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CROSS-SEASONAL ANALYSIS OF BACTERIOLOGICAL PROFILE OF WATER SOURCES AS A DISEASE RISK MEASURE

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ABSTRACT

Water is a natural resource and is essential to sustain life. Poor drinking water quality is the cause of several diseases. The aim of this paper was to investigate bacteriological profile of water sources as a measure of disease risk, aimed at providing useful information towards rural water resources management. Five hundred and twenty bacterial isolates (520) were obtained from waters samples collected during the period of study. Majority of the Isolates (305) representing 58.65% of the total were obtained during the dry season, as against (205) representing 41.35% in the rainy season. There was a statistical differences ($P > 0.05$) of the microbes isolated seasonally. The highest occurring was *Klebsiella* spp. (9.83 ± 6.99 , $P > 0.05$) in the dry season and the least *Shigella* spp. $P > 0.05$. Furthermore dam water sources was observed to poses a high disease risk among the five water sources investigated, while borehole water sources possess a lower diseases risk. An alarming observation was the presences of bacteria of public health importance in the water sources. These included *Shigella* spp. (dysentery), *Salmonella typhi* (typhoid fever and acute diarrhoeal infection), *Salmonella typhi* (typhoid fever), and *Vibrio cholerea* (cholera). In a nutshell, to reduce the level of bacterial contamination of drinking water sources there should be an incessant education on issues such as: environmental awareness, (cultivation sanitation habits and ensure that their surroundings and water sources are not indiscriminately polluted), causes, modes of transmission and prevention of water and sanitation related diseases.

Key words: *E. coli*, water, Public health and disease

L'ANALYSE SAISONNIÈRE DU PROFIL BACTÉRIOLOGIQUE DES SOURCES D'EAU COMME UNE MESURE DU RISQUE DE MALADIES

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Résumé

l'eau est une ressource naturelle et indispensable à la vie. La mauvaise qualité de l'eau potable est la cause de plusieurs maladies. L'objectif de cet article était d'étudier le profil bactériologique des sources d'eau comme mesure de risque de maladie, visant à fournir des informations utiles à la gestion des ressources en eau en milieu rural. Cinq cent vingt (520) des isolats bactériens ont été obtenues à partir des échantillons des eaux recueillies au cours de la période d'étude. La majorité des isolats (305) représentant 58,65 % du total ont été obtenus pendant la saison sèche, contre (205) représentant 41,35 % dans la saison des pluies. Il y avait une différence statistique ($p > 0,05$) des microbes isolés en saison. Le plus haut lieu de *Klebsiella* spp. a été ($9,83 \pm 6,99$, $P > 0,05$) pendant la saison sèche et la moins *Shigella* spp. $P > 0,05$. De plus les sources d'eau du barrage a été observé à pose un risque de maladie élevé parmi les cinq sources d'eau d'une enquête, les sources d'eau forage whiles possèdent un plus faible risque de maladies.

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Un constat alarmant a été la présence de bactéries d'importance pour la santé publique dans les sources d'eau. Ceci inclus les *Shigella* spp. (La dysenterie), *Salmonella typhi* (la fièvre typhoïde et les infections diarrhéiques aiguës), *Salmonella typhi* (fièvre typhoïde) et *Vibrio cholerae* (choléra). En un mot, pour réduire le niveau de contamination bactérienne des sources d'eau potable il devrait y avoir une éducation incessante sur des questions telles que : sensibilisation à l'environnement, la culture et les habitudes d'assainissement (s'assurer que leur environnement et les sources d'eau ne sont pas pollués sans discernement), causes, modes de transmission et prévention des maladies liées à l'eau et l'assainissement.

Mots clés: E. coli, de l'eau, de la santé publique et de la maladie.

INTRODUCTION

Water is essential for survival. It has been stated that our existence is "intimately connected with the quality of water available to us. [1,2]. An adequate supply of safe drinking water is one of the major prerequisites for a healthy life. Waterborne disease is still a major cause of death in many parts of the world, particularly in children, and it is also a significant economic constraint in many subsistence economies. Waterborne diseases are as a result of contaminations: the presence of elevated concentrations of substances in the environment above the natural background level for the area and for the organism [3-5].

Drinking water is derived from two basic sources: surface water, such as rivers and reservoirs, and groundwater such as wells and boreholes. All water contains natural contaminants, particularly inorganic contaminants that arise from the geological strata through which the water flows and, to a varying extent, anthropogenic pollution by both microorganisms and chemicals. In general, groundwater is less vulnerable to pollution than surface waters [6]. There are a number of possible sources of man-made contaminants, some of which are more important than others. These fall into the categories of point and diffuse sources. For example a badly sited latrines and septic tanks are a significant source of contamination, especially of wells [7].

