Microbiology Research Journal International

31(4): 77-88, 2021; Article no.MRJI.70303
ISSN: 2456-7043
(Past name: British Microbiology Research Journal, Past ISSN: 2231-0886, NLM ID: 101608140)

Bacteriological Quality of Potable Water Consumed in Cape Coast and Takoradi Metropolis, Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/MRJI/2021/v31i430314
Editor(s):
(1) Mehdi Razzaghi-Abyaneh, Pasteur Institute of Iran, Iran.
Reviewers:
(1) Dorota Porowska, University of Warsaw, Poland.
(2) Mohsen Mhadhbi, University of Tunis El Manar, Tunisia.
(3) S. Mazando, University of Zimbabwe,Z imbabwe.
Complete Peer review History: https://www.sdiarticle4.com/review-history/70303

Original Research Article

Received 27 April 2021
Accepted 04 July 2021
Published 15 July 2021

ABSTRACT

Background: Bacterial contamination of potable water remains a global canker and has been reported to result in deaths from gastrointestinal infections. Treatment of gastrointestinal infections is becoming difficult due to antimicrobial resistance. This study sought to assess the bacteriological quality of potable water consumed in Cape Coast and Takoradi Metropolis of Ghana.
Methodology: Eighty-seven (87) samples of potable water were collected from various vicinities of Cape Coast (43) and Takoradi (44). The samples were analyzed for their bacterial loads using various laboratory bacteriological procedures and the resulting colonies were subjected to standard identification techniques. Antimicrobial Susceptibility Testing (AST) was carried out to determine the susceptibility patterns of the various isolates.
Results: A total of 220 bacterial isolates were identified comprising 18 species, with *Bacillus cereus*. (13.6%), *Staphylococcus aureus* (8.5%), and *Klebsiella* sp. (10%), being predominant and *Pseudomonas* sp. (2.3%), *Streptococcus* sp. (1.8%), and *Serratia sp*. (0.5%) being less frequent. Antimicrobial Sensitivity Testing (AST) revealed multiple antimicrobial-resistant bacteria including, *Escherichia coli*, *Pseudomonas sp*., and *Klebsiella sp*. The average HPC and TCC of the various

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samples ranged from 0.20 - 1.94 x 10^8 CFU/ml and 0.00 - 2.39 x 10^8 CFU/ml respectively. **Conclusion:** Some potable water in Cape Coast and Takoradi metropolis including most sachet water sold on the streets were found to be highly contaminated with bacteria.

Keywords: Potable drinking water; cape coast; takoradi; antimicrobial resistance; bacteria.

1. INTRODUCTION

The provision of safe drinking water is vitally placed in achieving goal 6 of the sustainable development goals (SDGs) [1] . One-third of the global population (2.1 billion) lacks access to safe drinking water [2] . Water from boreholes, wells, and tap sources, has served domestic purposes in Sub-Saharan Africa and is used even for drinking [3] . However, water from these sources carries various pathogens [4,5]. Like most developing countries, Ghana battles with waterborne diseases and needs safe drinking water. It is believed that approximately 200,000 deaths occur in Ghana attributable to gut-associated diarrhoea-causing agents common as water-borne pathogens. Water considered to be safe for consumption had contained bacteria, protozoa, and even fungi [6–8]. Microbial agents such as enterococci, bacilli positive species, and enteric bacteria had been isolated from water sources in the country, leading to infections such as cholera, bacillary dysentery, hepatitis, shigellosis, gastroenteritis, among others [8–13].

The need for quality safe drinking water has led to the emergence of packaged water phenomenon [14] such as sachet water considered “Pure Water”, in addition to the direct drinking sources [15]. Despite undergoing well-regulated purification methods, sachet water has purity issues [16]. This is invariably caused by unhygienic handling and/or improper manufacturing procedures. Also, the bacteria contaminants in drinking water have been used as microbial indicators: heterotrophic plate count, total coliform, and faecal coliforms, to determine water purity for consumption, where the presence of *Escherichia coli* denotes existing faecal pollution [17].

