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Overview of Major Bacterial Contaminants of Drinking Water in Nigeria: A Review

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aim and Objectives: The objective of this study was to provide an overview of the microorganisms implicated in the contamination of household drinking water in Nigeria, their pattern of distribution and the regulatory gap(s) if any that is responsible for the cases of drinking water contamination and water borne diseases in Nigeria.

Study Design and Methodology: The methodology employed for this study involved a comprehensive and critical review of ten randomly selected studies to identify the major bacterial contaminants of drinking water in Nigeria and their distribution. This review was restricted to microbiological measures of drinking water contamination excluding chemical aspects of water quality.

Results: *Escherchia coli* was found to be the predominant microbial contaminant of drinking water in the studies reviewed with 70%, *Klebsiella* sp 60%, *Pseudomonas aeruginos* 60%, *Staphylococcus aureus* 50%, *Proteus* sp 50%, *Enterobacter aerogenes* 40%, *Streptococcus fecalis* 30%, *Salmonella typhi* 30% and 10% for *Vibrio cholerae* and *Shigella* sp.

Conclusion: The presence of microbes in drinking water especially *E. coli* reported in 70 percent of the studies reviewed is a source of concern. The presence of toxin producing strains of *E. coli* like the O157:H7 in drinking water can result in fatal consequences like hemorrhagic diarrhea and kidney failure. The widespread presence of other disease-causing organisms further confirms that

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a good number of the drinking water presented as safe for consumption across Nigeria are actually not fit for human consumption. The gaps reported in most of the studies reviewed were mainly oversight gaps in monitoring by the National Agency for Food and Drug Administration and control, NAFDAC, the agency charged with monitoring food and drugs in the country.

Keywords: Drinking water; pathogens; microbiological contamination; water quality.

1. INTRODUCTION

The quality of household drinking water is important for health and overall well being of household members. According to a UNICEF report, around 90.8 per cent of households in Nigeria drink water contaminated by faeces and other contaminating agents like *E. coli*, the report noted that although 64.1 per cent of the population of the country had access to improved drinking water sources, the states that make up the North-East region were lagging behind with 52.4 per cent, while South-West states top the chart with 87.3 per cent of its residents having access to improved water sources, about two out of every three households use improved water sources according to the report , while a little more than one-third use improved sanitation

compared to 58.5 percent and 31 per cent respectively in 2011 [1].

Drinking water is a major source of microbial pathogens in developing countries and gastrointestinal disease outcomes are also more severe, due to under-nutrition and lack of intervention strategies in these countries with protozoa and bacteria being the major causative agents of water borne diseases [2]. Poor water quality, sanitation and hygiene account for some 1.7 million deaths a year world-wide mainly through infectious diarrhea, nine out of 10 such deaths are in children and virtually all of the deaths are in developing countries due to the introduction of pathogens into drinking water leading to diseases such as cholera, amoebiasis, typhoid fever, giardiasis and



A Sample of Sealed Sachet Water In Nigeria



A Sample of Sealed Bottled Water In Nigeria



Young Girls Fetching Water Borehole in Nigeria

Fig. 1. Common sources of drinking water in Nigeria



Fig. 2. Showing map of Nigeria and six the geopolitical zones

dysentery [2]. In addition, microbial contamination of drinking water sources and the resultant diseases have become a major water quality concern all over the world [3]. It has therefore become imperative to synergistically synthesize knowledge from multiple fields covering comparative aspects of pathogen contamination, and unify them in a single place in order to present an overview of microbes implicated and proffer solution to the problem as a whole.

2. OBJECTIVE

The financial burden of treating water borne diseases can be high, especially for rural dwellers, the objective of this study is to aggregate the various findings and provide a clear overview of water quality and various microorganisms implicated in the contamination of household drinking water as well as the

activities that is principally responsible for drinking water contamination in Nigeria.

3. METHODOLOGY

The methodology employed for this study involved a comprehensive and critical review of ten studies to identify the major bacterial contaminants of drinking water in Nigeria and their distribution. This review was restricted to microbiological measures of drinking water contamination excluding chemical aspects of water quality.