The most common and deadly pollutants in drinking water in developing countries are of biological origin [8]. WHO [9] states that the "infectious diseases caused by pathogenic bacteria, viruses and protozoa or by parasites are the most common and widespread health risk associated with drinking water". The use of such water for drinking, cooking, contact with it during washing, bathing, or even inhalation of its fine droplets as aerosols, may then result in infection. The minimum infectious dose [the smallest number of ingested pathogens necessary to cause disease) for the average healthy adult varies widely for various microorganisms. This dose ranges from just a few organisms of

Salmonella typhi to produce typhoid, several hundred organisms of *Shigella flexneri* to cause dysentery, several million cells of *Salmonella* serotype to cause gastroenteritis, to as many as a hundred million cells of *Vibrio cholerae* to produce cholera.

The minimum infectious dose also varies by the age, health, nutritional and immunological status of the exposed individual. As WHO notes, "Those at greatest risk of waterborne disease are infants and young children, people who are debilitated or living under insanitary conditions, the sick, and the elderly. For these people, infective doses are significantly lower than for the general adult population"[10]. The size of the minimum infectious dose does not directly translate into ease of prevention of the relevant disease [since concentrations of the pathogens in the water are variable, too). However, it does point to the reasonableness of the approach to minimize disease risk by defining a maximum allowable concentration of an indicator organism in drinking water.

The published studies in sub Saharan Africa reviewed by this current study, appears largely aimed at determining the microbial contamination of selected water sources. However, it is not known how the various water sources [both ground and surface waters) relate in terms of microbial distribution. Furthermore, most of these studies seldom investigated microbial status across seasons (wet and dry season). This is very much needed in tracking contamination sources as well as anthropogenic influences. Moreover, most of the studies had looked at the presence of microbes in the population, while providing little or no information on the routes by which these bacteria contaminates the water source. Furthermore, the diseases risk assessments of the various water sources were not carried out in most cases. The aim of this paper is to determine the bacteriological profile of bacteria flora in the drinking water sources as a measure of disease risk assessment.

METHODOLOGY

Sample Size and Sampling Frequency

Four hundred and sixty four (464) water samples were collected for the study. The sample collection period spanned the two seasons in Ghana: the dry and rainy seasons. Table 1 shows the details of water samples collection.

TABLE 1 WATER SAMPLE COLLECTION DETAILS

WATER SOURCE	WATER SAMPLE COLLECTION DETAILS		
	RAINING SEASON	DRY SEASON	TOTAL
Dams	60	60	120
Bore holes	32	32	64
Streams	68	68	136
Hand-dug wells	60	60	120
River	6	6	12
Canal	6	6	12
TOTAL			464

Prior to water sampling, important observations were made of sanitary conditions and possible sources of contamination, both anthropogenic and natural events that occur in the proximity of water bodies and are likely to influence water quality from all the sources sampled. For example, it was observed that in some places, refuse dumps, and places of convenience (toilets) were sited close to water bodies. In other cases, organic and inorganic waste as well as wastewater from various human activities had been disposed off near or into water bodies, which also served as sources of water for some communities.

The importance of accurate field records when conducting water sampling cannot be over emphasized. Recording site details and other environmental factors help when interpreting the sample results later on. Field notes including the following were therefore recorded: Date, Time of sampling, Water body type, Site code, etc.

The following environmental factors were also recorded: Water clarity/turbidity (visual clarity in the water i.e. leaves, debris, algae), Weather conditions (temperature, wind, rainfall), presence of animals (birds) and other comments (e.g. faecal accidents).

Water sample collection procedure

All water sampling and preservation procedures were performed according to Standard Methods for the examination of water and wastewater

(APHA, 1998; APHA, 1995), and WHO guidelines for drinking water quality (WHO, 1996, 1982). Sampling for bacteriological analysis was done aseptically with care, ensuring no external contamination of samples. In the process, sterilized plastic Polyethylene (PET) bottles were used. The bottles were cleaned and rinsed carefully, given a final rinse with distilled water and then sterilized at 121°C for 15 minutes. Sterilization effectiveness was checked by putting sterilization strips on each sampling bottle and glassware in each run.

During samples collection, enough air space was left in each sampling bottle (at least 3 cm) to aid thorough mixing by the electronic shaker prior to examination. Samples collected were representative of the water being tested.

