Flood Hazard and Its Associated Health Impacts in Limbe Health District, Cameroon

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Summary

BACKGROUND

Floods make up 12 % of all natural hazards that occur yearly in Cameroon. The city of Limbe has been experiencing floods since 1999 due to rapid economic and population growth. This study sought to determine the following: 1) the trend in the prevalence of malaria, typhoid and diarrheal diseases; 2) the factors that increased community vulnerability to these diseases, and 3) the community's knowledge of the post-disaster health risks of floods.

MATERIALS AND METHODS

A retrospective cohort study, which involved a review of outpatient department (OPD) registers from 2005 to 2016, was used to collect secondary data for the diseases. A cross-sectional study that made use of questionnaires (384) and Focus Group Discussion with major stakeholders (50 people) was used to collect information needed to determine the underlying causes of the health hazards and understand the community's perception of floods.

RESULTS

The 2005 to 2016 trend in disease prevalence was 36-28 % for malaria; 1.1-4.4% for typhoid and 6.9-3.8% for diarrheal diseases. There was an unusually high prevalence of these diseases in 2005 and 2013, which corresponded to periods of flash flood occurrences. Flood frequency, delay in waste collection, absence of adequate toilet facilities and proximity to a river were the main determinants of the diseases ($p<0.05$). Heavy rainfall (44%), lack of drainage facilities (34%) and blockage of drains (18%) were the main causes of floods. The extent of damage was more to households (personal belongings: 95 %); agricultural land (55%) and lives (18%).

CONCLUSION

A significant number (68%) of houses in the study site were located in flat areas/swarms, which increased their exposure to floods. Findings from this study revealed that exposure to flooding will affect the burden of malaria, typhoid and diarrheal diseases. The principal factor responsible for the spread of these diseases is flood with a direct link to heavy rainfall.

Keywords: *Limbe, Flood Perception, Malaria, Typhoid, Diarrheal Diseases*

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Introduction

Floods are the most costly and wide-reaching of all natural hazards in both developed and developing countries. They are responsible for up to 50,000 deaths and adversely affect some 75 million people on average worldwide every year [1]. The July 2021 floods in Germany caused over 180 deaths affecting over 40,000 people [2]. In 2011, the USA alone recorded 3 separate historic floods [3]. From 1986 to 1995, flooding accounted for 31% of the global economic loss from natural catastrophes and 55% of the casualties [1]. The damaging effects of flooding are likely to become more frequent and more serious in the future.

For health purposes, floods are defined as scientific thresholds, descriptions of population effects and temporal perspectives [4]. They are also classified according to cause (high rainfall, tidal extremes, and structural failures) and nature (regularity and speed of onset) [3] [5]. In flood conditions, there is a potential for an increase in faecal-oral transmission of diseases (e.g. cholera, diarrhoea, typhoid, dysentery etc.), especially in areas where the population does not have adequate facilities of sanitation [6] [7] [8] [9] [10] [11] [12] [13]**.** Health is usually the first concern, followed by social and economic welfare [4].

Africa has been identified as one of those parts of the world most vulnerable to the impacts of climate change and its extreme weather events [14]. In early February 2000 due to climate change, exceptionally heavy rains with a return period of 200 years occurred over Mozambique and caused severe flooding that left over 700 people dead, and half a million homeless and also resulted in the outbreak of diarrheal diseases [15]. A similar phenomenon reoccurred in Sofala Province in March 2019 in the Central Region of Mozambique [16] where strong winds from Cyclone Idai caused extensive flooding that resulted in a massive loss of life (> 600 deaths with 1600 persons injured) and a cholera outbreak. Apart from the immediate health impacts of floods like drowning, floods usually give birth to more breeding grounds for mosquitoes which increases the risk of transmission of water vector-related diseases like malaria [17] [18]. Malaria remains a big public health problem in Sub-Saharan Africa where young children are the most vulnerable causing one in five childhood deaths [19] [20] [21] [22].

Floods make up 12 % of all natural hazards that occur yearly in Cameroon [23]. In 2012, the estimated number of flood-displaced people in Northern Cameroon reached 88,640 [23]. Malaria is endemic in Cameroon with a prevalence rate of 29 % accounting for more than 50% of morbidity among children under the age of five [24] [25]. Annual reports from the Ministry of Public Health suggest that the diagnosis of typhoid fever is becoming more and more frequent in health facilities resulting in a public scare [26] [17]. Diarrhoeal diseases kill more young children than Acquired Immunodeficiency Syndrome (AIDS), malaria and measles combined [27] [21]. In Cameroon, the prevalence of diarrheal diseases stands high at 23.8% and children under 24 months are highly affected [28] [24].

Limbe, like most cities in Africa, is experiencing rapid economic and population growth due to urbanization. Settlement in this city is characterised by spatial disorganization of houses [10] [11] [29] [30] in low-lying areas (along channels of surface water run-off) and steep hill slopes [18][31][20][32] made up of loose volcanic soils that easily disintegrate after absorbing rainwater causing landslides and flooding [20] [32] [22] [33] [25] [10]. From 1999 to the present, about 100 homes are flooded with at least one death. In some years as in 2001, 2007, 2013, and 2018 the situation became so critical that it required national emergency alerts. The worst was in 2001 when floods and landslides killed over 24 persons, displaced more than 2800 people and destroyed social amenities [13] [29]. Over 197 cases were reported for post-disaster-related illnesses [34] and wounds of which 82 were reported at the Limbe District Hospital alone. More than 80% of the population of Limbe is at risk of floods and landslides hazards and no data was found on the burden of these diseases associated with floods in this health district.

This study, therefore, sought to review clinical data on malaria, typhoid and diarrheal diseases (dysentery, cholera and paratyphoid fever) cases in the Limbe Health District and determine: **1)** the trend in the prevalence of these diseases correlating this with the years in which floods occurred; **2)** the factors that increase the vulnerability of the community to these health hazards, and **3)** the community's knowledge on the post-disaster health risks of floods.

Materials and Methods

The study was designed to make use of workshop findings (focus group discussions), and questionnaires and to integrate hospital data for the selected diseases collected from recognized health facilities within the Limbe District between the periods of 2005 to 2016. The target population included people of the age group from 18-78 years. The focus was to evaluate the health impacts of floods on the population living within the Limbe Health District in the South West Region of Cameroon.

