in any 100 ml water sample. "Sachet water is not sterile" according to Linda [3]. Although, sachet water is assumed to be free from certain pathogen during treatment processes, but certain organisms are used to confirm the sterility of the water such as coliforms which act as indicator organisms used to assess the safety of water and thus give an idea of the degree of contamination associated with intake of such sachet water [4,5]. Antibiotics is been revolutionized in medicine diversely, saving many lives because it had a major impact on the rate of survival of pathogens from infection. But with this great and remarkable benefit, it is sad to know it is also the bedrock of many other diseases due to their resistance strains. Recently, almost all important bacterial infections are becoming resistant to antibiotics, and these changing patterns caused a demand for new antibacterial agents. Antimicrobial resistance occurs when bacteria adjust or adapt in ways that permits them to stay alive in the presence of antibiotics designed to kill them, bacteria evolve resistance to these drugs, typically by acquiring chromosomal mutations and multidrug resistant plasmid which has become a public health concern [6,7,8]. Antibiotics were formally defined to distinguish their biochemicals which are produced by microorganism from the organic chemicals synthesized in the laboratory. But due to recent development, the distinction between both is no longer meaningful due to the fact that the biochemical structures of many naturally occurring antibiotics are now being synthesized by organic chemist and currently, many antibiotics used in medicals are in the chemically modified forms of microbial biosynthetic form [9].

Antibiotic resistance occurs when the sensitivity of an organism decreases against an antibiotic when compared to officially available breakpoints, usually measured as a decrease in "inhibition zone diameter". The increased use of antibiotics is often associated with increased resistance of bacteria to these chemicals, especially in the hospital setting [10]**.** A lot of transmissible diseases are waterborne. Many harmful microbial contaminants have been confirmed to be associated with potable water sources. Many people have resorted to patronizing sachet water with the belief that it is pure-hence, fondly called 'pure water'. It is possible that this so called pure water is not pure after all; hence it may harbour harmful microorganisms as producers of such water may not pay adequate attention to microbial quality. Identification of the major harmful microbial contaminants (*Escherichia coli, Salmonella, Shigella*, etc.) present in the sachet water is important in assessing its safety. Free from contamination with faecal matter is the most important parameter of water quality because human faecal matter is generally considered to be a greater risk to human health as it is more likely to contain human enteric pathogens [11]. There is need to constantly

access the water quality of water sources available to members of any community at intervals. This will help monitor or track and prevent the sudden outbreak of waterborne infections. It is also important to know the antibiotics susceptibility pattern of microorganism common in our environment in case of any outbreak. This research was borne as a result of the widespread use of sachet water in Nigeria especially in Akwa Ibom State, conflicting results on the safety conducted at different locations in the country and lack of data on safety of sachet water locally available. This research is aimed at determining the antibiotic resistant pattern of bacterial isolates obtained from sachet water by testing them against some of the commonly used antibiotics; taking notes of the antibiotic resistant strains.

2. MATERIALS AND METHODS

2.1 Study area

Three major areas in the major city of Uyo in Akwa Ibom State where strategically selected for this study. The areas comprised of towns where sachet-packaged drinking water is sold by hawkers. They included: Abak road, Aka road and Oron road.

2.2 Sample collections

A total of Thirty (30) sachet water of six different brands was collected randomly from various part of Uyo metropolis in Akwa Ibom state and taken to the laboratory for analysis. The samples were coded as; BC, GO, FD, RS, ML, and CV to reflect the respective brands. They were collected and transported in clean ice containers and stored at 4.0^{o}C for 30-60 minutes so as to maintain the properties of the sample before commencement of analysis. Hygienic and aseptic methods were also observed during sampling of the sachet water.

2.3 Sterilization

Microbiologically, sterilization is simply any process that eliminates, removes, kills, all forms of life and any other biological agents (such as bacteria, fungi etc) present in a specific region. This was achieved through the process of autoclaving (steam under pressure) and oven drying. Media, water, and other heat stable liquids were sterilized in the autoclaved at 121^{0}C for 15minutes, while glassware were sterilized at 160^{o}C for at least 2 hours. Also, the working environment was always kept neat, tidy and sterile by the process of disinfection.

