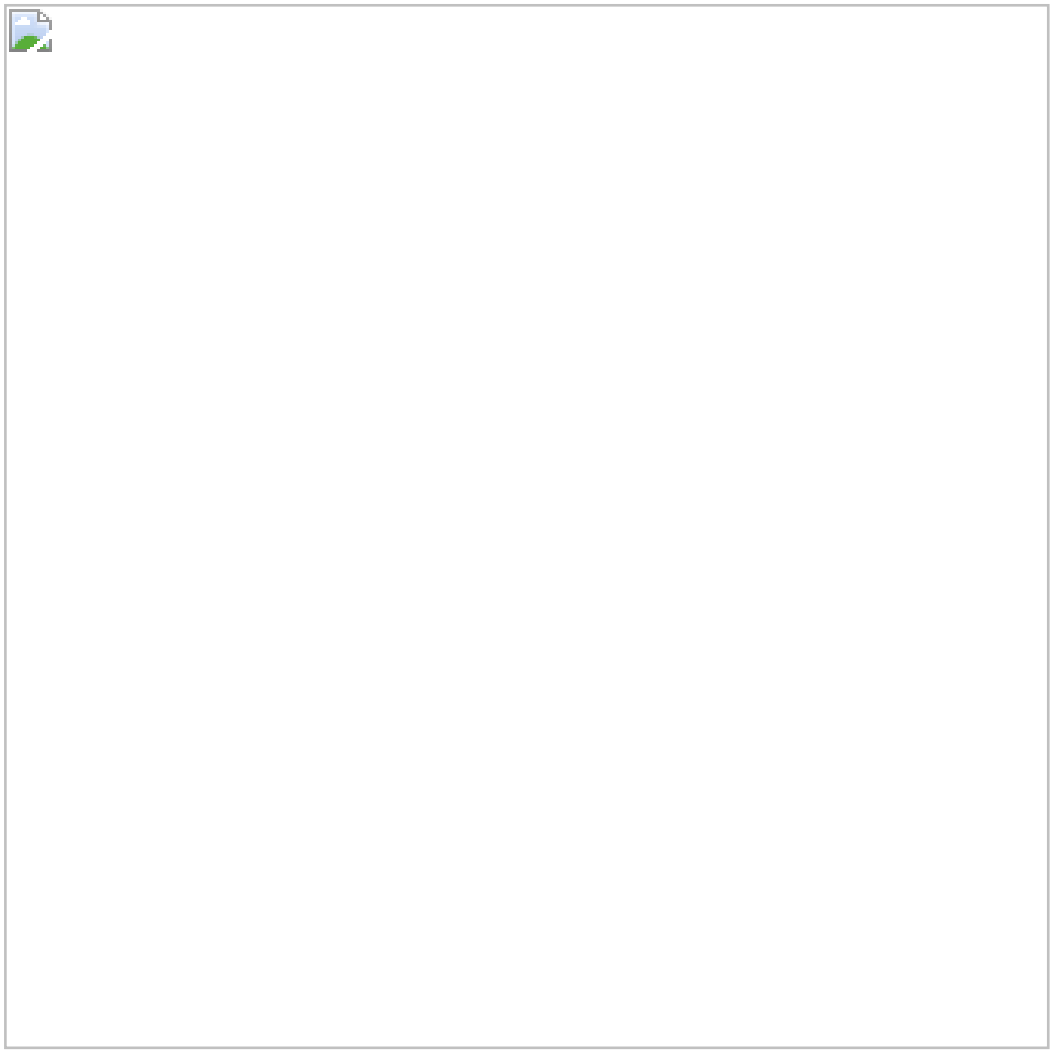

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Microbial Safety of Sachet Water in Ghana: A Systematic Review

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ABSTRACT

INTRODUCTION: Access to safe drinking water is crucial for health and survival, yet many developing countries face significant challenges in this regard. In West Africa, rapid urbanisation has outpaced efforts to improve access to potable water, compelling households to rely on private vendors for solutions, particularly through the growing market for sachet water. Widely consumed in Ghana, sachet water has become a convenient and affordable option, with over 37% of the population depending on it. However, concerns about its microbial safety persist, as studies indicate that sachet water often fails to meet necessary safety standards. This review consolidated existing research on microbial contaminants in sachet water, aiming to provide a representative overview of the microbial quality of sachet water in Ghana.

METHOD: The systematic review followed the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines. A thorough literature search was conducted across multiple databases, including PubMed, Web of Science, ScienceDirect, Scopus and the search engine Google Scholar, using relevant search terms. Eligible studies were identified based on established criteria, and data were subsequently extracted and analysed.

RESULTS: A total of 28 studies published from 2003 to 2024 were selected for inclusion in this review. Notably, 96% of these studies reported bacteria from 17 different genera, while 11% examined parasites from 5 genera. Some studies (7%) investigated both types of contaminants. Overall, 2,276 sachet water samples were analysed, with 1,727 (76%) showing microbial contamination. *Escherichia coli* was the most identified bacteria, while *Cyclospora cayetanensis* and *Cryptosporidium parvum* were the most identified parasites.

