

**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.*

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

22

## 23 **INTRODUCTION**

24 The quality of household drinking water is an important determinant of health and overall  
25 well being of household members. The major source of the microbial contamination of  
26 household drinking water has been traced to faeces, both human and animal. Humans get  
27 infected as a result of drinking, washing, bathing or preparing meals with contaminated  
28 water. According to the UNICEF report, around 90.8 per cent of households in Nigeria drink  
29 water contaminated by faeces and other contaminating agents like E coli. The report noted  
30 that although 64.1 per cent of the population of the country had access to improved  
31 drinking water sources, the states that make up the North-East region were, however,  
32 lagging behind with 52.4 per cent, while South-West states top the chart with 87.3 per cent  
33 of its residents having access to improved water sources. According to the report, about  
34 two out of every three households use improved water sources, while a little more than  
35 one-third use improved sanitation compared to 58.5 percent and 31 per cent respectively  
36 in 2011. <sup>[1]</sup>

37

38 **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

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Young Girls Fetching Water Borehole in Nigeria

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

46 responsible for diseases such as cholera, amoebiasis, typhoid fever, giardiasis and  
47 dysentery. Poor water quality, sanitation and hygiene account for some 1.7 million deaths a  
48 year world-wide (3.1% of all deaths and 3.7% of all DALY's), mainly through infectious  
49 diarrhea. Nine out of 10 such deaths are in children and virtually all of the deaths are in  
50 developing countries. <sup>[2]</sup> In addition, microbial contamination of drinking water sources  
51 and the resultant diseases have become a major water quality concern all over the world as  
52 evidenced by the increasing number of publications and interest in controlling water-borne  
53 pathogens. It has therefore become imperative to synergistically synthesize knowledge  
54 from multiple fields covering comparative aspects of pathogen contamination, and unify  
55 them in a single place in order to present an overview of microbes implicated and profer  
56 solution to the problem as a whole. <sup>[3]</sup>

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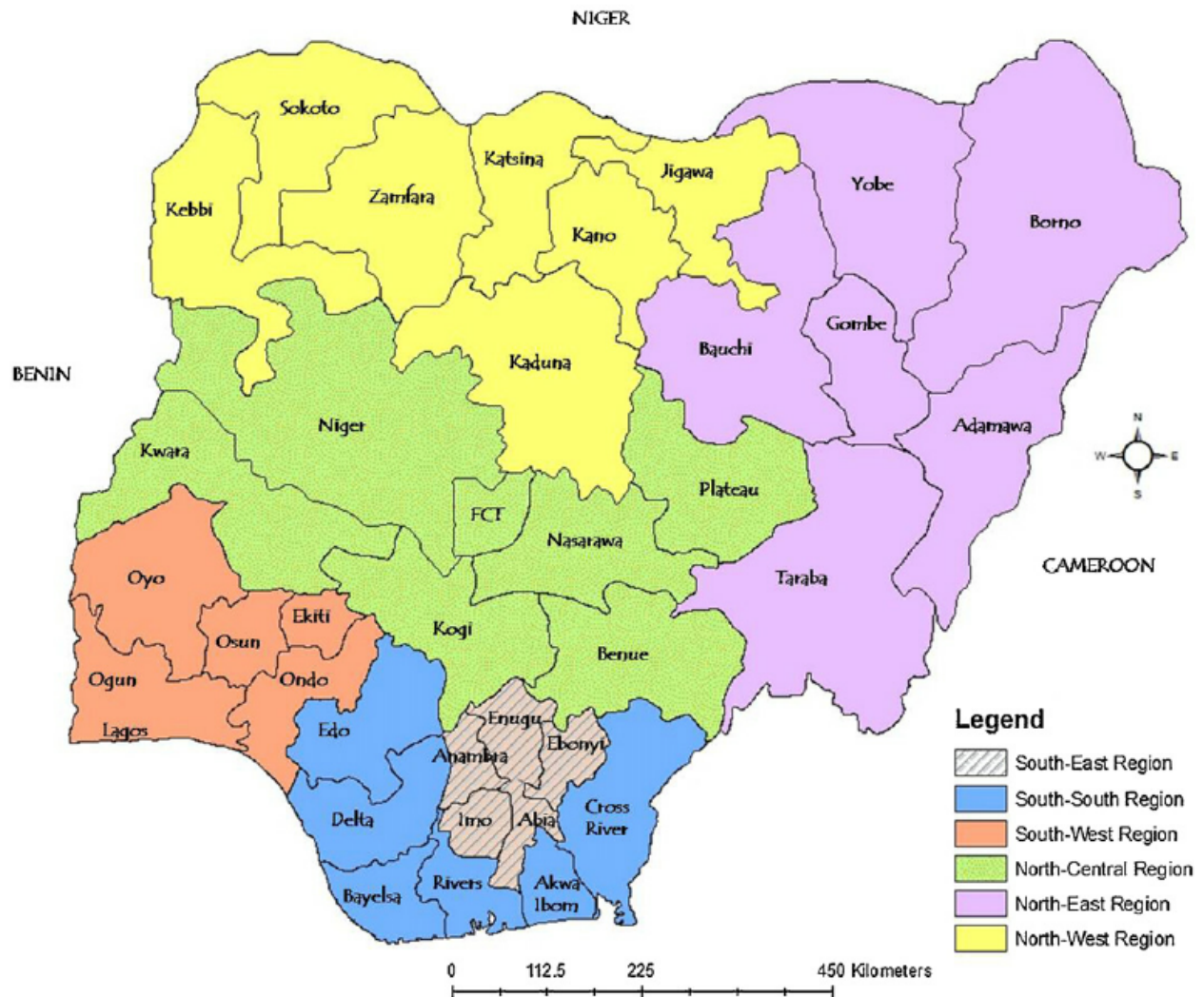
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65 Figure 2: Showing Map of Nigeria and Six the Geopolitical zones []