2.4 Enumeration of microbial load in water sample

2.4.1 Preparation of the samples

Using aseptic method, six (6) different beakers were labelled according to the 6 different brands of waters. Five sachets were mixed from each brand to obtain 100ml homogenous sample in the beaker.

2.4.2 Pour plating method

One millilitre of appropriate dilution was aseptically pipette into sterile labelled petri dish and this was done in duplicates. Appropriate medium (Nutrient agar, Eosin Methylene Blue, MacConkey agar, Salmonella-Shigella Agar) at 45^{o}C were poured aseptically into the inoculated petri dishes and swirled gently to mix. They were inversely incubated at 37^{o}C for 24-48hours. At the end of the incubation period, colonies were counted and the count for each plate expressed as colony forming units per gram (cfu/mL) of the sample suspended.
Nutrient agar (NA) to determine the total viable bacterial Count, Eosin Methylene Blue agar (EMB) to enumerate *Escherichia coli*, MacConkey agar (MAC) for coliform count and Salmonella-Shigella agar (SSA) for the determination of *Salmonella* and *Shigella* counts. Culture media were prepared according to the respective Manufacturers specification and sterilized in an autoclave at 121^{o}C at 15 psi for 15 minutes.

2.4.3 Purification of colonies

Using a fresh nutrient agar medium, 24 hours colonies were picked using a sterile wire loop from the plate and streaked on its surface and incubated for 24 hours at 37^{o}C to obtain pure culture. After incubation, discrete growths were observed on the lines of streak. Distinct colony was picked aseptically and cultured on a fresh nutrient agar slant and incubated for 24hours at 37^{o}C and stored in a refrigerator at 4^{o}C. The routine laboratory method of Cruickshank *et al.* [12] was used to characterize different isolates. The isolates were identified using their macroscopic, cultural, physiological and biochemical characteristics.

2.5 Morphological characterization (Gram's reaction)

Gram staining was carried out as described by Olutiola *et al*. [13]. Gram stain is one of the differential stains used to characterize bacteria into two main groups: Gram positive and Gram negative. Gram positive stains blue to purple while Gram negative stains pink to red. The colony of the pure cultures of each bacterial isolates was observed for morphological features using Bergey's Manual of Determinative Bacteriology as a standard for comparison. Cell shape was determined under X100 objective of the light microscope after Gram staining procedure. Bacterial smear (not too thick not too thin) was prepared on the slide using an inoculation loop. This was done by introducing a drop of distilled water on grease-free labelled slide followed by the sample and then smeared, air dried and heat fixed. The slide was flooded with crystal violet staining reagent for about 60 seconds, then washed using a gentle indirect stream of tap water for about 2 seconds. The slide was flooded with a mordant (Lugol's iodine) for 15-30seconds. The slide was decolorized using 70% ethanol for 10 seconds and washed off. Lastly, the slide was flooded with 0.5% counter stain (safranin) for 30 seconds, and then washed using indirect stream of tap water and air dried. A drop of immersion oil was dropped on the stained sample and observed under the microscope.

2.6 Biochemical Characterization and Identification of Isolates

Pure cultures of bacterial isolates were subjected to various biochemical tests according to standard techniques described by Olutiola *et al*. [13] Biochemical tests carried out include; Catalase test, Coagulase test, Indole test, Oxidase test, Citrate test, Fermentation of glucose, lactose, sucrose, maltose and mannitol [14]. Bacterial isolates were identified using Bergey's Manual of Determinative Bacteriology [15].

