Open Access

Advances in Environmental and Engineering Research

LIDSEN Publishing Inc.

Original Research

Coliform Bacteria Contamination of Water Resources and Implications on Public Health in Fako Division, South West Region, Cameroon

Yenlajai JaneFrances Banseka, Suiven John Paul Tume*

Department of Geography and Planning, The University of Bamenda, Cameroon; E-Mails: jbanseka@yahoo.com; wantume@gmail.com

***Correspondence:** Suiven John Paul Tume; E-Mail: wantume@gmail.com

Academic Editor: Andrea Capodaglio

Adv Environ Eng Res
2024, volume 5, issue 2
doi:10.21926/aeer.2402010

Received: March 03, 2024
Accepted: April 15, 2024
Published: April 19, 2024

Abstract

Bacteriological contamination of water sources, often due to improper handling of human waste, poses significant public health risks. This study investigates coliform bacteria contamination in water sources across the Fako Division of Cameroon. Twenty water samples were collected from various sources, including streams, community water, springs, boreholes, and wells, and analyzed for total coliforms using Violet-Red-Bile-Lactose (VRBL) Agar. Additionally, 352 household questionnaires were administered in four towns to assess water resource contamination. Results showed detectable coliform bacteria in 19 samples during the rainy and 15 during the dry seasons. Runoff during the wet season carries terrestrial biodegradable and non-biodegradable wastes into surface water bodies, while some infiltrate porous geology, polluting groundwater. Bacterial pollutants from dumpsites and human waste contribute to critical health issues like typhoid fever and gastroenteritis. Recommendations include landfilling with daily operations to minimize pollution, operational monitoring of domestic water systems, and integrated water quality management strategies. Participatory waste management involving administrators, stakeholders, and the population is crucial to minimize water contamination.

Keywords

Environment; water quality; pollution; contaminants; water resources; public health

1. Introduction

Water as a resource sustains life and enhances development, thus being the most critical natural resource [1, 2]. Water covers 71% of the Earth's surface, hence vital for life [3]. About 97% of water exists in oceans that are not suitable for drinking, and only 3% is freshwater, wherein 2.7% is comprised of glaciers and ice caps. The remaining little portion of 0.3% is available as surface and groundwater for human use [4]. Water is life; it is everyone's business and an indispensable resource in all aspects of life. It plays a crucial role in the development and socio-economic aspects of meeting the populations' essential needs like drinking, sanitation, food security, poverty, health, energy, and transport. Safe and clean drinking water is a basic need for good health and sanitation, and it is also a fundamental human right that is essential for the full enjoyment of life and all human rights [5]. Water is obtained from two sources: surface and groundwater, which people use daily for various purposes. Groundwater is an invaluable resource, and its pollution is a serious concern. Polluted water sources result from microbiological pathogens which may initiate water-borne diseases such as *gastroenteritis*, *diarrhoea*, *salmonellosis*, *cholera*, *typhoid fever,* and *giardiasis* [6]. Globally, about 80% of all diseases and deaths in developing countries are water-related due to polluted water [7, 8]. Surface water and groundwater are reservoirs that can feed into each other [9]. While surface water can seep underground to become groundwater, groundwater can resurface on land to replenish surface water. Surface water is more easily accessible than groundwater and is relied on for many human uses. It is an essential source of drinking water and is used to irrigate farmland. In most instances, surface water is polluted and contaminated by pathogenic organisms that cause waterborne diseases and chemicals that enter the water from surface runoff and upstream discharge [10]. The outcome of pathogenic contamination leads to structural water scarcity, thereby pushing affected communities to access potable water from doubtful sources. The water scarcity burden in urban and semi-urban areas in developing countries is also exacerbated by climate change [11-13].

The water quality in developing countries has deteriorated significantly due to rapid population growth, industrialization, the contamination of fresh water from household effluents, municipal waste, and agricultural practices [14]. As a result of water resources contamination from domestic and industrial effluents, many cities are facing an increase in organic and nutrient material in drinking water [15]. Drinking water quality standards, particularly for issues about bacteria, are reported to be higher for surface water [16]. Cameroon is a nation in Central Africa at the Gulf of Guinea, with its coastal plains in the South West Region. The region is characterized by rich volcanic soils and numerous watersheds from which streams and rivers rise. The growing population and the increase in water demand have reduced water availability alongside other factors, such as poor or no city planning in some towns in the world [5]. The inability of governments to meet the ever-increasing water demand has caused most of the population to resort to groundwater sources such as springs, boreholes, wells, rivers, and streams, which are alternative water sources commonly vulnerable to pollution.

The most common type of sanitation in the Fako Division is pit latrines, which pose a significant risk to the microbial quality of water resources. A septic tank can introduce bacteria to water that seeps into the ground and eventually ends up in the water table, where it can be drawn from

boreholes and wells. Poor sanitary completion of boreholes and wells may lead to groundwater contamination, and the proximity of some to solid waste dumpsites and animal droppings being littered around them [17] could also contaminate the quality of ground and surface water. The significant factors affecting the microbiological quality of surface water are the discharges from sewage works, runoff from informal settlements, and indiscriminate dumping of waste around or close to water sources. Domestic water is generally supplied to homes through private wells, boreholes, or public water companies. Water provided by public water companies is usually safe to drink. It does not pose a health risk since the quality of the water these companies offer is periodically checked. Water supplied by private sources is also usually safe to drink. However, it could be contaminated by harmful bacteria resulting from faulty septic tanks and indiscriminate waste disposal close to water sources.