The introduction of the sachet and bottled water as alternatives to the highly contaminated pipe-borne water, well water, and borehole water, for consumption, is a laudable innovation. Nonetheless, their unwholesomeness and the continuous introduction of new sachet water companies necessitated this study to evaluate bacteriological contamination of potable-drinking water in Cape Coast and Takoradi Metropolis, Ghana, and its significance in public health safety.

2. MATERIALS AND METHODS

2.1 Study Design and Sampling

In this study, random sampling was employed with bottled water serving as positive control. Duplicates of different brands of the sachet water (26|31) and bottled water (5|5), as well as borehole (4|2), well (4|1) and tap water (4|5) were conveniently sampled from retail and wholesale outlets and markets in Cape Coast and Takoradi. The samples were collected using sterilized 50 ml falcon tubes and immediately sent to the microbiology laboratory of the Department of Biomedical Sciences, University of Cape Coast (UCC) for microbiological analysis. Samples taken from Takoradi were transported on ice to the laboratory within 24 hours.

2.2 Bacterial Enumeration

Plate count agar (PCA) and Violet red bile agar (VRBA), both purchased from Oxoid, USA, were used for Heterotrophic Plate Count (HPC) and Total Coliform Count (TCC) respectively, using serial dilution and pour plate methods with 10^5 dilution factors as maximum. Bacteria enumeration was performed as described by the Standard Methods for the Examination of Water and Wastewater [18] with slight modifications.

2.3 Bacteria Culture and Identification

General, selective and differential media including Blood agar (OXOID CM0055), MacConkey agar (microgen DM 1081), Eosin Methyl Blue (EMB) agar (OXOID CM0055) and Salmonella Shigella (SS) agar (OXOID CM0099), Mannitol Salt Agar (OXOID CM085), Simmons Citrate agar (OXOID CM0155), Triple Sugar Iron agar (microgen DM1021), Tryptone Soya Broth (OXOID CM0129), were used in this study to identify the various bacterial cultures. The quadrant streak plate technique was used to

culture morphologically distinct bacteria isolates from the plate count agar onto Blood agar (BA) and MacConkey agar plates as well as selective and differential media including Eosin Methyl Blue (EMB) agar and Salmonella Shigella (SS) agar, and Mannitol Salt Agar (MSA) to isolate members of *Enterobacteriaceae* and *Staphylococcus*. The culture plates were incubated at 37˚C for 18-24 hours. Characteristics such as colonial morphology, swarming on nutrient agar, production of colour, haemolysis on blood agar, lactose-fermentation on MacConkey and Eosin Methyl Blue (EMB) agar, mannitol fermentation on Mannitol Salt agar (MSA), H_2S production on Salmonella Shigella (SS) agar and Triple sugar iron tests were recorded. Further identification was done based on the reactions to the gram stain and biochemical tests such as catalase, coagulase, citrate, urease, indole to identify some of the bacteria at the species levels [19] .

2.4 Antimicrobial Susceptibility Testing (AST)

ASTs were performed on isolates using modified Kirby-Bauer disc diffusion based on the Clinical and Laboratory Standards Institute (CLSI) guidelines [20]. Only one isolate of the various bacteria identified was used for the antibiotic susceptibility testing. Bacterial suspensions were prepared with physiological saline and adjusted to 0.5M McFarland standard and coated onto Mueller Hinton agar plates. Antimicrobial-impregnated disks (Axiom Laboratory, UK) were placed onto the inoculated media and incubated at 37˚C for 24 hours. Ampicillin/Sulbactam (AS)-20µg, Co-Trimoxazole (BA)-1.25/23.75µg, Cefotaxime (CF)-30 µg, Tazobactam/Piperacillin (TZP)-100/10µg, Chloramphenicol (CH)-30 µg, Ciprofloxacin (CP)-5µg, Ceftizoxime (CI)-30µg, Tetracycline (TE)-30 µg, Ofloxacin (OF)-5 µg, Gentamicin (GM)-10µg, Amikacin (AK)-30µg and Levofloxacin (LE)-5 µg were tested on the gram-negative isolates whereas Ampicillin/Sulbactam (AS)-20µg, Co-Trimoxazole (BA)-25µg, Cephalexin (PR)-30µg, Tetracycline (TE)-30µg, Cefotaxime (CF)-30µg, Ciprofloxacin (CP)-5µg, Prulifloxacin (PF)-5µg, Ofloxacin (OF)-5µg, Cloxacillin (CX)-5µg, Roxithromycin (RF)-15µg, Lincomycin (LM)-2µg and Gentamicin (GM)-10µg were tested on gram-positive bacteria.

