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# Assessment of Bacteriological Quality of Sources of Drinking Water in some Selected Communities in the Akuapem South District of the Eastern Region, Ghana

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**Abstract** The study was undertaken in three communities namely, Adamrobe, Aburi, and Pokrom-Nsaba, in the Eastern Region of Ghana. These communities depend on streams, wells, and springs for their drinking water requirements. The objective of the study was to assess the bacteriological quality of the drinking water sources used by the communities. Water samples were analyzed using methods designed in APHA, AWWA, and WEF over a period of twelve months for water quality parameters including faecal coliform, total coliform, and enterococci species. The results of the study revealed that faecal coliforms, total coliforms and enterococci in most water samples were above the World Health Organization and Ghana Water Company Limited recommended limits for drinking water. The pollution of the water sources was partly attributed to direct agricultural activities in the catchment area, lack of toilet facilities, improper disposal of both human and solid wastes as well as poor sanitation around the sources of water. The result indicates that none of these water sources investigated qualify as a suitable direct source of drinking water. The study therefore recommends that the government in collaboration with the District Assembly provide clear guidelines and by-laws in the land use planning process to protect community drinking water sources, land use systems, and to ensure that water resource management is integrated at the local level to minimize pollution from agricultural and other anthropogenic activities. Further studies should be conducted to determine the long-term health effects of the microbial quality of the drinking water sources used by the study communities.

***Keywords:*** *bacteriological quality, sources of drinking water, selected communities, Akuapem south district, eastern region, Ghana*

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## 1. Introduction

Water is the second most important natural resource of life after air [1]. As a result, there is an increasing demand for water in various aspects of human life including industries, mining, hydropower generation, agriculture, recreation, environmental enhancement and particularly domestic consumption. The rapid increase of population and urbanization in the major urban and peri-urban areas in Ghana in the last few decades has increased the demand for water and has added a new dimension to the already precarious water pollution problems in most communities. The issue of clean water becoming a 'scarce commodity' is becoming more and more alarming due to the heavy anthropogenic effects that contaminate our water bodies each passing day [2]. The situation becomes more alarming when the source of water serves as the main drinking water for a large population [3].

Water pollution problems resulting from human activities such as mining, agriculture, improper waste disposal, and sanitary landfills are on the increase. Despite improved methods for sewage treatment, lakes, rivers, and

underground waters throughout the world are becoming increasingly polluted [4]. Water pollution has become very serious these days and flushing it down the sink' does not work in today's crowded world [5]. United Nations Report indicated that about one and half billion people lack access to potable water and a greater percentage of this number is in the remote and rural areas and urban slums [6]. Traditionally, these rural communities have relied mainly for their water supply needs on sources which range from dug-wells, ponds, dug-outs, streams and springs to rainwater harvesting from roofs [7]. According to WHO and UNICEF, the World is facing 'Silence emergency' as billion people struggle without clean water or basic sanitation [8]. Water scarcity situation is severe in developing countries, with an estimated 1.2 billion people in 20 "water-scarce" developing countries without access to "safe water" [9]. By the year 2020, up to 30 countries mainly in Africa and Asia would be in this group. The World Commission for Water (2000) estimates that more than 1 billion people in developing countries do not have access to clean water whilst 2 billion lack adequate sanitation. The Global Water Project (GWP) forecasts that six West African countries, including Ghana and Burkina Faso, may experience water scarcity by 2025 mainly due to the expected rate of growth in population [10].

In the case of Sub-Saharan Africa, Rosen and Vincent [11] estimated that about 67% of the rural population (about 250 million people) lack safe and accessible water supply whilst 81% do not have access to sanitation facilities. Estimates show that available water per capita has declined 50% in Africa [12].

The water situation in Ghana followed global trends. The current annual population growth rate of 2.7 % [13] suggests future increases in water demand. Already, water demand by the current population outstrips supply [14] and projected per capita renewable freshwater availability by 2025 will further decline. This observation is more devastating in the rural areas compared to the urban centers. Access to potable water has, therefore, become a common problem in most rural communities in Ghana [15].