Study area

The Limbe Health District is found in the city of Limbe within the coordinates 4°01′N 9°13′E, with a population of approximately 120,000 inhabitants (Fig. 1). It has a surface area of 545 km^2 and a population density of 220 people per km^2. The city is characterized by a low-lying coastal plain, rising to a chain of horseshoe-shaped hills with slopes of varying intensities, with the highest points reaching 362 m above sea level. The area exhibits the characteristics of the Gulf of Guinea's tropical equatorial climate of hot, moist, and dry conditions. It is located about 16 km from Debundscha which used to be considered the second wettest place in the world after Cherrapunji in India [28] [24]. Limbe experiences very heavy torrential rains during the long rainy season (March-October) with the highest average monthly precipitation of about 700 mm recorded in June, July and August [35] [12], with an annual rainfall of 2000 mm and peak average rainfall of 3000 mm [36] [26]. Within the city, small streams flow into larger drainage streams that converge into two main rivers (Limbe and Jenguele) that empty into the Atlantic Ocean. These rivers frequently overflow their banks during the rainy season causing floods in the low-lying areas that are just 1–2 m above sea level. These are ideally the best parts for settlement but unfortunately properly conceived drainage channels have not been constructed in this area [22] [33].

Study design

The study made use of the transdisciplinary research approach. From its conception and design phase, focus group discussion sessions were held with scientific (environmental and earth scientists, medical personnel and sociologists) and non-scientific (mayors, media, traditional rulers, religious, civil protection, local community members) stakeholders in the community. From these discussions, the research questions and objectives used in this study were developed.

Ethical clearance to conduct this study was obtained from the institutional review board of the Faculty of Health Sciences, University of Buea while the administrative authority to conduct the study was obtained from the Dean of that Faculty. A second authorization was collected from the Regional Delegate of Public Health for the South West Region required to collect hospital data from the District Medical Officer (DMO) in Limbe and the directors of all the sampled hospitals.

Focus group discussions

Focus group discussions were organized in the form of workshops. The first workshop was held in Limbe city in August

2017 with major scientific and non-scientific stakeholders. The non-scientific stakeholders included the Municipal Government Delegate and Mayors, religious, civil protection, local and traditional rulers and their counsellors, media personnel and representatives from all other works of life operating within the Limbe District. The discussion centred on: 1) causes of floods and waste disposal practices; 2) health implications of floods and coping strategies for flood hazards and 3) human reactions/perception of floods. The second focus group discussion which took place in 2019, released findings from the study conducted to the stakeholders and proposed a way forward.

Data collection using questionnaires

Here a cross-sectional study was also carried out to collect information to determine the underlying causes of the health hazards, understand the community's perception of floods and their proposed measures to mitigate or prevent the post-disaster health risks of floods. In each of the four selected health areas, two communities were selected using simple random sampling and 50 households were randomly selected from the communities. The inclusion criteria included: heads of households who have been living in Limbe for the past 11 years; traditional rulers and their assistants. Traditional rulers (Chiefs) and their subordinates were targeted to get information on how they managed flood disasters using indigenous knowledge and traditional methods.

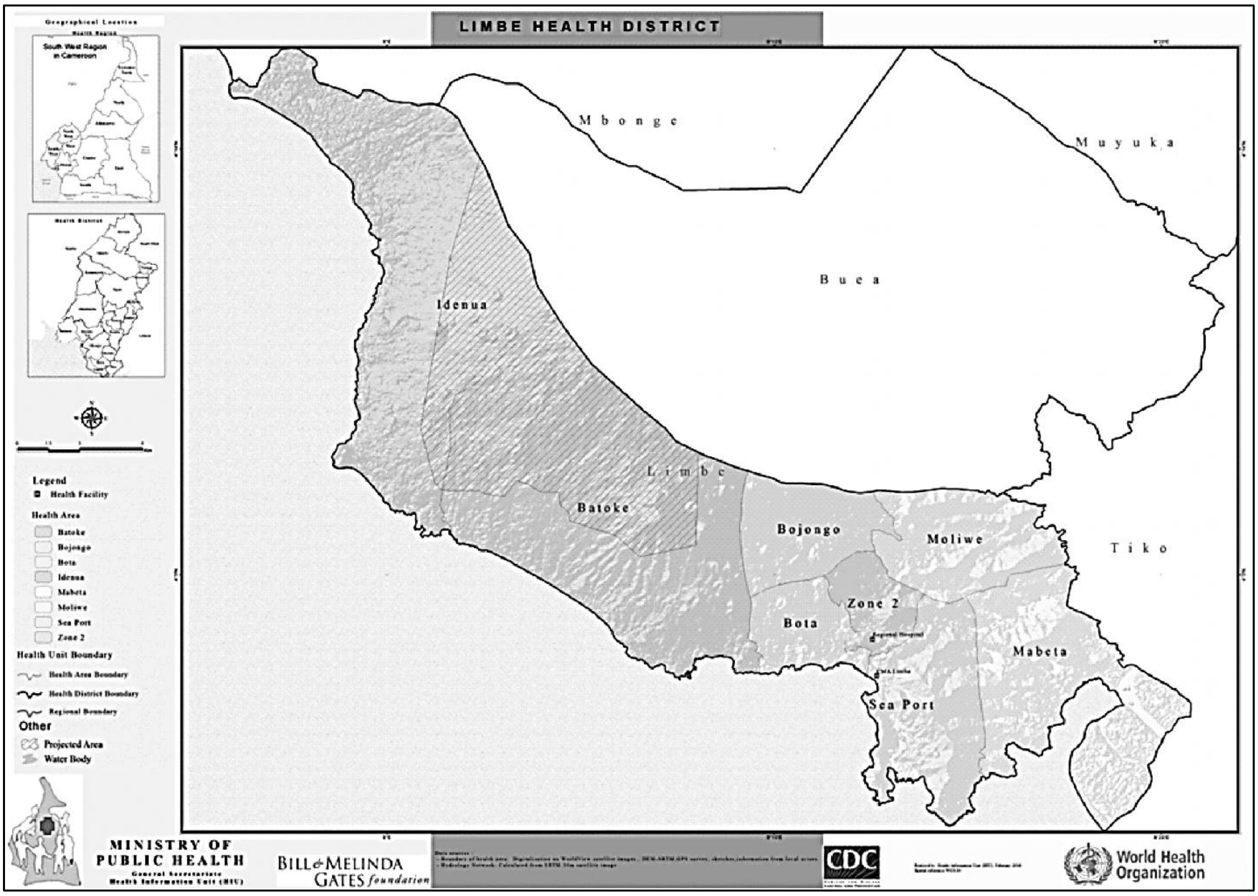

Figure 1:
Limbe Health District Map (shaded area)

The research targeted both males and females living within the area. The officials of the Limbe City Council, Government delegates to the Limbe City Council, Mayors and their deputies were also purposively included in the study to enable us to know the measures that have been implemented to prevent or mitigate health hazards associated with floods.