CONCLUSION: This study highlighted critical public health risks associated with sachet water in Ghana, particularly the presence of harmful bacteria and parasites. It is important to implement stricter manufacturing and sanitation standards and encourage safe handling practices to ensure the safety and quality of sachet water. Additionally, future research should focus on bridging existing gaps by investigating parasitic, viral, and fungal contaminants, to provide a holistic overview of the microbial contaminants in sachet water in Ghana.

KEYWORDS: Sachet water, pure water, sachet water quality, microbial safety, waterborne pathogens

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Introduction

Safe drinking water is an essential resource for the survival of all humans.[1,2] However, inadequate access to safe drinking water is a major problem in most developing countries.[2-5] In numerous West African countries, the pace of urbanisation has surpassed official initiatives to enhance the availability of safe drinking water.[6,7] As a result, many households have sought solutions from the private sector to meet their drinking water needs.[6] Among the various methods employed by private vendors is the market for sachet water.

The popularity of sachet water, commonly known as 'pure water', has surged significantly in West African countries over the past 20 years.[8,9] Packaged in a clear plastic bag, sachet water typically contains 500 ml of purified water, sealed at both ends using an electric heating process.[10] It provides a convenient and affordable source of drinking water to millions, particularly in low- and middle-income countries.[5-7] In Ghana specifically, it is widely accepted as a common source of drinking water.[6] Recent research indicates that it is the primary and most frequently consumed source of drinking water in Ghana, with over 37% of the population relying on it.[11]

Despite the widespread consumption of sachet water in Ghana, its microbial safety remains a significant public health concern.[10] Typically, the safety risks associated with sachet water mainly involve contamination by microbial pathogens, as well as heavy metals such as nickel, iron, lead, and mercury.[12,13] However, microbial pathogens pose the greatest risk of waterborne disease, even though chemical contaminants also present significant threats.[14] According to the World Health Organisation, microbial contaminants in drinking water may lead to significant public health issues, including cholera, dysentery, diarrhoea, hepatitis, typhoid and polio.[15] It is estimated that up to 505,000 deaths from diarrhoea each year are associated with the consumption of contaminated

water, with the majority of these fatalities occurring in sub-Saharan Africa.[15]

Like many other regions in sub-Saharan Africa, Ghana faces significant challenges in this regard. Research conducted in some low- and middle-income countries, has shown that sachet drinking water often fails to meet necessary microbial safety standards.[12,16-18] In Ghana for instance, this issue is further compounded by the growing influx of unregistered water producers.[10] As of October 2024, 1,544 packaged water producers have a valid product registration with the Food and Drugs Authority (FDA).[19] However, estimates suggest that the number of sachet water producers in Accra alone may reach 3,000 considering registered and unregistered producers.[20] The proliferation of unregulated sachet water producers raises concerns about the quality and safety of the water being sold to consumers.

It is important to consolidate studies on the microbial safety of sachet water throughout the country to provide a representative overview of the microbial safety of sachet water nationwide. This thorough evaluation of existing evidence is essential to offer vital insights that can assist policymakers, regulatory bodies and industry stakeholders in formulating and executing effective measures to ensure the production of safe drinking sachet water in Ghana. Several individual studies have reported on microbial contaminants in sachet water samples collected from various regions and communities across the country.[10] However, no study has aggregated this evidence to provide an overview of the scale and scope of the microbial safety issues associated with sachet water in Ghana. By consolidating the existing research on the microbial contaminants in sachet water, this review aimed to provide a valuable resource to inform evidence-based decision-making and drive targeted interventions to improve the microbial safety of sachet water and ensure the provision of safe drinking water for all Ghanaians.

Method

Literature search

This systematic review was undertaken following PRISMA guidelines.[21] A search was carried out in August 2024 across multiple electronic databases, including PubMed, Web of Science, Scopus and ScienceDirect, supplemented by a search in the Google Scholar web search engine. Search terms related to 'sachet water', 'microbial water safety', and Ghana were used across all databases and combined using the Boolean operators 'OR' and 'AND'. MESH terms such as 'drinking water'[Mesh], 'water microbiology'[MESH], bacteria[MESH], and 'bacterial load'[MESH] were used specifically in PubMed. The search had no date restrictions, but results were restricted to peer-reviewed journal articles in English. The full search strategy is presented in Supplemental Table 1.

Eligibility assessment

Based on the search results, studies were considered for eligibility if they were conducted in Ghana and reported on microbial contamination involving bacteria, fungi, viruses, or parasites in sachet water. Additionally, studies that provided information on the level of microbial contamination and specific microbial quality indicators of drinking water were also considered. Studies that assessed only other forms of drinking water aside from sachet water were excluded. Non-peer-reviewed studies, including grey literature, were also excluded. Studies that focused solely on other types of contaminants, such as chemical and physical contaminants, studies outside Ghana and those lacking sufficient data on microbial safety parameters were excluded.

Study selection

All titles and abstracts of the retrieved citations were exported to Rayyan QCRI[22] for screening. Initially, duplicates were identified and manually removed using the Rayyan QCRI software. The titles and abstracts of the remaining studies were then examined to select articles of interest. Finally, the full texts of all the studies that passed based on the title and abstract screening were thoroughly reviewed by all authors to identify relevant studies for inclusion. The PRISMA flow diagram (Figure 1) presents a detailed overview of the study selection process.