4. FINDINGS

4.1 *Escherchia coli*

This organism is a rod-shaped facultative anaerobe, belonging to the genus *Escherichia*

that mainly indicate fecal content contamination, most strains of this Gram-negative organism are harmless or cause relatively brief diarrhea but virulent strains, such as *E. coli* O157:H7 can cause severe symptoms including bloody diarrhea and vomiting [4]. This organism is the most common bacterial contaminant in drinking water as it was reported by 7 of 10 studies under review, representing 70% of the studies (Table 1).

4.2 *Klebsiella species*

Klebsiella species is a Gram-negative, non-motile, oxidase-negative, rod-shaped bacteria. Although *Klebsiella* species are found everywhere in nature, they frequently cause human nosocomial infections and account for a significant proportion of hospital-acquired pneumonia, septicemias, soft tissue infections and urinary tract infections [5]. As presented in Table 1, six out of ten (60%) studies under review reported the presence of this organism in drinking water samples analyzed.

4.3 *Staphylococcus aureus*

Staphylococcus aureus is a Gram-positive, round-shaped bacterium, It is a major human pathogen which causes a wide range of clinical infections and a leading cause of infective endocarditis, pleuropulmonary bacteremia, osteoarticular, skin and soft tissue, and device-related infections [6]. Fifty percent of the studies under review reported the presence of this organism in drinking water samples analyzed as presented in Table 1.

4.4 *Pseudomonas aeruginosa*

Pseudomonas aeruginosa is a Gram-negative, rod-shaped bacterium which has become an important cause of infection in patients with compromised defense mechanism, the organism has also emerged as the most important pathogen during the past two decades causing between ten and twenty percent of infections in most hospitals [7]. Studies which evaluated mortality among patients with *Pseudomonas aeruginosa* bloodstream infections reported a morbidity and a mortality rate ranging from eighteen to sixty one percent [8]. Of the studies under review, 60% reported the presence of this organism in drinking water samples as outlined in Table 1.

4.5 *Enterobacter aerogenes*

Enterobacter aerogenes is a Gram-negative, rod-shaped bacterium usually found in the human gastrointestinal tract and does not generally cause disease in healthy individuals but recognized as an important bacterial pathogen in hospital-acquired infections and opportunistic infections [9]. This organism was isolated in 40% of the studies that analysed drinking water samples.

4.6 *Streptococcus fecalis*

Streptococcus fecalis is a gram positive bacterium found in the gastrointestinal tracts of humans and other mammals, and it contributes to a number of infections especially in immunocompromised humans, which can include bacteremia, abdominal and pelvic infections, urinary tract infections, and oral infections [10]. This organism was isolated in 3 out of 10 studies representing 30% of the studies that analyzed drinking water samples.

4.7 *Proteus Species*

Proteus species are part of the Enterobacteriaceae family of gram-negative bacilli which are usually found in the human intestinal tract as part of normal intestinal flora [11]. *Proteus* organisms are implicated in the causation of serious infections in humans, along with *Escherichia*, *Klebsiella*, *Enterobacter*, and *Serratia* species [11]. This organism was also isolated in 3 out of 10 studies as presented in Table 2 representing 30% of the studies under review.

4.8 *Salmonella typhi*

Salmonella typhi is the causative agent of typhoid fever, a serious disease condition with an annual global burden of approximately 16 million cases, leading to 600,000 fatalities [12]. *S typhi* typically live in animal and human intestines and humans become infected by the consumption of contaminated water or food [12]. *S. typhi* was reported by 30% of the studies under review as shown in Table 2.

4.9 *Shigella species*

Shigella species is a group of gram-negative, intracellular pathogens. The organism is of public

Table 1. Shows the more predominant organisms isolated from drinking water in Nigeria

Organism	Number of studies reporting the presence of the organism	Percentage	Pathogenicity
<i>Escherchia coli</i>	7	70	Pathogenic
<i>Klebsiella species</i>	6	60	Opportunistic pathogen
<i>Pseudomonas aeruginosa</i>	6	60	Opportunistic pathogen
<i>Staphylococcus aureus</i>	5	50	Highly Pathogenic
<i>Proteus Species</i>	5	50	Opportunistic pathogen
<i>Enterobacter aerogenes</i>	4	40	Opportunistic pathogen

Table 2. Shows the less predominant organisms isolated from drinking water in Nigeria

Organism	Number of studies reporting the presence of the organism	Percentage	Pathogenicity
<i>Streptococcus faecalis</i>	3	30	Opportunistic pathogen
<i>Salmonella typhi</i>	3	30	Highly Pathogenic
<i>Shigella species</i>	1	10	Pathogenic
<i>Vibrio Cholerae</i>	1	10	Highly Pathogenic

health concern in most developing countries because it is a major cause of diarrheal diseases and mortality in humans, and there are approximately 163 million episodes of shigellosis and 1.1 million deaths annually [13]. Data from studies under review indicate that just 10% reported *Shigellas* species contamination of drinking water.