Following the 2010 census results, Limbe city and environs host a population of ~ 120,000 people [29] [30]. In the sample size determination, assuming a precision of 5% and the Limbe Health district population of 120,000 [29] [30], the estimated sample size for the household survey using the Slovene formula was:

$$n = \frac{N}{1 + N(e)^2}$$

Where n = Minimum sample size.
N = Population of Limbe Health District
e = Precision = 5% (Conventional)

$$n = \frac{120000}{1 + 120000(0.05)^2}$$

n = 398.67 (approximately 400)

However, just 384 respondents participated fully in this study. A unique identifier number was written on the door of each household that participated in the survey. Data collected on the questionnaire was entered at the end of each working day into a form designed on epi info version 7, later exported to Excel and imported to SPSS Version 21 for formatting and analysis. Pretesting of the questionnaire was done in the Konye Health District, situated 50 km from Limbe in the South West Region to avoid bias. This Health District has an undulating topography of hills on the Northern and Western sides and level lands on the South and eastern side, watered by the Mungo, Mengeh, Moke and Nyale rivers that run through its frame and physical space. The sensitive zones are Dikome, Konye, Kokaka, Matoh, and Ikiliwindi which have swamps, and Mbakwa Supe and Kurume which has flood zones and steep slopes. The high annual rainfall of 3000 mm – 4000 mm here puts these areas at risk of floods and landslides as is the case in the city of Limbe [10] [11].

Extraction of hospital data

This phase entailed a retrospective cohort study, which involved a review of outpatient department (OPD) registers and the weekly/monthly epidemiological report forms for disease surveillance used to collect secondary data on the number of malaria, typhoid and diarrheal disease cases. Hospital data were collected and recorded in a pre-designed form and confidentiality was maintained using ID codes to replace the names of the patients.

As inclusion criteria for the collection of health data for the identified diseases, health centres which existed before 2005 and were still functioning were chosen, whereas Health centres or hospitals created after 2005 were excluded. Four out of the eight health areas in the Limbe health district were also purposively selected because of their proximity to the sea. Using these criteria, health data on malaria, typhoid and diarrheal diseases was collected from all hospitals in Batoke, Bota, Idenau and Down Beach because inhabitants of these areas are closest to the sea, thus exposed to flood hazards. The Regional Hospital in Mile One, Limbe was also selected because of its capacity to handle complicated cases of diseases (Fig. 2). Hospital data collected was summarized at the end of each working day. The number of malaria, typhoid and diarrheal cases reported to the hospital were plotted on a line graph to show their trends. Pearson Chi-Square analysis was also done to determine the underlying factors related to the post-disaster health risk of floods.

Results

Flood hazard perception

Taking household frequency of floods in a year, of the 384 households sampled, almost all the houses 328 (85.4%) had their homes flooded at least once in a year while only 56 households (14.6%) have never experienced a flood within a year. The statistical data on flood hazards showed that many factors are responsible for this natural phenomenon as reported in Table 1.

Findings from the first workshop held with major stakeholders in Limbe city identified three main factors to be the cause of floods: 1) destruction of water pipes by road construction companies in the 90s. The Germans built these pipes during the colonialization period to channel water from the city into the ocean. 2) Infrastructural development and expansion of agricultural activities in restricted zones, which resulted in blockage of natural drainage. Lastly, 3) poor waste disposal practices by the community in general especially those living on topographic highs (dump waste in rainwater during heavy rainfall). The sampled population during the questionnaire survey thought that floods are caused by three major factors: heavy rainfall, lack and blockage of drainages (Table 1). However, some of the inhabitants attributed this phenomenon to witchcraft with some expressing ignorance. In terms of health impacts, the workshop participants cited the prevalence of diseases such as malaria (as stagnant waters breed more mosquitoes), athlete's foot (victims trapped in flood waters in homes for weeks), skin diseases (those confined in homes) and water-borne diseases (typhoid, dysentery, diarrhoea, cholera). Most of the questionnaire sampled participants (79.9%) were aware of the health impacts of flood hazards and believed both floods and their associated diseases can be prevented.

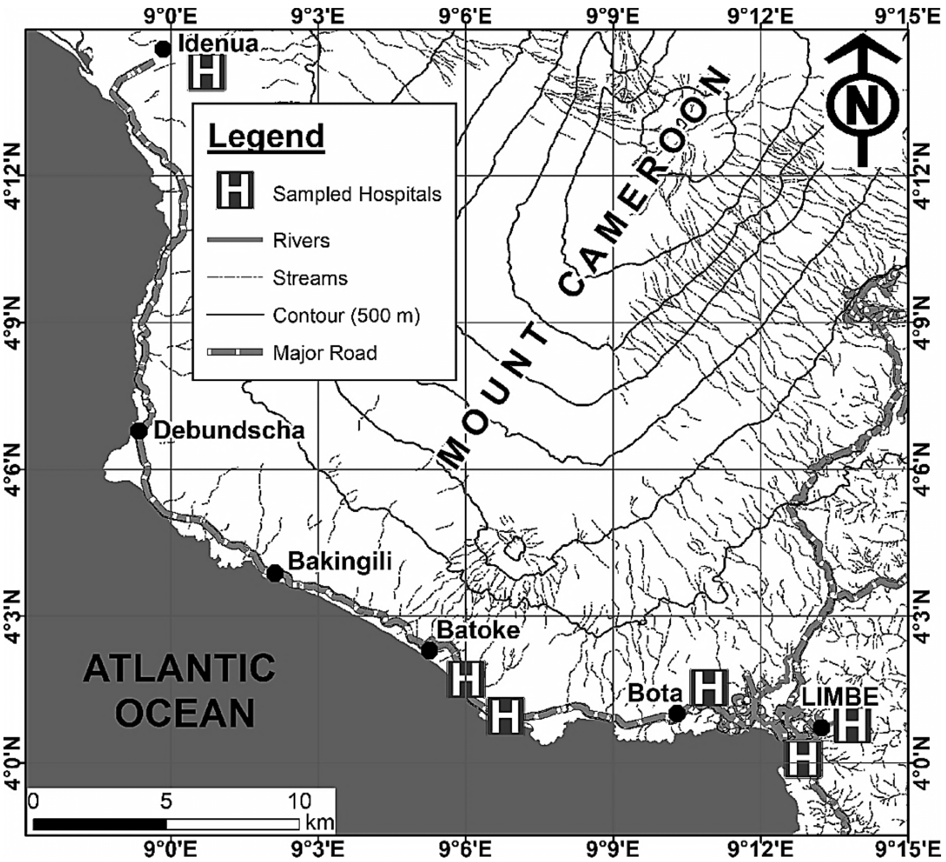

Figure 2:
Map Showing the Distribution of Sampled Hospitals in the Limbe Health District