2.5 Statistical Analysis

The raw data were entered into and statistically analysed using SPSS software for windows, version 21.0 (SPSS Inc., Chicago, IL).

3. RESULTS

3.1 Mean Heterotrophic Colony Count (HPC) in Sachet Water, Wells, Boreholes, Tap Water, and Bottled Water

The mean bacteria loads found in sachet water samples from Cape Coast ranged from 1.60×10^3 - 1.75×10^7CFU/ml compared to 0.00 - 5.22×10^9CFU/ml of Takoradi sachet water samples. Boreholes samples collected from Cape Coast had bacteria loads ranging from 3.89×10^5 - 5.22×10^5CFU/ml, and 2.00×10^2 - 2.02×10^6CFU/ml in Takoradi (Supplementary 1). The overall mean of HPC for well water, tap water, and bottled water were recorded to be 4.57×10^5 CFU/ml, 3.94×10^5 CFU/ml, and 2 CFU/ml in Cape Coast samples respectively, compared to 1.4×10^4 CFU/ml, 4.22×10^5 CFU/ml, and 0.2 CFU/ml in Takoradi samples respectively (Table 1).

Furthermore, while all of the bottled water had HPC values below 100 CFU/ml, all other samples had HPC values above 100 CFU/ml in Cape Coast. Meanwhile, 97% of sachet water sampled from Takoradi had HPC values above 100 CFU/ml (Table 3).

3.2 Mean Total Coliform Count (TCC) in Sachet Water, Wells, Boreholes, Tap Water, and Bottled Water

The mean TCC ranges from 1.0×10^1 - 4.73×10^4 CFU/ml, 9.10×10^3 - 1.21×10^4 CFU/ml, 1.37×10 - 2.45×10^4 CFU/ml, 1.34×10^4 - 2.32×10^4 CFU/ml, 0.00 CFU/ml for sachet water, borehole, well water, tap water and bottled water in Cape Coast respectively whereas in Takoradi the mean TCC ranged 0.00 - 5.20×10^9 CFU/ml, 1.00 CFU/ml, 8.00 CFU/ml, 0.00 - 47.00 CFU/ml and 0.00 - 1.00 CFU/ml (Supplementary 2).

The overall mean TCC of sachet water, boreholes, well water, tap water and bottled water was 2.72×10^3 CFU/ml, 1.44×10^4 CFU/ml, 2.04×10^4 CFU/ml 1.69×10^4 CFU/ml and 0.00 CFU/ml in Cape Coast respectively whereas in Takoradi, the overall mean TCC were 2.39×10^8 CFU/ml, 0.50 CFU/ml, 8.00 CFU/ml, 1.24×10^1 CFU/ml and 0.20 CFU/ml (Table 2).

3.3 Frequency of Bacteria Isolated from Water Samples

A total of 220 cultures produced 17 genera of bacteria isolates, some of which were identified

to the species level. 130 cultures were from samples collected in Cape Coast and 90 cultures from samples collected in Takoradi. The 18 bacterial species isolated species included; *Staphylococcus aureus* (8.5%), *Coagulase-negative staphylococcus* (8.5%), *Bacillus cereus* (13.6%), *Klebsiella sp*. (10.0%), *Salmonella sp*. (9.5%), *Enterobacter cloacae* (8.6%), *Shigella sp*. (7.7%), *Providencia sp*. (6.4%), *Listeria monocytogenes* and *Proteus mirabilis* (5.9%), *Nocardia sp* (5.0%), *Erysipelothrix rhusiopathiae* (4.1%), *Pseudomonas aeruginosa* (2.3%), *Escherichia coli* and *Streptococcus bovis* (1.8%), *Morganella sp*. (0.9%) and *Serratia sp*. and *Citrobacter freundii* (0.5%) (Table 4). The most predominant bacterium in all the cultures was *Bacillus cereus*.

