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Physico-Chemical And Bacteriological Quality of Water Consumed and Public Perception of Socio-Economic And Environmental Factors Associated With Typhoid Fever Prevalence and Related Water Borne Diseases In Rural (Miti-Murhesa) and Urban (Kadutu) Health Zones Of South-Kivu Province, Eastern of Drcongo

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ABSTRACT

A study on the quality of the water consumed and on the determinants of the prevalence of typhoid fever was carried out in two health zones (Kadutu and Miti-Murhesa) of the province of south Kivu from June to September 2021.The study aimed at contributing to the advancement of scientific knowledge that can be used in the control of water-borne disease crisis such as typhoid fever in rural areas of the DRCongo. The study carried out was of the analytical cross-sectional type with primary data collected from field using a semi-structured questionnaire. Water samples were collected and analyzed for bacteriological and physicochemical quality using standard procedures. The generalized linear model (GLM) with Gaussian identity model and or with a logarithmic link function, was applied to investigate socio-economic and environmental factors likely influencing the knowledge of respondents about the causes and health consequences of the current prevalence of typhoid fever in the health zones of Kadutu and Miti-Murhesa.

The results indicated that the greater majority of the respondents did not perceive the water they drink as possible source of diseases. In rural health zones, sanitary condition was generally poor, refuse disposal and toilet system still primitive. Most households from rural health zone do not treat the water they drink as they were using open and unprotected toilet systems, which Included open pit toilet, bush method, or use of lake/river banks. Urban communities with that had better social and economic facilities were less exposed to risks of typhoid fever, particularly during early rains of the rainy season.

There were significant differences ($p<0.05$) between the sites (health zone) as to the level of knowledge of the type of water consumed and its influence on the prevalence of typhoid fever. There was significant ($P<0.05$) variability in the values of the physico-chemical properties of the water consumed in the surveyed health zones, although values were in conformity with WHO standards for the Africa for potable water. Germs isolated in the water samples indicated bacterial pollution of water consumed by the public in the two health zones. The causative germ of typhoid fever was found being influenced by the sources where the samples were collected. In the Kadutu health zone, the level of knowledge of respondents of the determinants of the prevalence of the typhoid fever was positively influenced by the age (GLM : $Z= 3.33$, $P<0.001$), negatively influenced by the type of health zone where the respondent lived (GLM : $Z= -4.94$, $P<0.001$), the respondent's neighborhood of residence environment (GLM : $Z= -3.78$, $P<0.001$), the sex (GLM : $Z= -3.53$, $P<0.001$), the level of study (GLM : $Z= -3.69$, $P<0.05$), and to the fact that the respondent does or not wash the containers (GLM : $Z= -4.45$, $P<0.001$).. In the Miti-Murhesa health zone, the perception of the factors that determine the prevalence of typhoid fever was reported for being influenced negatively by whether or not to consume the food prepared a day before (GLM : $Z= -4.32$, $P<0.05$), and positively influenced by the civil status (GLM : $Z= 2.11$, $P<0.05$), the type of water consumed (GLM : $Z= 2.82$, $P<0.001$), the type of treatment applied to the drinking water (GLM : $Z= 3.20$, $P<0.001$). Overall, the result showed that the proposed water by the national water corporation company (REGIDESO) for human consumption was in the process of degradation. The results showed that the mean values recorded for physico-chemical parameters among the domestic water sources were within stipulated limits of WHO for safe drinking water, but not within REGIDESO standards. Due to the levels of microbes in the water, the water quality used by the population can be regarded as of poor quality. Thus, important measures should be taken by the health authorities to slow down the current process on order to reduce the future emergency and burden of the of water-borne diseases in rural and urban areas of South-Kivu, eastern DRCongo.

Keywords: Potable water quality; water-borne diseases, urban, rural, health, typhoid fever, eastern DRCongo.

1. INTRODUCTION

1.1. Context and background

The earth has an abundance of water but unfortunately, only about 0.3 % is usable by humans that comprise of freshwater and lakes (0.009%), inland seas (0.008%), soil moisture (0.005%), atmosphere (0.001%), rivers (0.0001%), groundwater (0.279%) and other composed of ocean (97.2%), glaciers and other ice (2.15%).

The most vital component of the ecosystem is water. Its quality is determined by the appropriate monitoring of its various physical, biological, and chemical parameters as defined by the World Health Organization (WHO)[1]. Water is at the center of the plant and animal life, the foundation upon which the health of human settlement and development of civilizations rely on[2,3,4].

Water is an essential part of human nutrition either directly as drinking water or indirectly as constituent of food and served in various other applications of our daily life[5,6]. Rapid growth of industrialization, urbanization and increase in human population around the globe has led to high demand for good quality water for domestic, recreational, industrial activities and other purposes have continuously threatened value of this resource. The vast majority of people living in undeveloped countries still rely on surface waters as their primary sources of water and simultaneously, as their means of waste disposal. A majority of this population depends on unprotected/or contaminated water sources as a means of drinking water which can cause outbreaks of waterborne diseases.

Water which is an essential compound in which life depends is derived mainly from sources like surface water; rain water and ground water[7,8]. When required for domestic consumption, it should posses a high degree of purity. Some natural sources of water like ground water is expected to be less contaminated, however its polarity and hydrogen bond makes water able to dissolves, absorbs, adsorbs or suspends impurities, therefore water from natural sources could get contaminants from natural and anthropogenic sources from its surrounding[9].

Access to drinking water has been defined as a human right since 2010[10,11]. In tropical regions, 80% of diseases are transmitted either by germs in the water, or by vectors staying in it (Ntouda et al. 2013). Unsafe water, inadequate sanitation, and poor hygiene are linked to about 88% of diarrhea cases worldwide. Besides microbial contaminants, heavy metal water resource contaminations have received much attention because of their substantial toxicity, even at lower concentrations[12,13].

Many waterborne diseases are zoonotic and are transmitted when animal or human waste is not properly collected, stored and treated before being released into the shared environment, such as a nearby water source[14]. Agricultural and storm runoff can transfer these organisms across multiple media such as soil, water, sand, and aerosolized particles to rest in locations where humans or animals may become exposed and infected. Contaminated water can lead to illness when humans or animals drink, breathe, or come in contact with infectious agents or toxins through their skin, eyes, ears, or other mucous membranes[15].

Access to water[16] and health care is one of the basic needs of the human being[17,18]. Availability of safe and reliable source of water is an essential prerequisite for sustainable development[19,20,21]. The consumption of clean and safe water has been linked to increased health outcomes globally .

Water is crucial for all life on earth. It can improve then health, economy, food production, environment, and social well-being of a community[22]. However, every year, millions of people use unsafe drinking water causing diarrhea, cholera, typhoid, and parasites[23].

Despite the achievements that have been recorded with increased access to potable water, millions of people suffer various health-related preventable diseases[24] due to the consumption of contaminated water[25,126]. The nature and impact of water-related infectious diseases are mediated by both ecologic and socioeconomic processes[27].

Transmission of infectious agents through water contact can lead to adverse health effects such as gastrointestinal illness/diarrheal disease, respiratory distress, reproductive and fertility problems, neurological disorders, and even death[28].

Supplying sufficient and clean drinking water has remained challenging in many countries and regions Among different water pollutants, waterborne pathogens, particularly viruses, pose a lasting threat to human health and well-being[29]. With inadequate sewage disinfection and poor hygiene, water-transmitted viral pathogens can find their pathway to potable water and cause human diseases[30]. In 1990 – 2018, 303 typhoid and paratyphoid fever outbreaks were reported with 180,940 affected cases as a result of unsafe drinking water and sanitization.

Diarrhoeal diseases and other digestive disorders are leading causes of morbidity and mortality worldwide, with the highest burden concentrated in tropical and subtropical areas that often lack access to clean water and adequate sanitation, and where hygienic conditions are generally poor[31].

It is widely known that drinking unsafe water may cause exposure to pathogens, which can result in waterborne diseases, such as cholera, gastroenteritis or hepatitis E[32]. However, inadequate water, sanitation and hygiene still caused several thousands diarrhoeal deaths world-wide which corresponds to about 60% of total diarrhoeal-related mortality rates. According to the WHO/UNICEF Joint Monitoring Programme (JMP), 29% of the world population does not have access to safely managed drinking water, free from microbial contamination.

Worldwide, water-associated infectious diseases are a major cause of morbidity and mortality. A conservative estimate indicated that 4.0% of global deaths and 5.7% of the global disease burden (in DALYs) were attributable to a small subset of water, sanitation, and hygiene (WSH) related infectious diseases including diarrheal diseases, schistosomiasis, trachoma, ascariasis, trichuriasis, and hookworm infections[33].

According to the World Health Organization (WHO), diarrhoea is classified into three different categories, namely (i) acute watery diarrhoea (lasting several hours or days); (ii) acute bloody diarrhoea (synonymous: dysentery); and (iii) persistent diarrhoea (lasting 14 days or longer). Chronic diarrhoea is often referred to as an individual term applicable to diarrhoea lasting more than 4-6 weeks, but it still lacks an unambiguous definition.

Adequate provision of water is central to human health and economic development in African regions where water scarcity is a serious impediment to growth and poses a threat to political stability. In Sub-Saharan Africa[34], groundwater resources are heavily relied upon and the focus of strategic development because of both the relative resilience of aquifers to anticipated climate change and the widespread contamination of surface water resources. Change in climate and water cycle will challenge water availability but it will also increase the exposure to unsafe water[35]. Floods, droughts, heavy storms, changes in rain pattern, increase of temperature and sea level, they all show an increasing trend worldwide and will affect biological, physical and chemical components of water through different paths thus enhancing the risk of waterborne diseases. Environmental change critical situations may be caused by floods, drought and warmer temperature that will lead to an increase of exposure to water related pathogens, chemical hazards and cyanotoxins if no adaptation measures are well developed.

Water has meaning for health, illness and wellbeing[36]. These meanings of water are related to the emergence of a new health consciousness in which responsibility for health has shifted from society to the individual. Water's meanings reflect tensions that arise from preventive health programs and the health industry, and provide avenues for expressing social identity for various groups within cultures.

In most low-income countries, water is usually abstracted from rivers, lakes, ponds, streams, springs, wells, dams and used without any treatment.Water quality is of a great concern globally because the decline in its quality due to contamination has great economic and public health burden. Consumption of untreated and inadequately treated water remains a major disease burden to public health and causes waterborne diseases such as cholera, typhoid, and dysentery. Furthermore, high levels of trace metals and anions in drinking surface water have been reported to cause various health complications, including gastric cancer, baby blue syndrome, altered reproduction potential, and mouth ulceration.

Poorly planned sensitization interventions/campaigns on change of household behaviours, living in environmental cleanliness, poor methods of water storage and treatment, and bad practices of hygiene and sanitation combined to the low level of educational of poverty are among drivers of waterborne outbreak and burden in urban and rural areas[37] .

Improved drinking water technologies such as piped water, public standpipes and boreholes, protected dug wells or springs, and even rainwater collection are more likely to provide safe drinking water than those characterized as unimproved. However, due to the difficulty in verifying safe drinking water at the household level, many more people than originally estimated drink unsafe water from improved sources[38].

Taps and wells are the major source of drinking water in the study area with limited information on water quality. This research is tailored to assess the water quality in the area under consideration, evaluates the portability of the taps and wells in terms of water quality information, inform water owners on the health implications associated with consumption of contaminated water, recommends factors to be considered before sitting of water treatment procedures both at home, during transportation[39].

Typhoid fever is a potentially fatal infection caused by the bacteria *Salmonella typhi.* It is usually spread by ingesting contaminated food or water. This disease is widespread in places where drinking water and sanitation are lacking. The transmission can be direct but most often it is indirect and occurs by ingestion of drinks (water) or food (seafood, raw vegetable) soiled under precarious sanitary condition with faecal contamination or by ingestion of food handled by a person infected or carrying the bacteria. A rash can occur in some patients even after symptoms disappear, the person can still carry the bacteria that cause typhoid fever and therefore transmit it through the feces[40,41].

Typhoid fever is one of the leading causes of morbidity and mortality across the world. Typhoid is caused by a bacterium of the genus Salmonella. *Salmonella* infection in humans can be categorised into two broad types, that caused by low virulence serotypes of *Salmonella enterica* which cause food poisoning, and that caused by the high virulence serotypes *Salmonella enterica* typhi (*S. typhi*), that causes typhoid, and a group of serovars, known as *S Paratyphi* A, B and C, which cause Paratyphoid . Humans are the only host of this latter group of pathogens. *S. Typhi* is a highly adapted human-specific pathogen, and the illness caused by these bacteria is a serious public health concern[42].

In the environment, the bacteria can survive for a very long time without multiplying. This is can survive on average 35 days in manure, 3 months in water and more than 2 months in soil. Some time, the survival of *S. typhi* is more than 6 months in the environment.

Salmonella microorganisms may survive for several days in the environment, especially in water at room temperature. They are inactivated by conventional disinfectants (1% sodium hypochlorite, 70% ethanol, and formaldehyde) and by heat greater than 70°C. According to WHO-2020, typhoid fever due to infection with *S. typhi* affects more than 21 million people each year. It is estimated that typhoid effect between 11 and 20 million people annually and causes about 128 000 to 161 000 deaths per annum.

The infection may result in sepsis (generalized infection) in the absence of treatment (4). Symptoms include high fever, headache, constipation or diarrhea. Paratyphoid fevers caused by the *Salmonella paratyphi* A, *paratyphi* B or *paratyphi* C (Enterobacteriaceae) serotypes are characterized by symptoms similar to those of typhoid fever but less severe and paratyroid fevers are notifiable in some countries.

The disease is endemic some areas in developing countries (Asia, Africa, America South) having areas where hygiene is poor, where drinking water is scarce and where there is often flooding and landslides or heavy soil erosion. In endemic areas, the disease is more common in children and adolescents (aged 1 to 15 years) . The risk of contracting the disease in developed countries is low. Poor communities and vulnerable groups, especially children are most at risk in African countries and related under developed countries. In Algeria, the epidemiological situation of typhoid fever has improved markedly by1.2% as compared to previous years.

They are microorganisms which may exist in the naturel state or be the result of contamination by faeces of human or animal origin. Surface water sources such as lakes, rivers and reservoirs are more likely to contain the typhoid bacteria.

. According to WHO/UNICEF, water quality may be polluted (degraded) with microbial agents and physicochemical agents. Dirty water is the cause of 9.1% of diseases and 6% of deaths recorded each year in the world, The number of deaths varies from 0.5% to 8% in developing countries. Dirty water is responsible for a 25% of children deaths in developing countries.

The related consequences of lack of access to water quality include: dehydration, faecal oral diseases (disease of dirty hand) such of diarrheal diseases but also dermatological (scabies) or ophthalmological diseases and diseases transmitted by lice and ticks by lack of hygiene body and washing clothes.

In addition, disaster events such as floods can indirectly promote the transmission of water-borne diseases, by promoting the multiplication of breeding sites for the bacteria. The proliferation of bacteria in water environment is may also depend on the variability in weather factors or conditions such as temperature, pH, humidity, heat…as well as hygienic conditions in the local environment (amount of waste thrown in water bodies). Indeed, the multiplication and resistance of various microorganisms and their endemic situation is above all facilitated by the variability in the water and environment parameters. It can also be linked to the inadequate level of hygienic, in particular the lack of hygiene the drinking water supply channel from the source to the household tap level. Also the excrement and waste disposal systems in an area, coupled to the variability in weather conditions, and disaster events (drought, landslides, soil erosion, floods, excessing runoff,..) may mix with drinking water from wells at uncontrolled source points till the point of consumption . Overall, access to drinking water and adequate sanitation, health education compliance with good hygiene practices in food handlers and vaccination are all effective ways to control typhoid fever.

Being a water-borne disease, typhoid fever is the cause of several health complications. The disease is currently a public health concern, especially in communities where on-going degradation of socio-economic and environmental condition coupled with over population, and bad governance are affecting the well-being and new behavior of the public. These factors are likely excreting the prevalence of typhoid disease. Current prevalence of typhoid fever may be due to several factors: current high demographic growth, current variability in the water consumption patterns and rapid increase in the volume of waste thrown in the environment daily, increase of population not educated on good hygiene practices of hood handling, may increase the risk of the water quality.

Also, there is risk to the quality of water to be degraded with cooking of fresh food washed with polluted water and or with cooked food sold at street market.

1.2. Problem statement & study justification

Understanding the relationships between human health, water, sanitation, and environmental health is a requirement to understanding the challenges that face researchers when it comes to addressing global health relating to water and sanitation[43]. Access to improved water and sanitation is not only a precondition to health, but to all aspects of daily living. Illnesses associated with recreational water are an increasing public health problem, causing a great burden of disease in bathers every year. Fecal and chemical contamination of water is a concern, especially in areas of non-point source pollution.

It is important to understand the key drivers, barriers and bottlenecks in complex situations; recommending actionable and contextualized measures to address these challenges; directing programming and interventions; and informing policy-making to tackle and solve these challenges.

Given the challenges facing communities regarding water and sanitation, it is essential for scientists, researchers, policy makers, water committees, health providers, and community members to design and implement strategies in water resource management and proper waste management. Communities and water committees would also be best served if they worked with government agencies to conduct concurrent testing of both recreational water and drinking water, especially since both them target many of the same parameters. This require a better understanding of the linkage water borne diseases and consumption of type of water made available for the public.

Investment in sanitation and drinking water infrastructure is essential for universal access to these services in developing countries.Universal coverage of water and sanitation services can prevent the dissemination of waterborne diseases and mitigate their adverse effects[44].

Quantitative evidence of health and environmental tradeoffs between individuals' drinking water choices is needed to inform decision-making[45]. The sustainability gain from consuming safe water may exceed the reduced health risk of due to exposure from consuming water from unsafe sources. There still several critical data gaps and methodological challenges in quantifying integrated health and environmental impacts of drinking water choices and options available in urban and rural settings.

In low and middle income countries, public perceptions of drinking water safety are relevant to promotion of household water treatment and to household choices over drinking water sources[46]. However, most studies of this topic have been cross-sectional and not considered temporal variation in drinking water safety perceptions. Perceived drinking water safety is primarily related to water taste, odour, and clarity rather than socio-economic or demographic characteristics. It is important explore trends in perceived drinking water safety and its association with disease outbreaks, water supply and household characteristics.

Despite the trillions of dollars spent on research and development projects, mortality rates by waterborne pathogens have risen with population growth. In fact, it is claimed that research has shown very poor results given the expenditure of such a great amount of funds. He blames it on "Planners" who seek to impose solutions from the top down rather than "Searchers" who adapt to real life and cultural circumstances from the bottom up. The mind set of "Planners" is a reason why water interventions designed by outsiders have a record of failure with few results pertaining to the reduction in the incidence of waterborne diseases[47].

Cultural beliefs, attitude, and practices of the people may be Important in understanding the Incidence and prevalence of water borne diseases in linkage with poverty level and the peasant nature of the economy of respondents.

This study assessed linkages between water and health, perception of environmental interactions, cultural practices, and behaviors as part of a larger ongoing effort to provide a baseline data set for planning water hygiene and health promotion programs in the study area. The effectiveness of locally-informed education programs has the potential for clarifying misconceptions, improving practical knowledge and instigating behavioral changes which in turn may reduce diarrhea-related mortality along a more sustainable long term platform than what has been undertaken to date in the region.

1.3. Research question

What are the pubic perceptions of risk factors for typhoid fever emergency in the heath zones of Miti-Muhesa and Kadutu?.

1.4. Objectives

1.4.1.General objective

To contribute to the advancement of knowledge that can be used in the control of water-borne diseases such as typhoid fever in rural areas of the DRCongo.

1.4.2. Specific objectives

(i) Assess the current physico-chemical and microbilogical characteristics of the water consumed in the health zones of Kadutu and Miti-Murhesa.

(ii) Assess the level of knowledge of the public about the determinants of the prevalence of typhoid fever and related water-borne diseases in the health zone of Kadutu and Miti-Murhesa.

(iii) To identify socio-economic and environmental risk factors associable with the degradation of the quality of water used by communities

1.5. Hypotheses

(i) The physico-chemical and microbiological qualities of drinking water is in a good status level in the Kadutu and Miti-Murhesa health zone.

(ii) The public does not know exactly the factors causing the pollution of the water (tape, well, sources) consumed in the health zone Kadutu and Miti-Murhesa.

(iii) Socio-economic and environmental risk factors associable with the degradation of the quality of water used by communities, remain largely unknown

1.6. Delimitation (scope)

The study was conducted in an one urban health zone of Kadutu (Bukavu town) and in one rural health zone of Miti-Murhesa (Kabare territory) from June to September 2021.

2. MATERIAL AND METHODS

2.1. Type of study: This study is of the transversal analytical type, carried out by interviewing several households with a semi-structured questionnaire in the Kadutu and Miti-Murhesa health zones.

2.2. Study areas description

The study was carried out in the urban health zone of Kadutu and in the rural health zone of Miti-Murhesa (Figure-1A,1B,1C,1D).

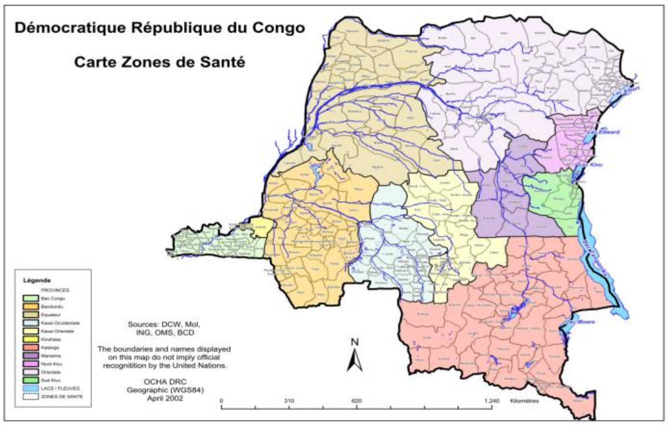

Figure 1A: A Map of the health zones within DRCongo

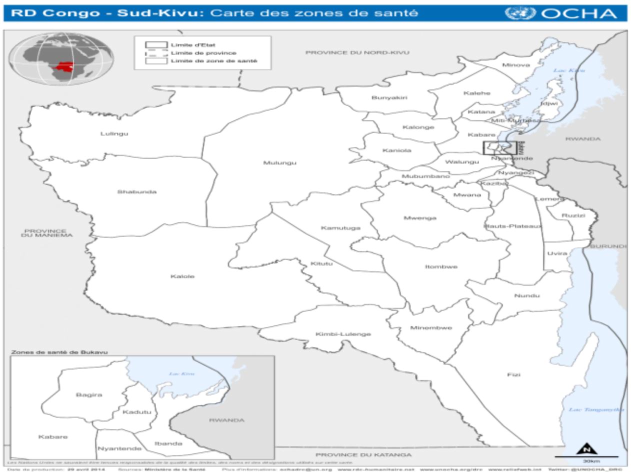

Figure-1B: A Map showing the different health zones(including Kadutu within Bukavu town and Miti-Murhesa within Kabare territory) within South-Kivu Province, eastern DRCongo

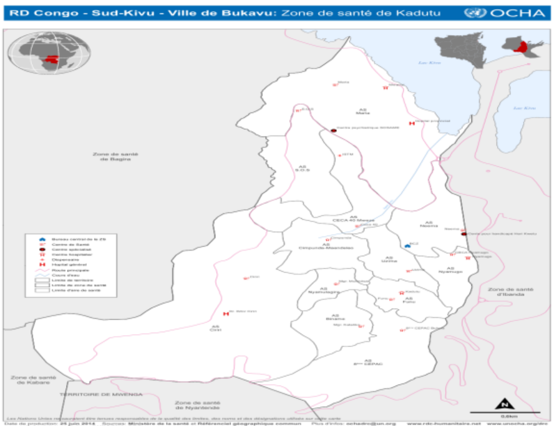

Figure 1C: A map showing different health areas (including those sampled: Nyamugo, Nyamuragira, Buholo,...) within Kadutu urban health zone(Bukavu town)

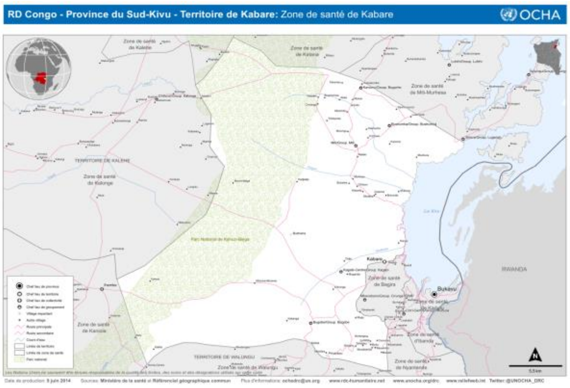

Figure 1D: A map showing different village health areas (including those sampled: Kavumu, Lwiro,...) within Miti-Murhesa rural health zone (Kabare territory), South-Kivu Province, eastern of DRCongo

2.2.1.Kadutu health zone

Kadutu health zone is limited, in the North, by the Wesha river which separates it from the urban health the Bagira/Kasha urban. I East, the Kadutu health is limited by the Kahuwa river and the main road of the industrial avenue which separates it from the urban health zone of Ibanda . I the WEST, Kadutu health zone is limited by the Kahuwa river which separates it from the rural health zone of Kabare. In 2019, the population of the urban health zone of Kadutu was estimated to be about 370 760 . The Health zone is divided into 13 health areas namely: Biname heath area, CECA 40 Camp Mweze health area, 8^{e} CEPAC health area, Maendeleo health area, CIRIRI 1^{e} health area, FUNU 1^{e} health area, FUNU 2^{e} health area, MARIA health area, NEEMA health area, Mgr Mulindwa health area, UZIMA health area, CBCA/ nyamugo health area, SOS health area.

2.2.2. Miti-Murhesa health zone

Geographic location : The Miti-Murhesa health zone is located at 33km from Bukavu town. The health zone is bordered with the katana health zone in the Northern part. The health zone is also bordered with the Kabare health zone in the southern part. In The Eastern part, the Miti-Murhese health zone is bordered by the Lake Kivu and valley bottoms. IN the Western part, the health zone share the border with Kahuzi Biega national parks located in the upper hills. Hydrographically, the area is crossed by several rivers, including the Langa, Nyabacuwesa, Lwiro, Mushuva and Mpungwe rivers. The water supply system is facilitated by the exiting network of shallow wells and rivers

Socio-economic situation : The main economic activities of the population of the health zone of Miti-Murhesa are include agriculture. Animal husbandry in the past was considered as the main resource of nearly 70% of the population revenue but the situation has considerably changed due to insecurity and its consequences (looting, displacement, rebel movements, violence,..). The key crops grown include cassava, beans, sweetpotatoes, banana, maize, sugar cane and vegetable crops). The staple food of the area is cassava foufou mixed with cassava leaves. Cattle, goat, pigs, rabbit, guinea pigs keeping are the key livestock species . Livestock is currently disturbed by episode/epidemic or frequent insecurity. Fishing is practiced in an artisanal way. The main source of fish consumed remain fishing on lake |Kivu and related rivers. Small trade activities are hampered by excessive government taxes. Theses tax barriers are found at several roadblocks located on the roads around the zone, and which cause the price of products to fluctuate regularly at market.

