Original Research Article

EPIDEMIOLOGICAL STUDIES OF WATERBORNE DISESASES IN RELATION TO BACTERIOLOGICAL QUALITY OF WATER

Abstract

Aim of the study: Waterborne diseases are global burden with increase in number of cases more especially in rural areas of developing countries. We investigated the epidemiological distribution of waterborne diseases and bacteriological quality of water in Bodinga Sokoto Nigeria.

Research design:
The study used a retrospective design and determined the prevalence of some selected waterborne diseases and sanitary inspection. An experimental design was used for determination of bacterial pollution in some water sources.
Place and duration: The study was conducted at the General Hospital Bodinga and Department of Microbiology Sokoto state University within the period of one year.

Methods: A retrospective data of health records were collected from out-patient register in Bodinga General Hospital, covered a period of three years from January to December (2015 -2017). A number of samples of water were collected from different sources in Bodinga, Danchadi and Takatuku and were analyzed using standard method.

Results: We found the most common waterborne diseases in the area are dysentery, 517(40.7%) typhoid 375(29.5%), gastroenteritis 202(15.9%) and diarrhea 105(8.3%), while skin infection and cholera account for 36(2.8%) each. We observed that the diseases are widely distributed in rainy season with high occurrence of 732(57.59%) cases than dry season having 539(42.41%) cases. Male are more prone to diseases with 706 cases than female having 565 cases and 25-above years as well as Children below the age of 5 are more vulnerable to diseases with occurrence of 481 and 331 respectively.

Conclusion: This study suggests a possible strong relationship between waterborne diseases and poor water quality which contributed to the spread of diseases in the study area.

Key words: Epidemiological studies; E. coli; Typhoid; Gastroenteritis; Skin infections; Borehole, Shallow well; Water; quality; Bodinga

1.0 INTRODUCTION

Water is an important means of sustenance that are needed by all forms of life. Diseases associated with water have mostly occurred as a result of ingestion of water contaminated with feacal matters. Globally, at least 2 billion people use a drinking water source contaminated with human or animal faeces [1]. Most of the population in developing countries particularly in rural live in extreme conditions of poverty and poor sanitation services in public places as well as inadequate water supply and poor hygiene including hospitals, health centers and schools [1]. **Statistically, at least 884 million people** do not have access to basic drinking water and almost 159 million people are dependent on rivers and lakes with almost 423 million people taking water from unprotected springs and wells [2].

Waterborne disease outbreaks are mainly occurred due to technical failures or failure to treat the water properly [3]. Waterborne diseases can be transmitted through faecal oral route and direct contact. Some parasites are capable of penetrating intact skin and cause severe infection such as skin infection. In developed countries, waterborne disease is no longer considered a constant threat [4].

In context to developing countries like Nigeria microbial quality of water is a downside due to lack of essential state of art facilities for treatment of water and financial allocations. However access to safe water, particularly to dwellers in rural, settlement and villages in remote areas, is difficult **within a brief distance**.

In addition, people consuming unfit drinking water become infected with pathogens if a proper measure to eliminate the pollutant in the water is not taken. In this work, we found that most of the people live in rural areas of Bodinga observe open laxation which can result in the contamination of sources as the fecal matters washed away during the rainy season. Lack of knowledge, sanitary healthful facilities, and sensible hygienic practice contribute meaningfully to the spread of waterborne diseases (WBD) within the area.

It has been reported the grazing of an animal nearby water sources significantly affects the quality water [5][6][7] and may lead to the entry of pathogens into the water bodies. Contaminations of drinking water with pathogens have additionally been reported in several towns in Nigeria [8] [9] [10].

Gastroenteritis is an abdominal infection associated with some similar symptoms as diarrhea which has heterogeneous causative agents.

The outbreaks of enteric disease due to water have occurred both when public drinking water supplies were contaminated with surface water and when surface waters contaminated with enteric pathogens have been used for the recreational purpose [11]. According to the UN Environment Programme (UNEP), 300 million people in Africa still do not have reasonable access to safe drinking water and nearly 230 million people defecate in the open [12].

Drinking water quality can be assessed by detecting indicator organisms which their presence indicate contamination with the biological origin and thus, present potential health impact and risk associated with the consumption of unfit water. *E coli* is the most reliable indicator organisms of water pollution which are considered as the organisms of choice to indicate recent faecal contamination in drinking water [13] [14] [15] [16].

Some strains of *E. coli* are non-pathogenic while other strains are found to be pathogenic which provide a clue on the presences of the enteric pathogen in water [15] but at present, *E. coli* appears to provide the best bacterial indicators of fecal contamination in drinking water [17].