The water situation in the study areas is not different from the aforementioned situations. The study communities-Adamrobe, Aburi, and Pokrom/Nsaba depend on streams, springs, boreholes, and wells as their sources of domestic water supply. A visual inspection of the study communities revealed that the people in each community generally share the same sources of drinking water. Increasing quantities of domestic wastes, sewage, and agro-chemicals are being discharged directly or indirectly to these water supply sources. The quality of these water sources continues to suffer from increased human activities including disposal of domestic wastes, sewage, and agro-chemicals directly or indirectly into these water sources [16]. The existing drinking water sources in the study communities are still unsafe. Yet, these communities continue to rely on them and the ultimate result of this is the persistent higher mortality and morbidity rates in these communities.

The need to identify the major human activities that are contributing to the poor water quality in these communities and suggest possible intervention measures to protect both life and the water resources cannot, therefore, be overemphasized. It is against this background that this study was conducted to assess the bacteriological status of the drinking water sources used by the study communities.

# 2. Materials and Method

## 2.1. Study Area Description

### 2.1.1. Akwapim South District

Figure 1 shows the Map of Akuapim South District and the three study communities. The study was undertaken in three communities namely Aburi, Pokrom and Adamrobe. These communities are located in the Akuapim South District of the Eastern Region. The population of Akwapim South District, according to the 2010 Population and Housing Census, is 37,501 representing 1.4 percent of the region's total population. Males constitute48.5 percent and females represent 51.5 percent. About three-quarters (73.4%) of the District's population lives in the rural areas, and has a sex ratio of 94 males to a hundred females [15]. About two-fifth (40.1%) of the population of the District is youthful (0-14 years) depicting a broad base population pyramid which tapers off with a small number of elderly persons (5.9%). The total age dependency ratio for the District is 76.7, and males have a higher dependency ratio of 81.6 compared to females who has a dependency ratio of 72.4. A little below half (48.2%) percent of households in the District are engage in agriculture. In the rural localities, five out of ten households (33.6%) are agricultural households while in the urban localities, 74.2 percent of households are into agriculture. Most households in the district (94.5%) are involved in crop farming. Poultry (chicken) is the dominant livestock reared in the district. Most households (65.8 %) in the Akwapim South District have their solid waste disposed of at the public dump, with 17.1 burned by the household. For liquid waste disposal, throwing waste onto compound (47.3%) and onto street / outside (24.9%) are the two most common methods used by households in the District [15].

### 2.1.2. Sampling Methods and Description

A reconnaissance survey was embarked upon between, 16-18 August, 2014 to establish the land-use and the type of of water sources used by most residents in the study area. Based on the survey, two sampling sites were identified in each community depending on the frequency of usage of the water sources by each community. At Aburi, the sampling water sources identified were hand dug wells and spring; at Pokrom / Nsaba, the water sources identified were stream and spring; and at Adamrobe, the water source identified was a stream (both upstream and downstream). These sites were chosen due to their ease of accessibility and also reflected different activities in the area, which affected the quality of the water. Table 1 shows the study communities, types of water sampled and a number of sampling sites.

