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MICROBIOLOGICAL QUALITY OF WATER SOURCES FROM THE LARGEST DISTRICT IN GREATER-ACCRA REGION, GHANA: A CALL FOR INNOVATIONAL SCHEMES TOWARDS RURAL WATER RESOURCES MANAGEMENT

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Abstract: Water is an essential requirement for all forms of life and needs protection from pollution which otherwise poses a threat to human life. Poor drinking water quality is the cause of several diseases of man. In rural areas of developing countries, the great majority of health-related water quality problems are the result of bacteriological contamination. The aim of this paper was to evaluate microbiological quality of water sources from the Dangme west district in Ghana, with the aim of providing useful information towards rural water resources management. Total of one hundred and twenty two (122) water samples were collected for assessment between June, 2011 and May, 2012.

The sample collection period spanned over the dry and raining seasons. Total and faecal coliform count for the water samples were as follows: dams ranged from 140MPN/100ml to >2400 MPN/100ml; bore holes ranged from 0 MPN/100ml to 33MPN/; Hand dug wells ranged from 0/100ml to 79 MPN/100ml; river ranged from 920/100ml to >2400MPN/; canal ranged from140/100ml to 1600 MPN/100ml. The rainy season samplings (778.27) were significantly different ($P < 0.05$) from the dry season collections (697.92). Among the water sources, significant differences ($P < 0.05$) were observed, dam recorded the highest total counts (1405.77) was significantly different ($P < 0.05$) from all the other water sources, followed by that of river (1393.73) which was also significantly different from ($P < 0.05$) carnal (989.62). Faecal coliform of rainy season isolates (671.80) were significantly different ($P < 0.05$) from the dry season isolates (481.91). Correspondingly, analyses from the different water sources significantly differed ($P < 0.05$) from one another. Canal recorded the highest faecal coliform count (1330.93), which was significantly different ($P < 0.05$) from dam (932.89), followed by stream (922.90), which was also significantly different ($P < 0.05$) from river (245.97). Borehole which recorded the least faecal coliform counts (9.91) was also significantly different ($P < 0.05$) from that of hand dug well (18.55). There was more bacteria growth (59) from water samples in the dry season than rainy (56) season. Stream samples had highest bacteria growth of 17, followed by dams (15). The least bacteria growth was recorded from rivers and canals, where a growth of three (3) was recorded for each. The most of water

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samples had high total and faecal account above the WHO standard of 0 MPN/100 for drinking water.
Keywords: Water sources, Microbiological quality, Innovational schemes, Rural water management, Ghana.

Introduction

Water is a natural resource and is essential to sustain life. Accessibility and availability of fresh clean water does not only play a crucial role in economic development and social welfare, but also it is an essential element in health, food production and poverty reduction (Ashbolt et al., 2001). However, safe drinking water remains inaccessible for about 1.1 billion people worldwide and the hourly toll from biological contamination of drinking water is 400 deaths of children below the age five (Gadgil, 1998). Water helps maintain the moisture of internal organs of the body (Gerald, 2011); maintains normal volume and consistency of fluids such as blood and lymph (Dooge, 2001) regulates body temperature; removes poisons or toxins from the body through urine, sweat and breathing (WMI, 2007) and is essential for regulating the normal structure and functions of the skin (Burton et al., 9187). The body loses about four liters of water every day (Gerald, 2011). It is therefore necessary to replenish this volume by drinking at least the equivalent amount of quality water every day. In developing countries with deteriorating environments, the demand for clean drinking water supply is growing rapidly in recent times (Gelover et al., 2006). In Ghana, the supply of piped water is inadequate in most communities. This inadequacy is both in quantity and quality of public water supply. Only 40% of the total urban population has direct access to piped water. On the whole, only about 10.3 million people (approx. 51% of the population) are reported to have improved water supplies (Allafrica, 2013).

