EVALUATION OF *Salmonella typhi* IN DRINKING WATER WITHIN SABON GARI LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

BY

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DECLARATION

I declare that the dissertation entitled Evaluation of *Salmonella typhi* in Drinking Water Within Sabon Gari Local Government Area of Kaduna State-Nigeria has been undertaken by me in the Department of Geography under the supervision of Dr. Yusuf.Y. Obadaki and Dr. R.O. Yusuf. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this project dissertation was previously presented for another degree or diploma at any university.

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CERTIFICATION

This thesis entitled **"Evaluation of *Salmonella typhi* In Drinking Water within Sabon Gari Local Government Area of Kaduna State-Nigeria"** by **Godwin Ediroro Ukeh** meets the regulations governing the award of the degree of Masters of Science Geography of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This piece of work is dedicated to The ‘Alpha and Omega’ the ‘Author and Finisher’ of my faith, also, to the loving memory of my beloved mother, Christiana Ukeh. Continue to rest in the bosom of our Lord Jesus.

ACKNOWLEDGEMENT

I am most grateful to God Almighty, the most gracious and merciful, to him I owe my utmost gratitude for my life and this project work.

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ABSTRACT

High prevalence of typhoid, diarrhea, cholera among infant and children has been traced to consumption of unsafe water and unhygienic practices. This study evaluates the presence of *Salmonella typhi* in drinking water within Sabon Gari Local Government Area of Kaduna State-Nigeria. The objectives are: to characterise the major sources of drinking water within the study area, examine the prevalence of *Salmonella typhi* in drinking water within the study area, assess the occurrence of typhoid fever in Sabon Gari LGA, determine the relationships between the prevalence of *Salmonella typhi* in drinking water and the occurrences of typhoid disease in the study area, and examine the social and environmental bases for the occurrence of *Salmonella typhi* and typhoid fever in the study area. The research employed field and survey methods and data was sourced from both primary and secondary sources. A systematic sampling technique was adopted to select 384 respondents. Twenty-four samples of drinking water were randomly collected from three wards which were systematically picked from the eleven wards that makes up the LGA. Among the 24 samples, 3 were sachet water, 3 were tapwater, 9 were boreholes and 9 were well water. Data were presented and analysed using descriptive statistical tools such as frequency tables and mean. The Analysis of Variance (ANOVA) revealed that the occurrence of *Salmonella typhi* count for all the samples collected were not significantly different in the entire sample tested at 0.05 significant levels where $F(2 \quad 16) = 0.190$, $P = 0.829$. Major findings of the study are that; the major sources of water within Sabon Gari LGA with the rate of usage are tapwater (139%), sachet water (86%), boreholes (77%), and well water (76%); *Salmonella typhi* were detected in the drinking water of some locations within the study area; there were cases of typhoid fever in Sabon Gari LGA where 1332 were recorded to have conducted typhoid test and 91.0% of the total test were significant cases in Ladiya, Al-Madinah, and Saidu Dange Hospitals, 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 constrain (33.3%), overcrowdings (48.2%) and lack of access to clean water (32.3%) were the common socio-environmental factors that promotes the occurrence of typhoid in the area. Maintenance of good personal and environmental hygiene are important steps to take when protecting drinking water from contamination by salmonella. There is need for further research on the role of food in transmission of typhoid disease within this LGA.

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CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Access to safe drinking water and improved sanitation is essential for healthy life and can significantly reduce public expenditure on preventable diseases and epidemics (e.g. cholera, diarrhea, typhoid, and dracunculiasis) arising from contaminated drinking water and unhygienic disposal of human waste (WHO, 2007). According to the same document, about 1.7 million deaths annually are related to drinking unsafe water and poor disposal of wastes. Children are the most vulnerable, due to their low natural immunity, and a high percentage of infant mortality is linked to contaminated water and lack of hygienic sanitation (Sunday and Martine, 2011).

Available estimate shows that 783 million people do not have access to clean water and almost 2.5 billion do not have access to adequate sanitation while 6 to 8 million people die annually from the consequences of water related diseases globally (UNESCO, 2013). Between 1999 and 2008, over ₦706 billion of public funds were devoted to provision of safe drinking water, improved sanitation, and health-related services by the Federal Government of Nigeria, excluding contributions by states and local governments (CBN, 2009). What is not clear, however, is the quality of water the government has been providing and its effects on the health outcomes of the people. About 42% of Nigeria's populations have no access to clean drinking water, which is almost 20% of Africa's population in the same position of difficulty (WHO/UNICEF 2010). The implication is that African children are exposed to deadly but preventable water-borne diseases, which affects their growth and health in general (Kingdon and Monk, 2010).

Viable bacteria (among them was *Salmonella typhi*) have been identified in the popular sachet packed water and has been seen to be microbially unsafe for human consumption,

constituting potential health risk, and this can be linked to the increasing incidence of typhoid fever among other food and water-borne infections (Edema, Omemu, and Fapetu, 2001). Commercialization of drinking water is inevitable considering the increasing population of Nigeria vis-avis incapability of supplying pipe-borne potable water through public water supply. Therefore, the production and distribution of commercial sachet-packaged water in Nigeria require increased attention and close monitoring by the regulatory agencies. Also most of the natural sources of drinking water (tap, tube well and well) can be highly contaminated. The detection of pathogenic enteric bacteria in different sources of drinking water in Kathmandu valley, Nepal with *Salmonella typhi* comprising 3.3% of the microorganism also reveals the alarming situation for water borne epidemics in the valley (Tista, Binod, Dev, Madhav, 2007).

The major danger associated with drinking water sources is the possibility of its contamination by sewage or human and animal excreta (Uzoigwe and Agwa, 2012). Another problem is the siting of drinking water system near a refuse dumpsite or landfill. Water is essential to sustain life and a satisfactory supply of drinking water must be made available to all consumers (WHO, 2006a). Potable water is the water that is safe enough to be consumed by humans or used with low risk of immediate or long term harm (WHO 2006b).

There are several rules and regulations guiding provision and supply of drinking water. In Nigeria, such regulations are monitored by the National Agency for Food and Drug Administration and Control (NAFDAC), which was established as a parastatal of the Federal Ministry of Health by Decree No. 15 of 1993. Surveillance carried out by NAFDAC between 2004 and 2005 revealed that some producers of packaged water indulge in sharp practices such as packaging of untreated water, production under unhygienic conditions, illegal production of unregistered water in unapproved premises, use of non-food grade sachets and release of

packaged water for distribution and sale without date marking (Edema, Atayese and Bankole, 2011). These malpractices compelled the agency to formulate guidelines for the production of wholesome packaged water. Despite the standards formulated by NAFDAC to address this problem, there is no evidence that the situation has improved.

Sabon Gari LGA is blessed with abundant water resource both ground and surface and the distribution of this resource have very little variation in both time and space amongst the sub-settlements (Yusuf, Iguisi and Bello, 2007). In spite of its potentials for good groundwater storage, there is incessant water shortage in Sabon Gari LGA. People are always complaining about inadequate drinking water because the distribution and supply system are very poor. Communities and sub-settlements served by the Sabon Gari Water Works had to go through periods of complete no tap water for days and weeks. Therefore, searching for drinking, bathing, washing and cooking water has become part of the daily routine for both children and married women. Where the supply is made, it does not exceed 2 hours in some areas. This poor distribution and supply of tap water has made people to constantly use well or boreholes (where possible), for multiple purposes.

This practice combined with unsafe storage of water is prevalent in Sabon Gari LGA and has contributed to increasing incidences of water borne diseases such as cholera and typhoid (Musa, Shehu and Lukman, 2009).In order to effectively solve the problem of contamination of potable water, there is a need to fully assess the extent of the problem. Moreover the reliance of people on public water sources calls for concern as some of these have been associated with some water-borne diseases. These issues are the focus of this research in Sabon Gari local government area of Kaduna State.

1.2 STATEMENT OF THE RESEARCH PROBLEM

It has been observed that high prevalence of diarrhoea amongst children and infants can be traced to the consumption of unsafe water and unhygienic practices. It is estimated that 150 000 to 200 000 children are lost to diarrhoea related death each year in Nigeria (Nigeria Support to the Federal Ministry of Water Resources Management and Policy, 2006). Cholera, typhoid, paratyphoid, guinea worm, and Schistosomiasis are all common. Mortality and morbidity rates are high due to the absence of clean and adequate sanitation, and where potable water is available, the potential gains are frequently negated by contamination of the water delivery due to poor sanitation. Water borne diseases account for one third of intestinal infections globally. Another study reported that poor hygiene was responsible for 40% of all death and 5.7% of total disease burden occurring worldwide (Nigeria Support to the Federal Ministry of Water Resources Management and Policy, 2006).

Sabon Gari LGA has limited supply of tapwater. In this area tap water sometimes runs for about 2 - 3 hours at 3-day interval on the average. The only alternatives are water from wells, boreholes, sachet water and purchased water from wheel truck pushers. Some wards, like Bomo, Zabi, and Samaru do not have piped water distribution system, making supply of wholesome drinking water in these wards critical. The piped water distribution system in Sabon Gari LGA is poorly managed. Most of the pipes that distribute tapwater in the study area have rusted and exposed to contamination while some of the sites for the production of sachet water are sometimes places being used to wash cloth, plate and other domestic use. Some of the pipes that convey tap water in Muchia and Gabas wards have been sited to be broken. These broken pipes pass through gutters while some of them pass through filthy areas where all kinds of unclean substances stick to them. Also, some boreholes and wells are sited near refuse dumpsites or

landfills, these have the possibility of contaminating the water meant for drinking, or to be packaged as sachet water. These have created doubt in the mind of the people as to the quality of drinking water being consumed in this local government area. Issues relating to incidence of diseases from drinking unwholesome water have been examined by several authors. Some of them are critically overviewed.

Tista *et al*, (2007), carried out microbial analysis of drinking water of Kathmandu valley, Nepal. 238 isolates of enteric bacteria were obtained and identified as *Escherichia coli* (26.4%), *Enterobacter spp* (25.6%), *Citrobacter spp* (22.6%), *Pseudomonas aeruginosa* (6.3%), *Klebsiella spp* (5.4%), *Shigella spp* (3.78%), *Salmonella typhi* (3.3%), *Proteus vulgaris* (2.9%), *Serratia spp* (2.52%), and *Vibrio cholerae* (0.84%). The results revealed that 31.5%, 43.7%, 16.0% and 8.8% of isolates were obtained from water samples of tube well, well, tap and stone spout sources respectively.

In Minna metropolis of Niger State, Nigeria, Omalu *et al* (2012), collected five brands of packaged water samples labelled A - E from different locations within the metropolis, for bacteriological and physico-chemical analyses. Results of the test indicates that water from brand A had the highest total coliform counts of 398 MPN/100ml followed by water from brand B having 49 MPN/100ml while the least was that of brand D. Results show that the total coliform count of these water samples were high, hence grossly contaminated. The organisms isolated were *Escherichia coli*, *Streptococci feacalis*, *Bacillus subtilis*, *Staphylococcus aureus*, *Salmonella typhi*, *Klebsilla spp,* and *Pseudomonas aeruginosa*. The isolates were initially differentiated on the basis of the cultural and morphological studies after which they were subjected to various biochemical tests. The presence of coliform groups in these water samples generally suggest that the water may have been contaminated with faeces either of human or

animal origin or contaminants enters the production cycle. The presence of *Salmonella typhi*, in the water sample could cause typhoid fever which is indicative of poor drinking water quality.

Dada (2009) studied the bacterial quality of sachet water sold in Lagos, Nigeria and identified the contributory factors that determine the fate of the packaged water product as it moves from catchment to consumers. The author observed that microbial quality deteriorated considerably as products moved farther down the distribution chain. As low as 6.6% showed contamination after production, 40% of the samples obtained from the distributors shed were contaminated, while the highest level of contamination (45%) was observed from samples obtained from the extreme part of the distribution chain.

Olaoye and Onilude (2009) assessed the microbiological quality of sachet-packaged drinking water in Western Nigeria and its public health significance. The authors collected ninety-two sachet-packaged water which were analysed for microbiological and metal contents. Total bacterial and coliform counts were determined, and the presence of *Escherichia coli*, an important water quality indicator, was tested. The level of conformity of the water processors with the guidelines of Nigeria's quality regulatory agency was also determined. The researchers discovered varying levels of microbial contamination in samples from the different sampling locations. The bacteria that were identified from the water samples included *E. coli, Pseudomonas aeruginosa, Enterobacter aerogenes, Klebsiella sp, Proteus vulgaris, Alcaligenes faecalis, Bacillus cereus, Staphylococcus aureus, Streptococcus lactis, Aeromonas sp.* and *Micrococcus luteum.* Many of the water processors did not comply with the guidelines of the quality regulatory agency. So the researchers concluded that some of the sachet-packaged samples of drinking water were of poor quality.

Uzoigwe and Agwa (2012) studied the microbiological quality of water collected from boreholes sited near refuse dumpsites in Port Harcourt, Nigeria. The author collected water samples from six private boreholes, three samples were from boreholes located near dumpsites, and the other three samples were from boreholes located in areas without dumpsite in Obio/Akpor and Ikwerre Local Government Areas (LGA) in Port Harcourt. Nine genera of microorganisms (or bacteria) were identified from a total of 21 isolates. These genera include: *Shigella, Esherichia, Salmonella, Vibrio, Enterobacter, Pseudomonas, Proteus, Staphylococus and Bacillus*. Out of the nine genera, *Shigella sp*. had the highest percentage frequency of occurrence (23.81%) followed by *Esherichia* and *Salmonella* (14.29%), then *Enterobacter* and *Vibrio* (9.52%).

This research work seeks to collect multiple samples of drinking water for microbiological analysis of *Salmonella typhi* within the study area so as to examine the areas with high probability of *Salmonella typhi* and incidence of typhoid fever, as most of the previous studies have only examined water sample from single sources. The questions this research seeks to address are,

1. What are the major sources of drinking water within the study area?
2. How common is *Salmonella typhi* in potable water within the study area?
3. How prevalent is typhoid fever in Sabon Gari LGA?
4. What is the relationship between *Salmonella typhi* in drinking water and occurance of typhoid fever in the study area?
5. Are there socio-environmental explanations for the occurrence of *Salmonella typhi* and typhoid fever in the study area?

1.3 AIM AND OBJECTIVES

The aim of this study is to evaluate the presence of *Salmonella typhi* in drinking water in Sabon Gari L.G.A. and the objectives are to:

i. characterise the major sources of drinking water within the study area
ii. examine the prevalence of *Salmonella typhi* in drinking water within the study area.
iii. determine the prevalence of typhoid fever in Sabon Gari LGA.
iv. establish the relationship between the concentration of *Salmonella typhi* in potable drinking water and the occurrence of typhoid disease in the study area.
v. examine the social and environmental bases for the occurrence of *Salmonella typhi* and typhoid fever in the study area.

