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Assessment of Bacteriological Quality of Tono and Vea Dams Water in the Upper East Region, Ghana

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Authors' contributions

This research is a collaborative work coordinated by the corresponding author. Author VN designed the study, wrote the protocol and performed the statistical analysis. The laboratory analysis was performed by all authors. The manuscript write-up was done by author VN and proof reading done by the other authors LAA, ACN, MG and ABA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim of the Study: This study was undertaken to assess the bacteriological quality of water from the Tono and Vea dams.
Study Design: Water samples from both Tono and Vea irrigation dams in the Upper East Region of Ghana were collected and analyzed to assess their bacteriological quality. A total of 64 water samples were collected from the dams.
Place and Duration: Vea and Tono dams in Navrongo and Bolgatanga were studied from March to April, 2011.
Methodology: Multiple Tube Fermentation (MTF) technique was used for the determination of total coliform and fecal coliform. Total heterotrophic bacteria counts and *Salmonella* counts were determined using standard plate count methods.

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Results: Mean Most Probable Number obtained for total coliform counts of the water samples from Tono ranged from 150 to 1600 mpn/100 ml while Vea samples ranged from 150 to >1600 mpn/100 ml. Mean faecal coliform counts of Tono water ranged from 79 to 920 mpn/100 ml while Vea water ranged from 70 to 920 mpn /100 ml. The mean total heterotrophic bacteria counts of Tono water ranged from 12 to >300 x 10^8 cfu/ml while Vea water ranged from 11 to >300 x 10^8 cfu/ ml. Mean *Salmonella* counts of both Tono water and Vea water ranged from 2 to 10 x 10^4 cfu/ ml. **Conclusion:** The contamination highlights more severe environmental problem in the study areas through faecal contamination. The environmental issues have jeopardized or compromised the quality of the dam water making the water unsuitable for drinking purpose without appropriate techniques for water purification before consumption. Based on the findings of this study, it is recommended that there should be regular surveillance of water sources for bacteriological quality and efforts to control the bacteriological contamination in order to meet millennium development goal 7.

Keywords: Ghana; dam water; bacteriological quality; Salmonella; total heterotrophic bacteria.

1. INTRODUCTION

The wellbeing of living organisms is largely dependent on water. Supply of clean, safe and potable drinking water to the community is of utmost important in maintaining positive health measures. The sustenance of human life on water as a natural resource can never be undermined. The availability of potable water does not only positively impact social and economic advancement but a critical resource in food processing, health promotion and poverty alleviation [1]. There has been an urgent and growing demand for clean water for human consumption in most developing countries where good sanitation has remained a challenge [2].

Pipe-borne water supply in Ghana is not commensurate with population in most communities. This deficit is expressed in terms of quality and quantity of the supplied water. 40% of the population of urban inhabitants is accessible to water from the pipe. In total only 10.5 million people representing 51% approximately of the nation's population has access to quality water supply [3]. The insufficiency of potable water coupled with inadequate sanitation measures results in a number water and food borne diseases such as cholera, *salmonellosis*, typhoid, dysentery and typhoid. These diseases claim several lives annually in developing countries. Diarrh**o**ea as a result of enteric pathogens accounts for about two million deaths in children below the age of five (5) annually world-wide [4]. It has been well documented that potable water has enormous potential in transporting microbial pathogens to large number of people and subsequently causing illness [5].

Faecal contamination of water bodies which give rise to health burdens gains entrance into these water bodies through humans, livestock and other wild animals. Wide range of pathogenic microbes can be found in water and routine monitoring for their presence and loads can be a tedious task. Water safety measurement used to depend on the absence of microorganisms that are of faecal origin [6]. Most bacteriological analysis of water is focused on detecting the indicator organisms of fecal contamination (coliform organisms). The presence of *Escherichia coli* in the water sample shows that the water is contaminated with human excreta. This makes the water unsafe for human consumption and other domestic activities. A coliform is an enteric organism which can survive for a long time in water. They are Gram negative organisms and the cells are rod like [7]. Coliform can ferment sugar (lactose) to produce gas and acid. Although *Pseudomonas aeruginosa* can be significant in certain settings such as health care facilities, there is no evidence that normal uses of drinking-water supplies are a source of infection in the general population [8].

Microbial quality of water is one of the main points that are directly relevant to personal and public health. Human life depends on safe water and efforts to provide safe water are a huge challenge. Many health problems in developing countries, is mainly due to the lack of clean water [9]. Underground water reservoirs and dam water are the main sources of water supply in cities that is used for most agricultural and industrial activities. Therefore, it should be exploited reasonably and prevent unnecessary use of it and also prevent the loss of its quality as much as possible. Studies showed that the amount of available water resources in the world is limited

and in low proportion to the growing population. Dam water is an essential and reliable source used by rural and urban folks in many countries [10]. Ground water and dam water are the important components of hydrological cycle therefore all human activities that result in the over-exploitation of them may have harmful effects on water resources and ecology of that area [11].