The pathogen load in the water body from several contamination sources varies strongly with time, often due to the prevalence and incidence of the disease in the community. Under epidemic conditions, pathogens are excreted from many more human or animal hosts than under endemic conditions. An increased pathogen load, which enters the water source with wastewater discharges or surface runoff, implies an increased risk for waterborne infections [18].

Furthermore, the current study aimed at investigating the epidemiological distribution of waterborne diseases in relation to the bacteriological quality of water in Bodinga town. Here, we shed a light on bacterial waterborne diseases that are prevalent in the study area. These cases had not been reported or documented properly within the study area in spite of studies conducted by [19] in two alternative areas of Sokoto, however, the researchers do not capture Bodinga. The number of cases discovered throughout our preliminary **survey necessitates the investigation of the occurrence** of waterborne diseases within the crony villages of Bodinga in order to create awareness and set an alarm to responsible authorities.

2.0 METHODOLOGY

2.1 Study Area

The area of study is Bodinga Local government in Sokoto State, Nigeria. Its headquarters are in the town of Bodinga. It has an area of 564 km² and a population of 175,406 at the 2006 census. The postal code of the area is 852. Bodinga town is11 km away from Sokoto town and it has limited rainfall from mid-May to October. It is also subjected to Sahara's harmattan from November to March.

2.2 Research Design

The study used a **retrospective design** and determined the prevalence of some selected waterborne diseases and sanitary inspection. An experimental design was used for determination of bacterial pollution in some water sources.

2.3 Determining Prevalence of Water Borne Diseases

The method described by [20] was employed and determined the type and frequency of distribution of water-borne diseases in Bodinga town. Retrospective data of medical records from outpatient record register in Bodinga general hospital for complete three years (36 months) from January to December (2017, 2016 and 2015) were reviewed to identify common waterborne diseases in the study area in respect to the year, month, age, gender and season. About 1271 cases were reviewed.

2.4 Bacteriological analysis of water/Collection of water sample

The samples were collected in the morning from three (3) different villages within the Bodinga local government. The village includes Takatuku, Danchadi, and Bodinga. In each of the mentioned villages, we consider two water sources for samplings, from each villages making a total of six different sources because they are frequently used by the inhabitant of the areas. Additionally, the method described by [7] with some modifications was adopted for collection of water samples. In brief, the water samples for bacteriological analysis were collected in sterile bottles from protected boreholes and shallow wells under sterile condition using labeled sterile glass bottles (250ml) and transported to the microbiology laboratory of Sokoto State University in a cool box at 4^{o}C for analysis.

At water sources, the cap of a 250 ml sterile bottle was removed aseptically. The bottles were filled from the water outflow pipe at boreholes. At the shallow well the cap of 250 ml sterile bottle was removed and tight with a clean rope, it was inserted inside the shallow well filled with water and pulled out. About one inch of space was left at the top of full bottles. The cap was replaced aseptically. The procedure was repeated throughout the period of sample collection. The bacteriological indicator of water quality analyzed was Escherichia coli using multiple tube fermentation techniques and estimation through most probable number (MPN) using the standard method described by [21] [22]. Detail description of the method was presented in supplementary 1.

2.5 Data Analysis

The data generated during the course of study were subjected to analysis using SPSS (version 20). And Microsoft excel 2010. Descriptive statistics using mean and standard error were used for the analysis of data. A simple graph and bar charts were also used for the presentation of data concerning the prevalence and distribution of waterborne diseases. Inferential statistics of t-test and analysis of variance was used to test significant differences between the variables

3.0 RESULTS

3.1 Prevalence and distribution of waterborne diseases in Bodinga Local government

The prevalence and distribution of waterborne diseases in Bodinga town was conducted by reviewing the out patients records from General Hospital Bodinga which covered a period of 2015 to 2017. About 1271 cases of waterborne diseases were investigated. The results for distributions of waterborne diseases in Bodinga town in general are shown in (figure 1) and details data of are also given in table 1 of supplementary sheet (S2).