3.4 Bacterial Distribution from Water Sources in Cape Coast and Takoradi

In Cape Coast, predominant bacteria isolated include *Bacillus cereus, Providentia sp.,* and *Enterobacter cloacae* and the least predominant bacteria were *Listeria monocytogenes*, *Erysipelothrix rhusiopathiae, Nocardia* and *Streptococcus bovis* isolated from sachet water. Most of the *Salmonella sp*. (10/12), *Klebsiella sp.* (8/11), and *Staphylococcus sp*. (20/22) were found in sachet water (Table 5). A similar outcome was observed in the water sources in Takoradi (Table 6) where *Providentia sp*., *Nocardia sp, Listeria monocytogenes* and *Streptococcus bovis* were only found in sachet water whereas *Bacillus cereus* was mostly found in sachet water.

3.5 Antibiotic Susceptibility Patterns of Selected Isolates

The isolated bacteria in this study were resistant to most of the antibiotics used, with *Klebsiella sp.* and *Salmonella sp.* being resistant to all the antimicrobials used (Table 7 and Table 8). *E. coli*, *Proteus mirabilis*., *Serratia sp*., and *Morganella sp*. had high resistance to the antibiotics (92%) with *Shigella sp*. being resistant to a few of the antibiotics.

Table 1. Overall mean values of HPC of water samples

Source of potable water	Overall mean of Heterotrophic plate count (CFU/ml)			
	Cape Coast	N	Takoradi	N
Sachet water	$1.61x10^6$	26	$1.94x10^8$	31
Borehole	$4.66x10^5$	4	$1.01x10^6$	2
Well water	$4.57x10^5$	4	$1.40×10^{4*}$	1
Tap water	$3.94x10^5$	4	$4.22x10^5$	5
Bottled water	2.00	5	0.20	5

**Not expressed in mean since only one well was sampled; N= the number of samples employed*

Table 2. Overall mean values of TCC of water samples

Type of potable water	Overall mean of Total Coliform Count (CFU/ml)			
	Cape Coast	N	Takoradi	N
Sachet water	$2.72x10^3$	26	$2.39x10^8$	15
Borehole water	$1.44x10^4$	4	0.50	2
Well water	$2.04x10^4$	4	8.00*	1
Tap water	$1.69x10^4$	4	$1.24x10^1$	5
Bottled water	0.00	5	0.20	5

**Not expressed in mean since only one well was sampled; N= the number of samples employed*

Table 3. Classification of samples according to WHO Criteria on Heterotrophic Plate Count (HPC) for drinking water

	Class	Grade	Presumptive count (CFU/ml)	Sachet water		Bore Hole		Well water		Tap water		Bottled water	
				N	%	N	%	N	%	N	%	N	%
Cape Coast	I	Safe	<100	0	0	0	0	0	0	0	0	5	100
	II	Unsafe	>100	26	100	4	100	4	100	4	100	0	0
Takoradi	I	Safe	<100	1	3	0	0	0	0	0	0	5	100
	II	Unsafe	>100	30	97	2	100	1	100	5	100	0	0

Table 4. Frequency of bacteria isolates in various water samples

Bacterial isolates	Number of bacteria N (%)		Total	Percentage
	Cape Coast	Takoradi	N	(%)
Staphylococcus aureus	11 (8.5)	12 (13.3)	23	15.5
Coagulase-negative Staphylococcus	11 (8.5)	0 (0.0)	11	5.0
Bacillus cereus	17 (13.1)	13 (14.4)	30	13.6
Enterobacter cloacae	17 (13.1)	2 (2.2)	19	8.6
Salmonella sp.	12 (9.2)	9 (10.0)	21	9.5
Shigella sp.	12 (9.2)	5 (5.6)	17	7.7
Klebsiella sp.	11 (8.5)	11 (12.2)	22	10.0
Providencia sp.	11 (8.5)	3 (3.3)	14	6.4
Listeria monocytogenes	8 (6.2)	5 (5.6)	13	5.9
Proteus mirabilis	5 (3.8)	8 (8.9)	13	5.9
Escherichea coli	4 (3.1)	0 (0.0)	4	1.8
Erysipelothrix rhusiopathiae	3 (2.3)	6 (6.7)	9	4.1
Nocardia sp.	3 (2.3)	8 (8.9)	11	5.0
Pseudomonas aeruginosa	2 (1.5)	3 (3.3)	5	2.3
Morganella sp.	1 (0.8)	1 (1.1)	2	0.9
Serratia sp.	1 (0.8)	0 (0.0)	1	0.5
Citrobacter freundii	0 (0.0)	1 (1.1)	1	0.5
Streptococcus bovis	1 (0.8)	3 (3.3)	4	1.8
Total	**130 (100)**	**90 (100)**	**220**	**100**