2. The Study Area and Methodology

Fako Division is in the South West Region of Cameroon, and it is located between latitudes 4°4′ and 4°2′ North of the Equator and longitudes 8°7′ and 9°25′ East of the Greenwich Meridian [14]. It is along the foot of Mount Cameroon, from the Bimbia River at the Gulf of Guinea. Fako Division shares boundaries to the North with Meme Division, the West with the Ndian Division, the East with the Littoral Region, and the South with the Atlantic Ocean. It comprises five Sub-divisions: Muyuka, Buea, Tiko, Limbe, and Idenau. The study is limited to the four main towns of Buea, Tiko, Mutengene, and Limbe (Figure 1). Fako Division has a total surface area of 2060 km^2. The area has perched aquifers, which either originate from lahars or terraced pyroclastic materials and basalts, underlain by either impermeable layers of basalts or clay that prevent the vertical percolation of water to deeper aquifers below [1]. This regional aquifer is found in the lowland areas less than 20 m above sea level, and it is at this level that the most excellent stream density exists.

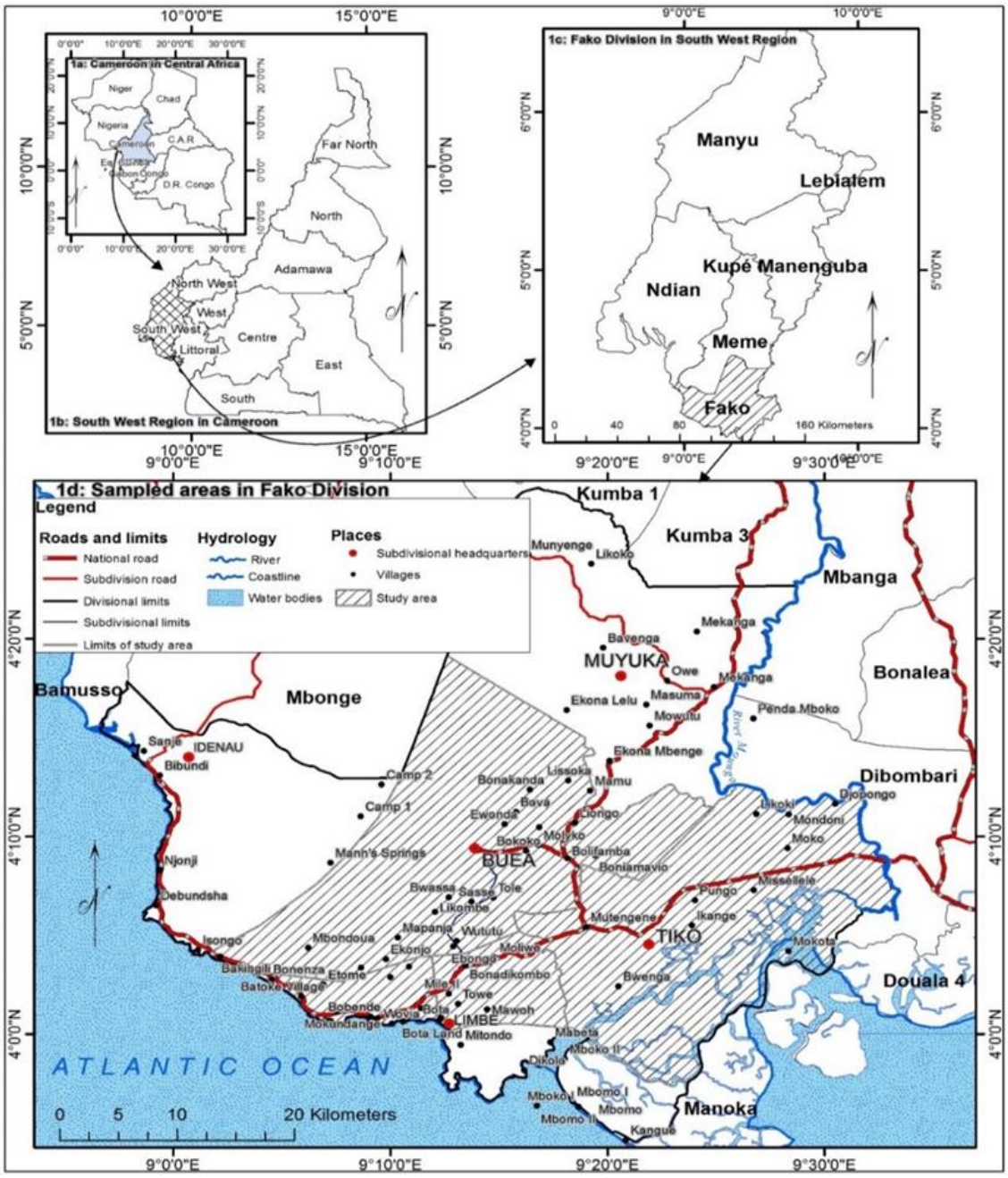

Figure 1 Location of the Study Area. Source: Administrative Map of Cameroon.

Mount Cameroon is a significant watershed with a radial drainage pattern. Most of the springs in the northeastern section of the mountain rise from the spring line, which runs from Botaland to North Owe in the northeast. The orientation follows the Mount Cameroon Volcanic Line (CVL) that traverses the region. This corresponds to the emplacement of lahar deposits and weathered clay materials that give the aquifers high storability and water retention capacity. Streams mainly originate from Muea and Mamu at higher altitudes before flowing into the mangrove vegetation in the Tiko estuary. Important rivers in the study areas are River Mungo, River Benoue, the Ombe River, and River Ndongo, which flow down to the Atlantic Ocean. Fako Division is composed chiefly of pyroclastic and jointed weathered fractured and columnar basalt, resulting in water-saturated volcanic fractured rock aquifers. The basalts have fractures that allow infiltration, as well as the spongy volcanic scoria. The indiscriminate dumping of waste will probably result in infiltration into

the aquifers of contaminants from the waste and spread over a wide range in the case of regional aquifers due to heavy monsoonal rains [18].

3. Methodology

Twenty (20) samples were collected in the wet season (September 29th 2020) and dry season (February 7th 2021) (Table 1).

Table 1 Sampled Water Sources in Fako.