Data extraction and analysis

Following the study selection, relevant data were systematically collected and recorded from all eligible studies. Study characteristics such as author(s), year of publication, location, total number of samples, number of samples contaminated, type of contaminants identified, level of contamination and specific microbial contaminants isolated were extracted. The regional distribution of the included articles was visualised on a map, while bar charts and tables were used to visualise the distribution of the study characteristics and findings. The bar charts were created using Microsoft Excel to illustrate the patterns of microbial contaminants and their occurrence levels in the included studies. This visualisation aided in identifying the most frequently reported pathogens. The data for these graphs were sourced from the individual studies included in this review.

Quality assessment

To assess the quality of the included studies, a modified ten-point criterion adapted from the study by Williams et al[18] was used. Two authors independently assessed and scored the articles, with discrepancies resolved through consensus among the authors. Articles with total scores of 8 to 10 were deemed to be of good quality, those scoring from 5 to 7 as fair and those scoring from 0 to 4 as poor quality. No studies were excluded solely due to low quality; instead, issues related to study quality, such as non-representative sampling, were addressed through narrative synthesis. The scoring system for quality appraisal and the assessment of included studies are provided in Supplemental Tables 2 and 3, respectively.

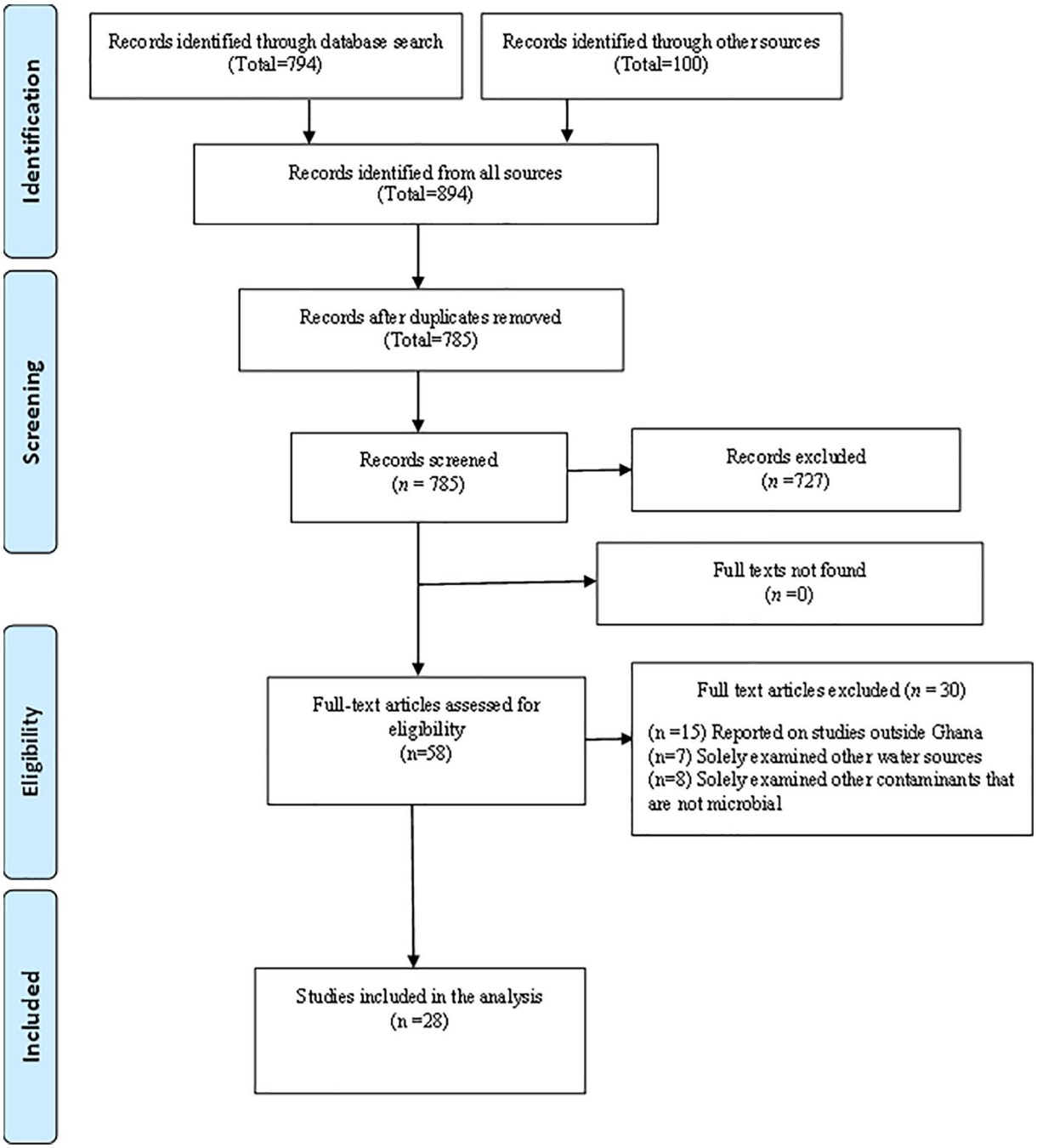

Figure 1. PRISMA flow diagram, showing the article selection process.