1.4 SCOPE OF THE STUDY

Spatial extent of this study are selected wards within Sabon Gari L.G.A. of Kaduna State, which include Gabas, Basawa, Auta Jushi, Jamaa, Dogarawa, Hanwa, Chikaji, Samaru, Bomo, Zabi and Muchia wards. Concerning the focus of the study, attention was on drinking water sources within the LGA including tap water, boreholes, well water, and sachet water. This is because they are the most readily available, and consumed drinking water in the location under study. The study evaluates the presence of *Salmonella typhi* on these waters and assesses the prevalence of typhoid fever in different wards of the LGA. The samples were collected for microbiological analysis in November, 2014.

1.5 SIGNIFICANCE OF THE STUDY

A reliable supply of clean wholesome water is highly essential to promoting healthy living among the inhabitants of a definite geographical location. New figure in the 2015 WHO/UNICEF Joint Monitoring Programme (JMP) reports showed worsening trend for Nigeria

in the areas of sanitation and open defecation as only 9% of the population has gained access to improve sanitation since 1990. The standard for delivering safe drinking water and sanitation technology in the industrialized world is, however, not affordable in most of the developing world (Dada, 2009). This potable water, however, is necessary to all living things as it makes up approximately 70% of the human body's weight and plays a role in its functions, such as digestion and cooling. They also serve as habitat for some pathogenic micro-organism (*Salmonella typhi* inclusive). Without clean drinking water, humans cannot survive. If drinking water within this local government is contaminated with *Salmonella typhi*, frequent diagnosis of typhoid fever among the inhabitant of this region will be the order of the day which may apparently explain some of the incidental health problem (typhoid) occasionally experienced.

The results of this study will hopefully be useful for agencies responsible for the provision of water within Sabon Gari LGA and other government institutions that are concerned with provision of water. It is hoped that the findings of this study would contribute to the understanding of the factors that influence the spread of typhoid fever in the study area. This study would shed light on whether the control measures in place are effective in the control of typhoid fever. It is hoped that the results would be of great use to programme planners, academics, policy formulators and implementers, donors, curriculum developers and other service providers in control of typhoid fever.

This research will further shed light on the need to examine properly drinking water consumed. Also, findings of this study when published will bring awareness to the people of this local government and the producers of sachet water the need to properly treat the packaged water for sale due to continuous contamination of rivers, public piping system and the site for the production of sachet water.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

The availability of good quality water sources is getting more and more limited and the impact of water-borne pathogens (Such as *Salmonella typhi*) in human health is expected to be significant (Suresh and Smith, 2004). It is therefore critical to understand the relevance of natural and drinking water contribution to transmission of this pathogenic microorganism. Salmonella is a ubiquitous enteric pathogen with a worldwide distribution that comprises a large number of serovars characterised by different host specificity and distribution. This microorganism is one of the leading causes of intestinal illness all over the world as well as the aetiological agent of more severe systemic diseases such as typhoid (Pond, 2005).

2.2 CONCEPTUAL FRAMEWORK

2.2.1 Typhoid Fever

Typhoid fever, also known as enteric fever, is a potentially fatal multisystem illness caused primarily by *Salmonella typhi*. The protean manifestations of typhoid fever make this disease a true diagnostic challenge. The classic presentation includes fever, malaise, diffuse abdominal pain, and constipation. Untreated, typhoid fever is a grueling illness that may progress to delirium, obtundation, intestinal hemorrhage, bowel perforation, and death within 1 month of onset. Survivors may be left with long-term or permanent neuropsychiatric complications. *Salmonella typhi* has been a major human pathogen for thousands of years, thriving in conditions of poor sanitation, crowding, and social chaos (Miller and Pegues, 2000).

Contaminated water with *Salmonella typhi* is one of the major routes of infection in human causing typhoid disease. Poor hygiene practices and poor waste disposal are expected to facilitate the occurrence of typhoid fever. Proper water treatment and treatment of people

suffering from typhoid, and vaccination of healthy people would reduce the prevalence rate of typhoid fever (Kibiru, 2011).

Typhoid fevers are caused by the bacteria *Salmonella typhi*. *Salmonella typhi* is passed in the faeces and urine of infected people. People become infected after drinking water that has been handled by a person who is infected or by drinking water that has been contaminated by sewage containing the bacteria. Once the bacteria enter the person's body they multiply and spread from the intestines, into the bloodstream.

Even after recovery from typhoid, a small number of individuals (called carriers) continue to carry the bacteria (*Salmonella typhi*). These people can be a source of infection for others. The transmission of typhoid in less-industrialised countries is mainly due to contaminated water and poor hygiene. In some countries, shellfish taken from sewage-contaminated beds is an important route of infection. Where water quality is high, and chlorinated water piped into the house is widely available, transmission will be greatly reduced. Typhoid fevers are common in less-industrialised countries, principally owing to the problem of unsafe drinking-water, inadequate sewage disposal and flooding (WHO, 2002).

2.2.2 Poor Sanitation

As a result of poor environmental sanitation within towns, many communicable diseases are prevalent among the people including typhoid fever (Winblad, 2004). Control measures to combat the prevalence of *Salmonella typhi in* drinking water and its eventual cause of typhoid disease include health education and antibiotic treatment. A vaccine is available, although it is not routinely recommended except for those who will have prolonged exposure to potentially contaminated food and water in high-risk areas. The vaccine however, does not provide full protection from infection (WHO, 2002).

Figure 2.1 shows how water source meant for drinking are contaminated with *Salmonella typhi* due to poor hygienic practice and poor waste disposal. From this figure, contaminated water meant for drinking causes high prevalence of typhoid disease. Proper water treatment, proper waste treatment, treating patient with typhoid fever and vaccination of healthy people helps to reduce the transmission of *Salmonella typhi* in drinking water and therefore, prevent the occurrence of typhoid.

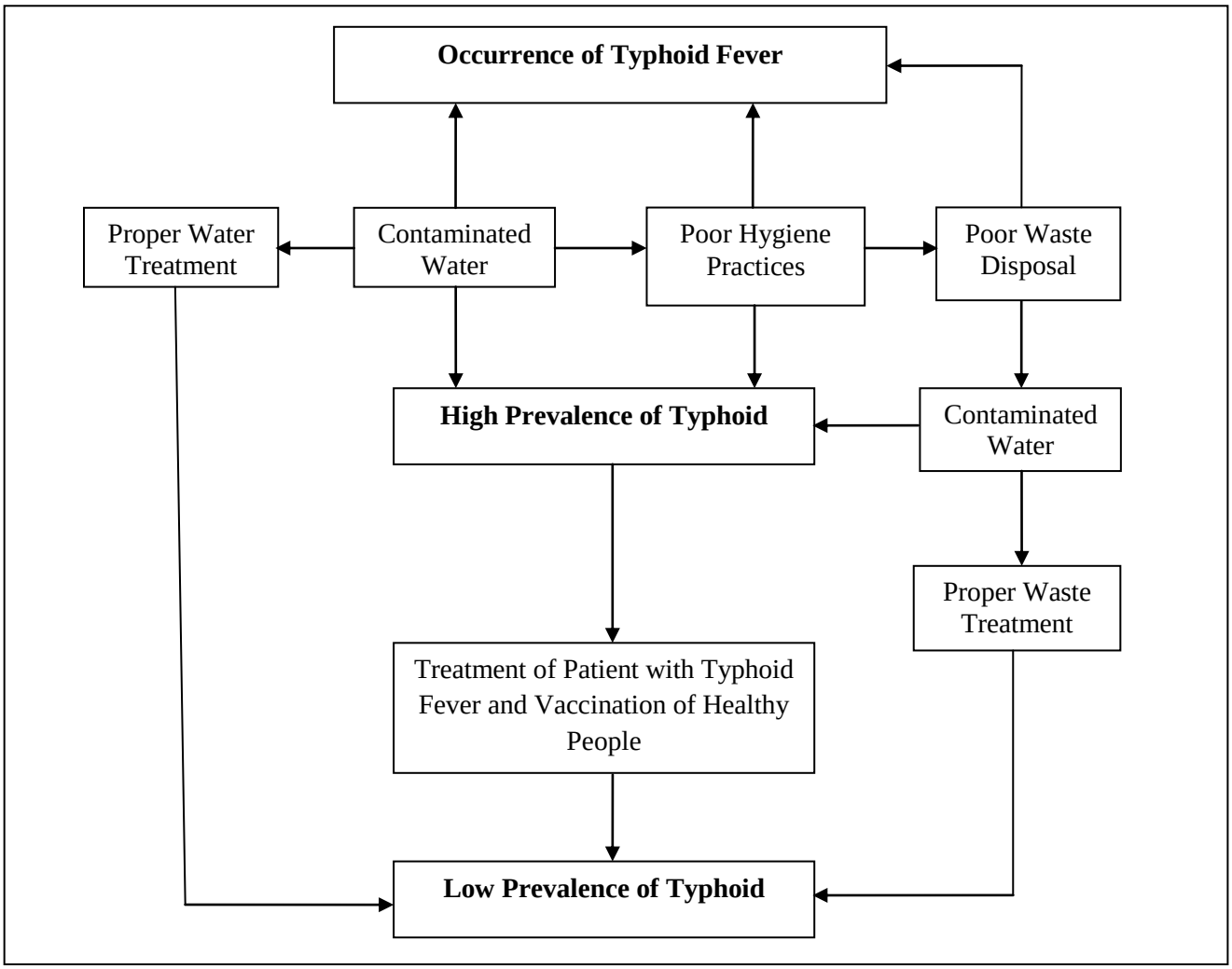


Fig 2.1: A Flow Chart from the Incidence of *Salmonella typhi* and Eventual Cause of Typhoid Disease

Source: Kibiru, 2011.

2.3 LITERATURE REVIEW

2.3.1 The Need For Potable Water Supply And Sanitation

Drinking water as well as natural waters are known to be important sources of transmission of these enteric microorganisms (Ashbolt, 2006; Leclerc, Schwartzbrod, and Dei-Cas, 2002). Salmonella, just like other enteric bacteria, is spread by the faeco-oral route of contamination. This microorganism can enter the aquatic environment directly through feces of infected humans or indirectly via sewage discharge or agricultural land run off.

Salmonellae are frequently found in environmental samples (water, sewage and food). They are usually present in large numbers in raw sewage and can still be present in waste water effluent after advanced secondary treatment including coagulation, filtration and disinfection (Maier, Pepper, and Gerba, 2000). In the aquatic environment this pathogen has been repeatedly detected in various types of natural waters such as rivers, lakes, coastal waters, estuarine as well as contaminated ground water (Haley, Cole, and Lipp, 2009; Levantesi *et al.,* 2010; Martinez-Urtaza et al., 2004; Martinez-Urtaza, Liebana, Garcia-Migura, Perez-Piñeiro, and Saco, 2004 and Wilkes *et al.,* 2009).

In addition to its widespread occurrence, elevated survival capacities in non host environment have been reported for Salmonella (Winfield and Groisman, 2003). The growth of Salmonella in non-host environments such as wastewater sludge and compost has also been reported (Zaleski, Josephson, Gerba, and Pepper, 2005) and the growth of Salmonella in water supplies is also considered possible, due to its ability to colonise surfaces and replicate in biofilms of distribution system pipes (Levantesi *et al,* 2010). However, standard disinfection procedures used in drinking water treatment processes are active against Salmonellae (Cicmanec, Smith, and Carr, 2004).

Typhoid is a severe, contagious systemic diseases caused by the infection of *Salmonella typhi*. Even though not common in developed countries, enteric fevers remain an important and persistent health problem in less industrialised nations. Overall, in 2003 an annual incidence of approximately 17 million cases of typhoid was reported worldwide (Kindhauser, 2003).

Differently from other Salmonella serovars, *Salmonella typhi* is host adapted and can only infect humans. Stools of infected persons are therefore, the original source of contaminations for these pathogens. Water contaminated with feces of human cases and carriers is one of the main vehicles of typhoid fever infections. The increased frequency of Salmonella strains in human infections are an emerging issue of major health concern (Lightfoot, 2004; Pond, 2005 and Lynch *et al.,* 2009). This issue is of particular concern in developing countries where the common use of untreated, low quality water as drinking water sources together with inappropriate use and self-prescribing of antibiotics increase the risk of drug resistance and the probability of wide dissemination of resistant strains are of human health concern (Srikantiah *et al.,* 2007; Oluyege, Dada, and Odeyemi, 2009).

In all, the above reported cases suggest that water might be an important source for the transmission of Salmonellae, not only for the typhoid disease. An increased knowledge on the prevalence, diversity and survival of this enteric bacterium in the environment, together with a proper assessment, through effective surveillance and epidemiological studies, of the relevance of the water environment in the transmission of Salmonella disease is desirable. This study therefore, evaluates *Salmonella typhi* in drinking water and access the prevalence of typhoid fever in the study area.

Also, access to water is a prerequisite for healthy living. This is why one of Millennium Development Goals (MDGs) targets is to ensure global access to potable water supply. The availability of potable water supply and sanitation infrastructures are widely recognised as an essential component of human rights, social and economic development (African Development Fund, 2005). The poor and marginalised people living in rural and semi-urban settlements are most in need of improved and safe drinking water, appropriate forms of sanitation and access to water for other domestic purposes (Crow, 2001). The WHO (2000) reports that polluted drinking water causes 1.8 million people to die from diarrheal diseases annually worldwide.

The proportion of the population in developing regions using some form of piped drinking water supply (piped on premises or public taps) increased from 46% in 1990 to 56% in 2008 (UNICEF/WHO, 2011). Meanwhile, the proportion of the population that uses other improved sources of drinking water increased in rural areas and remained static in urban areas of developing regions. This is of particular concern given the quality of water from wells, boreholes and springs. The proportion of the population in developing regions using unimproved drinking water sources decreased from 29% to 16%. Use of surface water has declined significantly, but 6% (table 2.1) of the rural population in developing regions still relied on surface water in 2008 (UNICEF/WHO, 2011).

Table 2.1: Estimates of the population in developing regions relying on different types of drinking water sources, 2008

Faculty type	Urban	%	Rural	%	Total	%
Piped on premises	1,751	73	929	31	2,680	49
Public tap/stand pipe	161	7	232	8	393	7
Boreholes/tubewell	218	9	1,026	34	1,244	23
Rainwater	12	0	51	2	63	1
Dug wells	165	6	434	13	599	11
Springs	40	2	165	5	205	4
Tanker trucks/small cart with drum	48	2	21	1	69	1
Surface water	15	1	176	6	191	4
Total	**2,410**	**100**	**3,034**	**100**	**5,444**	**100**

Source: UNICEF/WHO, 2011.