Table 5. Frequency of bacterial isolates in various water sampled from Cape Coast

Bacterial isolates	Number of Bacteria N (%)	Sachet water N=26	Borehole N=4	Well water N=4	Tap water N=4	Bottled water N=5
Bacillus cereus	17 (13.1)	17	0	0	1	0
Enterobacter cloacae	17 (13.1)	17	0	0	0	0
Salmonella sp.	12 (9.2)	10	1	0	0	1
Shigella sp.	12 (9.2)	11	1	0	0	0
Klebsiella sp.	11 (8.5)	8	2	1	0	0
Providencia sp.	11 (8.5)	11	0	0	0	0
Staphylococcus aureus	11 (8.5)	10	0	1	0	0
Coagulase-negative staphylococcus	11 (8.5)	10	0	1	0	0
Listeria monocytogenes	8 (6.2)	8	0	0	0	0
Proteus mirabilis	5 (3.8)	3	0	0	2	0
Escherichia coli	4 (3.1)	2	0	1	1	0
Erysipelothrix rhusiopathiae	3 (2.3)	3	0	0	0	0
Nocardia sp.	3 (2.3)	3	0	0	0	0
Pseudomonas aeruginosa	2 (1.5)	0	1	1	0	0
Morganella sp	1 (0.8)	0	1	0	0	0
Serratia sp	1 (0.8)	0	0	1	0	0
Streptococcus bovis	1 (0.8)	1	0	0	0	0
Total	**130 (100)**	**113**	**6**	**6**	**4**	**1**

Table 6. Frequency of bacterial isolates in various water sampled from Takoradi

Bacterial isolates	Number of Bacteria N (%)	Sachet water N	Borehole	Well water	Tap water	Bottled water
Bacillus cereus	13 (14.4)	11	0	2	0	0
Enterobacter cloacae	2 (2.2)	1	0	0	1	0
Salmonella sp.	9 (10.0)	7	1	0	0	1
Shigella sp.	5 (5.6)	3	1	1	1	0
Klebsiella sp.	11 (12.2)	6	1	1	2	0
Providencia sp.	3(3.3)	3	0	0	0	0
Staphylococcus aureus	12 (13.3)	8	2	1	1	0
Listeria monocytogenes	5 (5.6)	5	0	0	0	0
Proteus mirabilis	8 (8.9)	5	0	2	1	0
Erysipelothrix rhusiopathiae	6 (6.7)	3	1	1	1	0
Nocardia sp	8 (8.9)	8	0	0	0	0
Pseudomonas aeruginosa	3 (3.3)	2	1	0	0	0
Morganella sp.	1 (1.1)	1	0	0	0	0
Citrobacter freundii	1 (1.1)	0	1	0	0	0
Streptococcus bovis	3 (3.3)	3	0	0	0	0
Total	**90 (100)**	**66**	**8**	**8**	**7**	**1**

Table 7. Antibiotic sensitivity on Gram-negative bacterial isolates from water samples

Bacterial isolate	Antibacterial agent												
	AS	**BA**	**CF**	**TZP**	**CH**	**CP**	**CI**	**TE**	**OF**	**GM**	**AK**	**LE**	**Resistance (%)**
Klebsiella spp.	R	R	R	R	R	R	R	R	R	R	R	R	100
Escherichia coli	R	R	R	R	R	I	R	R	R	R	R	R	92
Enterobacter cloacae	R	R	I	R	R	R	R	I	R	R	R	R	83
Proteus mirabilis	R	R	R	R	I	R	R	R	R	R	R	R	92
Providencia spp.	R	R	R	S	S	S	R	R	R	R	R	R	75
Pseudomonas aeruginosa	R	R	R	R	R	I	R	R	R	S	R	R	83
Salmonella spp.	R	R	R	R	R	R	R	R	R	R	R	R	100
Shigella spp.	R	R	R	I	S	S	R	I	S	S	S	S	33
Serratia spp.	R	R	R	R	R	R	R	I	R	R	R	R	92
Morganella spp.	R	R	R	R	R	I	R	R	R	R	R	R	92