Results

A total of 28 studies were selected for inclusion in this review following the screening processes. The quality assessment of these studies revealed that 10 studies (36%) were of good quality, 15 studies (54%) were of fair quality, and 3 studies (11%) were of low quality. No studies were excluded based on the quality assessment criteria.

Characteristics of the eligible studies

Table 1 provides a summary of the characteristics of the 28 studies included in this review. Notably, 96% of the studies focused on bacteria, while only 11% examined parasites. Some studies investigated both types of contaminants, resulting in a combined total that exceeds the number of individual studies. The studies were published between 2003 and 2024, with 32% conducted from 2003 to 2013 and 68% from 2014 to 2024. Geographically, the studies were distributed across several regions in Ghana, with the Greater Accra region contributing the most, with 9 studies (32%). This is followed by the Ashanti region with 8 studies (29%), Central region with 5 studies (18%), Northern region with 4 studies (14%), Western and Volta regions with 3 studies each (11%). Bono, Eastern, and Upper East regions each contributed 2 studies (7%). The

Table 1. Characteristics of the included studies.

AUTHOR(S)	YEAR	LOCATION	IDENTIFICATION METHOD	SAMPLE SIZE	SAMPLES CONTAMINATED	TYPE OF CONTAMINANTS	LEVEL OF CONTAMINATION	ORGANISMS ISOLATED
Aboagye et al[23]	2024	Ho	Traditional culture method	10	10	Bacterial	0-9.42 × 10 cfu/ml	*Salmonella* spp. *Shigella* spp.
Addo et al[24]	2016	Kejetia	Traditional culture method	30	30	Bacterial	4.13×10^5 cfu/ml to 1.98×10^6 cfu/ml	Faecal coliforms *Escherichia coli* *Enterococci*
Agboli et al[25]	2018	Hohoe	Traditional culture method	36	4	Bacterial	0-5 cfu/100 ml	Total coliform *Escherichia coli*
Ahimah and Ofosu[26]	2012	New Juaben	Traditional culture method	60	24	Bacterial	0-4 cfu/100 ml	Total heterotrophic bacteria
Ahmed et al[27]	2022	Accra	Traditional culture method	190	17	Bacterial	0-28 cfu/ml	Total coliform *Pseudomonas aeruginosa* Heterotrophic bacteria
Akwetey et al[28]	2021	Cape Coast Takoradi	Traditional culture method	26	26	Bacterial	Cape Coast 1.60×10^3 to 1.75×10^7 cfu/ml Takoradi 0-5.22×10^9 cfu/ml	*Bacillus cereus* *Enterobacter cloacae* *Salmonella* spp. *Shigella* spp. *Klebsiella* spp. *Providencia* spp. *Staphylococcus aureus* Coagulase-negative *staphylococcus* *Listeria monocytogenes* *Proteus mirabilis* *Escherichia coli* *Erysipelothrix rhusiopathiae* *Nocardia* spp. *Streptococcus bovis*
Amuah et al[29]	2021	Damongo	Traditional culture method	120	120	Bacterial	Production sites 13.7-21.3 cfu/100 ml Vendors sites 55.3-77.3 cfu/100 ml	*Escherichia coli* *Salmonella* spp. Total coliform Faecal coliform Heterotrophic bacteria
Angnunavuri et al[30]	2022	Accra	Traditional culture method	120	120	Bacterial	0-976 cfu/100 ml	*Escherichia coli* Faecal coliforms
Angnunavuri et al[31]	2022	Greater Accra region	Traditional culture method	300	300	Bacterial	-	*Escherichia coli* Heterotrophic bacteria
Asamoah and Amorin[32]	2010	Tarkwa	Traditional culture method	12	0	Bacterial	0 cfu/ml	–

(Continued)

Table 1. (Continued)

AUTHOR(S)	YEAR	LOCATION	IDENTIFICATION METHOD	SAMPLE SIZE	SAMPLES CONTAMINATED	TYPE OF CONTAMINANTS	LEVEL OF CONTAMINATION	ORGANISMS ISOLATED
Aslan et al[33]	2020	Tamale Kintampo Techiman Kumasi Cape coast Accra	Molecular technique qPCR	175	152	Bacterial	Less than 1 to 1503 cfu/100ml	Total coliform *Escherichia coli* 23 s rDNA (copies/100 ml)
Awuah et al[34]	2014	Kumasi	Traditional culture method	50	41	Bacterial	0 to 36 cfu/ml for coliforms	*Escherichia coli* *Salmonella* spp. Other coliforms Bacteriaceae
Boadi et al[35]	2023	Kumasi	Traditional culture method	30	20	Bacterial	0-23.5 $\times 10^3$ cfu/ml	*Escherichia coli* Faecal coliform Total coliforms
Danso-Boateng and Frimpong[36]	2013	Kumasi	Traditional culture method	153	0	Bacterial	0 cfu/ml	Bacteria counts not detected
Dodoo et al[37]	2007	Cape Coast	Traditional culture method	180	180	Bacterial	-	*Escherichia coli* Faecal coliform Total coliform
Dzodzomenyo et al[38]	2018	Accra	Traditional culture method	112	112	Bacterial	All samples were less than 1 cfu/ml	*Escherichia coli* Total coliform
Cheabu and Ephraim[39]	2014	Obuasi	Traditional culture method	30	30	Bacterial	8.3-45 cfu/100 ml.	Total coliforms Faecal coliform
Kwakye-Nuako et al[49]	2007	Accra	Traditional culture method	27	21	Parasitic	-	*Microsporidia* spp. *Cryptosporidium parvum* *Cyclospora cayetenensis* *Sarcocystis* spp. Rotifers
Mosi et al[10]	2018	Ashanti Central Eastern Northern Volta regions	Traditional culture method	41	24	Bacterial	-	*Escherichia coli* Total coliform
Naabil et al[40]	2014	Bolgatanga	Traditional culture method	4	4	Bacterial	-	*Escherichia coli* Total coliform Faecal coliform
Ndur et al[41]	2015	Tarkwa	Traditional culture method	79	31	Bacterial Parasitic	-	Total coliform Faecal coliform *Ascaris lumbricoides* *Cyclospora cayetanensis* *Strongyloides stercoralis* *Cryptosporidium parvum*