2.7 Antimicrobial Sensitivity Testing

Commercially available antibiotic impregnated 8mm sensitivity discs (Abtek Biological Ltd, UK) was used to determine the drug sensitivity profile of the isolates. Seventeen different antibiotic discs comprising of Tarivia (OFX), Nalidixic acid (NA), Peflacine (PEF), Gentamycin (CN), Augumentin (AU), Ciproflox (CPX), Septrin (SXT), Ceporek (CEP), Streptomycin (S), Ampicillin (PN) for Gram negative and Levoxin (Lev), Amoxicillin (Amx), Norfloxacin (NB), Chloramphenicol (CH), Erythromycine (E), Ampiclox (APX), Rifampin (RD), Streptomycin (S), Ciproflox (CPX), Gentamycin (CN) for Gram positive organisms . The antimicrobial sensitivity test of each isolate was carried out as described by the Kirby – Bauer disc diffusion method as recommended by the National Committee for Clinical Laboratory Standards [16]

Procedures: The turbidity of the bacterial suspensions was compared with 0.5 Macfarland's standard by inoculating the organism into 10ml peptone water and incubate. The standardized bacterial suspension was then inoculated on to Muller Hinton Agar and left to dry for 10 minutes, before placing the antimicrobial sensitivity discs. After incubation, the diameter of the zone of inhibition were measured and compared with zone diameter of interpretative chart [17,18] to determine the sensitivity of the isolates to antibiotics.

3. RESULTS

All the water samples were National Agency for Food and Drug Administration and Control (NAFDAC) approved and had factory addresses on them (Table 1). They were all odourless, colourless and clear in appearance and had no batch number, also non had production and expiration dates meaning that the duration between production and consumption cannot be determined. Only FD contained little particles in it. Lastly, all were the same net volume of 50 cl.

Table 2 shows the Total viable count (TVC) after 48 hours of water samples on different media. All the water samples were contaminated with bacteria. A higher value of TVC on Nutrient agar (NA) was $1.34X10^2$ cfu/ml from sample FD, Eosin Methylene Blue agar (EMB) plate was $3.1X10^1$ cfu/ml from sample ML, MacConkey agar (MAC) plate was 25cfu/ml from sample ML and on Salmonella Shigella agar (SSA) plate it was 5.0 cfu/ml from sample FD. The highest number of organisms (on all the media) was $1.77X10^2$ cfu/ml in FD sachet water and the lowest was $7.6X10^1$ cfu/ml in CV sachet water.

Out of 29 bacteria isolate, 7 distinct isolates were obtained while others where replicates of the seven. *Klebsiella* sp. had the highest frequency showing 7 out of 29 representing 24.14%, followed by both *Staphylococcus* sp. *and Psuedomonas* sp. with the frequency of 5 out of 29 isolates representing 17.24%. Other bacteria isolated included; *Escherichia* sp. with the frequency of 4 out of 29 representing 13.79%, *Salmonella* sp. and *Citobacter sp*. with frequency of 3 out of 29 representing 10.34% and *Bacillus* sp. with the least frequency 2 out 29 representing 6.90% as shown in Figure 1.
Six brands of sachet water were analyzed and a total of seven bacterial isolates were identified from the sachet water samples. The isolates were initially differentiated on the basis of the cultural and morphological studies after which they were subjected to various biochemical characterization tests. These tests revealed their probable identity as *Klebsiella* sp., *Escherichia* sp., *Staphylococcus* sp., *Salmonella* sp., *Pseudomonas* sp., *Citrobacter* sp., *Bacillus* sp.
Klebsiella sp. was most resistant (70%), followed by *Escherichia* sp and *Salmonella* sp. *E Escherichia* sp was resistant to 6 (NA, CN, AU, SXT, S, PN and CEP) out of the 10 antibiotics tested against it. Same number of antibiotic resistance was recorded for *Salmonella* sp. (NA, CN, AU, S, PN and CEP). The least resistant gram negative isolate was *Citrobacter* sp. (NA, CPX, S, and PN) and *Pseudomonas* sp. All the Gram's negative isolates were resistant to PN and NA. The Gram's positive organisms were less resistant to all the antibiotics they were exposed to. *Bacillus* sp. was resistant to on ciproflox while Staphylococcus sp. was resistant to amoxicillin and Gentamycin (Table 3)

Table 1: Physical examination of the sampled Sachet water brands sold in Uyo metropolis for compliance. Table pattern according to Dada, 2009.