4.10 *Vibrio cholerae*

Vibrio cholerae is a Gram-negative, highly motile, gram-negative, curved or comma-shaped rods with a single polar flagellum, the organism is the causative agent of cholera, an acute diarrhoeal infection that results in 21 000 to 143 000 deaths worldwide [14]. This organism was also isolated in 1 out of 10 studies as presented in Table 2 representing 10% of the studies under review.

5. DISCUSSION

A physico-chemical and bacteriological analyses of water used for drinking and swimming in Abeokuta, South West Nigeria, reported that none of the samples analyzed complied with expected bacteriological standards required for potable water, it reported that the total coliform counts across samples exceeded the 1,600 MPN/ml stipulated, the pathogen count for organisms such as *Vibrio cholerae* and *Salmonella-Shigella* were also very high [15]. The findings from this study aligns with the results of the bacteriological quality assessment of the potability of water from some hand-dug shallow water wells in Awka metropolis in South Eastern Nigeria. The study reported the

presence of both *Salmonella typhi* and *Vibrio cholerae* in the water wells sampled [16]. This is in contrast with the findings of another study which analyzed the bacterial load of potable water in areas with reported cholera outbreaks in Ogun, Oyo and Lagos States, Nigeria which reported that although thermo-tolerant coliforms were isolated from some samples, *Vibrio cholera* was not isolated, but *Vibrio parahaemolyticus* was isolated from 5 (10%) of the well water samples [17]. This variation may be due to the difference in the sources and exposure of drinking water analyzed as stated in the studies.

A study which assessed the health and social economic implications of sachet water in Ibadan, South West Nigeria submitted that drinking water samples collected in Ibadan, showed bacterial growth which included: *Klebsiella sp* *Streptococcus faecalis* and *Pseudomonas aeruginosa* [18]. This agrees with the findings of a recent study which evaluated the physicochemical and microbial qualities and mineral profile of some elected brands of bottled water marketed and consumed in Asaba, Delta state, South South Nigeria which reported that 5.2% of tested samples analysed confirmed the presence of *Klebsiella sp.*, *Streptococcus faecalis* and *Pseudomonas aeruginosa* [19]. A similar study which analysed the quality of packaged water sold in Ibadan, Nigeria reported that 5% of the 78 samples of type A (packed and sealed bottled water by larger factories and sealed nylon sachets water by small scale industries) and 28% of the 30 samples of type B (Manually tied by itinerary vendors) showed positive coliform counts and the dominant

bacteria were also *Klebsiella* sp., *Streptococcus faecalis* and *Pseudomonas aeruginosa* [20]. These two studies align with the submission of Omalu et al. which affirmed earlier findings and linked the contamination of sachet drinking water in Nigeria with *Bacillus* sp., *Pseudomonas* sp., *Klebsiella* sp., *Streptococcus* sp., and oocysts of *Cryptosporidia* sp to the inadequacy of pipe borne water-supply and the resort to buying water from vendors [21]. In contrast, a study which also evaluated the quality of packaged drinking water in Edo state, South South Nigeria reported the presence of *Pseudomonas* sp and other microorganisms identified as *Staphylococcus aureus*, *Aeromonas* sp., *Corynebacterium* sp., *Bacillus* sp., *Bacillus badius*, *Proteus vulgaris* and *Escherichia coli* [22]. This variation in microbial contamination of water could be due to difference in geographical sites where the studies were conducted or samples collected [23].

