Review Article

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

ABSTRACT

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. Ten randomly selected studies were reviewed. 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. 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 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.

KEY WORDS: Drinking water, Pathogen, Contamination, Water Quality

INTRODUCTION

The quality of household drinking water is an important determinant of health and overall well being of household members ref. The major source of the microbial contamination of household drinking water has been traced to feaces, both human and animal ref. Humans get infected as a result of drinking, washing, bathing or preparing meals with contaminated water ref. According to the UNICEF report, around 90.8 per cent of households in Nigeria drink water contaminated by feaces and other contaminating agents like E coli ref. 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, however, 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. According to the report, about two out of every three households use improved water sources, while a little more than one-third use improved sanitation compared to 58.5 percent and 31 per cent respectively in 2011. [1]

Figure 1: Common Sources of Drinking water In Nigeria

A Sample of Sealed Sachet Water In Nigeria

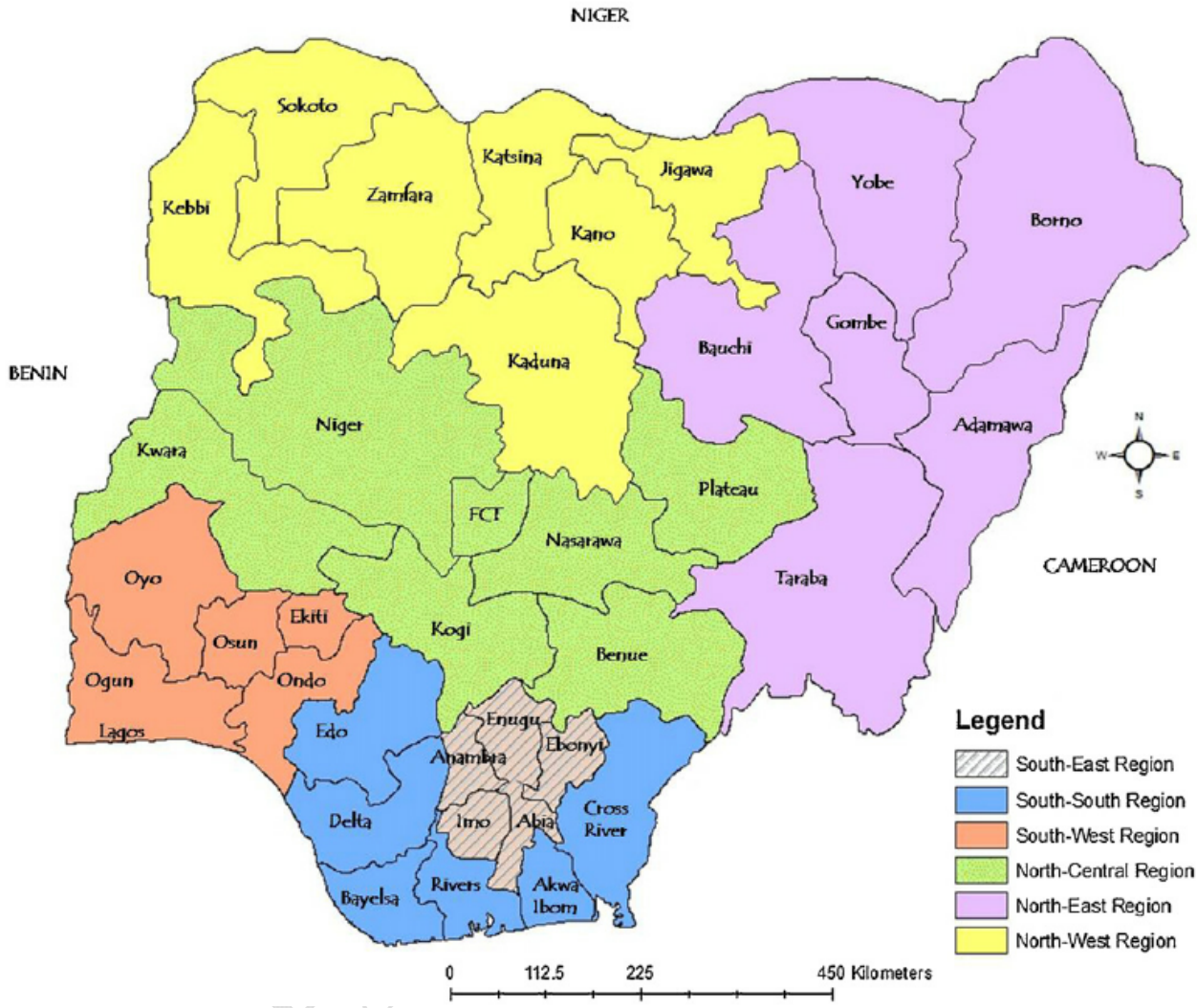
A Sample of Sealed Bottled Water In Nigeria