SAMPLE CODE	NAFDAC	PRODUCTION./ BEST FORE DATE	PRODUCERS' NAME & ADDRESS	COLOUR	APPEAR-ANCE	ODOUR	FLOATING PARTICLES	BATCH NO:	NET VOLUME
BC	+	_	+	_	_	_	None	_	50CL
FD	+	_	+	_	_	_	Few	_	50CL
RS	+	_	+	_	_	_	None	_	50CL
CV	+	_	+	_	_	_	None	_	50CL
ML	+	_	+	_	_	_	None	_	50CL
GO	+	_	+	_	_	_	None	_	50CL

KEY: +: displayed on sample sachet; -: not displayed on sample sachet

Table 2: Total viable count (TVC) after 48hours of culturing sachet water samples on different media

Sample/ Media	NA	EMB	MAC	SSA	Total no. of organism (cfu/ml)
BC	110	30	15	0	1.55×10^2
FD	134	29	9	5	1.77×10^2
RS	70	8	14	0	9.20×10^1
CV	25	31	20	0	7.60×10^1
ML	20	45	25	2	9.20×10^1
GO	118	18	12	1	1.48×10^2

KEYS: NA: Nutrient Agar; EMB: Eosin Methylene blue agar; MAC: MacConkey agar; SSA: Salmonela Shigella Agar

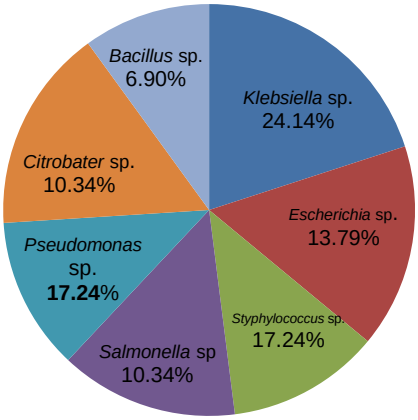

FIG. 1: Percentage frequency of bacteria isolates obtained from sachet water sold in Uyo metropolis

TABLE 3. Antibiotics susceptibility pattern of bacterial isolate from sachet water sold in Uyo metropolis.

		Gram Positive Isolates										Gram Negative Isolates										
S/N	Isolate	AMX	S	NB	CPX	CH	E	LEV	CN	APX	RD	OFX	NA	PEF	CN	AU	CPX	SXT	S	PN	CEP	% RESISTANCE
1	*E. coli*											S	R	S	S	R	S	R	R	R	R	60
2	*K. pneumonia*											S	R	S	R	R	R	S	R	R	R	70
3	*Bacillus* sp.	S	R	S	S	S	S	S	S	S	S											10
4	*S. aureus*	R	S	S	S	S	S	S	R	S	S											20
5	*Pseudomonas* sp.											S	R	S	S	R	S	S	S	R	R	40
6	*Citrobacter* sp.											S	R	S	S	S	S	R	R	R	S	40
7	*Salmonella* sp.											S	R	S	R	R	S	S	R	R	R	60

KEY: Tarivia (OFX), Nalidixic acid (NA), Peflacine (PEF), Gentamycin (CN), Augumentin (AU), Ciproflox (CPX), Septrin (SXT), Ceporek (CEP), Streptomycin(S), Ampicillin(PN) for Gram negative and Levoxin (Lev), Amoxicillin (Amx), Norfloxacin (NB), Chloramphenicol (CH), Erythromycine (E), Ampiclox (APX), Rifampin (RD), Streptomycin (S), Ciproflox (CPX), Gentamycin (CN).