In another study on drinking water quality Omezuruike et al. [24] reported the presence of *Staphylococcus aureus*, a major human pathogen which causes a wide range of clinical infections, *Salmonella* sp., and *Escherichia coli* among several other microorganism from drinking water samples collected in Abeokuta, Ogun State and Ojota in Lagos State all in South west Nigeria. Similarly, Ibiebele et al. [25] reported the presence of *Staphylococcus* spp., *Pseudomonas* spp., *Klebsiella* spp., *Proteus* spp., *Enterococcus faecalis*, *Aeromonas* spp., *Escherichia coli*, *Chromobacterium* spp, *Flavobacterium* spp., and *Serratia* spp from communal well water around Port Harcourt, South South, Nigeria. The discovery of these isolates in drinking water aligns with the findings of another study conducted in Nassarawa State, North Central Nigeria. The study published in the British Microbiology Research Journal analyzed five randomly selected water samples from different boreholes sources and isolated six genera of bacteria which were identified as *Staphylococcus* spp, *Escherichia* spp, *Klebsiella* spp, *Salmonella* spp, *Pseudomonas* spp and *Proteus* spp. [26]. This also agrees with a similar study which investigated the bacteriological contamination of drinking water from wells in Wukari, Taraba State, North east Nigeria. This study reported that *Staphylococcus aureus* was the highest isolated organism (53.33%) followed by *Escherichia coli* (46.67%), *Pseudomonas* species and *Proteus* species (33.37%), *Salmonella* species (26.67%), *Enterobacter* species (20.00%) while *Klebsiella* species and

Enterococcus species were the least with 13.33% occurrence respectively [27]. The findings of another study conducted on similar sample sources does not align with the findings above, the study which was conducted to determine the physicochemical and microbiological characteristics of groundwater in boreholes used as drinking water in Mgboushimini community in Obio Akpor Local Government Area of Rivers State, South South Nigeria reported that a total of four (4) genera of organisms were isolated from the water samples which were identified as *Klebsiella* spp., *Proteus* spp., *Citrobacter* spp, and *Candida* spp. This variation in microbial population despite similar sources of samples could be linked to geo-environmental and natural factors as reported by Sreekala et al. [28] and Khatri et al. [29].

Olaoye et al. [30] reported the presence of *E. coli*, *Pseudomonas aeruginosa*, *Enterobacter aerogenes*, *Klebsiella* sp., *Proteus vulgaris*, *Alcaligenes faecalis*, *Bacillus cereus*, *Staphylococcus aureus*, *Streptococcus lactis*, *Aeromonas* sp. and *Micrococcus luteum*, in sachet-packaged drinking water in Western Nigeria. This is similar to the findings of Oladipo et al. [31] in their work titled microbiological assessment of vended drinking water in Ogbomosho Osun State Nigeria. They isolated *Enterobacter aerogenes* in addition to *Proteus mirabilis*, *Bacillus subtilis* and *Pseudomonas putida*. Both findings are similar to the result of a bacteriological quality assessment and antibiogram profile of bacteria associated with sachet drinking water conducted in Zaria, North western Nigeria, a decade later which also reported the presence of *Enterobacter aerogenes* and other bacteria identified as *Escherichia coli*, *Salmonella* sp, *Citrobacter freundii* and *Proteus vulgaris* in samples of sachet-packaged drinking water analyzed [32]. However, this findings differ from another study on the bacteriological profile of packaged drinking water in bottles which reported that 5.2 % of tested samples had *Klebsiella* sp., *Streptococcus faecalis* and *Pseudomonas aeruginosa* [17]. This difference in the bacterial population of bottle and sachet water could be due to variation in the water purification techniques because both microbial activity and bacterial diversity during water treatment process show obvious spatial variation especially during chlorination [33].

Another study by Ezugwune et al. [34] analyzed the prevalence of bacteria in packaged sachets