(Continued)

Table 1. (Continued)

AUTHOR(S)	YEAR	LOCATION	IDENTIFICATION METHOD	SAMPLE SIZE	SAMPLES CONTAMINATED	TYPE OF CONTAMINANTS	LEVEL OF CONTAMINATION	ORGANISMS ISOLATED
Obiri-Danso et al[42]	2003	Kumasi	Traditional culture method	88	88	Bacterial	TVC 2-6.33 × 10^7 cfu/ml	*Escherichia coli* *Klebsiella pneumoniae* *Citrobacter freundi* *Enterococcus avium* Total coliforms Faecal coliforms *Faecal streptococci* Heterotrophs
Osei et al[43]	2013	Accra	Traditional culture method	60	60	Bacterial Parasitic	Less than 10 to TNTC	Heterotrophic bacteria Live Rotifers *Sarcocystis* spp. *Microsporidia* spp. *Cyclospora* spp. *Cryptosporidium* oocysts Small round worm Unidentified protozoa
Oyelude and Ahenkorah[44]	2012	Bolgatanga	Traditional culture method	120	90	Bacterial	Total coliform 12-63 cfu/100 ml Faecal coliform 2-23 cfu/100 ml	Total coliform Faecal coliform
Stoler et al[45]	2014	Old fadama Old Tulaku	Traditional culture method	60	60	Bacterial	THB 1-2900 cfu/ml	Total coliforms Heterotrophic bacteria
Stoler et al[46]	2015	Accra	Traditional culture method	80	80	Bacterial	-	Total coliforms Total heterotrophic bacteria *Pseudomonas aeruginosa*
Tagoe et al[47]	2011	Cape Coast	Traditional culture method	11	11	Bacterial	2.8 × 10^3 cfu/ml to 5.9 × 10^5 cfu/ml	*Escherichia coli* *Enterococcus faecalis* *Staphylococcus aureus* *Bacillus cereus* *Listeria monocytogenes* *Coagulase-negative staphylococcus* *Enterobacter* spp. *M. catarrhalis* *Citrobacter* spp. *Serratia marcescens* *Shigella* spp. *Klebsiella. aerogenes* *Proteus* spp.
Wuni and Adetunde[48]	2015	Tamale	Traditional culture method	72	72	Bacterial	<1.8-14 mpn/100 ml	Total coliform Heterotrophic bacteria

Oocysts-Tiny protective forms of certain germs specifically protozoan parasites, that are found in faeces.
TVC- Total viable count
THB- Total heterotrophic bacteria
TNTC- Too numerous to count
qPCR- Quantitative polymerase chain reaction

distribution of these studies across the various regions is illustrated in Figure 2.

Conventional methods for culture and identification, such as gram staining, biochemical reactions and physiological techniques, were employed in 96% of the studies to identify bacterial and parasitic contaminants in water samples. Only one study (4%) used a molecular technique (qPCR) for organism identification. Overall, the studies analysed 2,276 sachet water samples, with 1,727 showing microbial contamination, resulting in a contamination prevalence of 76% in sachet water across Ghana.

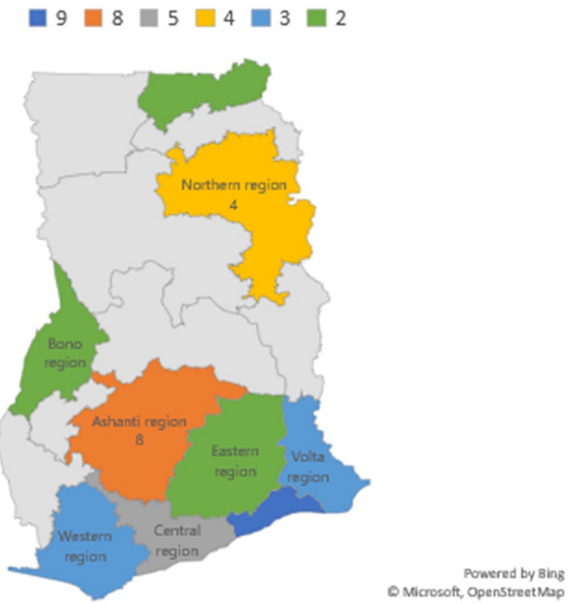

Figure 2. Map of Ghana showing the geographical distribution of the Reviewed studies.