In 2008, almost one quarter of the population in developing regions used boreholes or tubewells (table 2.1); making this category the second most commonly used technology after piped on premises. In rural areas boreholes/tubewell was the most common type of drinking water source (UNICEF/WHO, 2011)

Edema *et al.,* (2001), collected different sources of drinking water and examined them in Abeokuta, South Western Nigeria, and all the samples including dug well, stream and tap water samples were contaminated with bacteria above the WHO stipulated guidelines. Though the values obtained for sachet water in his study were higher than those obtained from other drinking water sources as examined by Edema *et al.,* (2001). It is likely that the contamination of samples in this research work can be traced to the source of the water packed. Bacterial growth in water may be unnoticed even in transparent packaged water and the presence of some of these microorganisms may pose a potential risk to consumers.

As indicated by ADF (2005), over one third of women in developing countries spend more than two hours for each water collection trip. This fact is aggravated by the poor supply efficiency of drinking water source which cannot satisfy the entire populations from different

villages sharing the same water source and increased queuing time is common during the dry seasons (Admasu, Kumie and Fentahum, 2003). This will ultimately lead to household water insecurity (less water available than is needed for drinking, cooking, and sanitation) in rural areas, especially for those households for which the demand is higher due to large family size (Demeke, 2009). Because of these conditions, it is difficult to think about personal hygiene and sanitation especially for the rural communities. Despite the scarcity of water, many give priority to drinking and cooking purposes. Rural communities use unprotected springs and hand-dug wells commonly for cooking and drinking purposes. Whereas rivers, besides their use for washing clothes, are also used for drinking purposes.

This results in not only sickness and death, but also economic crises. Therefore, safe drinking water is an essential component of primary health care and is vital for poverty alleviation.

2.3.2 Water Quality Parameters

Drinking water (or potable water) is water safe enough to be consumed by humans or used with low risk of immediate or long term harm. In most developed countries, the tap water supplied to households, commerce and industry meets the water quality potability standards, even though only a very small proportion is actually consumed or used in food preparation. Other typical uses include washing, toilets, and irrigation.

Over large parts of the world, humans have inadequate access to potable water and use sources contaminated with disease vectors, pathogens or unacceptable levels of toxins or suspended solids. Drinking or using such water in food preparation leads to widespread acute and chronic illnesses and is a major cause of death and suffering worldwide in many different

countries. Reduction of waterborne diseases and development of safe water resources is a major public health goal in developing countries.

2.3.2.1 Perception of drinking water

In terms of drinking water quality, user perception is one of the most important things, sometimes exceeding actual quality of water especially when it concerns the quality of drinking water for the user communities (Sheat, 1992; Doria, 2010). There are different factors that influence the perception of drinking water quality as identified by Doria (2010).

a. Human sensory perceptions of taste, odour and colour of water are related with mental factors and some extent taste, which is more important because it may detect water contamination related to chemicals.
b. People may perceive risks if they experience health problem caused by water.
c. Experience with the previous water source status based on its taste, colour and odour change. For example the change in the colour of water from yellowish to bluish gives the impression that the water is not good water.
d. Information plays a great role in changing people's perception on the water source behaviour. It may be person to person or using media (like newspapers, brochures etc.) but in rural areas and poor urban residents, interpersonal information is important.

2.3.2.2 Disease Transmission

Illnesses related to water, sanitation and hygiene include the following (Public Health Guide for Emergencies, 2012):

a. Water-borne diseases occur when a disease-causing agent enter the body through drinking water
b. Water-washed diseases occur because of inadequate hygiene conditions and practices

c. Water-based diseases include those illnesses that are spread through a disease vector that lives in water

d. Food-borne illnesses result when disease-causing agents enter the body through food

e. Vector-borne diseases are spread by means of insect or rodent vectors.

Testing the bacterial contaminants in water can be simplified by utilizing the presence of an indicator organism. An indicator organism may not necessarily pose a health risk but it can be easily isolated and enumerated, if present in large numbers, is more resistant to disinfection than pathogens, and does not multiply in water and distribution systems (Gadgil, 1998).

The risk of coliform presence can depend on the health or sensitivity of the consumer. The risks of *E. coli* presence, slightly greater than WHO Guideline's zero count per 100ml may be of only low or intermediate risk according to Michael (2006), about risk classification for thermotolerant coliforms or *E. coli* of rural water supplies as shown on the table 2.2.

Table 2.2: Water Quality Counts per 100ml and the Associated Risk

Count per 100ml	Risk Category
0	In conformity with WHO guidelines
1-10	Low risk
11-100	Intermediate risk
101-1000	High risk
>1000	Very high risk

Source: Michael, 2006.

2.3.3 Microbiological Aspects of Drinking Water

The most common and widespread health risk associated with drinking water is contamination, either directly or indirectly, by human or animal excreta, particularly faeces. If such contamination is recent, and if those responsible for it include carriers of communicable enteric diseases, some of the pathogenic microorganisms that cause these diseases may be

present in the water. Drinking the water, or using it in food preparation, may then result in new cases of infection.

The pathogenic agents involved include bacteria, viruses, and protozoa, which may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, or typhoid fever. Most of them are widely distributed throughout the world. Faecal contamination of drinking water is only one of several faeco-oral mechanisms by which they can be transmitted from one person to another or, in some cases, from animals to people.

One ingested waterborne pathogen, namely guinea worm (*Dracunculus medinensis*), is not faecal in origin and deserves special mention. It is the only human infection that is solely transmitted by the waterborne route, and the World Health Assembly (WHA) has committed itself to the eradication of dracunculiasis by the end of 1995 (WHA, 1991). Dracunculiasis has not been eradicated as the WHO 2015 reported that the decline in the number of guinea-worm disease cases continues, with fewer confirmed reports during the first 7 months of 2015.

Other pathogens cause infection when water containing them is used for bathing or for recreation involving water contact, rather than by the oral route. Some may also cause infection by inhalation when they are present in large numbers in water droplets, such as those produced by showers and some air-conditioning systems or in the irrigation of agricultural land (CAC, 2001). It is not only by causing infection that microorganisms in drinking water can affect human health. In some circumstances, cyanobacteria can produce toxins that may remain in the water even when the cyanobacteria themselves have been removed. Finally, there are some organisms whose presence in water is a nuisance, but which are of no significance for public health.

2.3.4 Agents of Significance

The human pathogens potentially transmitted in drinking water are listed in Table 2.3. Some general information on those included in table 2.3 is given below.

Table 2.3: Waterborne Pathogen and their Significance in Water Supplies

Pathogen	Health significance	Main route of exposure[a]	Persistence in water supplies[b]	Resistance to chlorine[c]	Relative infective dose[d]	Important animal reservoir
Bacteria						
Campylobacter jejuni, C. coli	High	O	Moderate	Low	Moderate	Yes
Pathogenic *Escherichia coli*	High	O	Moderate	Low	High	Yes
Salmonella typhi	High	O	Moderate	Low	High	No
Other Salmonellae	High	O	Long	Low	High	Yes
Shigella spp.	High	O	Short	Low	Moderate	No
Vibrio cholera	High	O	Short	Low	High	No
Yersinia enterocolitica	High	O	Long	Low	High (?)	Yes
Legionella	Moderate	I	May multiply	Moderate	High	No
Pseudomonas aeruginosa	Moderate	C, IN	May multiply	Moderate	High (?)	No
Aeromonas spp.	Moderate	O, C	May multiply	Low	High (?)	No
Mycobacterium, atypical	Moderate	IC	May multiply	High	?	No

Source: WHO, 1996.
? = not known or uncertain
[a] O = oral (ingestion); I = inhalation in aerosol; C = contact with skin; IN = ingestion in immunosuppressed patients
[b] Detection period for infective stage in water at 20 °C: short = up to 1 week; moderate = 1 week to 1 month; long = over 1 month
[c] When the infective stage is freely suspended in water treated at conventional doses and contact times: resistance moderate, agent may not be completely destroyed; resistance low, agent completely destroyed.
[d] Dose required to cause infection in 50% of healthy adult volunteers.

2.3.4.1 Agents of High Health Significance

Not all potentially waterborne human pathogens are of equal public health significance (Table 2.3). Some of them, including most of the ingested pathogens, present a serious risk of disease whenever they are present in drinking water, and their elimination from it should be given high priority. Examples include strains of *Escherichia coli*, *Salmonella*, *Shigella*, *Vibrio cholerae, Yersinia enterocolitica,* and *Campylobacter jejuni*.

While most of the pathogens of high significance in Table 2.3 are found worldwide, others are a public health problem only in limited regions of the world, e.g. guinea worm is found only in certain countries of Africa and Asia. Historically, pandemics of cholera have spread from well defined regions where the outbreaks first occurred. Although high priority should be given to control of these pathogens in drinking water, this is of regional significance only.

2.3.5 Salmonella

2.3.5.1 General Description

The genus Salmonella is a member of the family Enterobacteriaceae. The genus is currently subdivided into the subgenera I-IV, on the basis of biochemical characteristics. Most salmonella strains isolated from humans and warm-blooded vertebrates belong to subgenus I, while subgenera II, III (also called Arizona) and IV are more frequently associated with reptiles, in which they reside commensally. Currently more than 2000 serotypes are named. There are considerable regional variations in the prevalence of serotypes (Leminor, 1981).

The virulence of *Salmonella spp*. depends on serotype and strain specificity in host range and infective dose and on host status. *S. typhi* is a specific human pathogen. In particular, *S. typhi, S. paratyphi* A, and *S. paratyphi* B are able to invade tissues and cause septicaemia with

high temperature rather than diarrhoea. This is known as enteric fever. In humans, the majority of the other serotypes give rise to a transient intestinal infection manifesting itself as acute gastroenteritis with diarrhoea. Certain serotypes are highly pathogenic for humans, while others are devoid of any pathogenic action. Many Salmonella infections are asymptomatic (Lloyd, 1983).

2.3.5.2 Routes of Exposure

In the case of *S. typhi* and *S. paratyphi* A, human carriers are the source of infection, whereas milk-borne transmission can also occur with *S. paratyphi* B. The incidence of enteric fever decreases as a country becomes more highly developed in terms of controlled sewerage systems and drinking water supplies, and the supply of pasteurized milk and dairy products. Most Salmonellae are primarily pathogens of animals, which constitute important reservoirs for those infections (Holliday and Beuchat, 2003; Itah, 2005).

Salmonellae may be present in all kinds of food grown in faecally polluted environments, and are commonly isolated from poultry and livestock and foods prepared from them. Furthermore, animal feedstuffs and fertilizers prepared from animal products may be highly contaminated with salmonellae, and they are also widely distributed in the environment. The contamination of food and animal feedstuffs by water contaminated with salmonellae is considered to be an additional risk factor (Holliday and Beuchat, 2003). Dumping of unprocessed slaughterhouse wastes into rivers has been found to be a cause of Salmonellae infections. Contamination by Salmonellae and conditions favouring their regrowth should be avoided at all stages of the production, transport, storage, and preparation of food, feedstuffs, and drinking water. Sludge disposal and irrigation must always be accompanied by appropriate hygienic precautions.

The transmission routes of Salmonellae are highly complex. Person-to-person transmission may occur, but the relative importance of the human and non-human reservoirs depends on the dietary, agricultural, and sanitary situation in a particular community (Itah and Akpan, 2005).

2.3.5.3 Significance of Salmonella typhi in Drinking Water

Waterborne outbreaks have been chiefly associated with *S. typhi* and much less frequently with *S. paratyphi* B or other Salmonella serotypes (Nguendo-Tongs, 2011). Epidemiological studies of outbreaks suggest that the ingestion of relatively few cells of *S. typhi* may cause typhoid fever, whereas studies in volunteers indicate that, for other Salmonella serotypes, millions of cells are usually required to cause gastroenteritis.

Salmonella typhi may be found in drinking water from sources that have been contaminated with the faeces of infected humans or animals (Ashbolt, Kirk, 2006). Various pathways may be responsible for the contamination of potable water with Salmonella, including sewage overflows, polluted storm water run-off and agricultural run-off (Centre for Disease Control and Prevention [CDCP] 2008). The most common symptoms of Salmonella include diarrhea, fever, and abdominal cramps. Fully boiling water for one minute will eliminate any Salmonella that may be present (CDCP, 2008).

Penetration of pathogens into water sources must be avoided by the protection of groundwater and surface water catchment areas. A review of the literature has shown that, in general, pathogens will not travel further than the distance that the groundwater flows in 10 days, except in fissured rocks such as limestone and heavily fissured soils ((Nguendo-Tongs, 2011).

Drinking water must be of low turbidity after treatment if adequate chlorination is to be achieved. Furthermore, a low load of assimilable organic carbon (AOC) in the treated water is

considered to be an important factor in reducing survival time and preventing the regrowth of Salmonellae within the distribution system. Reported survival times for Salmonellae in drinking water range from a few days to over 100 days.

Several outbreaks have been caused by the deposition of contaminated sediments in the distribution system for drinking water, especially in water basins and pipes. Sediments may be shifted to new positions in the system by water pressure oscillations or temporary scarcity of water. Regular flushing of the distribution system is therefore recommended.

2.3.6 Typhoid Disease and Sanitation Practices

Since *Salmonella typhi* bacteria live in humans, it is only humans who can be carriers. Persons with typhoid fever carry the bacteria in their bloodstream and intestinal tract. In addition, a small number of persons, called carriers, recover from typhoid fever but continue to carry the bacteria. Both ill persons and carriers shed *Salmonella typhi* in stool (WHO, 2005). When people who are carriers of typhoid fail to wash their hands thoroughly with soap and clean water after defeacation they risk passing the causative organism to others.

Sanitation refers to the safe collection, storage and disposal of various wastes resulting from human activities. These include solid wastes, refuse and liquid wastes (effluent) from sewage works, kitchen sink and even hazardous waste from industries. It also refers to the general maintenance of the human environment in a safe condition free from pollution. It involves the behavioural change and availability of adequate facilities that ensure a hygienic environment (WHO, 2006; Desalegn, 2013). Poor sanitation practices are a cause of bacterial, viral, protozoa and helmintic infections (Feachem, 1983).

In many developing countries there exists a high prevalence of water and sanitation related diseases causing many people to fall sick or even die (WHO, 2006a). Faeces can be the

source of much sickness in the community if it is accessible to flies, fingers, field, and fluid and eventually to food. This is referred as the five-F connection (Wood, Vaughan, Glanville, 1992). This pathway is known as the faecal-oral route of disease transmission (Donald, 2004).

Food and water is rendered unfit for human consumption when contaminated with *Salmonella typhi* (Government of Kenya [GOK], 2005) and many naturally occurring water sources are liable to such contamination at some point (WHO, 1996). Typhoid fever is spread in faecal contaminated food and water and it often comes in epidemics, therefore, it is one of the dangerous infections (David, Carol and Jane, 1993).