water sold in Nnewi, South East, Nigeria and reported that percentages of the different organism isolated from drinking water, were *E. coli* (36%), *Streptococcus faecalis* (19.4%), *Klebsiella pneumoniae* (19.4%) and *Staphylococcus aureus* (25%). This is in agreement with the findings of a study which analyzed a total of 50 drinking water samples comprising; 20 well water, 15 sachet water, 10 borehole water and 5 river water in Sokoto, Northwest Nigeria, the distribution of the bacteria isolated and identified from the study indicated that *Escherichia coli* had the highest total prevalence of (40.31%) occurring in all the water samples, *Klebsiella* spp had (17.13%) occurring in all the sources, *Salmonella* spp (7.44%) occurring in all the sources except for borehole, *Pseudomonas* species (15.22%) occurring in all the sources, *Staphylococcus aureus* with 115 (19.90%) occurring in all the sources except for borehole [35]. The finding reported above are at variance with a similar study on bacteriological evaluation of sachet drinking water in Owerri, Imo State, South east Nigeria which reported that *Klebsiella pneumoniae* [7(29.2%)] was the most predominant, closely followed by *Serratia* spp. [6(25.0%)] and *Proteus mirabilis* [6(25.0%) while *Pseudomonas aeruginosa* [3(12.5%)] and *Chromobacterium* spp. [2(8.3%)] was least predominant [36]. In a separate study conducted in Maiduguri, North eastern Nigeria, Muazu reported that 55% of the brands of packaged sachet water analyzed had fecal coliforms, 25% had *Pseudomonas aeruginosa*, 15% had *Salmonella* sp. while 5% of the sample brand had *E. coli*. [37]. Majority of drinking water samples analyzed were unsafe for human consumption as reported by Onifade et al. [38] who in addition to the presence of *Escherichia coli*, *Staphylococcus aureus*, *Streptococcus faecalis*, and *Enterobacter aerogenes* also isolated *Alcaligenes faecalis*, *Bacillus subtilis*, and *Micrococcus luteus*. The presence of these organisms constitutes public health significance which agrees with the conclusion of another study which analyzed a total of 30 samples from 10 brands of sachet water and 42 samples from 21 communal boreholes serving as drinking water sources in seven different wards of Mubi, Adamawa state, North east Nigeria and isolated 49 non-repetitive bacterial species [39]. This conclusion is in contrast with the conclusion with the findings of a similar study which despite reporting the isolation of *Escherichia coli*, *Enterobacter aerogenes*, *Salmonella* sp, *Citrobacter freundii* and *Proteus vulgaris*, concluded that most (90%) of the water analyzed

fell within the statutory limits. While, the remaining (10%) which recorded high bacterial counts beyond the standard of safe drinking water set by water and food regulatory bodies fell within the contamination level, [32] a conclusion also reported by Osagie et al. [40,41].

6. CONCLUSION

The presence of *E. coli* in 70 percent of the studies reviewed is a source of concern, because although most strains of *E. coli* are harmless and form a substantial part of the normal flora of the intestines, the presence of toxin producing strains of *E. coli* like the O157:H7 in drinking water is a major public health concern because of its ability to cause diseases like hemorrhagic diarrhea and kidney failure. The isolation of several pathogenic and opportunistic pathogens from drinking water sources in Nigeria clearly indicates that drinking water processing and handling procedures in Nigeria needs to be reviewed to meet global best practices that will ensure that drinking water does not continue to serve as a major portal for the introduction disease causing microorganisms into the body. The presence of these organisms in drinking water used by households in Nigeria cannot be extricated from recent water borne disease outbreaks recorded in some parts of the country and the reported level of non-compliance with standards and guidelines by both public and private water processing and packaging firms. It is imperative to improve the level of oversight by the regulatory agencies and review the parameters for licensing and registration of drinking water processing and packaging companies as well as the intervals for unscheduled routine inspection to drinking water processing and packaging plants to enhance drinking water quality in Nigeria.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. National Bureau of Statistics, & UNICEF. Multiple Indicator Cluster Survey 2016-17, Survey Findings Report; 2017.
2. Ashbolt NJ. Microbial contamination of drinking water and disease outcomes in developing regions. *Toxicology*. 2004; 198(1):229-238.
3. Pandey PK, Kass PH, Soupier ML, Biswas S, Singh VP. Contamination of water