Physical and environmental factors influencing exposure to the post-disaster health risk of floods

The physical factors that influenced exposure to post-disaster health risks from floods investigated in this study included house type; proximity to water sources; topography and the presence of gardens (Table 2). The study revealed that 65.1 % of the sampled houses were built with reinforced concrete, with a significant number (130 houses; 33.9 %) built with softwood. One hundred and forty-five (37.8 %) of these houses were built within 100 m of surface water sources (river, stream or ocean). A significant number (68 %) of these houses were located in flat areas and swarms below sea level, thus increasing exposure to floods. The remainder of the houses (32 %) were found on slopes, which are prone to sliding during flooding events (Table 2). Close to half (49.2 %) of these houses hosted vegetable gardens.

Social factors influencing susceptibility to flooding hazards

The social factors investigated in this study included: access to drinking water; availability of drainage facilities and household disposal waste practices (Table 3). A significant population of the respondents (93.8%) had access to pipe-borne water (Table 3); had manageable drainage systems that collect water and transported it away from their surroundings (72.1%) and disposed of their waste at HYSACAM (waste company in the area) collection points (82.8%).

Table 1:
Causes of Floods within the Limbe Health District area

Causes of flood	Frequency	Percentage (%)
Heavy rainfall	320	44%
Lack of drainage	257	35%
Blockage of drainage	134	18%
Witchcraft	17	2%
No idea	5	1%
Others	2	0%
Total	**735**	**100%**

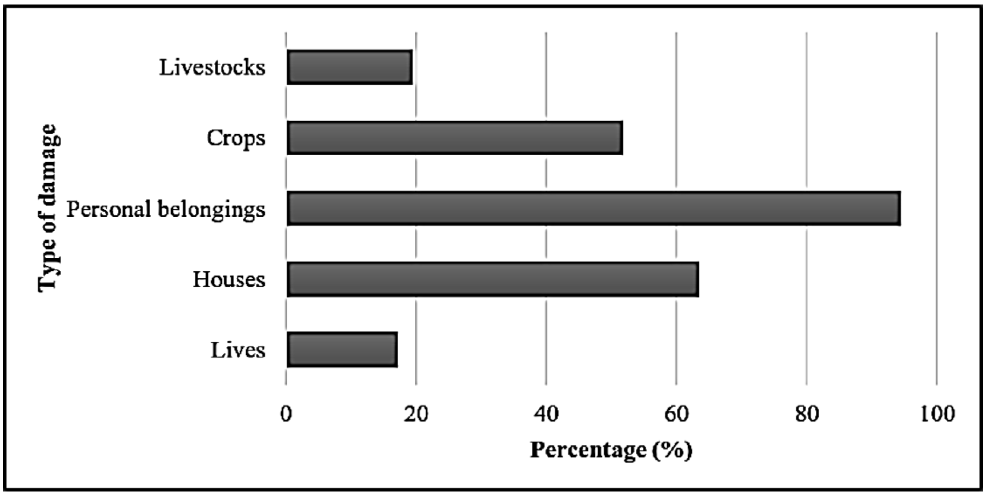

Figure 3:
The extent of flood damage as reported by households

Relationship between age group, education level and awareness of health risk

There was a significant relationship between age group and disease awareness ($\chi 2$ = 13.252, P = 0.039) (Table 4). The majority of the respondents who are aware of the post-disaster health risk of floods are in the 28-37 age group. There was also a significant relationship between education level and awareness ($\chi 2$ = 24.846, P = 0.002). As the educational level increased, awareness also increased.

Trends in disease prevalence (2005 to 2016)

The prevalence of malaria in the Limbe Health District ranged from 36 % in 2005 to 28% in 2016, with a high prevalence of 34.6 % in 2013 (Fig. 4). The prevalence of typhoid also ranged from 1.1 % in 2005 to 4.4 % in 2016 with a high prevalence of 13.3 % in 2013. Diarrheal disease prevalence ranged from 6.9 % in 2005 to 3.8 % in 2016 with a high prevalence of 10.3 % in 2013. The year 2013 corresponded to the year when there was a flash flood in the city of Limbe (Fig. 4).

A comparative analysis of the monthly trends of malaria, typhoid and diarrhoeal diseases for the periods: 2012, before the 17th July 2013 floods, during and after the flooding event (2014) is presented in Fig. 6a-c. A high malaria prevalence of 47.4% was recorded in March 2012, 63.2 % in July 2013 and 30.9 in January 2014 (Fig. 5a).

The statistics for typhoid showed significant highs and lows recorded in different periods from 2012 to 2014 (Fig. 5b). The observed trend for diarrhoeal diseases from 2012 to 2014 is similar to that of typhoid (Fig. 5c).

Table 2:
Physical and Environmental Factors Exacerbating Post Disaster Health Risk From Floods

Physical/Environmental Factors	Variable	Frequency	Percentage (%)
House Type	Reinforced Concrete	250	65.1
	Wood (‘carabout’)	130	33.9
	Mud	4	1
Proximity to River/Stream/Ocean	< 100 m	187	48.7
	100-300 m	145	37.8
	> 300 m	52	13.5
Topography	Flat area	261	68
	Slope	123	32
Gardens	Present	189	49.2
	Absent	195	50.2

Table 3:
Social factors influencing susceptibility to flooding hazards

Social Factors	Variable	Frequency	Percentage (%)
Access to potable water	Pipe borne	360	93.8
	River	4	1
	Spring	14	3.6
	Hand-dug well	6	1.6
Availability of drainage systems	Present	277	72.1
	Absent	107	27.9
Household Waste Disposal Practices	HYSACAM	318	82.8
	Open Dumps	48	12.5
	Streams/Bushes	18	12.7

Factors associated with malaria, typhoid and diarrheal diseases

The result of this survey showed that surviving victims of the Limbe floods suffered from several diseases during and after a flood event. These included: malaria, typhoid, diarrhoea, cholera and pneumonia. Malaria disease accounted for about 30% of health problems in the flood victims followed by diarrheal diseases with 8%, cholera at 6%, typhoid at 5% and pneumonia at 2% (Table 5). However, over 50% of health cases were not properly diagnosed probably because routine medical check-up is not a common practice in the country and as such there are many diseases that the inhabitants prefer to handle using traditional medicine.