Those who do not have access to safe water, as well as those who have access but cannot afford, rely on other sources of water with questionable quality (Addo et al., 2009). However, the potential of drinking water to transport microbial pathogens to great number of people, causing subsequent illness is well documented in countries at all levels of economic development (Payment, 1997, Dufour et al., 2011). It is well known fact that, most sporadic cases of water borne intestinal illness will not be detected or if detected, may not be recognized as water related (Issac-Renton, 1996). Several researchers have attempted to estimate the total burden of water borne diseases worldwide. Water borne disease might account for one-third of the intestinal infections world-wide (Hunter, 1997), while it is estimated that water, sanitation and hygiene are responsible for 40% of all deaths and 5.7% of

the total disease burden occurring worldwide (Pruss et al., 2002). Human, livestock and wild animals are all sources of faecal contamination; in general, human faecal waste gives rise to the highest risk of water borne diseases (Craun, 1996). A wide spectrum of pathogenic agents can be found in water and monitoring for their presence on a routine basis is impractical. Traditionally, microbial safety of drinking water has been confirmed by monitoring for absence of microorganisms of faeces origin (Le-Chavallier and Au, 2004). The aim of this study was therefore to determine the bacteriological quality of water available to rural communities in Ghana, with the view to providing information useful to policy planers towards rural water resources management.

Materials and methods

Demarcation of the study area

The Dangbe West District is situated in the Southeastern part of Ghana, lying between latitude 5°45' south and 6° 05' North and Longitude 0°05' East and 0°20' West. The District has a total land area of 1,442 square kilometers, making it the largest in the Greater Accra Region. The land size represents 41.5% of the regional land. The Dangme west was selected because its characteristics represent most rural communities in Ghana.

Sample collection sites

After several preliminary visits to various communities in the districts, 57 sampling sites comprising 6 different water sources that include dams, boreholes, stream sources, rivers, canals and hand-dug wells in 27 communities were selected. Samples were taken from locations that were representative of the water sources and/or distribution networks at which water is delivered to the inhabitants and/or points of use based primarily on factors such as population and extent of usage or level of patronage of water from these sources. Farmers dominate most of the communities. Each community selected had at least a borehole or a stream as the principal sources of water for the inhabitants.

In selecting the sampling points, each locality was considered individually; however, the sampling points were selected such that the samples taken were representative of the different sources from which the community obtains water. These points included those that yielded samples representative of the conditions at the most unfavorable sources or places in the supply system, particularly, points of possible contamination.

Site Observation Details

Prior to water sampling, important observations were made of sanitary conditions and

possible sources of contamination, both anthropogenic and natural that occur in the proximity of water bodies and/or 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. Field records for 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/ducks). Other comments (e.g. system problems i.e. disinfection/filtration equipment, faecal accidents)

Sample size and sampling frequency

Total of one hundred and twenty two (122) water samples were collected for assessment between June, 2011 and May, 2012. The sample collection period spanned over the two seasons in Ghana i.e. the dry and raining seasons. 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. All samples were transported to the laboratory within 2 hours.

Total and fecal Coliform count

The total coliform count (TC) and the Feacal coliform count (FC) were determined using, the Most Probable Number (MPN) Method. MacConkey Broth inoculums were incubated at 37^{O}C and 44 ^{O}C for total coliform count (TC) and Feacal coliform count (FC) respectively and recoded as MPN/100ml. Ten millilitres (10ml) of sample was measured with a sterile 10ml disposable pipette (Sarstedt) and aseptically dispensed into each of the five tubes containing 10ml of double strength purple MacConkey broth (Oxoid CM5a) each with an inverted Durham tube. One milliliter of the same sample was dispensed into five tubes and 0.1ml also dispensed into another five tubes all containing the single strength purple MacConkey broth. The tubes were closed tightly and then shaken to distribute the sample uniformly throughout the medium and then incubated at 37^{O}C and 44^{O}C. The procedure was carried out in a clean-lighted flow hood. The chamber was always disinfected with 70% alcohol before and after the analysis. After 24-48 hours, Growth in the medium was confirmed by visible turbidity and a colour change, gas and acid formation. The

corresponding Most Probable Number (MPN) index was then determined from the probability table (McCrady).