- resources by pathogenic bacteria. *Amb Express*. 2014;4(1):51.
4. Gillard A, (Ed.). *Food-borne diseases*. Greenhaven Publishing LLC; 2011.
 5. Podschun R, Ullmann U. *Klebsiella* spp. as nosocomial pathogens: Epidemiology, taxonomy, typing methods, and pathogenicity factors. *Clinical Microbiology Reviews*. 1998;11(4):589-603.
 6. Tong SY, Davis JS, Eichenberger E, Holland TL, Fowler VG. *Staphylococcus aureus* infections: Epidemiology, pathophysiology, clinical manifestations, and management. *Clinical Microbiology Reviews*. 2015;28(3):603-661.
 7. Bodey GP, Bolivar R, Fainstein V, Jadeja L. Infections caused by *Pseudomonas aeruginosa*. *Reviews of Infectious Diseases*. 1983;5(2):279-313.
 8. Kang CI, Kim SH, Kim HB, Park SW, Choe YJ, Oh MD, Choe KW. *Pseudomonas aeruginosa* bacteremia: Risk factors for mortality and influence of delayed receipt of effective antimicrobial therapy on clinical outcome. *Clinical Infectious Diseases*. 2003;37(6):745-751.
 9. Jha P, Kim CM, Kim DM, Chung JH, Yoon NR, Jha B, Jeon DY. Transmission of *Enterobacter aerogenes* septicemia in healthcare workers. *SpringerPlus*. 2016; 5(1):1397.
 10. Graninger W, Ragette R. Nosocomial bacteremia due to *Enterococcus faecalis* without endocarditis. *Clinical Infectious Diseases*. 1992;15(1):49-57.
 11. Gonzalez G, Bronze MS. *Proteus* infections: Background, pathophysiology, epidemiology [Internet]; 2016. [Cited 2016 Nov 3]
 12. Kaljee LM, Pach A, Garrett D, Bajracharya D, Karki K, Khan I. Social and economic burden associated with typhoid fever in Kathmandu and surrounding areas: A qualitative study. *The Journal of Infectious Diseases*. 2017;218(Suppl_4):S243-S249.
 13. Sahl JW, Morris CR, Emberger J, Fraser CM, Ochieng JB, Juma J, Rasko DA. Defining the phylogenomics of *Shigella* species: A pathway to diagnostics. *Journal of Clinical Microbiology*. 2015;53(3):951-960.
 14. Ali M, Nelson AR, Lopez AL, Sack DA. Updated global burden of cholera in endemic countries. *PLoS Neglected Tropical Diseases*. 2015;9(6):e0003832.
 15. Shittu OB, Olaitan JO, Amusa TS. Physico-chemical and bacteriological analyses of water used for drinking and swimming purposes in Abeokuta, Nigeria. *African Journal of Biomedical Research*. 2008;11(3).
 16. Deji-Agboola MA, Museliu O, Olajubu FA, Osinupebi OA, Idowu AO. Bacteriological analysis of potable water in areas with reported cholera outbreaks in Ogun, Oyo and Lagos States, Nigeria. *Annals of Health Research*. 2017;3(2):105-111.
 17. Samuel O, Rosemary E, Frederick O. Bacteriological quality assessment of hand-dug shallow water wells in Awka Metropolis, Anambra State, Nigeria. *Universal Journal of Applied Science*. 2016;4(2):17-24.
 18. Adekunle LV, Sridhar MKC, Ajayi AA, Oluwade PA, Olawuyi JF. An assessment of the health and social economic implications of satchet water in Ibadan, Nigeria: A public health challenge. *African Journal of Biomedical Research*. 2004;7(1).
 19. Owamah HI. Examining the physico-chemical and microbial qualities and mineral content of selected brands of bottled water marketed and consumed in Asaba, Delta State, Nigeria. *Journal of Applied Sciences & Environmental Management*. 2018;22(12).
 20. Ajayi AA, Sridhar M, Adekunle L, Oluwade PA. Quality of packaged waters sold in Ibadan, Nigeria. *African Journal of Biomedical Research*. 2008;11(3).
 21. Omalu ICJ, Eze GC, Olayemi IK, Gbesi S, Adeniran LA, Ayanwale AV, Chukwuemeka V. Contamination of satchet water in Nigeria: Assessment and health impact. *Online Journal of Health and Allied Sciences*. 2011;9(4).
 22. Daniel EO, Daodu AA. Bacteriological analysis of satchet water vended in Ugbor, Benin City, Nigeria. *SAU Science-Tech Journal*. 2016;1(1).
 23. Liu R, Yu Z, Zhang H, Yang M, Shi B, Liu X. Diversity of bacteria and mycobacteria in biofilms of two urban drinking water distribution systems. *Canadian Journal of Microbiology*. 2012;58(3):261-270.
 24. Omezuruike OI, Damilola AO, Adeola OT, Enobong A. Microbiological and physicochemical analysis of different water samples used for domestic purposes in Abeokuta and Ojota, Lagos State, Nigeria. *African Journal of Biotechnology*. 2008;7(5):617.