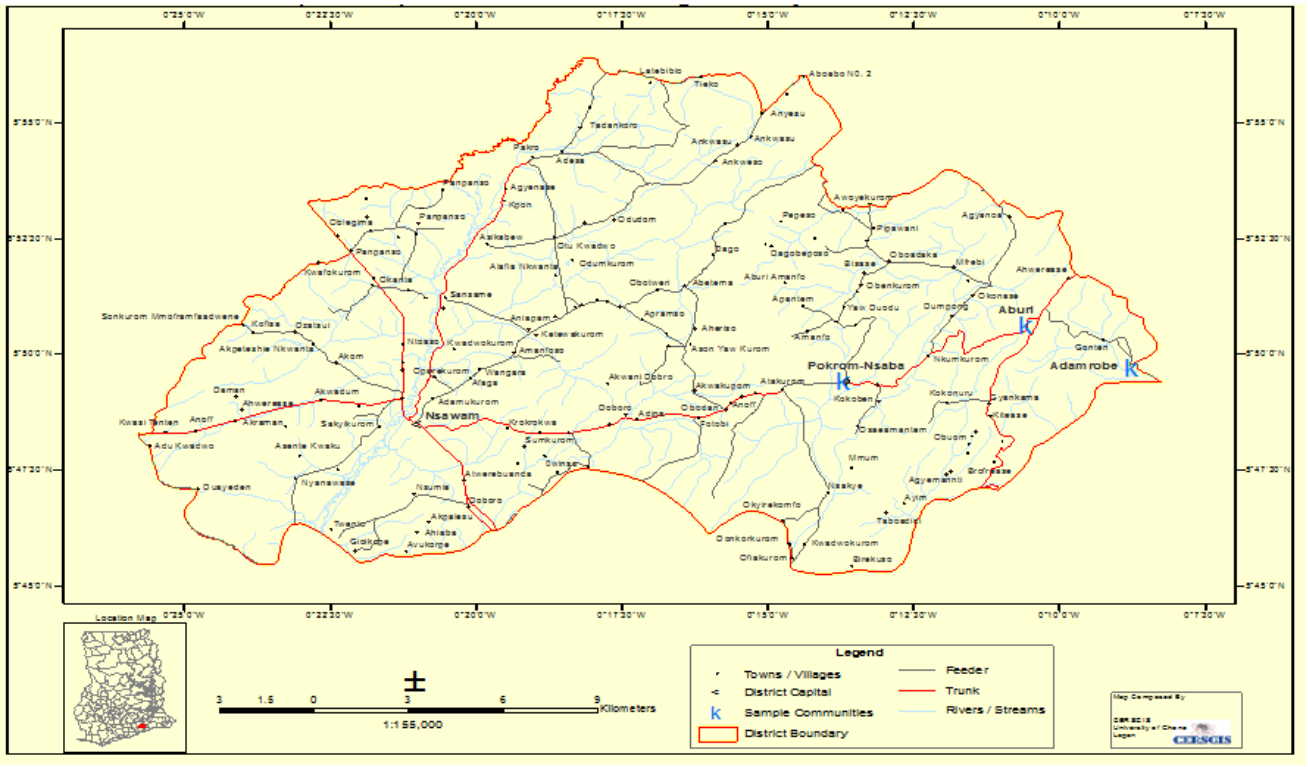


**Figure 1.** Map of study Area

**Table 1. Study communities, types of water resource and number of sites**

| Community | Types of Water Resource | Number of Sampling Sites |
|---|---|---|
| 1. Adamrobe | Stream (Upstream & Downstream) | 2 |
| 2. Aburi | Well & Spring | 2 |
| 3. Pokrom-Nsaba | Stream & Spring | 2 |

The following abbreviations were used to distinguish one sampling site from the other. Adamrobe upstream (AUST), Adamrobe downstream (ADST); Aburi well (ABW); Aburi spring (ABSP); Pokrom stream (POST) and Pokrom spring (POSP). Water Sampling was carried out within a period of twelve months beginning from September 2014 to August 2015, covering both dry and wet seasons. November–April and May–October constituted the dry and wet seasons respectively. Four water samples were collected from each sampling site each month. The geographical locations of the water sources were determined using global positioning satellite (GPS) device (Model, GARMIN etrex 20). Glass bottles with metal cap were used to collect the water sample. All glassware used for the sampling were sterilized in an autoclave at 160$^{o}$C for 1 hour and the mouth was covered with aluminum foil to avoid contamination during sampling. After collection the samples were stored on ice in an ice chest to avoid the multiplication of the bacteria. The bacteriological quality was analyzed using Membrane filtration technique. A membrane filter with 0.45µm pore size was sterilized in an incubator and used to filter 100ml of water mixed with 10ml of the sampled water. The membrane filter was lifted from the system with a sterilized forceps after filtration and carefully placed on the sterile media in petri dish. Escherichia coli/ coliform selective medium was used as the growth medium for the culture of the faecal and total coliforms. 2 ml of sterilized *E. coli*/ coliform selective media was poured on an absorptive pad placed in a petri dish. The petri dish was covered and incubated at 37 ℃ for total coliform and 44℃ for faecal coliforms for 24 hrs. After 24 hours the petri dishes were removed from the incubator and the colonies were counted using a colony counting chamber (Gallenkamp, UK) and recorded in coliform forming units per 100ml (CFU/100ml) [17].