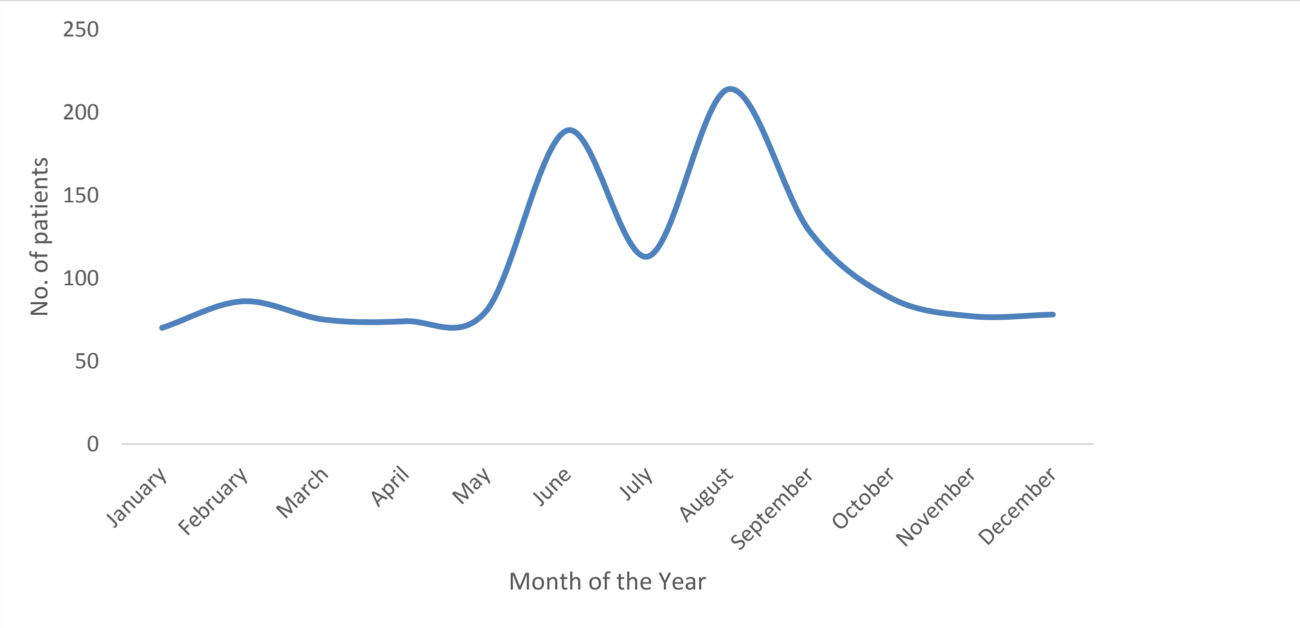

Figure 1: Distributions of waterborne diseases in Bodinga Local government area

Figure 1 shows how the diseases are distributed within the different months of the year in Bodinga town. Generally, the month of August has observed with the highest variety of diseases (214) June (189), September (127), and July (113) with the month of January recording the lowest number of cases. The fashion of the diseases is cyclic in nature, with the first cycle moving to the right direction by increasing from January and peaking in June, which falls down in July and the next cycle begins. The second cycle increases from July to October. The average number of the second cycle is 117±52 cases which are higher than 98.14±39.40 cases as in the first one. Although an independent t-test shows a significant difference (2.571 at p = 0.05), this pattern is extremely vital for planning in the health center in terms of budgeting and allocation of human resources. Even though most of these diseases are preventable, awareness and prevention programs can be planned during January – June as well as July –November window.

Dysentery 517(40.7%) typhoid 375(29.5%), and gastroenteritis 202 (15.9%) (Supplementary 3) are the highest most contributors of waterborne diseases in Bodinga local government area. **The distributions of these** diseases with time are shown in figure 2 below.