Results

Table 1. Total and fecal coliform count (MPN/100ml) of water samples from dams

Sample number	Rainy season		Dry season	
	Total count	Faecal count	Total count	Faecal count
D1	>2400	>2400	>2400	>2400
D2	920	540	1600	920
D3	540	180	920	220
D4	540	140	540	140
D5	920	540	>2400	920
D6	920	920	1600	920
D7	920	280	920	280
D8	920	350	>2400	920
D9	>2400	1600	>2400	1600
D10	920	920	920	920
D11	1600	540	1600	920
D12	920	920	1600	1600
D13	>2400	1600	>2400	1600
D14	540	220	1600	1600
D15	920	920	1600	920
WHO standards	0	0	0	0

Source: Fieldwork

Total and faecal coliform count for samples from dam water sources is presented in table 1. Total of fifteen (15) different well samples were analyzed. The total count for the rainy season ranged from 540 MPN/100ml to >2400 MPN/100ml. Samples number D1, D9, and D13 had the highest record of count of>2400 MPN/100ml. Samples numbers D3, D4, and D 14 recorded the lowest count of 540 MPN/100ml. The faecal count for the rainy season ranges from 140MPN/100ml to >2400 MPN/100ml. Samples number D1, had the highest record of count of >2400 MPN/100ml. This was followed by D9 and D13 each with a faecal

count of 1600 MPN/100ml. Sample number D4, had the lowest count of 140MPN/100ml, followed by samples D3 with a faecal count of 180 MPN/100ml.The total count for the dry season ranges from 540 MPN/100ml to >2400 MPN/100ml. Samples number D1, D5, D8 and D13 had the highest record of count of>2400 MPN/100ml. Samples numbers D4, recorded the lowest count of 540 MPN/100ml. The faecal count for the dry season ranges from >2400MPN/100ml to 140 MPN/100ml. Samples number D1, had the highest record of faecal count of>2400 MPN/100ml. This was followed by D9, D12, D13, and D14 each with a faecal count of 1600 MPN/100ml. Sample number D4, had the lowest faecal count of 140MPN/100ml and followed by samples D3 with a faecal count of 220 MPN/100 ml. In general, both total and faecal counts were generally low during the rainy reason.

Table 2. Total and fecal coliform count (MPN/100ml) of water samples from bore holes

Sample number	Rainy season		Dry season	
	Total count	Faecal count	Total count	Faecal count
B1	0	0	4	2
B 2	12	2	17	2
B 3	11	5	26	7
B 4	0	0	2	0
B 5	12	7	33	12
B 6	17	5	22	5
B 7	0	0	0	0
B 8	17	6	21	6
WHO standards	0	0	0	0

Source: Fieldwork

Total and faecal coliform count for samples from bore holes water sources is presented in table 2. A total eight (8) different bore hole samples were analyzed The total count for the rainy season ranges from 0 MPN/100ml to 17 MPN/100ml. Samples number B6, and B17 had the highest record of count of 17 MPN/100ml. Samples numbers B1and B2 recorded the counts of 0MPN/100ml. The faecal count for the rainy season ranges from 0/100ml to 7 MPN/100ml. Samples number B5, had the highest record of count of 7MPN/100ml. Sample

numbers B1 and B7 had 0 MPN/100ml, counts. The total count for the dry season ranges from 0MPN/100ml to 33 MPN/100ml. Samples number B5, had the highest record of count of 33 MPN/100ml. Samples numbers B7, recorded count of 0 MPN/100ml.The faecal count for the dry season ranges from 0MPN/100ml to 12 MPN/100ml. Samples number B5, had the highest record of faecal count of 22 MPN/100ml. This was followed by sample B3, faecal count of 7 MPN/100ml. Sample numbers B4 and B7, faecal count of 0/100m followed by samples B1 and B2 with a faecal count of 2 MPN/100ml each.