Number	Sample Location	Sample Name
1.	Buea (Bonduma)	Spring 001
2.	Buea (Muea)	Spring 002
3.	Limbe (Mokundange)	Spring 003
4.	Limbe (Upper Towe)	Spring 004
5.	Tiko-Douala Road	Spring 005
6.	Buea (Bomaka Chief Street)	Well 001
7.	Buea (Bomaka, Khawa street)	Well 002
8.	Limbe (Slaughterhouse)	Well 003
9.	Limbe (Mabeta)	Well 004
10.	Tiko Town	Well 005
11.	Tiko-Douala Road	Well 006
12.	Mutengene	Well 007
13.	Buea	Borehole 001
14.	Limbe	Borehole 002
15.	Tiko	Borehole 003
16.	Mutengene	Borehole 004
17.	Mutengene	Community Water
18.	Buea (Ndongo River)	River 001
19.	Mutengene (River Benoua)	River 002
20	Limbe	Stream

The analysis for total coliforms (*E. coli)* (bacterial indicator for faecal contamination) was carried out using the Violet Red Bile Lactose (VRBL) Agar (ISO). This is a selective medium for isolating and enumerating coliforms in environmental samples at the University of Buea Microbiology Laboratory. This was complemented by 352 questionnaires administered in a stratified sample in the four towns of Buea, Mutengene, Tiko, and Limbe. Data on the outbreak of waterborne diseases (typhoid fever, diarrhoea with and without blood, severe acute gastroenteritis and cholera) were collected from the Regional Delegation of Public Health for the South West Region in Buea.

4. Results and Discussion

4.1 Bacteriological Pollutants

Fako Division has no treatment of municipal sewage, yet urban wastewater is increasingly being used directly or channeled from receiving waters into irrigated agricultural land. There is the

cultivation of vegetables and tomatoes along marshy areas in Bolifamba and Muea, where the irrigation of vegetable and tomato gardens uses water from doubtful sources, commonly surface water from nearby polluted rivers and streams. This has resulted in microbiological contamination of food crops stemming from the use of water polluted by human wastes and runoff from grazing areas and stockyards. This applies to using polluted water for irrigation and directly contaminating foods by washing vegetables, fruits, and food with polluted water before consumption. The most common diseases associated with contaminated irrigation water are cholera, typhoid, ascariasis, amoebiasis, giardiasis, and *E. coli*. Crops that are most implicated in the spread of these diseases are ground crops that are eaten raw, such as cabbage, lettuce, carrots, cucumber, and others. The use of contaminated groundwater and surface water resources by the population of Fako has led to microbial pollution with a mean occurrence (Figure 2) calculated with the twenty water samples collected and analyzed in Fako during the dry and rainy seasons.

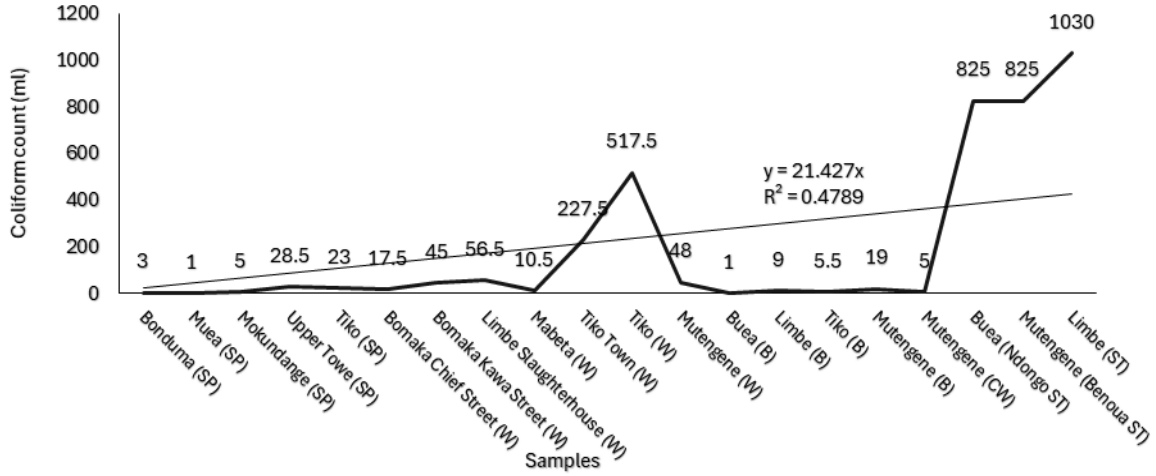

Figure 2 Mean coliform count (dry and rainy seasons).

The mean coliform count in the twenty water samples analyzed for the dry and rainy seasons indicates that the wells had high levels of coliform count. In contrast, the streams, which are surface water bodies, had the highest coliform count. The springs and boreholes, being groundwater sources, had reduced bacteria levels for the two seasons.

4.2 Water Pollution and Water-Borne Diseases Nexus

The laboratory analysis of the samples of water resources from the Fako Division, precisely in the municipalities of Buea, Tiko, and Limbe, indicated an alarming level of microbiological pollution. Cases of water-borne diseases such as typhoid, cholera, diarrhoea, and severe acute gastroenteritis are recurrent in Fako, and these have been traced to be from the use of water from shallow, unprotected hand-dug wells and other polluted water sources. These water-related infections result from the pollution of the water sources due to anthropogenic influences and indiscriminate waste disposal. A vast majority of the population of these towns does not have access to pipe-borne water. They are compelled to turn to alternative sources like springs, boreholes, wells, and streams, which are untreated and whose microbial qualities are significantly compromised by their proximity to both point and diffuse sources of pollution. These untreated sources are contributing significantly

to water-related infectious diseases such as cholera, dysentery, and typhoid. Waterborne diseases are infectious diseases which are spread primarily through polluted water.