2.3. Study population, target population and sampling

Target population : the target population was composed of households residing in the health zone and whose age was above 18 years and Miti-Murhesa.

Sampling : this study used the second stage cluster sampling technique, the first stage was made up of the health area level and the second stage was limited to the household level in each health zone.

Sample size :

The sample size was calculated using the Fisher's formula including :

$$n = \frac{\varepsilon^2.p.q.d}{a^2} <=> \frac{(1.96)^2 x\ (0.5\ x\ 0.5\ x\ 1)}{(0.05)^2} <=> \frac{3.8416x\ 0.5\ x\ 0.5\ x1}{0.0025} <=> \frac{0.9604}{0.0025} = 384 \text{ respondents.}$$

Where:

n = sample size of the study population

Ɛ= risk of error allowed, Ɛ= 1.96 at the required confidence interval of 95% CI, Z = 1.96),

p= prevalence of the studied phenomenon, the prevalence being unknow in the study areas, therefore the value of 0.5(50%) of probability (p) was considered in this study.

The gender proportion of respondents being affected by typhoid fever in the health zones, in previous years, was is unknown, therefore maximum heterogeneity was assumed (ie, a 50/50 split in males and females) with p=0.5.,

p = the probability for an event to occur.,

q = the probability for an event not to occur., with p+q=1, hence, q=1-p=0.50

α= the acceptable error rate during sampling or desired precision or margin of error (α= 0.05 associated with 95% CI)., d= degree of sampling accuracy (d=1).

2.4. Inclusion and exclusion criteria

To be part of the study it was required that the respondent be permanent resident of the health zones, be heading a household and accept to answer freely to the questions of researchers. On the other hand, any person who did to meet these criteria was not interviewed even when found in the study areas.

2.5. Collection of data with the questionnaire

The data collection took in to account the health areas of the Kadutu and Miti-Murhesa health zones. The survey concerned people in the household of these two health zones, whose age varies between 15 and 45 years. Individual interview (sometimes followed with focus group discussions) took place at the target sites. As recommended[48], interviews were conducted in local language (Kiswahili or Mashi) the resident of the respondent having a tape or accessing drinking water within 1Km radius. The researcher explained to the respondents the purpose of the research before starting the dialogue with the respondents. Each respondent was interviewed for about 30 minutes. After interview, field ground truthing followed to see what was said during the interviews.

2.6. Study variables

Independent variables included**:** socio-demographic and economic characteristics and environmental factors associated with disease, quality of drinking water.

Dependent variables included**:** prevalence of typhoid fever and type of water used .

2.7. Sampling collection, transport, preservation of water samples

Clean plastic bottles of 100mL were used to collect water samples for chemical analyses and carefully washed and sterilized 500mL glass bottles for bacteriological analyses samples. All samples were labeled, stored in a clean cool box at 4ºC, and transported to the laboratory on the same day for analysis. A sample sheet containing information on the origin, the date of collection, and the sanitary conditions of the collection stations completed for every sampling occasion, accompanied each sample set as recommended[49]. All the samples were properly labeled, stored in an iced insulated container and transported to the laboratory for analysis.All the samples were properly labeled, stored in an iced insulated container and transported to the laboratory for analysis following the classical standards procedures for analysis if ISTM-Bukavu. Laboratory analysis of samples was carried out at the ISTM-Laboratory (Bukavu, DRCongo). Mean values of results obtained were compared with the World Health Organization (WHO) Standards to ascertain the extent of departure from or conformity with the international guidelines as recommended[50].

2.7.1.Physicochemical variables of water

In order to assess the level of pollution of the water consumed by the population, water samples were collected from the different types of water sources available in rural and urban areas. These samples were analyzed (for the presence of bacteriological germs) and for the physico-chemical properties. The analyzes were carried out at the ISTM laboratory following the protocol previously developed by laboratory technicians in the medical biology section of ISTM-Bukavu. Water sample collection was conducted at each wells, tape or sources that has been made available for the population by the National Water Corporation Company and partners. The samples were analyzed at the Laboratory of Microbiology of the department of Biological Medical of ISTM-Bukavu.

Physico-chemical parameters (pH, TDS, EC and Temperature) of the water samples were also measured in situ. Water temperature (WT) , hydrogen potential (pH) and dissolved oxygen(DO) were carried out in situ using a portable multiparametric probe HANNA (HI 9828, USA). The samples were taken to the laboratory and analyzed for the following parameters: pH, temperature, dissolved oxygen biochemical oxygen demand , total hardness, dissolved solids, total solids, nitrate, chloride, conductivity total bacterial count, and total coliform count. On site measurement and laboratory analyses were carried out as per standard methods[51,52].

Physical parameters like Temperature, pH, conductivity, salinity, turbidity and dissolved oxygen were all done in-situ. Temperature was measured using mercury in glass thermometer, pH using HACH SESSION + digital pH meter, turbidity using HACH 20100N turbidity meter, conductivity, salinity, dissolved oxygen and total dissolved solid were measured using HACH 20100N conductivity meter. Chemical analysis were carried out in the laboratory applying standard spectrophotometric techniques using ultraviolet-visible (UV/VIS) spectrophotometer (Spectronic@R 20 Genesys, USA) as recommended[53]. Physicochemical and bacteriological parameters were evaluated following standard procedures as describe in in the manual of procedures at ISTM-Bukavu.

2.7.2. Bacteriological variables of water

Samples for microbial analysis were collected using pre-sterilized equipment and stored in pre-sterilized glass bottles followed by analysis in the laboratory within 6hrs. The microbial analysis included bot total coliform and fecal coliform.

From each sample, 100 ml of water were drawn through a membrane of 0.45 mm pore size using a vacuum pump. The filters were then place d in sterilize d petri dishes containing M-FC agar and incubated for 24 hours at 44.5º C to optimize the growth of fecal coliform only. After 24 hours the fecal coliform colonies developed were then counted under a magnifying lens. Another 100 mL of water were filtered using the same procedure and the filter paper was placed in the nutrient agar medium for 24 hours at 37°C to produce yellowish-brown colonies which were then counted under the lens[54,55,56].

Quantification of bacterial pollutants (mesophilic aerobic bacteria-MAB, total coliforms, faecal coliforms-FC, faecal streptococci) was performed by the membrane filter method. Depending on the degree of the sample turbidity, 1-10mL were filtered through the sterile cellulose acetate membrane (47mm diameter and 0.45 µm porosity) and placed on respective selective agar plates into petri dishes in triplicate. Colonies were enumerated on plate count agar after 24hours incubation at 37ºC. Suspected highly contaminated samples were diluted up to 10^{-5} with distilled/sterilized water according to its contamination degree. Three plates for each dilution were plated, and then typical colonies were counted to determine the average number of colony forming units per unit volume of water analyzed after correction by the corresponding dilution factors. The same method was replicated on MacConkey Agar incubated for 24 hours at 37ºC-44ºC for 48 hours. For the pathogenic strains identification, different agar was used such as Simmons Citrate Agar, Kigler Iron Agar and sulfide Indole Mobility as recommended by previous workers[57,58].

The total coliforms were enumerated by the membrane filtration (MF) techniques. Colonies with black spots were recognised as Salmonella and confirmed by the production of H_2S, ureas test and citrate utilisation, differentiating it from Shigella which also grow on the same medium as normal colonies. The total colony forming unit per mile (cfu/ml) of Salmonella typhi for each water samples were compared with World Health Organization guideline of <10 cfu/ml of this pathogen[59].

Microbiological organism (Typhoid, Escherichia, Enterococcus) levels in the water samples were evaluated using Membrane Filtration technique. Cultural media such as Agar was prepared for micro-organism enumeration and determination of contamination levels[60]. The agars were prepared according to the manufacturer's guidelines and procedures at the Bioscience laboratory of ISTM-Bukavu. The samples (100 mL) of water were filtered through sterile membrane filters using a vacuum pump and a manifold by adhering to the protocols of the American Public Health Association adopted locally in DRCongo by the national Microbiological laboratory systems. The filter paper containing the test organisms was incubated for 24-48hours at room temperature or appropriate temperature for colony emergency (37◦C-45 ◦C). The results were reported as colony-forming units per 100 mL of sample as well as per presence-absence of the micro-organism in the water sample.

2.8. Data analysis

Raw data was coded and sorted out in Excel 2017 before conducting statistical analysis. Multivariate and descriptive statistical analysis was applied on water parameter data. The preliminary data analysis began with a statistical description of the variables (calculation of percentage, frequency, mean, coefficient of variation, minimum and maximum values for the variables quantitative) . Generalized linear models (GLM) were constructed to determine the probability of association of independent factors with dependent factors. In general, the GLM test, are applied to test the influences of dependent variables, see it they are linked linearly to the factors and to the coaxial through, a specific binding function. The model can be used even if the dependent variable is not normally distributed. GLM models integrate other types of model conventionally used by researchers such as linear regressions for dependent variables with the normal distribution, the logistic model for binary data.

In this study, the GLM test was chosen with a Gaussian normal distribution error and a logarithmic function followed by a probability test (log-likelihood) with three levels of interaction. The model had remained by the determination of simplified criteria of information of Akaike (AIC) and BIC (Schwarz's Bayesian Criterion). Generalized Linear Models were built in STATA version 11 for windows 2012.

2.9. Ethical consideration

Data collection took place in a climate of confidence, respect for the human rights of representatives and the freedom to answer the questionnaire without constraint, discretion being observed in the responses given. In addition, there is no conflict of interest in the data.

3. RESULTS

3.1. Socio-economic and demographic characteristics of respondents, access to clean water, water treatment methods, knowledge of influence of water and sanitation and hygiene and related socio-economic factors on the burden of Typhoid fever and related water borne disease

With regard to the socio-demographic characteristics of the respondents in the Kadutu health zone, there were more male than female (p=0.037) married respondents. The highest level of respondents who were single was found at Karhale (63.33%) whereas the lowest level (P=0.037, $\chi2$=8.47, df=3) was found at Nyamugo (35.71%). Concerning the profession status of respondents, there was a significant difference [$\chi^2(3) = 24.75$, p<0.0001] in proportion(%) of housewife between the Buholo (0%), Nyamugo (21.43%), Karhale (16.67%) and Kasali (6.90%) healh areas. In Kadutu health zone, 38.46% of respondents from Buholo health area had a University level of education against 17.24% of respondents (P=0.032, $\chi2$=8.78, df=3) from Kasali. Across health areas, most respondents did (p=0.003) attend the primary level of education (Table-1a).

In Kadutu health zone, the age of respondents oscillated between 16and 45 years (coefficient of variation of 29.90% across study health areas). The average household size oscillated between 5 and 6 persons (coefficient of variation of 35.55% across health areas).

In the Miti-Murhesa health zone, the level of knowledge of determinants of the prevalence of typhoid fever was gender imbalanced since more (p=0.001) male were aware of some key risk factors than did female respondents. The average age of 25 years (minimum: 15 years, maximum: 45 years) across health areas.

-With regards to water sanitation facilities, the public water tap was the main source of water in urban zone of Kadutu health zone **(Table-1b).** Also, the main type of toilet was the flush to toilet pouring into evacuation waste water canal **(Table-1b).** Borehole, standpipe and piped water into home compound was the main source of safe improved drinking water in rural areas **(Table-1c).** The flush toilet pouring into the piped sewer system or in pit latrines were the main type of improved own toilet facilities in rural areas. Also, open it latrines dominated non improved toilet type available in rural health zone of the Miti-Murhesa **(Table-1c).**

From the **(Table-1c)**, someone can observe that as compared to bush defecation, benefits of latrine ownership as perceived by respondents include avoid discomforts of the bush, gain prestige from visitors, avoid dangers at night, avoid snakes, reduce flies in compound ,avoid risk of smelling or seeing feces in bush, protect human feces from enemies, have more privacy to defecate, keep house or property clean, feel safer, save time , make my house more comfortable, reduce my family's health care expenses, leave a legacy for my children , have more privacy for household affairs , make my life more modern, feel royal , Make it easier to defecate because of age or sickness, be able to increase my tenants' rent.

Other perceptions of respondents about drivers of typhoid fever prevalence and related water borne diseases are presented in **(Table-2).** Also, general knowledge of respondents about typhoid fever are presented in **(Table-3)**.

3.2. Level of knowledge of rural and urban populations on the health dangers related to the consumption of poor quality water in the health zone of Kadutu and Miti-murhesa

In Kadutu health zone, the major source of water consumed by the public was water supplied by the national water corporation (REGIDESO) or water from wells. Across health areas, water was conserved in containers (can, trunk) although they were irregularly cleaned before, and mostly not well treated. In fact, the majority (92.13%) of respondents indicated that they kept water in the barrel, and doing some time treatment (boiling before) for water dedicated to children **(Table-4)**.

In Kadutu health zone, the time (hours) of water conservation (boiling water) was about 1 to 4 hours (Coefficient of variation of 44.22%).The time (minutes) for washing or cleaning water containers was on average of 2-10 minutes (coefficient of variation of 33.72% across health areas).

In Miti-Murhesa health zone, the household size was on average of 5 persons (coefficient of variation of 25.10% across health areas). On average, respondents spent 2 to 4 minutes for cleaning water containers. They also spent on average 2 hours for boiling water. Boiled water could be ready for drinking after 24 hours. Level of knowledge on respondents about risks of being victim of typhoid when consuming water of poor quality in Kadutu and Miti-Murhesa health zone.

Respondents indicated that they were consuming water from the REGIDESO (54.08%) or from well protected source (45.92%) . However, respondents were worried about the quality of water provided by the REGIDESO since currently there is leak in pipes carrying water. They suspect that the water may be contaminated on the way to households.

3.3. Level of knowledge of respondents on the probability of being a victim of typhoid fever following the consumption of unhygienic food and following no-compliance with hand hygiene in the kadutu and Miti-murhesa health zone.

In Kadutu health zone, as for knowledge of the dangers of no-compliance with hygienic standards and the risk of catching water-borne diseases, half (50%) of respondents at Karhale and Buholo (50%) mentioned ($p<0.001$) not having habit of eating raw food or unhygienic foods or street vended foods. On the contrast, respondents from Kasali (10.34%), Nyamugo (100%) and Kasali (89.66%) indicated ($p<0.001$) that they were eating the raw foods without bothering about the health issues.

For the washing hand before eating, respondents from Buholo (61.54%) significantly ($p<0.001$) mentioned that the rest that they did not wash their hands before eating food on the street or raw foods such as fruits and vegetables. As for the preparation of food the day before, a portion of respondents from Nyamugo (28.57%)

indicated they were used to eat freshly prepared (cooked) food (p<0.001) as compared to respondents from Buholo (11.54%), Karhale (10%) and Kasali (17.24%). Respondents from Nyamugo (100%) indicted being aware of typhoid fever being borne from consuming unhygienic foods more significant way (p<0.001) than respondents Karhale (60%), Buholo (61.54%), Kasali (65.52%) health areas **(Table-5)**.

In Miti-Murhesa health zone, as to knowledge about the danger of no-compliance with food hygiene standards at the risk of catching water-borne diseases, respondents from Kavumu (41.67%) confirmed more significantly (p<0.001) having the habit of eating raw food without washing then hands than respondents from Murhesa (38.24%) and Miti (11.76%) health areas.

Respondents from Kavumu (100%) and Murhesa (97.06%) mentioned that they frequently ate food cooked a day before without worming it before consumption. However, only respondents from Miti (76.47%) reported frequently suffering (p<0.001) with typhoid fever than respondents from Kavumu (47.92%) and Murhesa (35.29%).

3.4. Respondents knowledge of determinants and risk factors of exposure to typhoid fever infection

As shown in Table-6 below, the likelihood of being aware that consuming poor quality water may exposure to typhoid fever found to be statistically significant for the factor variable of health zone (P=0.004). The likelihood of knowing the risks of consuming water of poor quality increases by 7.5% as with the civil status (married or not) .It implies that respondent who were married were more sensitive to understand and know the risk of consuming poor quality of water since most of the responsibilities in managing and keeping the quality of water safe are handled by the head of the household. This also suggest that the civil status may should be taken into account and help advise on how to tackle water born diseases in the rural and urban area.

-The likelihoods of education level was also found to be significantly (P=0.012) in knowing the dangers of consuming water of poor quality and being exposed to typhoid fever. The probability of keeping high quality water decreased with the level of education . This implies that uneducated respondent had high probability of not knowing that someone can be exposed to typhoid fever by consuming poor quality water.

In Kadutu health zone , the GLM model (Gausian identity model) **(Table-6)** indicated that the level of knowledge of risks of suffering from typhoid fever by respondents was negatively associated with the type of health zone (GLM : Z=-2.88, p=0.004) where the respondent lived, with the level of education (GLM : Z=-2.53, p=0.012), the existence of leaked water pipe incident in the area (GLM : Z=-2.22, p=0.003), the amount of time (minutes) for cleaning water containers (GLM : Z=-2.70, p=0.007), by the fact that respondent reported to have suffered with typhoid fever in the past time before the study (GLM : Z=-5.57, p<0.05). The level of knowledge of risks of suffering from typhoid fever was also found to be positively associated with the civil status (GLM: Z=2.99, p<0.05), with the profession (GLM: Z=2.86, p<0.05) of the respondent, with the habit of treating water before its consumption (GLM : Z=6.06, p<0.05), and to the habit of fact of eating or not the raw food (GLM : Z=2.99, p<0.05) without washing hands (GLM : Z=5.35, p<0.001).

The Gaussian model determined the likelihood of perceiving the risks of typhoid fever infection. The dependent variable in the selection equation is binary indicating whether or not a respondent perceives the risks of being exposed to typhoid infection ; the dependent variable in the outcome equation is also binary indicating whether or not a respondent perceived any infection risk. The likelihood function for the Gaussian identify model was significant (AIC = 1.08574, BIC= -2186.941, Log likelihood= -194.9765228, with P < 0.0001), showing a strong explanatory power.

As shown in **(Table-7)** above, the likelihood of perceiving the risks of typhoid infection found to be statistically significant (p=0.025) for the factor variable of the household size. The likelihood of perceiving infection risk due to typhoid decreased by 2.11% as the household size increased. It implies that respondents with big household size were more vulnerable(more exposed) to the risks of typhoid infection than respondents with small size of the household. Respondents with small family size were less exposed to more burden of typhoid fever and related water borne diseases since few people handle water conserved for consumption. In bigger family, everyone touches the water and can contaminate it. In small size family, only parents manipulate suspend containing boiled water dedicated for home consumption.

The Generalized Linear Model (Gaussian identity model) indicated that the level of knowledge of risks of being exposed to typhoid fever was linked negatively to the level of education (GLM: *Z*= -2.93, *P*=0.003), the profession (GLM: *Z*= -2.76, *P*=0.006), the household size (GLM: *Z*= -2.23, *P*=0.025), to the source of type (kind) of water consumed daily (well, spring) by respondent (GLM: *Z*= -2.22, *P*=0.026), to the habit of regularly eating raw foods (GLM: *Z*=-8.47, *P*<0.0001) **(Table-7).**

-The level of knowledge of risks of being exposed to typhoid fever was also positively linked to the sex (GLM: *Z*=2.000, *P*=0.046), age (GLM:*Z*=2.81, *P*=0.005), location of the residence of the respondent (GLM: *Z*=2.95, *P*=0.003), to the habit of eating food prepared the day before (GLM: *Z*=2.49, P=0.013), to the habit of washing hands with water before eating (GLM: *Z*=3.10, *P*=0.002), to the fact that respondent has ever suffered with typhoid fever in previous time before the survey took place (GLM: *Z*=2.99, *P*=0.003) **(Table-7)**.

3.5. Knowledge of drivers of water physico-chemical pollution and microbial contamination on the prevalence of typhoid fever and related water borne diseases

3.5.1. The density, frequency and type of micro-organisms (Enterbacteriaceae) isolated in the health zones of kadutu and Miti-murhesa .

The germs *Ecoli*, *Enterbacter* and *Salmonella* sp were the most frequent germs in water samples taken in the Kadutu health zone **(Table-8)**. In the Miti-murhesa, *Citrobacter*, *Enterbacter, Proteus* were the most frequent germs detected in water samples from various sampling sites **(Table-9)**.

Bacterial analysis indicates the presence of fecal coliform. Fecal coliform is an indicator of bacterial contamination from excreta of human and other warm blooded animal. High level of fecal coliform in water can affect public health and community economy. Fecal coliform cause diseases like cholera, dysentery and diarrhea. The possible source of these high coliform is from excreta of human or warm blooded animal diffusing into the tap/well form poorly constructed septic tank in urban areas.

3.5.2.The physico-chemical and bacteriological characteristics of water consumed in the heath zone of Kadutu and Miti-Murhesa.

In the Kadutu and Miti-murhesa health zones, there was variability in the average physico-chemical properties (temperature, pH, conductivity, dissolved oxygen, and chloride) of the water consumed between the different sites of collection of samples that have been analyzed **(Table-10, Table-11)**. The averages are within the standards for the WHO for the African zone.

The temperature range was neither low or high. The temperatures were in acceptable range as specified by the national water corporation company (REGIDESO). pH defines the hydroxonium ion concentration in solution which expresses the degree of acidity and alkalinity. In the study area, the pH ranged had various range values. Water in the study area was slightly acidic also the trend was not similar in urban and rural areas. The possible reasons for the acidic level may be as a result of breaking down of organic waste from human, animal waste and organic vegetation, or leaching of minerals into the water sources from mineral rich rock in urban areas.

Electrical conductivity (EC) in water is the ability of the water to conduct electricity due to the presence of dissolved mineral salts, total suspended solid, salinity and leaching of minerals into the water by mineral rich rocks. EC in the study area had various range values in both rural and urban areas. EC Values were lowest in urban areas and highest in rural water samples . The measured EC values were all within the acceptable limit as defined by REGIDESO. Turbidity is the level of cloudiness of water sample due to the presence of suspended particles. High turbidity value indicates the abundance of pathogens. Turbidity values were in specified range values defined by the REGIDESO.

Salinity is the amount of the salt content in water. The salts are mostly soluble chlorides and sulphates. High level of salinity in ground water is mostly due to seawater intrusion into the ground water (water well). In the study area, mean salinity value was had the highest value in rural areas and lowest values were recorded in urban areas. However, these values were within than the acceptable limits of REGIDESO. From these results, it can be concluded that there is no seawater intrusion in the area under study.

Total hardness (TH), is the amount of soluble magnesium or calcium carbonates, bicarbonates or both present in water. The total hardness is the reflection of the amount of magnesium and calcium carbonates or bicarbonates or both in the water. Total hardness values in all the water samples were within the acceptable limits of REGIDESO and WHO standards for central Africa .In fact, WHO classifies water with calcium carbonate level (0–60 mg/L) as soft water. The currently recorded TS value may lead to consider the water in the study area as soft water. Total dissolved solid (TDS) is the amount of total suspended solids and dissolved minerals presence in water. In the study area, the measured TDS values were in acceptable values limit set by the regulatory body company (REGIDESO) .

Alkalinity as the degree of buffering of acidity in water. Alkalinity in water is due to the presence of carbonate ions CO_3^{2-}, bicarbonates HCO_3^{-}, hydroxides OH^{-}. The mean value from the study area was within the acceptable limit of as defined by REGIDESO

Dissolved oxygen (DO), shows concentration of oxygen gas that dissolved in water. In the area under consideration, the measured DO had the lowest value in rural areas and the lowest values in Urban health areas. Mean DO value of the study health zones was below than the specified limit set by the national REGIDESO standards. Low value of DO may be associated with high level of organic waste decomposition, high bacteria activity and bacterial contamination in urban health zone.

Biological oxygen demand (BOD_5) is the amount of oxygen needed for bacterial metabolic activities. It is an important water hygiene indicator. High value implies that the water is seriously contaminated with sewage, organic matter, nitrate and phosphate. Water samples in the study health zones showed considerable high values of BOD5. The values ranged from low (urban health zone) to high (rural heal zone) values, generally, BOD5 values were higher than the acceptable value limit (range) by the REGIDESO.

4. DISCUSSION

In this study, it was hypothesized that (i) the quality of water consumed may be good in the health zone of Kadutu and Miti-Murhesa; and that (ii) the public does not know exactly factors causing pollution water (tape, well) consumed in the health zone of Kadutu and Miti-Murhesa. According to the finding, these assumptions were consistent as they will be discussed in the following sections.

4.1. Socio-economics determinants and water treatment techniques , access to clean water resources, and the prevalence of water-borne diseases (including typhoid fever).

In this study, it was observed that household size, educational status, type of water source, frequency of water collection, covering drinking water storage vessels, cleaning drinking water storage vessels, and method to withdraw water from storage vessel were factors likely being associated with adoption of best household water treatment practice. Some respondents were getting water from piped water source, and a majority of the respondents store their drinking water for 3 or more days in a bucket, suspend, jerrycan, clay-pot,.. . Some other respondents reported that they washed their water storage container before storing water, and very few of them used detergent/soap for cleansing their water storage container. However, the weakness was that the water storage container were easily accessible to children and visitors. Furthermore, most of the participants reported washing the container before collecting drinking water, although few of them used soap to wash their hands before eating. Respondents treated water at home and the common practice was boiling water. Very few respondents indicated to strain water through a cloth or add chlorine chemical occasionally (whenever available).

Problems related to environmental health are clean water, waste management, disposal of waste water flowing directly on the channel/river and sanitation.This causes siltation of the channels/rivers, blocking the channel/river due to waste. In the rainy seaons, is always flooding and cause disease. Protections of groups vulnerable to hazardous environmental conditions are still considered a low prioritiy. However, the impact of environmental risk factors of human health is growing, both in magnitude and diversity. Based on the aspects of sanitation, high rates of diseases caused by community-based environment that unmet need for clean water, latrine uses remain low, contamination of soil, water, and air as household waste, industrial waste, agricultural waste, transportation, physical and possibly environmental condtions.

-The data showed more than half of the public have access to water sources as water wells, in addition to the river water, swamp water, rain water.The water quality of water soruces used by people of unknown quality.Based on observations in the initial study conducted by rsresearchers, there are still many people who use the river water, swamp water, rain water for daily life. There are still many people wh use river water for daily living such as bathing, brushing teeth, washing, cooking and other while on the other hand is still a lot of to put the toilet on the riverbank.The possibility may lead to a change in the status of public health.Water quality and quantity is always an important issue at the lowland ecosystem of eastern DRCongo. Low domestic water supply sanitation is considered as having an important contribution on the high frequency of water borne disease in the area.