Table 3. Total and fecal coliform count (MPN/100ml) of water samples from streams

Sample number	Rainy season		Dry season	
	Total count	Faecal count	Total count	Faecal count
S1	920	440	>2400	920
S 2	920	220	1600	220
S 3	540	140	920	140
S 4	540	94	920	140
S 5	540	220	1600	920
S 6	350	94	540	350
S 7	920	140	920	280
S 8	540	220	1600	920
S 9	920	220	1600	540
S 10	540	220	920	350
S 11	540	220	540	220
S 12	920	350	1600	350
S 13	1600	920	1600	540
S 14	540	140	540	180
S 15	1600	920	1600	920
S16	>2400	350	>2400	540
S17	1600	350	1600	920
WHO standards	0	0	0	0

Source: Fieldwork

Total and faecal coliform count for samples from steam water sources is presented in table 3. A total seventeen (17) different stream water samples were analyzed The total count for the

rainy season ranges from >2400MPN/100ml to 350 MPN/100ml. Samples number s16, had the highest record of count of >2400 MPN/100ml. this was followed by Samples numbers S13 and S15 with counts of 1600MPN/100ml each. Sample number S6 had the lowest count of 350MPN/100ml. The faecal count for the rainy season ranges from 94 MPN/100ml to 920MPN/100ml. Samples number s13, and S16, had the highest recorded count of 920MPN/100ml each. Sample numbers S4 and S6 had the lowest rainy season faecal count of 94/100ml. The total count for the dry season ranges from 540 MPN/100ml to >2400 MPN/100ml. Samples number S1 and S16 had the highest record of count of>2400 MPN/100ml. Samples numbers S6, S11 and S14, recorded the lowest count of 540 MPN/100ml for each. The faecal count for the dry season ranges from 920MPN/100ml to 140 MPN/100ml. Samples number S1, S5, S8, 1S15 and S17, had the highest record of faecal count of 920 MPN/100ml. This was followed by S9, S13 and S16, each with a faecal count of 540 MPN/100ml. Sample number S3 and S4, had the lowest faecal count of 140MPN/100ml, followed by samples S11 with a faecal count of 220 MPN/100ml.

Table 4. Total and fecal coliform count (MPN/100ml) of water samples from hand dug wells

Sample number	Rainy season		Dry season	
	Total count	Faecal count	Total count	Faecal count
H1	12	0	17	2
H 2	14	2	21	2
H 3	17	2	26	7
H 4	0	0	0	0
H 5	26	2	43	6
H 6	22	5	49	5
H 7	14	0	33	0
H 8	17	2	21	6
H 9	12	2	79	2
H 10	17	2	70	2
H 11	26	4	26	7
H 12	0	0	21	0
H 13	22	4	33	12
H 14	17	5	22	5

H15	26	2	33	6
WHO standards	0	0	0	0

Source: Fieldwork

Total and faecal coliform count for samples from hand dug well water is presented in table 4. A total of fifteen (15) different hand dug water samples were analyzed. The total count for the rainy season ranges from 0/100ml to 26 MPN/100ml. Samples number H5, H11 and H15, had the highest recorded of count of 26 MPN/100ml each. This was followed by Samples numbers H6 and SH13 with counts of 22MPN/100ml each. Sample number H12 and H4 had count of 0MPN/100ml. The faecal count for the rainy season ranges from 0 MPN/100ml to 5MPN/100ml. Samples number H6 and H 17 had the highest recorded count of 5MPN/100ml each. Sample numbers H1, H4, H7, and H12 all had rainy season faecal count of 0MPN/100ml. The total count for the dry season ranges from 0 MPN/100ml to 79 MPN/100ml. Samples number H9 had the highest recorded faecal count in the dry season of 79MPN/100ml. this was followed by sample number H10 with a count of 70MPN/100ml. Samples numbers H4 had a count of 0MPN/100ml. The faecal count for the dry season ranges from 0MPN/100ml to 12 MPN/100ml. Samples number H4, H7 and H12 had a count of 0MPN/100ml. This was followed by H1, H2, H9 and H10, each with a faecal count of 2 MPN/100ml.

Table 5. Total and fecal coliform count (MPN/100ml) of river water sources

Sample number	Rainy season		Dry season	
	Total count	Faecal count	Total count	Faecal count
R1	920	140	1600	140
R 2	920	180	920	240
R 3	1600	240	>2400	540
WHO standards	0	0	0	0