Ampicillin/Sulbactam (AS), Co-Trimoxazole (BA), Cefotaxime (CF), Tazobactam/Piperacillin (TZP), Chloramphenicol (CH), Ciprofloxacin (CP), Ceftizoxime (CI), Tetracycline (TE), Ofloxacin (OF), Gentamicin (GM), Amikacin (AK), Levofloxacin (LE), Cephalexin (PR), Cefotaxime (CF), Prulifloxacin (PF), Ofloxacin (OF), Cloxacillin (CX), Roxithromycin (RF) and Lincomycin (LM) S: Susceptible, I: Intermediate, R: Resistance

Table 8. Antibiotic sensitivity on Gram-positive bacterial isolates from water samples

Bacteria isolate	Antibacterial agent												
	AS	BA	PR	TE	CF	CP	PF	OF	CX	RF	LM	GM	Resistance (%)
Staphylococcus aureus	R	R	R	R	R	S	R	S	R	R	R	S	75
Coagulase negative staphylococcus	R	R	R	R	R	S	R	S	R	R	R	S	75
Bacillus spp.	R	R	R	R	R	R	I	S	R	S	R	S	67
Listeria monocytogenes	R	R	I	R	R	S	S	S	R	S	R	S	50
Streptococcus bovis	R	R	S	R	R	S	S	S	R	S	R	S	50

Ampicillin/Sulbactam (AS), Co-Trimoxazole (BA), Cefotaxime (CF), Tazobactam/Piperacillin (TZP), Chloramphenicol (CH), Ciprofloxacin (CP), Ceftizoxime (CI), Tetracycline (TE), Ofloxacin (OF), Gentamicin (GM), Amikacin (AK), Levofloxacin (LE), Cephalexin (PR), Cefotaxime (CF), Prulifloxacin (PF), Ofloxacin (OF), Cloxacillin (CX), Roxithromycin (RF) and Lincomycin (LM), S: Susceptible, I: Intermediate, R: Resistance

4. DISCUSSION

Water-related infections are of public and global health care concerns [21]. Following the work on the outbreak of cholera in London through water consumption [22], the field of quality water production, has had recognition. As such, the introduction of the sachet and bottled water as handy and convenient drinking alternatives to the pipe-borne water, well-water and borehole water poses grave concern. The Cape Coast metropolis is a well-known tourist centre in Ghana with lots of attractions and significantly noted for its rich history. It is also one of the country's educational hubs attracting international persons for tourism and education purposes. Takoradi metropolis, on the other hand, is gradually becoming cosmopolitan due to the recent discoveries of oil fields in the western part of Ghana. Several reports of unwholesomeness of alternative drinking water on the markets of these two significant metropolises, necessitated this investigation. The study sought to evaluate the microbial quality of potable water likely to be consumed by visitors, tourists, international and local students and the inhabitants of these two metropolises.

From this current study, approximately 95% of all the sampled water from sources in Cape Coast and Takoradi metropolises were contaminated with bacteria. This is consistent with previous work carried out in other parts of the country [7, 23–25]. The Heterotrophic plate count (HPC) of the samples were beyond the safely levels for human consumption. According to the WHO, the Heterotrophic plate count (HPC) for safe drinking water should not exceed 100CFU/ml [26]. The HPC indicates the overall load of aerobic and facultative anaerobes in a water sample [27]. Although HPC does not indicate the kind of microorganisms present, it serves as a guide to wholesomeness or otherwise of potable water along the distribution chain.