In urban-rural Kenya, poor sewage disposal, often next to waterways, leads to runoff that eventually ends up in rivers and ponds. Water drawn from such rivers and ponds is rarely treated because of a lack of awareness and, to some extent, poverty and scarcity of fuelwood to boil water[61]. Although it is likely that most water is contaminated at the source, there is often re-contamination during collection, storage, and use at home. In the village, residents typically collect water from rivers in 20-L plastic containers and then store water in the house in large pots for several days. A cup or tin is frequently dipped into the pot to draw drinking water. Multiple people often use the cup, which is rarely cleaned, thus, introducing contaminants, chief among them bacteria such as *Escherichia coli* and typhoid-causing *Salmonella*, into the water.

Between urban and rural consumers, there exist a variability in organoleptic properties rating (taste, smell, colour, clarity) of their water as being or good (safe to drink) and to use for domestic purposes. Very few rural respondents are concerned (or very concerned) about the overall safety of the water they consume from their source of supply in Miri-Murhesa health zone. Differences between perceptions among consumers of rural and urban health zones are sometimes statistically significant ($p < 0.05$) across the South-Kivu Province according to the national water company corporation.

The level of pathogenic micro-organisms may be of low levels at the source(well) sites(collection point). After handling at the site collection, transportation, and storage, clean water can become tainted with over 10 times more bacteria than water drawn from the contaminated open source, suggesting that bacteria may be introduced by villagers handling the domestic water(poor handling practices of fetched water). Respondents in some sites wash their hands, containers and cups in their stored water, while others do not. Leaving storage container lids open or closed also may affect potential contamination, as does the frequency with which storage containers are cleaned. By the fact, in Senegal, it was observed that contamination by E. *coli* and by pollution by faecal Streptococcus may low in some water points where water is collected , but he handling, distribution and domestic storage conditions methods may favor the bacterial multiplication more than to the collecting points[62]. ON the contrast, in Cameroun (Dschang), water used as drinking water are not pre-treated before consumption[63].

Overall, household water treatment technologies can safe-guard public health in areas persistently challenged by efforts to achieve universal access to safe water. Several types of water treatment technologies are being used, such as boiling, chlorination, and filtration, and newer technologies such as biochar and gravity-driven membrane-based water treatment.

It has been shown that in rural areas of underdeveloped countries , a large majority of the population are genuinely convinced that the water is safe to use without treatment[64]. The population is not aware or willing to pay for chlorine treatment because they perceive no risk for the untreated water from any source of water in the village. To avoid further pollution/contamination problem of water sources (tap, wells) in the study area, there must be enforcement of standards for location, construction and operation of best water sources while the surrounding environment should be kept clean and tidy. Disinfection of water by chlorination and continuous monitoring to determine any change in the level of pollution at the sources are also recommended. More so, each water source should have its own fetcher that will be used by everybody.

In Ethiopia, access to safe drinking water is very low, and even safe water at the point of distribution is subjected to frequent and substantial contamination during collection, transport, and storage[65]. The level of household water treatment practices and associated factors in rural households of the Sodo Zuria district, southern Ethiopia were among others, higher estimated monthly income, older household heads, fetching water twice per day, washing the water storage container weekly, and dipping techniques to draw water from water storage containers. Thus, proper hygiene of water storage, and engaging the community in income generating activities were recommended.

Enhanced water quality monitoring improved operational strategies safeguarding the microbial water quality. Microbial contamination of the drinking water at household level could point at recontamination in the distribution or unsafe hygienic practices at household level while picking water in the water storage containers. Presence of faecal contamination at household level indicates potential presence of pathogens posing a health risk to consumers. Increasing chlorine dosage ensured good microbiological drinking water quality but changing the number of supply cycles had no such effect.

Water treatment methods are effective in improving household health than other types of interventions, such as treating water at the point of collection or at the source. However, households often do not treat water regularly and even abandon water treatment over time. Previous studies have shown that only households that regularly treat their water experience the maximum health benefit (i.e., a sustained reduction in the rate of diarrhea). Socio-environmental characteristics, like parental educational level or local culture, and behavior determinants, like perceived health threat due to bad water quality or willingness and ability to pay for water treatment product, have been found to influence successful adoption of various water treatment methods in rural areas.

Household water treatment and safe storage such as boiling, filtering, or chlorinating water at home, have been shown to be effective in improving the microbiological quality of drinking water. However, estimates of their protective effect against major killer water-borne diseases such as diarrhea and typhoid fever, have varied widely[66].There is a need to that environmental interventions are implemented with varying levels of coverage and uptake in settings where the source of exposure represents one of many transmission pathways. It is necessary to make accessible these sanitary and environmental interventions to exposed populations while securing their consistent adoption and long-term use to eradicate water born diseases.

Clean water is an essential part of human healthy life and wellbeing. More recently, rapid population growth, high illiteracy rate, lack of sustainable development, and climate change;faces a global challenge in developing countries[67]. The discontinuity of drinking water supply forces households either to use unsafe water storage materials or to use water from unsafe sources.

A study was conducted in North-Ethiopia to identify the determinants of water source types, use, quality of water, and sanitation perception of physical parameters among urban households. It was found that 78.95% of households used improved and 21.05% of households used unimproved drinking water sources. Households accessibility to drinking water sources were significantly ($P<0.05$) associated with factors such as the age of the participant, educational status ,source of income, monthly income , availability of additional facilities, cleanness status, scarcity of water and family size, availability of toilet facility. Hence, the uses of drinking water from improved sources were determined by different demographic, socio-economic, sanitation, and hygiene-related factors. Also several psychosocial factors that influence people's behaviours with regards to the use of safe water sources were recorded in RSA[68]. In Nepal, prevalence of waterborne diseases was found to be 50.7%, and, education, was found to be an influential factor for the occurrence of the waterborne diseases in the study sites[69].

Many rural must travel several kilometers to fetch adequate water and many still do not have adequate sanitation facilities. Such poor access to clean water forces people to spend an inordinate amount of time and energy collecting water-time and energy that could be used for more useful endeavors. Furthermore, the difficulty in getting water means that people use less water than they need to for optimal health and well-being.

Improved water sources are not equally available in all geographical regions of Ethiopia[70]. Populations dependent on unsafe water sources are recommended to treat their water at point-of-use using adequate methods to reduce associated health problems. Promoting households to treat water prior to drinking is essential to reduce health problems.

In Mopti region (Mali), recontamination of drinking water seems to be a prevailing issue. Some villages have access to clean water but contamination seems to take place during transport and storage within the household. Respondents do not believe their drinking water could cause diarrheal diseases. Most women do not associating diarrhea with their drinking water, they do not know to prevent diarrhea nor they did not know the cause of diarrhea.

4.2. Influences of water, sanitation and hygiene (WaSH) methods, strategies on the prevalence of typhoid fever and related water-born borne diseases

In this study, it was observed poor compliance to WaSH requirements by respondents. Overall, inadequate access to water, sanitation and hygiene (WaSH) exposes many vulnerable populations, especially women and girls, to preventable diseases around the world. In fact, it was reported from Kenya that inadequate access to WaSH was significantly associated with increased water collection burden on women and children, environmental pollution, poor educational outcomes, loss of time due to water collection and poor sanitation infrastructure[71].

Some barriers to change behaviour that were identified included financial barriers and inadequate government support. The identified risks and barriers were said to be important considerations for the design, evaluation and mainstreaming of WaSH programs in resource constrained setting. WASH services remain essential for a dignified and healthy life. These are more than a prerequisite for development. It is also known that inadequate WASH has an economic, environmental and social impact[72].African urban population has been increasing mostly in response to climate change, environmental degradation, conflicts, migration, and poverty, thereby generating poor urban areas with problematic sanitation, access to drinking water, and hygiene issues.

Furthermore, inadequate access to WASH services has many health consequences; it is the main contributor to the burden of typhoid fever and diarrheal diseases , maternal mortality, and respiratory infections. Diarrhoea, acute respiratory infections, malnutrition and schistosomiasis require improvements of drinking water and sanitation services and increased hand washing with soap[73]. Also to reduce the WASH-attributable malaria disease burden, interventions will be required that lead to environmental modification and manipulation ,including waste resource management as main component, and changes of the human habitat, including siting of settlements away from breeding sites.

In fact, in Ethiopia[74], the use of basic water and sanitation services has been found to be associated with several health risk perceptions and health-protective behaviours: perceiving water quality as good increased the odds of using basic water services as opposed to believing the water quality was poor (OR 3.94; CI 3.06–5.08; p ≤ 0.001). Believing that drinking unsafe water was the main cause for diarrhoea increased the odds of using basic water services (OR 1.48; CI 1.20–1.81; p ≤ 0.001). The use of basic sanitation was associated with households who had previously received sanitation training, as opposed to such who had not (p ≤ 0.001). Perceiving dirty space as the main cause of diarrhoea (p ≤ 0.001), and privacy when using a latrine (p ≤ 0.001), were associated with higher odds of using basic sanitation. Households that indicated a disadvantage of owning a latrine was maintenance costs were less likely to use basic sanitation (p ≤ 0.001). Risk perceptions were important determinants of use of basic services. Risk perceptions motivating the application of positive WaSH-related and health-protective behaviours.

In Ethiopia, respondents believed that the presence of human faeces (93%) and flies in contact with faeces via food (96%) as well as animal faeces on the compound (69%) may contribute to the burden of water borne diseases in Ethiopia. Thus, washing hands with water, ash, soap once in a day, drinking safe , treated water as well as maintaining good hygiene practices such as washing hands after using a latrine or before eating or covering food, maintaining the household clean, were perceived as enough measures and activities to prevent water-borne diseases such as typhoid and cholera. Awareness and perception of health risk factors related to inadequate WaSH was highly depending on the use of basic water and sanitation services supplied to the population. Hence, well-designed health risk communication strategies may be effective for engaging households in changing towards adoption and implementation of positive healthy WaSH behaviour practices. Hand-washing, presence of a sanitary latrine, general household cleanliness, maintenance of the safe water chain and the households' knowledge about and adherence to sound sanitation practices may be as important as access to clean water sources[75].

Therefore, adequate fencing, proper diversion ditch construction and hygiene promotion should be done to protect water sources from faecal contamination. Furthermore, latrines and other point sources of contamination should be located at least 10 m away or at a lower elevation from water sources.

Knowledge that washing hands can prevent typhoid fever[76], and stated habit of handwashing habits before cooking or after toileting and plate-sharing with typhoid fever disease risk is often associated with increased risk of disease in Kikwit city in DRCongo[77].The outbreak of typhoid fever is often strongly associated with drinking water from the municipal drinking water supply; often with high levels of faecal contamination. In fact, typhoid was found to be associated with ever using tap water from the municipal supply (OR = 4.29, 95% CI 2.20-8.38). Visible urine or faeces in the latrine was also associated with increased risk of typhoid and having chosen a water source because it is protected was negatively associated with the risk of being victim of typhoid fever. Residents of areas with water supplied via gravity on the mains network were at much greater risk of disease acquisition (risk ratio = 6.20, 95%CI 3.39–11.35) than residents of areas not supplied by this mains network. Residents who were dependent on the central gravity system were five times more at risk compared to residents on the northern (pumped) network (RR = 6.20 vs. 1.21), and about three times more at risk compared to those on the central pump system (RR = 6.20 vs. 2.25),.

In Rwanda, poor water supply, lack of adequate sanitation, and bad hygiene practices with attendant diseases are killing many people each year, and children under the age of five are the most vulnerable[78]. In both rural and urban areas people have no to little knowledge on the causes several water borne and related diseases. Rural more than urban have limited knowledge on causes and prevention method for Shigellosis, trachoma, Diarrhea, Cholera, Malaria, and typhoid diseases. Although water supplied appeared to be physically clean, respondents(66.7%) interviewed in areas supplied through the municipal water system claimed that low supply pressure, frequent water shortage presence of pit latrines near water points and lack of improved sanitation facilities(toilets not often clean, absence of hand washing facilities or absence of soap in toilets). Developing programs by authorities which will specifically educate the public and students on the importance of washing hands after using the toilets, washing hands and warming raw food before eating and on the causes and prevention of water, sanitation and hygiene related diseases is an emergent issues , as well as raising awareness the consequences of living in an area with advanced levels of environmental degradation, including monitoring/ implementation of UNICEF/WHO/National guidelines and dissemination of WASH related diseases message in health centers, clinics and hospitals after treating WASH diseases related patients is recommended.

In Douala town (Cameroun), majority of respondents were married (76%) living in residences made out of hard materials(43%) and were supplied with of water especially by CAMWATER network (49% of households) and wells (50% of households) (Ndjama et al.2008). However, the majority of households (56%) evacuate solid waste in public refuse vats. Household’s wastewater is especially discharged around the houses (21% of households) and in rivers (20% of households). The companies present in the quarters discharge their wastewater in the drains also. More than half of respondents (52%) deposit their excrements in latrines. In quarters surveyed, diarrhoea (70% of households), dysenteries (74% of households), typhoid fever (72% of households), malaria (32% of households) and skin diseases (76% of households) were the most frequent diseases reported (Ndjama et al.2008). Thus, the need to conduct research for the improvement strategies for hygiene conditions in the populations of an urban environment[79].

4.3. Environmental risk factors for water microbial contamination (pollution) and prevalence of water-borne diseases

In this study, it was found that rural respondents were using more contaminated water than urban respondent. Also in Benin, it was reported that most (64.18%) rural households use traditional wells and do not observe basic hygiene rules around these water points[80]. This situation is explained by the pollution of the water with the appearance of microbes, and therefore poor quality water. Thus, the populations of Houéyogbé (Benin) are exposed to many waterborne diseases including typhoid fever, gastro enteric and especially malaria.

Human behaviour and environmental risk factors are among the key drivers of water-borne diseases in Africa[81]. Water contaminations are perhaps traceable to have originated from human activities (septic tanks, latrines, dumpsites) that affect the quality of groundwater. Fecal coliform is an indicator of bacterial contamination from excreta of human and other warm blooded animal. High level of fecal coliform in water can affect public health and community economy. Fecal coliform cause diseases like cholera, dysentery and diarrhea. The possible source of these high coliform is from excreta of human or warm blooded animal diffusing across poorly constructed septic tank.

Some biological contamination in water resources such as pathogenic bacteria (*Escherichia coli*, *Vibrio cholerae*, *Salmonella*, etc.), viruses (*hepatitis* A virus, *hepatitis* E virus, rotavirus, etc.), parasites

(*Giardia, Entamoeba, Cyclospora*, etc.), and parasitic worm (*Ascaris lumbricoides, Ancylostoma duodenale, Strongyloides stercoralis,*) are transmitted to humans through the fecal–oral route .

In the current study , there were unacceptable levels of coliforms in water. Coliform bacteria (fecal coliforms and E. coli) are indicator organisms whose presence suggests that water-borne pathogens of fecal origin may be present. . In both Canada and Uganda, the maximum acceptable concentration of total coliforms in potable drinking water is zero detectable colonies per 100 mL.

In the current study, it was found that the drinking-water was contaminated by *Escherichia coli* . Also in Toffo commune (Togo) , water is subjected to environmental pollution since water samples were found to be highly contaminated with bacteria germs (fecal coliforms, total coliforms and faecal streptococci). Anthropogenic pollution of water was related to sewage, garbage and defecation[82]. According to WHO, once bacterial microorganisms (*Vibrio cholerae*, *Salmonella typhi*) and related pathogenic micro-organism of faecal origin are found in water samples, such water may considered as contaminated[83].Once the prevalence of *Eschericia coli* is above 30 cases per 1000 inhabitants, such water may considered as a real public health problem because the WHO standard for this is 0.01 cases per 1000 inhabitants.

Fecal coliform , *Streptococcu*, and *Eschericia coli,* are indicators of the presence of biological contamination of water likely leading to the risk of water-borne diseases(Dysentery, Typhoid, and Hepatitis A) that can affect the people living in and around urban areas such as Wadi Gaza **(Taleb 2014)**. In Tigrai (Ethiopia), most water sources in are contaminated by faecal coliforms. Therefore, regular sanitary inspection, bacteriological analysis, and adequate fencing should be mandatory to protect drinking water sources from faecal contamination[84].

In Nouakchott city (Mauritania), bacteriological analysis indicated that 93% of the non-piped water sources supplied at water points were contaminated with 10-80 coliform bacteria per 100 ml (Traoré et al.2013). Environmental factors (e.g. lack of improved water sources) and bacteriological aspects (e.g. water contamination with coliform bacteria) were the main drivers explaining the spatio-temporal distribution of diarrhea[85].

In Mali, it was observed that well water (94.7%) and drilling water(5.3%) were more contaminated with for non-conformity to health and environmental (ISO/WHO//international/National) water standards of potability. *Escherichia coli* and coliforms thermo-tolerant have been both sources of contamination of non-conformity waters, apart from the non-protection of the wells and the absence of the basic hygiene rules.

Water quality and socio-economic conditions within villages are linked to incidences of water-borne diseases (diarrhea). *E. coli* was detected more frequently in water sources in the drier Kondoa district than in the wetter Arusha region of Tanzania.

In the Creek Town River (Nigeria) , it was found that the most prevalent bacteria isolated from water sample included 11 bacterial genera: *Escherichia coli*, *Klebsiella* spp., *Pseudomonas* spp., *Bacillus* spp., *Enterobacter faecalis*, *Streptococcus* spp., *Salmonella* spp., *Staphylococcus aureus*, *Proteus* spp., *Shigella* spp. and *Citrobacter* spp.[86]. Thus, water from Creek Town River was not suitable for direct human consumption and it poses a serious threat to the health of the consumers. Water treatment is therefore recommended before it can be used for domestic purposes.

In the Commune of Abomey-Calavi (Benin), there is insufficiency of hydraulic works installed for the supply of drinking water. The drinking-water is contaminated by *Escherichia coli*, of total and total coliforms at the water source points. This prevalence is 30.37 cases per 1000 inhabitants in 2017, whereas WHO standard is set for 0.01 cases per 1000 inhabitants for the country (Hondjenou et al. 2019). Microbiological analyzes show that waters used in Cameroun contain fecal bio-indicators. They have a high faecal contamination of animal origin (faecal streptococci, 1260 CFU / 100 mL and 687000 UFC / 100 mL) than of human origin (faecal coliforms, 130 CFU / 100 mL and 17785 UFC / 100 mL)[87].

In Lesotho, bacterial contamination of drinking water is a major public health problem in rural areas of Mohale basin (Lesotho). Unimproved water sources are a major reservoir of *Escherichia coli* (E. coli) causing severe diarrhoea in humans. Drinking water quality from different sources was linked to water source protection status and neighbourhood sanitation and hygiene practices in rural villages. Thus, community-led sanitation and hygiene education and better water source protection were urgently needed and recommende.

Environmental management and access to potable water remain key concerns (challenges) of public health, they require sensitization and education of the public of how to make more potable water for consumption, especially in rural areas of Kasai provinces (DRCongo) where all sources of water (spring, well, borehole, rivers, streams, ponds, tap water,…) are frequently found being microbially contaminated at both the source point and in water storage instruments.

The faecal indicator bacteria in association with physicochemical parameters were monitored twice a month from 2017 to 2019 in the Kahuwa, Wesha, Tshula, Bwindi and Nyamuhiga rivers and their tributaries in Bukavu town (south-Kivu Province, eastern DRCongo). The results showed severe faecal contamination of waters compared to the WHO standards. The presence of pathogenic bacteria such as *Eschericia coli*, *Salmonella typhi*, *Streptococcus sp.*, *Shigella dysenteriae*, *Aeromonas* sp., *Vibrio cholerae*,.. were indicative of faecal contamination of water.

The evaluation of the Physico-Chemical and Bacteriological Quality of Well Waters in the Spontaneous District of Luwowoshi (Democratic Republic of the Congo) indicated that that the analysis of the physico-chemical parameters obtained showed acid values of pH as well as strong contents of chlorides representing the main agent affecting the quality of water of everyday consumption[88]. Bacteriologically, this waters are heavily loaded and are home to many pathogenic germs of fecal contamination (total coliforms, fecal coliforms (*E. coli*) and intestinal enterococci) that have been observed in all samples, except in those of the drill holes.

In Ethiopia, the majority of the water sources in internally displaced people sites were tested positive for faecal coliforms. In fact, the presence of latrines in uphill, other sources of pollution , inadequate fencing and lack of diversion ditch, drawing water using a bucket with rope and unsanitary well cover are factors significantly associated with faecal contamination of springs and wells. Dug wells that had a latrine within 10 m , other pollution sources within 10 m , inadequate fencing , drawing water using a bucket with rope and unsanitary well cover are factors significantly associated with faecal contamination of water wells.

Boreholes used to access drinking water in Nigeria are polluted with several bacteria include: Enterobacter sp., Alcaligenes sp., Escherichia coli, Proteus sp., Klebsiella sp., Pseudomonas aeruginosa, cinetobacter sp., Staphylococcus aureus and Bacillus sp.[89].The vulnerability of the selected boreholes to bacteria means that, water resources in this area is not suitable for human consumption, hence water borne diseases.

In the North West region of Cameroon, although the public perceive that water has no odour and looks clean, it contains infectious bacteria (entero-bacteria, *Escherichia coli*, *Streptococcus, Salmonella* and

Proteus) and the[90] contamination by different extents by faecal forms of bacteria and heavy metals may be due to lack of disinfection, uncontrolled defecation, pipe leakages and the use of fungicides for agricultural activities, and thus should be treated by chlorination or boiling before use.

In western Cameroun, water pollution had several origins, the most important of which are related to spilled household discharges, without any prior treatment in rivers, manure from livestock and used in agriculture. The level of microbiological risk is very high for consumers and typhoid is the most recurrent waterborne disease in western Cameroun.

The protozoan pathogen *Cryptosporidium* is an important cause of diarrhoeal disease[91], but in many contexts its burden remains uncertain, especially in African areas where communities lack stable drinking water supplied and consume (with no treatment prior to consumption) contaminated surface water where the pathogen has established.

In western Cameroun it was found that the most frequently consumed springs water and standpipes are contaminated with *Escherichia coli*, *faecal Streptococci and Salmonella*, which makes populations vulnerable to diseases such as typhoid (57%), amoebiasis (47.2%) and diarrhea (45.5%). A study evaluated the contamination of well waters consumed in the Garoua metropolis (North-Cameroun)with *Salmonella* sp . and *Vibrio cholerae* , in view of preventing waterborne diseases caused by these bacteria[92]. The results revealed that these water sources were not always of good quality, though they are highly consumed in the study zone. These water sources host faecal bacterial pathogens and comensal bacteria in some urban areas with high level of environmental degradation. In Dschang (Cameroun) , the recurrent water borne diseases include typhoid fever (51 % of prevalence), amoebic dysentery (22.5 % of prevalence) and itching (17 % of prevalence) was attributed to pollution of water resources. In addition, urban runoffs and effluents of wastewater (poor effluent management) are water bodies representing significant public health hazards as key sources of faecal contamination of water sources in RSA[93].

In Cameroun , most of the mortality associated with water related diseases is due directly or indirectly to infectious agents which infect man through ingesting pathogenic bacteria, viruses or parasites (protozoans and helminthes) in food and water polluted by human or animal faeces or urine.

Diseases in this category include cholera (*Cholera vibrio*), shigellosis (dysentery caused by *Shigella* species), typhoid (*Samonella typhi*), paratyphoid (*Samonella paratyphi*), diarrhea (*Escherichia coli*), hepatitis (*Hepatitis virus*) and poliomyelitis (*Polio virus*),.These diseases (scabies, yaws, skin ulcers, conjunctivitis, and trachoma,..) are often associated with scarcity of water for personal hygiene (bathing, hand washing), laundry and cleaning of cooking utensils.

In Cameroun, The health problems issuing probably from these potential polluted water points include malaria (100% of households), diarrhoea (24% of household), dysentery (24% of household), typhoid (0.07% of household), skin disease (0.07% of households)[94].

In Benin, the public believe that insalubrity due to poor hygiene, negligence of compound cleaning, poor sanitation and management of wastes, poor body and food hygiene) were strongly associated with health-risks. Poor hygiene and sanitation may favor (attract, increase) disease vectors and pathogens in the habitat environment of human being. Dirty environment may favor the emergency of some diseases such typhoid fever, cholera, malaria, diarrheas,…[95].

Among risk factors for water pollution include, agriculture as major anthropogenic activity, implying the high use of fertilizers and phytosanitary products, as well as soil erosion on sloppy lands (Nguefack et al.2018).Also , the vast majority of people dump their garbage and wastewater into the wild. These different practices constitute real risk factors for pollution of water resources and emergency of water borne diseases.

As it was reported from Nigeria[96], solid waste collected and often disposed in uncontrolled dumpsites and or burnt in the open spaces and may consequently cause significant anthropogenic pollution on surface water, groundwater and the air. However, water quality may remain good and improved in conformity with standards once dumpsite are located far away from the water point. Uncontrolled accumulation of leachates from dumpsite may pose potential risk to the source of water from the community if wild dumping of waste and garbage continue at the current trend, until they are related from the residential area and nearby water point.

In Africa , various water supply most used (well, drilling, public network) are confronted with the physical, chemical and microbiological pollution[97]. The quality of water for domestic use in urban environments is affected by several factors. Waters, even being drinkable originally, can undergo a contamination along the chain of supply .The sources of pollution are in general anthropic origins. As compared to tap water supplied by national water companies, spring and well waters are more exposed to the pollution. Water pollution constitutes a threat for public health users. The level of pollution is due to the germs of fecal contamination and pathogenic, the nitrogenized pollutants and the toxic metal pollutants. Among key driving factors of water pollution, there were the lack of sanitation of the environment and the precarious living conditions and poor hygiene maintenance of urban dwellers. Climatic and physical conditions of the environment influence the level of pollution waters.

In urban Nigeria, water may be polluted by several factors including sewage leakages, flooding, high population density, vehicle combustion, oil spillage, menace of waste from palm industries and water hyacinth, heavy metal, toxic waste disposal at sea, industrial waste dumped into water bodies, house hold chemicals, mineral processing plant wastes, pollution of ground water through drilling activities, pesticides-herbicides-fertilizers from agricultural lands, rain runoff carrying waste deposits into waters during rainy seasons, eroded sediments, deforestation debris, failing septic system, animal wastes[98].

In Southeast Asia, agriculture has been implicated as a potential driver of human infectious diseases[99]. However,the generality of disease-agriculture relationships has not been systematically assessed,hindering efforts to incorporate human health considerations into land-use and development policies.

Agricultural land are on average 1.74 (CI 1.47 – 2.07) times aslikely to be infected with a pathogen than those unexposed. Effect sizes are greatest fore xposure to oil palm, rubber, and non-poultry based livestock farming and for hookworm (OR2.42, CI 1.56 – 3.75), malaria (OR 2.00, CI 1.46 – 2.73), scrub typhus (OR 2.37, CI 1.41 – 3.96) and spotted fever group diseases (OR 3.91, CI 2.61 – 5.85). In contrast, no change in infection risk is detected for faecal-oral route diseases. Although responses vary by land-use and disease types, results suggest that agricultural land-uses exacerbate many infectious diseases.