These diseases are more prevalent in the areas around streams and rivers with poor sanitary conditions. Dumping waste directly into surface water bodies or indirectly through infiltration into underground water is responsible for water pollution in Fako. The population of Fako in the municipalities of Buea, Limbe, and Tiko, which encompasses Mutengene suffer from severe acute gastro-intestinal diseases, cholera, diarrhoea with and without blood, and typhoid fever, which are infectious and transmitted through the consumption of polluted water. Various disease-causing pathogens like viruses, bacteria, protozoa, and parasites are found in the faeces of infected persons.

If faeces from infected people are not correctly contained and treated, the pollutant *E-coli* can get into the surface and groundwater. *E. coli* can cause many illnesses, such as pneumonia, urinary tract infections, diarrhoea, typhoid, cholera, and dysentery [19]. The limited garbage bins and dumpsites for waste disposal in the municipalities in Fako could account for the use of surface water bodies as alternative waste dumping sites. It was observed that inhabitants in some communities and towns adopt unhygienic activities, particularly the defecation and urination directly into streams, in the open, and drains, which eventually get into water bodies. Frequent exposure to highly contaminated water causes health problems like schistosomiasis, skin irritation, and standing and stagnant water, which serve as habitats for mosquitoes responsible for malaria's continuous prevalence.

These four towns in Fako for the past nine years, from 2012 to 2020, showed typhoid fever affecting the population the most, followed by severe acute gastrointestinal diseases, diarrhoea without blood, diarrhoea with blood, and cholera. The cases of Typhoid fever, as shown in the graph, increased from low levels in 2012 and 2013 and rose in 2014 in all the municipalities. There was a drastic drop in 2015, and it started growing again in 2016, gradually reaching very high cases in 2018 and 2019. The majority of the cases of typhoid fever were recorded in Buea from 2014 to 2020, with the highest in Buea in 2020 (Figure 3).

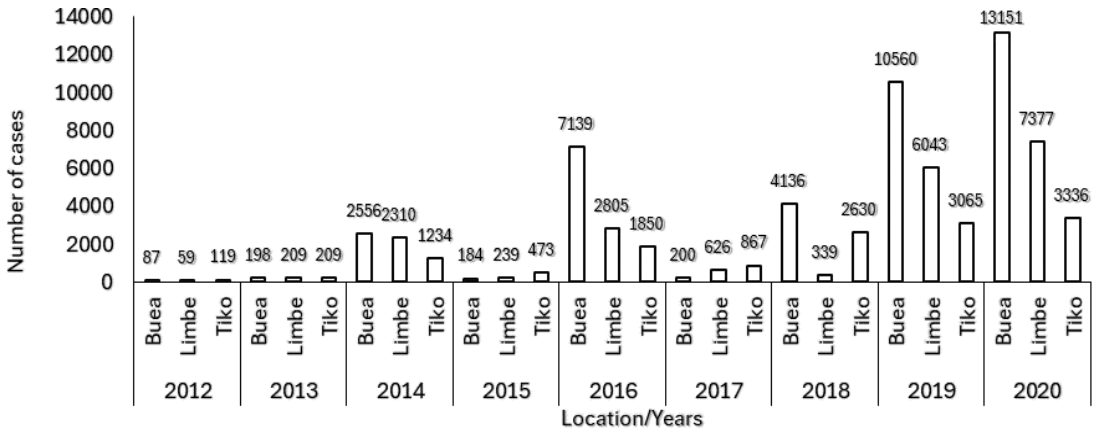

Figure 3 Typhoid fever cases (2012-2020) in Fako Division. Data source: Regional Delegation of Health, SW Region.

Diarrhoea without Blood cases increased gradually from 2012 through 2013 to a jump in 2014, with the highest number of cases in Tiko and Limbe (Figure 4).

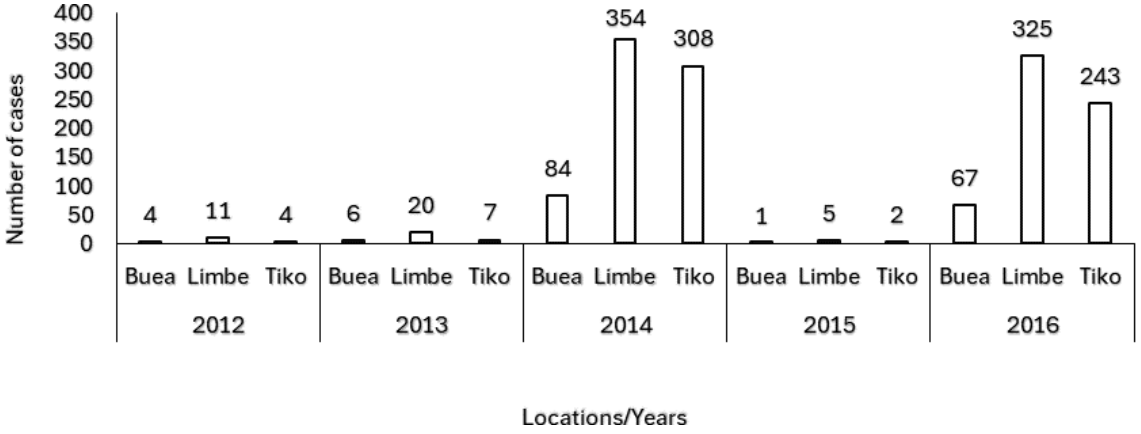

Figure 4 Diarrhoea without blood cases in Fako Division (2012-2016). Data source: Regional Delegation of Health, SW Region.

There was a drastic drop in 2015, then a jump again as the cases increased in 2016 with the highest cases still recorded in Tiko and Limbe. The cases of diarrhoea with blood were recorded in small numbers of thirty-four (34) in Limbe in 2016 and four (4) cases in Tiko (Figure 5).