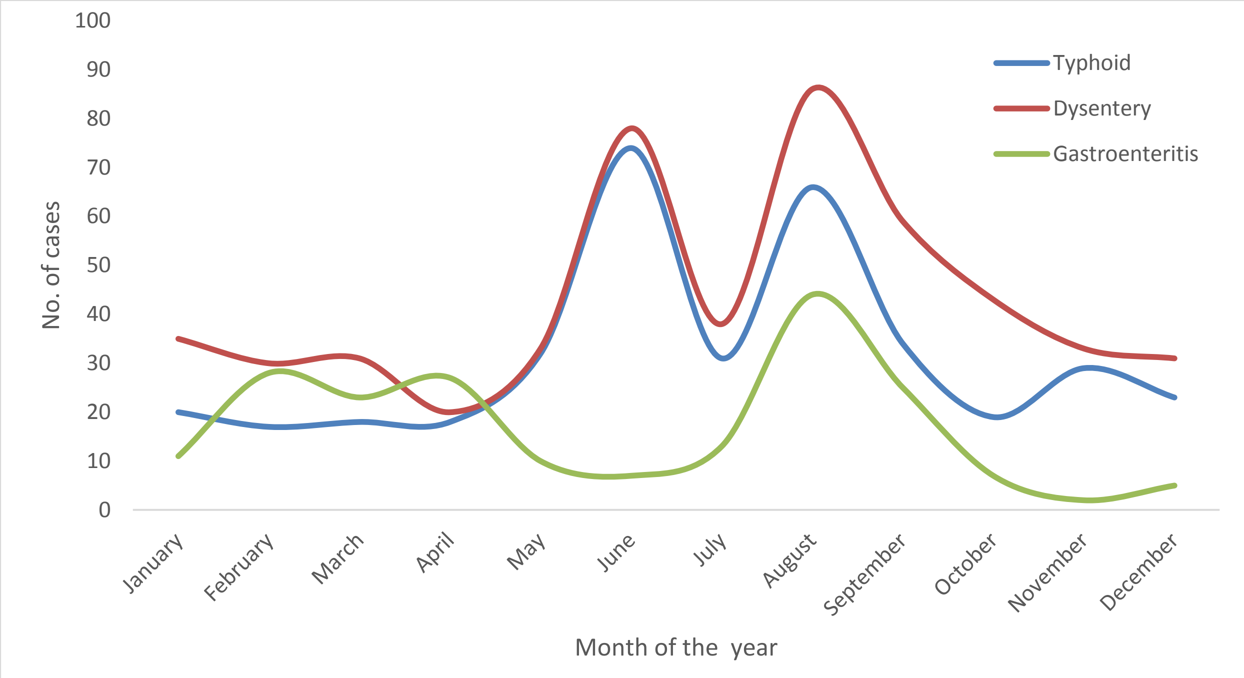

Figure 2: Distribution of typhoid, dysentery and gastroenteritis in Bodinga Local government area

Diarrhoea 105(8.3%), cholera and skin infections 36(2.8%) (Supplementary 3) are most contagious diseases that fortuitously contribute least to the overall number of waterborne diseases in Bodinga local government area. These diseases can affect a number of the population causing inflicting vital impacts within a short time. It is therefore important to understand how these three occur within the year. The distributions of diarrhoea, cholera and skin infection with time are shown in figure 3.

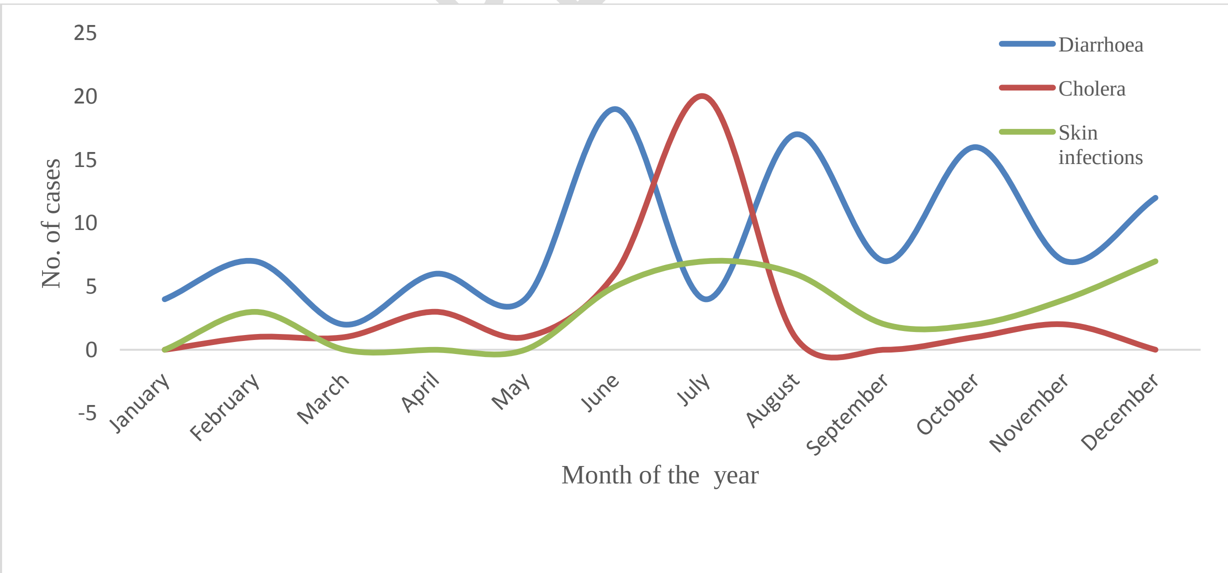

Figure 3: Distribution of Diarrhoea, cholera and Skin infection in Bodinga Local government area

3.2 Seasonality Distribution of Waterborne diseases

Table 1: Seasonal distribution of water borne diseases

Season	Waterborne diseases						Total
	Typhoid	Dysentery	Diarrhoea	Cholera	Gastroenteritis	Skin infection	
Dry season	157	213	42	8	105	14	539
Wet season	218	304	63	28	97	22	732
Total	375	517	105	36	202	36	1271

Seasonal patterns of waterborne diseases event suggests the hypotheses about how transmission of diseases occurs. Water serves as a vehicle for the transmission of diseases. The results represent seasonal characteristic pattern and variation in these diseases that might be because of flooding, washed away of soil and other alternative contaminants into the water sources.