In West Bank, Palestine, it was found that the microbial and chemical pollution of groundwater is postulated to inadequate waste water management, high use of fertilizers, and uncontrolled disposal of animal manure[86]. Therefore, it is crucial to disinfect drinking water at the source of production before supply as an immediate action, followed by implementing pollution prevention measures[100].

Pollution of surface water bodies, resulting from anthropogenic activities, is a growing concern worldwide[101]. Assimilating or carrying off municipal and industrial wastewater and runoff from agricultural land by river inflows may contribute to main pollutants to most lakes in a watershed (depending on the topographic conditions of the urban area crossed by the water body) thereby tending to induce serious domestic, industrial, ecological and sanitary problems. Major regular and persistent anthropogenic activities (such as washing of clothes, rugs/carpets and cars as well as effluents and wastes from abbatoir, dredging) have cumulative impact on quality of water resources used by the population for material cleaning, drinking, bathing, cooking, industrial, aquaculture purposes in Nigeria.

In Nigeria most ground water sources are unsuitable for drinking. Bacterial pollution is more common in boreholes than pollution by heavy metals., thus boreholes are recommended to be located at above 15 m away from septic tank or latrine to reduce contamination from coliform. Dump/ landfill is a major source of contamination of groundwater. Leachate leakage from dumpsite may be a major source of groundwater pollution with organics, salts and heavy metals as pollutants[102]. Another factor leading to water contamination in Africa is environment insalubrity or massive presence of garbage in the urban space stems from the transfer of rural cultural modes[103,104]. Although, solid waste problem is everyone's concern i.e. men, women, social groups and different communities still bear socio-cultural models inherited from their village customs and beliefs and behavior wild even when fetching water.

4.4.Socio-economic and Environmental-climatic drivers of Typhoid fever prevalence and related waterborne diseases

In the current study, the prevalence of typhoid fever with found to be more higher in rural health zone and than in urban health zone. Also the prevalence of *Typhoid* (5.4 cases per 100.000 populations) , *E-Coli* (1.9 cases per 100.00 populations), *Streptococcus*, (11-14 cases per 100.000 populations) were reported in contaminated water in Gaza and were higher than what WHO data for the region **(Taleb 2014)**.

In Vietnam, shigellosis rates per 100,000 population (70±41 cases) were higher and more widespread than rates for typhoid fever (23±7 cases) and cholera (2.7±03 cases. The distinct geographical patterns of each disease appear to be driven by a combination of different ecological factors within Vietnam.

Other factors that may contribute to the risk of emergeny of typhoid fever include, the adoption or not of best hygienic practices of water treatment (boiling, filtering or using chlorine drugs), the use of long lasting latrines (above 2 years of duration before change or construction of a new latrine), poor maintenance of water sources, the habit of washing hands before eating, after eating and after having defecation in a toilet, the presence or not of human and animal fecal waste in enclosures or habitat compounds, the wild discharge of domestic a
nd sold waste on street or avenues and abesence of dust bins in the household compounds, as we ll as the loe level of education/sensitsation of the population on basic hygienic a sanitation practices.

Currently, Typhoid fever, caused by *Salmonella enterica* serovar Typhi (S. Typhi), is a diminishing public health problem in Vietnam[105]. The reduction in the burden is difficult to disaggregate the roles of immunization and water, sanitation, and hygiene (WASH) interventions in typhoid reduction in Vietnam. Given the limitations of typhoid vaccines, the practical elimination of typhoid is largely driven by economic development and improvement in general population living standards.

Thus, improvement in water quality (odor, taste, appearance, turbidity, clean), sanitation, and personal hygiene will make it possible to reduce considerably the propagation of water born diseases[106] . It is therefore important to provide to the populations with the necessary equipment for an adequate drinking water. Salmonella (*Salmonella typhi*) belongs to the Enterobacteriaceae family, a gram-negative, non-spore-forming, rod-shaped, motile, and pathogenic bacteria that transmit through unhygienic conditions[107]. Typhoid is a common infection in regions with poor economic development and limited public health infrastructure. *Salmonella enterica* serotype *Typhi* and *S. enterica* serotype *Paratyphi* A, B (tartrate negative), and C cause typhoid and paratyphoid fevers. They are characterized by relatively long incubation periods (14 days on average) and are common in tropical regions[108], including South and Southeast Asia.

A large typhoid fever outbreak occurred in Kampala, Uganda, with 10,230 suspected cases in 2015. During the outbreak, area surgeons reported a surge in cases of typhoid intestinal perforation (TIP), a complication of typhoid fever[109]. Delay in seeking treatment increased the risk of TIPs in Uganda. In Tanzania, Typhoid intestinal perforation is still endemic in our setting and carries high morbidity and mortality[110].

This study has attempted to determine the factors that statistically influence mortality in typhoid perforation in the environment.

In 2010, *Salmonella enterica* serotype Typhi (S. Typhi) was estimated to cause over 200,000 deaths and more than 21 million illnesses worldwide, including over 400,000 illnesses in Africa[111]. In Pemba Island (Tanzania), a study was conducted on qualitative data provided descriptions of home-based treatment practices and use of western pharmaceuticals, and actual healthcare use for culture-confirmed typhoid fever. Survey data indicate health facility use was associated with gender, education, residency, and perceptions of severity for symptoms associated with typhoid fever. It was suggested that education of policy makers and health administrators, and the design and implementation of surveillance studies, and community-based interventions were necessary to prevent disease outbreaks, decrease risks of complications, and provide information about disease recognition, diagnosis, and treatment.

Among serotypes, *Salmonella enteritidis* and *Salmonella typhi* have significant adverse effects and have been reported to cause severe and occasional life-threatening diseases like typhoid fever, sepsis, diarrhea, and gastroenteritis.

A study conducted to assess the prevalence of typhoid fever and its risk factors in rural and urban community in Ethiopia, indicated that 76.9% of the respondents had knowledge about typhoid fever[112].

The study revealed that 58.6% males and 60.4% females claimed to have suffered from typhoid fever in the past. Typhoid fever was higher in illiterate, elementary school and high school students than respondents with certificate, diploma and degree holders ($p<0.001$). The study found out that 93% of respondents who used pit latrine, 61.6% were suffered with typhoid fever. Also 60.3% of the respondents disposed the solid wastes on field that have direct proportional relation for prevalence of typhoid fever($p<0.001$). In case of water supply and prevalence of typhoid fever, largest percent (75%) who drink from river water were suffered with typhoid fever. Additionally, the study found out that 54.9% patients had typhoid fever based on clinical examination and serological test results (Eba & Bekele 2019). This indicated that the risk factors were still continued to be discovered. Therefore, the understanding of environmental and sanitation factors that influence the occurrence of typhoid fever has not reached to its ends.

In Nigeria, it was realized that only a smaller percentage (23.8%) of urban respondents had access to public tap and private well in their houses/compound[113].Also, incidence of diarrhea (23.3%), stomach ache (20.2%) and typhoid (14.8%) was found to be higher in peri-urban and rural areas than in urban areas over populated or not.

The maximum risk of exposure to typhoid and diarrhea-causing pathogens, is strongly related to household income level in Tanzania. Incidences of diarrhea per year vs. household expenses per month. The majority of households spent an average of $15/month (bout 10% of average annual income of the household) for the management of health care related risk exposure to diarrhea and related water borne diseases.

In Extreme north of Cameroun, poor personal hygiene and sanitation, the lack of good latrine and drinking water of good quality are the key factors favoring the occurrence of this typhoid fever epidemic in areas with precarious hygiene. It is important to involve all health partners in the sensitization campaigns as well as declaring all suspected cases for effective control.

Sharing latrines with more than one family, in a military camp in Kikwit (DRCongo) may favor the Typhoid fever outbreak[114]. The proximity of camps (transmission hotspots) to the general population might have been responsible for disseminating Typhoid fever to the general population of Kikwit.

In rural areas of Tanzania, prevailing water borne diseases as reported/mentioned were diarrhea (31%), cholera (16%), worms(10%),malaria (18%), pointed out Schistosomiasis (6%) other pointed out typhoid fever (19%) being a common problem in their areas. In urban area, the disease ratio was: typhoid (20%), cholera(7%), hepatitis(13%), worm infestation (7%), diarrhea (27%), skin infection (23%), eye infection (13%), stomach problems (53%) and allergies (33%) ,[115]. In Tandale (Tanzania) mot (64%) respondents reported that waterborne diseases(typhoid fever,…) affect their families because of poor water supply . The respondents who confirmed to have been infected were mostly those who said they do not boil their drinking water. Interestingly, these respondents showed their happiness and stated clearly that their stomachs are used to un-boiled water so it is very hard for them to get sick. They stated further that the only people who get sick are those with weak stomachs, who are not used to the way of life in the informal settlements. Those who denied to have been infected in their families are largely those who take appropriate precaution in ensuring that they boil water before drinking. About 14% of the respondents said that when wastes piles up during the rain it causes pollution and houseflies which are diseases vectors accumulate (waterborne diseases are caused by poor waste collection, which in the end causes pathways for waterborne diseases to spread in the communities),

In Mauritius typhoid fever is mainly an imported disease, but indigenous cases of the illness occur rarely and sporadically[116]. In Bangladesh, bear a disproportionate burden of diarrhoeal diseases such as Cholera, Typhoid (due to *Salmonella enterica typhi*), and Paratyphoid seem to be aggravated by a number of social and environmental factors such as lack of access to safe drinking water, over crowdedness and poor hygiene brought about by poverty. Quality of Life index is also linked to typhoid occurrence and risk.

In Zaria state (Nigeria), high prevalence of typhoid, diarrhea, cholera among infant and children has been traced to consumption of unsafe water and unhygienic practices.A study determined the relationships between the prevalence of *Salmonella typhi* in drinking water and the occurrences of typhoid disease in Zaria state(Nigeria) and examine the social and environmental bases for the occurrence of *Salmonella typhi* and typhoid fever in Zaria state. It was observed that major sources of water used included tap water (13.9%), sachet water (86%), boreholes (77%), and well water (76%).*Salmonella typhi* were detected in the drinking water of some location water samples (91%) . There were high relationships between the concentration of *Salmonella typhi* in drinking water and occurrence of typhoid disease, lack of education (27.6%), poor hygiene (37.8%), economic constraints (33.3%), overcrowdings (48.2%) and lack of access to clean water (32.3%) were the common socio-environmental factor that promotes the occurrence of typhoid in the area. Sanitation and hygienic conditions (household-level hygiene and food and water contamination, including handling practices) contribute to the disease burden[119] . Also, limited knowledge and understanding of risk factors and the causes of typhoid fever by the public, c lack of the basic amenities influenced their hygiene practices, health belief model, ability and willingness to change behaviors, environmental behavior and living conditions of eating and sleeping on a floor harboring fecal materials may affect typhoid fever prevalence. However, positive social change may result from the policy changes tailored to educating on the effects of the disease and improving the environment for the villagers by providing the needed essential amenities.

Typhoid disease is very common in South Asia. In Malaysia, the direct fecal-oral route is the main transmission mode, but indirect environmental transmission could occur, particularly in urban settings[120] for the increase of typhoid fever infection in urban areas. A temporal epidemic curve reveals that yearly typhoid incidence rate was 8-11 persons per 100,000 people with monthly variable peak incidences. Environmental factors are known to have impact on the distribution and transmission of typhoid in other endemic settings. Monthly records demonstrated that almost half of the reported cases had occurred during rainy season of July-October, indicating a distinct seasonal pattern.. Rainfall for instance, substantially affected the occurrence of typhoid by increasing the faecal contamination in the water supply and the transmission of typhoid bacterium is to some extent influenced by rainfall, particularly in low lying areas where people rely on surface water for their daily needs, including drinking and domestic purposes . When natural runoff drains and transports rubbish, including human wastes to the surrounding water bodies during the rainy seasons, surface water becomes heavily contaminated, resulting in a higher number of cases of typhoid as the case of Cholera. Since water logging and flooding become pervasive during the rainy seasons, contamination of surface water and tube wells by flooding are likely to result in a peak incidence at that time. Furthermore, flooding, either natural or caused by human modification of the land surface could lead to the occurrence of typhoid , particularly in wet areas.

In Abuja and Kano cities (Nigeria), typhoid fever still poses a serious health challenge(as major health security issue). Driving contextual factors attributable to fluctuation (erratic trends) in prevalence of typhoid fever and diarrheal mortality include, antibiotic drug resistance, unavailability of sufficient typhoid vaccines, female level of literacy, access to improved safe water supply, improvement in gross domestic product, and reduction in poverty level while access to improved sanitation facilities decreased over time and space nationally[142]. In Bangladesh, significant developments for sanitation facilities, drinking water supply, female literacy, and reduction in poverty head count ratio, poorly planned unplanned development of water supply and sewerage system, stability in population density are the contextual factors explaining fluctuation in typhoid fever prevalence[122]. In RSA and Malawi, improved socioeconomic circumstances have been temporally associated with decreasing incidence rates and trend fluctuation of typhoid fever over a 35 year period (1980-2015). Ongoing challenges remain including potential for large outbreaks, a large immigrant population, and emerging antimicrobial resistance continued active surveillance is mandatory[123,124].

Reasons for typhoid fever disease burden in a given area are many, including [125]: water source (well, bore, spring, tap, river, stream, lake) contamination, cessation of chlorination application, multiple drinking water spout contamination with sewage, contamination of stored water, lack of toilets or lack of water to flush toilets, unchlorinated water supply through pipes, drinking water pipes close to open drainage and intermittent water supply, multiple foodborne and drinking water source contamination due to sewage exposure to municipal water supply, drinking water contamination with unchlorinated river water which had direct sewage drainage, drinking water contamination and consumption of unchlorinated water (dislike for chlorine smell), drinking river water which had sewage (latrine) drainage, drinking water sources from deep wells and ponds contaminated with drainage from latrines situated in the proximity, drinking of un-boiled surface water outside home during the hot and dry season months, drinking any water source contaminated, or untreated water supply from unprotected springs and natural streams, or drinking untreated water supply from venders, fecal contaminated sources due to an open well supplying water facilities, municipal water supply exposed to contamination at workplace or drinking of unchlorinated water from venders, consumption of raw vegetables irrigated with sewage water from the city, habit of consuming street food, poor hygienic practices such as no use of soap for handwashing, sharing of food, and no toilet in the household and household crowding at home, lack of soap availability at handwashing place, frequently eating outside home and crowing at home.

More than 40% of people are admitted daily in hospitals in Burkinafaso for malaria, typhoid fever and diarrheas[192]. Water from unprotected wells(springs), inundations poor environmental sanitations of the living areas and wild drop of solid waste at the source point of drinking water and establishment of pit latrines near point sources and taps or well are the main source of pollution and degradation of the microbiological quality of drinking water in Burkinafaso and in central Cameroun[127,128].

In Zanzibar Town (Tanzania), domestic wells are mushrooming due to inadequate supply of tap water. The well water is used for domestic purposes including drinking. In many cases the wells are situated very close to pit latrines/septic tanks increasing the risk of contamination(especially during rainy seasons) with water borne diseases such as cholera and typhoid fever . The degree of contamination was found being affected by the depth of a domestic well, and combination of number and location of a septic tanks surrounding a well at a particular location.

Global warming has led to an increase in the average temperature around the globe, which has been heavily impacting on water resources. Africa and Asia already encountered the consequences of water stress. Increases in population and anthropogenic activities may heavily influence water resources and increased water pollution.The increase of water pollution is likely to lead (influence) to the burden of water-related diseases affecting the health of many citizens in developing countries. Due to the shift in seasons, in some locations as a result of climate variability, new water resources may emerge or re-emerge. Provision of safe drinking water to the general public and development of adaptation strategies such as protection of water resources and watershed management should be adopted to cope with unforeseen situations (water related challenges) and to alleviate/decrease the water-related disease burden. Education and social awareness may play a major role in confronting and controlling water pollution, waterborne, and water-related diseases, and subsequently in improving human health in developing countries.

Increased public health risk caused by pathogen contamination in water is a serious issue and mitigating the risk requires improvement and understanding of existing microbial monitoring plans (strategies). Increased agricultural activities, use of animal waste as fertilizers, and combined effect of rainfall and temperature may also act as potential determining factors behind the elevated of microbial contamination (*E. coli*) levels in water resources.

Meteorological factors including temperature, precipitation, humidity and radiation influence infectious disease by modulating pathogen, host and transmission pathways. Meteorological disasters such as droughts and floods directly impact the outbreak and transmission of infectious diseases. Climate change indirectly impacts infectious diseases by altering the ecological system, including its underlying surface and vegetation distribution. In addition, anthropogenic activities are a driving force for climate change and an indirect forcing of infectious disease transmission. International travel and rural-urban migration are a root cause of infectious disease transmission. Rapid urbanization along with poor infrastructure and high disease risk in the rural-urban fringe has been changing the pattern of disease outbreaks and mortality. Land use changes, such as agricultural expansion and deforestation, have already changed the transmission of infectious disease.Accelerated air, road and rail transportation development may not only increase the transmission speed of outbreaks, but also enlarge the scope of transmission area. In addition, more frequent trade and other economic activities will also increase the potential risks of disease outbreaks and facilitate the spread of infectious diseases.

The potential impact of climate change on human health from waterborne and vector-borne infections may be observed through; increased frequency of heavy rainfall events, with associated flooding-soil erosion landslide and increased temperature.Increased temperature could lead to climatic conditions favourable to increases in certain vector-borne diseases. It is considered unlikely that climate change will lead to an increase in disease linked to mains drinking water, although private supplies would be at risk from increased heavy rainfall events. Flooding is associated with increased risk of infection to waterborne diseases in Africa where frequently drinking water is compromised. Numerous reported of outbreaks that followed flooding that led to contamination of underground sources of drinking water. Heavy rainfall also leads to deterioration in the quality of surface waters that could adversely affect the health of those in water contact.

The availability of water resources of depends on biophysics conditions such as climate, topography, geology, vegetation and soils. Rainfall variability may affects the replenishment of groundwater and consequently compromises access to drinking water for the populations. Heavy rainfall is associated with increased risk of waterborne disease. The risk increment may differs between rainy and dry seasons. Hospitalization risks are frequently higher during few days after heavy rainfall days. In rural areas , hospital admissions 1-4 days after heavy rainfall increases mostly in areas (800-2500m of altitude) with short to long-term rainfall are reported. Climate change may with increasing intensity of precipitation(with more severe, and possibly more frequent, droughts and flooding) may increase the rise in waterborne diseases burden[129].

The effect of climate and damage caused by drought, flooding of infrastructure, forest fires, etc. can be increased by extremely hot weather as well. Studies highlighted the evidence of the link between climate change and air pollution as driving factors and increased water borne disease mortality and morbidity as health outcomes[130]. It is important to give priority to improving the environmental conditions affecting food-borne and water-borne infectious diseases under climate change[131].

Waterborne pathogens respond similarly to hydro-climatic changes, indicating that disease outbreaks may be more frequent and severe than usual[32] . Thus, climate variables (such as temperature and precipitation) are likely to, influence *E. coli* concentrations in surface, bathing and drinking water resources as it was reported from Pakistan.

Typhoid is a serious and sometimes fatal disease caused by the bacterium *Salmonella enterica* serovar Typhi (S. Typhi). It spreads through contaminated food and water and poor sanitation. Although typhoid has been largely eliminated in industrialized countries, it continues to be a substantial public health problem in many low and middle-income countries. Globally, there are nearly 12 million cases and more than 128,000 deaths due to typhoid each year.

Increases in typhoid transmission are a possible consequence of climate change and the resulting increase in extreme weather events, including floods and droughts that lead to more severe surface water contamination.

In Vietnam, typhoid fever is highly endemic in Vietnam and is a significant disease in both preschool and school-aged children[133].The peak occurrence of Typhoid fever is reported at the end of the dry season in March and April.

Enteric fever due to *Salmonella Typhi* (typhoid fever) occurs in urban areas (elevated or not or climatic rainfall seasonality) with poor sanitation, especially in tropical regions. While direct fecal-oral transmission is thought to be the predominant mode of transmission, recent evidence suggests that indirect environmental transmission may also contribute to disease spread[134].

Generally, typhoid is endemic in impoverished areas of the world where the provision of safe drinking water and sanitation is inadequate and the quality of life is poor. Although contaminated food and water have been identified as the major risk factors for typhoid prevalence, a range of other factors have been reported in different endemic settings such as poor sanitation, close contact with typhoid cases or carriers, level of education, larger household size, closer location to water bodies, flooding , personal hygiene, poor life style, and travelling to endemic areas. In addition, climatic variables such as, rainfall, vapour pressure and temperature have an important effect on the transmission and distribution of typhoid infections in human populations.

Anarchic urbanization and inadequate hygiene conditions were additional factors enhancing the sanitary risk of these water points, particularly during rainy seasons in Cameroun[135].

The prevalence of infections with waterborne pathogens, such as *Vibrio cholerae*, *Cryptosporidium* and *rotavirus* is well known world wide to be climate related. Several other water-borne related diseases (typhoid fever, rheumatism, dysentery, asthma, diarrhea, bronchitis, allergic, eye disease, skin diseases, intestinal disease, gastritis, dental caries,..) are reported in Southern Africa(Mozambique) as strongly associated with precipitation.

In Ramotswa area (Botswana), there exist critical indirect linkages between climate change, sanitation, groundwater quality, and water security and safety in a given area. Thus, improved sanitation, groundwater protection and remediation, and local water treatment would enhance reliable access to water, de-couple the community from reliance on surface water (ponds & flood water) and associated water shortage risks, and help prevent transboundary tension over shared aquifer systems.

In Mali, it was found that the seasonal flux of the Niger River Inland Delta had a profound influence on water management, hygiene, sanitation conditions, and accessibility to health clinics. Hence, it was found that, diarrhea was a seasonally driven and accentuated by climate variability. Water borne and diarrheal disease management was found being influenced by (i) the tremendous seasonal fluctuations in environmental factors, (ii) water use behaviors and low awareness of the relationship between poor water quality, oral-fecal disease transmission, and waterborne disease .Thus, interventions to mitigate the high incidence of diarrhea and degraded water quality may be limited by local socio-economic, cultural, and institutional factors., since respondent level of health knowledge is socially and culturally dependent.

Climate change may affect human health through multiple and interactive pathways that include safe water quality and security/scarcity[136]. Sometimes, lack of safe drinking water is a severe crisis due to climate change in Sierra Leone. Local community believes that climate change is having substantial impacts on freshwater sources and health. Diarrhea, dysentery, and skin diseases as the prime waterborne health risks that occur through climate-related safe water scarcity.

Climate change imposes many risks to human health, among which the provisioning of safe drinking water constitutes a global problem. Drought, increased rainfall, higher temperature and more frequent and severe natural hazards of various kinds will affect the availability and quality of drinking water. Water supplies can be contaminated by nutrients, toxic chemicals, and microbes such as protozoa, algae, bacteria and viruses. Increased risk of outbreaks of waterborne diseases is noted in a number of studies[137]. Several outbreaks of waterborne diseases in recent years can be traced back to extreme hydrometeorological events.

In rural China, the public perceives themselves to be living in a high-risk area, of which climate-related disasters such as storms (44.4%) and droughts (38.9%)[138]. In Nepal, seasonal variations and climate change are important causes of waterborne disease outbreaks including Typhoid fever, intestinal worms, amoebic dysentery and viral diarrhea that result in a sharp rise in number of patients during the rainy season[208]. In Kenya, climate variability has a strong influence on disease prevalence and subsequently on economic vulnerability and wellbeing of the affected households from areas prone to droughts, land slides, floods and those with relatively unstable weather[139]. Malaria, respiratory tract infection, typhoid, pneumonia, diarrhoea, bilharzia, stomach ache, and skin diseases are major diseases among the Lake Victoria basin residents (Kenya side) can often be affected by unseen subtle effects of adverse climatic conditions.

4.5. Multi-drug resistance of pathogens, the co-infection typhoid fever-malaria and other water-borne related diseases

Typhoid fever and malaria co-infection is a major public health problem in many developing countries of the world. Typhoid fever is an acute, life threatening febrile illness caused by the bacterium *Salmonella enterica*, with an estimated 22 million cases of typhoid fever and 200,000 related deaths occurrence world wide each year[140]. This disease has been associated with major negative economic impact in regions where it is widely spread such as high costs of health care, working days lost due to sickness, days lost in education, decreased productivity due to brain damage from cerebral malaria, loss of investment and tourism[141].

Gastroenteritis is recognized as a serious public health problem in India. It is a syndrome that can be caused by different bacterial, viral and parasitic pathogens[142]. Of the frequently recorded enteric pathogens, the predominant isolates were Diarrheagenic *Escherichia coli* (DEC) (46.3%) followed by Salmonella, *Shigella, Vibrio cholerae* and parasites. Indiscriminate use of antibacterial agents has resulted in the development of multidrug resistant organisms.

Typhoid fever is a significant contributor to infectious disease mortality and morbidity in low- and middle-income countries, such as South Asia, where health literacy is failing to increase. With increasing antimicrobial resistance, commonly used treatments are less effective and risks increase for complications and hospitalizations. Typhoid fever may cause several financial and time costs burden on households. During an episode of typhoid fever, households experience multiple social and economic costs that are often undocumented. Children may contract typhoid fever and their caregivers, families, and communities, as well as health providers and outreach workers. The impact of limited laboratory diagnostic equipment and tools may reduce healthcare providers' abilities to distinguish typhoid fever from other febrile conditions and administer unappropriated treatments thereby increasing challenges associated with antimicrobial resistance.In such countries there is an urgent need to identify and implement effective preventive measures including vaccination policies and programs focused on at-risk populations and endemic regions such as Nepal.

Plasmodium falciparum malaria and non-typhoid Salmonella (NTS) bacteraemia are both major causes of morbidity and mortality in children in sub-Saharan Africa[143]. Antimicrobial resistance is becoming widespread in invasive NTS serotypes, making empirical treatment problematic, and increasing the need for prevention measures. Observational studies indicate that interventions to reduce malaria transmission might also have a substantial impact on decreasing the incidence of NTS bacteraemia.

Malaria and typhoid fever are both endemic in the tropics and pregnant women constitute one of the high risk groups[144]. The rate of co-infection (typhoid fever/malaria) has been found to be of 11.4% of the population in peri-urban area of Nigeria[145]. The rate of malaria- typhoid co-infection in pregnant women attending antenatal clinics in general hospital Abuja(Nigeria) indicated that out of 200 sampled, 16(8%) were infected with malaria parasite while 77 (38.5%) were infected with typhoid, 9 (4.5%) had the malaria typhoid co-infection.

The prevalence of co-infections between malaria and bacterial febrile illnesses (such as Typhoid fever) is of about (39.5%) in Malawi[146]. The study has underscored the importance of febrile bacterial diseases including zoonoses such as leptospirosis and brucellosis in febrile children, and thus such illnesses should be considered by clinicians in the differential diagnoses of febrile diseases.