That is a basis for the submission by Charles (1995) that to reduce diseases caused by inadequate sanitation more efficient installation of facilities should be encouraged with measures taken to dispose of wastes. In regions of the world where sanitation and garbage disposal are insufficient, typhoid fever continues to destroy life (Donald, 2004). Moreover, the rapid increase in the population combined with a massive migration to urban areas has led to the formation of urban centres of high population density in many countries. The increase in urban population has occurred at such a pace that it has outstripped the development of the health related infrastructure including basic sanitation. The majority of urban populations are tenants in informal settlements where basic services such as water and sanitation are inadequate. Visiting or living in areas where the disease occurs is a risk (Goss and Richard, 2008).

2.3.7 Risk Factors Associated With Contaminated/Polluted Water and Prevalence of Typhoid Fever

The bacterium *Salmonella typhi* lives inside humans. The bacterium lives and multiplies in the blood stream and digestive tract of infected persons. Transmission is through contaminated feaces in water or food (Ray, 2002). Faecal pathogens are frequently transferred to the water borne sewage system, through flush toilets and pit latrines subsequently contaminating

surface and ground water (Pruss and Corralan, 2006). In regions with poor sanitation, the bacteria often spread after water supplies are contaminated by humans waste (WHO, 2000).

The principal carrier of typhoid bacteria is water. Water can be extremely dangerous when it becomes the vehicle of the transmission of disease. The principal sources of water contamination are man, animal and bird excreta (Twort, Law and Crawley, 1990). Untreated sewage is dangerous to public health because it contributes to water, land and air pollution. Discharging highly polluting waste into a body of water has negative effects on human, animal and plant life. Too many pollutants reduce the self-purification capacity of water, especially at the point of mixing and, they promote excessive growth of aquatic plants. Polluted waters are aesthetically unacceptable because they emit unpleasant odours (Rukunga, 2001).

Pathogenic organisms that cause typhoid fever enter into the water as a result of a damaged or faulty sewer or water pipes, excreta soaking through the surface solid into subsoil water, deep well contaminations due to faulty construction, maintenance or personal carelessness and contamination of animals or birds particularly seagull (Twort, Law and Crawley, 1990). Water which sewage gain access into cause's diarrhoea (Notter, 1994). Water borne diseases are the prime cause of premature deaths worldwide, especially for young children (WHO, 2002). Increase in urban population may lead to an increased risk in food and water supply contamination (WHO, 1992).

2.3.8 Protection And Improvement of Water Quality

It is a basic principle, long established as a result of the lessons learned from serious outbreaks of waterborne disease, that a single barrier to the spread of pathogenic organisms is not sufficient to ensure the purity of drinking water (Department of National Health and Welfare [DNHW], 1993; Wright, Gundry, Conroy, 2004). Purity is not the only requirement, however; the drinking water supply must also be capable of meeting the anticipated demand. Inadequate supply, together with geographical factors, often means that raw water of poor microbiological quality and possibly containing significant amounts of wastewater has to be used. A second principle is that to ensure that the drinking water delivered to the consumer is free from pathogens; the level of treatment should be related to the degree of pollution expected in the source water. In the case of contaminated water sources, several treatment processes, designed primarily for such water will be necessary. Together, these processes will progressively remove pathogens and other contaminants from raw water and consistently produce a safe and wholesome supply of drinking water. Ideally, safety should be achieved before the final treatment step, so that the failure of any one process will not result in waterborne disease, i.e. the system is fail-safe. The protection of the source from pollution and the provision of adequate and properly operated treatment processes constitute the essential barriers to the transmission of disease on which the supply of wholesome water depends (Wright, Gundry and Conroy, 2004).

2.3.8.1 Selection and Protection of Water Sources

Ince, Bashire, Oni, Awe, Ogbechie, Korve, (2010) in their research work reveal that before a source of drinking water supply is selected, it is important to ensure that:

1. the quality of the water is satisfactory or can be improved by treatment to make it suitable for drinking.

2. the source will yield enough water to meet the needs of the community not only under the normal conditions of the average annual cycle but also under conditions which are unusual but can be expected once in 10 years
3. under normal abstraction conditions, the change in local water flow patterns will not cause any unacceptable deterioration in the quality of the water abstracted, and the water to be abstracted can be protected against pollution.

A full sanitary and microbiological survey of the catchment area should be carried out to locate all the sources of pollution. It may be that the treatment or diversions of a small polluting discharge could make a large potential source acceptable (Ince *et al.*, 2010). If remote upland sources of surface waters are being considered, it is important to assess whether access by people or livestock can be prevented and whether wild animals are likely to be vectors of Salmonellae, Giardia, and Cryptosporidium.

In the past, isolation of the watershed from human activity was an important means of protecting a waterway or aquifer from contamination. The rising cost of land and increases in population have made this procedure more costly and difficult, especially when new sources must be found in an area that is already developed. It is still desirable for water suppliers to own or control the land to the extent that this is feasible (DNHW, 1993).

Another important precausion is to prevent polluting activities in the area which may be a source of infection. This means, for instance, defining areas where sewage sludge may not be applied, and exercising strict control over discharges of sewage effluents and agricultural wastes, the location of sites for the dumping of garbage and toxic wastes, and drilling, mining, and quarrying. Control of such activities does not necessarily mean that they should be banned, but that, in the interests of public health, they should be licensed and open to inspection and

monitoring whenever water quality could be affected. Where potentially harmful substances are handled or made, steps should be taken to ensure that any effluents are either adequately treated or conveyed safely over the catchment area (Ince, *et al.*, 2010).

Sources of groundwater such as springs and wells should be sited and constructed so as to be protected from surface drainage and flooding. Zones of groundwater abstraction should be fenced off to prevent public access, kept free from rubbish, and sloped to prevent the formation of pools in wet weather. Animal husbandry should be adequately controlled in such zones (Akinyemi, *et al.*, 2005)

Protection of open surface water is difficult. It may be possible to protect a reservoir from major human activity, but the protection of a river, if possible at all, may be feasible only over a limited stretch. Often it is necessary to accept existing and historical uses of a river or lake and to design the treatment accordingly. Adequate sewage treatment is important in preserving water quality at downstream intakes (Akinyemi, *et al.*, 2005).

2.3.8.2 Treatment Processes

The fundamental purpose of water treatment is to protect the consumer from pathogens and from impurities in the water that may be injurious to human health or offensive. Where appropriate, treatment should also remove impurities which, although not harmful to human health, may make the water unappealing to drink, damage pipes, plant, or other items with which the water may come into contact, or render operation more difficult or costly.

These purposes are achieved, as previously mentioned, by introducing successive barriers, such as coagulation, sedimentation (or flotation), and filtration, to remove pathogens and impurities. The final barrier is disinfection. The function of the entire system, and indeed of

much of water treatment, may with some justification be regarded as that of conditioning the water for effective and reliable disinfection (WHO, 2008).

In rural areas, protection of water source may be the only "treatment" possible. In large communities, the demand for water is high and can often be met only by using sources of poor microbiological quality.

Two considerations are of paramount importance: firstly, the quality of drinking water is totally dependent on protection of the source, treatment of the water, and maintenance of the integrity of the distribution system; and secondly, microbiological monitoring can influence water quality only if its findings, and those of the agency responsible for surveillance, are made known to the water engineer and any remedial measures necessary are implemented (DONHW, 1993).

Groundwater extracted from well protected aquifers is usually free from pathogenic microorganisms, and the distribution of such groundwater without treatment is common practice in many countries. However, the catchment area must be protected by effective regulatory measures and the distribution system adequately protected against secondary contamination of the drinking water. If the water, in its passage from source to consumer, cannot be protected at all times, disinfection and the maintenance of adequate chlorine residuals are imperative (Hamidullah, Halil, and Ahmet, 2008).

The extent to which faecal bacteria, viruses, and parasites are removed by properly designed and operated equipment for flocculation, coagulation, sedimentation, and rapid filtration is equivalent to that achieved by slow sand filtration.

Additional treatment, such as ozonation, will have a considerable disinfecting action besides converting part of the total organic carbon into a biodegradable form. If it is followed by

activated carbon treatment or other biological filtration stage, some of the biodegradable organic carbon will be removed by microbial activity, thus reducing the potential for after growth of nuisance bacteria in distribution networks.

Disinfection should be regarded as obligatory for all piped supplies of surface water, even if derived from high quality, unpolluted sources, since there should always be more than one barrier against the transmission of infection by a water supply. In large, properly run waterworks, the criteria for the absence of *E. coli* and coliform bacteria can then be met with a very high degree of probability (WHO, 2008).

Table 2.5 shows that conventional urban water treatment relies on pre-treatment and terminal disinfection to remove much of the microbial contamination. Nevertheless, conventional treatment can be effectively operated as a three stage multiple barrier system involving: coagulation and settling or flotation, rapid filtration and terminal disinfection (Meseret, 2012).

Table 2.4: The Level of Performance available in Removal of Turbidity and Thermotolerant Coliform Bacteria in Conventional Urban Water Treatment

Stage and process	Turbidity			Thermotolerant coliform bacteria		
	Removal[a] (%)	Average loading (NTU)[b]	Maximum loading (NTU)[b]	Removal[a] (h) %	Average loading (per 100 ml)	Maximum loading (per 100 ml)
Micro-straining	NA[c]	NA	NA	NA	NA	NA
Pretreatment[d]	NA	NA	NA	99.9	1000	10000
Coagulation/settling[e]	90	50	300	NA	NA	NA
Rapid filtration[e]	>80	5	30	80	1	10
Terminal chlorination	NA	1	5	>99.9	<1	2
Mains distribution	NA	<1	<5	NA	<1	<1

Source: Meseret, 2012.
[a]Required performance.
[b]NTU, nephelometric turbidity units.
[c]NA, not applicable, Process not designed to remove turbidity and/or bacteria. Micro-straining removes micro-algae and zooplankton
[d]Pretreatments that can result in significant reductions in thermotolerant coliform bacteria are storage in reservoirs for 3-4 weeks, and pre-disinfection.
[e]Taken together, coagulation, settling, and rapid filtration should be expected to remove 99.9% of thermotolerant coliform bacteria.

The multiple-barrier concept, as applied in the treatment of surface water for urban supplies, can be adapted for use in rural and remote regions. A typical series of processes would include:

1. Storage, sedimentation, or screening
2. Triple-stage gravel prefiltration
3. Slow sand filtration
4. Disinfection.

Table 2.6 lists typical performance objectives for the removal of turbidity and thermotolerant coliform bacteria in such plants.

Table 2.5: An Example of Performance Objectives for Removal of Turbidity and Thermotolerant Coliform Bacteria in Small-Scale Water Treatment

Stage and process	Turbidity			Thermotolerant coliform bacteria		
	Removal[a] (%)	Average loading (NTU)[b]	Maximum loading (NTU)[b]	Removal[a] (h) %	Average loading (per 100 ml)	Maximum loading (per 100 ml)
Screening	NA[c]	NA	NA	NA	NA	NA
Plain sedimentation	50	60	600	50	1000	10000
Gravel pre-filters (3-stage)	80	30	300	90	500	5000
Slow sand filter	>90	6	60	95	50	500
Disinfection	NA	<1	<5	>99.9	<3	25
Distributed water	NA	<1	<5	NA	<1	<1

Source: Meseret, 2012.
[a]Required performance.
[b]NTU, nephelometric turbidity units.
[c]NA, not applicable. Process not designed to remove turbidity and/or bacteria.

2.3.9 Distribution Networks

A distribution network transports water from the place of treatment to the consumer. Its design and size will be governed both by the topography and the location and size of the community. The aim is always to ensure that the consumer receives a sufficient and uninterrupted supply and that contamination is not introduced in transit. The shape of the network will be influenced by the location of consumers (WHO/UNICEF, 2000; WHO, 2008).

Distribution systems are especially vulnerable to contamination when the pressure falls, particularly in the intermittent supplies of many cities in developing countries. Suction is often

created by direct pumping from the mains to private storage tanks, a practice which should be prohibited (WHO, 2008).

The bacteriological quality of water can deteriorate during distribution, and there are a number of places where contamination can be introduced. If the water contains significant assimilable organic carbon and adequate residual levels of disinfectant are not maintained, or if water mains are not flushed and cleaned frequently enough, growth of nuisance bacteria and other organisms can occur. Where the water contains appreciable assimilable organic carbon and where the water temperature exceeds 20°C, a chlorine residual of 0.25 mg/litre may be required to prevent the growth of Aeromonas and other nuisance bacteria. Attached microorganisms may grow even in the presence of residual chlorine (Craun, Nwachuku, Calderon, and Craun, 2002)

Underground storage tanks and service reservoirs must be inspected for deterioration and for infiltration of surface water and ground-water. It is desirable for the land enclosing underground storage tanks to be fenced off, both to prevent access by people and animals and to prevent damage to the structures (Wright, *et al.*, 2004).

Repair work on mains provides another opportunity for contamination to occur. Local loss of pressure may result in back-siphonage of contaminated water unless check valves are introduced into the consumers' water system at sensitive points, such as supplies to ornamental pools, garden irrigation, urinals, and water closets. When repairs to mains have been completed or when new mains are installed, it is essential that the pipes are cleaned, disinfected, and then emptied and refilled with mains water. The water should then be tested bacteriologically after 24 hours, and new mains should not be brought into service until the water quality is bacteriologically satisfactory. If the main has been damaged and water from a fractured sewer or drain may have entered, the situation is most serious and, in addition to chlorination of the water

in the repaired main, the level of chlorination should be increased and the main not returned to service until the water quality is satisfactory. These and other actions to be taken should be specified both in national codes of practice and in local instructions to waterworks staff (Khanna, 2008).

As already mentioned, microbial contamination can occur as a result of the use of unsuitable materials for items coming into contact with water; such materials include those used for washers, jointing and packing materials, pipe and tank lining compounds, and plastics used in pipes, tanks, and faucets, all of which can deteriorate to form substances that support the growth of microorganisms. Such materials should be subject to approval by the authority responsible for the water supply system (WHO, 2008).

Drinking water source within Sabon Gari LGA are mainly boreholes, well water, tap water and sachet water (Bichiand, Bichi and Gadanya, 2012). *Salmonella typhi* outbreaks have always been associated to drinking unwholesome water (Edema *et al.,* 2001). The portability of drinking water within Sabon Gari LGA cannot be guaranteed as most of the site where drinking water sources is located are not hygienic and these can easily contaminate the water meant for drinking (Bichiand *et al.,* 2012). This is why this study seeks to examine the prevalence of *Salmonella typhi* in drinking water within Sabon Gari LGA, assess the occurrence of typhoid fever in Sabon Gari LGA, and examine the social and environmental bases for the occurrence of *Salmonella typhi* and typhoid fever in Sabon Gari LGA.

CHAPTER THREE: MATERIALS AND METHODOLOGY

3.1 INTRODUCTION

This chapter focuses on the background information of the study area which includes: location of the area, historical development, growth and distribution, the economy, health facilities, social organization and the aspect of methodology.