Each of the sachet water sampled in Cape Coast (n=26), had HPC values above the WHO standards as observed in a study by Onifade and Ilori [21] . All but one sachet water sample from Takoradi had an HPC value (0.00CFU/ml), below WHO HPC standards. Consequently, all the samples of the borehole water, well water and tap water were deemed unsafe for drinking according to the WHO HPC standardisation. The HPC values of borehole water, well water and tap water ranged from 2.00×10^2 - $2.02\text{x}10^6$ CFU/ml, $1.40\text{x}10^4$ - $5.13\text{x}10^5$ CFU/ml and 4.0×10^2 - $2.10\text{x}10^6$ CFU/ml respectively. Sachet water samples had the highest HPC mean; $1.61\text{x}10^6$ CFU/ml and $1.94\text{x}10^8$ CFU/ml in Cape Coast and Takoradi respectively. This gives an indication of water production flaws such as non-compliance to quality treatment procedures, poor handling practices as well as improper storage techniques employed by producers, retailers and vendors. This also may suggest that most sachet water companies in these metropolises just seal and package directly from well water, borehole water, and/or tap water sources for distribution to markets with very little or no treatment. On the other hand, bottled water used as positive controls recorded the lowest mean HPC value; 2.00CFU/ml and

0.200CFU/ml for Cape Coast and Takoradi respectively suggest strict adherence to quality procedures by bottled water companies. It is therefore recommended that bottled water is the most quality and safe source of drinking water for visitors and indigenes.

The total coliform count (TCC) was carried out on all sampled water, though it is not mostly used as an indicator of faecal contamination, it serves as an indicator of quality treatment checks and to detect the presence of biofilms [27]. The sachet water recorded a mean TCC range of 0.00 - $5.20x10^9$CFU/ml, affirming their poor handling. The water from borehole, well water, tap water and bottled water had TCC of 1.00CFU/ml - 1.21×10^4 CFU/ml, 8.00CFU/ml - 2.45×10^4CFU/ml, 0.00CFU/ml - 2.32×10^4CFU/ml, and 0.00 - 1.00CFU/ml respectively. WHO reports that the TCC in drinking water should not exceed 100CFU/ml. All the sachets of water (100%) showed the presence of total coliforms exceeding the WHO standard, as opposed to 45% of sampled sachet water investigated in Kumasi metropolis in Ghana [24] and previously in Cape Coast metropolis, Ghana (23). Consequently, 100% of bottled water from Kumasi recorded 0.00CFU/ml TCC as reported by Obiri-Danso et al. [24]. Sachet water recorded the highest TCC mean values of $2.72x10^3$CFU/ml and $2.39x10^8$CFU/ml in Cape Coast and Takoradi respectively. This could be due to bacteria potential to resist the treatment procedures established by these water producers. The interplay of poor environmental conditions, ineffective sterilization of vending equipment, and poor personal hygiene could account for the tremendous increase in TCC value above WHO standards.

Additionally, seventeen (18) bacteria isolates namely *Listeria sp.*, *Bacillus cereus*, *Streptococcus sp.*, *Staphylococcus aureus*, *coagulase-negative staphylococcus*, *Erysipelothrix rhusiopathie* as well as the Enterobacteria: *Escherichia coli*, *Klebsiella sp*., *Salmonella sp*., *Enterobacter sp*., *Shigella sp*., *Proteus sp*., *Pseudomonas sp*., *Providencia sp*., *Morganella sp*., and *Serratia sp*. and *Citrobacter* sp. were detected, all of which have previously been recorded in similar water investigation studies [8,12,28–31]. The most prevalent bacteria isolated, *Staphylococcus spp.* (n=34) comprised 15.5% of total isolates similar to findings by Tagoe et al. [32]. The presence of this pathogenic microbe in potable water especially on the market poses danger to tourists, visitors, and indigenes of the two cosmopolitan metropolis. The abundance of the *Staphylococcus spp* demonstrates improper handling of packaged water during production or in post-production settings, as some of these microbes form part of the normal flora, particularly of the skin of humans.