Borehole water samples were taken from boreholes fitted with hand pumps. Before samples were taken, the pumps were continuously operated for about 5 minutes, after which the mouth of the borehole was cleaned with cotton wool soaked in 70% concentrated alcohol and then flamed for about 5 minutes. Water was again pumped out for a further 3 minutes to allow the metal to cool. Water samples were then collected by direct flow into sterilized bottles and carefully sealed. For hand-dug wells, a sterilized bottle was tied to a rope and lowered into the wells. The lid was first removed and the bottle lowered into the well to a depth of about 1m below the water surface. The bottle was removed and quickly covered. Immediately after collection, samples were placed in an insulated box (an ice chest) filled with ice cubes to keep the temperature below 4°C. Water samples from streams/river were also collected from depths of about 1m from the active part of the streams/river where people normally collected water for domestic purposes. Steps were taken at all times to avoid contamination using standard procedures. All other equipment used for the exercise was sterilized by autoclaving on the eve of each sampling day. All samples were transported to Noguchi Memorial Institute for Medical Research (NMIMR) of University of Ghana within 2 hours for analysis.

Bacteria isolation and identification

All gram-positive organism were identified by conventional methods, such as Gram reaction, positive catalase, Tube coagulase and Deoxyribonucleases (DNAse) test, Indole test, Methyl-red test, Voges-Proskauer test, Citrate utilization test, Triple sugar iron (TSI) agar test,

Motility test , Oxidase test etc, whiles an API 20E kit was used to identify the gram negative organism.

RESULTS

Figure 1 shows the distribution of gram-negative bacteria isolated during the rainy season. Dam water sources recorded the highest number of 57 gram-negative bacteria. This was followed by hand-dug wells with 43 gram-negative bacteria isolates.

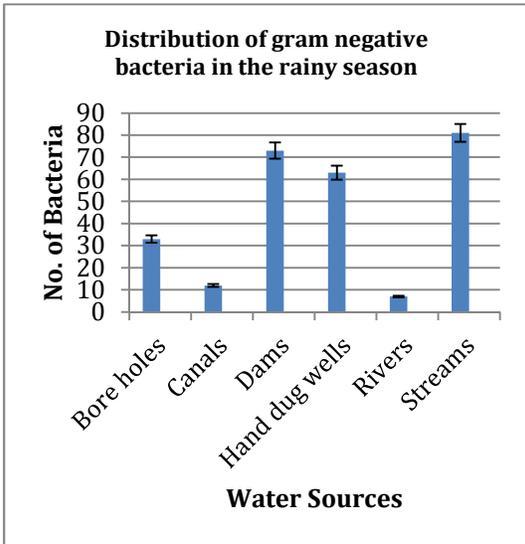


FIGURE 1: THE DISTRIBUTION OF GRAM-NEGATIVE BACTERIA ISOLATED IN THE RAINY SEASON

The least number of gram-negative bacteria isolates in the rainy season was obtained from river water sources with 12 isolates.

Figure 2. shows the distribution of gram-negative bacteria isolates during the dry season. Dam water sources recoded the highest (73) number of gram-negative bacteria isolates in the dry season. This was followed by Hand-dug wells with 63 isolates. The least number of isolates (7) was obtained from river water sources

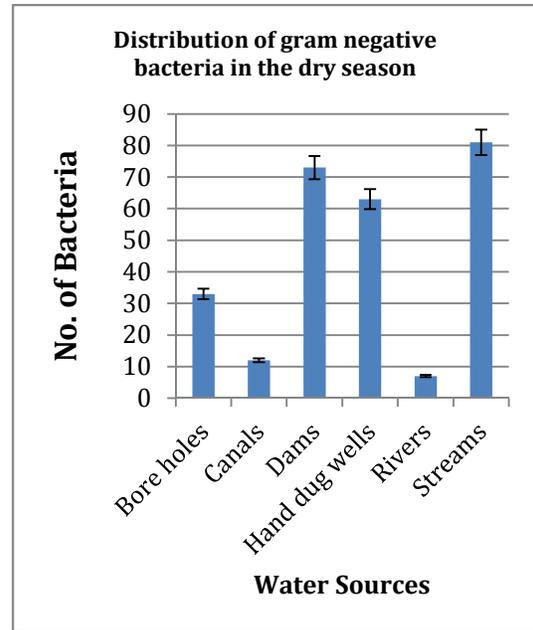


FIGURE 2: THE DISTRIBUTION OF GRAM-NEGATIVE BACTERIA ISOLATED IN THE DRY SEASON.