3.2 THE STUDY AREA

3.2.1 Location and Size of the Study Area

Sabon Gari LGA is one of the important LGA in Kaduna State. It was created on 27 August 1991 from the defunct Zaria Local Government Area of Kaduna state. It is located in the Guinea Savannah zone of the Northern Nigeria, Latitudes 11º6′0′′N - 11º10′30"N and Longitudes 7º37′30"E - 7º43′30"E about 5 kilometers from Zaria City and 65 kilometers from Kaduna Town. It is 660 meters above sea level with a total land area of approximately 600km ^{2} (Sabon Gari Administrative Map, 2012). It has boundaries with neighboring LGAs such as the north by Kudan LGA, to the east by Soba LGA, to the west by Giwa LGA and Zaria LGA to the south (Fig 3.1).

Its existence is linked to the railway, commerce and provincial administration with railway to Kano, and formally to Jos. Recently the local market itself has become more important with an increase in the number and size of educational institutions and factories.

The Government Residential Area (GRA) forms the largest part of the old European location, composed of large plots (1-2 acres) with spacious houses and public offices surrounded by extensive planting of ornamental trees and shrubs. The curved streets, trees lined and shady, are broad and well maintained (Sabon Gari Local Government Secreteriate)

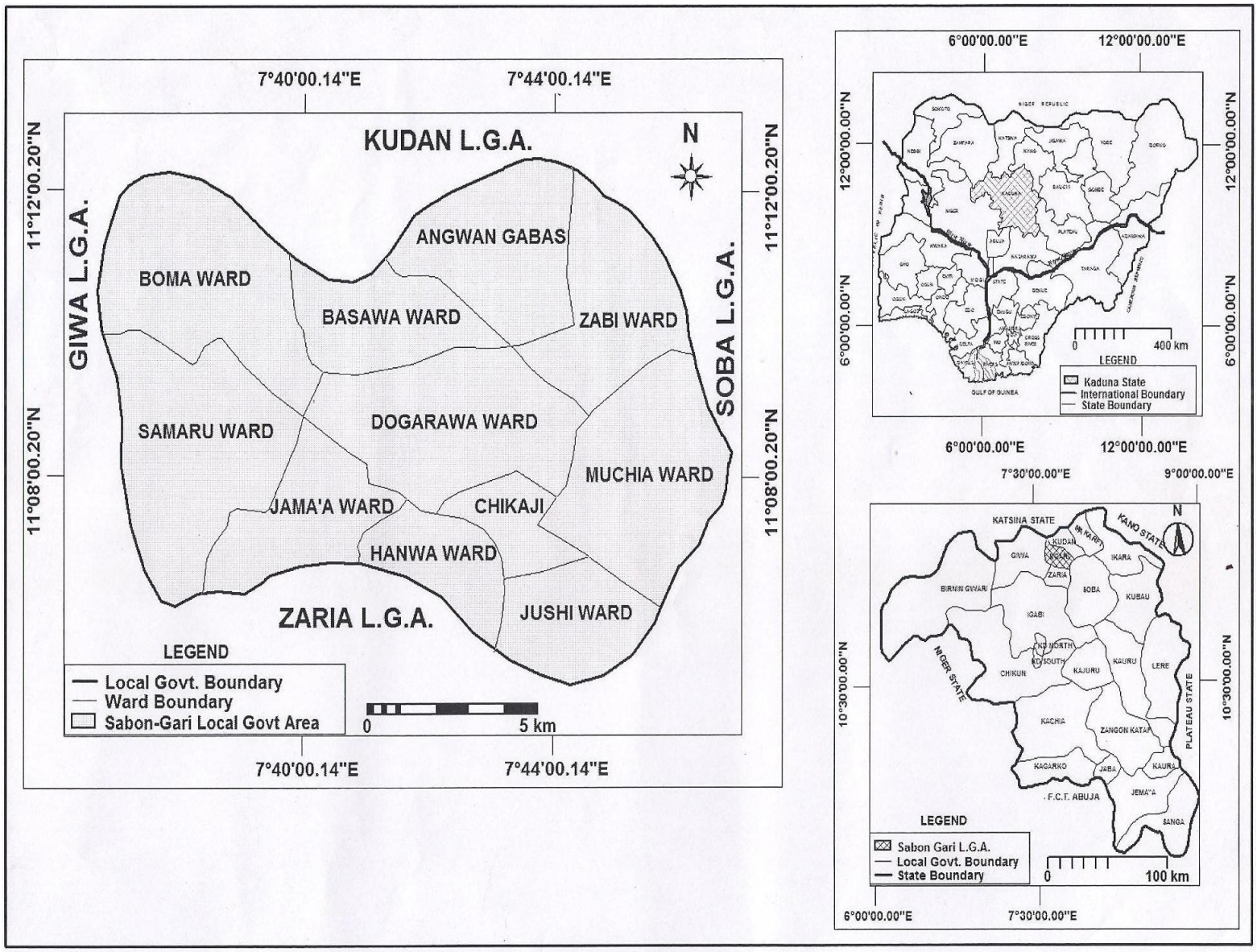


Fig.3.1 : Sabon Gari Local Govt. Area Showing Wards

Source : Adapted and modified from Sabon Gari Administrative map 2012

The Zaria club with its polo ground race course and golf course separates the GRA from the residential compounds of the senior railway officials, creating an open park in the midst of an ideal type of English suburban life in which house gardens, trees open space and quiet set the tone.

The Commercial area south of the GRA popularly known as Hanwa flyover has spacious environment. The roads are crossed at right angle and bound large plots on which both trade and residence can go on with little conflict.

Sabon Gari is the gateway to important towns of Kano, Funtua, Gusau, Katsina and Sokoto. It is home to some of the best educational institutions in Nigeria like Ahmadu Bello University, Nigerian Institute of Leather and Science Technology (NILEST), Institute for Agricultural Research (IAR).

3.2.2 Climate

Sabon Gari possesses a tropical continental climate which also falls under the AW of Koppens Climatic classification with a mean daily maximum temperature which gets to its peak in April and drops to minimum in October. The mean minimum temperature of 11^{o}C occurs in December and January and a high temperature of about 40^{o}C in July and August. Sabon Gari enjoys a tropical savannah climatic type, dry season practically varies and wet season with high sun. The mean annual rainfall is about 1200-1500mm, these seasonal characteristics affect vegetation cover (Oluwatoyin, 2013).

The dry season (winter-harmattan period) covers from November to February; fluctuations in daily November temperature are from 16^{o}C to 32^{o}C, in which the frequency of dust increases. As the season moves on, the relative humidity falls from 36% in November to 35% in January (Oluwatoyin, 2013).

The harmattan winds become intense during December-January period and thus lower further the temperature to 14^{o}C in January and because of the variation of temperature between morning, night and afternoon, it fluctuates between 14^{o}C and 31^{o}C with a variation of 17^{o}C. During the hot season (March-April), humidity jumps from 20% in February to 31% in April which is considered to be the hottest month (36^{o}C). Clouds appear to reduce the temperature by as much as 6^{o}C.

The period between May-June is known as thunder storm season. Humidity at this period rises from 69% in May to 77% in June with maximum temperature of 33^{o}C in May and 31^{o}C in June. The wet season starts from July to October.

The overall weather and climate of Sabon Gari depend to a large extent on the interplay between two air masses, the tropical continental air mass, which comes from north-east and the tropical maritime air mass which comes from southwest over the Atlantic Ocean. These two air masses in their boundaries form the inter-tropical discontinuity (ITD or ITCZ) (Oluwatoyin, 2013).

3.2.3 Relief and Drainage

The study area is underlain by igneous rocks such as granites (mainly, the older granites), gneisses, migmatites and meta-sediments. The area is located at a height of about 670m (2,200 feet) above sea level, with an undulating plain known as the high plains of Northern Nigeria.

The Galma River is a major tributary of river Kaduna. All other streams are seasonal, flowing only during and after the rains. There are two types of drainage basins in the area, the first is the high stream frequency and drainage densities, examples are River Kubani and Saye. The second types consist of basins with low stream frequencies and drainage densities and drainage densities such as Awai, Marmara, and Kuban (Oluwatoyin, 2013).

3.2.4 Soils and Vegetation

The soil of the area is predominantly of the leached ferruginous tropical type which is derived from both the basement complex and the sedimentary rock. A few occupying depressional areas and valley bottoms are hydromorphic soils (Oluwatoyin, 2013).

The soils are characterised by a pH of about 7.70, the total porosity of 35% and a low cation exchange capacity. The soils contain 41% sand, 44% silt and 15% clay proportions. There are variations from place to place of these parameters, due to irregularity of rainfall and absence of vegetal cover, high intensity of rain generates surface runoff that results in stripping and gullying (Bello, 2002).

The vegetation is of guinea savannah. It is characterised by relatively dispersed trees surrounded by thick bushes of grasses and shrubs (Jaiyeoba, 1986). Dominant among the trees found around residential areas are *Isoberlina doka*, *Tamarindus Indica*, Locust bean, Silk Cotton and baobab. The height of matured trees ranges from 10-15 meters. Some of the grasses found in the study area are *Hyparrheria spp, Schizochyrium smiberbe* and *Andropogan spp*.

However, human activities have greatly influenced the natural vegetation of this area. This led to evolution of concept known as the exotic or man-made vegetation. Some of the trees are non-native of the original vegetation (Oluwatoyin, 2013).

3.2.5 Historical Growth and Development

Sabon Gari Local Government Area (LGA) of Kaduna State is a unique home of business men and women, centre of academic excellence and one of the food baskets of the state, it has its headquarters at Dogarawa, a growing village located at the centre of the LGA. Sabon Gari LGA came into being through several transcend of Sabon gari town with Native Authority Administrative system (now the local Government system).

Sabon Gari town from which the local Government derived its name was established as a result of the development of communication, commerce and military establishment in the area after it was formally created by the British in the colonial administration in the north as a rehabilitation centre for railway workers in 1903 (Sabon Gari Local Government Secretariat)

It became one of the five urban centres in the northern part of this country; the others are Kano, Jos, Kaduna and Zungeru. This development facilitated the migration of the people from all the different parts of the country into Sabon Gari town to give it a unique cosmopolitan nature and outlook. Localities such as Dogon Bauchi, JushinWaje, Tsugugi, Unguwar Kanawa, Muchiya, Chikaji, Hanwa, Palladan, Jama'a, Basawa, Samaru, Bomo, Gwanda, Zangon Darbarno, Zabi, Shika, Katanga, Tobu, Hayin Dogo, Ungwar Jaba, Daurawa, Kwangila, Ungwar mai Gwado, G.R.A. and the Local Government Headquarters, Dogarawa to form one Administrative block, which gave it a district status (Sabon Gari Local Government Secretariat).

When the local Government councils were first created in Nigeria, Sabon Gari District, which was itself being transformed from Native Authority System to a Local Government system subsequently, Sabon Gari District and Soba District were derived out of Ikara Local Government and merged to create Sabon Gari Local Government council. Created on the 27th of August 1991, by the then Military Administration under retired General and President Ibrahim Badamasi Babangida, carved out Sabon Gari District from Soba Local Government council to form the now existing Sabon Gari Local Government Area (LGA) which now have eleven (11) wards (Sabon Gari Local Government Secreteriat)

3.2.6 Population Growth and Distribution

The population of the old Sabon Gari district in 1932 was 3,109, but by 1939 it rose to 6,657. The inflow of people from all parts of Nigeria is what is responsible for the multi-

ethnicity of the people present in urban Sabon Gari today. The old Sabon Gari District continued to grow after the Second World War, the population was 10,717. In 1962, the population increased to 15,842. Based on the 1991 census, the population was 48,858. In March 2006, the total population was 291,358, with female and male population of 142,247 and 149,111 respectively (NPC, 2009).

A great majority of the population of Sabon Gari are Northerners of different origins. There are a lot of southerners (Igbo's, Yoruba's, Efiks and Ibibio's), and foreigners from America, Europe, India, Pakistan, Sudan, Niger Republic and so on. Since the inception of Sabon Gari in 1903 it has kept on growing and has since given rise to satellite towns such as Tudun Wada, Samaru, Palladan, Muchia and Chikaji (Oluwatoyin, 2013).

3.2.7 Economy and Commerce

Being an urban settlement, the people of Sabon Gari LGA are mostly civil servants and traders with a larger population in the rural area involve in subsistence farming. The economy of Sabon Gari is agricultural supplemented by various non-agricultural traditional industries. Some of the main agricultural crops cultivated are yam, cassava, cocoyam, maize, cowpea, guinea corn and millet. Some of the major cash crops cultivated in Sabon Gari include; cotton, ginger, groundnut, and soya beans. Indeed, the British American Tobacco (BAT) Industry in Sabon Gari owes its existence to the high quality tobacco leaves cultivated everywhere around Sabon Gari.

Sabon Gari LGA is also well endowed with institutional and crafts or cottage industries which are labour intensive, and they provide employment for the ever increasing population as a result of the continuous migration from the rural areas. The study area is also endowed with a number of flourishing markets where people from far and near conduct business transaction daily (Oluwatoyin, 2013).

3.2.7.1 Transportation

The Baro-Zaria railway line was constructed in 1911, when the old cart road to Zungeru was abandoned. This was followed by road construction in the 1970s, which made Sabon Gari an important route centre effectively linked to the various parts of Nigeria.

Transportation land use in Sabon Gari consists of the presence of road networks which are mainly trunks A.B.C roads. A good example is the dualized road from Kofar Doka (Zaria City) to PZ and other road networks.

3.2.7.2 Education

Sabon Gari is undisputedly referred to as "educational nerve centre" of Northern Nigeria; with massive concentration of institutions of higher learning. The Ahmadu Bello University (A.B.U) was established in 1962 from three previous independent institutions. These were the Zaria branch of Nigeria College of Arts, Science and Technology, Institute of Administration, Tundun Wada and the Regional Research station of the ministry of agriculture now Institute for Agricultural Research (IAR) in Samaru (Oluwatoyin, 2013).

Other institutions include the Nigeria College of Aviation Technology (NCAT), National Institute of Transportation Technology (NITT), National Research Institute of Chemical Technology (NARICT), Federal College of Education (FCE), Nigerian Institute of Leather and Science Technology (NILEST) and Nuhu Bamali Polytechnic, Zaria among others. There are also sixty nine(69) primary schools and thirty-one (31) secondary schools spread all over the LGA (Oluwatoyin, 2013).