Source: Fieldwork

Total and faecal coliform count for samples from river water is presented in table 5. A total of three (3) different river water samples were analyzed The total count for the rainy season ranges from 920/100ml to 1600 MPN/100ml. Sample number, R3 had the highest recorded of

count of 1600 MPN/100ml each. This was followed by Samples numbers R1 and R2 with counts of 1600MPN/100ml each. The faecal count for the rainy season ranges from 140 MPN/100ml to 240MPN/100ml. Samples number R3 had the highest count of 240MPN/100 ml, whiles samples numbers R1 and R2 had counts of 140MPN/100ml and 180MPN/100ml respectively. The total count for the dry season ranges from140 MPN/100ml to 540 MPN/100ml. Samples number R1 had the highest recorded count in the dry season of > 2400MPN/100ml. Numbers R1 and R2 counts of 1600MPN/100ml and 920MPN/100ml followed this respectively. The faecal count for the dry season ranges from 140MPN/100ml and 240 MPN/100ml respectively.

Table 6. Total and fecal coliform count (MPN/100ml) of canal water sources

Sample number	Rainy season		Dry season	
	Total count	Faecal count	Total count	Faecal count
C1	1600	350	>2400	920
C 2	920	540	920	540
C 3	1600	920	1600	1600
WHO standards	0	0	0	0

Source: Fieldwork

Total and faecal coliform count for samples from canal water is presented in table 6. A total of three (3) different canal water samples were analyzed. The total count for the rainy season ranges from 920/100ml to 1600 MPN/100ml. Sample number, C3 and C1 had the highest recorded of count of 1600 MPN/100ml each. This was followed by Sample number C21 with count of 920 MPN/100ml each. The faecal count for the rainy season ranges from 350 MPN/100ml to 920 MPN/100ml. Samples number C1 had the highest count of >2400MPN/100ml; whiles sample numbers C2 and C3 had counts of 1920MPN/100ml and 1600MPN/100ml respectively. The faecal count for the dry season ranges from 540MPN/100ml to 1600 MPN/100ml. Samples number C3 had the highest recorded count in the dry season of >1600MPN/100ml. sample numbers C1 and C2 recorded counts of 920MPN/100ml and 160MPN/100ml respectively. The total count for the dry season ranges from 920MPN/100ml to >2400MPN/100ml . Samples number C3 had the highest recorded

count in the dry season of >1600MPN/100ml. sample numbers C1 and C2 recorded counts of 920MPN/100ml and 540 MPN/100ml respectively.

Table 7. Mean seasonal counts from different water sources (ANOVA)

Season	Water source						Mean
	Bore hole	Carnal	Dam	Hand dug well	River	Stream	
Rainy	3.16	604.82	1624.18	2.13	1643.13	310.08	778.27
Dry	8.74	1374.42	1187.37	16.09	1144.32	938.66	697.92
Mean	5.95	989.62	1405.77	9.11	1393.73	624.37	738.09

Lsd (0.05): Season = 1.033; Water sources = 1.788; Season x water sources = 2.529

Pertaining to total coliform counts (Table 4.2.7) of the various water sources sampled for the study, it was revealed that, the rainy season samplings (778.27) were significantly different ($P < 0.05$) from the dry season collections (697.92). Likewise, among the water sources, significant differences ($P < 0.05$) were observed such that, dam which recorded the highest total counts (1405.77) was significantly different ($P < 0.05$) from all the other water sources, followed by that of river (1393.73) which was also significantly different from ($P < 0.05$) carnal (989.62). Similarly, carnal (989.62) significantly differed ($P < 0.05$) from hand dug well (9.11) which also varied from bore hole significantly at $P < 0.05$. In terms of interaction between seasons and water sources, carnal river recorded the highest value (1643.13) during the rainy season, which was significantly different ($P < 0.05$) from all the other water sources implying the extent to which rivers are contaminated during down pours of rain. However, hand dug well recorded the least total coliform counts (2.13) which was not significantly different ($P = 0.05$) from that of bore-hole (3.16). In the same manner, the dry season counts were significantly different ($P < 0.05$) amongst the water sources. Carnal which recorded the third highest total coliform counts in the rainy season had the highest counts (1374.42) in the dry season analyses which was significantly different ($P < 0.05$) from all the other water sources followed by dam (1187.37) which was also significantly different ($P < 0.05$) from the river, stream hand dug well and bore hole. Nonetheless, bore-hole recorded the least total counts (8.74) in the dry season which was significantly different ($P < 0.05$) from that of hand dug well (16.09).