Figure 3 shows the distribution of gram-positive bacteria isolated during the rainy season. Stream water sources had the highest number (10) of gram-positive bacteria in the rainy season.

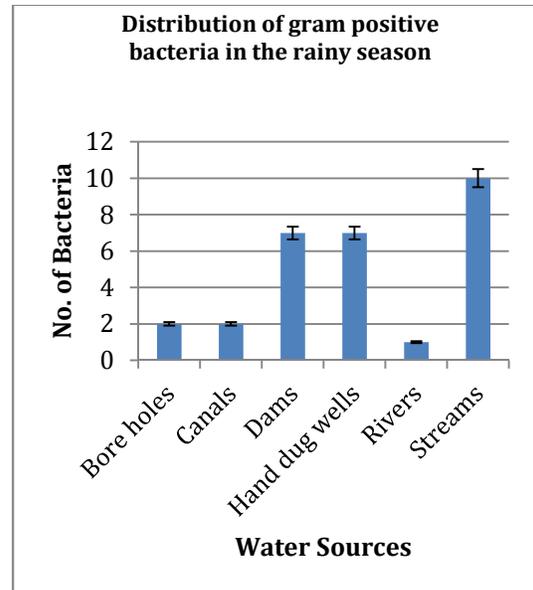


FIGURE 3: THE DISTRIBUTION OF GRAM-POSITIVE BACTERIA ISOLATED IN THE RAINY SEASON

his was followed by hand-dug wells and dam water sources with (7) bacteria isolate each. The least number (1) of gram-positive bacteria were obtained from river water sources.

Figure 4 shows the patterns of gram-positive bacteria isolated in the dry season. Hand-dug wells presented with the highest number (11) of bacteria. The second highest number (10) of gram-positive bacteria isolates in the dry season was observed in dam water sources. The least number (1) was recorded in river water sources.

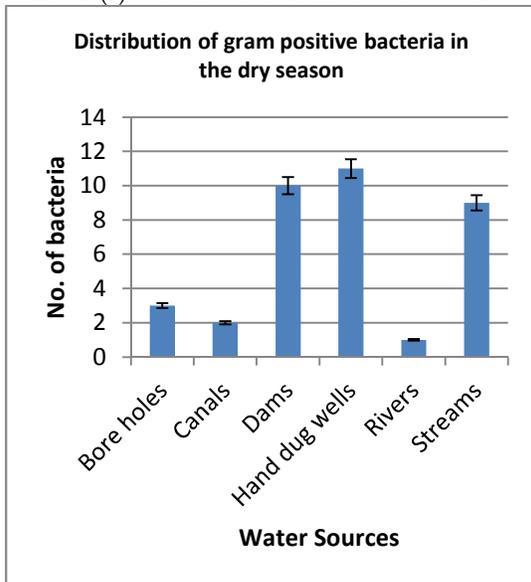


FIGURE 4: THE DISTRIBUTION OF GRAM-POSITIVE BACTERIA ISOLATED IN THE DRY SEASON

Generally, there were more gram-positive bacteria isolated in the dry season as compared to the rainy season.

Figure 5 shows the overall percentage distribution of bacteria isolated from the various water sources in terms of gram stain reactions. Five hundred and twenty (520) bacteria were isolated. Four hundred and fifty two (452) representing 87.5% were found to be gram negative; while sixty eight (68) representing 12.5% were gram positive.

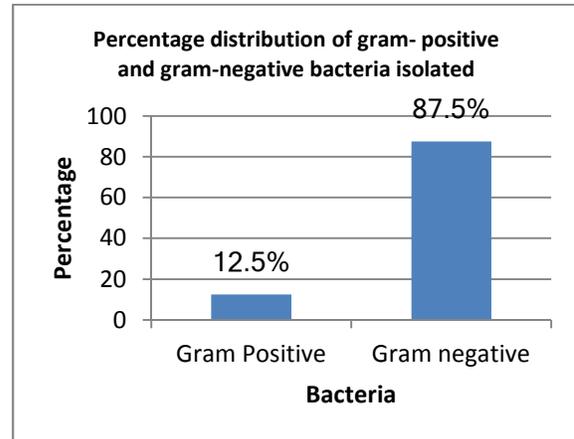


FIGURE 5: PERCENTAGE DISTRIBUTION OF GRAM-POSITIVE AND GRAM-NEGATIVE BACTERIA ISOLATES

Microbiological pathogens that are transmitted by the faecal-oral route, especially those originating from human feces are of particular concern for public health. Result from the bacteria isolation analysis (tables 2 and 3), indicates the presents of these oral-faecal pathogens in the various drinking water sources. Bacteria that cause faecal-oral infections include *Escherichia coli* (diarrhoeal infection or dysentery), *Shigella* spp. (dysentery), *Salmonella typhi* (typhoid fever and acute diarrhoeal infection), *Salmonella typhi* (typhoid fever), and *Vibrio cholerae* (cholera), were isolated.