The prevalence of malaria and typhoid co-infection may be due to misleading Widal[147]. In Ghana municipal hospital, the co-infection of malaria and typhoid fever using Widal test and blood culture were found to be of 5.73% and 1.91% respectively. No isolate of *Salmonella typhi* were susceptible to gentamicin, cefuroxime and co-trimoxazole. Other species of Salmonella were also not susceptible to tetracycline, ampicillin, co-trimoxazole and cefuroxime. All of the *Salmonella* isolates were susceptible to ciprofloxacin and amikacin. All of the *Salmonella* isolates were susceptible to ciprofloxacin and amikacin[148].Concomitant infection of typhoid and malaria is very dangerous as most malaria cases are not properly managed and most cases treated as malaria were in fact typhoid cases, as the two diseases present common symptoms[149]. It is therefore suggested that regular screening for malaria and concomitant bacteraemia be carried out in rural communities so as to improve diagnosis and treatment of malaria and typhoid cases.

In Fayoum (Egypt), estimates incidence of typhoid fever was 59/100,000 persons/year[150]. Multidrug-resistant (MDR) *Salmonella Typhi* (resistant to chloramphenicol, ampicillin, and trimethoprim-sulfamethoxazole) was isolated from 26 (29%) patients. The emergence and spread of antimicrobial resistance in *Salmonella typhi* (Enterobacteriaceae) and the long-term efforts needed to deliver water and sanitation improvements has focused increasing attention on the use of typhoid vaccine[151]. In Bangladesh, important challenge being faced on is *Salmonllea typhi* resistance to antibiotics[152].

In addition, five interventions were perceived to have been effective for typhoid control: increasing access to safe water, toilet construction, vaccinations , market cleaning , and banning of wastewater for irrigation[153]. Hence, It is important to invest in clean water, sanitation and hygiene (WASH) strategies, health and immunization strategies, food safety regulations, or socioeconomic development remain unclear. Similar trend results in the reduction of the typhoid fever incidence are observed in Thailan[154].

Although typhoid is endemic to Southeast Asia, very little is known about the disease in Laos. Typhoid vaccination is not included in the national immunization program. Although sanitation has improved, one million people still do not have access to basic clean water source[155]. Although typhoid multidrug resistance and fluoroquinolone resistance are not currently major issues in Laos, continued surveillance and improved antibiotic stewardship are necessary to forestall worsening of the situation. Cost-effectiveness analysis is needed to inform decisions regarding typhoid vaccine introduction. Typhoid conjugate vaccines represent a new tool for typhoid control. However, incidence data are needed to inform decisions about introduction in Lao People's Democratic Republic..

4.6. Management of Typhoid fever with natural products and medicinal plants.

Commercially available culinary organic honeys possess remarkable antimicrobial activity against several important human bacterial pathogens including *S.typhi*[156].

There are limited studies reported for anti *S. typhi* activity from traditional medicinal plants like *Vitex doniana* (root), *Cassia tora* (Leaf), *Alstonia boonei* (bark), *Stachytarpheta jamaicensis* (leaf), and *Carica papaya*. Similarly, methanolic extract of *Glycyrrhiza glabra* and *Azadirachta indica* has been reported for anti-typhoid activity, broad spectrum, anti-bacterial activity against gram-positive and gram-negative bacteria[24]. Leaf extracts of *Bidens pilosa* and *Dichrostachys cinerea* are potential sources of antioxidant and antimicrobial agents, which can find application in the treatment of water borne diseases including typhoid fever and bacterial diarrhoea conditions[157].

In Ghana, a study was conducted to assess the antibacterial activity of *Phyllanthus amarus* (Schum and Thonn) extract against *Salmonella typhi* causative agent of typhoid fever at the laboratories. Significant differences were observed among the extracts and the control in both 10g/200ml and 20g/200ml concentrations ($P<0.05$). Aqueous and ethanol extracts of *P. amarus* proved inhibitory to S. typhi[158].

In South-Benin, traditional medicine practitioners have proposed some medicinal plants against human *Salmonella* spp. caused diseases including typhoid fever. These plants include *Senna siamea* (Lam.) H.S. Irwin & Barneby, *Phyllantus amarus* Schum. &. Thonn, *Uvaria chamae* P. Beauv., *Vachellia sieberiana* (DC.) Kyal.

& Boatwr, *Heterotis rotundifolia* (Sm.) Jacq.- Fél., *Crateva adansonii* DC., *Citrus aurantiifolia* (Christm.) Swingle, *Acanthospermum hispidum* DC., *Corchorus olitorius* L. et *Dialium guineense* Willd. On-going laboratory bio-essays exists for the treatment of typhoid fever that has become more and more multi-resistant , especially in areas where people are infected after consumption of water and food contaminated by the bacteria in several areas of Africa[159].

4.7.Type of food consumed, poor hygiene sanitation and typhoid prevalence

-The knowledge of risk of being a victim of food poisoning (caused by typhoid, aflatoxine micro-organisms) was found being associated ($p<0.001$) with the habit of consuming food prepared the day before, the health zone ($p<0.001$) or residence location ($p<0.001$), the profession ($p<0.05$), the level of education ($p<0.001$), the source of type of water consumed ($p<0.001$). The fact that the level of education was linked to the probability of being exposed to typhoid infection in both urban and rural areas, may be explained by the fact that educated people tend to understand and put in practices preventive measures to avoid water-born diseases. Illiterate people do not care of cleaning hands or bother about eating food prepared a day before. They are generally careless about hygienic issues, especially in rural areas

. The probability of being victim of typhoid depend on the health zone environment where a person reside. In fact , the environment where a person is living and socialize as well as the environment where he was born have impact on his life styles. The home stead may influence the feeding behavior as well as the kind of water found in the environment. Currently, there is shortage in water supply by the REGIDES in several avenues of Bukavu town. Because potable water is rare, some people think that eating without cleanings the hands or warming the food is a strategy to economize potable water

. The educated people may be easily involved in preventing practices. They can easily avoid not friendly hygienic practices. In fact, during interviewing in rural areas, respondents who reported to have ever suffered with typhoid fever, were those could not was hands or who were used to consume food prepared a day before.

Foodborne diseases continue to be a global public health problem with an estimated 600 million people falling ill annually[160]. Foodborne illnesses are caused by many bacterial pathogens including *Salmonella*, *Campylobacter*, *Enterohaemorrhagic Escherichia coli* , and *Listeria monocytogenes*, but norovirus and typhoid are responsible as well for large disease burdens. FAO/WHO food safety systems guidelines suggest to focus on five elements including food law and regulations, food control management, inspection services, laboratory services, food monitoring, and epidemiological data, information, education, communication, and training, to build and strengthen blocks of a national food control system, as well as to assess the effectiveness of the systems.

The presence of the enteric organisms (*E. coli*, *Salmonella* spp, *Shigella* spp, *Campylobacter*, *Giardia lamblia* and *Cryptosporidium parvum*) are food and water-related pathogenic agents that portend public health risk in the tropics. *E. coli* incidences (outbreaks linked to the consumption of fresh vegetables), contamination of fish by environmental pollutants (organochlorine contaminants), accidently contamination of food destined for the human food chain affect bot acute and chronic food safety and hazards and occurrence of a food safety incident[161]. Enteric fever, due to *Salmonella enterica* serotype Typhi (S Typhi) and Paratyphi (S Paratyphi) A, B, and C, are causing an estimated 14 million illnesses and 136 000 deaths worldwide in 2017. Illness is caused by ingesting faecally contaminated food or water[162].

Microbial contamination is the biggest threat to food safety and it is vital to ensure human exposure to harmful bacteria through this pathway is limited[163,164]. Leafy greens, including ready-to-eat packaged salads, are consumed raw with no heat treatment prior to human consumption, increasing the risk of human exposure to pathogenic bacteria through this food source. There have been a number of outbreaks reported globally that have been associated with the consumption of leafy greens contaminated by pathogenic strains of E. coli. In Ghana, it was found a widespread and often high levels of fecal contamination in both public and private domains and the food supply. The dominant fecal exposure pathway for young children in the household was through consumption of uncooked produce[164]. .

There exist diverse risk factors related to socio-economic aspects, type of food consumption, knowledge and awareness about typhoid fever and hygienic practices. Determining the public health impact of food and water-borne diseases poses a number of challenges[165,166]. Mostly, food-borne and water-borne diseases are linked with environmental factors and climate change/variability in tropical zones.The role of quality and quantity of water to the general burden of infectious diseases deserves attention, as its effects go beyond the food chain. Unsafe water used for the cleaning and processing of food is a key risk factors contributing to food-borne diseases.

The virulence patterns of *Salmonella enterica* serovar typhimurium (Enterobacteriaceae) was found being associated with soft cheese vended on the street in Nigeria[167]. In Kenya, a prevalence of typhoid of 6.3% was reported being associated with risk factors such as low education level, leaking drainage systems, the type of houses used, water pollution and eating food from commercial kiosks among others.

In Pendjari locality (Benin) social representations associated with typhoid fever indicated that the public perceive that the disease is cause poor hand hygiene(10% of the respondents), poor food hygiene (20.95%), adoption of bad practices of water quality maintenance (22.86%). People living at risks are those with overall poor hygiene habits (45%). The results show that civil servants in restaurants do adopt high-risk practices for contracting typhoid fever as opposed to other professions (agriculture, commerce, crafts) implementing medium to high-risk practices of food and water quality management.

Although the public is increasingly concerned about food-related risks, the rise in food poisoning cases suggests that people still make decisions on food consumption, food storage and food preparation that are less than ideal from a health and safety perspective[168]. The majority of the population of may know what they should be doing in their kitchen from a food safety perspective but they are not, in many cases, following the best practice guidelines and regard less than ideal food handling practices as safe. Furthermore, even food safety knowledge levels are high, the level of food science knowledge is often rather low among respondents. Important determinants of risk perceptions associated with foods are the extent to which the potential hazards are perceived to have technological or naturally occurring origins, together with the acute vs. chronic dimension in which the potential hazard is presented (acute or chronic),.

In KwaZulu Natal (RSA), it has been found that many children came from households that lacked latrine or adequate hand-washing facilities and relied on river or stream as the main source of water supply . Probably, in many such households, food is prepared at premises filled with houseflies, which undoubtedly play a significant part in the transmission of typhoid fever . Furthermore, a faster pace of life and the migration of villagers to the city are making street food, often prepared and distributed under unhygienic conditions, an increasingly important part of life.

However, dryness may not limit the spread of typhoid fever in urban areas. In many developing countries, during dry season, untreated wastewater is used for irrigation in peri-urban vegetable farms. The vegetables grown in such periurban farms are often eaten raw without having been thoroughly washed (e.g., salads) and this has been linked with major outbreaks of typhoid fever in urban areas . Based on the notification data, the case-fatality rate of typhoid fever in South Africa is 4.1%-12%.

In Mbombela (RSA) day care centre for school children, most day care centres' food preparation areas do not comply with minimum requirements of the regulations for kitchen compliance, personal hygiene compliance and storage compliance. Not complying with the requirements of the regulations poses a health threat to the children. *Streptococcus* (29.2%), *S.aureus* (38.4%), *Micrococcus* (9.2%), *E. coli* (64.60%), *Salmonella* (3%), *Salmonella typhi* (44.60%), *Shigella* (15.3%), *Compalobacter jejuni* (17%) were found present in the food preparation areas of day care centres since food handlers were not trained on food safety and the importance of compliance[169].

A study was carried out on enteropathogens and the epidemiological risk factor in asymptomatic indigenous communities of Mérida (Venezuela). The results indicated that *Blastocystis hominis* (47.0%) and *Salmonella* spp. (43.9%) were the most frequently detected enteropathogens in samples from rural communities consuming raw food. The variety of food in the daily diet was the risk factor strongly associated with the presence of parasites and/or enteric bacteria ($p = 0.024$). The high prevalence of enteropathogen (gastrointestinal infections) in indigenous communities was found to be statistically related to quality of food consumed.

4.8. Governance policy and strategies for water resources access and supply and management

In eastern DRCongo, the actual situation shows that the level of the populations‟ access to drinking water and sanitation is low. In addition to the problem of water quantity, is that of its quality. Indeed, the bacteriological quality of tap, well and spring water is not assured in eastern DRCongo. Poor hygiene and sanitation practices are likely to contribute to the degradation water quality in eastern DRCongo. Water catchment points are not protected in many health areas both in rural and in urban centers. Overall, the coverage of REGIDESO network is less than 10% in both urban and rural areas . The low production, the low extension of the network and the discontinuity of offered services are among factors at the origin of insufficient water supply to the local population especially in rural areas. Also, the low purchasing power of households may not allow them to subscribe to a connection.

Similarly, in rural areas of northern Cameroun , the rate of access to drinking water is at 30%[170], although the water and sanitation sector is managed by a collection of texts which favour the intervention of many actors with different policies.The unequal distribution of water and sanitation substructures, recurrent breakdowns and absence or the poor functioning of the management committee do influence on the quantity of water used in households in Cameroun.

In Nigeria (as in Goma and Bukavu cities of eastern DRCongo) water vendors supplied households irrespective of season with their lorry collecting(pumping) water from unsafe water points (Lake shore, wetlands, rivers) . retail vendors buy a 20 liter jerrican at $0.013 from wholesale vendors and resale at $0.065 during dry and $0.055 during rainy season[171]. The price is 28 and 40 times the cost of in-house connection from by the State Water Board (KNSWB) during rainy and dry season. Vendors who buy from hand-dug wells pay $0.33 per day and draw as much water within that day.Furthermore, willingness-to-pay for in-house connection was elicited as $1.20, lower than monthly flat fixed tariff set by KNSWB. People's perception on water should be changed through education and enlightening. Further research should focus on estimating total volume of water supplied by water vendors. The study recommends recognizing vendors formally in form of public private partnership so that technical and financial support be given, thus their activities and charges be regulated, but also running a programs to check the quality of water supplied to communities is essential to prevent water borne diseases. To cover these water availability gaps, water vendors exist and ignoring their role is potentially deceptive since they meet peoples' need and several household's are willingness-to-pay for such supply without checking if the water supplied is improved and of good quality. Total economic costs of the inadequate water supply and sanitation situation is high in some urban centers, thus vulnerable groups such as women are most likely to bear a disproportionate amount of the economic costs associated with low levels of access and poor quality of basic water supply and sanitation services.

In Younde city (Cameroun), population growth and rapid urbanization have led to major demographic changes in the urban centres, potentially resulting in serious environmental problems and impact impacts on the hygiene conditions in the most populated cities. Households with informal settlements, about 17% only had a private connection to national company of drinking water distribution (CAMWATER) because of the lack of infrastructure and the high cost of the connection(Kuitcha et al.2008). The households which are unable to afford the cost of getting connected to CAMWATER network, exploit water from CAMWATER public paying fountain (56% of household dwellings), wells (17% of households), springs (4% of households), boreholes (0.07% of household) and rivers (0.001% of household) and stagnant ponds to satisfy their needs. However, the majority of these water points (wells, springs and rivers) may be polluted, because of the informal nature of settlements which leads to proximity of habitats to latrines and to points of discharge of waste (solid and liquids).

As it was suggested from Algeria, the diagnosis of the defects in the water supply network and the frequency of areas at risk of waterborne diseases is high in urban and peri-urban center[172]. Inconsistent supplies of water from the water companies have led many people to invest in storage tanks which, if operated correctly, can provide water throughout the day even when the supply from the main is low or zero. While these individual systems help to guarantee a more constant supply of water, they may impact water quality when it does reach the household tap. The aged tanks could become breeding grounds for vectors of human disease and may also affect the concentrations of bacteria, heavy metals and organics in the water[173].The greatest risk factors seen were poor water quality and household beliefs like the security and safety of water storage containers were assured, although high levels of pollution by fecal coliforms were recorded during the study.

A cross-sectional study in which a total of 15 brands of bottled drinking water manufactured in 10 regions which constitute four geographical zones of Tanzania were analyzed for total and faecal coliform using membrane filtration method. Analysis for the presence of *Cryptosporidium* oocysts and total coliform was detected in 15 brands having a microbial load exceeding 500 cfu/ml[174].

In Ethiopia, it was found that financial resources are crucial to improving the urban potable water supply in developing countries that are characterized by low-cost recovery rates and a high and rapidly growing demand for more reliable services. This study examined households, willingness to pay (WTP) for the improvement of water services by identifying their water choice decisions and the mode of water supply that they prefer the water supply authority to use among several alternative water supply options[175].Generally, household WTP is sensitive to scope (i.e., extent of service improvement linked to potable water), household income, affixed price, and the method of stated preference elicitation. In particular, the demand for improved water services is significantly related to the price of service and income and to some extent to the educational attainment of the households. This suggests that the demand for safe drinking water could be higher if income levels are high. Moreover, like household income, the WTP of well-informed households is higher than that of households that are not informed or less aware of the situation, and if people have sufficient access to information and awareness of the health risks as-sociated with inferior water quality, they are more likely to have a higher WTP. Therefore, increasing awareness about the adverse health effects of unsafe drinking water will increase the demand for an improved drinking water supply. Importantly, the influences of these factors follow the theoretical predictions and intuition.

Problems linked to the poor management of water and sanitation services lead to sanitary, socio-economic and environmental consequences. In order to ameliorate access to drinking water and sanitation the government should transfer human, material and financial resources to deconcentrated services so as to permit them to effectively carry out their roles. Added to this political will, there is a need for local leaders and populations to collaborate and being highly implicated in water and sanitation management schemes. The participation of populations in water and sanitation projects may help to determine their interests, their availability to cooperate and capacity to participate in building operations to maintain local water supply systems , as well as their aptitude in managing and or taking care of installations and to collect revenues that allow and assure its functioning and supervision and finally, their level of appropriation of the water infrastructures for local governance and management. Public participation in water resource management is crucial for community development and resource sustain-ability[176].

-It is important to have participation of the general public (i.e. non-scientists) in the generation of new scientific knowledge related to monitoring and governance of water resources. Local community have a greater understanding of their local eco-hydrology, a sense of responsibility of their water resources, and a sense of being a research partner in a community project[177].

Water crises are more a consequence of poor management than resource scarcity. Addressing water management issues through better coordination, identification of problems and solutions, and agreement on common objectives to operationalize integrated water resources management could greatly improve water governance.

The training program increases public awareness, perception of severity of waterborne diseases; water treatment and source protection. It also increased self-efficacy on household water health and sanitation[178].

4.9. Physicochemical characteristics of drinking water and health outcome

Results revealed also high variability in the mean values of the physico-chemical (temperature, pH, conductivity, dissolved oxygen and chloride) properties of the water consumed by respondents. Interestingly, the average values were within the standards for the WHO Africa zone. However, data indicated an advanced level of degradation of water supply infrastructures in both urban and rural health zones, thus keeping consumers on daily risks to water borne disease. From the field observations, it was realized that both urban and rural populations were exposed to the risk of seeing a rapid increase (emergency) in water-borne diseases in future.

Water is a fundamental part of human life. Given that it is an essential and indispensable resource for human existence, there is need to ensure that it exists in high quality[179]. Although, most of the physico-chemical and biological substances determined are naturally found in water, the primary aim in assessing water quality is to ensure that they do not exceed levels which are likely to be of concern to human health. It appears that poor water from the study area was polluted.

The quality and chemical composition of water depends on the mineralogy, precipitation model and quantity, geology of watershed and aquifer, reactivity of the drift materials and the equilibrium degree established between rock and water[180].

The Nsimeyong (Damas) residential areas of Yaounde (Cameroon) experiences water shortages making residents rely on other sources of water including streams, springs, boreholes and wells. Heavy metals (Pb and Cd) were found to be at high levels in alternative water sources people use when the official water supply system in down[181] . It was found that these alternative water sources were not safe in conformity International Organization for Standardization (ISO) and with World Health Organization recommendation. Moreover, *E.coli* and *Klebsiella* spp were detected in 16.7% and 11.1% of water samples from alternative sources, respectively. Additional household treatment such as filtration, to remove heavy metals and boiling before use of such water is necessary to achieve the standard bacteriological quality for human consumption thereby reducing risk of exposure to waterborne diseases.

Similarly, during a study conducted in Bukavu town (eastern DRCongo), water temperature and dissolved oxygen were found being within the WHO standards for surface waters, except for pH for some stations on some rivers, where it was highly alkline. The highest nutrient concentrations ($P0_4^{3}$-, NH_4^+, $N0_2^-$, $N0_3^-$) were recorded in the dry seasons from the midstream to downstream stations of the river Kahuwa crossing Kadutu health zone (one of the study area of the currently presented study). The current degradation status of these rivers requires a rapid waste management strategy and an efficient sanitation plan of development along each catchment. Installation of wastewater treatment plants with biological treatment can mitigate the ecological and health risks of the rivers and the coastal zone of Lake Kivu.

Medical Geology can be defined as the branch of geology dealing with the relationship between natural geological aspects and health in organisms (humans and animals), trying to determine the influence of ordinary environmental factors on the geographical distribution of health issues[182]. People are overexposed to fluorides since the severity of dental fluorosis was found to be linked to fluoride concentration in groundwater used for human consumption the Julimes municipality in Chihuahua of Mexico.

In Uganda, surface water and spring water were found being unsafe for drinking because they had favourable physicochemical parameters for propagation of waterborne diseases including cholera and Typhoid fever. In Northern Burkinafaso[183], the parameter which downgrades these drilling groundwaters as drinking water is the arsenic content which is higher than the standard of WHO (0.01 mg / L). In rural Morocco, chemical contamination for wells is reported being of agricultural origin and / or industrial and domestic wastes.

A study conducted in Nigeria, it was also found that a strong positive correlation between the total bacteria count (Enterobacter, proteus, Escherichia, Salmonella and Shigella) and physico-chemical parameters, which suggested that the parameters influenced bacterial growth.

Bacteriological, metallic and toxicological risks associated the consumption of water of un protected water wells and Lakes are among concern s of public health leaders. The consumption of vegetable grown in contaminated soils, exposes the populations, especially children, to the risk of of metallic (Pb, Cd, As) poisoning. Drinking water contaminated (*Escherichia coli* and faecal *enterococci*) also exposes the public to various health risks.

Toxic heavy metals found in the environment come from atmospheric precipitation, geologic weathering or of discharges from contaminated waste products and other human activities. These heavy metals accumulate in soils and sediments and cannot be broken down; however, they can migrate through different media to the aquatic environment. The concentration of radionuclides, heavy metals, and other poisonous microbes or infectious agents in water can assume hazardous proportions under certain environmental matrix, which can result in both carcinogenic and non-carcinogenic risks. The major exposure pathways are through inhalation ingestion and dermal contact or absorption. Health hazards such as respiratory and cardiovascular difficulties, inflammation, lung cancer, asthma and even mortality have been linked with exposure to radioactive particles. Furthermore, exposure to significant concentrations of heavy metals such as Cadmium, Copper, Nickel, Lead, and Silver, have been associated with various health risks, including dysfunction of the kidney, liver, Central Nervous System and the immune system, hair and skin discoloration, dermatitis, irritation of the upper respiratory tract, metallic taste in the mouth and nausea. Specifically, exposure to Pb has been found to affect several body functions such as the Central Nervous System, hematopoietic, hepatic, and renal system causing serious disorders. Hence, the measurement of heavy metal and radionuclides concentrations in water can give information on the potential radiological and chemical risk of ingestion and dermal absorption. This is important because contaminated waste from the mining and mineral processing activities find its way into the drinking water sources.

Heavy metal pollution has become a concern because industrial wastewater con-taining copper, cadmium, zinc, lead, mercury and manganese etc. are often deliberately or accidentally released into local water resources[184].The treatment of heavy metals is of particular concern because of their resistant nature and their persistence in the environment. Unlike organic contaminants, heavy metals tend to accumulate in living or-ganisms and many heavy metals are known to be toxic or carcinogenic like Cad-mium (Cd), mercury (Hg) and lead (Pb) . Toxic heavy metals present special concerns in industrial wastewater treatment containing zinc, copper, nickel, mercury, cadmium, lead and chromium. They are transferred through the aquatic environment to fish, humans and other piscivorous animals and can have negative impacts on the environment and human health. Thus, aquatic life may be exposed to high concentrations of heavy metals and trace metals depending on their bioavailability and the particular organism exposed and may become persistent in the environment and constitute a degradation challenge aggravated by the lack of available data.

Similarly, inorganic form of germanic acid (H_4GeO_4) mostly found in thermal water from young volcanic regions, is reported to have both beneficial and undesirable health effects[185]. Germanium seems to be an interesting goal of research as it exerts prophylactic and therapeutic effects in the treatment of serious diseases. There are no reports concerning acute germanium toxicity, but prolonged consumption of inorganic germanium supplements has resulted in severe adverse effects including various organ dysfunctions and even death. Initial symptoms include anorexia, weight loss, fatigue, headaches, vomiting, diarrhoea, and muscle weakness, while longer intoxication causes renal dysfunction and failure accompanied by systemic symptoms such as muscle and nervous system damage. Renal function does not return to normal even when germanium has been withdrawn. However, the toxicity of organic germanium compounds has been found to be lower and less severe. The beneficial effects of germanium administration described in the literature, concern its use to prevent or treat cancer, HIV infection, autoimmune diseases, arthritis, and senile osteoporosis.

Depending on its concentration, fluoride in water can have both beneficial and harmful effects on the environment and human health[186]. The concentration of fluoride around 1 mg/L in drinking water can help in teeth decay prevention. However, the long-term consumption of water containing an excess of fluoride can lead to fluorosis of teeth and bones.Globally, fluoride has become a source of some health concern when consumed either at very low or very high concentrations. A fluoride concentration of 1.5 mg/L is the amount recommended by the World Health Organization in drinking water. Exposure to lesser concentrations than this recommended amount can lead to tooth decay; whiles prolonged exposure to greater concentrations does have harmful effects such as dental fluorosis, retarded growth of children, and skeletal defects. The contamination of water with fluoride can occur naturally in regions with geological deposits of marine origin and at the foot of volcanic mountains such. Furthermore, groundwater gets polluted due to deep percolations from intensively cultivated fields due to various ecological factors either natural or anthropogenic, liquid and solid wastes from industries, disposal of hazardous wastes, sewage disposal, etc. Wen drinking water amount of fluoride concentration (level) of above 20 mg/L is observed in water resource, defluoridation of drinking water is necessary recommended for human health.

In Turkana (Kenya) it was realized that drinking water with an elevated concentration of fluoride can lead to health-related issues like dental or skeletal fluorosis or even to hypocalcaemia while precipitating CaF_2 in the human organism. Some prevention programs and water treatment should be applied to prevent negative (even serious) health problems that may result from the consumption of contaminated groundwater[187].