Statistics show that the prevalence of these diseases has fluctuated over the years with a decrease from 2004, followed by a gradual rise in 2007, having a peak in 2013 (Fig. 3). According to these statistics, malaria disease has been most common during the wet season. Meanwhile, the spread of other diseases like typhoid and diarrhoea has a link to the infiltration and contamination of ground and surface water resources, foodstuffs, crops, air, and the body of the victims.

Table 4:
Relationship between Disease Awareness, Age Group and Educational Level

		Disease awareness				
		I don't know	No	Yes	$\chi 2$	**P value**
Age group	18-27 years	10 (7.9)	11 (8.7)	106 83.5)	13.252	0.039
	28-37 years	13 (7.7)	20 (11.9)	135 (80.4)		
	38-47 years	5 (8.3)	7 (11.7)	48 (80.0)		
	48 + years	8 (27.6)	3 (10.3)	18 (62.1)		
Education Level	No formal education	4 (17.4)	4 (17.4)	15 (65.2)	24.846	0.002
	Primary	11 (19.6)	7 (12.5)	38 (67.9)		
	Secondary	20 (8.8)	28 (12.4)	178 (78.8)		
	University	1 (1.9)	2 (3.8)	49 (94.2)		
	Vocational	0	0	27 (100)		

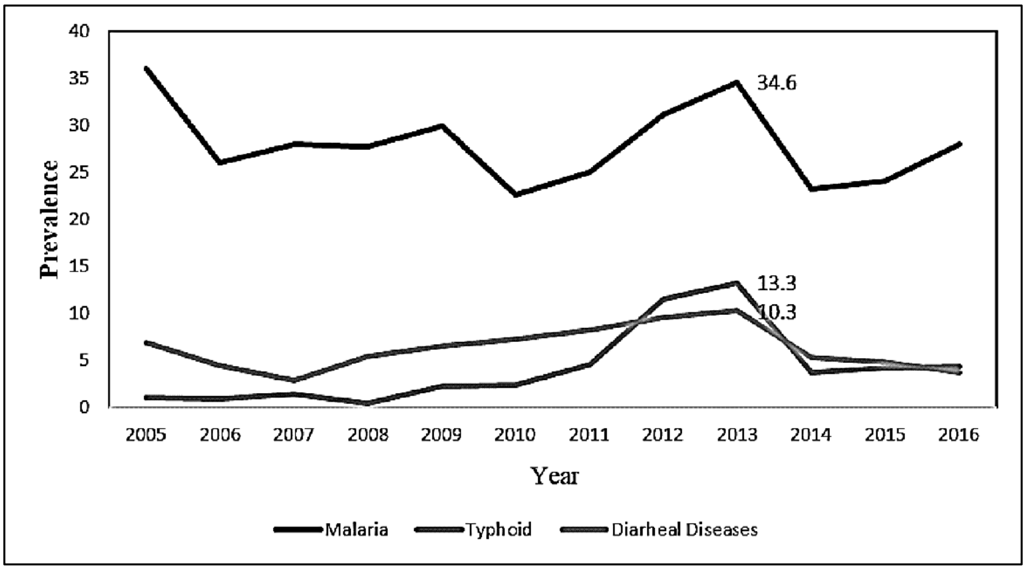

Figure 4:
The trend in the prevalence of Malaria, Typhoid and Diarrheal diseases from 2005-2016 in the Limbe Health District

Disease prevalence in flood-prone areas is influenced by flooded water and sometimes other related human-induced causes. In the Limbe area, human activities like irregular waste collection, poor toilet facilities, and the proximity of households to surface water bodies showed a strong effect on the prevalence of disease during flood periods. In this survey, diseases like typhoid and diarrhoea increased during flood periods, especially among victims living in dirty environments associated with poor toilet facilities and surrounded by streams and rivers. The test results show that aside from the frequency of floods, households situated <100 m close to a water source (river, stream or ocean) are more vulnerable to malaria disease than those whose houses are further away from the surface water bodies and probably due to the stagnated water that stayed behind after the floods water recessed (Appendix 1).