Bacterial contaminants in sachet water in Ghana

Bacterial contaminants were found in sachet water in the majority of the studies reviewed (96%).[10,23-48] Bacteria from 17 different genera were isolated. Notably, 61% of the studies reported total coliforms in sachet water,[10,25,27,29,33-35,37-42,44-46,48] while faecal coliforms and total heterotrophic bacteria were reported in 36% and 29% of the studies, respectively. Some specific bacterial contaminants identified include *Escherichia coli* (54%), *Salmonella* spp. (14%), *Shigella* spp. (11%), and *Enterococcus* spp. (11%), *Bacillus cereus* (7%), *Pseudomonas aeruginosa* (7%), *Klebsiella* spp. (7%), *Citrobacter* spp. (7%), *Enterobacter* spp. (7%), *Staphylococcus aureus* (7%), and *Coagulase-negative Staphylococci* (CoNS; 7%). Additionally, *Listeria monocytogenes* (7%), *Proteus mirabilis* (7%), and *Streptococcus* spp. (7%), *Erysipelothrix rhusiopathiae* (4%), *Serratia marcescens* (4%), *Moraxella catarrhalis* (4%), and *Nocardia* spp. (4%) were also isolated. Figure 3 shows the percentage distribution of bacteria identified in this review.

Multiple studies in this review have reported varying levels of bacterial contamination in sachet water samples, ranging from as low as 0 cfu/ml to levels too numerous to count. The study by Agboli et al[25] reported that out of 36 sachet water samples analysed from the Hohoe municipality, 11.1% had detectable total coliforms at a level of 5 cfu/100 ml. Additionally, 6% of the samples were found to contain *Escherichia coli*, with

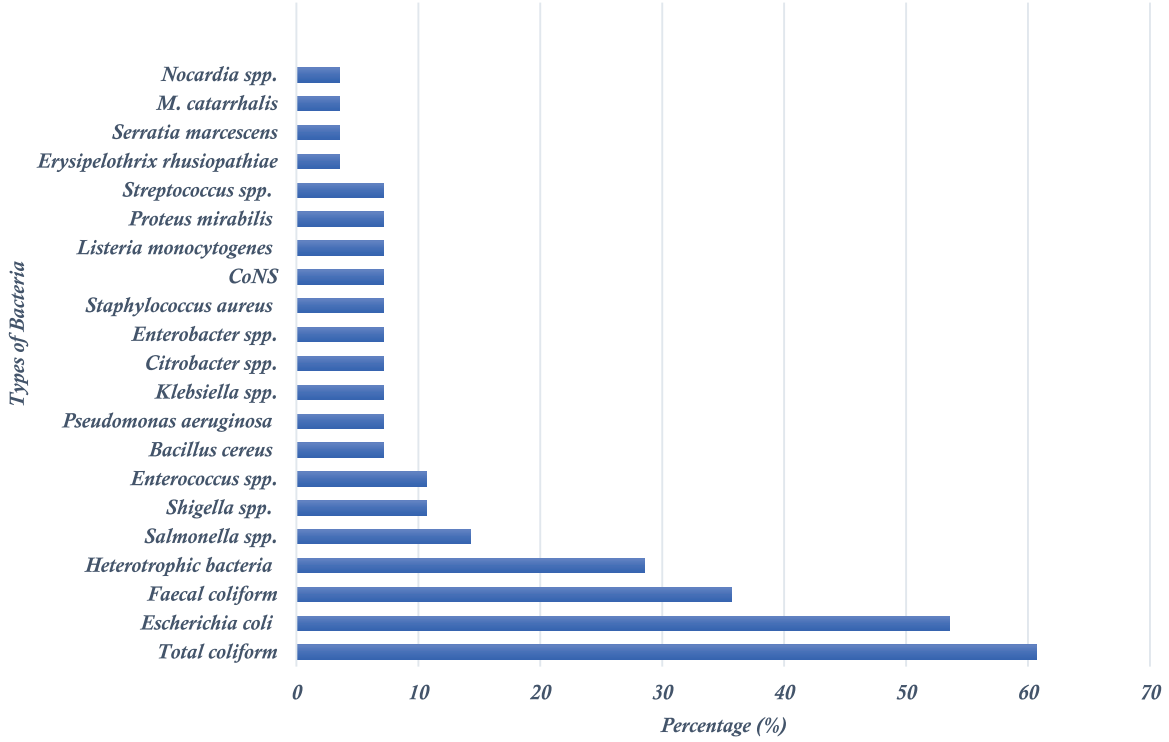

Figure 3. Percentage frequency of bacterial contaminants identified across the included studies.

counts between 4 and 5 cfu/100 ml. Another study by Amuah et al, [29] which analysed sachet water samples from production and vendor sites in Damongo, revealed that the faecal coliform count ranged from 0 to 1.3 cfu/100 ml at production sites, while samples obtained from vendors showed a slightly higher range of 0.7 to 1.3 cfu/100 ml. Total coliform counts of samples from production sites were between 4.0 and 8.7 cfu/100 ml, and those from vendors ranged from 5.7 to 10.2 cfu/100 mll.[29] *Salmonella* counts were between 0 and 1.0 cfu/100 ml at production sites, and 0.3 to 1.3 cfu/100 ml at vendor sites. *Escherichia coli* counts at production sites were from 0.3 to 1.0 and 0.7 to 1.3 cfu/100 ml at vendor sites. The total heterotrophic bacteria (THB) count was significantly higher at vendor locations, ranging from 55.3 to 77.3 cfu/100 ml, compared to production sites, which had counts between 13.7 and 21.3 cfu/100 ml.[29]