Table 8. Faecal Coliform Counts of different water sources in different seasons

Season	Water source						Mean
	Bore hole	Carnal	Dam	Hand dug well	River	Stream	
Rainy	4.29	1019.80	1059.45	4.16	306.05	497.72	671.80
Dry	15.53	1642.06	806.34	32.93	185.88	1348.08	481.91
Mean	9.91	1330.93	932.89	18.55	245.97	922.90	576.86

Lsd (0.05): Season = 0.678; Water sources = 1.175; Season x water sources = 1.662

Relating to the faecal coliform counts (Table 4.2.8) of the diverse water sources, it was realized that the rainy season isolates (671.80) were significantly different ($P < 0.05$) from the dry season isolates (481.91). Correspondingly, analyses from the different water sources significantly differed ($P < 0.05$) from one another. Carnal recorded the highest faecal coliform counts (1330.93) which was significantly different ($P < 0.05$) from dam (932.89), followed by stream (922.90), which was also significantly different from ($P < 0.05$) river (245.97). Borehole which recorded the least faecal coliform counts (9.91) was also significantly different ($P < 0.05$) from that of hand dug well (18.55). In the same way, interaction between seasons and water sources were not spared in terms of significance ($P < 0.05$) in faecal coliform counts. In the rainy season, dam recorded the highest value (1059.45), which was significantly different ($P < 0.05$) from carnal (1019.80). Stream (497.72) also differed significantly ($P < 0.05$) from river (306.05). However, hand dug well which recorded the least faecal coliform counts (4.16) was not significantly different ($P = 0.05$) from that of bore hole (4.29). In the same way, the dry season faecal counts were significantly different ($P < 0.05$) among the water sources. Carnal recorded the highest faecal coliform counts (1642.06) which was significantly different ($P < 0.05$) from all the other water sources followed by stream (1348.08) which was also significantly different ($P < 0.05$) from that of the dam (806.34). River (185.88) likewise significantly differed ($P < 0.05$) from hand dug well (32.93), which was also significantly different ($P < 0.05$) from bore-hole (15.53).

Table 9. Number and Percentage of growth and no growth of bacterial isolates in samples collected from the water sources

Water source	Rainy season		Dry season	
	Growth	No growth	Growth	No growth
Dams	15(100%)	0(0%)	15(100%)	0(0%)
Bore holes	5(62.5%)	3(37.5%)	7(87.5%)	1(12.5%)
Streams	17(100%)	0(0%)	17(100%)	0(0%)
Hand-dug wells	13(88.6%)	2(13.3%)	14(93.3)	1(6.6%)
Rivers	3(100%)	0(0%)	3(100%)	0(0%)
Canals	3(100%)	0(0%)	3(100%)	0(0%)
Total	56(91.8%)	5(8.2%)	59(96.7%)	2(8.2%)

Source: Fieldwork

Number and Percentage of bacteria growth and no bacterial growth of samples collected from the water sources are presented in table 8. There was more bacteria growth (59) from water samples analyzed in the dry season against bacterial growth (56) in the rainy season. Water samples from stream sources showed the highest bacteria growth of seventeen followed by dams (15). The least bacteria growth was recoded from rivers and canals, where a growth of three (3) was recoded for each. The dry season has the highest number of growth recoded from streams (3) followed by dams (15). Rivers and canal recorded the least growth with three (3) each.

Discussions

The quality of drinking water is a global issue due to the fact that it is an important environmental determinant of health which is directly linked to the socio-economic development of nations. Unfortunately, about 1 billion people in developing countries lack access to safe drinking water (WHO, 2004). This growing deficit of good quality water in developing countries has spurred the need to utilize other sources of water either than conventional treated waters at maximal risk of microbiological and chemical pollution. As a result, developing countries particularly, are plagued with water related diseases such as diarrheal diseases (Aderigbe *et al.,* 2008; Park, 2002) which account for 10% of the disease

burden in developing countries (Park, 2002). Inhabitants in the study area did not have access to safe and/or quality water in terms of microbial contamination.