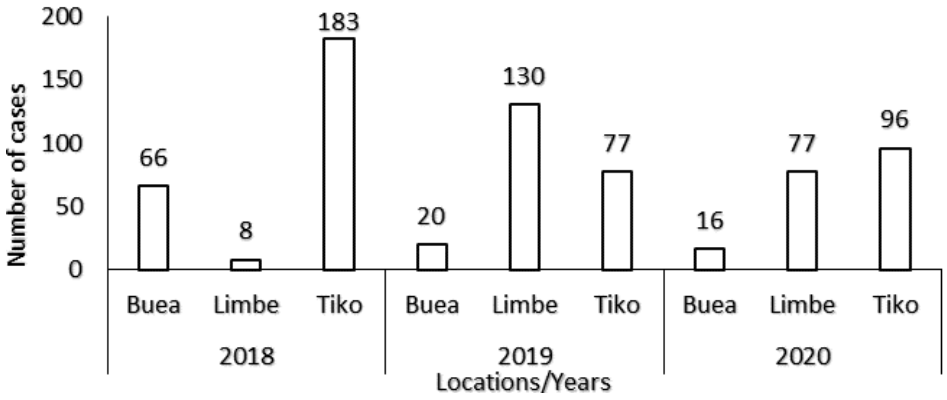

Figure 5 Diarrhoea with Blood Cases in Fako Division (2018-2020). Data source: Regional Delegation of Health, SW Region.

The majority of the cases in the three municipalities of Tiko, Limbe and Buea in Fako were recorded from 2018 to 2020 as shown in the graph above. In 2018 the highest cases were in Tiko followed by Buea then Limbe. In 2019 Limbe registered the highest number of cases, followed by Tiko, while the cases for Buea dropped, and in 2020 Limbe and Tiko maintained their high numbers while cases in Buea dropped gradually. Gastroenteritis cases in 2017 were recorded only in Tiko from the graph because Limbe had just three (3) while Buea recorded none in that year (Figure 6).

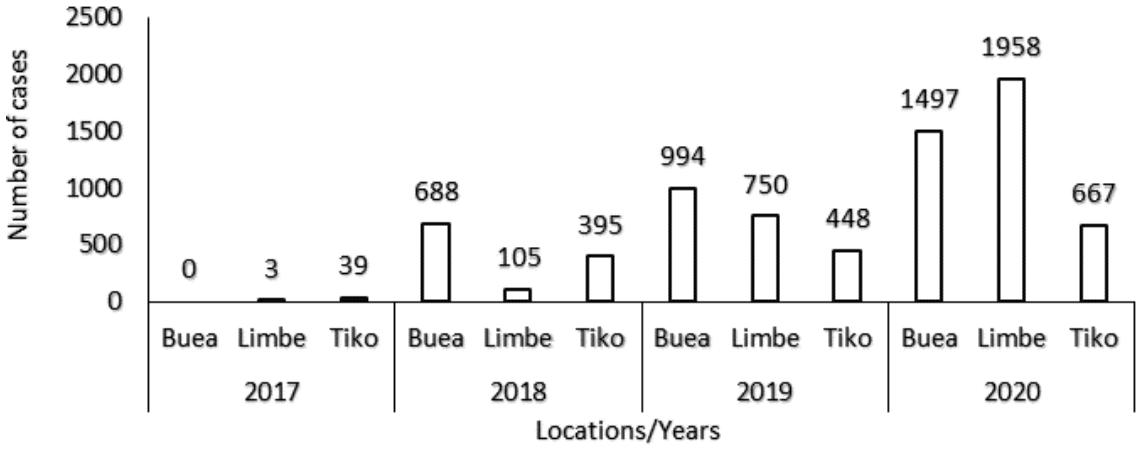

Figure 6 Severe Acute Gastro Enteritis (2017-2020). Data source: Regional Delegation of Health, SW Region.

In 2018 Buea registered the highest number of cases of gastroenteritis, followed by Tiko and then Limbe. The cases continued to rise in 2019 and 2020, with the highest in Buea and Limbe. Cholera cases were also recorded in the Fako Division, with five (5) cases in Limbe in 2016 and one (1) case in Buea in 2019. Most cases were registered in 2020 in all three municipalities as represented below, with the highest number of cases in Limbe (Figure 7).

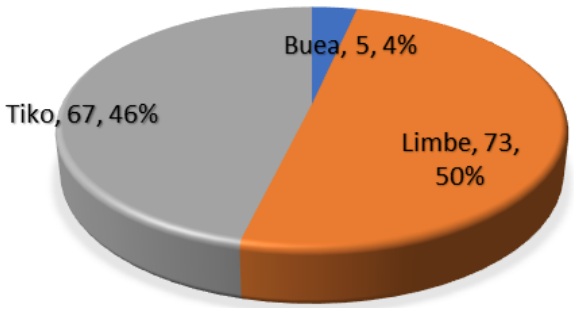

Figure 7 Cholera Cases in Fako Division (2019 and 2020). Data source: Regional Delegation of Health, SW Region.

The prevalence of these waterborne diseases in Fako and the increase in cases as the years go by are probably caused by the rise in the population in the various towns, which is causing haphazard or unplanned construction of houses and residential areas. This has led to the construction of septic tanks, pit latrines sewage disposal, and waste dumping, especially in households close to water sources like wells, boreholes, and surface water. The sinking of boreholes and wells has been very common in the Fako Division since the lone water supplier, CAMWATER cannot meet the water demands of the growing population. These wells and boreholes have been constructed without consideration of their distance from the standard open waste dumpsites and sewage systems in residential areas. These have exposed the water resources to bacteriological contamination in drinking and domestic water.

Bacteriological pollutants of Fako water resources are directly proportional to human land use intensity. Microbial concentration in water sources also comes from different land uses, such as poor waste disposal systems and human faecal waste, which causes severe water contamination and health problems. This is supported by field evidence of human faecal waste disposal (Figure 8).