The physico-chemical and bacteriological qualities of water was not acceptable, despite the efforts of supplying water to the population by different actors. Currently used water sources were unfit for drinking purposes although being used. High level of salt in water may increase the risk of hypertension as well as increasing the risk of teeth born malformation, especially if the level of 3mg/l. People may develop bad structure of tooth. Further epidemiological studies are needed to measure mortality and morbidity level for oral health and hypertension and nutritional pathologies related to the consumption of water with excessive level of minerals.

During rainy and dry seasons in rural and peri-urban areas, water samples (spring water, lake water, river water, tap water) was analyzed for physicochemical characteristics(fluoride, phosphate, chloride, magnesium, calcium) and the results indicated no potential risk factors for dental pathologies in North and South Kivu Provinces (eastern DRCongo) as compared to WHO standards[188].

As it was suggested from a case study from Tanzania, is important to create awareness about the danger of using heavy mineral polluted water(such as using arsenic and fluoride contaminated water) .More research and development efforts from scholars, researchers, and government institutions should be invested for further investigations and solutions for development of affordable and environmental friendly water purification technologies[189].

The heavy metals like Zinc, Iron, Lead, Cadmium, Chromium and Manganese in have the potential of being carcinogenic, causing kidney failure, neurological disorder and metabolic dysfunction. According to REGIDESO, Zinc has no known health impact in drinking water. The permissible limit for zinc in portable water is 3 mg/L. High concentration of Iron affect the colour and taste of water. Lead is implicated in serious health issues like cancer, interference with vitamin D metabolism, toxic to central, peripheral nervous system and obstruction of proper infant mental development. Cadmium is a heavy metal known for its toxicity to kidney. Chromium is known to be carcinogenic especially when it is found in the water beyond the acceptable limit of 0.02 mg/L.

Heavy metals contamination in ground water has been considered a serious environmental issue. These metals are found in groundwater in soluble form. Their presence in water could either come from eroded mineral within sediments, draining of mineral deposits and volcanic eruption residues or from human activities like solid or liquid discharged from industrial or domestic processes.

In Benin, organic and bacteriological pollution constitutes a real risk for natural waters, causing several diseases[190]. One of the risks associated with anthropogenic actions is the accumulation of heavy metals in water, soil and vegetables. Most heavy metals are likely to accumulate in the body through food and thus generate oxidative stress which impairs its vital functions.

Direct ingestion and dermal absorption by skin (showering/bathing and swimming) are usually considered to be the common exposure pathways for human beings . The exposure dose and health risk assessment due to heavy metals (Fe, Mn, Cu, Pb, Cr, Zn, and Cd) and trace elements (Al, As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) with hazard Index and cancer risk[191] in surface water and groundwater. Some trace elements have the potential to pose adverse risk to human health with the increasing of the concentrations of pollutants in water body if contaminated water was used for potable supply. Other elements may pose carcinogenic risk to human health such As, Cd, Cr and Pb, through ingestion and dermal pathways for children and adults.

Environmental pollution by trace metals (Mn, Co, Ni, Cu, Zn, As, Cd, Pb, U) is of concern in the African Copperbelt, a region of intense mining situated on either side of the border between the Democratic Republic of Congo (DRC) and Zambia[192] . In drinking water (and leafy vegetable grown nearby) found close to mining, concentrations (µg/L) of trace elements, were found to be substantially worse/higher in DRCongo than Zambia, exceeding international standards in most DRC samples. Thus metal contamination of drinking water and locally grown vegetables near mining activities in Zambia and DRC imposes several health and food security problems to the residents. Surface water quality of the mining city of Kakanda (Lualaba Province in the DRCongo) has been found being chemically (cobalt and manganese) polluted from mining activity[193]. Mining activities pollute rivers and streams crossing the city.

In Bangladesh, it was found that Cancer risks posed by these toxic metals through ingestion and dermal exposure to the residents. Cd exposure may create adverse health effects like lung cancer, kidney damage, and bone fractures[194]. The contents of Pb, Cr, and Cd in waters were considered to have the potential to create cancer risks to the human when one is exposed. Thus, there are also possibilities of cancer risks from the contaminants to the residents of the area through the cumulative oral and dermal exposure routesal. As regards carcinogenic health risks, on average there is a possibility of 5 persons in every 106 developing cancers due to life time exposure to Cd through ingestion of groundwater. Long term use of poor-quality water may pose a hazard to human health, crops, and soils, and therefore require to be treated before using those waters for drinking, domestic and irrigation purposes.

CONCLUSION & RECOMMANDATION

The general objective of this study was to contribute to the advancement of scientific knowledge likely to be used in the management and prevention of water-born disease such as typhoid fever. The specific objectives were: (i) to determine the physical characteristic chemical and bacteriological water consumed in the Kadutu and Miti-murhesa health zones ; (ii) identify the level of knowledge of determinants (influencing factors) of the prevalence of typhoid fever and other water-borne disease in the Kadutu and Miti-murhesa health zone. For this, the data was collected on the quality of the water consumed and on the perception of the socio-economic and environmental factors associated with typhoid fever in the health zone of Kadutu and Miti-murhesa, South-Kivu province, eastern DRCongo.

The analysis revealed that the water consumed by the populations is often polluted. Poor human practices contribute to the degradation of the water quality. This situation is at the root of the waterborne diseases (diarrhoea, typhoid fever) that may prevail or emerge in the studied health zones.

Findings indicated that typhoid fever was present in these two health zones surveyed. It was observed that this situation may be caused by different factors in the environment (quality of water consumed, source of water supplied, quality of food eaten, level of knowledge of the public about water food and sanitation and hygiene,..). Overall, several socio-economic, cultural and environmental factors played a significant role in the current level of prevalence of the disease.

Water is essential for the life, but many people lack the accessibility to clean and healthy drinking water and die as a consequence of water-borne infections[195]. The presence of pathogenic bacteria, protozoa, and viruses is one of the serious threats to human health. Infectious diseases caused by pathogenic bacteria, viruses and parasites are the most common and widespread health risk associated with drinking water. Microbial pollution in the water body is one of the major issues concerning the sanitary quality of drinking and recreational water. The dissemination of pathogenic microbes is responsible for several enteric outbreaks . The pollution of water samples by bacteria can become also the cause of the severe epidemic of enteric diseases. The elimination of all these agents from drinking water is priority in Africa. The provision of a safe supply of drinking water depends upon use of either a protected high-quality water resource or a properly selected and operated series of treatments capable to reduce pathogens and other contaminants to the negligible health risk.There is a need for monitoring drinking water especially groundwater and compact units that will be consumed by the people.

Limited water availability coupled with the lack of hygienic and reliable water sources plague rural areas throughout the developing world. Tanzania like DRCongo has abundant fresh water sources, yet delivery, disinfection, and conservation outside of large towns is lacking or minimal at best for the management and control water-related diseases and poverty.

The physico-chemical and bacteriological analyses show that water of health areas investigated in eastern DRCongo are subject to physico-chemical and bacteriological contamination above the admissible level. The waters of from the rural health zone was found to be more prone to pollution than that of from urban health zone both from physicochemical and bacteriological point of view. The causes of such pollution reside in ignorance of treatment methods and non-compliance with certain rules of hygiene and sanitation. Therefore, proposals to monitor and improve water quality are necessary under development schemes for South Kivu province.

The health risk associated with the consumption of water polluted by humans in Africa, is a real public health problem.There is a need for new approaches to address the challenges of water-related infectious disease. There is also a need to promote combined effort of water quality interventions with improved hygiene, water storage, water supply, or sanitation practices that are environmentally friendly.

Consequently, it is important that the populations be sensitized for a greater awareness of the dangers of non-compliance with basic sanitary rules and the disregard of traditional and socio-cultural values in the management of water in the village.

Household water treatment practice or managing water at the point-of-use provides a means of improving drinking water quality and preventing diarrheal diseases[196]. Thus, efforts should be made to increase the level of household water treatment practice especially among those with no formal education and further studies should be conducted to understand the behavioral factors associated with household water treatment practice.

Provision of adequate sanitary infrastructure will help prevent source water contamination, and public health education aimed at improving personal, household and community hygiene is imperative. There is also a need to monitor water related health information in urban and rural areas so as to guide local decision making on the public health emergencies. In health planning, knowledge of area sensitivity and vulnerability water-borne diseases (diarrheal diseases) can be useful for setting suitable and effective strategies for disease and health intervention strategies that are able to adequately address neighborhood environmental health determinants.

Improving access to clean water sources, ensuring that pathogen concentration in drinking water sources is controlled within acceptable limits, and taking special interest on the vulnerable members of the society can reduce susceptibility and therefore risk of waterborne diseases in the developing countries. In addition, making and enforcing improved sanitary and hygiene policies can enhance water quality, reduce contamination of food and water, and reduce the risk of waterborne diseases in the developing countries. For example, ban open defecation; provide adequate public toilets; regulate the siting of residential drinking water wells/boreholes and septic tanks/latrines; encourage business/public places to provide running water; enforce hand washing practices; engage sanitary inspectors, etc.

It is also important to better control of waterborne disease agents (bacteria, viruses,....) at the drinking water treatment plants or sources (wells, springs) to protect public health. Coagulation, sedimentation, and disinfection are crucial in controlling waterborne viruses. Coagulation and sedimentation processes take effect in the effect of subsequent disinfection. The effect of coagulation and sedimentation significantly impact the subsequent disinfection step. Indicator viruses or bacteriophages with various sensitivities are needed to investigate the performance and mechanisms of reducing virus during coagulation and sedimentation, for a better control of waterborne diseases in the subsequent disinfection with less disinfectant' s addition.

As it was suggested from Costa Rica, agricultural inputs and withdrawal, greywater urban inputs, community water use, and natural features of the watershed including climate concerns must be managed together to improve water quality and provide adequate water resources[197]. Community involvement, along with a water quality index useable by the general public.

Pollution (by solid or liquid wastes) dangerously affects the quality of available water resources and makes supply of water more precarious throughout Benin. In order to ameliorate water quality, the preventive management of water catchment points is very beneficial. The reduction of water contamination at the source permits to limit the magnitude of necessary treatments and by ricochet to reduce the spread of water borne diseases. To assure an efficient and sustainable management of drinking water supply points and sanitation substructures. Reducing disease from unsafe drinking-water is a key environmental health objective in rural Sub-Saharan Africa, where water management is largely community-based[198].

-The level of knowledge of the dangers of non-compliance with food hygiene standards and the risks of catching water-borne diseases was relatively low much as urban citizen had more knowledge than rural respondents ($P<0.001$). Yet the consumption of non potable water and un hygienic food would increase the risk of being a victim. In fact, pathogenic microorganisms develop well and multiply faster in raw food or cleaned food as compared to cooked foods. Cooking temperature has the ability of destroying food-borne micro-organisms. Some respondents reported washing hands before eating and this was in contradiction with field observations. Most respondents visited in rural areas during surveys were found eating with unclean hands, sometime cold food or food prepared a day before. When asked why you are eating without cleaning your hands with soap, they all indicated that "african does not die of microbe, especially while working in garden". Other respondents indicated that "soil from the garden is clean and it does not contain bad micro-organisms". Other indicated that you get typhoid if you drink water from the Lake or water harvested on the roof. With such kind of feeding behaviour or eating practices, germs can thrive well and can easily cause typhoid fever to the most vulnerable group.

Yet the disease is classified among the disease of dirty hands, but villagers do not find the relevance of washing hands before eating. WHO has defined the 5 best times to wash hands: before eating, after washing, after washing children clothes, before preparing food and before breastfeeding the child. Of all these rules are not practiced by rural respondents, yet they can help to prevent the emergency of diseases of dirty hands, including typhoid fever

-Some respondents at Miti-murhesa acknowledge the presence of typhoid fever in their villages and surrounding environments, they said that about 10 persons per week visit nearby hospitals and ends by being diagnosed for suffering with typhoid fever. However respondents were not sure of the origin of the disease and refused that raw foods or tape water or well water can be source of the microorganism causing the disease. Thus, they were not aware of preventive measures to apply.

The level of knowledge of risk of exposure to water-borne disease was found being negatively associated with the profession ($p<0.001$) of the respondent. This explained why some respondents could not have a tape at the homestead. According to the national water corporation company (REGIDESO), people with no profession (as source of revenue) do not deserve a tape because they will to pay subscription bills regularly. The current REGIDESO bill being expensive, not every citizen can afford to maintain a tape at his homestead.

Hence, low earner or jobless are forced to seek drinking water from any source, even dirty water drawn under unsanitary conditions (river, waste water, Lake, flood water, soil erosion water, roof rainfall water). Even when such water is collected for drinking, it is rarely cleaned.

There prevails in several areas water spring wells not well maintained and massively visited by children collecting water or by women cleaning clothes closer. Such kind of well water may be harbor pathogenic microbes harboring, exposing users more ($P<0.001$) than users of REGIDESO tape to typhoid fever, sooner or later.

In Miti-Murhesa health zone, the habit of treating water in containers was found being associated the time taken to treat water ($p<0.001$). Water treated was conserved in containers and consumed until it gets finished. In some cases, treated water was consumed for a week and more. WHO Africa recommends that the water not can exceed 3 days in the container, if it exceeds it must no longer be used for drinking but rather for other purposes. But in rural areas people can still consume such water for more than 10 days assuming it will remain clean for long time. Such situation can promote the increase in the prevalence of the prevalence of typhoid fever in the health zone environment. Injecting chlorine drug or boiling water for few hours is not enough to increase the quality of water. In fact, in urban areas, respondents reported leakage of pipes bringing water to urban citizens. They suspected chemical pollution at some point sources and were worried on how to remove mineral pollutants from water during the cleaning process.

The analysis revealed that the level of knowledge of health risks related to the consumption of untreated water was associated with the household size ($P<0.001$) and the age ($P<0.05$) of the respondent. This may be explained by the fact that that when there are too many people in a household, there is high need and consumption of water. Over use activities of water contained in containers may lead to the degradation of the quality of water as everybody need to serve himself. For some aged people, it is difficult to convince them about the necessity of treating water since they assume treated water does not taste and always say that their grandparents were drinking raw water (not treated) and could not get typhoid.

It was observed that it is important that factors likely leading to water-borne disease emergency are identified and plan of their mitigation is well established and implemented. There is a need to revisit the current strategies of the government to fix good lifestyle and behavior or attitudes towards WASH (water, food, sanitation and Hygiene) for both urban and rural urban people. People should be aware of hygienic practices that can reduce the load and eliminate germs that may be in drinking water or food. For example, people need to be reminded about good practices for treating, conservation water as well as about food and hand hygiene and about waste management as well as cleaning the compound environment where reside a respondent.

In West African cities, domestic rainwater harvesting has the potential to reduce diarrheal disease burden by 9%, if implemented alone with 400 L storage[199].If implemented in conjunction with point of use treatment, this reduction could increase to 16%.

Typhoid fever is transmitted by the feco-oral root though ingestion of contaminated food or water that contain *Salmonella typhi*.[200]. Poor knowledge and risk perception towards typhoid fever contributed to the prolonged transmission of diseases in the community. Thus, typhoid fever outbreaks of potentially waterborne disease need an integrated response that includes epidemiology and environmental microbiology during early stages of the outbreak. For that, community from adopting healthy behaviors and adequate water management behaviors[201].

There still emerging threats, critical gaps in knowledge, and public health needs that need to be identified to be able[202] to recommend strategies to guide future activities to ensure the safety of drinking water supply to communities.

Health must be included in resilience-building initiatives at the individual, community, and national levels. Efforts should be made to contribute to the development of the broadly framed concept of health resilience to meet the needs of people at risk.

Understanding tradeoffs and synergies among WaSH policy actors, knowledge gaps, research needs, and challenges to linking water consumption and the emergency of water-borne diseases.

Further research is needed for controlling microbial risk posed by waterborne disease agents through setting good strategies for drinking water treatment system, the crucial barrier to prevent the transmission of waterborne diseases. It is important that performance of conventional and emerging disinfection techniques are regularly checked and continuously monitored such as engineering improvements are done to confine annual disease risks to acceptable levels[203-240].

TABLES

Table-1a: Socio-demographic characteristics of respondents from Kadutu health zone

		% of respondents from Kadutu health zone						
		Name of health areas within Kadutu health zone				**Statistics (Chi-square test)**		
		Buholo (N=52)	**Nyamugo (N=28)**	**Karhale (N=60)**	**Kasali (N=58)**	***DF***	***χ2***	***P-Value***
Sex	Female	30.77	50.00	53.33	34.48	3	8.89752	**0.031**
	Male	69.23	50.00	46.67	65.52	3	6.48183	0.091
Civil status	Single	57.69	35.71	63.33	58.62	3	8.4762	**0.037**
	Divorced	3.85	14.29	6.67	10.34	3	7.00079	0.072
	Married	38.46	50.00	30.00	31.03	3	6.82731	0.078
Profession	Businessman	7.69	14.29	16.67	10.34	3	3.92356	0.271
	Pupils	0.00	0.00	0.00	3.45	3	10.3448	**0.016**
	Student	34.62	21.43	26.67	17.24	3	6.73061	0.081
	Official	50.00	28.57	26.67	51.72	3	13.8514	**0.003**
	House wife	0.00	21.43	16.67	6.90	3	24.7564	<**0.0001**
	Un-employed	7.69	14.29	13.33	10.34	3	2.3589	0.501
Level of education	Primary	15.38	14.29	13.33	13.79	3	0.163906	0.983
	Illiterate	15.38	7.14	13.33	17.24	3	4.35396	0.226

	Secondary	30.77	42.86	43.33	51.72	3	5.29001	0.152
	University	38.46	35.71	30.00	17.24	3	8.78067	**0.032**

Table-1b: Water and sanitation characteristics of respondents interviewed in the Kadutu health zone

	Kadutu health zone					
	(% of respondents) **Kadutu health area names**				**Statistics**	
Characteristics	**Buholo**	**Nyamugo**	**Karhale**	**Kasali**	**Chi-square test**	
Main sources of access to safe & improved drinking water	**(N=52)**	**(N=28)**	**(N=60)**	**(N=58)**	***χ2(DF=3)***	***P-Value***
Piped water into home (dwelling/yard/plot)	12.87	6.67	30.67	45.21	38.502	**<0.0001**
Public shared tap (standpipe)	70.72	62.65	3.54	5.23	110.18	**<0.0001**
Tap water (from neighbourhood)	13.96	27.41	63.74	47.65	37.853	**<0.0001**
Stored in reservoir	0.00	0.00	0.00	0.00	No test applied	
Bore hole (Covered well)	0.00	0.00	0.00	0.00	No test applied	
Borehole (Tube well)	0.00	0.00	0.00	0.00	No test applied	
Protected dug well	0.00	0.00	0.00	0.00	No test applied	
Protected spring	0.00	0.00	0.00	0.00	No test applied	
Bottled water	2.51	1.55	2.46	1.76	0.3441	0.952
Non-improved source to obtain water /during water shortage)	**(N=52)**	**(N=28)**	**(N=60)**	**(N=58)**	***χ2(DF=3)***	***P-Value***
Open well (un-protected well)	0.00	0.00	0.00	0.00	No test applied	
Unprotected dug well/unprotected spring	0.00	0.00	0.00	0.00	No test applied	
Lake/River/stream water	26.41	31.33	21.94	11.29	9.6295	**0.022**
Surface water (wetland/flooded water)	0.00	0.00	0.00	0.00	No test applied	
Rainwater (harvested from roof/fall in tank)	73.55	69.54	78.34	89.52	2.8052	0.411
Tanker (from tanker truck supplied)	0.00	0.00	0.00	0.00	No test applied	
Time to obtain drinking water (per round trip)	**(N=52)**	**(N=28)**	**(N=60)**	**(N=58)**	***χ2(DF=3)***	***P-***

						Value
Water on premises	25.44	34.65	55.32	19.52	21.867	**<0.0001**
Less than 30min	50.32	48.55	31.67	46.34	4.9289	0.177
More than 60 min	24.21	15.32	11.31	26.65	8.1451	**0.043**
Do not know/unsure/can not estimate	0.65	1.72	2.43	7.75	9.553	**0.023**
Improved, not shared own toilet facility (within the home compound)	**(N=52)**	**(N=28)**	**(N=60)**	**(N=58)**	*χ2(DF=3)*	***P-Value***
Flush/pour flush to piped sewer system	6.76	13.87	23.32	13.65	9.6375	**0.022**
Flush/pour flush to septic tank	74.88	55.87	57.56	39.65	10.92	**0.012**
Flush/pour flush to pit latrine (covered)	18.65	29.54	19.44	45.98	17.101	**0.001**
Non-improved toilet facility where to defecate (around the compound)	**(N=52)**	**(N=28)**	**(N=60)**	**(N=58)**	*χ2(DF=3)*	***P-Value***
Flush/pour flush to evacuation waste water canal)	24.34	41.34	16.67	34.96	12.313	**0.006**
Pit latrine (with open pit)	44.43	40.56	62.34	44.16	6.0242	0.111
No facility (outdoor defecation in bush, field, beach)	1.46	2.46	1.74	3.95	1.5506	0.671
Any facility shared with other households	26.54	10.66	17.23	12.54	9.0122	**0.029**
Other facilities (Public toilet, undeveloped plot)	3.54	5.54	2.65	4.31	1.1225	0.772

Table-1c: Water and sanitation characteristics of respondents interviewed in the Miti-Murhesa health zone

	Miti-Murhesa health area names				Statistics	
Characteristics	**Lwiro**	**Kavumu**	**Miti**	**Murhesa**	**Chi-square test**	
Main sources of access to safe & improved drinking water	**(N=56)**	**(N=96)**	**(N=34)**	**(N=68)**	**χ2(DF=3)**	**P-Value**
Piped water into home (dwelling/yard/plot)	19.69	20.12	4.46	3.87	20.608	**<0.0001**
Public shared tap (standpipe)	18.78	25.11	20.56	24.77	1.3188	0.725
Tap water (from neighbourhood)	11.7	19.65	31.43	25	9.5478	**0.023**
Stored in reservoir	9.7	5.98	9.91	7.76	1.2258	0.747
Bore hole (Covered well)	26.43	12.45	23.09	25.97	5.8119	0.121
Borehole (Tube well)	0.00	0.00	0.00	0.00	No test applied	
Protected dug well	0.00	0.00	0.00	0.00	No test applied	

Protected spring	11.81	15.45	9.97	12.21	1.2609	0.738
Bottled water	2.44	1.52	0.86	0.512	1.6191	0.655
Non-improved source to obtain water /during water shortage)	**(N=56)**	**(N=96)**	**(N=34)**	**(N=68)**	***χ2(DF=3)***	***P-Value***
Open well (un-protected well)	26.71	13.23	21.58	15.88	5.6144	0.132
Unprotected dug well/unprotected spring	8.72	5.98	6.76	9.99	1.2745	0.735
Lake/River/stream water	15.78	21.66	34.43	15.53	10.759	**0.013**
Surface water (wetland/flooded water)	14.45	21.86	21.45	11.52	4.5926	0.204
Rainwater (harvested from roof/fall in tank)	34.6	38.06	16.54	46.56	14.126	**0.003**
Tanker (from tanker truck supplied)	0.00	0.00	0.00	0.00	No test applied	
Time to obtain drinking water (per round trip)	**(N=56)**	**(N=96)**	**(N=34)**	**(N=68)**	***χ2(DF=3)***	***P-Value***
Water on premises	2.74	5.67	1.55	2.75	2.9065	0.406
Less than 30min	16.55	12.11	15.11	21.78	2.9922	0.393
More than 60 min	54.74	54.67	65.43	59.89	1.3399	0.721
Do not know/unsure/can not estimate	26.11	27.67	18.54	16.43	4.1418	0.247
Improved, not shared own toilet facility (within the compound/home)	**(N=56)**	**(N=96)**	**(N=34)**	**(N=68)**	***χ2(DF=3)***	***P-Value***
Flush/pour flush to piped sewer system	51.56	48.99	13.89	4.72	57.868	**<0.0001**
Flush/pour flush to septic tank	6.89	7.78	10.86	6.88	1.3172	0.725
Flush/pour flush to pit latrine (covered)	41.61	43.89	75.71	88.87	26.433	**<0.0001**
Non-Improved toilet facility where defecate (around the compound)	**(N=56)**	**(N=96)**	**(N=34)**	**(N=68)**	***χ2(DF=3)***	***P-Value***
Flush/pour flush to evacuation waste water canal)	0.44	0.98	1.51	2.411	1.5843	0.663
Pit latrine (with open pit)	75.32	44.37	65.32	55.35	8.8017	**0.032**
No facility (outdoor defecation in bush, field, beach)	17.89	47.87	24.21	34.98	16.589	**0.001**
Any facility shared with other households	6.78	4.98	8.76	5.98	1.1629	0.762
Other facilities (Public toilet, undeveloped plot)	0.54	0.91	0.76	1.76	0.8611	0.835

Table-2: Statement about perception of the importance, opinion, knowledge, attitude, behaviour (negative, positive) and management of water resources and waterborne diseases. Data are mean(X±SE) score responses of respondents from 5 health areas (Kadutu urban health zone) and 5 villages (Miti-Murhesa rural health zone) about health literacy and water related diseases

	Kadutu urban health zone	**Miti-Murhesa rural health zone**
Statements	Mean (X±SE) score	Mean (X±SE) score
Perceptions and attitudes (negative/positive) towards water quality, importance, treatment and management **(1=Do not believe at all, 2=Slightly believe, 3= Somewhat believe, 4=Moderately believe,5=Extremely belief)**		
I feel water is a natural resource & a habitat of aquatic life	4.12 ± 0.242	2.01 ± 0.118
I believe water is a public goods (Sense of ownership)	4.43 ± 0.261	4.98 ± 0.292
I believe provided water quality in my home is good.	3.06 ± 0.161	3.76 ± 0.224
High quality water is needed for economic growth	3.04 ± 0.178	3.87 ± 0.213
There is adequate water to supply at household level	2.01 ± 0.118	4.56 ± 0.289
Drinking water contamination is not a problem where I live	1.04 ± 0.061	4.54 ± 0.267
I have no objection of using water from any sources e.g. tap, bottle water	4.11 ± 0.242	4.97 ± 0.298
Safe drinking water leads to healthy/quality living standard	4.98 ± 0.292	4.93 ± 0.297
Tap water at home has unpleasant taste/unusual color	3.04 ± 0.179	3.67 ± 0.215
Tap water at home consists of suspended solids	4.14 ± 0.2435	3.89 ± 0.228
Tap water at home has unpleasant smell/odor	4.07 ±0.2394	3.79 ± 0.228
I believe the tap water has too much chlorine sometimes.	4.01 ± 0.236	3.87 ± 0.227
I believe that tap water delivered to my home follows WHO standard and/or Ministry of Health standard	4.03 ± 0.237	4.08 ± 0.254
Water is filtered or boiled at home to reduce the unpleasant taste/odor or unusual colour of tap water	4.92 ± 0.289	4.05 ± 0.213
Water is filtered to reduce the suspended solid found flowing from the tap water	4.89 ± 0.287	3.07 ± 0.161
Access to safe drinking water is a human right	3.08 ± 0.181	3.07 ± 0.161
Sometimes supplied water is partially treated	4.97 ± 0.292	4.05 ± 0.213
Water is an unlimited resource	4.08 ± 0.241	3.04 ± 0.161
Water (specifically freshwater) should be made available to all at no/low price.	4.02 ± 0.236	4.87 ± 0.256
Clear, odorless water always indicates good quality.	4.99 ± 0.294	3.43 ± 0.184
Water should be saved or conserved	3.02 ± 0.177	3.08 ± 0.162
Rainwater should be collected for other water needs and use purposes	4.06 ± 0.238	3.05 ± 0.154
Water in your spring/well should be shared to other people	3.45 ± 0.202	3.98 ± 0.206
Water system should be established to bring spring waters to every household user.	4.07 ± 0.239	4.65 ± 0.244
Fees should be collected in bringing the spring/well water to your doors.	4.56 ± 0.268	2.96 ± 0.156
Clearing of vegetation near the spring/well can reduce water flows.	4.12 ± 0.242	2.05 ± 0.121
Perception (awareness-knowledge) of the value of water and cultural beliefs, change in water quality and use beyond drinking **(1=Do not believe at all, 2=Slightly believe, 3= Somewhat believe, 4=Moderately believe,5=Extremely belief)**		
I believe water can only be used for drinking purpose	3.04 ± 0.238	3.76 ±0.224
I believe water is sacred (best purifier) and has an image of God, was created for the glory of God	4.01 ± 0.308	3.06 ± 0.187
I believe human as a top creation can use water as much as needed	4.04 ± 0.311	3.45 ± 0.208
I believe although water is beyond human comprehension, it is however affected by human misbehavior	4.06 ± 0.312	3.67 ± 0.213
I believe union with God in the trinity is accomplished through contemplation of water	4.16 ± 0.321	3.41 ± 0.201