4. DISCUSSION

This experiment was carried out to determine the microbial quality and the antibiotics resistance pattern among the bacterial isolates from sachet water sold in Uyo with the view of creating public health awareness concerning drinking such water sample. In Nigeria, sachet water is largely taken and they are obtained either from surface or underground sources, and are subjected to various treatment to make it fit for individual consumption, but unfortunately, most of them still fall below the WHO standard from the physical and microbiological analysis [19]. From this analysis, one out of six water samples had particles in it. Meanwhile, all were odourless, colourless, and registered with NAFDAC. Bacteria occurrence was recorded in all the sachet-water samples and the TVC for some were higher than what is acceptable for drinking water (1.0×10^1 cfu/ml) [20].

The presence of pathogenic bacteria (opportunistic pathogens) was recorded which is above the WHO standard for portable water [4]. High occurrence of *Klebsiella* sp. was recorded, followed by *Staphylococcus* sp*.* Others included *Pseudomonas* sp*, Escherichia* sp., *Salmonella* sp, *Citrobacter* sp*.* and the least frequent was *Bacillus* sp. Total Viable Count on EMB and MAC for coliform bacteria and the various values obtained for each water sample signified possible faecal contamination. This indicates that the sachet-water samples were contaminated especially with faecal materials, thereby not safe for drinking. Presence of coliforms (*Escherichia* sp. and *Klebsiella* sp. and Citrobacter sp.) maybe that some of the water were prepared from shallow and contaminated boreholes. Most of these bacteria are indigenous to aquatic environments [20]. *Salmonella* is also as a result of contaminated water and improper treatment, *Pseudomonas* sp. were also found in water and are considered opportunistic pathogens and *Staphylococcus* sp*.* isolated from the water samples may have entered the water during packaging or handling since the organism is a normal flora of the human skin [21]. The ingestion of these bacteria with contaminated water constitute public health risks to the immunocompromised members of the population, especially newborn babies, elderly and sick people [22]. The presence of relative heavy load of bacteria in water packaged for drinking purposes has been previously documented in literature [23, 24, 25, 26]. The result of the antibiotics susceptibility testing showed various percentages of antibiotic resistance among the bacterial isolates from packaged water samples. *Escherichia* sp. was highly resistant to six antibiotics and sensitive to only four antibiotics which were; Tarivia (OFX), Gentamycin (CN), Peflacine (PEF) and Ciproflox (CPX). *Klebsiella* sp. was resistant to seven antibiotics and sensitive to Tarivia (OFX), Peflacine (PEF) and Septrin (SXT). *Bacillus sp.* was sensitive to all antibiotics and resistant to only Streptomycin (S). *Staphylococcus* sp. was also highly sensitive to all the antibiotics except Amoxicillin (AMX) and Gentamycin (CN). *Pseudomonas* sp*.* was also sensitive to most antibiotic except Nalidixic acid (NA), Augumentin (AU), Ampicillin (PN) and Ceporek (CEP). *Citrobacter sp.* was more sensitive to the antibiotics and resistant to only four antibiotics; Nalidixic acid (NA), Septrin (SXT), Streptomycin (S), Ampicillin (PN). *Salmonella sp.* was highly resistant to all the antibiotics except four; Tarivia(OFX), Peflacine(PEF), Ciproflox (CPX) and Septrin (SXT). Generally most of the isolates were resistant to Amoxil, Ceporex, Augmentin, Ampicillin, Nalidixic acid and Stretomycin. The resistance exhibited by *Pseudomonas aeruginosa and E. coli* to some of the antibiotics corroborates earlier report from South Eastern Nigeria [27]. The presence of the same type of faecal bacteria in almost all brands shows common source of contamination. It is documented that bacteria habour series of antibiotic resistant genes which can be transferred to others horizontally [28].

Therefore from observation, a lot of sachet water producers and sellers have emerged making it their major source of income. With this, appropriate health authorities should ensure that producers comply with the government regulations since some of these packaged water may have been produced under unhygienic conditions. Water can be seen as one of the most important, as well as one of the most abundant of those compounds and it is particularly, vital to living organisms [29]. Also, water is like the life wire of the body and

as the basis of life; it is a critical part of human diet. Water constitutes about 90% by weight of the human body [30]. So, water should be treated and the necessary biochemical and microbiological test should be carried out to protect the general public from water-borne disease outbreak.