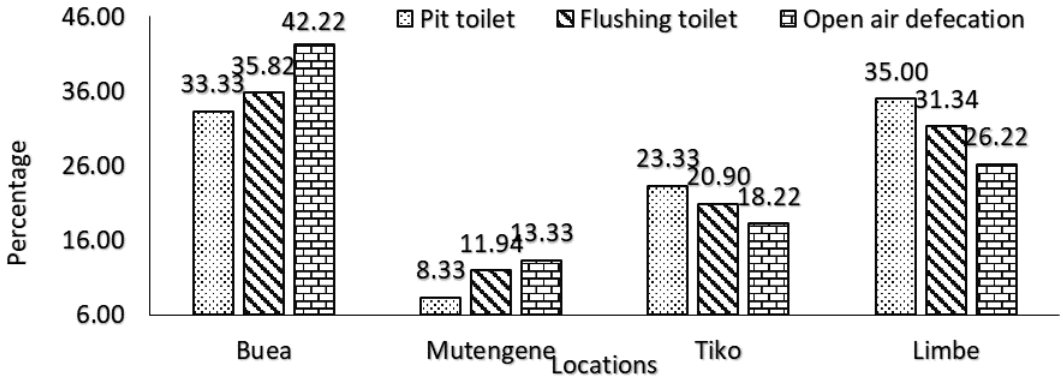

Figure 8 Human fecal waste disposal in Fako Division.

About 64% of the sampled population confirmed that human faecal waste is disposed of in the open air, most often in streams. This is noted in Mile 16 (Bolifamba), Buea, Tiko, and Mutengene. It should also be recalled that 19 of the 20 water samples collected for this study were contaminated with coliform counts. This could be averted by treating water for domestic use (Figure 9).

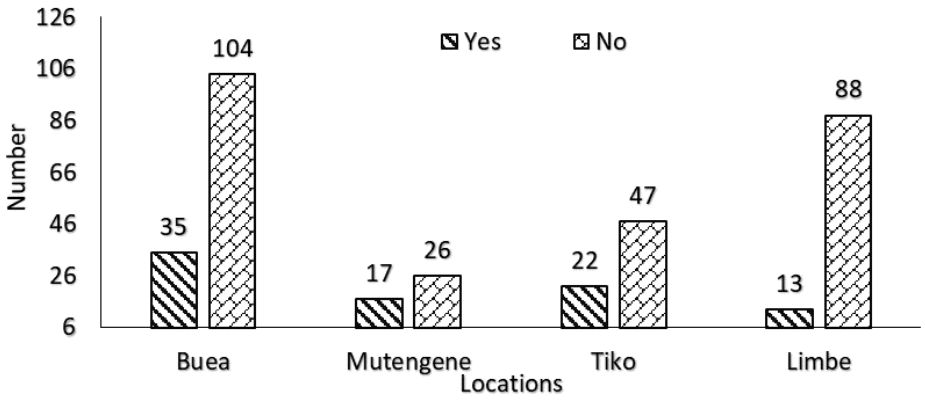

Figure 9 Domestic water treatment in Fako.

The majority of the population does not treat water before drinking. It can be affirmed that this was the cause of the major cholera outbreak in the Fako Division in March 2022. By April 2022, the following cases were recorded: 2,385 cases in Limbe, 542 in Buea, 409 in Tiko, and 76 fatalities in Fako Division.

Results indicate that 95% of water resources in Fako contained high levels of microbial content, with the levels in the rainy season being higher in more samples than in the dry season. The pollution is caused by the waste generated by human activities in agricultural, industrial, commercial, and residential areas, which has been dumped carelessly on the land surface and reacted with precipitation. These infiltrate through the porous substratum of the region into groundwater resources or are carried to surface water by runoff, which is fascinated by impervious surfaces. The rainy season has hefty downpours, allowing easy and increased runoff into surface water and infiltration into groundwater resources. The open waste dumps poorly managed in Fako get rotten, and the bacteria that forms is washed by runoff into water resources. The population's use of organic manure in farms also causes bacteria to be washed into water sources by runoff, causing contamination.

The location of septic tanks and pit latrines in residential areas in a haphazard manner close to water sources and the infiltration of bacteria into groundwater resources are the reasons for the high microbial content in the Fako Division. The population of some of the areas, for example, in Mile 16 Bolifamba in Buea and those living along the Ndongo river flowing through Tiko town, due to the absence of toilets and pit latrines, use buckets for human faecal disposal, which are subsequently emptied in the rivers and streams causing contamination. The pollution of water resources in Fako by high levels of microbes has led to the prevalence and recurrence of waterborne diseases like typhoid, Diarrhoea, and cholera.

Pollution thus leads to the development and propagation of pathogenic waterborne microorganisms like *Escherichia coli (E. coli)*. Naturally, *E. coli* is an anaerobic bacterium that inhabits the large gastrointestinal tracts of warm-blooded animals and is a major normal flora associated with the human colon [20]. *E. coli* in food or water normally signals recent faecal contamination or poor hygienic conditions in food processing facilities [21]. Faecal contamination, poor sanitation measures, and poor storage conditions significantly influence the *E. coli* population [9, 22]. The mere existence of *E. coli* in water does not necessarily imply the presence of disease-causing microbes. It indicates the possible existence of fecal-borne microorganisms such as Salmonella and hepatitis A [23]. This accounts for using *E. coli* as an indicator microbe to examine food and water samples to detect faecal contamination levels [23].

The present study is in line with the findings of [24], who posited that sanitation in African cities (60-95%) is generally dominated by autonomous systems: bathrooms, septic tanks, restrooms, and [25], reported that about 3.8 million Cameroonians, lack access to adequate sanitation. None of the major cities in Cameroon have central sewage treatment plants, and the few plants that have been constructed for some housing estates have all been abandoned, thereby allowing untreated sewage to flow into the environment [25]. The intrusion of these faecal effluents in the aquifers can generate various diarrhoea in the human population and contribute to a significant part of the deterioration of public health [25]. These results are similar to those of [26, 27] carried out in communities that rely on untreated sources such as streams, dams, boreholes, wells, and rivers to meet their basic needs, such as drinking, sanitation, and cooking, and for their sustainable development.