Bacillus cereus, the second most prevalent (13.6%) isolate, was also observed in a study by Oladipo, Onyenike, & Adebiyi, [33]. The presence of *Bacillus cereus* denotes contamination of potable water through unhygienic production machinery, storage as well as rainwater runoffs into groundwater, as they are found in the environment, soil and are airborne. *Enterobacter cloacae* (8.6%) is a member of the *Enterobacteriaceae* family, which includes coliforms. Coliform bacteria in the water are indicative of faecal contamination among others, with ineffective water quality treatment methods. The coliforms recorded in the study included *Klebsiella sp*. (10.0%), *Proteus mirabilis*. (5.9%), and *Escherichia coli* (1.8%). More specifically, *Escherichia coli* in potable water predicts sewage and/or excreta pollution [6,31,34]. The isolation of *Erysipelothrix rhusiopathie* from some of the water samples can be attributed to contamination of water source by infected animals like pigs [35] as they may share with humans some of these water sources. Also, the presence of *Nocardia sp.* and *Listeria monocytogenes* in potable water may be indicative of contaminations via runoffs of soil into groundwater or by faecal deposits [36].

The high patronage of sachet water in the country is based on the perception that the water is subjected to a thorough purification process from production through to packaging. However, a comparison of the microbial contamination of the portable water in Cape Coast and Takoradi as illustrated in Table 5 and Table 6 revealed that sachet water is the most contaminated. This raises concerns about the safety of sachet water vended on the various markets within the metropolis for human consumption.

In Cape Coast and Takoradi, the majority of the populace patronize unprescribed antibiotics from the open market leading to abuse and/misuse of antibiotics and may contribute to the increasing resistance of some bacteria to previously known effective antibiotics [33]. In this study, ten (10) gram-negative organisms and five (5) gram-positive bacteria were subjected to antibiotic

susceptibility testing with multi-disc antibiotics. All the bacterial isolates were resistant to more than two of the commonly used antibiotics in the metropolis and were consistent with previous studies [37], however with a marked increase in resistance.

The gram-negative organisms in the following pairs; *Klebsiella sp*. and *Salmonella sp*., *Escherichia coli* and *Serratia sp*., as well as *Enterobacter sp*. and *Pseudomonas sp*. demonstrated 100%, 92%, and 83% resistance to all twelve (12) antibiotics respectively, while *Shigella sp*. was the least resistant (50%) to the antibiotics. This result showed a marked increase in multiple antibiotic resistance of *E. coli* which was reported to be 100% sensitive to Gentamicin, Ciprofloxacin, and Cefotaxime by Felicitas et al [38] . Also, the high resistance of *Klebsiella sp*., in this study contradicted a report by Tagoe et al., [32] which stated a 37.5% resistance in *Klebsiella sp*. For the individual antibiotic activity on gram-negative bacterial isolates, Ampicillin/Sulbactam and Co-Trimoxazole were ineffective against all the bacteria isolates. The following antibiotics Cefotaxime, and Gentamicin, were not strongly effective against the bacteria isolates. Ciprofloxacin showed moderate susceptibility (50%) against all the isolates. Amongst the gram-positive bacteria, Staphylococcus strains, *Bacillus cereus*., and *Listeria sp*., showed 75%, 67%, and 50% resistance against all twelve (12) antibiotics respectively. Both Lincomycin and Cloxacillin were 100% ineffective against gram-positive organisms whiles Gentamicin and Ofloxacin being 100% effective on all gram-positive bacteria isolated.

5. CONCLUSION

This study showed that the bacteriological quality of potable water, except for bottled water, is questionable and requires effective purification before human consumption. The water sources were contaminated with eighteen (18) different bacteria which are known to be causative organisms for various infections of the gastrointestinal system. Bacteria isolates such as *Bacillus cereus*, *Enterobacter cloacae*, *Staphylococcus spp*., *Klebsiella spp*., and *Providencia spp*., were found to be frequent in sachet water particularly, with *Serratia spp*., *Morganella spp*., and *Streptococcus bovis*, being less the frequent bacteria. Heterotrophic plate count and Total coliform count for all sampled potable water and except for bottled water were above the standardised 100 CFU/ml count of the World Health Organization (WHO). Furthermore, this study revealed some evidence of antibiotic resistance as *Klebsiella spp*., *Salmonella spp*., *Escherichia coli*, *Proteus mirabilis*., and *Pseudomonas aeruginosa* showed marked increase in Multiple Antibiotic Resistance (MAR). It is therefore necessary for the water production guidelines established to be strictly adhered whereas external quality control officers continue to test the quality of water from time to time.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/70303