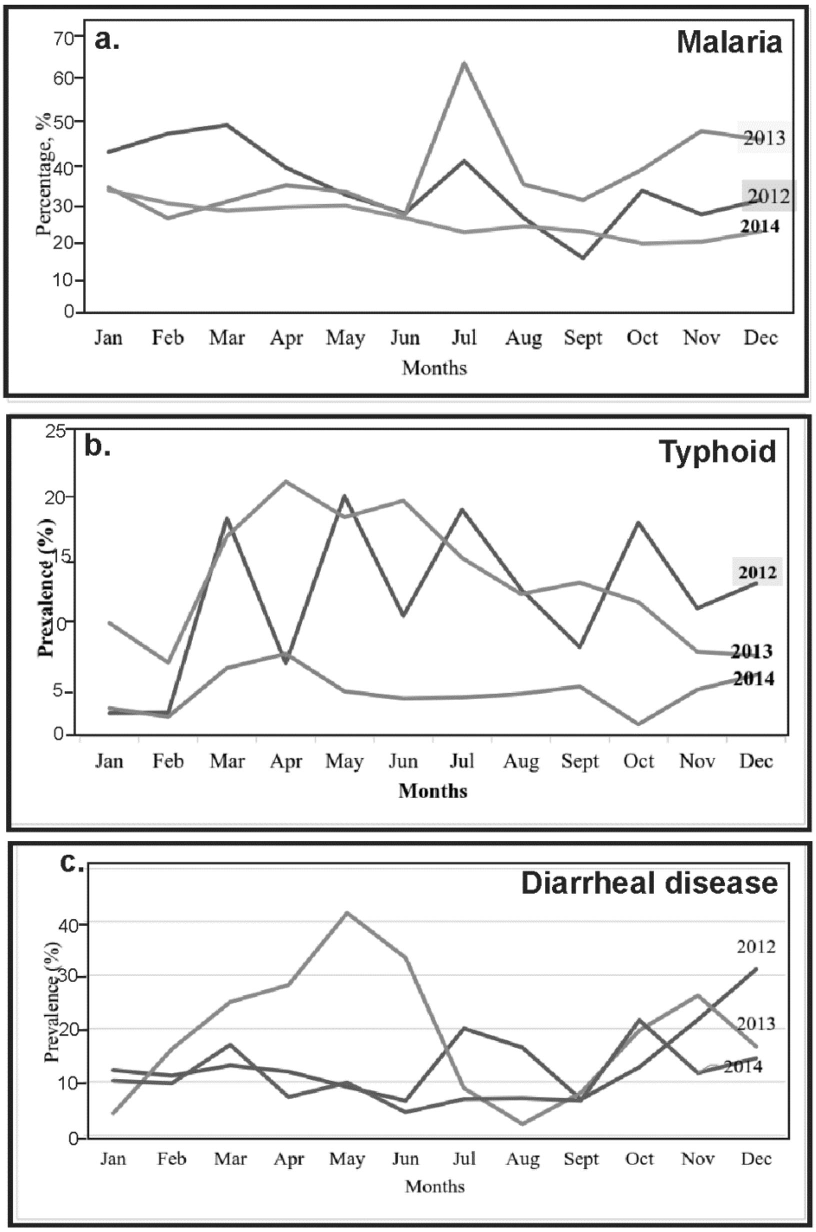

Figure 5.
The trend in the monthly prevalence of a) malaria, b) typhoid and c) diarrheal disease before, during and after the July 2013 flash flood in Limbe.

On the other hand, typhoid and diarrheal diseases show an increase in vulnerability in residents living 100 m close to surface water bodies, residents with poor toilet facilities and areas with delays in waste collection as indicated by the test results p-values <0.05 (Appendix 2).

Discussion

Malaria, typhoid and diarrheal disease prevalence and flooding

In this study, we established the trends in the prevalence of malaria, typhoid and diarrheal diseases from 2005-2016 which was characterised by a very high number of patients diagnosed with these diseases during and immediately after periods of floods in the city of Limbe. The overall trend in the prevalence of malaria showed a decline from 36 % in 2005 to 28 % in 2016. This trend is in line with the WHO 2016 World Malaria report for Cameroon [37] [34] as well as the Cameroon Ministry of Public Health monthly diseases surveillance report [38] [27]. However, the 36 % prevalence in 2005 is relatively higher than the expected malaria prevalence range of 25-35 % in malaria-endemic areas in Cameroon [39] [28]. This high prevalence can be attributed to the flash floods that hit the city of Limbe seasonally. The trend also shows a peak prevalence of 34.6 % in 2013. This sharp rise coincides with the 2013 flash flood that occurred in the Cassava farms, Mbonjo, Motowo and Jengele areas in the month of July killing one person and destroying many properties [39] [28]. The trend shows a huge decline in 2014 when the Ministry of Public Health subsidized the treatment for malaria and made it free for children 0-5years old and for pregnant women to combat maternal and infant mortality [39] [28].

During a flood, all breeding sites of mosquitoes are swept away by the floodwaters. However, immediately after the floods, the remnants of the water are found everywhere and in all holes. This increases the breeding sites of mosquitoes and hence malaria transmission [40] [35]. The high prevalence of malaria after floods observed in this study is consistent with results obtained from a similar study conducted in a hospital setting in South East of Asia immediately after a flood [41] [36] and in a long-term retrospective study conducted years after floods [42] [37].

At the level of the household, more males (33.6%) had malaria when compared to females (26.4%). This is in line with a study carried out in Ethiopia [43] [38] from a ten-year trend in malaria cases which showed that males (52.7%) were more affected than females (47.3%). The results are also in line with results obtained from a longitudinal cohort study carried out in 2014 in the North West Region of Cameroon where an almost equivalent prevalence of 30.9 % was recorded for males with 29.2 % for females, with the males being at a higher risk of contracting malaria than females (OR=1.08) [44] [39].

Table 5:
Statistical data on the prevalence of different diseases during flood period in the Limbe area

Health Consequences	Frequency	Percentage (%)
Cholera	43	6
Typhoid	41	5
Diarrhoea	61	8
Malaria	229	30
Pneumonia	15	2
Others	384	50
Total	**773**	**100**

This might be attributed to the lifestyle of males who are more active struggling to meet up with the demands of life and the restricted access for women to access health care as stated by WHO [45] [40].

The trend in typhoid prevalence in this study showed an increase from 1.1% in 2005 to 4.4% in 2016, with a peak prevalence of 13.3% in 2013 which is more than five times higher than the 2002 estimated prevalence of 2.5% in Cameroon [46] [41]. The high prevalence of 13.3% in 2013 corresponds to the 2013 flash floods in the city that affected several communities.

Diarrheal diseases in our study constituted dysentery, cholera and paratyphoid fever. This disease according to WHO is the second leading cause of death in children under 5 years [44] [39]. The results show a decline in the prevalence of diarrheal disease from 6.9 % in 2005 to 3.8% in 2016 with a peak prevalence of 10.6% in 2013 which corresponds to the year a flash flood occurred in the city of Limbe [47][42]. This prevalence range of 6.9% to 3.8% is relatively lower than the results obtained in a study carried out in the Northern Zone of Cameroon in 2012 where a 13% prevalence of diarrheal diseases was reported [48][43]. This percentage difference affected is because the 2012 study in the Northern Zone of Cameroon was conducted mainly on children below 5 years and diarrheal diseases disease affects this age group the most. The results suggest that flash floods would cause more diarrheal disease cases, which is consistent with findings observed both in underdeveloped and developed countries. A study in Texas, USA, found that people in flooded areas were more likely to suffer from diarrheal diseases than those in non-flooded areas (OR = 10.8, $p < 0.01$) [49] [44]. Another study conducted in Germany also suggested that contacting the floodwater was a major reason for diarrheal diseases (OR = 5.8, 95% CI = 1.3–25.1) [49] [44]. A survey on impacts of the tropical storm Alison discovered that diarrheal diseases was significantly correlated with people living in flooded areas (with OR = 6.2, 95% CI: 1.4–28.0) [50] [45]. People in flooded areas are significantly correlated with increased incidences of gastroenteritis during floods (RR: 1.7, $p < 0.05$) [51] [46]. The results from this study are also consistent with some studies carried out in China. In Qingdao, floods are positively associated with bacillary dysentery incidences (RR = 1.42, 95% CI = 1.22–1.64) [52] [47]. Another study showed that the RRs of floods on bacillary dysentery were 11.47 (with 95% CI: 8.67–15.33), 2.75 (with 95% CI: 1.36–4.85) and 1.35 (with 95% CI: 1.23–3.90) respectively in Kaifeng, Zhengzhou, and Xinxiang in Henan Province [53] [48]. Compared to these studies conducted in China, America and Asia, our study area is located in Limbe, Cameroon and has quite different climatic, social and economic conditions with similar results still obtained. These findings indicate that floods could be an independent risk factor for diarrheal disease incidences after the adjustment of potential confounders.