Table 2 shows the numbers and distribution of bacteria isolated during the rainy season. The results show that 215 bacteria were isolated from the different water sources during the rainy season. *Klebsiella* spp. was the highest isolated bacteria (45) representing 20.9% of the total bacteria isolated. *E. coli* followed with 39 isolates representing 18.1% of the total isolates in the rainy season. This was followed by: *Pseudomonas auriginosa* (15.8%); *Enterobacter* spp. (14.0%); *Proteus vulgaris* (12.6%); *Enterococcus faecali* (910.7%); *Streptococcus* spp. (2.8%); *Salmonella typhi* (21.4%).

TABLE 2: DISTRIBUTION OF BACTERIA SPECIES ISOLATED FROM DIFFERENT WATER SOURCES IN THE RAINY SEASON

Type of Bacteria	Number of bacteria isolates from each water source						Total (%)
	Bore holes	Canals	Dams	Hand-dugwells	Rivers	Streams	
<i>E. coli</i>	4	3	12	10	0	10	39 (18.1)
<i>Enterobacter spp.</i>	2	1	11	8	0	8	30 (14.0)
<i>Klebsiella spp.</i>	4	3	12	10	1	15	45 (20.9)
<i>Salmonella typhi</i>	2	0	0	1	0	1	4 (1.9)
<i>Streptococcus spp.</i>	0	1	2	2	0	1	6 (2.8)
<i>Proteus vulgaris</i>	2	0	10	5	0	10	27 (12.6)
<i>Vibrio cholerae</i>	0	0	1	1	0	2	4 (1.9)
<i>Shigella spp.</i>	0	0	1	0	0	2	3 (1.4)
<i>Pseudomonas aeruginosa</i>	2	1	10	8	1	12	34 (15.8)
<i>Enterococcus faecalis</i>	2	1	5	5	1	9	23 (10.7)
	Total						215 (100)

The least isolated organism was *Vibrio cholerae* (1.9%) and *Shigella spp.* (1.4%). The three most significant bacteria isolates in terms of public health importance isolated during the rainy season were *E. coli*, *Vibrio cholerae* and *Shigella spp.* *E. coli* was isolated in all the water sources except river. *Vibrio cholerae* was isolated in two (2) water sources namely: streams, and dams, while *Shigella spp.* was isolated in streams, and dams water sources only. The highest occurring gram positive organism isolated was *Enterococcus faecalis* (23) representing 10.7% while that of gram negative organisms *Klebsiella spp.* (45) 20.9%. Generally, the patterns of bacteria isolated in the dry season (table 4.12) did not differ much from that observed in the rainy season. However,

the total bacteria isolated in the dry season were 305.

The highest occurring bacteria isolated during the dry season were *Klebsiella spp.* (59), accounting for 19% of the total bacteria isolates of 305. *E. coli* followed with (58) 19.3%, thus almost the same percentage as that of *Klebsiella spp.* The occurrences of the other bacteria were: *Pseudomonas aeruginosa* (15.4%); *Enterobacter spp.* (8.2.0%); *Proteus vulgaris* (13.4%); *Enterococcus faecalis* (9.10.7%); *Streptococcus spp* (2.8%); *Salmonella typhi* (21.4%). The least isolated organism was *Vibrio cholerae* (0.7%) and *Shigella spp.* (1.0%). *Vibrio cholerae* was isolated from bore hole and stream sources, whilst *Shigella spp.* were isolated from stream sources only.

TABLE 3: DISTRIBUTION OF BACTERIA SPECIES ISOLATED FROM DIFFERENT WATER SOURCES IN THE DRY SEASON

Bacteria	Number of bacteria isolates from each water source						Total (%)
	Bore holes	Canals	Dams	Hand-dug wells	Rivers	Streams	
<i>E. coli</i>	7	3	16	14	2	16	58 (19.0)
<i>Enterobacter spp.</i>	6	2	15	13	1	13	50 (16.4)
<i>Klebsiella spp.</i>	6	3	16	14	2	18	59 (19.3)
<i>Salmonella typhi</i>	2	1	2	2	0	2	9 (3.0)
<i>Streptococcus spp.</i>	0	0	7	3	0	1	11 (3.6)
<i>Proteus vulgaris</i>	5	1	12	9	0	14	41 (13.4)
<i>Vibrio cholerae</i>	1	0	0	0	0	1	2 (0.7)
<i>Shigella spp.</i>	0	0	0	0	0	3	3 (1.0)
<i>Pseudomonas aeruginosa</i>	6	2	12	11	2	14	47 (15.4)
<i>Enterococcus faecalis</i>	3	2	3	8	1	8	25 (8.2)
	Total						305 (100)