The presence of bacteria in drinking water could come from anthropogenic activities, especially from animal and/or human faeces that have infiltrated or leaked into the water supply. In drinking water, total coliform and faecal coliform can lead to health challenges like cholera, diarrhoea, jaundice, and nausea [28, 29]. Faecal coliforms were present in all the 20 samples collected in the towns of Limbe, Buea, Tiko, and Mutengene, which is possibly the cause of the major cholera outbreak in the Fako Division in January and March 2022. The consumption of food crops from farmlands irrigated with wastewater and ill-treated wastewater effluents could put people who feed on them at risk for several diseases, some of which only become evident after many years of exposure [30].

The key sources of water pollution in Fako come from anthropogenic activities caused mainly by the poor, uncultured, hygienic living habits of people as well as the unhealthy practices of factories, industries, homes, and corporate bodies as they discharge untreated effluents and waste into water bodies [31]. The effects of human activities on water quality are widespread and varied in the degree to which they disrupt the ecosystem and water. For example, water pollution caused by human faeces is attributable to only one source. The reasons for this type of pollution, its impacts on water

quality, and the necessary remedial or preventive measures are varied. Furthermore, bacterial pollutants in dumpsites, human waste, and heating systems could be drained into the water sources during the wet season, after which rapid multiplication occurs [32]. These sources are, thus, probable sources of transmitting pathogens, resulting in more critical health problems. Similar observations have been made where coliform organisms have long been recognized as suitable microbial indicators of drinking water quality [33] because these organisms are common inhabitants of the intestinal tracts of both humans and warm-blooded animals and are generally present there in large numbers [34]. The presence of coliforms in water is, therefore, suggestive of faecal contamination [35]. Water chlorination is known to be lethal to coliforms, and their detection in treated water supplies indicates inadequate treatment or post-process contamination [36, 37].

5. Conclusions

Residential, commercial, agricultural, and industrial activities in Fako Division do not sort their wastes at the points of generation, be it biodegradable, non-biodegradable or hazardous. The wastes are simply dumped in HYSACAM trash cans, which are eventually transported to open dumps at Isokolo (Limbe) and Mussaka (Buea). The case of Tiko and Mutengene with no waste management facilities, practice indiscriminate waste dumping along the streets and directly on land and water bodies as was the case in the stream running by the Tiko market. These wastes are washed by runoff into surface water bodies, while some get rotten and infiltrate groundwater. The leachate from the unsanitary landfills managed by the HYSACAM Company infiltrates the ground through the decaying waste, finding its way into underground water, and causing water pollution. The presence of bacteria in water samples is responsible for the prevalence of waterborne diseases (severe acute gastrointestinal diseases, cholera, diarrhoea with and without blood, and typhoid) affecting the Fako population. The fact that the towns of Mutengene, Tiko, Buea, and Limbe are undergoing rapid population growth associated with the rapid increase in urbanization, industrial, agricultural, and residential land uses make the impacts of water contamination on human health (public health), and water quality a severe issue. Fako Division groundwater and surface water contamination could be acute and exacerbate typical public health issues such as hygiene and infectious diseases.

Acknowledgements

We wish to thank all those who assisted us in field data collection. We also acknowledge the Regional Delegations of Public Health, Water and Energy for the Southwest, for providing us with secondary data.

Author Contributions

Both authors designed the study and wrote the first draft manuscript. Yenlajai JaneFrances Banseka collected field data. Suiven John Paul Tume revised the manuscript.

Competing Interests

The authors have declared that no competing interests exist.

References

1. Banseka Y, Lambi C, Fogwe N. Physico-chemical contamination of water resources in Fako-Division, Southwest Region, Cameroon. Curr J Appl Sci Technol. 2022; 41: 23-39.
2. United Nations Educational Scientific and Cultural Organization (UNESCO). Water for people, water for life: UN world water development report [Internet]. Geneva, Switzerland: UN-Water; 2003. Available from: https://www.unwater.org/publications/un-world-water-development-report-2003?__cf_chl_tk=fojeoAKVZntx7gl77fPpLFmojflqqu.Kbfirqm2dzBI-1713234151-0.0.1.1-1599.
3. Annan K. 'Water is essential for life'. New York: UN General Assembly Report; 2005; A/60/158.
4. Miller GT. Environmental science: Working with the earth. 6th ed. Belmont, CA: Wadsworth Publishing Company; 1997.
5. United Nations Environment Programme (UNEP). Making the case for ecosystem-based adaptation (Mt EbA Programme). Nairobi, Kenya: United Nations Environment Programme (UNEP); 2010.
6. Alley WM. Regional groundwater quality. Stafford BC, Australia: John Wiley & Sons; 1997.
7. Ayeni A, Balogun I, Soneye A. Seasonal assessment of physico-chemical concentration of polluted urban river: A case of Ala river in southwestern Nigeria. Res J Environ Sci. 2011; 5: 22-33.
8. Aderibigbe S, Awoyemi A, Osagbemi G. Availability, adequacy and quality of water supply in Ilorin Metropolis, Nigeria. Eur J Sci Res. 2008; 23: 528-536.
9. Agensi A, Tibyangye J, Tamale A, Agwu E, Amongi C. Contamination potentials of household water handling and storage practices in Kirundo Sub-County, Kisoro District, Uganda. J Environ Public Health. 2019; 2019: 7932193.
10. DWAF. Water quality management series guideline document U1.5. Guideline for the management of waterborne epidemics, with the emphasis on Cholera. 1st ed. DWAF; 2002.
11. Tume SJP. Impact of climate change on domestic water accessibility in Bamenda III Sub-Division, North West region, Cameroon. J Cameroon Acad Sci. 2021; 17: 131-145.
12. Ndikebeng KR, Forba CF, Tume SJP, Yenlajai BJ, Kimengsi JN, Kimengsi JN. Land cover dynamics and implications on water resources in Bamenda III Sub-Division, North West Region, Cameroon. Int J Global Sustainability. 2023; 7. doi: 10.5296/ijgs.v7i1.21031.
13. Tume SJP, Kongnso ME. Standardized precipitation index valuation of the impact of climate variability and change on domestic water accessibility in Bamenda III Municipality, North West Region, Cameroon. J Sci Fron Res Environ Earth Sci. 2022; 22: 39-55.
14. Banseka JY. Physico-chemical water quality assessment on the eastern flanks of Mount Cameroon. Bamenda, Cameroon: The University of Bamenda Printing Press; 2023.
15. Ray B, Lamsam A, Annachhatre A. Treatment and management of wastewater from an acrylic fibre industry. GMSARN International Conference on Sustainable Development: Issues and Prospects for GMSAt; 2006 December 6-7; Bangkok, Thailand. Berlin, Germany: ResearchGate GmbH.
16. World Alliance for Patient Safety. Global Patient Safety Challenge: Clean Water is Safety Care, 2005-2006. Geneva, Switzerland: World Health Organization; 2005. pp.1-25.
17. Bello OO, Osho A, Bankole S, Bello T. Bacteriological and physicochemical analyses of borehole and well water sources in Ijebu-Ode, Southwestern Nigeria. Int J Pharm Biol Sci. 2013; 8: 18-25.