A study conducted by WHO [54] [49] showed that about 20 % of the drinking water samples collected during flood periods were contaminated with *Shigella*, *Vibrio cholerae*, *Salmonella*, *Staphylococcus aureus* and other pathogens. This means the risk of water-borne diseases may increase because of water contamination during flood periods [55] [50]. This is specifically tied to heavy rains. There are several possible ways by which heavy rainfalls during floods might influence water pollution and increase the incidence risk of typhoid and diarrheal disease. During floods, excessive rainfall is more likely to cause the risk of overflows in sewers [56] [51], which move pathogens into wells, rivers, springs and seas. More extreme rainfalls will increase disorders and cause sediment re-suspension, scattering the accumulated pathogens [55] [50]. Also, more animal excreta and manure on the surface of soil or subsurface will be run off, which might form more pathogens on the surface of the waters. Consequently, severe floods after extreme precipitation would worsen water quality via diverse means and increase the risk of waterborne diseases [40] [35]. The Limbe health district area is known for its high rainfall during the wet season that spans from March to October with monthly rainfall frequency measuring up to 500 and 1000 mm [57] [52]). This part of the country falls within the wet tropical climate making torrential annual rainfall inevitable.

Factors increasing vulnerability to the post-disaster health risk of floods

Results from this study show that 79.9% of all study participants were aware of the post-disaster health risk of floods, 83.7% were aware of one or more causes of floods and 66.1% believed health hazards associated with floods can be prevented. Good knowledge of the causes, transmission and health impacts of flood hazards helps reduce the susceptibility, and exposure and build resilience to floods [58] [53].

For malaria, those who have experienced a flood or who have had their homes flooded at least once in a year are at an increased risk of developing malaria ($p = 0.029$, COR = 4.75 95% C.I: 0.18-0.80) and are 4.75 times at higher risk of developing malaria than those who have never experienced a flood or have their homes flooded. This factor was also statistically significant for typhoid and diarrheal diseases ($p = 0.024$) and proved that those who have never experienced a flood have a reduced risk of developing typhoid and diarrheal diseases. These results are consistent with findings from a study in China that confirmed that flood frequency affects the occurrence of diseases [50] [45].

Furthermore, the closer a house is (< 100 m) to a river, the greater the chances of developing malaria, typhoid and diarrheal diseases during or after a flood. This factor was statistically significant for malaria ($p = 0.03$, COR = 5.0) and also significant for typhoid and diarrheal diseases ($p = 0.018$). This result is consistent with those obtained in Nigeria in 2007 [59] [54], and Germany in 2006 [60] [55] where it was established that the closer a house is to a river source, the higher the chances of inhabitants being infected with communicable diseases during heavy downpour or floods.

This study showed that the presence or absence of a toilet facility was statistically highly associated with the occurrence of typhoid and diarrheal diseases after a flood ($p = 0.001$). This is confirmed by a study carried out in Bangladesh, where it was observed that unsafe food after a flood due to contamination of water sources from destroyed sewage systems was one of the main causes of diarrheal diseases [61] [56]. Another 6-year cohort study carried out from 2004 to 2010 in China confirmed that floods empty and destroy sewers which contaminate water sources increasing the transmission of water-borne diseases [56] [51].

Our study found that a delay in the waste collection was statistically significant with the occurrence of typhoid and diarrheal diseases ($p = 0.003$). This result is in line with those obtained from a study carried out in 2007 in China [62] [57]. The authors confirmed that large amounts of waste are being generated during floods which contaminate water sources and increase the risk of waterborne diseases [62] [57]. Another study carried out in 2009 in Nigeria [63] [58], found that the infrequency of the solid waste collection increases the transmission of waterborne and vector-borne diseases after heavy rainfalls and floods. It is a fact that the longer waste stays in collection containers, it starts to decompose, creating a very favourable environment for the growth of bacterial and parasites which are being dispersed during floods into homes, food reserves and drinking water sources, contaminating them and causing many health problems [64] [59].

It has been observed in the past that, waste management in this area was very poor and uncontrolled. Some of the common practices include the roadside open dumping of waste and also within the gutters. The waste is often carried by runoffs and spread on the road, and households and also blocking the waterways normally being dumped at any corner of the road or in the gutters and has contributed to most floods that affected the area in the past. Within some parts of the city, inhabitants practically use waterways as waste disposal sites. Some of these wastes include plastic bags and bottles, soils, and vegetation that turn to clog the waterways. Occasionally, uncontrolled waste disposal habits turn to cause small-scale induced floods, but the situation usually gets worse when other factors like overdue torrential rainfall take place.

It is common nowadays that most reasons for an increase in vulnerability of local communities to hazards and disasters are due to violations of building codes. This is seen in Cameroon and in the Limbe area in particular where the local population construct in areas where the building code does not permit them to do so. Some of these areas include shorelines, hill slopes, marsh areas, and river and stream banks.

Reports have shown that most cases of severe damage and death from floods and landslide hazards come within these forbidden areas. During the month of July 2018, heavy rainfall in the Limbe municipality resulted in floods of several torrents flooding the roads with a water depth of over 150 cm. Reports have shown that the geographical location of this community is an additional factor, if not a major cause of floods and landslides in the area [57] [52]. It should be noted that this area falls within a low coastline that is linked to the steep topography of Mount Cameroon to the East and the Atlantic Ocean to the West. Such a geographical setting results in high water recharge in the area creating a lot of runoffs coming from the mountain slope and the waves from the sea all contribute to triggering a major flood if water discharge is not promotional.