3.3 Gender classification of WBD

The distribution pattern of WBD in respect to gender answered the research question how can variations of diseases occurred across the gender of the patients. Statistically, an independent t- test show a significant difference between the gender of the patients and waterborne diseases.

Table 2: Gender of the patient

		Waterborne diseases						Total
		Typhoid	Dysentery	Diarrhoea	Cholera	Gastroenteritis	Skin infection	
Gender of the patient	Male	215	290	61	17	106	17	706
	Female	160	227	44	19	96	19	565
Total		375	517	105	36	202	36	1271

3.4 Secular Trends of WBD

A secular trend in the occurrence of the diseases indicates that there is a steady increase of diseases for the long-term in the near future. The year 2017 accounting highest prevalence of some diseases compared to others. **The possible explanation could be due to increase in population and open defecation within the area** which contaminate water sources during rainfall.

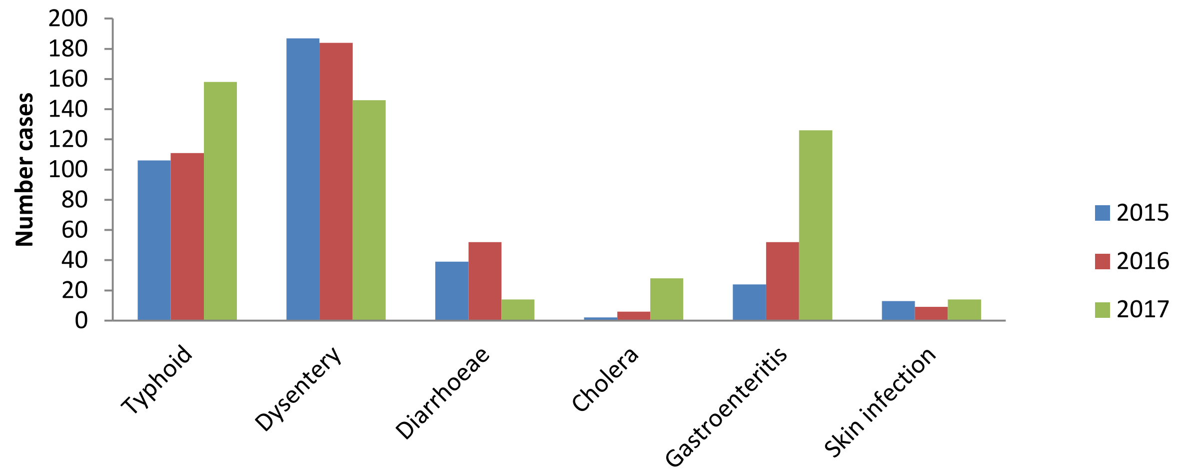

Figure 4: Secular trend of waterborne in Bodinga town

3.5 Age group distributions of WBD

The results of the prevalence of waterborne diseases according to different age groups showed that, 25-above group has the highest prevalence in each disease with 481 (37.8%), groups followed by 0-4 with 331(26.0%), cases and 10-14 has 152(12.0%), while 5-9, 15-19 have the same prevalence with 99(7.8%) each, and the last group 20-24 has 109 (8.6%), as shown above in Table 3. The level of vulnerability of the patient i.e. Age and specific waterborne disease is also shown in table 3. It is evident that generally in all age groups, dysentery and typhoid were the foremost common disease. The age groups 0-4years and > 25 years were additionally prone to all diseases with the exception seen in cholera where 0-4 recorded the highest case. Further analyses of mean ± SE have subsequent values. The results of the different age groups of waterborne diseases disclosed the statistical significant differences between the age groups in table 3

Table 3: Age groups classification of waterborne diseases

Age groups	Waterborne diseases						Total	Average ± Std. Error
	Typhoid	Dysentery	Diarrhoea	Cholera	Gastroenteritis	Skin infection		
0-4	73	151	34	14	58	1	331	2.50±.075
5-9	25	40	13	0	15	6	99	2.58±.156
10-14	51	57	13	2	25	4	152	2.30±.122
15-19	28	37	9	7	15	3	99	2.53±.151
20-24	34	41	10	4	19	1	109	2.41±.139
25-above	164	191	26	9	70	21	481	2.36±.070
Total	375	517	105	36	202	36	1271	