I believe water can be used for recreation, healing and contact with spirit of some ancestors	3.04 ± 0.237	2.45 ± 0.144
I believe several anthropogenic activities contaminate water	3.01 ± 0.231	2.78 ± 0.163
There is adequate water in my area to meet future generation	4.05 ± 0.311	4.75 ± 0.256
There is infrastructural protection of drinking water source	2.01 ± 0.154	3.12 ± 0.182
Need stronger local law and policy for the protection of quality of water resources	4.97 ± 0.382	2.45 ± 0.144
Tough water protection laws hurt economic development and prosperity	3.05 ± 0.234	2.07 ± 0.121
The national water corporation company (REGIDESO) maintain better quality of supplied drinking water	2.06 ± 0114	4.06 ± 0.234
Water management committee is a good initiative for community level in rural and urban areas	4.01 ± 0.222	4.99 ± 0.292
Campaign and public meeting will help the authority to know individual interest	2.07 ± 0.115	1.04 ± 0.075
Public participation is important for water resource management	4.97 ± 0.276	4.99 ± 0.348
There is adequate environmental education through engagement of stakeholders	1.87 ± 0.103	3.09 ± 0.206
There are no adequate progressive research and institutional funding	3.67 ± 0.203	3.04 ± 0.202
Water planning is important for the sustainable environment of any administrative entity	3.54 ± 0.196	3.05 ± 0.203
There are lacks in institutional capacity and governance, absence of state governance at all levels	3.07 ± 0.175	3.02 ± 0.201
Water is essential for ritual-spiritual religious practices/ceremonies and for the transmission of traditional knowledge to future generation	4.12 ± 0.229	4.05 ± 0.276
Children and community aware aware-informed about past stories (ecosystem services, benefits, health, dangers) of water resources in the village	4.09 ± 0.227	3.67 ± 0.244
Even when you compound in clean is living in neighborhood where common defecation occur, some one can still be exposed to typhoid fever and diarrheas	4.97 ± 0.281	4.56 ± 0.305
Land-use changes and related anthropogenic causes of water change are affecting the population	4.03 ± 0.224	4.95 ± 0.334
Contamination has changed the quality and quantity (amount) of water theses days in the community	3.01 ± 0.176	4.55 ± 0.07
Knowledge & opinions towards drinking water resource management program **(1 = Strongly Disagree, 2 = Disagree, 3 = Neither or not idea or Neutral, 4 = Agree, 5 = Strongly Agree)**		
I know about the source of household water supply	4.05 ± 0.192	4.66 ± 0.03
I know that the household supplied water has been treated	3.01 ± 0.143	4.98 ± 0.554
I know about the water borne diseases	4.87 ± 0.231	3.34 ± 0.376
There are campaigns to reduce river pollution by waste management	3.06 ± 0.145	3.08 ± 0.432
I know there are communications such as advertise in the newspaper, radio and television to reduce water pollution at residence Place	4.05 ± 0.192	1.78 ± 0.197
I live in urban area and it is easy for me to participate in stakeholders ' meeting.	4.02 ± 0.191	3.02 ± 0.333
I live in semi urban area and it is not easy for me to participate in stakeholders ' meeting.	3.04 ± 0.144	3.05 ± 0.338
I live in rural area and it is difficult for me to participate in stakeholders ' meeting.	4.02 ± 0.189	4.12 ± 0.457
I live in urban area and I have better chances to get quality water supply than the people live in semi-urban and rural area.	3.07 ± 0.146	4.05 ± 0.456
I live in semi-urban area and I have better chances to get quality water supply than the people live in rural area	4.67 ± 0.223	4.07 ± 0.156
I live in rural area and I have better chances to get quality water supply than the people liv in urban and semi-urban area.	4.91 ± 0.233	4.06 ± 0.571
Trust and opinion towards water governance **(1=Do not believe at all, 2=Slightly believe, 3= Somewhat believe, 4=Moderately believe,5=Extremely belief)**		
I have confidence that REGIDESO and related actors do their jobs and perform their functions as they should.	2.05 ± 0.157	3.45 ± 0.287
The leaders, staff of and other personnel in charge are water supply to community are competent to perform their functions and meet their responsibilities.	2.07 ± 0.159	3.06 ± 0.255

There are plenty of reasons to believe that the personnel of REGIDESO are motivated to do their jobs and fulfill their responsibilities	1.06 ± 0.08	2.04 ± 0.174
I feel a sense of loyalty to governance of drinking water committee and will always support their activities in our area	2.08 ± 0.165	3.43 ± 0.287
People should follow the decisions and policies of water governance agency even when they disagree with them.	3.03 ± 0.233	3.12 ± 0.267
REGIDESO was established through lawful procedures and should operate in compliance with the government policy while taking care of needs and desire of the population	3.06 ± 0.235	3.34 ± 0.278
Only God can regulate and legitimate authority on surface water use and regulation	4.03 ± 0.314	2.78 ± 0.231
I feel like the decision makers do not listen to the public opinion, they do not treat consumers with dignity and respect	2.05 ± 0.157	1.45 ± 0.123
I can freely express my points of view to decision makers, they frequently respect our rights.	2.09 ± 0.91	1.11 ± 0.092
I believe that public interest will be served by the final decision.	3.02 ± 0.232	3.45 ± 0.061
I think that the influence of my opinion in this decision is similar to the influence of other people	1.45 ± 0.111	3.56 ± 0.297
I think the decision makers have people's best interests in mind while making this decision and are using fair procedures to make their decision	4.05 ± 0.311	2.04 ± 0.121
***Willingness to Participate of People in Water Resource Management* (1 = Strongly Disagree, 2 = Disagree, 3 = Neither or not idea or Neutral, 4 = Agree, 5 = Strongly Agree)**		
I will participate in stakeholder ' s meeting	4.67 ± 0.467	4.06 ± 0.369
I will recommend other to participate in stakeholder ' s meeting	4.95 ± 0.416	4.95 ± 0.431
I will bring my family members and friends to participate	4.12 ± 0.412	4.44 ± 0.403
I will consider this meeting at first place compare to other programs	4.09 ± 0.856	4.87 ± 0.445
I will put forward my interest/opinion in the stakeholder ' s meeting	4.05 ± 0.651	4.27 ± 0.388
***Perception of concerns and perceived Health Risk* (1=Not at all aware,2=Slightly aware, 3= Somewhat aware, 4=Moderately aware, 5=Extremely aware)**		
I am aware that tap water should be free of health risk problem	4.08 ± 0.23	3.06 ± 0.178
I am convinced the tap water is associated with health risks	4.97 ± 0.331	3.01 ± 0.156
I know the tap water at home is unsafe for drinking	4.67 ± 0.314	3.45 ± 0.181
My household consumes bottled water for drinking most of the time.	4.87 ± 0.325	4.04 ± 0.213
I am aware that my household uses tap water for drinking purpose most of the time	4.98 ± 0.332	4.99 ± 0.08
I am afraid that the tap water has too much lime scale	4.13 ± 0.271	3.97 ± 0.209
I think the tap water is contaminated with dangerous contaminants/ chemicals	4.06 ± 0.276	3.06 ± 0.161
I think the tap water at home is contaminated with water borne bacteria and fungus	4.05 ± 0.267	3.66 ± 0.102
Tap water has caused water borne illness to me or to someone in my family previously		
***Basic knowledge, opinion, perception on typhoid-diarrhea-cholera diseases environmental risk factors* (1=Not at all concerned,2=Slightly concerned, 3= Somewhat concerned, 4=Moderately concerned,5=Extremely concerned)**		
I know that I can get these diseases (typhoid-diarrhea-cholera,...) through water that is contaminated	4.95 ± 0.291	4.65 ± 0.273
It is also possible that I can get diseases (typhoid-diarrhea-cholera,...) through dirty food	4.08 ± 0.243	2.12 ± 0.124
Practicing open defecation may be a way to spread these diseases to me and my family members	4.06 ± 0.238	3.45 ± 0.202
Theses diseases are transmitted by the germs	4.04 ± 0.238	1.11 ± 0.065
Someone is having cramp leg or vomiting profusely water, then he either have cholera and diarrhea	4.09 ± 0.241	3.45 ± 0.202
Water should be of taste, no smell, good color, good temperature…	4.56 ± 0.268	4.98 ± 0.292
Water quality should not change its quality change either in rainy or dry seasons whatever source where it comes from	4.87 ± 0.131	4.65 ± 0.292
Drinking water should not be dirty or silty, it should safe to drink at any time someone	4.01 ± 0.234	3.05 ± 0.191

needs it		
The person collecting water or the material used to carry collected water at home may contaminate the water before reaching home	4.99 ± 0.08	3.01 ± 0.188
Water can be contaminated during storage or handling by children and made	4.65 ± 0.273	2.32 ± 0.145
Treating water before you drink it (boil, pasteurize, chlorinate,) may lead to lost of is taste and quality	3.12 ± 0.183	4.65 ± 0.291
I believe, made, domestic workers, visitors, animals and very young babies (before they can walk) can spread typhoid fever and diarrhea through feces	4.54 ± 0.267	3.54 ± 0.221
I believe in supernatural forces and witch people bring the typhoid fever in public drinking water	3.56 ± 0.209	4.89 ± 0.305
I believe in natural remedies such as plants to remove and kill the bad germs in water	4.07 ± 0.239	2.99 ± 0.199
Do you trust that medical facilities in the village are capable to treat well patient suffering with typhoid fever	4.06 ± 0.238	3.88 ± 0.242
Do you do self medication or administer yourself medication to ill people or visit nearest health clinics?	3.78 ± 0.229	3.77 ± 0.235
Staying/living in dirty and over-crowded rooms/places/houses may be a way that cholera-typhoid can spread	4.98 ± 0.295	4.67 ± 0.291
Disaster (overflowing of rivers, floods, landslides, soil erosion) situations can spread typhoid-cholera in the villages	4.76 ± 0.287	3.88 ± 0.245
Water shortage or scarcity can expose people to diseases by using any water available	4.06 ± 0.238	3.45 ± 0.215
The germs that causes theses diseases can be found in any kind of water resource in the village	4.89 ± 0.291	3.13 ± 0.195
Living or having a homestead near dumping site of solid waste or near evacuation canals can expose some one to these water diseases	4.15 ± 0.243	3.44 ± 0.215
Crowded rooms and places may be a way that cholera can spread	4.17 ± 0.245	4.67 ± 0.291
During flooding situations, cholera can spread in the community and my household members and I can get cholera	4.16 ± 0.244	4.88 ± 0.306
In the event of water shortage, it is possible for cholera-typhoid cases to increase in the community	3.07 ± 0.185	2.54 ± 0.343
The germ that causes cholera can be found in coastal-not boiled-spring-pond-wetland water	4.89 ± 0.298	3.32 ± 0.207
***Perception of importance of complying with hygiene and sanitation recommendations* (1=Not at all important, 2= slightly important, 3=somewhat important,3=Moderately important, extremely important)**		
It is important to wash hands (with soap) every time before and after eating/ visiting toilet, and maintain all time the bathroom clean	4.43 ± 0.316	3.87 ± 0.227
Typhoid fever-diarrheas can spread even with apparently clean hands (show hands- no black or dirt) of people	4.56 ± 0.327	2.13 ± 0.125
Germs that cause diarrheas-Typhoid fever-Cholera mostly spread from hands of dirty people	4.89 ± 0.349	4.67 ± 0.275
Previous trainings and education opportunities on any hygiene or sanitation can help in preventing the burden on water-related diseases in the villages	4.12 ± 0.294	2.33 ± 0.137
It is important to clean before eating raw foods from local market because some may be contaminated at the market places	4.89 ± 0.349	3.76 ± 0.224
It is important into to keep child dirty nappies in the compound to avoid spreading cholera-diarrheas germs in the compound	4.97 ± 0.419	2.88 ± 0.169
***Personal hygiene and Food safety practices (*1 = Strongly Disagree, 2 = Disagree, 3 = Neither or not idea or Neutral, 4 = Agree, 5 = Strongly Agree)**		
I do wash my hands regularly because I do not want to get cholera or typhoid	3.02 ± 0.177	4.55 ± 0.543
I always wash my hands with soap after I have used the toilet to avoid getting cholera-diarrheas	4.43 ± 0.265	3.54 ± 0.445
I often wash my body with soap daily to avoid getting cholera-Diarrheas	4.89 ± 0.287	3.72 ± 0.671
I always wash my hands with soap before eating to avoid getting cholera	4.66 ± 0.274	2.65 ± 0.334
My food is prepared with clean water and in a clean environment in my home to avoid waterborne diseases	4.76 ± 0.287	3.13 ± 0.143

I or whoever prepares my food washes their hands after they have used the toilet before preparing the food or touching water	2.13 ± 0.125	3.76 ± 0.234
I believe not eating on the street and raw foods can enable me to avoid typhoid fever	4.65 ± 0.273	2.23 ± 0.131
Someone can get cholera-typhoid germs through contaminated food and water or by playing in a an open defecation place	4.87 ± 0.286	2.52 ± 0.1451
Others *statements on waste management* (1 = Strongly Disagree, 2 = Disagree, 3 = Neither or not idea or Neutral, 4 = Agree, 5 = Strongly Agree)		
Septic tanks can contaminate water sources	2.64 ± 0.377	3.15 ± 0.186
Placing of animals near the springs cannot contaminate the water.	4.45 ± 0.635	3.03 ± 0.178
The use of pesticides, veterinary products and related chemicals in farms may contaminate spring waters.	4.12 ± 0.588	3.01 ± 0.178
It is okay to throw plastics and other wastes in the spring vicinity after washing or bathing.	4.45 ± 0.635	3.05 ± 0.179
Dumping of wastes anywhere will contaminate water sources	4.09 ± 0.584	3.06 ± 0.187

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Table-3: Perception(belief), knowledge of typhoid fever by respondents in different health areas of the Kadutu urban health zone and of Miti-Murhesa rural health zone, South-Kivu Province, eastern DRCongo

	Kadutu health zone						**Miti-Murhesa health zone**					
	Health areas (% respondents)						**Health areas (% of respondents)**					
	Buholo	**Nyamugo**	**Karhale**	**Kasali**	**Statistics**		**Lwiro**	**Kavumu**	**Miti**	**Murhesa**	**Statistics**	
Perception (belief) & Knowledge of typhoid	**(N=52)**	**(N=28)**	**(N=60)**	**(N=58)**	***χ2 (DF=3)***	***P-Value***	**(N=56)**	**(N=96)**	**(N=34)**	**(N=68)**	***χ2 (DF=3)***	***P-Value***
Based on your knowledge, what is typhoid fever (Have you ever heard of typhoid fever)?												
An illness caused by bacteria due to poor personal hygiene and poor sanitation	46.67	12.95	45.94	24.95	25.149	**<0.0001**	17.45	23.56	51.12	20.76	25.432 5	**<0.0001**
An illness which affects only children	12.76	23.56	34.64	34.97	12.667	**0.005**	74.67	34.65	33.54	33.12	28.545 5	**<0.0001**
Typhoid fever do not exist	34.65	34.76	12.73	23.78	12.522	**0.006**	3.45	17.87	3.54	40.78	56.65	**<0.0001**
It is when somebody has fever	5.95	28.98	6.75	16.88	23.799	**<0.0001**	4.56	23.65	11.81	5.34	206107	**<0.0001**
What are the signs and symptoms associated to typhoid fever?												
There's no sign and symptom	23.54	82.65	4.67	12.21	122.52	**<0.0001**	50.32	73.43	1.33	4.12	116.70 7	**<0.0001**
Anger, poverty, short height, hunger	12.67	4.34	11.21	3.89	7.773	0.051	3.33	12.67	19.98	83.12	132.10 9	**<0.0001**
Fever, vomiting, malaise, diarrhea, headache	48.67	12.67	84.78	87.12	63.567	**<0.0001**	45.65	12.65	67.12	11.54	64.039 2	**<0.0001**
Overweight, hallucination, loss of hair	15.86	0.43	0.23	4.64	30.505	**<0.0001**	1.54	1.98	12.12	1.87	18.282 9	**<0.0001**
How do we get typhoid fever?												
By talking with people	34.12	23.12	6.12	0.76	44.223	**<0.0001**	18.65	5.43	1.87	39.34	52.856 1	**<0.0001**
By ingesting/eating contaminated food and water	65.12	58.78	89.45	13.21	53.657	**<0.001**	3.78	45.76	82.76	13.91	104.14 1	**<0.001**

By walking on the way	0.88	17.12	3.65	77.87	156.55	**<0.0001**	65.12	45.43	12.98	1.98	80.9086	**<0.0001**
By staying in the hospital	0.43	1.54	0.93	8.98	16.424	**<0.0001**	12.67	3.12	1.87	44.95	77.5761	**<0.0001**
What factors contribute to the spread of typhoid fever?												
Going to school	5.34	7.76	26.98	77.98	115.64	**<0.0001**	5.12	56.1	1.32	1.76	133.415	**<0.0001**
Smoking, alcohol	23.12	27.98	12.87	5.34	17.925	**<0.0001**	53.75	2.12	1.34	19.65	93.9167	**<0.0001**
There's no factor	49.65	34.56	4.12	11.66	52.523	**<0.0001**	39.65	7.97	90.12	78.56	78.2711	**<0.0001**
Poor hygiene and sanitation	22.56	30.67	56.76	5.87	46.604	**<0.0001**	2.12	34.12	7.12	0.65	66.8544	**<0.0001**
Can typhoid fever be prevented/cured?(If "Yes", how can it be done?)												
By sleeping in the night	4.31	0.99	1.24	10.87	14.583	**0.002**	46.78	6.78	12.54	4.56	65.9028	**<0.0001**
Avoid breathing	2.76	89.56	2.54	1.65	236.63	**<0.0001**	44.62	5.12	8.67	75.67	99.1621	**<0.0001**
Playing under the rain	12.34	6.9	0.09	1.16	18.795	**<0.0001**	6.12	75.76	74.76	1.87	128.402	**<0.0001**
Good personal hygiene, use of clean water and food	80.65	2.76	96.78	87.12	83.867	**<0.0001**	3.45	12.76	4.56	18.76	15.866	**0.001**
Suitable measures taken against typhoid & other water related health problems												
Personal water filter ,boiling water, add chlorinate drug	15.45	27.67	6.05	28.09	17.484	**0.001**	12.78	9.65	34.12	30.76	21.1222	**<0.0001**
Piped water supply acquire from REGIDESO	18.76	8.76	56.78	1.45	84.734	**<0.0001**	17.78	7.89	34.65	17.87	18.9242	**<0.0001**
Purchase of potable water	5.34	1.76	3.56	18.54	23.953	**<0.0001**	0.09	3.12	0.045	0.913	5.98372	0.113
Rainwater harvesting systems installation at homestead/Stocking of water in advance	23.67	3.56	17.54	9.67	17.133	**0.001**	22.63	20.32	4.56	11.76	13.8942	**0.003**
Periodical medical check	2.79	1.65	0.65	12.67	20.857	**<0.0001**	0.04	0.67	0.34	5.76	13.8941	**0.003**
Balanced wise use of water for different purposes	3.62	13.65	5.66	1.65	13.53	**0.004**	32.34	42.71	0.08	6.68	60.6982	**<0.0001**
Monitoring disease spread through TV/newspaper and calling for lab analyses	1.54	11.67	0.32	0.12	26.988	**<0.0001**	0.98	4.78	1.65	8.65	9.18379	**0.027**
Changes in food pattern us and comply with food hygiene measures	16.76	3.23	7.56	3.67	15.155	**0.002**	12.12	7.87	22.24	6.44	12.5523	**0.006**
Maintenance of personal hygiene and sanitation	12.45	28.98	2.56	24.56	25.08	**<0.0001**	1.54	3.78	2.45	11.76	13.4367	**0.004**
Challenges to implement adaptive practices in the prevention against these diseases												
Poor social cohesion in the community	15.67	7.88	18.96	45.94	37.163	**<0.0001**	21.56	11.12	32.56	54.23	34.1932	**<0.0001**
Lack of governmental as well as other organizational	68.45	38.23	12.65	18.56	55.059	**<0.0001**	5.76	11.95	6.78	2.54	6.7695	0.081

support												
Very poor socio-economic conditions	12.34	45.67	4.67	21.78	45.031	**<0.0001**	18.76	45.71	1.78	19.67	45.8965	**<0.0001**
Very far distances to fetch safe drinking water sources	2.34	5.64	41.45	0.98	88.955	**<0.0001**	19.54	23.56	46.87	4.78	38.5072	**<0.001**
Social unrest, wars, insecurity, children lack of respect of hygienic measures	1.45	3.56	22.65	12.97	27.893	**<0.0001**	34.64	7.89	12.67	18.98	21.9619	**<0.0001**
What are the clinical symptoms of typhoid fever disease?												
Fever (>37.5C)	20.12	12.13	18.54	76.12	83.946	**<0.0001**	9.76	0.65	19.54	12.34	17.2765	**0.001**
Fatigue	14.12	4.87	6.75	0.89	13.843	**0.003**	0.32	24.67	0.91	8.56	44.7986	**<0.0001**
Headache	10.78	0.66	39.98	8.67	59.079	**<0.0001**	0.56	20.12	0.89	1.08	49.2417	**<0.0001**
Anorexia	2.34	2.12	0.76	0.65	1.6054	0.658	1.56	4.56	58.76	0.45	147.507	**<0.0001**
Constipation	6.54	1.87	8.93	1.11	9.1371	**0.028**	33.92	1.54	7.87	1.43	63.9907	**<0.0001**
Diarrhea	46.76	78.98	25.65	12.65	61.327	**<0.0001**	54.56	48.89	12.56	77.12	44.4773	**<0.0001**
Other clinical symptoms or diseases (illnesses) or associated (related) to consumption of dirty water or driven when in contact with typhoid infection												
Malaria	22.23	12.45	5.78	20.89	11.607	**0.009**	24.56	11.76	4.34	3.12	26.5774	**<0.0001**
Dysentery/cholera	23.45	2.12	3.12	4.56	37.117	**<0.0001**	2.12	5.67	7.12	7.34	3.13667	0.371
Bilharziasis/verminosis	1.45	0.45	17.78	1.56	39.187	**<0.0001**	4.67	17.89	2.23	1.87	25.9028	**<0.0001**
Asthma/Pneumonia	12.54	8.33	1.45	0.67	16.887	**0.001**	1.43	1.34	24.55	2.12	53.5814	**<0.0001**
Cough/Flu	4.56	11.45	4.67	12.67	6.738	0.081	0.98	11.65	0.67	8.34	16.5647	**0.001**
Vomiting (Nausea)	5.76	53.23	24.12	1.45	78.661	**<0.0001**	13.56	0.54	18.56	3.54	23.5978	**<0.0001**
Abdominal pains	9.67	0.35	6.78	35.32	54.335	**<0.0001**	3.56	4.67	6.78	23.12	26.3846	**<0.0001**
Anemia	1.45	0.07	0.02	4.12	7.8265	**0.049**	17.87	0.34	5.32	6.78	21.6495	**<0.0001**
Confusion	0.56	1.12	4.56	1.65	4.8269	0.185	13.12	9.56	0.66	18.54	16.1616	**0.001**
Stomach ache	9.76	1.11	13.56	0.45	20.227	**<0.0001**	0.05	5.43	13.45	0.14	25.0641	**<0.0001**
Toothache	1.23	0.045	0.06	4.78	9.8269	**0.02**	0.03	11.23	4.53	1.33	17.5537	**0.001**
Chest pain	0.78	0.04	0.07	0.09	1.5629	0.668	0.06	1.21	2.34	1.65	2.09042	0.554
Ear infection	0.87	1.65	5.12	0.08	7.6687	0.053	0.09	3.12	7.12	1.08	10.1862	**0.017**
Conjunctivitis	0.34	0.05	12.92	0.04	36.701	**<0.0001**	2.12	0.05	0.08	3.12	5.23536	0.155
Epilepsy	0.06	0.01	0.02	0.05	0.0049	**0.007**	0.01	0.04	0.08	1.45	3.76329	0.288
Rheumatism	1.65	2.45	0.04	8.45	12.868	**0.005**	5.67	12.11	0.03	9.65	12.1503	**0.007**
Obesity	1.11	0.01	0.04	0.08	2.7607	0.431	0.03	0.06	1.45	4.55	8.89161	**0.031**
Stroke/Heart disease	0.45	0.32	0.45	0.56	0.0649	0.995	0.65	0.34	1.45	3.12	3.34288	0.342
Neck Pain/Backpain	2.56	4.56	0.05	0.23	7.4122	0.061	6.76	2.12	0.05	0.03	13.4487	**0.004**
Reproductive tract illness in women	0.34	0.21	0.04	0.56	0.5018	0.918	0.45	0.09	0.06	0.031	0.73294	0.865

Measles	0.05	0.031	0.04	1.95	5.2831	0.152	2.34	1.56	0.04	0.02	4.0311 1	0.258

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Table-4. Level of knowledge of respondents on the health risks related to the consumption of water of poor quality in Kadutu and Miti-Murhesa health zones, South-Kivu, eastern of DRCongo

		% of respondents from Kadutu health zone						
		Name of health areas of Kadutu health zone				**Statistics (Chi-square test)**		
		Buholo (N=52)	**Nyamugo (N=28)**	**Karhale (N=60)**	**Kasali (N=58)**	***DF***	***χ2***	***P-Value***
Origin of water consumed by household	Regideso Tape	88.46	50.00	86.67	55.17	3	17.673	**0.001**
	Source (well)	11.54	50.00	13.33	44.83	3	41.385	**<0.0001**
Leak on water pipe	Yes	100.00	100.00	100.00	100.00	3	0.0006	0.999
Methods of water conservation	Can	96.15	92.86	93.33	86.21	3	0.5779	0.901
	Trunk	3.85	7.14	6.67	13.79	3	6.77304	0.079
Regular practices of washing of water containers	Yes	100.00	100.00	100.00	100.00	3	0.000761	0.999
Water treatment before consumption	No	100.00	100.00	100.00	100.00	3	0.00081	0.9999
Kind of water available at the household level	Regideso Tape	0.00	28.57	0.00	0.00	3	85.7143	**<0.0001**
	Developed source (well)	34.62	42.86	43.33	20.69	3	9.48592	**0.023**

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Tab-5: Level of knowledge of the dangers of food consumption and the risk of exposure to water-borne diseases (typhoid fever) by respondent in the Kadutu health zone.