Study limitations

The development of the disease from exposure to diagnosis at hospitals up to being reported in the surveillance system usually takes 1–9 days. Some of the health facilities visited had just monthly data. Therefore, more frequent data like daily or weekly incidences of the disease, if available, would be more accurate than monthly data obtained in some facilities. Secondly, under-reporting is unavoidable in the research of infectious diseases, including malaria, typhoid and diarrheal diseases. The reported cases included in this study were those who presented serious symptoms and were diagnosed in hospitals. Cases with mild clinical symptoms and treated at home usually do not seek health services, which may lead to an underestimation of the incidence risk of floods. Lastly, most OPD registers could not be found to obtain data by sex and age group in the identified years used by the study.

Conclusions

Floods are a common hazard during the wet season in the Limbe community. The results from this study indicate that flooding plays an important role in the epidemic of malaria, typhoid and diarrheal diseases during the rainy season. This study confirms that exposure to flooding will affect the burden of malaria, typhoid and diarrheal diseases as exemplified in the high malaria prevalence of 36% in 2005 relatively higher than the expected malaria prevalence range of 25-35% in malaria-endemic areas in Cameroon. The trend also shows a high prevalence of 34.6% for malaria, 13.3% for typhoid and 10.6% for diarrheal diseases in 2013 due to repeated flash floods. Since floods are the leading cause of disaster fatalities worldwide, the increased risk and prevalence of malaria, typhoid and diarrheal diseases associated with floods make preventive measures a priority.

Recommendations

The authors urge the government to empower the councils in the Limbe area alongside the traditional rulers to enable them to map out houses constructed in flood-prone areas and develop plans to evacuate or possibly relocate the inhabitants in the worst-case scenarios. Councils should enforce proper town planning regulations so that inhabitants can be conscious and not engage in activities that will lead to environmental hazards and disasters such as floods. Hospitals should create electronic databases for data storage to avoid cases of missing data. Also, the Ministry of Public Health should put in place policies expected to strengthen national health systems while putting in place effective detection and alert systems. This can be realised by equipping the Mile One Regional hospital in Limbe (which covers the whole South West Region) with an emergency response team.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All funders have been duly acknowledged within the work.

Authors Contribution

1. Wantim M.N.: made substantial contributions to the conception and design of topic, acquisition of data (focus group discussions), analysis and interpretation of data, questionnaire development; manuscript development, correction and review of all manuscript versions.
2. Nde Fon P: made substantial contributions to the conception and design of the topic, acquisition of data (hospital data), data interpretation, and development of the first draft of the manuscript.
3. Ndohtabi J.E.: made substantial contributions to the acquisition of data (hospital data and questionnaire survey), analysis and interpretation of data, and development of the first draft of the manuscript.
4. Asong F.Z.: made substantial contributions to the conception and design of the topic and acquisition of data (focus group discussions).
5. Mero Y.: made substantial contributions to the conception and design of the topic, acquisition of data (focus group discussions) and first draft manuscript preparation.
6. Mbua R.L.: made substantial contributions to the conception and design of the topic and acquisition of data (focus group discussions).
7. Emmanuel V.Y.: made substantial contributions to the conception and design of the topic, acquisition of data (focus group discussions) and development of questionnaires.
8. Samuel N.A.: supervised the entire work and made substantial contributions to the conception and design of the topic, acquisition of data (focus group discussions) and correction of the developed manuscript.

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Data availability

The data for this work is found in excel sheets (kept by the authors), the MSc. thesis of Ndohtabi Jerry found at the University of Buea Library and on the University of Buea LIRA website.

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APPENDICES

Appendix 1:
Factors associated with occurrence of Malaria in Households

Variables	Positive N (%)	Negative N (%)	P value	COR	95% C.I.	
Flood Frequency			0.08			
At least once a year	203 (61.9)	125 (38.1)	**0.03**	4.75	0.18	0.80
Never	26 (46.4)	30 (53.6)				
Waste Disposal			0.56			
HYSACAM collection point	201 (52.3)	117 (30.5)	0.79	0.64	0.03	16.37
Open dumping	20 (5.2)	28 (7.3)	0.47	0.35	0.02	6.26
Others	10 (2.6)	8 (2.1)				
House Type			0.25			
Block	156 (40.6)	94 (24.5)	0.46	0.30	0.01	7.27
Carabout	70 (18.2)	60 (15.6)	0.15	0.14	0.01	1.95
Distance of house from River			0.07			
Close to house (<100m)	91 (23.7)	54 (14.1)	0.68	1.78	0.11	27.81
Far from house (100-300m)	120 (31.3)	67 (17.4)	**0.03**	4.71	1.16	19.11
Experience flood			0.17			
Yes	69 (60.5)	195 (72.5)	**0.04**	4.99	1.07	23.19
No	45 (39.5)	75 (27.8)	0.08	0.35	0.11	1.15

COR: Crude Odds Ratio
N: Number

Appendix 2:
Factors associated with typhoid and diarrheal diseases in Households

		Typhoid and Diarrheal Diseases, N (%)			
		No	**Yes**	**χ2**	**P value**
Waste Disposal	Collection point	226(71.1)	92 (28.9)	0.87	0.646
	Open dumping	31 (64.6)	17 (35.4)		
	Others	13 (72.2)	5 (27.8)		
Waste Collection Times	>Thrice weekly	9 (40.9)	13 (59.1)	12.36	**0.03**
	Daily	89 (70.1)	38 (29.9)		
	Don't know	13 (81.3)	3 (18.8)		
	Never	24 (82.8)	5 (17.2)		
	Thrice weekly	43 (69.4)	19 (30.6)		
	Twice weekly	92 (71.9)	36 (28.1)		
Toilet facility	Absent	5 (33.3)	10 (66.7)	10.23	**0.001**
	Present	265 (71.8)	104 (28.2)		
House distance from the river	<100mg from the house	94 (64.8)	51 (35.2)	8.02	**0.018**
	100-300m from the house	144 (77.0)	43 (23.0)		
	>300m from the house	32 (61.5)	20 (38.5)		
Ever experienced a flood?	No	75 (62.5)	45 (37.5)	5.10	**0.024**
	Yes	195 (73.9)	69 (26.1)		
Potable Water Source	Pipe borne	253 (70.3)	107 (29.7)	0.77	0.856
	River	3 (75.0)	1 (25.0)		
	Spring	9 (64.3)	5 (35.7)		
	Well	5 (83.3)	1 (16.7)		