5. CONCLUSION

The study revealed that bacteriological quality of the sachet water brands sold failed to meet the standard for drinking water, even though the bacterial load did not exceed the maximum range of microbial load. However, the bulk of sachet water brands were contaminated by coliform bacteria. It is therefore necessary for sachet water brands to be properly treated and handled to meet the WHO standard for drinking water. To minimise the problem of poor quality of sachet water, government agencies like the NAFDAC and the Environmental Protection Agency should ensure that packaged water manufacturers comply with good manufacturing practices. It is a serious threat to the people of the area if proper measurements are not taken by the concerned authorities. The water sources were contaminated with *Klebsiella* sp., *Escherichia* sp., *Staphylococcus* sp., *Salmonella* sp., *Pseudomonas* sp., *Citrobacter* sp., and *Bacillus* sp. thus posing a very serious threats to the society. Antibiotic resistance is considered a major problem because many disease causing bacteria are becoming more resistant to the commonly used antibiotics. The bacteria *Klebsiella* sp., *Escherichia* sp., *Citrobacter* sp., showed greater antibiotic resistances. The overuse and misuse of antibiotics can create the conditions for the development of antibiotic resistant bacteria.

5.1 Recommendation

There is need for NAFDAC to intensify efforts in the routine monitoring of activities in the packaged drinking water industry ensuring the safety of sachet drinking water through comprehensive regulatory programs at both the federal and state levels. Also, sample collection and testing of market samples will be a good way of detecting if the water is truly pure as claimed by these producing companies. High emphasis should also be placed on enforcing compliance with Good Manufacturing Practice (GMP) with emphasis on management of raw water source to the consumer product point. Hence, routine monitoring of producers of sachet water should be enforced to ensure adherence to drinking water standard.

COMPETING INTERESTS

Authors have declared that no competing interest exist.

REFERENCES

1. Spellman FR, Drinan J. The Drinking Water Handbook. Lancaster, Pennsylvania, USA: *Technomic Publishing Company Incorporated*. 2000. Pp. 260.
2. World Health Organization. Drinking Water Quality Guideline 4th Edition. World Health Organization (WHO), Geneva, Switzerland. 2011;1-28.
3. Linda OA, Uchenna CO, Moses NI, Chinelo KU, Charles, OE. Microbial Evaluation and Antibiotic Susceptibility Profile of Isolates of Popular Sachet Water Brands Sold in Anambra State. *British Microbiology Research Journal,* 2016;12(4), 1-9.
4. Bitton G. *Wastewater microbiology*. 3rd Edition. Wiley series in ecological and Applied Microbiology. 2005