In summary, analysis of results from Tables 2 and 3 show that five hundred and twenty bacterial isolates (520) were obtained during the period of study. More of the Isolates (305) representing 58.65% of the total were obtained during the dry season, as against (205) representing 41.35% in the rainy season. The most commonly occurring organism in the water samples was *Klebsiella spp.* (20%). The next most occurring bacterial isolate after *Klebsiella spp.* was *E. coli* (18.7%) of the total bacterial Isolates. This was followed by: *Pseudomonas aeruginosa* (15.61%); *Enterobacter spp.* (15.4%); *Proteus vulgaris* (13.1%); *Enterococcus faecalis* (9.2%); *Streptococcus spp.* (3.1%); *Salmonella typhi* (2.4%). The least isolated organism was *Vibrio cholerae*

(1.2%) and *Shigella spp.* (1.2%). *Vibrio cholerae* was isolated in four (4) water sources namely: stream, borehole, hand-dug wells and dam water sources, while *Shigella spp.* was isolated in stream, borehole and dam water sources only.

Table 4 presents the statistical summary of the bacteria species isolated from different water sources. Generally there was a statistical differences ($P > 0.05$) of the microbes isolated seasonally. The highest occurring was *Klebsiella spp.* ($9.83 \square 6.99$, $P > 0.05$) in the dry season and the least *Shigella spp.* $P > 0.05$. negative; while sixty eight (68) representing 12.5 % were gram positive.

Bacteria	Rainy season				Dry season				P value
	Mean±SD	Min	Max	d.f	Mean±SD	Min	Max	d.f	
<i>E. coli</i>	6.5±4.81	0	10	5	9.67± 6.47	2	16	5	0.01
<i>Enterobacter spp.</i>	5±4.56	0	11	5	8.33±6.12	1	15	5	0.00
<i>Klebsiella spp.</i>	7.5±5.61	1	15	5	9.83±6.99	2	18	5	0.01
<i>Salmonella typhi</i>	0.67±0.82	0	2	5	1.5±0.84	0	2	5	0.02
<i>Streptococcus spp.</i>	1±0.89	0	2	5	1.83±2.79	0	3	5	0.20
<i>Proteus vulgaris</i>	4.5±4.64	0	10	5	6.83±5.78	0	14	5	0.01
<i>Vibrio cholerae</i>	0.67±0.82	0	2	5	0.33±0.52	0	1	5	0.20
<i>Shigella spp.</i>	0.5±0.84	0	2	5	0.5±1.23	0	3	5	0.50
<i>Pseudomonas aeruginosa</i>	5.67±4.93	1	12	5	7.83±5.23	2	14	5	0.00
<i>Enterococcus faecali</i>	3.83±3.13	1	9	5	4.16±3.06	1	8	5	0.33

TABLE 4: STATISTICAL SUMMARY OF BACTERIA SPECIES ISOLATED FROM DIFFERENT WATER SOURCES

SD= standard deviation, df= degree of freedom, Min= minimum, Max= maximum

Figure 6 shows the number of bacteria that was isolated from each water source across seasons. The highest number (70) of bacteria isolated in the rainy season was obtained from stream water sources. This was followed by dam water sources with 64 bacteria isolates.

The least number (3) of bacteria isolated was obtained from river sources. The highest number (90) of bacteria isolated in dry season was obtained from stream water sources. This was followed by dam water sources with 83 isolates. The least (3) num 155 bacteria isolated in the dry season was from river water sources. The highest number of bacteria isolated per water source across both the dry and

rainy season was 160 representing (21%) this was obtained from stream water sources. The least was 12 (2.1%) obtained from river water sources. Figure 7 shows the percentage distribution of coliform bacteria and non-coliform isolated from the various water sources. Coliform bacteria are generally lactose fermenters and belong to the family enterobacteriaceae. Out of the five hundred and twenty (520) bacteria isolated, three hundred (300) representing 57.7 % were found to be coliform bacteria; while two hundred and twenty (220) representing 42.3 % were non-coliform bacteria.