Young Girls Fetching Water Borehole in Nigeria

Drinking water is a major source of microbial pathogens in developing countries, although poor sanitation and food sources are integral to enteric pathogen exposure ref. Gastrointestinal disease outcomes are also more severe, due to under-nutrition and lack of intervention strategies in these regions ref. Protozoa and bacteria are the major causative agents of water borne diseases ref. The introduction of pathogens into drinking water is

responsible for diseases such as cholera, amoebiasis, typhoid fever, giardiasis and dysentery ref. Poor water quality, sanitation and hygiene account for some 1.7 million deaths a year world-wide (3.1% of all deaths and 3.7% of all DALY's), mainly through infectious diarrhea ref. Nine out of 10 such deaths are in children and virtually all of the deaths are in developing countries. [2] In addition, microbial contamination of drinking water sources and the resultant diseases have become a major water quality concern all over the world as evidenced by the increasing number of publications and interest in controlling water-borne pathogens ref. 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 profer solution to the problem as a whole. [3]

Figure 2: Showing Map of Nigeria and Six the Geopolitical zones []



OBJECTIVE

For decades Nigerians have spent the bulk of their healthcare budget treating preventable diseases, the objective of this study is to aggregate the various findings and provide a clear overview of various microorganisms implicated in the contamination of household

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

METHODOLOGY

Review of Literature

FINDINGS

Escherchia coli

This organism is a rod-shaped facultative anaerobe, belonging to the genus Escherichia that mainly indicate feacal content contamination ref. 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 references under review, representing 70 % of the studies.

Klebsiella species

Klebsiella *species* is a Gram-negative, non-motile, oxidase-negative, rod-shaped bacteria ref. Although Klebsiella species are found everywhere in nature, they frequently cause human nosocomial infections ref. They account for a significant proportion of hospital-acquired pneumonia, septicemias, soft tissue infections and urinary tract infections.[5] Six out of ten

(60%) studies ref. under review reported the presence of this organism in drinking water samples analyzed.

Staphylococcus aureus

Staphylococcus aureus is a Gram-positive, round-shaped bacterium ref. It is a major human pathogen which causes a wide range of clinical infections ref. It is a leading cause of infective endocarditis, pleuropulmonary, ~~bacteremia ,~~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 .

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 ref. The organism has also emerged as the most important pathogen during the past two decades ref. It causes 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~~a morbidity and a mortality rate ranging from eighteen to sixty one percent~~.~~[8]~~.~~ About 60% of the studies under review report the presence of this organism in drinking water samples analyzed.

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 ref. However, it is 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.

Streptococcus fecalis

Streptococcus fecalis is a gram positive bacterium found in the gastrointestinal tracts of humans and other mammals ref. This organism contributes to a number of infections especially in immunocompromised humans, some of which can be life-threatening ref. This can include bacteremia, abdominal and pelvic infections, urinary tract infections, oral infections, particularly with root canals, septicemia, wound infections, enterococcal meningitis [10]. This organism was isolated in 3 out of 10 studies representing 30% of the studies that analyzed drinking water samples.

Proteus Species

Proteus species are part of the Enterobacteriaceae family of gram-negative bacilli ref. They are usually found in the human intestinal tract as part of normal intestinal flora, 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 representing 50% of the studies that analysed drinking water samples.

Salmonella typhi

Salmonella typhi typically live in animal and human intestines and are shed through feces ref. Humans become infected by the consumption of contaminated water or food ref. *S. 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* was found in drinking water analyzed by 30% of the studies under review.

Shigella species

Shigella species is a group of is a group of gram-negative, intracellular pathogens ref. This organism is a major public health problem in most developing countries ref. The organism cause significant diarrheal disease and mortality in humans, as 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 S*higellas* species contamination of drinking water.

Vibrio Cholerae

Vibrio cholerae is a Gram-negative, highly motile, gram-negative, curved or comma-shaped rods with a single polar flagellum ref. This organism is the causative agent of cholera, an acute diarrhoeal infection caused by ingestion of food or water contaminated with the bacterium ref. Researchers have estimated that each year there are approximately 1.3 to 4.0 million cases, and 21 000 to 143 000 deaths worldwide due to cholera. [14]. This organism was also isolated in 1 out of 10 studies representing 10% of the studies under review.

Table 1. Shows the distribution of organisms found in drinking water.