For the enumeration of enterococci in water samples, Nine ml of Phosphate buffered saline (PBS) was added and transferred into a sterile test tube to make a $10^{-1}$ dilution. One milliliter of the sample was aseptically transferred from the$10^{-1}$ dilution into the second test tube ($10^{-2}$) with a sterile pipette and mixed. This was repeated until the test tube labeled $10^{-4}$ serial dilutions from $10^{-2}$ to $10^{-4}$ was obtained. With the aid of a pipette, one hundred microliters of each dilution was transferred into respective labeled and sterilized petri-dish. A plate count agar (PCA) was prepared according to the manufacturer's instruction and allowed to cool to about 45°C. 2 ml each of sterilized plate count agar (PCA) media was poured into their respective labelled Petri dish. The dishes were then thoroughly mixed to facilitate distribution of the sample throughout the medium. The Petri dish was covered and the plates were labeled, allowed to solidify, inverted and finally incubated at 37°C for 48 hours. After 48hours the petri dishes were removed from the incubator and the colonies were counted using a colony counting chamber (Gallenkamp, UK) and recorded in coliform forming units per 100ml (CFU / 100 ml). Plates showing counts between

30-300 a colony were selected and their total colony forming unit per 100ml was calculated by multiplying the count by the dilution factor [17];

#### 2.1.3. Quality Assurance

Proper quality assurance procedures and precautions were taken to ensure the reliability of the results. The samples were carefully handled to avoid any external influences that could interfere with the quality of the sample and contaminate it. Triplicate determination of the samples was made and the data was presented as means. Glasswares were properly cleaned; deionized water was used throughout the study. For validation of the analytical procedure, repeated analysis of the samples against internationally certified/standard reference material (SRM-1570) of National Institute of Standard and Technology were used. The precision was also calculated as a percentage relative standard deviation (%RSD) of replicate analysis of the prepared standard, and was found to be less than 7%.

**Statistical Analysis**

In this study, the experimental results obtained were statistically analyzed using SPSS version 23.The values were expressed as means which were obtained from a set of observations. The significance of the difference among the concentrations of bacteriological quality among the different sampling locations were assessed with one factor Analysis of Variance (ANOVA). A $p \leq 0.05$ was considered statistically significant.

## 3. Results and Discussion

### 3.1. Bacteriological Parameters

#### 3.1.1. Faecal Coliform (FC)

Faecal coliforms are the product of human faeces and their presence in water bodies indicates anthropogenic pollution from warm-blooded animals [18,19]. The FC counts recorded ranged between 0.00 cfu/100ml at ABW in January and 5.528 $\times 10^3$ cfu/100ml at AUST in September. The mean FC values registered during the study period are presented in Figure 2. The wet season's mean values varied from $3.4 \times 10^1$ cfu/100ml at ABSP to $1.267 \times 10^3$ cfu/100ml at AUST and that of the dry seasons ranged between $1.03 \times 10^2$ cfu/100ml at ABW and $1.205 \times 10^3$ cfu/100ml at ADST. Analysis of variance of the mean FC counts of the water samples from all the sampling sites indicated no significant difference between the wet and dry seasons at 95% confidence level ($p = 0.144$).

Point sources of water such as and protected springs represent a very significant proportion of the improved water supplies provided to communities in developing countries [9]. Such supplies are very common in rural areas and also represent a very significant proportion of the water supplies available and used for domestic purposes (including drinking) by low-income urban populations [20,21].