25. Ibiebele DD, Sokari TG. Occurrence of drug-resistant bacteria in communal well water around Port Harcourt, Nigeria. *Epidemiology and Infection*. 1989;103(01): 193-202.
26. Adogo LY, Ajiji MA, Anyanwu NCJ, Ajide B. Bacteriological and physico-chemical analysis of borehole water in Auta Balefi Community, Nasarawa State, Nigeria. *British Microbiology Research Journal*. 2016;11(4):1-7.
27. Agwaranze DI, Ogodo AC, Nwaneri CB, Agyo P. Bacteriological examination of well water in Wukari, Nigeria. *Inter J Sci Res Environ Sci*. 2017;5(2):0042-0046.
28. Sreekala MS, Sareen SJ, Rajathi S. Influence of geo-environmental and chemical factors on thermotolerant coliforms and *E. coli* in the groundwater of Central Kerala. *Journal of the Geological Society of India*. 2018;91(5): 621-626.
29. Khatri N, Tyagi S. Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Frontiers in Life Science*. 2015;8(1): 23-39.
30. Olaoye OA, Onilude AA. Assessment of microbiological quality of sachet-packaged drinking water in Western Nigeria and its public health significance. *Public Health*. 2009;123(11):729-734.
31. Oladipo IC, Onyenike IC, Adebisi AO. Microbiological analysis of some vended sachet water in Ogbomoso, Nigeria. *African Journal of Food Science*. 2009;3(12):406-412.
32. Umar M, Kambai J, Mohammed IB, Oko JO, Obafemi AA, Murtala I, Idris S. Bacteriological quality assessment and antibiogram profile of bacteria associated with sachet drinking water sold at Zaria, Northern Nigeria. *International Journal of Pathogen Research*. 2019;1-13.
33. Hou L, Zhou Q, Wu Q, Gu Q, Sun M, Zhang J. Spatiotemporal changes in bacterial community and microbial activity in a full-scale drinking water treatment plant. *Science of the Total Environment*. 2018;625:449-459.
34. Ezeugwunne IP, Agbakoba NR, Nnamah NK, Anahalu IC. The prevalence of bacteria in packaged sachets water sold in Nnewi, South East, Nigeria. *World J Dairy Food Sci*. 2009;4(1):19-21.
35. Iduh MU, Spencer TI, Mohammed K, Garba KM, Ashcroft FO, Nataala US, Mubarak WH. Bacteriological examination of drinking water from different sources in Sokoto State Nigeria. *Journal of BioMedical Research and Clinical Practice*. 2018;1(4):241-247.
36. Mgbakor C, Ojiegbe GC, Okonko IO, Odu NN, Alli JA, Nwanze JC, Onoh CC. Bacteriological evaluation of some sachet water on sales in Owerri metropolis, Imo State, Nigeria. *Malaysia Journal of Microbiology*. 2011;7(4):217-225.
37. Muazu J, Muhammad-Biu A, Mohammed GT. Microbial quality of packaged sachet water marketed in Maiduguri Metropolis, North Eastern Nigeria. *British Journal of Pharmacology and Toxicology*. 2012;3(1): 33-38.
38. Onifade AK, Ilori RM. Microbiological analysis of sachet water vended in Ondo State, Nigeria. *Environmental Research Journal*. 2008;2(3):107-110.
39. Onifade AK, Ilori RM. Microbiological analysis of sachet water vended in Ondo State, Nigeria. *Environmental Research Journal*. 2008;2(3):107-110.
40. Pauline EA, Osagie IBHADODE, Razzaq AA, OmoniyiMoses SOSANOLU. Experimental determination of drinking water quality in Abeokuta Metropolis, South-Western Nigeria; 2018.
41. Ekong PS, Ducheyne E, Carpenter TE, Owolodun OA, Oladokun AT, Lombin LH, Berkvens D. Spatio-temporal epidemiology of highly pathogenic avian influenza (H5N1) outbreaks in Nigeria, 2006–2008. *Preventive Veterinary Medicine*. 2012; 103(2-3):170-177.

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