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68 **OBJECTIVE**

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

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

74

## 75 **METHODOLOGY**

76 Review of Literature

## 77 **FINDINGS**

### 78 ***Escherchia coli***

79 This organism is a rod-shaped facultative anaerobe, belonging to the genus *Escherichia* that  
80 mainly indicate fecal content contamination. Most strains of this Gram-negative organism  
81 are harmless or cause relatively brief diarrhea but virulent strains, such as *E. coli* O157:H7  
82 can cause severe symptoms including bloody diarrhea and vomiting.<sup>[4]</sup> This organism is the  
83 most common bacterial contaminant in drinking water as it was reported by 7 of 10 studies  
84 under review, representing 70 % of the studies.

### 85 ***Klebsiella species***

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

90 (60%) studies under review reported the presence of this organism in drinking water  
91 samples analyzed.

92

### 93 ***Staphylococcus aureus***

94 *Staphylococcus aureus* is a Gram-positive, round-shaped bacterium. It is a major human  
95 pathogen which causes a wide range of clinical infections. It is a leading cause of infective  
96 endocarditis, pleuropulmonary, bacteremia , osteoarticular, skin and soft tissue, and  
97 device-related infections.<sup>[6]</sup> Fifty percent of the studies under review reported the presence  
98 of this organism in drinking water samples analyzed .

### 99 ***Pseudomonas aeruginosa***

100 *Pseudomonas aeruginosa* is a Gram-negative, rod-shaped bacterium which has become an  
101 important cause of infection in patients with compromised defense mechanism. The  
102 organism has also emerged as the most important pathogen during the past two decades. It  
103 causes between ten and twenty percent of infections in most hospitals. <sup>[7]</sup> Studies which  
104 evaluated mortality among patients with *Pseudomonas aeruginosa* bloodstream infections  
105 reported a morbidity and a mortality rate ranging from eighteen to sixty one percent.<sup>[8]</sup>  
106 About 60% of the studies under review report the presence of this organism in drinking  
107 water samples analyzed.

108

### 109 ***Enterobacter aerogenes***

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

### 115 ***Streptococcus fecalis***

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

### 123 ***Proteus Species***

124 *Proteus* species are part of the Enterobacteriaceae family of gram-negative bacilli. They are  
125 usually found in the human intestinal tract as part of normal intestinal flora, *Proteus*  
126 organisms are implicated in the causation of serious infections in humans, along with  
127 *Escherichia*, *Klebsiella*, *Enterobacter*, and *Serratia* species. <sup>[11]</sup> This organism was also  
128 isolated in 3 out of 10 studies representing 50% of the studies that analysed drinking water  
129 samples.

### 130 ***Salmonella typhi***



131 *Salmonella typhi* typically live in animal and human intestines and are shed through feces.  
132 Humans become infected by the consumption of contaminated water or food. *S. typhi* is  
133 the causative agent of typhoid fever, a serious disease condition with an annual global  
134 burden of approximately 16 million cases, leading to 600,000 fatalities. [12] *S. typhi* was  
135 found in drinking water analyzed by 30% of the studies under review.