The higher mean FC counts recorded from ADST and AUST were attributed to inadequate sanitation facilities in the community which led to poor sanitation practices like open defecation, and improper disposal of solid waste. [22] have reported that poor sanitation system affects drinking water resources. Due to the shallow nature of the stream, people entered the water before fetching it. Containers brought from homes to fetch the water were also washed in the stream. Community members having farms and quarrying sites beyond the stream crossed the stream on foot before getting to their farms. Some carried their livestock along to graze as they work. These animals also passed through the stream. Direct washing and bathing into the stream were common practices among the community members especially those close to it. These cultural practices might have introduced faecal matter into the stream and thus augmented its microbial population load. Communities dotted along the bank of the stream at the upstream did not have any toilet facilities. They used the bush as places of convenience. These faecal matters are washed into the stream when it rained and carried downstream via the stream flow. Several authors in Europe and North America have reported that microbial pollution is driven by rainfall events [23,24,25,26]. This improper disposal of human excreta contributed to the increased faecal coliform counts observed at this sampling station. The downstream where most of the community members withdraw water was about 20 meters from the town. Due to its proximity, animals such as goats, sheep, fowls, and pigs visited the downstream to drink water. These activities contributed to the increased bacteriological load registered in the ADST. According to [27], human activities contribute a significant microbial load to rivers and their tributaries and this is more pronounced when the human fecal matter is involved [17]. Analysis of variance of the mean FC counts of the six sampling sites for the wet and dry seasons indicated a significant difference between sampling points ($p=0.010$. A Post Hoc Test conducted revealed that FC water samples collected from ABW, ABSP, POST, POSP were statistically different from that of ADST. Comparison of the FC loads of the various water sources used by the study communities indicated no significant difference between ABSP and POSP. ADST was, however, significantly different from the POST in FC loads ($p<0.05$). This difference was attributed to poor sanitation such as open defecation, indiscriminate disposal of solid wastes, poor cultural practices like stepping in the water before fetching, walking through the water and washing hands and feet in the water.

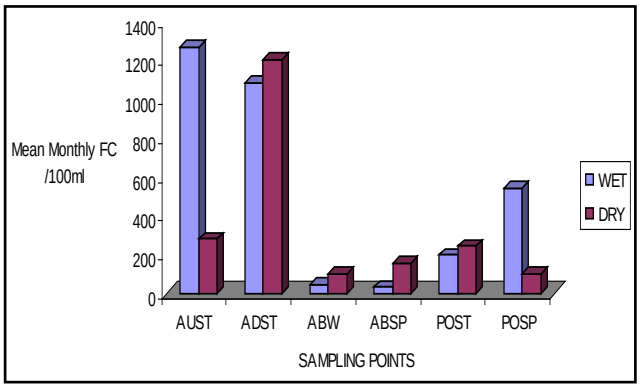


**Figure 2.** Mean faecal coliforms in water samples during wet and dry seasons

### 3.1.2. Total Coliform (TC)

The TC in the water samples collected from all the sampling points in the three communities during the dry season ranged between 15 cfu / 100ml at ABW and 4.189 × $10^3$ cfu / 100 ml at ABSP and that of the wet season varied from 0.00 cfu/100ml to 5.580 × $10^3$ cfu / 100 ml. The mean values for TC during the dry season ranged between a minimum of 4.41 × $10^2$ cfu / 100 ml at ABW and a maximum of 1.737 × $10^3$ cfu / 100 ml at ADST (Figure 3). The wet season's mean values also fluctuated between a minimum of 3.35 × $10^2$ cfu at ABSP and 2.764 × $10^3$ cfu at ADST. Though there were spatial variations in mean TC among the water samples from the water sources, Analysis of Variance of the mean TC counts of the water samples from all the sampling sites indicated no statistically significant difference between the wet and dry seasons (p = 0.069).