3.6 Bacteriological Analysis of water

The analysis based on the bacteriological quality of water, suggested the level of contamination of the most reliable sources of drinking water in these communities revealed by the presence of indicator organism. Thus, their presence in the drinking water generally indicates the presence of pathogenic microorganisms in the water. The data presented in figure 5 is the mean values of routinely samples analyzed from each sampling points. Table (S4) summarizes the results of faecal contamination of drinking water sources analyzed in three villages of Bodinga town (Bodinga Danchadi and Takatuku).

The number of E.coli detected in all samples were found outside the limit recommended by WHO and NCWR. The average number of indicator organisms in boreholes was 54.1 and shallow well was 171.2 across all the three villages. Briefly, the average mean of faecal contamination in Bodinga borehole was 35.1 and shallow well 160.7, as well as the average highest contamination of boreholes and wells, were recorded in Takatuku 210.4, 73.2 and least in Danchadi 53.9, 142.5 (supplementary S4) showing an increased in feacal contaminations of water sources in the areas. The analysis of variance revealed a significance difference for the concentration of E.coli in water (2.477 at p = 0.005).

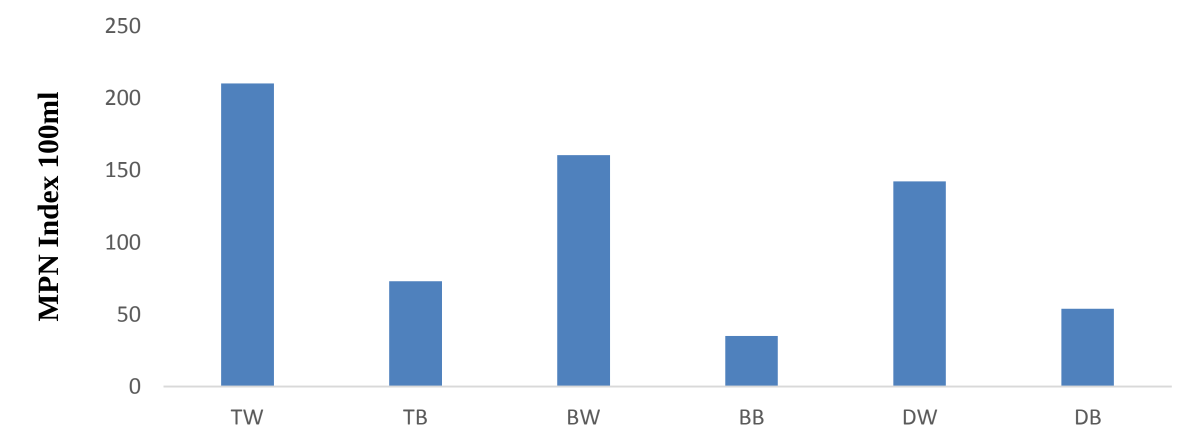

Figure 5: Bacteriological analysis of water in Bodinga Town

Figure 5: Bacteriological analysis of water in Bodinga Town. All the water samples analyzed were in triplicate for each sampling point**.** The result is the average of the amount of *E. coli* detected in the different water sources covered by the sampling points and each bar is representing the sampling point (TW = Takatuku well, TB = Takatuku borehole, BB = Bodinga borehole, BW = Bodinga well, DB = Danchadi borehole and DW = Danchadi well).

4.0 DISCUSSION

Generally, the results of the present study for the distribution and variation of waterborne diseases in Bodinga Local Government indicated that almost all of the waterborne diseases are high in June and August. **Presumably, could be as a result of high intensity of rainfall in these months which increases water percolation and runoff that** may be carrying pollutants. Ejaz [23], reported waterborne diseases **were most prevalent during the wet seasons**.

The poor environmental conditions around the drinking water sources contribute to the high incidence of cases. The findings conjointly indicated the month of August recording the highest quantity of cases followed by June while the months of January and November have the lowest quantity of cases. The month of June and August have a high occurrence of cases **suffering from waterborne diseases** within the study area.

The most frequent contributors of waterborne diseases in Bodinga local government are dysentery, typhoid, and gastroenteritis. Similarly, the study of [24] indicated typhoid fever, dysentery, cholera, and diarrhoea, are the foremost reportable waterborne disease in Ammassoma, Niger Delta, Nigeria.

This is in line with the findings of [25] who found that there is a significant relationship between hygiene and waterborne disease.