### 136 ***Shigella species***

137 *Shigella species* is a group of is a group of gram-negative, intracellular pathogens. This  
138 organism is a major public health problem in most developing countries. The organism  
139 cause significant diarrheal disease and mortality in humans, as there are approximately  
140 163 million episodes of shigellosis and 1.1 million deaths annually. [13] Data from studies  
141 under review indicate that just 10% reported *Shigellas* species contamination of drinking  
142 water.

### 143 ***Vibrio Cholerae***

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

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

Research	VC	ST	SPP	KP	SF	SA	PA	EC	ET A	PR	
Shittu et al	+	+	+								
Adekunle et al				+	+		+				
Omezuruike,etal		+		+		+	+	+	+	+	
Olaoye et al				+		+	+	+	+	+	
Ibiebele et al				+		+	+	+		+	
Ezeugwunne et al				+	+	+		+			
Oladipo et al								+	+	+	
Mgbakor et al				+			+			+	
Muazu et al		+					+	+			
Onifade et al					+	+		+	+		
Percentage %	10	30	10	60	30	50	60	70	40	50	

151

152 **CODES**

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

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

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

156 *PR= Proteus Species*

157

## 158 **Discussion**

159 A physico-chemical and bacteriological analyses of water used for drinking and swimming  
160 purposes conducted in Abeokuta, South West Nigeria, reported that none of the samples  
161 analyzed complied with expected bacteriological standards required for potable water.  
162 They reported that the total coliform counts across samples exceeded the 1,600 MPN/ml  
163 stipulated and the pathogen count for organisms such as *Vibrio cholerae* and *Salmonella*-  
164 *Shigella* were very high. [15] The findings from this study aligns with the results of the  
165 bacteriological quality assessment of the potability of water from some hand-dug shallow  
166 water wells in Awka metropolis in South Eastern Nigeria used for drinking and other  
167 domestic purposes. The study reported the presence of both *Salmonella typhi* and *Vibrio*  
168 *cholerae* in the water wells sampled. [16] This is in contrast with the findings of another  
169 study which analyzed the bacterial load of potable water in areas with reported cholera  
170 outbreaks in Ogun, Oyo and Lagos States, Nigeria which reported that although, thermo-  
171 tolerant coliforms were identified from some samples, *Vibrio cholera* was not isolated,  
172 but *Vibrio parahaemolyticus* was isolated from 5 (10%) of the well water samples. [17] This  
173 variation may be due to the difference in the sources and exposure of drinking water  
174 analyzed as stated in the studies

175 A study which assessed the health and social economic implications of sachet water in  
176 Ibadan, South west Nigeria submitted that drinking water samples collected in Ibadan,  
177 showed bacterial growth which included: *Klebsiella sp Streptococcus faecalis* and  
178 *Pseudomonas aeruginosa*. [18] This agrees with the findings of a recent study which  
179 evaluated the physicochemical and microbial qualities and mineral profile of some elected  
180 brands of bottled water marketed and consumed in Asaba, Delta state, South South Nigeria  
181 which reported that 5.2 % of tested samples analysed confirmed the presence of *Klebsiella*  
182 *sp., Streptococcus faecalis* and *Pseudomonas aeruginosa*. [19] A similar study which  
183 analysed the quality of packaged waters sold in Ibadan, Nigeria reported that 5% of the 78  
184 samples of A type (packed and sealed bottled water by larger factories and those sealed in  
185 nylon sachets by small scale industries) and 28% of the 30 samples type B (Manually tied  
186 by itinerary vendors) showed positive coliform counts and the dominant bacteria were  
187 also *Klebsiella sp., Streptococcus faecalis* and *Pseudomonas aeruginosa*. [20] These two  
188 studies align with the submission of Omalu *et al* which affirmed earlier findings and linked  
189 the contamination of sachet drinking water in Nigeria with *Bacillus sp., Pseudomonas sp.,*  
190 *Klebsiella sp., Streptococcus sp.,* and oocysts of *Cryptosporidia sp* to the inadequacy of pipe  
191 borne water-supply and the resort to buying water from vendors, and sachet or bottled  
192 water. [21] In contrast, a study which also evaluated the quality of packaged drinking water  
193 in Edo state, South South Nigeria reported the presence of *Pseudomonas sp* and other  
194 microorganisms identified as *Staphylococcus aureus ,Aeromonas sp., Corynebacterium*  
195 *sp., Bacillus sp., Bacillus badius, Proteus vulgaris* and *Escherichia coli*. [22] This variation in  
196 microbial contamination of water could be due to difference in geographical sites where  
197 the studies were conducted or samples collected. [23]