3.2.8 Health Care System

In Nigeria, primary health services are expected to provide basic preventive and health promotion services, as well as simple curative services. Sabon Gari LGA also gives premium to this sector of the economy. There are eighteen (18) clinics and eighteen hospitals with labs attached to them for both private and government own establishment within Sabon Gari LGA, with an additional twenty four (24) Primary Health Care centre which are primarily owned by the local government with emphasis on preventive community health care and environmental and personal hygiene (Sabon Gari Local Government Secretariat). The immunisation of children against the six killer diseases has been expanded. However, there are no readily available data to describe the impact of these programmes on the people. Health services provided free in the state include immunisation against infectious diseases, the child killer diseases (diphtheria tuberculosis, whooping cough, measles and poliomyelitis) and treatment of cerebrospinal meningitis. These programmes are however in line with the national policy on health, which emphasises preventive health programmes through the primary health care (PHC) Programmes (Sabon Gari Local Government Secretariat).

3.2.9 Social Organisation

Sabon Gari LGA is characterised by high Small and Medium-sized Enterprises (SMEs) which are mainly sachet water factories and printing press. The socio-economic characteristics of the population and the cultural beliefs and practices are mutually interrelated and these are known to affect behavioral patterns, sanitation level and waste disposal pattern.

However, the current patterns of social organisations are largely detected by religious beliefs. There is a very strong tendency among the people to live very close to people from their tribal areas and of their religion. The problem of religions antagonism is finding vivid expression

in the state and it appears as if social issues relating to locating residential mobility and spatial interaction are strongly influenced by religion.

3.3 METHODOLOGY

3.3.1 Reconnaissance Survey

A reconnaissance survey was carried out within the study area to ascertain the different areas that have access to tap water, boreholes, well water and locate sachet water factories within the study area. It also helped to determine the sample size and sampling techniques.

3.3.2 Types of Data

For proper evaluation and easy comparison, the types of data used for this research work was divided into primary and secondary data.

3.3.2.1 Primary Data

i. Sources of water consumed mostly as drinking water
ii. Drinking water samples for analysis
iii. Amount of *Salmonella typhi* (cfu/ml) in drinking water.
iv. Prevalence of typhoid fever in the LGA

3.3.2.2 Secondary Data

i. Total number of registered sachet water factories within the study area
ii. Surveillance data on typhoid illness from 3 hospitals within the LGA

3.3.3 Sources of Data

The sources of data differ according to the purpose of data collection, however, the source of data for both primary and secondary data are listed below,

i. Sampled tap water, boreholes, wells and sachet water in Sabon Gari LGA

ii. Questionnaire administration to the inhabitants of Sabon Gari LGA where samples was collected

iii. Microbiological analysis of *Salmonella typhi* in drinking water collected within the LGA

iv. Data from Sabon Gari local government council secretariat on the amount of sachet water factories within the local government

v. Data of typhoid illness from hospitals within the LGA.

3.3.4 Sampling Techniques

It is practically difficult to collect all the samples within the Local Government Area, and also a total research is relatively expensive. Therefore twenty-four samples were randomly selected among three wards which were systematically picked within the eleven wards present in the LGA. In order to select the wards where drinking water samples were collected, all the wards within Sabon Gari Local Government Area were alphabetically arranged and every third ward was then picked systematically as represented in Table 3.1.

Among the 24 samples selected, 3 were sachet water, 3 were tapwater (1 sample from each ward selected), 9 were boreholes (3 samples from each ward selected in area of high, middle and low resident) and 9 were well water (3 samples from each ward selected in area of high, middle and low resident). To obtain the water samples from tap and boreholes, the nozzle of each of the tap was sterilised with cotton wool soaked in acetone-alcohol. The tap was turned on and allowed to run for two minutes after which, sterilised containers are carefully uncapped and held under the running tap. For that of well water, a clean fetcher was used to fetch the water sample from the well (shallow well) and quickly transferred into a sterilised container and taken for microbial analysis.

Table 3.1: All the 11 Wards within Sabon Gari LGA in an Alphabetical Order

S/N	Wards	Selected Wards
1	Auta Jushi ward	
2	Basawa ward	
3	Bomo ward	✓
4	Chikaji ward	
5	Dogarawa ward	
6	Gabas ward	✓
7	Hanwa ward	
8	Jamaa ward	
9	Muchia Ward	✓
10	Samaru ward	
11	Zabi ward	

Sachet water factories in the selected wards are represented in Table 3.2. The sachet water was grouped according to their wards. The most commonly consumed sachet water in each of the three selected wards was sampled. These are Aqua Divine Water, Shobos water and Simi water for Chikaji, Gabas and Muchia wards respectively. Since the sachet water is already sealed, it was purchased directly from the factory immediately after production and taken to the lab for microbial analysis.

Table 3.2: List of Pure/Table Water within Sabon Gari L.G.A

S/N	**Chikaji Ward**	S/N		S/N	**Muchia Ward**
1	Jovick Water	13	Emasol Water	27	Akogba Water
2	Aqua Divine Water	14	Nasiba Water	28	Salwa Water
3	Himan Water	15	De Concord Water	29	Simi Water
4	Dan Arewa Water	16	Annur Water	30	Sabo Water
5	B-Best Water	17	Aishat Water		
6	Bol-Mac Water	18	Sadom VIP Water		
7	Kemdal Water	19	Fersco Water		
		20	Shimak Water		
	Gabas Ward	21	San Water		
8	Nazib Water	22	Shobos Water		
9	New Era Water	23	Naib Water		
10	Kassa Water	24	Empire Water		
11	Aderems Water	25	H.R Water		
12	Ollan Water	26	Ausbliss Water		

Source: Sabon Gari Local Government Secretariat

All the samples collected were immediately taken to the laboratory for analysis. Analyses were carried out within 8 hrs after sampling. Where immediate microbiological evaluation was delayed, the samples were refrigerated at 4^0C and analysed within 24 hours of collection

From the foregoing representation, the wards selected are Bomo, Gabas, and Muchia ward. However, during reconnaissance survey it is observed that Angwan Bomo does not have tap water supply therefore; samples are collected from the next ward after Angwan Bomo which is Angwan Chikaji as represented systematically. Figure 3.2 show the sampling points for borehole and well water within the 3 wards selected.

For easy tabulation, each of the wards picked was assigned an alphabet. Angwan Chikaji is represented with letter 'C', and the three different sample of drinking water collected within the ward (tap, borehole, and well) was designated $C_{t,}$ $C_{1b,}$ $C_{2b,}$ $C_{3b,}$ and $C_{1w,}$ $C_{2w,}$ and C_{3w} accordingly. The same was designated for the other wards picked, only that the alphabet varied. Like the case of potable water, the three brands of sachet water sampled are designated with alphabets: SW_1, SW_2, and SW_3 accordingly. The results of microbiological analysis for the tap water, boreholes, well water and that of the sachet water were represented in a table for easy computation.

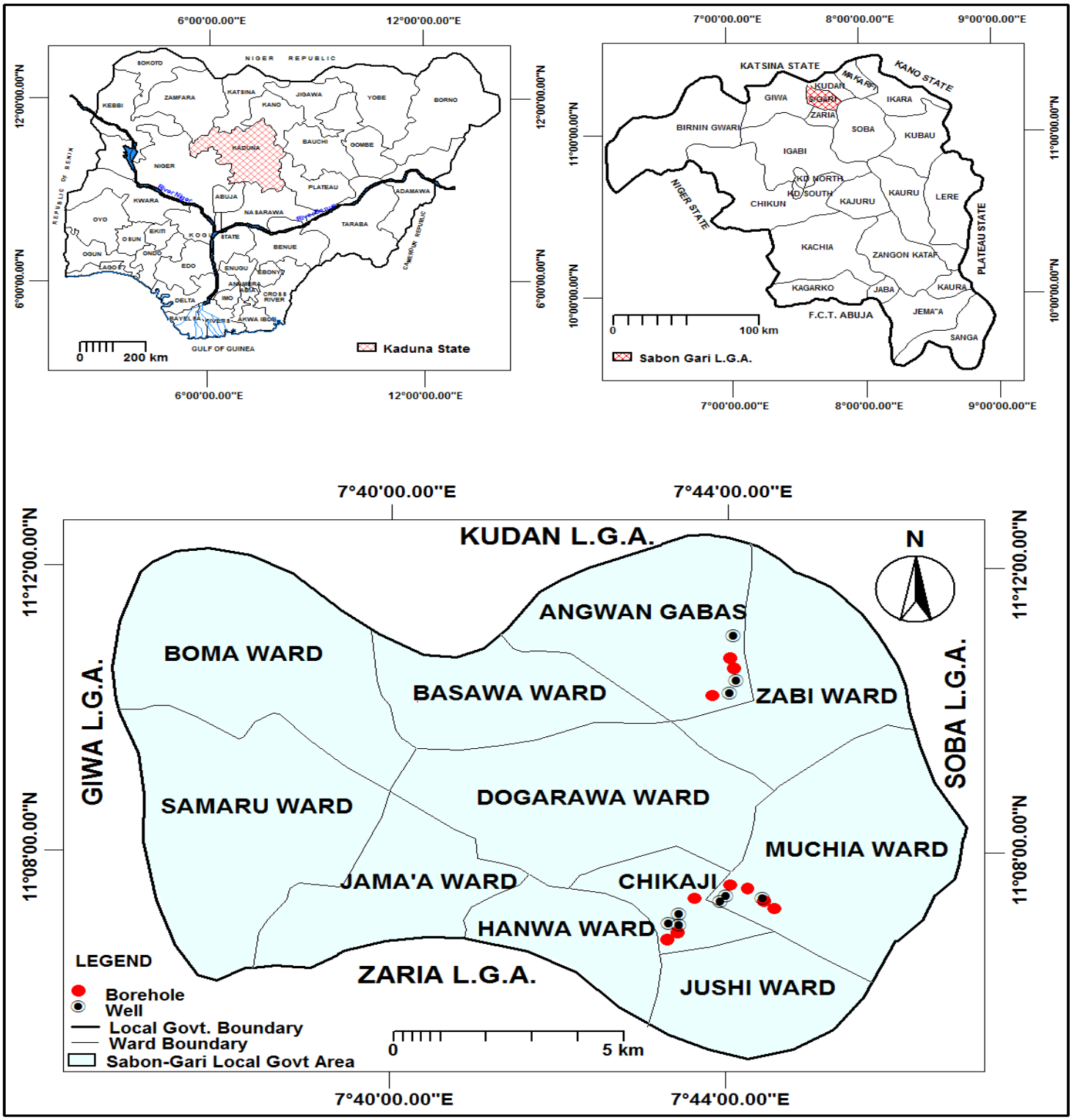


Fig. 3.2: Sabon Gari Local Govt. Area Showing the Sampling Points

Source: Adapted and Modified from Political Map of Sabon Gari L.G.A.

The number of respondents to be administered questionnaire was determined by using the population proportion formula below (Scott, 2013).

$$n = \frac{(Z_{\alpha/2})^2 \text{ x } p(1-p)}{E}$$

Description:

n = sample size for the questionnaire

Z = confidence level at 95% (standard value of 1.96)

p = number of variance expected from the respondents (0.5 is the forgiving value to use when survey is not yet administered since it ensures that one's sample will be large)

E = margin of error or confidence interval of ±5% (0.05)

The questionnaire was distributed within the 3 wards selected; specifically within the areas where samples were collected (areas of high, middle and low population concentration). Since there are 9 points in all the 3 wards where samples were collected (3 in each wards) a total of 42 copies of questionnaire were distributed in areas of low population concentration (Free town, Yoruba/Lagos Street, and Zobe Road) and 43 copies each in areas of high and moderate concentrations (Angwan Jebba, Chikaji, Kings Road/Hanyan Ojo and Benin Street, Railway Quarters, Ondo Street respectively). These summed up to 384 copies of questionnaire that are distributed in total.

A surveillance data on typhoid illnesses were collected from 3 hospitals, Ladiya Hospital in Benin Street, Al-Madinah Hospital inside GRA and Saidu Dange Hospital in railway quarters (Appendix 3) in the LGA within the previous two months on date of surveys. These, together with the information gotten from the retrieved questionnaire were used to assess the prevalence of typhoid fever in the LGA.

3.3.5 Laboratory Analysis

For the microbiological analysis of *Salmonella typhi* in drinking water ten milliliters of each water sample for bacteriological evaluation was aseptically transferred into 90 ml of 0.1% sterile peptone water, mixed thoroughly, and an appropriate dilutions up to 10^4 was made for microbiological studies. Afterward, a 10^1 dilution of each water sample was enriched in tetra thionate broth (Difco), incubated at 37^oc for 6 hrs before inoculation on Salmonella-Shigella agar (oxoid) for isolation of Salmonellae. 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.

3.3.6 Statistical Analysis

Both descriptive and inferential statistical test were employed in the analysis of data in the study. The descriptive statistics were mostly those of measures of central tendency and dispersion used in summarising data gathered. The inferential statistics were also used to test for significant difference among the sample mean.

The percentage of respondent who used different sources of drinking water was determined from the collated questionnaire returned by the respondents. The highest percentage of respondents was used to determine the sources of drinking water mostly consumed and preferred.

The mean value of total colony forming unit (cfu) of *Salmonella typhi* for each water sample collected was determined and the Analysis of Variance (ANOVA) was used to test for

significant difference among the sample means.

The percentage of significant cases of typhoid fever was determined from the surveillance data collected on reported cases of typhoid fever. These figures were used to indicate the degree of prevalence. Figures with high percentage indicate high prevalence while figures with low percentage indicate low prevalence of typhoid in the study area.

The ANOVA results for the microbiological analysis of drinking water were compared with the percentage of significant cases of typhoid fever. When there was no significant difference among the sample mean and the percentage of significant cases of typhoid is high it means the drinking water consumed results in new cases of infection by *Salmonella typhi* and therefore, responsible for the incidence of typhoid within the LGA.

Socio-environmental factors affecting quality of drinking water was determined from the responses in the LGA. The frequency and percentage of those who agreed to the existing socio-environmental factors indicated in the questionnaire was calculated and comparism was made with other respondent to determine the significant cases.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents tables of microbiological analysis of sachet water, tapwater, boreholes and well water. The tables are first presented before discussion

4.2 MAJOR SOURCES OF DRINKING WATER WITHIN THE STUDY AREA

Water is a vital element in each of our lives. Not only is it essential to our health, it is also used for numerous household tasks. Every day water is used for cooking, bathing, and cleaning, and drinking, but we sometimes do not think about its source, where does the water come from, how is the water treated, and how do we know whether it is safe for drinking. Table 4.1 characterizes the major sources of drinking water within Sabon Gari LGA.

Table 4.1: Types of Water consumed mostly and preferred within Sabon Gari LGA

Sources of water	Used Most	Preferred	Percentage of Most Used (%)	Percentage of Preferred (%)
Sachet Water	86	137	22.4	35.7
Tap Water	139	126	36.2	32.8
Well Water	76	53	19.8	13.8
Boreholes	77	46	20.1	11.0
Others (bottle water)	6	22	1.5	5.7
TOTAL	**384**	**384**	**100**	**100**

Source: Field Survey, 2014.