Research	VC	ST	SPP	KP	SF	SA	PA	EC	ETA	PR	
Shittu et al. insert year	+	+	+								
Adekunle et al.insert year				+	+		+				
Omezuruike,et al. insert year		+		+		+	+	+	+	+	
Olaoye et al.insert year				+		+	+	+	+	+	
Ibiebele et al.insert year				+		+	+	+		+	
Ezeugwunne et al.insert year				+	+	+		+			
Oladipo et al.insert year								+	+	+	
Mgbakor et al.insert year				+			+			+	
Muazu et		+					+	+			

al.insert year											
Onifade et al.insert year					+	+		+	+		
Percentage %	10	30	10	60	30	50	60	70	40	50	

CODES

VC= Vibrio Cholerae SA=Staphylococcus aureus PA= Pseudomonas aeruginosa.

SF= Streptococcus fecalis EC= Escherchia coli KP= Klebsiella species

ST = Salmonella typhi SPP= Shigella species ETA = Enterobacter aerogenes

PR= Proteus Species

Discussion

A physico-chemical and bacteriological analyses of water used for drinking and swimming ~~purposes conducted~~purposes conducted in Abeokuta, South West Nigeria, reported that none of the samples analyzed complied with expected bacteriological standards required for potable water ref. They reported that the total coliform counts across samples exceeded the 1,600 MPN/ml stipulated and ~~the pathogen~~the pathogen count for organisms such as *Vibrio cholerae* and *Salmonella-Shigella were* 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 used for drinking and other domestic purposes ref. 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 identified~~were identified 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 satchet water in Ibadan, South west Nigeria submitted that drinking water samples collected in Ibadan, showed bacterial growth which included: *Klebsiella sp Streptococcus faecalis a*nd *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 waters sold in Ibadan, Nigeria reported that 5% of the 78 samples of A type (packed and sealed bottled water by larger factories ~~and those~~and those sealed in nylon sachets by small scale industries) and 28% of the 30 samples 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*. *inset year* 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~~resort to buying water from vendors, and sachet or bottled water. [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*~~of Pseudomonas sp and other microorganisms ~~identified as~~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*. ~~(~~2007~~)~~ reported the presence of *Staphylococcus aureus,* a major human pathogen which causes a wide range of clinical infections , Salmonella sp., and *Escherchia coli* among several other microorganism from drinking water samples collected in Abeokuta , Ogun State and Ojota in Lagos State all in South west Nigeria. [24] Similarly, Ibiebele *et al*. ~~(~~2009~~)~~ reported the presence of *Staphylococcus spp., Pseudomonas spp., Klebsieila 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.[25]. The discovery of these isolates in drinking water aligns with the findings of another study conducted in Nassarawa State, North Central Nigeria ref. 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 ref. The 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 ref. 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~~South Nigeria reported ~~that a~~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 [28] and [29].

Olaoye (2009) 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.[30]. This is similar to the findings of Oladipo et al. ~~(~~2009~~)~~ in their work titled microbiological assessment of vended drinking water in Ogbomosho Osun State Nigeria. ~~They isolated~~They isolated *Enterobacter aerogenes* in addition to *Proteus mirabilis,s Bacillus subtilis* and *Pseudomonas putida*.[31].

Both findings are similar to the result 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 in ~~2009 analyzed~~2009 analyzed the prevalence of bacteria in packaged sachets water sold in Nnewi, South East, ~~Nigeria . .~~Nigeria. The percentages of the different organism isolated from drinking water, are *E. coli* (36~~%)~~%), *Streptococcus faecalis* (19.4%), *Klebsiella pneumoniae* (19.4%) and *Staphyloccocus aureus* (25%). [34]. 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 ref. The distribution of the bacteria isolated and identified from the study indicated that, Escherichia coli had the highest total prevalence of (40.31%) and occurring in all the water samples ref. 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 and closely followed by Serratia spp. [6(25.0%)] and Proteus mirabilis [6(25.0%)]ref. 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 Onifade *et el.insert year* who in addition to the presence of *Escherichia coli*, *Staphylococcus aureus Streptococcus faecalis* and *Enterobacter aeogenes* also isolated *Alcaligenes faecalis*, *Bacillus subtilis*, and *Micrococcus luteus*.[38]. 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%) fell within the contamination level, which recorded high bacterial counts beyond the standard of safe drinking water set by water and food regulatory bodies.[32]. A conclusion also reported by Osagie et al.[40].

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 trigger hemorrhagic diarrhea and kidney failure. Despite the increased access to drinking water, the quality of drinking water in many locations across Nigeria needs much to be desired. The diversity of bacterial contamination of drinking water especially the presence of pathogens is of public health concern. The isolation of several pathogenic and non pathogenic bacteria 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 epidemic recorded in some parts of the country and with the reported level of non-compliance with standards and guidelines by water processing and packaging firms and the low level of oversight by the regulatory agency. There is also the need to review the parameters for licensing and registration of drinking water processing and packaging companies and the intervals for unscheduled routine inspection to drinking water processing and packaging plants to enhance drinking water quality in Nigeria.

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