In spite of the fact that various studies have reported inaptly high levels of microbial contamination in many water sources such as dams, streams, rivers, bore holes, dug out wells and others, many rural people continue not only rely on these water sources but also depend but at times even show preference for water from these sources for domestic use including drinking (Canadian International Development Agency/Ghana Water Resources Commission, 2006; Gyampoh et al., 2008).

A few general trends observed in the study were that, during the rainy seasons, bacteria counts in the water samples of almost all the water sources were lower in comparison with the dry seasons for all the water samples dealt with. For instance, samples collected from dam in the dry season had comparatively more coliforms than similar water samples from the same dam in the rainy season (Table 1). Stream, bore hole, river, hand dug well and canal water sources were not exception. The likelihood for these happenings may be due to an infiltration of coliform-rich surface water through porous soil profiles into the shallow aquifers of the boreholes and hand dug wells whiles in the case of river, stream, dam and canal, coliform-rich surface water might have flown directly into them. Again, it is more likely that, hand dug wells and bore-holes might have been dug either near/around toilet facilities or human/animal faeces are been disposed closely since faecal coliform (*E. coli*) detection in water gives the indication of faecal contamination (Wasfy et al., 2000).

Most often, in rainy season, the frequency and/or number of total and faecal coliform (*E. coli*) in water sources increases as faeces of human and/or animal are washed into creeks, rivers, streams, lakes or ground water. However, in the dry season, the number/frequency of *E. coli* is higher (Obi et al., 1998) due to concentration of the organism during the dry season. Though, the analyses conducted proved microbial presence or contamination of the various samples collected; the degree to which each sampling site was contaminated really differed. For instance, in dam water, Total coliform isolated at sites, D_1, D_9 D_{13} in the rainy season were the highest (> 2400 MPN/100 ml) whilst site D_4 recorded the least number of isolated colifrom (540 MPN/100 ml) (Table 1). Likewise in stream, site, S_6 had a lower value than site, S_{16} (Table 3). The differences in the sites' isolates give indication of the extent to which each sample site had been habituated by either humans or animals as these are the major sources of microbial contamination of water sources especially, with respect to faecal coliform. The high number of isolates obtained from dam in both seasons may be attributed

to the fact that dam water is torpid and therefore, when contaminated with faecal coliforms the number keeps rising and reduces at low pace in contrast to river water, streams and canals which flows downstream; usually leaving the main source with less and/or no contaminants.

In fact, the point sources of coliform-rich water near or around the various water samples might have been influenced by the anthropogenic influences, such as insanitary conditions that generally prevailed around or near them. Unlike boreholes and hand-dug wells, river, dam, streams and canals are more or less open to contamination from diverse points and diffuse sources in the surrounding environment which accounted for the high microbial contamination as also reported by Anima et al. (2010).

The high incidence of total coliform counts recorded in the dry were more than the rainy season for dam and river suggest that, more bacterial contaminants from incinerators, refuse dumps and human effluents might have been washed down into such water sources making them highly contaminated and potential sources of conveying microbial pathogens (Dufour et al., 2003); this, then creates greater health hurdle in the Ghanaian community especially, the rural areas since most inhabitant patronize these two water sources even, in the rainy season. However, hand dug well, bore hole, canal and streams which rather recorded the highest total counts in the dry season than the rainy season may be accounted to the fact that, in the dry season the volume of these water sources reduces thereby increasing the concentrations of micro organisms. Furthermore, in the dry season, most hand dug wells and bore holes are de-silted by equipment and/or people of poor microbial standard suggesting that the high coliforms registered could have resulted from contamination of human activity which affirms study by Anima et al. (2010). In terms of faecal coliform counts, similar trend was recorded such that apart from dam which recorded lower faecal isolates than in the dry season, all the rest had an inverse results. This agrees with the aforementioned reasons that there might have been accumulation of bacteria in the respective water sources due to reduction in the water volume. It may also be likely that, animals hurdle around these water sources in search of drinking water and as such might have deposited in or near the water sources which is in accords with results of Wasfy et al. (2000).