From Table 4.1 it can be seen that tapwater was the major source of drinking water for (36.20%) followed by sachet water with a percentage of 22.4%. Other sources of drinking water are not much consumed as only 1.5% utilizes them. Well water and boreholes are almost consumed at the same rate with a 19.80% and 20.10% consumption rate among the inhabitants. The source of water consumed most does not indicate its preference in the LGA.

The table also shows that sachet water was mostly preferred (35.68%) while 32.81% indicate they preferred tapwater, followed by well water and boreholes with a respective percentage of 13.80% and 11.98%. Those that prefer other sources of drinking water are not that much as only 5.73% indicate for other sources of water. Choosing the best drinking water is a rather subjective process. There are personal preferences to consider such as taste, source and quality. These cause preference to vary among the respondents. One type of water does not satisfy everyone. So the plethora of options available that influence the choice of the respondents in selecting source of drinking water is discussed.

Tapwater may not be the best drinking water, but let's anchor those assumptions in some facts. A reconnaissance survey carried out in Sabon Gari LGA reveals that the quality of tapwater supply to the inhabitant of Sabon Gari LGA has created doubt in the mind of the people considering the physical appearance of the water sometimes supplied. However, in Table 4.1 tapwater is mostly used but not mostly preffered. Tapwater as the name implies is expected to be clean and free of pathogens, because it has undergone so many processes of purification hence the government supplies them with this water. With regards to boreholes and well water, tapwater is still preffered as it is pipe borne and treated. This mentality together with economic constrain might have contributed to the frequent use of tapwater in this LGA even though they still have doubt in their minds as to the quality of tapwater supplied to them.

Sachet water is believed to have been carefully processed to supplement the need of drinking water and therefore, more potable than tapwater. This explains the reason why sachet water is mostly preferred than other source of drinking water within the LGA. Boreholes and well water are mostly used for drinking when tapwater and sachet water are not readily available or too expensive to afford.

The results in Table 4.1 slightly agree with the study of Anyebe *et al*, (2008), however, the researcher did not include sachet water in his study. The result indicated that the major sources of drinking water in Zaria were tapwater (44%), and well water (42.3%). Only 9.0% of the respondent used water from the borehole while 4.4% used water from streams in his study.

4.3 PREVALENCE OF Salmonella typhi IN DRINKING WATER WITHIN THE STUDY AREA

Water pollution caused by *Salmonella typhi* contamination is a serious problem due to the potential of contacting diseases from pathogens. Frequently, concentrations of pathogens from faecal contamination are small, and the numbers of different possible pathogens are large. As a result, it is not practical to test for one pathogen alone in a water sample collected. Instead, the presence of pathogens is determined with indirect evidence by testing for an "indicator" organism such as coliform bacteria. Coliforms come from the same sources as pathogenic organisms. Coliforms are relatively easy to identify, are usually present in larger numbers than more dangerous pathogens, and respond to the environment, wastewater treatment, and water treatment similarly to many pathogens. As a result of these, testing for coliform bacteria alongside *Salmonella typhi* can be a reasonable indication of whether other pathogenic bacteria are present. The tables 4.2a, 4.2b, 4.2c, show the occurrence of coliform, faecal coliform, Shigella and Salmonella in different water samples collected in selected wards within Sabon Gari LGA.

Salmonella and Shigella are the leading agents causing gastrointestinal infections, especially in developing countries. One of the sources of infection with these bacteria in human is water, which is necessary for life and health (WHO, 2000). Shigella is represented in the tables 4.2a, 4.2b, 4.2c, together with Salmonella, because Shigella is (a genus of gram-negative facultative anaerobic, non spore-forming, non-motile rod shaped bacteria) closely related to

Salmonella. They are both enterobacteriaceae commonly found together in water. They are two types of bacteria that cause abdominal distress. While many of the symptoms are the same, differences exist in the method of contamination, treatment and duration. Laboratory tests usually confirm the presence of the Shigella or Salmonella bacterium (Uzoigwe and Agwa, 2012).

Table 4.2a: Enumeration of Coliform, Feacal Coliform, Shigella and Salmonella on Different Water Sample in Chikaji Ward

S/N	Sample Code	MPN/100ml	Feacal Coliform Count (cfu/ml)	Shigella Count (cfu/ml)	Salmonella Count (cfu/ml)
1	C_1W	8	1.23×10^5	7.0×10^3	-
2	C_1B	< 2	-	-	-
3	C_2W	17	3.8×10^4	-	-
4	C_2B	5	-	1.4×10^4	-
5	C_3W	28	-	9.6×10^4	1.52×10^5
6	C_3B	28	-	3.3×10^4	-
7	C tap water	< 2	-	-	-
WHO Acceptable Limit		0	0	0	0

Source: Laboratory analysis, 2014.
MPN = Most Probable Number
cfu/ml = colony forming unit per milliliter; - = no growth

Table 4.2a presents the result of microbiological analysis of water samples collected from Chikaji ward. Only well water at point three Chikaji ward (C_3W) contains *Salmonella typhi.* Well water at point one and of the ward contain high amount of feacal coliform count making it unfit for drinking. Other water samples shown in the table 4.2a indicate the presence of pathogens like Shigella despite the fact that *Salmonella typhi* and feacal coliform count were not detected. Tapwater in this ward is free microorganisms as indicated in Table 4.1

Table 4.2b: Enumeration of Coliform, Feacal Coliform, Shigella and Salmonella on Different Water Sample in Gabas Ward

S/N	Sample Code	MPN/100ml	Feacal Coliform Count (cfu/ml)	Shigella Count (cfu/ml)	Salmonella Count (cfu/ml)
1	G_1W	26	1.83×10^5	5.3×10^4	-
2	G_1B	2	-	-	-
3	G_2W	350	-	3.3×10^4	8.0×10^3
4	G_2B	79	-	8.1×10^4	1.5×10^4
5	G_3W	170	7.8×10^4	-	1.9×10^4
6	G_3B	32	-	6.7×10^4	2.0×10^4
7	G tap water	< 2	-	-	-
WHO Acceptable Limit		0	0	0	0

Source: Laboratory analysis, 2014.
MPN = Most Probable Number
cfu/ml = colony forming unit per milliliter
- = no growth

Table 4.2b presents the result of microbiological analysis of water sample collected from Gabas ward. Most of the water samples tested in this ward indicates the presence of *Salmonella typhi* count. Only the tapwater, borehole and well water in point one within the ward tested negative for *Salmonella typhi* however, the well water in point one contains a significant amount of feacal coliform count hence, not suitable for drinking despite the fact that it does not test positive to *Salmonella typhi*.

Table 4.2c: Enumeration of Coliform, Feacal Coliform, Shigella and Salmonella on Different Water Sample in Muchia Ward

	Sample Code	MPN/100ml	Feacal Coliform Count (cfu/ml)	Shigella Count (cfu/ml)	Salmonella Count (cfu/ml)
1	M_1W	540	4.2×10^4	1.7×10^4	-
2	M_1B	1600	-	4.2×10^4	6.6×10^4
3	M_2W	920	9.7×10^4	7.2×10^4	-
4	M_2B	< 2	-	-	-
5	M_3W	1600	3.8×10^4	2.2×10^4	-
6	M_3B	< 2	-	-	-
7	M tap water	2	-	-	-
WHO Acceptable Limit		0	0	0	0

Source: Laboratory analysis, 2014.
MPN = Most Probable Number
cfu/ml = colony forming unit per milliliter
- = no growth

Table 4.2c presents the result of microbiological analysis of water samples collected from Muchia ward. *Salmonella typhi* was found in point one Muchia borehole (M_1B). But for the other water samples in Muchia Ward, *Salmonella typhi* was not detected. However, their mean feacal coliform count was high indicating the presence of other pathogens therefore, not potable. The only exception to this was the tapwater and borehole water sample collected at points two and three whereby feacal coliform count was not detected and the water sample was free of *Salmonella typhi*.

The WHO standard for Salmonella in potable water supplies states that the total Salmonella count should be 0 cfu/ml (WHO, 2008). Based on the WHO standards, the water samples from C_3W, G_2W, G_2B, G_3W, G_2B, and M_1B are unacceptable for human consumption because of their high Salmonella loads. According to US Environmental Protection Agency standards, water samples in which coliforms are detected should be considered unacceptable for drinking water as they are regarded as the principal indicators of water pollution.

The numbers of indicator bacteria in these water samples were comparatively higher than permissible values (WHO, 2002). Itah and Akpan, 2005 reported similar bacterial load indicative of poor water quality. Relatively high aerobic colony counts are indicative of poor, unhygienic handling and processing, while indicator organisms like *Salmonella typhi*, and *Escherichia coli* are likely to result from sewage contamination (Grant, Pendroy, Mayer, Bellin and Palmer, 1996).

The results in table 4.2a, 4.2b, 4.2c are similar to the research conducted by Tista, Binod, Dev and Madhav (2007) in Nepal. In that study, 238 isolates of enteric bacteria were identified in which Salmonella constitute 3.3% in totality. Total plate count for total bacterial count performed for all the water samples showed that only 17.4% were within the WHO guideline value (0 cfu/ml). Based on the analysis of various sources of water, 71.1% of tube well, 89.5% of well, 82.4% of tap and 100% of stone spout water samples exceeded the guideline value.

In this present work, 28.6% of the water samples have been found to be contaminated by Salmonella of which 4.8% came from the water samples from wells (C_3W) in Chikaji ward, 4.8% came from the water samples from borehole (M_1B) in Muchia ward and 19% from well water and boreholes (G_2W, G_2B, G_3W, G_3B) in Gabas ward. The total plate count for Salmonella in tapwater within the three wards were in conformity with WHO guidelines (IRC, 2002)

In Table 4.2d where the results of microbiological analysis of sachet water is presented, shows that all the sachet water tested negative to *Salmonella typhi*, *Faecal coliform* count and even Shigella indicating that the sachet water are free of these pathogen and are therefore suitable for drinking.

The results in Table 4.2d conform to the work of Adegoke, Bamigbowu and Okpo (2012). In that study, five (5) brands out of 10 of the sachets water the researchers studies met

the standard of WHO guideline value and this could be as a result of proper location of the water source and effective treatment which the water has undergone, therefore the members of public who drink these sachet water brands could be free from water borne diseases. Egwari, Iwuanyanwu, Ojelabi, Uzochukwu and Effiok (2005) in Lagos, Southwest Nigeria and Ekwunife, Okafor, Ukaga, Ozumba and Eneanya (2010) at Awka, Southeast Nigeria in their bacteriology study of sachet water found no enteric pathogens and *Salmonella typhi* in the water studied.

Egwari *et al.* (2005) in their study on bacteriology of sachet water sold in Lagos reported that organisms contained in sachet water were inevitably the source of contaminants on the sachet surface. The water vendors and their patrons contributed to the overall contamination of hawked sachet water in Lagos. In this research work the absence of *Salmonella typhi* and other enteric bacteria in the sachet water tested (Table 4.2d) may be attributed to the fact that the samples were collected at the point of production and quickly transported for microbiological analysis. The possibility of water vendor and their patrons contributing to contamination during storage, transportation and sales have been removed.

Table 4.2d: Enumeration of Coliform, Feacal Coliform, Shigella and Salmonella on the Three Most Popular Sachet Water Sampled

S/N	Sample Code	MPN/100ml	Feacal Coliform Count (cfu/ml)	Shigella Count (cfu/ml)	Salmonella Count (cfu/ml)
1	SW_1	< 2	-	-	-
2	SW_2	< 2	-	-	-
3	SW_3	< 2	-	-	-
WHO Acceptable Limit		0	0	0	0

Source: Laboratory analysis, 2014
MPN = Most Probable Number
cfu/ml = colony forming unit per milliliter
- = no growth

The water samples studied in this work (C_1B, G_1B, M_2B, M_3B, and all the tapwater and sachet water) are in conformity with the WHO standard which could be attributed to the effective water treatment and proper location of water source away from contaminations. In order to protect public health and ensure that water is safe for public use, any water intended for drinking treated or untreated, piped or unpiped must meet certain microbiological standard. A violation of set standards warrants treatment of the present source or the need for an alternative water supply as is the case with the water samples in C_3W, M_1B, G_2W, G_2B, G_3W, G_3B investigated in this research work.

Earlier investigation conducted on safety of drinking water has shown that water in the market are of good microbiological quality while the quality of some factory bagged sachet and hand filled polythene bagged drinking water was noted to be doubtful (Obiri-Danso, Okore-Hanson and Jones, 2003). Adegoke *et al.* (2012) reported the presence of *Salmonella typhi, Proteus sp, Klebsiella sp, Enterobater sp, Pseudomonas sp, Staphylococcus sp and Escherichia coli* in borehole water at Oyigbo, Rivers state suggesting that those borehole water did not meet WHO standard.

4.4 OCCURRENCE OF TYPHOID FEVER IN SABON GARI LGA

A surveillance data on typhoid illness was collected from three hospitals; (Ladiya Hospital, Al-Madinah Hospital and Dange Hospital) within Sabon Gari LGA. Malaria is presented in the result because test for malaria or typhoid are mostly conducted together. Other ailments are also reflected to enable the easy computation of results in term of percentage. The surveillance data collected from these hospitals are presented in Tables 4.3a, b and c after which a detailed discussion of the three tables is made.

Table 4.3a presents the results for the microbiological analysis of typhoid illness for the month of September and October, 2014.

Table 4.3a: Reported Cases of Typhoid Fever in Ladiya Hospital

Parameters & Pathogens	**Number of individual who came for test**	**Type of test conducted**	**Total number of test conducted**	**Significant cases**	**Insignificant cases**	**Percentage of significant cases (%)**	**Percentage of insignificant cases (%)**
Typhoid	454	widal	447	417	30	93.3	6.7
Malaria		mp	454	453	01	99.8	0.2
Others	284	FBS, PCV, RBS, HVS, etc…	736	NN	NN	NN	NN
TOTAL	**738**	**-**	**1637**	**NN**	**NN**	**NN**	**NN**

Source: Ladiya Hospital laboratory analysis book
NN = Not Needed
FBS = Fasting Blood Sugar; PCV = Pack Cell Volume; RBS = Random Blood Sugar; HVS = High Vagina Swab

From table 4.3a it can be seen that 738 patients came for laboratory test, 454 did malaria and widal test while the remaining 284 did test on other ailment. The test for typhoid is normally called widal test as can be seen in the table 4.3a, b and c.

Table 4.3a shows that 447 of the patients did widal test among the 454 that actually came for malaria and typhoid. There are 417 significant cases of typhoid fever among the test conducted. The total number of test conducted by the patients within the months of September and October (2014) are 1637 as can be seen in table 4.3a. The percentage of insignificant cases of widal test among the total test conducted was 6.7 % while 93.3% were significant cases, indicating high prevalence of typhoid fever.