18. Tume SJP. Standardized precipitation index comparison along the Limbe-Bamenda Axis of the Cameroon Gulf of Guinea. Adv Environ Eng Res. 2022; 3: 002.
19. Daffi R, Alfa M, Ibrahim E. Gis-based analysis of water quality parameters of groundwater with proximity to onsite wastes pits in vom community of Jos South, Nigeria. J Eng Res Rep. 2020; 10: 6-18.
20. Nguyen HTM, Le QTP, Garnier J, Janeau JL, Rochelle-Newall E. Seasonal variability of faecal indicator bacteria numbers and die-off rates in the Red River basin, North Viet Nam. Sci Rep. 2016; 6: 21644.
21. Odonkor ST, Ampofo JK. Escherichia coli as an indicator of bacteriological quality of water: An overview. Microbiol Res. 2013; 4: e2.
22. Kayembe JM, Thevenon F, Laffite A, Sivalingam P, Ngelinkoto P, Mulaji CK, et al. High levels of faecal contamination in drinking groundwater and recreational water due to poor sanitation, in the sub-rural neighbourhoods of Kinshasa, Democratic Republic of the Congo. Int J Hyg Environ Health. 2018; 221: 400-408.
23. Price RG, Wildeboer D. E. coli as an indicator of contamination and health risk in environmental waters. In: Escherichia coli-recent advances on physiology, pathogenesis and biotechnological applications. London, UK: IntechOpen; 2017. pp. 125-139.
24. Coulibaly L, Diomandé D, Coulibaly A, Gourène G. Utilisation des ressources en eaux, assainissement et risques sanitaires dans les quartiers précaires de la commune de Port-Bouët (Abidjan; Côte d'Ivoire). VertigO. 2004; 5. doi: 10.4000/vertigo.3299.
25. Katte V, Fonteh M, Guemuh G. Domestic water quality in urban centres in Cameroon: A case study of Dschang in the West Province. Afr Water J. 2003: 43-54. Available from: https://www.africabib.org/rec.php?RID=Q00038749&DB=h.
26. Lacina C, Dramane D, Adama C, Germain G. Utilisation des ressources en eaux, assainissement et risques sanitaires dans les quartiers précaires de la commune de Port-Bouët (Abidjan; Côte d'Ivoire). VertigO-la revue électronique en sciences de l'environnement. 2004; 5. doi: 10.4000/VERTIGO.3299.
27. Odonkor ST, Addo KK. Prevalence of multidrug-resistant Escherichia coli isolated from drinking water sources. Int J Microbiol. 2018; 2018: 7204013.
28. Banseka JFY. An assessment of the potable water quality in the Tiko municipality Southwest Region of Cameroon. Int J Resour Environ Manage. 2019; 4: 63-78.
29. Warberton DW, Peterkins PI, Weiss KF, Johnston MA. Microbiological quality of bottled water in Canada. Can J Microbiol. 1999; 4: 34-40.
30. Jain P, Sharma J, Sohu D, Sharma P. Chemical analysis of drinking water of villages of Sanganer Tehsil, Jaipur District. Int J Environ Sci Technol. 2005; 2: 373-379.
31. Liu H, Probst A, Liao B. Metal contamination of soils and crops affected by the Chenzhou lead/zinc mine spill (Hunan, China). Sci Total Environ. 2005; 339: 153-166.
32. Alabaster J, Lloyd R. Water quality criteria for freshwater fish. London, UK: Butterworths; 1980.
33. Odonkor ST, Mahami T. Escherichia coli as a tool for disease risk assessment of drinking water sources. Int J Microbiol. 2020; 2020: 2534130.
34. Adesiyun A, Adekeye J, Umoh J, Nadarajah M. Studies on well water and possible health risks in Katsina, Nigeria. J Hyg. 1983; 90: 199-205.

35. World Health Organization. Guidelines for drinking-water quality, 2nd ed. - Volume 3: Surveillance and control of community supplies. Geneva, Switzerland: World Health Organization; 1997.
36. Brock TD, Madigan MI, Martinko JM, Parker J. Biology of microorganisms. 6th ed. New York, NY: Prentice-Hall International Inc.; 1991.
37. LeChevallier MW, Evans T, Seidler RJ. Effect of turbidity on chlorination efficiency and bacterial persistence in drinking water. Appl Environ Microbiol. 1981; 42: 159-167.