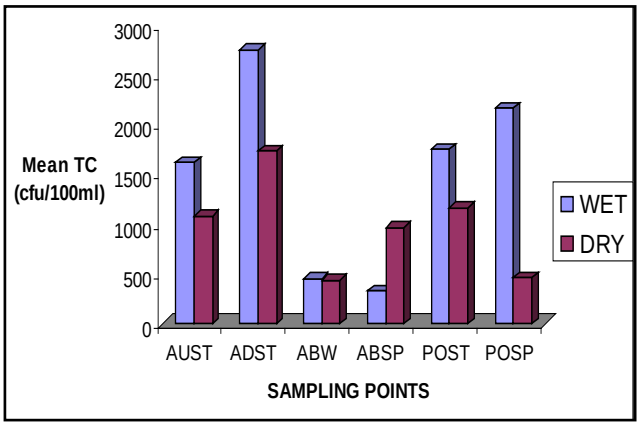


**Figure 3.** Mean total coliforms in water samples during wet and dry season

Comparatively, the wet season's mean values were higher than that of the dry season (Figure 3). This was attributed to runoffs from the stream's catchments areas carrying coliform laden materials such as sediments into the stream. [28] carried out a review of studies by some students at the KNUST on the quality of the streams and rivers passing through Kumasi. The results show that these water bodies were heavily polluted with very high levels of suspended solids and faecal coliform. This was attributed to human activities within the stream's catchments areas. The highest mean TC load recorded in ADST in the wet season was attributed to poor sanitation practices at the water sites. These included defecating in the bush close to the stream, washing, and bathing at the water site as well as seepage from the pit latrines constructed close to the streams. Comparison of the mean total coliform counts registered from the various water sources during the dry seasons indicated the following trends: ADST was significantly different from the POST ($p<0.05$). POSP, however, was not significantly different from ABSP ($p>0.05$). This suggested that similar environmental conditions prevailed in these sampling sites during the wet and dry seasons.

### 3.1.3. Enterococci

The mean indices of Enterococci species in the water samples collected from the various sampling sites during the study are shown in Figure 4.

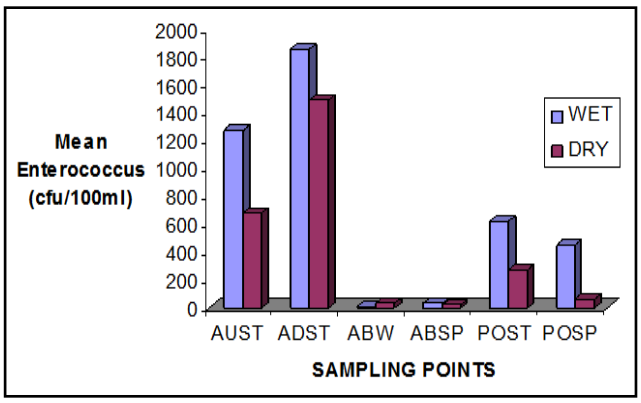


**Figure 4.** Mean levels of enterococci in water samples during wet and dry season

The highest mean values of Enterococci species for the dry season ranged between 7.0 × $10^2$ cfu / 100 ml) at AUST to 1.6 × $10^3$ cfu / 100 ml at ADST and that of the wet season varied from 1.3 × $10^3$ cfu / 100 ml at AUST to 1.848 × $10^3$ cfu / 100 ml ADST. Analysis of variance of the mean Enterococcus counts of the water samples from all the sampling sites indicated no significant difference between the wet and dry seasons (p = 0.072). The highest value recorded at ADST during the wet season was attributed to runoff carrying animal faecal matters from the banks of the stream and were deposited into the stream. These faecal matters originated from animals including fowls, goats sheep, pigs and dogs that visited the water to drink. This was a true reflection of the stream's proximity to the community. The distance between a pollution source and the water resource determines the levels of microbial and chemical pollution of the water resource [29]. The higher values recorded at ADST coincided with the onset of the rainy season suggesting that large bacterial population were in the substrate of the sampling sites and these were washed into the stream by runoffs.