198 In another study on drinking water quality Omezuruike *et al* (2007) reported the presence  
199 of *Staphylococcus aureus*, a major human pathogen which causes a wide range of clinical  
200 infections , *Salmonella sp.*, and *Escherchia coli* among several other microorganism from  
201 drinking water samples collected in Abeokuta , Ogun State and Ojota in Lagos State all in  
202 South west Nigeria. <sup>[24]</sup> Similarly, Ibiebele *et al* (2009) reported the presence of  
203 *Staphylococcus spp.*, *Pseudomonas spp.*, *Klebsiella spp.*, *Proteus spp.*, *Enterococcus faecalis*,  
204 *Aeromonas spp.*, *Escherichia coli*, *Chromobacterium spp.*, *Flavobacterium spp.*, and *Serratia*  
205 *spp* from communal well water around Port Harcourt, South South, Nigeria.<sup>[25]</sup> The  
206 discovery of these isolates in drinking water aligns with the findings of another study  
207 conducted in Nassarawa State, North Central Nigeria. The study published in the British  
208 Microbiology Research Journal analyzed five randomly selected water samples from  
209 different boreholes sources and isolated six genera of bacteria which were identified as  
210 *Staphylococcus spp*, *Escherichia spp*, *Klebsiella spp*, *Salmonella spp*, *Pseudomonas spp* and  
211 *Proteus spp.*<sup>[26]</sup> This also agrees with a similar study which investigated the bacteriological  
212 contamination of drinking water from wells in Wukari, Taraba State, North east Nigeria. The  
213 study reported that *Staphylococcus aureus* was the highest isolated organism (53.33%)  
214 followed by *Escherichia coli* (46.67%), *Pseudomonas species* and *Proteus species*  
215 (33.37%), *Salmonella species* (26.67%), *Enterobacter species* (20.00%) while *Klebsiella*  
216 *species* and *Enterococcus species* were the least with 13.33% occurrence respectively.<sup>[27]</sup>  
217 The findings of another study conducted on similar sample sources does not align with the  
218 findings above. The study which was conducted to determine the physicochemical and  
219 microbiological characteristics of groundwater in boreholes used as drinking water in  
220 Mgboushimini community in Obio Akpor Local Government Area of Rivers State, South

221 South Nigeria reported that a total of four (4) genera of organisms were isolated from the  
222 water samples which were identified as *Klebsiella* spp., *Proteus* spp., *Citrobacter* spp, and  
223 *Candida* spp. This variation in microbial population despite similar sources of samples  
224 could be linked to geo- environmental and natural factors as reported by [28] and [29]

225 Olaoye (2009) reported the presence of *E. coli*, *Pseudomonas aeruginosa*, *Enterobacter*  
226 *aerogenes*, *Klebsiella* sp., *Proteus vulgaris*, *Alcaligenes faecalis*, *Bacillus cereus*,  
227 *Staphylococcus aureus*, *Streptococcus lactis*, *Aeromonas* sp. and *Micrococcus luteum*, in  
228 sachet-packaged drinking water in Western Nigeria. [30] This is similar to the findings of  
229 Oladipo et al (2009) in their work titled microbiological assessment of vended drinking  
230 water in Ogbomosho Osun State Nigeria. They isolated *Enterobacter aerogenes* in addition  
231 to *Proteus mirabilis*, *Bacillus subtilis* and *Pseudomonas putida*. [31] Both findings are similar  
232 to the result a bacteriological quality assessment and antibiogram profile of bacteria  
233 associated with sachet drinking water conducted in Zaria, North western Nigeria, a decade  
234 later which also reported the presence of *Enterobacter aerogenes* and other bacteria  
235 identified as *Escherichia coli*, *Salmonella* sp, *Citrobacter freundii* and *Proteus vulgaris* in  
236 samples of sachet-packaged drinking water analyzed. [32] However, this findings differ from  
237 another study on the bacteriological profile of packaged drinking water in bottles which  
238 reported that 5.2 % of tested samples had *Klebsiella* sp., *Streptococcus faecalis* and  
239 *Pseudomonas aeruginosa*. [17] This difference in the bacterial population of bottle and  
240 sachet water could be due to variation in the water purification techniques because both  
241 microbial activity and bacterial diversity during water treatment process show obvious  
242 spatial variation especially during chlorination. [33]