The patterns for diarrhoea, skin infection and cholera diseases are similar to that in figure 3 showing a dual cyclic pattern. This implies the intervention period suggested earlier still works for interference and management of these diseases. Estimated cases of waterborne diseases are 4.1% of the global burden with almost 1.8 million human deaths annually during which 88% is attributed to unfit water supply, sanitation and poor personal hygiene [2].

The results of these studies seem to point out that the highest cases of the waterborne diseases in Bodinga town occur during the wet season e.g. June – October. The results for Diarrhoea, cholera and Skin infection are not exceptional of this observation with the pattern quite different from others (Figure 3). **These could be due to contamination of water sources. The use of pit latrine by most of the community live in Bodinga town is seemingly to be an important factor that faecal matters find its way into sources especially groundwater**. Harper [26] reported that runoff is capable of transporting pathogens into water sources, increasing the risk of human exposure and infection.

The seasonal event of **WBD** increases over the years as the rate of flooding increases. The rainy season greatly contributes to the spread of WBD in the area due to some factors that increase the risk of diseases that embody agricultural runoff, washing away of fecal materials into open and surface water sources. In our previous study, we reported some factors that increase the rate of diseases in rainy season these includes blocked drains, increase in precipitation, flooding sewer and compromised the system. Curriero [27] reported floods can increase human susceptibility to pathogens due to the spread of contaminants by floodwaters.

The high risk of WBD as a result of rainfall is an index of water pollution. Shallow well water is contaminated as a result of sinking faecal matter which is carried by flood during a heavy rainfall [7]. Infection with waterborne pathogens has been shown to be higher during the wet season. Thus, the high risk of water-borne diseases during the period of heavy rains is key to higher water pollution. Going by the finding of [28] cholera cases in Ibadan were more common during the rainy season.

Distribution of WBD according to age classification is important as a result of most of the health-related events varies with age. We found that 25-above age groups (especially old people) are more susceptible to waterborne diseases, probably, due to weakened immune systems not competent enough to fight against many infectious agents. The group has inadequate awareness and educational background in reference to diseases in relation to water contamination from direct or indirect sources. Crump [29] support the argument, ignorance on waterborne diseases may additionally play an important role in health awareness in a household.

Children of 0-5 age group are more vulnerable to some waterborne disease due to the weak immune system. Richard [30] reported a number of factors that vary with age behind association with health events such as susceptibility, the opportunity for exposure, the latency of diseases and physiological response which affect the development of diseases.

Gender of the patient is one of the most critical parameters in epidemiological studies and analysis of diseases distribution. We analyzed diseases distribution according to gender specification in which men are at greatest risk of experiencing WBD in Bodinga than women as shown in table (4). Based on our finding, men are prone in almost all diseases with the exception of cholera and skin infection in which women account high cases. This is disagreement with [7] women are more prone to WBD due to their role in water collection, clothes washing and other domestic activities. Men are spending more time in farms which make them at great risk of acquiring the infection as they are exploited surface water for farming activities. An inherent characteristic of people, acquired characteristics, activities and conditions in which they live determine to a large degree who is at risk of becoming more prone to or infected with a particular diseases organisms [30].

The most probable number techniques for estimation of bacteria in water showed that there is a greater concentration of Escherichia coli in MPN/100ml compared to the standard of WHO and National council on water resources [31]. This means water from these sources are unfit for consumption and therefore, the residence of those areas are at risk of being infected with water pathogens. The high occurrence of waterborne diseases in the town is linked to water contamination that might be attributed due to the proximity of households to water sources. During the course of study, the luxuriant grasses have been observed within the premises of water sources attract the domestic animals to visit the area for grazing, **which in turn leave excretes that could be the likely**

main contaminant for the drinking water available in the study area. This is more likely to be rampant in the rural areas since they do not have access to central waste disposal systems and effective monitoring is lacking since the study area is remote.

5.0 CONCLUSION

The finding of the current studies suggests a relationship between waterborne diseases and poor water quality which contributed to the spread of diseases as well as potential causes of microbial pollution to evaluate rural drinking water supply projects in Bodinga town which is possibly due to poor sanitation and hygienic conditions that include contamination of sources and open defection in the area.

The study discovered some common waterborne diseases that communities within the study area are suffering, some of these diseases are contagious causing drastic impact to the human within a short time interval after being contacted with the agent of the disease. Children and male are observed to be more prone to the diseases than their counterpart female and other age categories. A number of factors contributed to spreading of diseases in the area had been mentioned which includes presences of animals, the proximity of households to groundwater sources and agricultural activities which in turn contributed to contamination of waters sources. The data of water quality seemingly suggested the concentration of *Escherichia coli* in **MPN/100ml** which is above the average recommended by both national and international standard for thermotolerant fecal coliform bacteria. The maximum fecal contamination was found in shallow well waters and the lowest concentration in boreholes.