Aslan et al[33] in a study conducted in 6 different cities across Ghana reported that 87% of sampled sachet water tested positive for culturable total coliform, while no *Escherichia coli* colonies were detected. However, quantitative polymerase chain reaction (qPCR) results indicated the presence of *Escherichia coli* genes in 44.6% of the samples, with concentrations reaching as high as 3166 copies of *Escherichia coli* genes per 100 ml. The study also revealed through microbial source tracking analysis that the *Escherichia coli* genes did not originate from sewage, as the human-associated HF183 marker was absent.[33] Figure 3 shows the percentage distribution of bacteria isolated from the studies.

The study by Tagoe et al reported bacterial counts ranging from 2.8×10^3 to 5.9×10^5 cfu/ml in sachet water samples from the Cape Coast Metropolis.[47] The identified isolates included *Escherichia coli*, coagulase-negative *Staphylococcus*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Klebsiella aerogenes*, *Moxarella catarrhalis*, *Bacillus cereus*, *Listeria monocytogenes* and *Enterobacter* spp. The study also assessed the antimicrobial susceptibility of these isolates, revealing significant multidrug resistance to broad-spectrum antibiotics. Notably, *Listeria monocytogenes*, *Enterobacter* spp., and *Shigella* spp. exhibited the highest resistance at 87.5%. All isolates showed 100% resistance to ampicillin, flucloxacillin and penicillin.[47]

Parasitic contaminants in sachet water in Ghana

Only 11% of studies in this review reported the presence of parasitic contaminants in sachet water in Ghana.[41,43,49] The most reported parasites were *Cyclospora cayetanensis* and *Cryptosporidium parvum*, both of which were identified in all studies that examined parasitic contaminants.[41,43,49] Kwakye-Nuako et al, in a study conducted in Accra, reported that parasitic organisms were present in approximately 78% of sachet water samples collected for analysis.[49] Common pathogens, primarily of faecal and zoonotic origin, identified include *Microsporidia* spp. (51.2%), *Cryptosporidium parvum* (63.0%), *Cyclospora cayetanensis* (59.3%) and *Sarcocystis* spp. (66.7%). Additionally, rotifers and Charcot-Leyden crystals were also detected in 18.5% and 44.4% of the sachet water samples, respectively.[49]

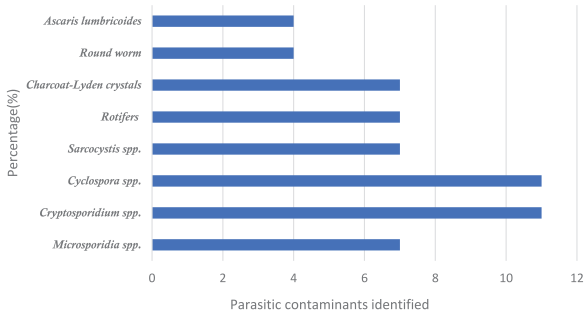

Figure 4. Percentage frequency of parasitic contaminants identified across the included studies.

Another study by Osei et al[43] also reported the presence of similar parasitic contaminants in approximately 52% of sachet water samples from Accra. The identified parasitic contaminants included *Sarcocystis* spp., *Microsporidia* spp., *Cyclospora* spp., oocysts of *Cryptosporidium*, live rotifers, Charcoat-Lyden crystals and small round worms.[43] Figure 4 shows the percentage distribution of parasitic contaminants identified from the studies. Ndur et al[41] identified *Ascaris lumbricoides*, *Cyclospora cayetanensis*, *Strongyloides stercoralis* and *Cryptosporidium parvum* in sachet water samples from Tarkwa.

Discussion

This review highlights significant findings regarding the microbial safety of sachet water in Ghana. Predominantly, the reviewed studies focused more on bacterial contaminants than parasitic contaminants, with bacterial organisms being extensively researched and isolated in the majority of cases (96%). Notably, none of the studies in this review reported on fungal or viral contaminants, a finding consistent with the study by Udoh et al.[50] This emphasis on bacteria may be attributed to the fact that most national and international organisations prioritise bacterial quality parameters when assessing the safety of drinking water.[51] Although it is often stipulated that wholesome drinking water should be free from any microorganisms and parasites, as well as any substances that could pose a potential danger to human health, the mandatory microbial drinking water parameters (*E. coli*, *Enterococci*, coliforms or *clostridia*) have no indicative value of fungal contamination.[51]

In this review, bacteria from 17 different genera were isolated, with total coliforms being the most frequently reported contaminant. This finding is consistent with a meta-analysis conducted in Nigeria on the microbial contamination of sachet water, which identified total coliforms as the most commonly reported contaminants in sachet water.[50] The coliform group is widely recognised as an important indicator of water quality and has historically contributed to the framework of public health protection.[52] Their presence in water suggests that

the water source may be susceptible to contamination by more harmful organisms.[52] Ideally, treated water should be free of coliforms[10]; however, total coliforms and faecal coliforms were identified in sachet water samples across the country.[10,24,25,27-31,33-35,37-39,41,42,44-47] The presence of faecal coliforms in water signifies contamination by sewage, indicating a significant risk associated with their consumption.[10,53]