Enteric organisms from grazing animals can enter a stream in runoff from the grazing lands, and animals with access to a stream have been shown to deposit a portion of their daily faecal matter directly therein [30]. Work undertaken recently in the Dargle catchment in Ireland has shown that human activities, especially in urban settlements, contribute a significant microbial load to the river and its tributaries [27]; importantly, the results suggested the involvement of human faecal sources.

The mean species of Enterococci obtained from water samples collected from ABW were comparatively low and this can be attributed to inaccessibility of animals to these water sources. The walls of the well were one meter above the ground. The higher wet season's mean values of Enterococci counts compared to the dry season suggested that bacteria-laden sediments were washed into the stream via runoff. The wet season values were comparatively higher than that of the dry season, suggesting that during the rainfall regime, microbial producing materials found their way into the water body via storm drains and run-offs. The sources of these microbes included the indiscriminate disposal of human excreta within the stream's catchments areas. Analysis of variance of the mean Enterococcus counts from the water samples for the wet and dry seasons indicated spatial variations between the sampling sites ($p<0.05$). A Post Hoc Test conducted

revealed that water samples collected from the AUST, ABW, ABSP, POST, and POSP during the wet and dry seasons were significantly different in Enterococci counts from that of ADST. This significant difference between ADST and the other sampling points was attributed to the drying of the ADST during the greater part of the dry season-January to May. This resulted from the clearing of the vegetation around the water source for farming and construction purposes. Deforestation is a major problem throughout Africa, although its causes and magnitude vary by region. Destruction of vegetation's has caused wells, springs, streams and even major rivers to cease flowing, at least during the dry seasons. Generally, tree roots soak up water in the wet periods and release it slowly and evenly during the dry season to keep water supplies adequately restored [31].

Generally, the streams recorded higher Enterococci bacteria counts than the springs and the well (Figure 4). This was due to the fact that the stream is a surface water and therefore prone to more pollutants via storm drains and runoffs compared to the springs and the well. Water bodies with zero Enterococci bacteria are safe for drinking [32]. In this respect, the water sources used by the study communities had Enterococci bacteria counts above the WHO guideline values and therefore may not be safe for drinking.

# 4. Conclusion and Recommendations

## 4.1. Conclusion

The mean concentrations of the microbial counts thus TC and enterococci analyzed in the water samples used by the three communities were all above the drinking water quality standard and therefore pose a serious health hazard to the communities. The pollution of the water sources was the direct result of agricultural activities being undertaken within the catchment areas of the water sources, lack of toilet facilities and landfill sites resulting in the improper disposal of both human and solid wastes and poor sanitation at the water sites. None of these water sources, therefore, qualified as a suitable direct source of drinking water.

## 4.2. Recommendations

Based on the findings of the study, the following are recommendations to offset any future impacts of human activities on the drinking water resources used by the study communities.

There is the need to increase the lateral separation between pollution sources in these communities and their sources of drinking water supply to reduce the risk of microbial contamination. It is, therefore, necessary that town committees / opinion leaders should provide the longest distance possible between water sources and the major potential anthropogenic sources of contamination available in the communities. People should be educated on the need to avoid washing and bathing near the water sources. Getting to know the effect of these unhygienic practices on the quality of the water will make them refrain from these activities. Open defaecation should not be allowed near community water sources, especially where the water is used as drinking water source. This is very crucial as there is the possibility of microbial organisms being carried into this water via storm drains and runoffs. It was obvious that agriculture is the largest contributor to water pollution caused by runoff in the study communities. The Government in collaboration with the District Assembly should, therefore, provide clear guidelines and by-laws in the land use planning process for the protection of community drinking water sources so that land and water resource management are integrated at the local level to minimize pollution from agricultural activities.

Geographic Information System (GIS) Department in conjunction with the Ghana Water Management Sector should identify all point and non-point sources of pollution in the study communities and develop strategies based on local initiatives to safeguard further pollution of community drinking water sources.

Finally, there is the need to undertake further study to cross-check the long-term health effects of human activities on drinking water sources in three studied communities. This study will provide the baseline data for effective monitoring and sound environmental management practices.

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