Percentages of coliform and non-coliform bacteria Isolated

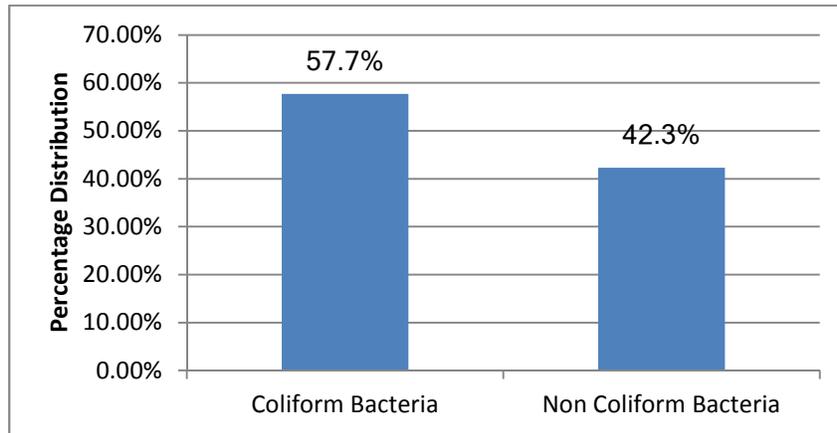


FIGURE 7: PERCENTAGE DISTRIBUTION OF COLIFORM AND NON-COLIFORM BACTERIA OBTAINED FROM WATER

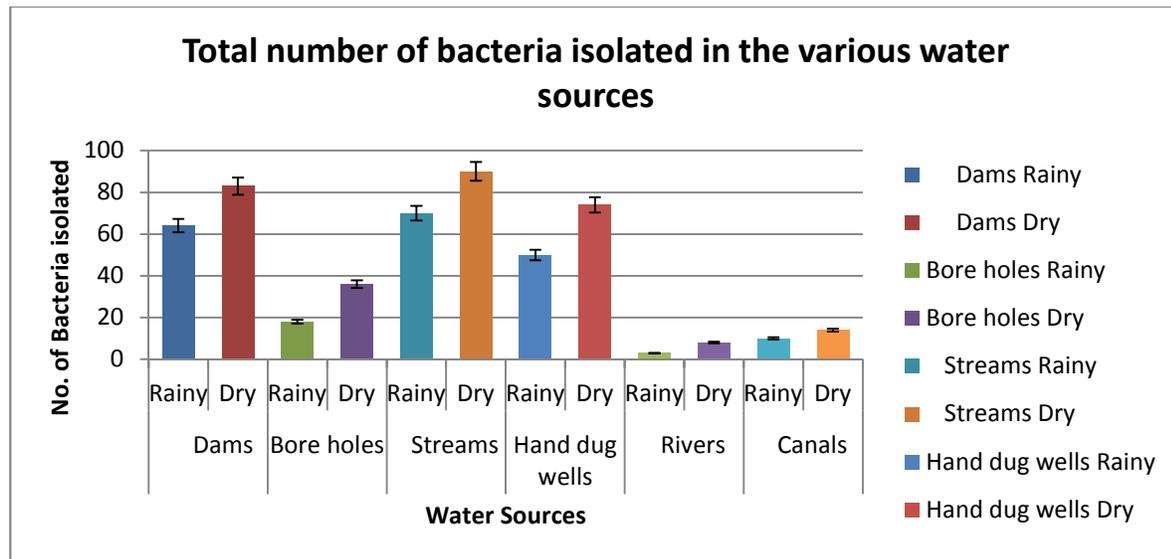


FIGURE 6: TOTAL NUMBER OF BACTERIA ISOLATED ACROSS SEASONS, PER WATER SOURCE

The coliform bacteria (tables 1 and 2) isolated included: *E. coli*, *Enterobacter spp*, *Klebsiella spp*, *Proteus vulgaris*, *Salmonella typhi*, and *Shigella spp*. The non-coliform bacteria isolated were: *Streptococcus spp*, *Vibrio cholera*, *Pseudomonas aeruginosa*, and *Enterococcus faecalis*.

DISCUSSION

There is increasing recognition that continual surveillance has a legitimate place in the consideration of options for water quality management. This is because they are sensitive indicators of changes or deterioration in overall water quality, providing a useful addition to physical, chemical and biological information. The effects of

the high bacteriological contaminants in the drinking water sources are cause for concern. They could trigger outbreaks of epidemics and isolated water borne diseases in the very near future if measures are not taken to get the water decontaminated before consumption.