The occurrence of pathogenic *E. coli* in processed and packaged drinking water has been linked to instances of diarrhoea, renal failure, haemolytic anaemia and dysentery.[30] Also, pathogenic bacteria found in packaged water have been directly associated with cholera outbreaks in developing nations.[54,55] Such outbreaks of diseases linked to drinking water can result in severe acute, chronic, or even fatal health effects, especially among immunocompromised populations.[52,53] In Ghana, multiple cholera outbreaks have been associated with the consumption of sachet water. A study by Issahaku et al[56] which reported a prolonged cholera outbreak in the Central Region of Ghana identified street-vended sachet water as a contributing risk factor. Another study by Dzotsi et al[57] which also focused on cholera outbreak in the Greater Accra region revealed a 6-fold increase in the likelihood of contracting cholera by consuming street-vended sachet water.

Specific pathogens such as *Salmonella* spp. and *Shigella* spp. were identified in sachet water, all of which are associated with diseases such as diarrhoea, typhoid fever and bacillary dysentery.[53,58] This finding is mirrored in studies conducted in Nigeria[50] and Cote d'Ivoire.[59] Other bacterial pathogens, including *Klebsiella* spp., *Citrobacter* spp., *Enterococcus* spp. *and Enterobacter* spp., were also found in sachet water in Ghana. This trend is supported by findings from other African countries.[12,60] The presence of these pathogens in drinking water may also be an indication of faecal contamination[61] and hence pose a significant health threat to consumers.

Parasitic contaminants were also detected in the reviewed studies. Among the parasites identified, *Cyclospora cayetanensis* and *Cryptosporidium parvum* were the most common across all the studies that investigated parasitic contaminants. In studies from other West African nations, parasites were observed in sachet water samples, the most commonly reported parasites were *Ascaris lumbricoides*, *Entamoeba histolytica* and *Giardia lamblia*.[62,63] These microorganisms are potential pathogens associated with waterborne diarrhoea outbreaks in healthy individuals and can be particularly harmful to those with compromised immune systems.[49,64] A notable trait of these organisms is their low infectious dose, which ranges from just 1 to 10 oocysts.[49]

The microbial contamination of sachet water, can originate from various sources, including contamination from the water source, failure to adhere to standard manufacturing practices, lack of basic sanitation, substandard storage facilities and insufficient water treatment.[10,29] In addition to these factors, inadequate storage and mishandling by vendors also pose a serious risk.[62] According to Udoh et al, total coliforms and faecal indicator bacteria are notably vulnerable to traditional water disinfection methods such as chlorination and ultraviolet (UV) light treatment.[50] In West Africa, sachet water production machines commonly feature UV filters, and chlorination is a standard practice during manufacturing.[50,65] Hence, the significant presence of microbes highlighted in this review could be attributed to ongoing disinfection challenges and low adherence to water treatment measures in the production and distribution processes. A study by Brown and Clasen[14] highlighted that higher adherence to water treatment interventions is crucial for ensuring safe water quality and maximising health benefits. Their research found that strong adherence to these interventions is associated with significant reductions in diarrhoeal diseases. Specifically, a drop in adherence from 100% to 90% can result in a reduction of predicted health gains by up to 96%.[14] This stresses the need to enforce adherence to treatment and safety measures in the production and distribution of sachet water in Ghana.

Conclusion and Recommendations

This systematic review has emphasised critical concerns regarding the microbial safety of sachet water in Ghana. The prevalence of bacteria and certain parasites indicate significant public health risks associated with the consumption of sachet water. This is particularly concerning given their links to severe waterborne diseases, including cholera and diarrhoea-related illnesses. It is thus important that stricter manufacturing and sanitation standards and the promotion of safe handling and storage practices throughout the sachet water supply chain are enforced. Consumers should prioritise safety when buying sachet water by verifying manufacturing and expiry dates, packaging integrity and storage conditions. Also, while there has been an increase in research activity over the past decade, there is a clear need for a more balanced approach to studying all microbial contaminants in sachet water. Future research should aim to fill the existing gaps by investigating parasitic, viral, and fungal contaminants to provide a holistic overview of the microbial contanminants in sachet water in Ghana.

Limitations

Although this systematic review provided some important insights into sachet water contamination in Ghana, it is subject to several limitations. One such limitation is the potential publication bias resulting from the exclusion of non-peer-reviewed studies, which may overlook valuable data. Additionally, the studies included in this review were sourced from only 9 out of the 16 regions of Ghana, meaning that regions not represented could have distinct water quality challenges or contamination issues that may alter the general findings of this review.

Author Contributions

Conceptualisation, ESD; methodology, WKA and ESD; validation, ESD; formal analysis, WKA; resources, ESD; data

curation, WKA; writing—original draft preparation, WKA and ESD; writing—review and editing, WKA, and ESD; visualisation, WKA, and ESD; supervision, ESD.

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Supplemental Material

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