Dams (Tono and Vea) are the important drinking water sources to people who reside in Navrongo and Bolgatanga catchment areas. Preliminary investigation (field observation in the dams) was undertaken and attempt was made to include as many conflicting variables as possible, which could have a potential to reduce the surface water quality, like proximity to agricultural and irrigation activities, drainage system, dumping of domestic wastes and open defecation, swimming in the dams, livestock drinking from the dams just to mention a few. It was clear that the above mentioned conflicting issues were common challenges jeopardizing or compromising the water quality in the dams. In view of this, the main aim of this research was to assess the bacteriological quality of the water in the dams: Tono and Vea irrigation dams.

2. MATERIALS AND METHODS

The Tono irrigation dam was constructed over the Tono River in the year 1975. The dam occupies an area of about 1800 hectares with a major bank north of the dam. Source of water to the dam includes runoff water and flowing streams. It is chiefly fed by two major streams. The dam is drained by a constructed outlet, northwest of the dam's bank. The water shed within which the dam lies is purely grass savanna with few scattered shrubs. The water shed lies bare during the dry season and is therefore severely eroded by the early rains. The Vea irrigation dam was constructed from 1965-1980. The dam occupies an area of about 408 hectares with its bank west of the dam. Sources of water to the dam include runoffs and flowing streams. The dam is used for irrigation, recreation, fishing and treatment for portable water distribution to Bolgatanga Township. The dam has savanna vegetation lying within its water sheds.

Four (4) sampling sites of 25 m^2 and at least 100 m apart were selected at random to prevent activities of one site interfering with the other. This enabled wider area coverage of the dams during the study. Water samples were collected using one litre sterilized water bottles. Four samples each from the East, West, South and North of the dams were taken totaling sixteen samples for each dam. These were collected four times within two months for analysis at Navrongo Campus of the University for Development Studies Laboratory. Sampling was done at intervals of two weeks for the months of March and April, 2011.

2.1 Enumeration of Total and Feacal Coliform

Three sequential stages were carried out in this test.

2.1.1 Presumptive test

Multiple Tube Fermentation technique as spelled out by APHA [12] was used in the determination of Total coliform and faecal coliform. The Most Probable Number (MPN) technique of three tube assay was used to determine the coliform count. This test was conducted using lactose broth (oxoid) as medium. 10 ml of sterile double strength broth was used in the first three tubes while the last two (second and third) had 10 ml of sterile single strength broth. Durham tubes were fitted into all the tubes before sterilization took place. 10 ml, 1 ml and 0.1 ml of water samples from the dams were put into all the three tubes with the aid of sterile pipettes. They were kept in an incubator at 37°C for 24-48 hours for determination of total coliforms and faecal coliform at 44.5°C for 24-48 hours and examination for gas and acid production. Change of broth colour was determinant of acid production while gas produced contained by entrapment in Durham tubes. The MPN was then determined from the MPN table for the three sets of tubes. Durham tubes with gas production at 10% or more were recorded as positive and those that did not show were incubated for another 24 hours. After 48 hours, those that show these changes were recorded as positive and Durham tubes with no gas production were considered negative. The Most Probable Number (MPN) of coliform bacteria was read from the MPN statistical table [13]

2.1.2 Confirmatory test

Confirmatory test was conducted by taking a loopful of culture from a positive presumptive test tube, inoculated on Eosin Methylene Blue (EMB) agar and incubated for (24- 48) hours at 37°C for pure colonies. Colonies that exhibited green

metallic sheen were confirmatory to the presence faecal coliform in the tube with Lactose broth (oxoid) with inserted Durham tubes. The tubes were incubated at 37°C for 24-48 hours for total coliform and 44.5°C for faecal coliforms and observed for gas production.

2.1.3 Completed test

Completed test was carried out by picking a colony from confirmed test and streaked onto nutrient agar slant and inoculated onto lactose broth containing Durham tube. These were incubated at 37°C for 24-48 hours. The cultured tubes were observed for gas production and microscopic examination revealed the morphology of the coliform bacteria from nutrient agar slant to confirm faecal coliforms (*E. coli*). They were gram-negative, non-spore forming rod shaped bacillus which is an indication of positive completed test.

2.2 Enumeration of Total Heterotrophic Bacteria or Total Viable Counts

Total heterotrophic bacteria in the water samples were obtained using the pour plate method. Dilutions of 10^{-1} to 10^{-8} of the samples were prepared in 0.1% buffered peptone water (oxoid) and duplicate 1 ml aliquots of each 10^{-8} dilution was inoculated into 15 ml each of molten plate count agar (PCA) cooled to 45°C in universal bottle. These were then thoroughly mixed and poured into sterile petri-dish plate and incubated at 37°C for 24 hours. Colonies were then enumerated using cubic colony counter. Petri-dishes from dilutions containing between 30 and 300 discrete colonies were counted and the result expressed as the numbers of bacteria per millilitre [12,14].