		% of respondents from Kadutu health zone						
		Name of health areas of Kadutu health zone				**Statistics (Chi-square test)**		
		Buholo (N=52)	**Nyamugo (N=28)**	**Karhale (N=60)**	**Kasali (N=58)**	***DF***	***χ2***	***P-Value***
Usually eat raw foods,	No	50.00	0.00	50.00	10.34	3	74.7845	**<0.0001**

un-cleaned fresh foods	Yes	50.00	100.00	50.00	89.66	3	28.4893	<**0.00001**
Usually wash hands before eating	No	61.54	0.00	50.00	34.48	3	58.7721	<**0.0001**
	Yes	38.46	100.00	50.00	65.52	3	33.7901	<**0.0001**
Most often eat food prepared the day before	No	11.54	28.57	10.00	17.24	3	12.6311	**0.006**
	Yes	88.46	71.43	90.00	82.76	3	2.55741	0.465
Have ever been victim of typhoid fever in the past ?	No	61.54	100.00	60.00	65.52	3	15.0389	**0.002**
	Yes	38.46	0.00	40.00	34.48	3	38.2223	<**0.0001**

Table-6: Generalized linear model (GLM) testing the influences of independent variables on the level of knowledge of the dependent variable (*are you aware of that consuming poor quality water may exposure to typhoid fever?*)by respondents in the health zone of Kadutu,

GLM (**Gaussian identity model**)						
Dependent (outcome) variable : Quality of water consumed daily	Coef.	OIM Std.Err.	z	P>|z|	[95% Conf. Interval]	
Independent (explanatory) variables						
Health zone	-.1617953	.0561229	-2.88	**0.004**	-.2717941	-.0517965
Residence	-.0043296	.0056396	-0.77	0.443	-.0153831	.0067239
Age	-.0012149	.0033212	-0.37	0.715	-.0077243	.0052945
Sex	-.0108576	.0476869	-0.23	0.820	-.1043222	.082607
Civil status	.0751943	.0251785	2.99	**0.003**	.0258453	.1245433
Profession	.0522331	.0182662	2.86	**0.004**	.0164319	.0880342
Household size	-.0019247	.0095748	-0.20	0.841	-.0206909	.0168415
Level of education	-.0571927	.0226446	-2.53	**0.012**	-.1015753	-.0128102
Water storage time (hours) before consumption	.0155395	.0292626	0.53	0.595	-.0418141	.0728931
Leak on water pipe	-.1188242	.0534912	-2.22	**0.026**	-.2236651	-.0139833
Methods of water conservation	-.0913337	.0548506	-1.67	0.096	-.1988388	.0161714
Usually washing hands before eating	-.0365496	.0693388	-0.53	0.598	-.1724511	.0993519

Time in minute for washing containers	-.0896628	.0332217	-2.70	**0.007**	-.1547762	-.0245494
Methods of treatments to obtain potable water	.3032412	.0500042	6.06	**0.000**	.2052348	.4012477
Eat raw foods	.1532929	.0513047	2.99	**0.003**	.0527375	.2538483
Regularly washing containers	.2921824	.0545949	5.35	**0.000**	.1851784	.3991865
Kind of water available at household level	-.0111267	.0525732	-0.21	0.832	-.1141682	.0919148
Habit of eating food prepared the day before	.0920112	.0476346	1.93	0.053	-.0013509	.1853733
Has ever suffered from typhoid fever	-.2707292	.0486332	-5.57	**0.000**	-.3660486	-.1754098
Cons	.447245	.1458881	3.07	0.002	.1613096	.7331804
Other statistics: AIC (Akaike's Information Criterion)= 1.09885, BIC(Schwarz's Bayesian Criterion) = -2186.122., Log likelihood= -197.572271.						

Table-7: Generalized linear model (GLM) testing the influences of independent variables on the level of knowledge of the dependent variable (*are you aware of that consuming poor quality water may exposure to typhoid fever?*) by respondents in the health zone of Miti-Murhesa

GLM (**Gaussian identity model**)						
Dependent variable: Exposure to typhoid fever infection risks	Coef.	OIM Std.Err.	Z	P>|z|	[95% Conf. Interval]	
Independent variables						
Health zone	-.0718395	.0562472	-1.28	0.2021	-.1820819	.0384029
Residence	.0163274	.0055436	2.95	**0.003**	.0054622	.0271927
Sex	.1369487	.0685483	2.00	**0.046**	.0025965	.2713009
Age	.0926763	.0329783	2.81	**0.005**	.02804	.1573126
Civil status	.0015301	.0226865	0.07	0.946	-.0429347	.0459948
Level of education	-.0734383	.025024	-2.93	**0.003**	-.1224844	-.0243922
Profession	-.0501729	.0181597	-2.76	**0.006**	-.0857654	-.0145805
Household size	-.0211129	.0094502	-2.23	**0.025**	-.039635	-.0025909
Time in minute of washing containers	-.0018551	.0032987	-0.56	0.574	-.0083205	.0046102
Washing containers	.0911294	.0471449	1.93	0.053	-.001273	.1835317

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Leak on your water pipe and tapes	.0759274	.0473961	1.60	0.109	-.0169673	.1688221
Preserved water in containers	.0011955	.050267	0.02	0.981	-.0973261	.0997171
Water treatment	-.0537809	.0519763	-1.03	0.301	-.1556526	.0480908
Suffered with typhoid before	.1512963	.0506365	2.99	**0.003**	.0520506	.2505421
Retention time in hours	-.0315949	.0290366	-1.09	0.277	-.0885056	.0253158
Source of kind of water consumed	-.1180147	.0531419	-2.22	**0.026**	-.222171	-.0138584
Food prepared the day before	.1352724	.054246	2.49	**0.013**	.0289521	.2415926
Eat raw foods	-.4369212	.0515574	-8.47	**0.000**	-.5379718	-.3358706
Washing hands with water before eating	.1600371	.0515766	3.10	**0.002**	.0589488	.2611254
Cons	.5841557	.1436093	4.07	**0.000**	.3026866	.8656249
Other statistics: **Log likelihood**= -194.9765228, **AIC**(Akaike's Information Criterion) = 1.08574, **BIC**(Schwarz's Bayesian Criterion) = -2186.941						

Table-8: Frequency of germs in samples from different sites (avenues=health areas) in the Kadutu health zone

	Names of sites (avenues, health areas) where water samples were collected to detect the presence of pathogenic germs in Kadutu health zone												
	AvAM=Avenue AMBE, **AvB**=Avenue BIASI, **AvK**=Avenue KAWA, **AvKi**=Avenue KIbongo, **AvL**=Avenue LWAMA, **AvU**=Avenue URU, **AvV**=Avenue Virunga, **AvMA**=Avenue Mandeleo, **AvCar**=Carrefour, **AvF**=Avenue Funu, **AvKA**=Avenue Kabwakasire, **AvLY**=Avenue LyceeWima, **AvNy**=Avenue Nyamuragira												
Isolated germs	AvAM	AvB	AvK	AvKi	AvL	AvU	AvV	AvMA	AvCar	AVF	AvKA	AvLY	AvNY
Aeromonas sp.	0	0	0	0	0	1	0	0	0	0	0	0	0
Citrobacter frendii	0	0	0	0	0	0	0	0	0	0	0	0	1
Citrobacter sp	1	0	1	0	0	0	0	0	0	0	1	1	0
E.coli	2	4	0	6	1	1	0	4	1	0	2	3	3
Edwardsiella sp.	0	0	1	0	0	0	0	0	0	0	0	0	0
Edwardsiella tarda	0	0	0	0	0	0	1	0	0	0	0	0	1
Enterobacter aerogenes	0	0	0	1	0	0	0	0	0	0	0	0	0

Enterobacter cloacae	1	0	0	0	0	1	1	0	1	0	0	0	0
Enterobacter sp.	2	2	1	0	1	2	1	0	0	2	1	1	1
Klebsiella sp.	2	0	3	0	0	1	0	0	1	0	0	0	0
Proteus mirabilis	1	0	0	0	0	0	0	0	0	0	0	0	0
Proteus sp.	1	1	1	0	2	1	1	0	0	1	0	0	0
Pseudomonas sp.	0	0	0	0	0	0	0	1	0	0	0	1	0
S.aureus	0	2	0	0	0	1	0	0	0	0	0	0	0
S.aureus.	0	0	0	1	0	0	0	0	0	0	0	0	0
Salmonella enterica	0	0	0	0	0	0	0	0	1	0	0	0	0
Salmonella enterica typhi	0	1	0	0	1	0	0	0	0	0	0	0	1
Salmonella paratyphi B	0	0	0	0	0	1	0	0	0	0	0	0	0
Salmonella sp.	2	2	1	1	0	0	2	0	0	0	0	0	0
Shigella sp.	0	1	0	0	1	1	0	0	0	0	0	0	0
Unknown *staphylococcus*	0	2	0	0	0	1	0	0	0	0	0	0	0
Feacal streptococcus	0	1	0	0	0	2	0	0	0	0	0	0	0
Except for P*seudomonas* sp sprouts. (Pseudomonadaceae) and staphylococci, faecal streptococci, *S.aureus* (Micrococaceae) which can cause various diarrhea, suppurations etc. food-borne illness);…. all other isolated germs were from the family Enterobacteriaceae .Several species from that family may cause different type of diarrhea ...													

Table-9: Frequency of pathogenic germs isolated in water samples from different health areas (villages-sites) of Miti-Murhesa health Zone.

	Names of sites (villages, health areas) where water samples were collected to detect the presence of pathogenic from Miti-Murhesa health zone										
	Bushumba	Cibumbiro	CIFUMA	Kajeje	Kalwa	Kavumu	Lwiro	Muganzo	Mulungu	Murhesa	Saint pie IX
Isolated germs (Enterobacteriaceae)											
Citrobacter sp	1	2	0	1	2	1	1	1	**5**	1	**3**
Edwardsiella tarda	0	0	0	0	1	0	0	1	**3**	1	0
Enterobacter cloacae	0	0	0	0	**3**	0	1	0	0	0	1
Enterobacter	0	1	0	1	**4**	0	1	1	**5**	2	1

sp.											
Escherishia coli	1	0	0	0	0	0	0	1	0	0	0
Klebsiella sp.	1	0	1	0	2	0	2	0	**3**	0	1
Proteus mirabilis	0	0	0	0	0	0	0	0	1	0	0
Proteus sp.	1	0	0	0	0	2	1	2	**5**	**3**	1
Pseudomonas sp.	0	0	0	0	1	0	0	0	0	0	0
Salmonella enterica	0	2	0	0	0	0	0	1	2	1	0
Salmonella enterica typhi	0	1	1	0	1	0	0	0	0	0	0
Salmonella sp.	2	2	1	0	2	2	0	1	4	3	0
Apart from the germs *Salmonella enterica typhi* (Enterobacteriaceae) which can lead to typhoid fever, the remains of isolated germs, also from Enterobacteriaceae family, can cause diarrhea and various infections, especially in vulnerable human groups such as children and elders											

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Table-10: Physico-chemical characteristics of water samples analyzed for the presence of pathogenic germs in the different sites (avenues) of the Kadutu health zone

Parameters measured	Water sampling site names	Mean	SE Mean	StDev	CoefVar (%)	Minimum	Maximum
Temperature (°C)	Av AMBE	24.525	0.131	0.454	1.85	24.000	25.000
	AV BIASI	24.913	0.235	0.939	3.77	22.800	26.600
	Av KAWA	24.725	0.264	0.746	3.02	23.500	25.800
	Av Kibonge	24.444	0.235	0.704	2.88	23.600	25.600
	AV LWAMA	24.833	0.324	0.794	3.20	24.000	26.000
	AV URU	24.462	0.146	0.525	2.15	23.800	25.000
	Av VIRUNG	24.433	0.430	1.054	4.31	23.000	26.000
	AV.Maendeleo	24.580	0.188	0.421	1.71	23.900	25.000
	Carréfour	24.425	0.338	0.675	2.76	23.700	25.000
	Funu A	25.233	0.393	0.681	2.70	24.700	26.000

	KABWAKASIRE	24.225	0.392	0.785	3.24	23.500	25.000
	Lycée Wima	24.333	0.422	1.033	4.24	23.000	25.000
	Nyamulagira	23.900	0.282	0.746	3.12	23.000	25.000
pH	Av AMBE	8.358	0.354	1.225	14.66	6.500	9.400
	AV BIASI	8.219	0.318	1.274	15.50	6.000	9.500
	Av KAWA	8.188	0.431	1.218	14.88	7.000	9.400
	Av Kibonge	8.611	0.302	0.905	10.51	6.900	9.500
	AV LWAMA	8.300	0.492	1.205	14.52	6.800	9.400
	AV URU	8.208	0.286	1.032	12.57	6.800	9.400
	Av VIRUNG	8.183	0.490	1.201	14.67	6.900	9.400
	AV.Maendeleo	8.540	0.382	0.853	9.99	7.200	9.300
	Carréfour	8.500	0.647	1.294	15.22	6.900	9.600
	Funu A	8.767	0.393	0.681	7.76	8.000	9.300
	KABWAKASIRE	7.900	0.610	1.219	15.43	6.700	9.000
	Lycée Wima	8.133	0.510	1.250	15.37	6.800	9.400
	Nyamulagira	7.886	0.360	0.953	12.08	6.900	9.200
Conductivity (μs/cm)	Av AMBE	911.1	69.1	239.5	26.29	590.0	1208.0
	AV BIASI	935.6	63.8	255.2	27.28	507.0	1238.0
	Av KAWA	881.6	88.2	249.4	28.29	569.0	1234.0
	Av Kibonge	989.1	67.2	201.6	20.38	698.0	1209.0
	AV LWAMA	960	109	267	27.78	570	1242
	AV URU	895.5	60.2	217.0	24.23	547.0	1203.0
	Av VIRUNG	771	110	269	34.89	489	1140
	AV.Maendeleo	994.0	70.1	156.9	15.78	792.0	1208.0
	Carréfour	934	136	273	29.20	695	1204
	Funu A	941	130	225	23.89	690	1124
	KABWAKASIRE	1057	136	273	25.80	692	1322
	Lycée Wima	923.5	93.2	228.4	24.73	598.0	1133.0
	Nyamulagira	822.6	88.2	233.4	28.37	589.0	1160.0
Dissolved O_2(mg/L)	Av AMBE	10.97	1.66	5.75	52.42	5.10	24.00
	AV BIASI	10.36	1.52	6.10	58.86	4.00	22.00
	Av KAWA	14.19	3.14	8.87	62.54	5.00	25.00
	Av Kibonge	10.26	2.70	8.10	78.96	4.00	29.00
	AV LWAMA	9.30	2.19	5.35	57.56	4.60	18.00
	AV URU	10.13	1.48	5.34	52.71	4.00	20.00
	Av VIRUNG	15.95	3.93	9.62	60.30	5.90	27.00
	AV.Maendeleo	9.98	3.79	8.47	84.88	4.00	24.00
	Carréfour	17.38	4.85	9.71	55.86	9.60	30.00

	Funu A	11.50	3.97	6.87	59.77	5.50	19.00
	KABWAKASIRE	6.97	1.49	2.98	42.70	3.90	10.00
	Lycée Wima	7.33	2.14	5.23	71.34	3.40	17.00
	Nyamulagira	10.57	1.90	5.03	47.57	4.00	18.00
Chlorine (mg/L)	Av AMBE	1.066	0.221	0.764	71.68	0.300	2.500
	AV BIASI	20.1	13.4	53.5	266.25	0.4	187.0
	Av KAWA	1.214	0.304	0.859	70.79	0.380	2.500
	Av Kibonge	2.128	0.354	1.063	49.94	0.550	3.650
	AV LWAMA	1.762	0.451	1.105	62.73	0.580	3.620
	AV URU	2.115	0.688	2.480	117.29	0.430	7.690
	Av VIRUNG	0.583	0.151	0.371	63.62	0.250	1.060
	AV.Maendeleo	1.168	0.192	0.430	36.79	0.550	1.550
	Carréfour	1.750	0.829	1.659	94.79	0.450	4.000
	Funu A	0.773	0.304	0.526	67.99	0.450	1.380
	KABWAKASIRE	1.488	0.360	0.719	48.35	0.550	2.300
	Lycée Wima	1.027	0.174	0.427	41.61	0.500	1.500
	Nyamulagira	1.633	0.431	1.139	69.76	0.350	3.400

Table-11: Physico-chemical characteristics of water samples analyzed for the presence of pathogenic germs in the different sampling sites (villages) from Miti-Murhesa health zone.

Variable	Name of the site (village) where water sample was collected	Mean	SE Mean	StDev	CoefVar (%)	Minimum	Maximum
Temperature(°c)	Bukunda	24.450	0.550	1.100	4.50	22.800	25.000
	Bushumba	23.933	0.422	1.033	4.32	22.000	25.000
	Cibumbiro	24.250	0.358	0.876	3.61	22.800	25.000
	Cirhogole	24.533	0.291	0.503	2.05	24.000	25.000
	Cironge	24.260	0.466	1.043	4.30	22.800	25.000
	Cituzo	24.800	0.115	0.200	0.81	24.600	25.000
	Cizimwe	23.200	0.200	0.283	1.22	23.000	23.400
	INERA	25.000	0.000	0.0000	0.00	25.000	25.000
	Kafurumaye	24.300	0.700	0.990	4.07	23.600	25.000
	Kajeje	23.557	0.368	0.973	4.13	22.000	24.600
	Kavumu	24.400	0.234	0.619	2.54	23.400	25.000
	Konge II	23.650	0.465	0.929	3.93	22.800	24.800
	Lwiro	23.800	0.668	1.337	5.62	22.000	25.000

	Malalo	24.500	0.451	0.781	3.19	23.600	25.000
	Miti-Centre	24.336	0.189	0.706	2.90	22.800	25.000
	MudakaCentre	24.027	0.296	0.983	4.09	22.000	25.000
	Muganzo	23.600	0.529	0.917	3.88	22.800	24.600
	Murhala	24.100	0.545	1.089	4.52	22.800	25.000
	Murhesa	24.300	0.300	0.424	1.75	24.000	24.600
	Mwendo	23.650	0.236	0.473	2.00	23.000	24.000
	Ndundazi	23.500	0.500	0.707	3.01	23.000	24.000
	Nshebeyi	24.00	1.00	1.41	5.89	23.00	25.00
pH	Bukunda	6.500	0.220	0.440	6.76	6.000	7.000
	Bushumba	6.550	0.145	0.356	5.44	6.200	7.000
	Cibumbiro	6.467	0.163	0.398	6.16	6.000	7.000
	Cirhogole	6.600	0.265	0.458	6.94	6.100	7.000
	Cironge	6.580	0.162	0.363	5.52	6.100	6.900
	Cituzo	6.767	0.233	0.404	5.97	6.400	7.200
	Cizimwe	6.550	0.350	0.495	7.56	6.200	6.900
	INERA	6.9500	0.0500	0.0707	1.02	6.900	7.000
	Kafurumaye	6.650	0.350	0.495	7.44	6.300	7.000
	Kajeje	6.743	0.222	0.588	8.73	6.000	7.300
	Kavumu	6.743	0.151	0.399	5.92	6.200	7.200
	Konge II	6.775	0.217	0.435	6.42	6.200	7.200
	Lwiro	7.0750	0.0750	0.150	2.12	6.9000	7.200
	Malalo	6.933	0.267	0.462	6.66	6.400	7.200
	Miti-Centre	6.743	0.116	0.433	6.42	6.200	7.300
	MudakaCentre	6.4455	0.0976	0.3236	5.02	6.0000	7.000
	Muganzo	6.900	0.100	0.173	2.51	6.700	7.000
	Murhala	6.450	0.263	0.526	8.15	6.000	7.200
	Murhesa	7.2500	0.0500	0.0707	0.98	7.2000	7.3000
	Mwendo	6.850	0.194	0.387	5.65	6.300	7.200
	Ndundazi	6.850	0.450	0.636	9.29	6.400	7.300
	Nshebeyi	6.600	0.400	0.566	8.57	6.200	7.000
Conductivity (µs/cm)	Bukunda	998.0	42.1	84.1	8.43	893.0	1099.0
	Bushumba	973.7	85.3	209.0	21.47	603.0	1206.0
	Cibumbiro	988.5	56.6	138.7	14.03	838.0	1235.0
	Cirhogole	1005.7	62.7	108.6	10.80	900.0	1117.0
	Cironge	961	121	271	28.23	692	1322
	Cituzo	1206.0	7.37	12.8	1.06	1192.0	1217.0
	Cizimwe	851	258	364	42.82	593	1108

	INERA	902	207	293	32.55	694	1109
	Kafurumaye	701.50	7.50	10.61	1.51	694.00	709.00
	Kajeje	942.3	73.2	193.7	20.56	603.0	1206.0
	Kavumu	860.9	91.6	242.4	28.16	508.0	1206.0
	Konge II	1082.8	78.9	157.8	14.58	900.0	1235.0
	Lwiro	882	140	279	31.65	603	1217
	Malalo	897.7	94.4	163.6	18.22	709.0	1000.0
	Miti-Centre	1050.2	55.5	207.7	19.78	508.0	1322.0
	MudakaCentre	829.9	69.2	229.7	27.67	508.0	1209.0
	Muganzo	1004	206	357	35.54	593	1235
	Murhala	953.0	84.5	169.0	17.73	709.0	1099.0
	Murhesa	1045	139	197	18.81	906	1184
	Mwendo	1032.8	63.6	127.3	12.32	900.0	1206.0
	Ndundazi	808	300	424	52.51	508	1108
	Nshebeyi	948.5	55.5	78.5	8.28	893.0	1004.0
Disolved O_2 (mg/l)	Bukunda	1.850	0.411	0.823	44.46	0.800	2.600
	Bushumba	2.383	0.644	1.578	66.20	0.800	4.800
	Cibumbiro	1.367	0.262	0.641	46.89	0.600	2.300
	Cirhogole	2.233	0.470	0.814	36.47	1.300	2.800
	Cironge	1.580	0.373	0.835	52.84	0.300	2.600
	Cituzo	1.267	0.318	0.551	43.48	0.700	1.800
	Cizimwe	1.100	0.800	1.131	102.85	0.300	1.900
	INERA	1.050	0.250	0.354	33.67	0.800	1.300
	Kafurumaye	1.000	0.700	0.990	98.99	0.300	1.700
	Kajeje	1.271	0.284	0.752	59.16	0.300	2.600
	Kavumu	1.886	0.273	0.722	38.29	0.800	2.800
	Konge II	1.750	0.371	0.742	42.38	0.800	2.600
	Lwiro	1.400	0.534	1.068	76.26	0.300	2.700
	Malalo	2.7000	0.0577	0.1000	3.70	2.6000	2.8000
	Miti-Centre	1.657	0.195	0.730	44.07	0.300	2.800
	MudakaCentre	1.636	0.269	0.891	54.47	0.300	2.600
	Muganzo	1.767	0.133	0.231	13.07	1.500	1.900
	Murhala	1.575	0.566	1.132	71.90	0.600	2.700
	Murhesa	1.700	0.800	1.131	66.55	0.900	2.500
	Mwindo	2.275	0.309	0.618	27.19	1.600	2.800
	Ndundazi	1.050	0.750	1.061	101.02	0.300	1.800
	Nshebeyi	1.250	0.550	0.778	62.23	0.700	1.800
Chlorate (mg/l)	Bukunda	0.5450	0.0703	0.1406	25.80	0.3500	0.6800

	Bushumba	1.050	0.185	0.454	43.26	0.500	1.460
	Cibumbiro	1.255	0.413	1.011	80.56	0.350	2.460
	Cirhogole	1.350	0.444	0.770	57.02	0.500	2.000
	Cironge	0.948	0.222	0.497	52.44	0.500	1.600
	Cituzo	1.177	0.652	1.129	95.95	0.500	2.480
	Cizimwe	0.875	0.375	0.530	60.61	0.500	1.250
	INERA	1.4200	0.0600	0.0849	5.98	1.3600	1.4800
	Kafurumaye	1.4200	0.0600	0.0849	5.98	1.3600	1.4800
	Kajeje	1.200	0.209	0.554	46.17	0.390	1.890
	Kavumu	1.091	0.410	1.084	99.36	0.350	3.460
	Konge II	1.225	0.319	0.639	52.14	0.550	2.000
	Lwiro	1.502	0.449	0.897	59.72	0.500	2.680
	Malalo	0.860	0.310	0.537	62.43	0.550	1.480
	Miti-Centre	1.677	0.309	1.155	68.89	0.350	3.900
	MudakaCentre	1.561	0.257	0.853	54.68	0.550	3.500
	Muganzo	1.437	0.102	0.176	12.26	1.250	1.600
	Murhala	1.315	0.505	1.011	76.88	0.500	2.680
	Murhesa	0.815	0.215	0.304	37.31	0.600	1.030
	Mwendo	2.162	0.528	1.056	48.85	0.890	3.460
	Ndundazi	0.675	0.175	0.247	36.66	0.500	0.850
	Nshebeyi	1.120	0.770	1.089	97.23	0.350	1.890

Parameter values according to WHO-2010 as reported by Oboh & Osuala (2017),include = [Temperature: 25 °C], [(pH):6.5-9.2), [EC(ms/cm): 500)], [TDS (mg/l) : 500], [DO(mg):6.2], [BOD(mg/l):0.05], [Bicarbonate(mg/l):600], [Sulfate(mg/l):400], [Nitrate(mg/l):10], [Phosphate(mg/l):10],[Chloride(mg/l):200-250], [Calcium(mg/l):200)], [Magnesium (mg/l):50-150], [Sodium(mg/l):150],[Copper(mg/l):1.5], [Zinc(mg/l):1.5], [Iron(mg/l):1.0]

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