5. Barrell R, Hunter PG. Microbiological Standards for Water and their Relationship to Health Risk. *Communicable Diseases and Public Health,* 2000;3(1): 8-13.
6. Finch RG, Greenwood D, Norrby SR, Whitley RJ. Antibiotic and chemotherapy: Anti-infective agents and their use in therapy. 8th ed. Edinburgh: *Churchill Livingstone*. 2003. 964.
7. Nichol K, Zhanel GG, Hoban DJ. Molecular epidemiology of penicillin resistant and ciprofloxacin resistant *Streptoccocus pneumoniae* in Canada. *Antimicrobial Agents and Chemotherapy*. 2003;47:804-808.
8. Kummerer K. Resistance in the environment. *Journal of Antimicrobial Chemotherapy* 2004;54:311–320.
9. Sharma BC, Rai B. Incidence of multi-drug resistance in *Escherichia coli* Strains isolated from three lakes of tourist attraction (Mirik Lake, Jorepokhari Lake and Nakhapani Lake) of Darjeeling Hills, India. *Indian Journal of Fundamental and Applied Life Sciences*. 2012; 2(2):108-114.
10. Swartz MN. Use of antimicrobial agents and drug resistance. *The New England Journal.* 1997; 45-68.
11. Scott ME, Melton-Celsa AR, O'Brien AD. Mutations in hns reduce the adherence of Shiga toxin-producing *E. coli* 091:H21 strain B2F1 to human colonic epithelial cells and increase the production of hemolysin. *Microbial Pathogenesis*, 2003;34:155–159.
12. Cruickshank R, Duguid JP, Marmion BP, Swain, RHA. Medical Microbiology, Volume II, 12th edition. Churchill Livingstone, Edinburgh, London and New York. 1975.
13. Olutiola PO, Famurewa O, Sonntag HG. *An Introduction to general microbiology: A practical approach*: HeidelbergerVerlagsansalt und DruckereiGmbH. Heidelberg. 1991; P. 267
14. Harrigan WF, McCance EM. *Laboratory Methods in Food and Dairy Microbiology*. Academic Press, London, New York, San Francisco, 1976; 452 pp.
15. Buchanan RE, Gibbon NE. *Bergey's Manual of Determinative Bacteriology*. 9th Edition, Williams and Wilkins Co., Baltimore. 1974
16. National Committee for Clinical Laboratory Standards. Performance standards for antimicrobial disk susceptibility tests. Approved standard M2-A4. Wayne, Pa: National Committee for Clinical Laboratory Standards; 1990.
17. CLSI 2009. Performance standards for antimicrobial susceptibility testing; 19th informational supplement M100–S19. Clinical and Laboratory Standards Institute, Wayne, PANational Committee for Clinical Laboratory Standards. Performance standards for antimicrobial disk susceptibility tests. Approved standard.
18. NCCLS document M2-A5. Wayne, Pa: National Committee for Clinical Laboratory Standards; 1993
19. WHO 2003
20. Berger, P.S., Oshiro, R.K. Source water protection: Microbiology of source water,. *In*: *Encyclopedia of Environmental Microbiology*. G.Bitton, Editor-in-chief, Wiley InterScience, New York. 2002; Pp2967-2978
21. Ollos PJ, Huck PM, Slawson, RM. Factors Affecting Biofilm Accumulation in Model Distribution Systems. *Journal of American Water Works Association,* 2003; 95: 87–97.
22. LeChevallier MW, Seidler RJ, Evans TM. Enumeration and characterization ofstandard plate count bacteria in chlorinated and raw water supplies. *Applied EnvironmentalMicrobiol*ogy 1980; 40:922–930.
23. Onifade AK, Ilori RM. Microbiological Analysis of Sachet Water Vended in Ondo State, Nigeria. *Environmental Research Journal,* 2008; *2: 107-110.*
24. Oladipo IC, Onyenika IC, Adebiyi AO. Microbialanalysis of some vended sachet water in Ogbomoso, Nigeria. *African Journal of Food Science*, 2009; 3(12): 406-412.

25. Oyedeji O, Olutiola PO, Moninuola MA. Microbiological quality of packaged drinking water brands marketed in Ibadan metropolis and Ile-Ife city in South Western Nigeria. *African Journal of Microbiology.* 2010; 4: 96-102.
26. Onilude AA, Adesina FC, Oluboyede OA and Adeyemi BI. Microbiological quality of sachet packaged water vended in three local governments of Oyo State, Nigeria. *African Journal of Environmental Microbiology.* 2013; 4(9): 195-200.
27. Nwachukwu E, Emeruem CM. Presence of antibiotic resistant bacteria in sachet water produced and sold in the eastern Nigeria. *Research Journal of Microbiology,* 2007; 2(10):782-786
28. Piddock, L. J. Clinically relevant chromosomally encoded multidrug resistance efflux pumps in bacteria. *Clinical Microbiology Review,* 2006; **19**, 382–402.
29. Tortora JG, Funke RB, Case LC. Microbiology An introduction*. Media update of 7 Edition including bibliography and index publisher.* Daryl Fox. 2002; 258-260.
30. William C, Sonzogoni P, Standridge J, Bussen M. Madison Preservation and survival of *Escherichia coli* in well water sample*. Wisconsin State Laboratory of Hygiene, University of Wisconsin*. 2002; 4-10.