2.3 *Salmonella* Counts

1 ml of dilution 10^{-4} was transferred into Petri dishes by pour plate method and Bismuth Sulphite Agar cooled to 45°C was added to it. This was allowed to solidify and incubated at 37°C for 24-48 hours for suspected colonies. The plates were examined after incubation for colonies which developed a black color.

3. RESULTS

The results of total coliform, faecal coliform, total heterotrophic bacteria and *Salmonella* counts are presented in Tables 1 and 4 respectively. Table 1 shows the mean values of total coliform counts of samples of water collected bi-weekly over a period of 8 weeks from the dam. Mean total coliform counts of Tono samples and Vea samples ranged from 150 mpn/100 ml to 1600 mpn/100 ml. In Table 2 shows the mean faecal coliform bacteria counts of the samples from Tono samples ranged from 79 mpn/100 ml to 920 mpn/100 ml while samples from Vea dam ranged from 70 mpn/100 ml to 920 mpn/100 ml.

Table 1. Mean total coliform bacteria counts in water samples from tono and vea dams

Tono Sampls	Mean Total coliform counts mpn / 100 ml	Vea samples	Mean total coliform counts mpn / 100 ml
NTDS1	280	NVDS1	>1600
ETDS1	350	EVDS1	150
WTDS1	1600	WVDS1	350
STDS 1	220	SVDS1	>1600
NTDS 2	220	NVDS2	280
ETDS 2	220	EVDS2	350
WTDS 2	220	WVDS2	150
STDS 2	350	SVDS2	>1600
NTDS 3	280	NVDS3	280
ETDS 3	150	EVDS3	220
WTDS 3	280	WVDS3	220
STDS 3	220	SVDS3	280
NTDS 4	220	NVDS4	1600
ETDS 4	220	EVDS4	350
WTDS 4	280	WVDS4	280
STDS 4	280	SVDS4	150

Sample codes: Northern part of Tono Dam Sample (NTDS), Southern part of Tono Dam Sample (STDS), Eastern part of Tono Dam Sample (ETDS), Western part of Tono Dam Sample (WTDS)

The mean value of total heterotrophic bacteria counts is presented in Table 3. The range of total heterotrophic bacteria from Tono samples water was 12 to >300 × 10^8 cfu / ml while that of Vea samples ranged from 11 to >300 × 10^8 cfu / ml. The salmonella counts from the dams are presented in Table 4. The range of *Salmonella* spp from Tono samples ranged from 2 to 10 × 10^4 cfu / ml with a mean of 5.67±2.22 × 10^4 cfu / ml while that of Vea samples ranged from 2 to 10× 10^4 cfu / ml with a mean of 6.33±2.53 × 10^4 cfu / ml.

4. DISCUSSION

Potable water for human usage should be pathogen-free. Total coliform MPN obtained for the dam were studied ranged from 150 to 1600 index/100 ml that generally exceeded WHO limits for potability. The occurrence of coliforms detected in water is a direct measurement of injurious effects of pollution on human health. The coliforms count obtained did not show any clear significant difference in between the two dams studied. The confirmatory test for the presence or absence of faecal coliform from Tono and Vea dams water confirms faecal coliform presence in all samples collected. It is evident from the results that all the dam water samples contained coliforms exceeding the water quality standards of zero per 100 ml of water samples as per safe drinking water act depicting pollution of the dam water. However, similar studies conducted in Accra, Ghana and Maharashtra, India respectively recorded higher total and faecal coliforms counts as compared to this present study [15,16].

The presence of faecal coliform bacteria indicates fresh contamination of the dam water with faecal waste from humans or animals. The contamination highlights more severe environmental problem in the study areas in the form of faecal contamination. These include runoff from human settlements lacking proper sanitation facilities, agricultural activities, livestock and human activities in the proximity of the dams in the rural communities. The number of domestic animals in an urban watershed may be another cause of elevated faecal coliform levels [17]. These findings are also consistent with earlier reports that, dam water resource contamination is most often from diverse or point sources within the dam's surroundings where good sanitation is impractical leading to high microbial load [18]. Microbial growth and physical water quality are considered to be priority parameters and have to be monitored in the dam catchments [19].