The presence of total and faecal coliform bacteria in the various water sources in the current study, present a serious call for water resources management in rural Ghana and, indeed, in most parts of sub-Saharan Africa. Although, water sources in the rural and peri-urban areas in Ghana are unsafe in terms of microbial quality but rural inhabitants still patronize in their usages (for domestic and drinking purposes). This could be attributed to certain prevalent

socio-cultural preferences and beliefs, proximity (i.e. ready access or availability) and absence or lack of suitable alternative sources of potable water (Ormston, 2005). In many communities, such water bodies or areas around them serve as recipients of various forms of domestic and agricultural waste which easily infiltrate the soil and eventually leach out into the streams, canals, dams and rivers (Freeman, 1989). Many hand-dug wells and bore holes constructed also tap water from shallow aquifers which are highly

prone to surface pollution. Also, the dumping of refuse and human excreta in and around water bodies is still prevalent (Anima et al., 2010) suggesting the possibility of contamination from pathogenic bacteria and other sources. Detection of coliforms in borehole water, no matter how low the counts (in cfu/100 ml), without doubt introduces much concern regarding the bacteriological safety of the water. In some communities, significantly high coliform bacteria in borehole water appear to qualitatively correlate with levels of possible pollution in the immediate surroundings (Anima et al., 2010). In addition, the levels of investment involved and the significance attached to borehole development as a preferable substitute to dams, river, stream and canal water for rural communities make any such observation highly significant. Furthermore, the unrelenting prominence on borehole development by governments, development agencies and NGOs for supply of safe drinking water in rural communities in many developing countries especially Ghana, laudable though it may seem, may have to be re-examined in so far as sustainable management of rural water resources is concerned (Anima et al., 2010). The most crucial factor to be considered first is the appropriate site selection for borehole construction. Indeed, many hydro-geologists and geophysicists involved in the selection of water points actually give little or no consideration to environmental issues, their main objective for success being determined by the ability to "hit" water. Most often at times, rural folks locate water sources close to their residence for the purpose of convenience and/or proximity. However, the nearby surroundings are at the same time polluted by them making it environmentally unfriendly highly susceptible to contamination with time. Sites allotted for or made readily available by communities for hand dug wells and borehole construction are usually low lying, flood prone, near refuse or waste dumps and public toilets (abandoned or active) where there is not much land use competition, conflict or ownership. Likewise, the situation in dams, streams, rivers and canals.

Residents pressure, land degradation and intrusion on low-lying areas including wetlands for housing and other forms of development frequently render areas around previously existing water sources liable to pollution from domestic and other forms of waste which contaminates

water in aquifers (Anima et al., 2010). In adding up, is the lack of dexterity and/or poor regulatory regime amongst the various service providers in the rural water sector. For example, apart from boreholes constructed under the direct supervision of CWSA, a number of water facilities are also provided by stakeholders, such as religious bodies, NGOs and Community-Based Organizations (CBOs) without active participation of and/or prior knowledge or approval by CWSA. In addition, even though CWSA, the Ghana Water Resources Commission (WRC) and Environmental Protection Agency (EPA Ghana) have developed policy guidelines for construction of boreholes and abstraction of water, the "non-binding" nature and weak to non-existent enforcement place enormous constraints on effective service delivery at the community level.

In the case of rivers, canals, dams and streams in surveyed rural communities, virtually nothing is done on their quality water supply although, these water sources are highly utilized by the community members principally, during periods of water shortages. This confirms findings of Anima et al. (2010) that, streams are highly patronized by rural communities in times of water scarcity. Due to the alarming contamination from diverse human and animal activities nearby the various water sources, use of river, dam, canal, stream, hand dug well and bore hole water may render many rural folks highly defenseless to waterborne diseases resulting from the presence of pathogenic bacteria in their water. Anima et al. (2010) observed that, many rural communities depend on contaminated water sources in spite of the presence of significant coliform bacteria.

Conclusion

This study proves that rural folks residing at the Dangme West District really encounter serious challenges in regards to safe and portable water. Cyclic assessment of the quality of water available to the rural communities may not only deem 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 readiness to safe and portable water, it may deem necessary to consider all the water sources for rural communities rather than concentrating on only bore holes which may not only serve a handful of the residents but also accompanied with high drilling costs. In a nut shell, there should be an

incessant education on environmental awareness and capacity building to enhance water resources management programmes in the rural and peri-urban communities.

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