COMPETING OF INTEREST

Authors declared that there is no competing of interest exist.

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Supporting information

Supporting information

Bacteriological analysis	**S1**
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S1 Bacteriological analysis of water

1 Multiple Tube Test

The test comprised of three different steps

Step 1: Presumptive Test

Nine tubes were set up and Label each tube with the amount of water that is to be dispensed into it i.e. (10ml in the first three test tubes, second three test tubes1.0ml, and 0.1ml in remaining 3 test tubes). Shake water sample very well to obtain a homogeneous solution. Using pipette, transfer 10ml of sample to each first three tubes, 1.0ml of water to each of the middle set of a test tube, and 0.1ml to each of the last three tubes. Incubate all the tubes at 35oC for 24 hours. Examine the tubes and record the number of tubes in each set that has gas present. Determine the MPN by referring to MPN Determination Table.

Step 2: Confirmed test

The positive for gas then it's probable that the sample contains coliforms and therefore the confirmed take a look at is completed by vaccinating EMB from a gas positive tube. Inoculate associate EMB plate along with your original sample of water. Incubate at 35^{o}C for 24 hours. Observe plate for coliforms (appear purple colonies with dark centers), *E. coli* appear green sheen. Step

Step 3: Completed test

Coliform colonies from EMB were inoculated again into Lactose Broth with a Durham tube and checked for gas, and inoculated on NA and checked through Gram stain for Gram-negative reaction. If these tests are positive it shows that coliforms (not another gas producer) are present and indicates that the water sample was contaminated.

References

32. Cheesbrough M., 2006. *District Laboratory practice in tropical countries*. Part 2. Cambridge University press U.K. 149-154.
33. American Public Health Association (APHA). *Standard Methods for the Examination of Water and Waste Water*. American Workers Association Water Environment Federation Edited by Arnold E. Greenberg, Lenore S. Clesceri, and Andrew D. E., 1992. APHA 1015 Fifteenth Street, NW Washington, Office of Ground Water and Drinking Water 200 Pennsylvania Avenue, NW Washington, DC 20460 EPA 816-K-02- 003. 9-53.

Table S2: Monthly distribution of waterborne diseases

The result of waterborne distributions in Bodinga in relation to the months and presenting total number of cases account to each particular diseases identified in the area. These were counted from the outpatient register in the health and record department of hospitals in Bodinga town.

	Waterborne diseases						Total
	Typhoid	Dysentery	Diarrhoea	Cholera	Gastroenteritis	Skin infection	
January	20	35	4	0	11	0	70
February	17	30	7	1	28	3	86
March	18	31	2	1	23	0	75
April	18	20	6	3	27	0	74
May	32	33	4	1	10	0	80
June	74	78	19	6	7	5	189
July	31	38	4	20	13	7	113
August	60	86	17	1	44	6	214

	September	34	59	7	0	25	2	127
	October	19	43	16	1	7	2	88
	November	29	33	7	2	2	4	77
	December	23	31	12	0	5	7	78
Total		375	517	105	36	202	36	1271

Table S3: Different mean and SE, Frequencies and percentages of some selected waterborne diseases

The values of frequency, percentages and mean average and standard error difference of waterborne diseases.

Waterborne diseases	Frequency	Percent	Mean ± Std. Error [a]
Typhoid	375	29.5	6.86± .151
Dysentery	517	40.7	6.87± .136
Diarrhoea	105	8.3	7.52± .304
Cholera	36	2.8	6.61± .302
Gastroenteritis	202	15.9	5.72± .210
Skin infection	36	2.8	8.31± .479
Total	**1271**	**100.0**	**6.77± .085**

a- The average mean value and standard error of waterborne diseases

Table S4. The average value of feacal contamination of drinking water

Villages	Source Name	n	Ave	Stdv	Permissible limit **WHO[a] /NCWR[b]/100ml**
Bodinga	Borehole	10	210.4	322.14	0
	S. well[c]	10	73.2	61.73	0

Danchadi	Borehole	10	160.7	158.08	0
	S. well	10	35.1	39.90	0
Takatuku	Borehole	10	142.5	127.60	0
	S. well	10	53.9	44.37	0

S. well = Shallow well, Ave. = average, Stdv = standard deviation; WHO = World health organization, NCWR = National council on water resources.