Table 2. Mean feacal coliform bacteria counts in water samples from tono and vea dams

Tono samples	Mean feacal coliform counts mpn /100 ml	Vea samples	Mean feacal coliform counts mpn /100 ml
NTDS1	170	NVDS1	920
ETDS1	220	EVDS1	94
WTDS1	920	WVDS1	220
STDS 1	140	SVDS1	920
NTDS 2	170	NVDS2	170
ETDS 2	110	EVDS2	280
WTDS 2	110	WVDS2	79
STDS 2	280	SVDS2	920
NTDS 3	170	NVDS3	140
ETDS 3	79	EVDS3	140
WTDS 3	140	WVDS3	140
STDS 3	170	SVDS3	210
NTDS 4	140	NVDS4	920
ETDS 4	110	EVDS4	220
WTDS 4	210	WVDS4	170
STDS 4	170	SVDS4	70

Sample codes: Northern part of Vea Dam Sample (NVDS), Southern part of Vea Dam Sample (SVDS), Eastern part of Vea Dam Sample (EVDS), Western part of Vea Dam Sample (WVDS)

Table 3. Mean total heterotrophic bacteria count in water samples from tono and vea dams

Tono sample code	THB cfu/ml×10^8	Vea sample code	THB cfu/ml×10^8
From Tono		From Vea	
NTDS1	31	NVDS1	21
ETDS1	>300	EVDS1	>300
WTDS1	25	WVDS1	26
STDS 1	35	SVDS1	45
NTDS 2	35	NVDS2	39
ETDS 2	33	EVDS2	32
WTDS 2	43	WVDS2	27
STDS 2	21	SVDS2	41
NTDS 3	19	NVDS3	44
ETDS 3	22	EVDS3	34
WTDS 3	23	WVDS3	29
STDS 3	39	SVDS3	>300
NTDS 4	37	NVDS4	11
ETDS 4	>300	EVDS4	33
WTDS 4	>300	WVDS4	43
STDS 4	12	SVDS4	32

Table 4. Mean *Salmonella* spp count in water samples from tono and vea dams

Tono sample code	× 10^4 cfu/ml	Vea sample code	× 10^4 cfu/ml
NTDS1	3	NVDS1	3
ETDS1	5	EVDS1	5
WTDS1	6	WVDS1	6
STDS 1	2	SVDS1	2
NTDS 2	5	NVDS2	5
ETDS 2	6	EVDS2	6
WTDS 2	8	WVDS2	8
STDS 2	10	SVDS2	10
NTDS 3	4	NVDS3	10
ETDS 3	5	EVDS3	5
WTDS 3	8	WVDS3	6
STDS 3	5	SVDS3	8
NTDS 4	5	NVDS4	10
ETDS 4	5	EVDS4	8
WTDS 4	8	WVDS4	6
STDS 4	5	SVDS4	4
Min	2		2
Max	10		10
Mean	5.67		6.33
STD	2.22		2.53

The mean total heterotrophic bacteria count from Tono seemed a bit higher than that of Vea. Comparatively, there is no significant difference between THB counts from the dams. WHO [8] specified that heterotrophic plate count must not be more than 500 bacterial colonies per milliliter for untreated water. This study recorded some high values indicating contamination level of the two dams. High heterotrophic bacteria counts may be due to the presence of indigenous bacteria and soil dwelling bacteria which were washed into the dams. Also human activities such as defecation, urination, washing, bathing farming may contribute to higher counts. Their presence in the water does not indicate pollution by faeces because soil bacteria and aquatic bacteria are part of the counts.

Total heterotrophic bacteria has no health effects, its presence in drinking water is used to measure the variety of bacteria that are common in the water and their high number in water is not an evidence that water is dangerous but undesirable as they may contribute to food

spoilage problems. However, similar studies conducted revealed elevated concentrations of total heterotrophic bacteria in the Around Beed District, Maharashtra, India and in the Ero and Ureje Dams in Ekiti State, Southwest, Nigeria [16,20] respectively. The *Salmonella* count exceeded WHO limit for potability. The presence of salmonella may be due to defecation of sick people or carriers into the dam. Hence, using the dams water for drinking purpose or other domestic chores could cause *Salmonella* related diseases such as enteric fever (typhoid fever), Bacteremia and Enterocolitis [21]. Per the observation of *Salmonella* spp values recorded, no significant difference in terms of pollution levels occurred between the two dams.

5. CONCLUSION

It is revealed that the dam water samples did not satisfy the standard of drinking water. The samples are contaminated with coliform bacteria and salmonella. The environmental issues have jeopardized or compromised the quality of the dam water making the water unsuitable for drinking purpose without appropriate techniques for water purification before consumption. Based on the findings of this study, it is recommended that livestock and agricultural activities should be reduced or stopped entirely to minimize the bacteriological load of the water which is now used for human consumption. Education on consciousness of critical environmental issues and building inhabitants' capacity in catchment areas should be done as a matter of urgency to reduce the microbial loads of the dam to an acceptable level in order to meet the millennium development goal 7.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

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