243 Another study by Ezugwune et al in 2009 analyzed the prevalence of bacteria in packaged  
244 sachets water sold in Nnewi, South East, Nigeria . The percentages of the different organism  
245 isolated from drinking water, are *E. coli* (36% ), *Streptococcus faecalis* (19.4%), *Klebsiella*  
246 *pneumoniae* (19.4%) and *Staphylococcus aureus* (25%). [34] This is in agreement with the  
247 findings of a study which analyzed a total of 50 drinking water samples comprising; 20 well  
248 water, 15 sachet water, 10 borehole water and 5 river water in Sokoto, Northwest Nigeria.  
249 The distribution of the bacteria isolated and identified from the study indicated that,  
250 *Escherichia coli* had the highest total prevalence of (40.31%) and occurring in all the water  
251 samples. *Klebsiella* spp had (17.13%) occurring in all the sources, *Salmonella* spp (7.44%)  
252 occurring in all the sources except for borehole, *Pseudomonas* species (15.22%) occurring  
253 in all the sources, *Staphylococcus aureus* with 115 (19.90%) occurring in all the sources  
254 except for borehole. [35] The finding reported above are at variance with a similar study on  
255 bacteriological evaluation of sachet drinking water in Owerri, Imo State, South east Nigeria  
256 which reported that *Klebsiella pneumoniae* [7(29.2%)] was the most predominant and  
257 closely followed by *Serratia* spp. [6(25.0%)] and *Proteus mirabilis* [6(25.0%)].  
258 *Pseudomonas aeruginosa* [3(12.5%)] and *Chromobacterium* spp. [2(8.3%)] was least  
259 predominant.[36] In a separate study conducted in Maiduguri, North eastern Nigeria, Muazu  
260 reported that 55% of the brands of packaged sachet water analyzed had fecal coliforms,  
261 25% had *Pseudomonas aeruginosa*, 15% had *Salmonella sp.* while 5% of the sample brand  
262 had *E. coli*. [37]. Majority of drinking water samples analyzed were unsafe for human  
263 consumption as reported Onifade *et el* who in addition to the presence of *Escherichia coli*,  
264 *Staphylococcus aureus* *Streptococcus faecalis* and *Enterobacter aeogenes* also isolated  
265 *Alcaligenes faecalis*, *Bacillus subtilis*, and *Micrococcus luteus*. [38] The presence of these

266 organisms constitutes public health significance which agrees with the conclusion of  
267 another study which analyzed a total of 30 samples from 10 brands of sachet water and 42  
268 samples from 21 communal boreholes serving as drinking water sources in seven different  
269 wards of Mubi, Adamawa state, North east Nigeria and isolated 49 non-repetitive bacterial  
270 species. [39] This conclusion is in contrast with the conclusion with the findings of a similar  
271 study which despite reporting the isolation of *Escherichia coli*, *Enterobacter aerogenes*,  
272 *Salmonella sp*, *Citrobacter freundii* and *Proteus vulgaris*, concluded that most (90%) of the  
273 water analyzed fell within the statutory limits. While, the remaining (10%) fell within the  
274 contamination level, which recorded high bacterial counts beyond the standard of safe  
275 drinking water set by water and food regulatory bodies. [32] A conclusion also reported by  
276 Osagie et al. [40].

277

## 278 **Conclusion**

279 The presence of *E.coli* in 70 percent of the studies reviewed is a source of concern, because  
280 although most strains of *E.coli* are harmless and form a substantial part of the normal flora  
281 of the intestines, the presence of toxin producing strains of *E.coli* like the O157:H7 in  
282 drinking water is a major public health concern because of its ability to trigger  
283 hemorrhagic diarrhea and kidney failure. Despite the increased access to drinking water,  
284 the quality of drinking water in many locations across Nigeria needs much to be desired.  
285 The diversity of bacterial contamination of drinking water especially the presence of  
286 pathogens is of public health concern. The isolation of several pathogenic and non  
287 pathogenic bacteria from drinking water sources in Nigeria, clearly indicates that drinking



288 water processing and handling procedures in Nigeria needs to be reviewed to meet global  
289 best practices that will ensure that drinking water does not continue to serve as a major  
290 portal for the introduction disease causing microorganisms into the body. The presence of  
291 these organisms in drinking water used by households in Nigeria cannot be extricated from  
292 recent water borne epidemic recorded in some parts of the country and with the reported  
293 level of non-compliance with standards and guidelines by water processing and packaging  
294 firms and the low level of oversight by the regulatory agency. There is also the need to  
295 review the parameters for licensing and registration of drinking water processing and  
296 packaging companies and the intervals for unscheduled routine inspection to drinking  
297 water processing and packaging plants to enhance drinking water quality in Nigeria.

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