In the bacteriological analysis of the water sources, the study found that there are significantly high counts in total coliforms, faecal coliforms, and *E. coli* across seasons but specifically higher in the dry season as against the rainy season. This was observed despite, run-off, and heavy rain during the rainy season. Second, was the observation of a correlation between faecal coliform and total coliform counts in

the dry season and the rainy season.

What could account for the high *E. coli* counts observed in the water sources? Human activities as well as faecal discharges from animals may be major contributing factors. However the relative importance of specific animals as contributors to the high faecal coliform numbers observed here is difficult to assess with confidence and was not formally examined in this study. However, it is probably related to factors such as animal population density and utilization of the territory adjacent to the sample sites.

However, some observations in the district suggest the reasons for human faecal contaminations of the waters sources. For example, lack of proper and permanent disposal sites for both solid and liquid wastes in the district may result in the use of streams as receptacles for these untreated wastes. In addition, some residents resort to insanitary practices such as defecating or urinating into open space, gutters which ultimately find their way into bodies of water. Furthermore, the groundwater (wells) did not have proper physical barriers. For example the wells were observed to have missing covers, lockable sanitary lids and well linings, which could prevent overland runoff containing human, animals and domestic wastes from contaminating the water sources. This could account for the detection of bacteria of faecal origin in groundwater in the study area.

WHO [15] reported that groundwater is less vulnerable to contamination due to the barrier effect, and that once the protective barrier is breached direct contamination may occur. In the cases of boreholes, Chapman [16] noted that due to the relatively slow movement of water through the ground, once polluted, a groundwater body could remain so for decades, or even centuries.

Another interesting and important observation of this study was the apparent predominance of *Klebsiella* spp. (Table 3). *Klebsiella pneumoniae* is a rod shaped non-motile, gram negative, lactose fermenting and facultative anaerobic bacterium, which are usually found in the normal flora of skin, mouth, and intestines. *Klebsiella* spp. is responsible for pneumonia (the destructive lung inflammation disease). Besides *Klebsiella* is found to cause infections in the urinary and lower biliary tract [17,18]. *Klebsiella* is an opportunistic pathogen that primarily attacks immune-compromised individuals and hospitalized patients [19]. The predominance of *Klebsiella* spp. as opposed to *E. coli* is because *Klebsiella* spp. can survive and remain physiologically active under diverse environmental conditions under which they are exposed [20]. Second, they multiply to high numbers

in waters rich in nutrients, such as pulp mill wastes, etc. The environmental condition of the water sources in the area under study therefore made it conducive for their growth and survival than *E. coli*. Earlier works done though inconclusive appears to support the observation in the current study [21].

Furthermore dam water sources was observed to poses a high disease risk among the five water sources investigated, while borehole water sources possess a lower diseases low risk. Even much more alarming was the observation of the presence of bacteria of public health importance in the water 158 . These included *Shigella* spp. (dysentery), *Salmonella typhi* (typhoid fever and acute diarrhoeal infection), *Salmonella typhi* (typhoid fever), and *Vibrio cholerae* (cholera).

The various observation made above led to the conclusion that majority of the water sources used for drinking and domestic purposes in the study area are usually highly contaminated with faecal coliforms above the recommended standards (WHO, GSA) for drinking water. Both animals and humans are the possible sources of faecal bacteria contamination of the drinking water sources. Most of the faecal coliform isolates identified are opportunistic pathogens capable of causing infection and disease.

The implication and importance of this finding is momentous and cannot be overemphasized. Findings from this study indicate that rural folks residing in the Dangme West District of Ghana are at high risk and are highly vulnerable to waterborne diseases resulting from the presence of pathogenic bacteria in the water. This results from several activities, which include increased pollution from various human activities.

Cyclic assessment of the quality of water available to the rural communities may not only be deemed expedient but also fitting. Since many rural people usually rely chiefly on untreated water sources, the presence of coliform bacteria in all the water bodies then calls for concern from the government, corporate bodies as well as the council of elders of the respective communities involved in rural water provision. Taking into account the socio-economic significance of access to safe and potable water, it may be deemed necessary to consider all the water sources for rural communities rather than concentrating on only a single source such as boreholes which may not only serve a handful of the residents but also be accompanied by high drilling costs.

In a nutshell, to reduce the level of bacterial contamination of drinking water sources there should

be an incessant education on issues such as: environmental awareness, (cultivation sanitation habits and ensure that their surroundings and water sources are not indiscriminately polluted), causes, modes of transmission and prevention of water and sanitation related diseases. Furthermore, education on

modes of storing water in proper storing facilities, proper handling of stored water, the treatment of collected water and hand-washing, etc. to help reduce the consumption of contaminated water should be done.

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