The table 4.3b shows the results for the laboratory analysis in Al-Madinah Hospital for the month of September and October. In this case, more patients came for test compared to Ladiya Hospital. However, the statistical computation of results looks the same. In the month of September and October 1764 patients came for test, 874 for typhoid and malaria test. Of this figure, 846 did widal test and 782 were significant. The total number of test conducted in this hospital for the month of September and October are 3086, the percentage of insignificant cases of widal test conducted was 7.6% while 92.4% were significant cases also indicating high occurrence of typhoid.

Table 4.3b: Reported Cases of Typhoid Fever in Al-Madinah Hospital

Parameters & Pathogens	**Number of individual who came for test**	**Type of test conducted**	**Total number of test conducted**	**Significant cases**	**Insignificant cases**	**Percentage of significant cases (%)**	**Percentage of insignificant cases (%)**
Typhoid	874	widal	846	782	64	92.4	7.6
Malaria		mp	865	861	04	99.5	0.5
Others	890	FBS, PCV, RBS, HVS, etc…	1366	NN	NN		NN
TOTAL	**1764**	**-**	**3086**	**NN**	**NN**	**NN**	**NN**

Source: Al-Madinah hospital laboratory analysis book
NN = Not Needed
FBS = Fasting Blood Sugar; PCV = Pack Cell Volume; RBS = Random Blood Sugar; HVS = High Vagina Swab

Saidu Dange Hospital also known as railway hospital is the hospital put in place specifically for railway staff. It is expected that most of the staff perform their laboratory test in this hospital. The likelihood of these staff going to other hospital is very rare. Table 4.3c shows a

surveillance data on typhoid illness collected within the month of September and October in Saidu Dange Hospital.

Table 4.3c: Reported Cases of Typhoid Fever in Saidu Dange Hospital

Parameters & Pathogen	**Number of individual who came for test**	**Type of test conducted**	**Total number of test conducted**	**Significant cases**	**Insignificant cases**	**Percentage of significant cases (%)**	**Percentage of insignificant cases (%)**
Typhoid	46	widal	39	13	26	33.3	66.7
Malaria		mp	46	39	07	84.8	15.2
Others	15	FBS, PCV, RBS, HVS, etc…	57	NN	NN	NN	NN
TOTAL	**61**	**-**	**142**	**NN**	**NN**	**NN**	**NN**

Source: Saidu Dange Hospital laboratory analysis book
NN = Not Needed
FBS = Fasting Blood Sugar; PCV = Pack Cell Volume; RBS = Random Blood Sugar; HVS = High Vagina Swab

From this table, it can be seen that the number of individuals who came for test in the month of September and October are not much compared to that of Ladiya Hospital and Al-Madina Hospital. In the month of September and October, 61 staff came for test in Saidu Dange Hospitals, 46 of this patient came for malaria and typhoid test among which 39 conducted test on typhoid only. The total number of test conducted was 142 out of which 66.7% were insignificant cases of widal test and 33.3% were significant cases (table 4.3c). In this case the significant cases of widal test was low compared to that of Ladiya and Al-Madinah Hospitals. The prevalence rate of typhoid fever compared to the other two hospitals is not much (about one third) which might

not be unconnected to their healthy environment that is better planned and less congested. Typhoid fever is common in less industrialised countries, principally owing to the problem of unsafe drinking water, inadequate sewage disposal and flooding (Kibiru, 2011).

Table 4.3d shows a summary of all the surveillance data collected in the 3 hospitals. From the table it can be seen that the exposure to *Salmonella typhi* is very high (91.0%) indicating high probability of cases of typhoid fever among the inhabitant of the LGA.

Table 4.3d: Summary of Surveillance Data on Typhoid Illness Collected from Ladiya, Al-Madinah and Dange Hospital in the Month of September and October

Parameters & Pathogens	**Number of individual who came for test**	**Type of test conducted**	**Total number of test conducted**	**Significant cases**	**Insignificant cases**	**Percentage of significant cases (%)**	**Percentage of insignificant cases (%)**
Typhoid	1374	widal	1322	1212	120	91.0	9.0
Malaria		mp	1374	1353	12	99.1	0.9
Others	1189	FBS, PCV, RBS, HVS, etc…	2159	NN	NN	NN	NN
TOTAL	**2563**	**-**	**4855**	**NN**	**NN**	**NN**	**NN**

Source: Summary of Laboratory Analysis, 2014.
NN = Not Needed
FBS = Fasting Blood Sugar; PCV = Pack Cell Volume; RBS = Random Blood Sugar; HVS = High Vagina Swab

The findings on prevalence of typhoid in the three (3) hospitals studied share similarity with previous works. For example, Okonko *et al.* (2010) carried out a research on the prevalence of *Salmonella typhi* among patients in Abeokuta, South-Western Nigeria. In their study, 673 (80.1%) of the 840 blood samples were significant cases which is a bit lower than the significant cases of typhoid fever statistically in table 4.3d (a summary for the 3 hospitals). This indicates a

high prevalence of typhoid fever among the sampled population. This is also in agreement with the observations of Outi, Risto and Kaisa (1989) and Adeleke, Adepoju and Ojo (2006) in a similar study on widal reaction as being more relevant in diagnosing post-infection complications when *S. typhi* may not be isolated. For a more definite diagnosis of typhoid fever, serologic test and blood culture as well as stool culture from every patient are quite relevant. Therefore, efforts must be made to confirm the diagnosis by paired sera investigation (Okonko *et al.*, 2010).

Furthermore, from the 384 copies of questiontionnaires that were distributed to assess the prevalence of typhoid fever in the LGA. Table 4.3e shows the frequency and percentage of respondents on prevalence of typhoid disease in the LGA. From the table, 261 agree they fell sick due to typhoid fever, and 123 of the respondent never felt sick due to typhoid fever. The percentage of respondents that had typhoid fever was about 70% which is high compared to the other respondents. This is an indication also of the occurrence of typhoid fever in the LGA. Other respondent who claim they have never been diagnosed of typhoid might have been vaccinated or rather less vulnerable to typhoid infection as might be seen with the people staying in Railway Quarters. Typhoid vaccine can prevent about 50% to 70% of cases and may be effective for up to 7 years (Wain, Hendriksen, Mikoleit, Keddy and Ochiai, 2005)

Table 4.3e: Prevalent of Typhoid Fever among Respondent

Frequency of typhoid illness	**Frequency**	**Percentage (%)**
Never	123	32.03
Rarely	129	33.60
Often	132	34.37
TOTAL	**384**	**100**

Source: Field Survey, 2014.

Several reports on the occurrence of typhoid fever mainly in developing countries have been reported. Reports on typhoid fever epidemics in developing countries consistently indicate that contamination of drinking water sourced from well water (Farooqui, Khan and Kazmi, 2009) and piped municipal drinking water (Kim *et al*., 2003; Lewis *et al*., 2005; Bhunia *et al*., 2009) were the main sources of outbreaks.

Anyebe *et al.,* (2008) carried out a research on the social and clinical correlate of typhoid fever infection in Zaria, Northern Nigeria where it was revealed that there were cases of typhoid fever among the inhabitants. A total of 188 patients were admitted with a diagnosis of typhoid fever within the study period (June 2000 to June 2005). The disease appeared to have a higher cumulative incidence between the months of May and June for the five years under study. October to March had relatively low incidences. However, on the whole, the incidence ranged from 20 cases in 2000 to 53 cases in 2005 with a mean incidence of 31.5 cases per year.

4.5 RELATIONSHIPS BETWEEN THE PREVALENCE OF *Salmonella typhi* IN DRINKING WATER AND THE OCCURRENCE OF TYPHOID DISEASE IN THE STUDY AREA

From the tables presented (4.2a, 4.2b, 4.2c) it can be seen that the prevalence of *Salmonella typhi* in some of the water sample collected for microbiological analysis predispose the inhabitant of Sabon Gari LGA to typhoid fever. The mean values for *Salmonella typhi* detected in some of these water samples are very high (C_3W, G_2W, G_2B, G_3W, G_3B and M_1B in Tables 4.2a, 4.2b and 4.2c respectively) which may be responsible for the frequent exposure of *Salmonella typhi* to the inhabitants of these LGA. The absence of *Salmonella typhi* in tapwater and sachet water can be attributed to the fact that standard disinfection procedures used in drinking water treatment process are active against *Salmonella typhi* at point of production. The water sample for this research work were collected at point of production and quickly taken for

microbiological analysis.

A reconnaissance survey on the LGA carried out (2014) showed that most of the households don't consume sachet water and tapwater directly from the point of production. Some of the water are been consumed weeks after production. The tapwater and sachet water are usually stored for a period of time before being consumed.

Sunday, Michael, and Adindu (2011) studied storage effect on the quality of sachet water produced within Port Harcourt Metropolis, Nigeria and noted a gradual increase of total aerobic heterotrophic bacterial counts in all the brands tested up to week 8 followed by decrease in counts up to the end of the experiment, a growth pattern typical of microorganisms growing in closed system. Treated water is not completely sterile, it may not be entirely free of all infectious microorganisms as Tables 4.2a, 4.2b, and 4.2c indicate for tapwater and sachet water. The potential danger associated with treated water is contamination, which is a factor of source of the water itself, treatment, packaging materials and closure (Omalu *et al*., 2012). Under prolonged storage of treated water at favorable environmental conditions, total aerobic heterotrophic bacteria can grow to levels that may be harmful to humans (Sunday *et al.*, 2011). Therefore, infection from sachet water and tapwater presented in Tables 4.2a, 4.2b and 4.2c, might occur during scooping of tapwater from the container or drinking the sachet water already stored for weeks. Sharma *et al.,* (2009) showed that the unsafe use of water, namely scooping out water from containers instead of using piped water or water stored in a narrow mounted container at home was associated with typhoid fever.

The results in Table 4.3e do not fully compliment the results of microbiological analysis in Table 4.2a, 4.2b and 4.2c with respect to the percentage. In the results of the microbiological analysis, the prevalence of *Salmonella typhi* in drinking water sources is not that rampant as only

few (< 50%) selected ones show the presence of this pathogen compared to about 70% of the respondents falling sick due to typhoid as indicated in Table 4.3e. However these results justify the findings of Sunday *et al.* (2011) and Sharma *et al.* (2009) which states that treated water stored for long before use have the possibility of being contaminated and scooping of tapwater from container at home was associated with typhoid fever. This findings account for the 70% of respondent falling sick as a result of typhoid as part of the sachet water and tapwater presented in Tables 4.2a, 4.2b, 4.2c possibly contributed to the spread of this pathogen during storage.

Several studies describe Salmonella prevalence in drinking water in African countries, mainly in South Africa and Nigeria (Potgieter *et al.,* 2005; Akinyemi, Oyefolu, Salu, Adewale and Fasure, 2006; Momba, Malakate, and Theron, 2006; Oguntoke, 2009; Oluyege, Dada and Odeyemi, 2009). In Nigeria surface and groundwater used as drinking water sources in rural communities were also shown to be reservoirs of Salmonella (Akinyemi *et al.,* 2006; Oguntoke, Aboderin, and Bankole, 2009; Oluyege *et al.,* 2009). In addition, the surveys of Salmonella prevalence in drinking water in Nigeria undertaken by Oluyege *et al.* (2009) showed that all the Salmonella strains isolated were resistant to several antibiotics. Furthermore, multi-drug resistance (MDR) to more than 4 antibiotics was observed in most of these isolates (Oluyege *et al*., 2009). Therefore, it can be seen that the prevalence of Salmonella in drinking water is inevitably the major cause of typhoid as some of the strains of Salmonella detected by these authors are resistance to some typhoid antibiotics, this justifies the frequent diagnosis of typhoid as earlier described above in Sabon Gari LGA even after treatment with these antibiotics.

The results in table 4.2a, 4.2b and 4.2c revealed that most of the well water and some of the boreholes are grossly contaminated with *Salmonella typhi*. According to one way Analysis of Variance conducted on the prevalence of Salmonella in all of the water samples as presented in

Table 4.4, there is no significant difference on the *Salmonella typhi* count in all the wards at 0.05 significant level. Though tapwater and sachet water tested negative to *Salmonella typhi* notwithstanding their sample size (total of 6) does not cause a significant difference among the sample mean. This result slightly conforms to the work of Uzoigwe (2011) where the researcher also showed that all the water samples (boreholes) from both areas in his research work had very high counts of Salmonella and faecal coliforms.

Table 4.4: ANOVA Showing Mean Difference between and Within the Groups of Samples Collected for Microbiological Analysis

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	565341353.383	2	282670676.692	0.190	0.829
Within Groups	23818342857.143	16	1488646428.571		
Total	24383684210.526	18			

4.6 SOCIO-ENVIRONMENTAL FACTORS AFFECTING THE OCCURRENCE OF *Salmonella typhi* AND TYPHOID FEVER IN THE STUDY AREA

The incidence of typhoid fever point to the problem of general water supply in most parts of Zaria metropolis (Anyebe *et al,* 2008). Patients who use tap water and well water for drinking had similar incidences of typhoid (42.6% and 41%). An explanation for this is the possible contamination and inadequate treatment of tapwater, especially during the rainy season, a period often associated with high microbial contamination of surface flowing water.

Although contaminated water (Kelly-Hope, Alonso, Theim, Anh, and Canh, 2007) have been identified as the major risk factor for typhoid prevalence, a range of other factors have been reported in different endemic settings such as poor sanitation (Karkey, Arjyal, Anders, Boni and

Dongol, 2010), close contact with typhoid cases or carriers (Tran *et al.,* 2005), level of education, larger household size (Sur, Ali, Seidlein, Manna and Deen, 2007; Karkey *et al*. 2010), personal hygiene (Kelly-Hope *et al.,* 2007), poor life style (Kothari, Pruthi and Chugh, 2008), and travelling to endemic areas (Whitaker, Franco-Pardes, del Rio and Edupuganti, 2009).

The socio-environmental factors that contribute to the prevalence of typhoid fever within Sabon Gari LGA have been identified and the respondents have been able to give their own view on these factors. These factors have been found to correspond with previous research works mentioned above.

Table 4.5 presents the results of the respondents based on their attitude and perceptions regarding the socio-environmental factors that contribute to the prevalence of typhoid fever in the area.

Table 4.6: Respondents Views on Socio-Environmental Factors Affecting Sources of Drinking Water

Parameters	**The environment of the sources of drinking water are not sanitized**		**The sources of drinking water is not clean**		**Low economic (income) status**		**Large size of household (more than 6)**		**Low educational status**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Agree	145	37.76	124	32.29	128	33.33	185	48.18	106	27.60
Disagree	212	55.21	190	49.48	197	51.30	171	44.53	254	66.15
Neutral	27	7.03	70	18.23	59	15.37	28	7.29	24	6.25
TOTAL	**384**	**100**	**384**	**100**	**384**	**100**	**384**	**100**	**384**	**100**

Source: Field Survey, 2014.

After careful analysis of the respondents from the 384 copies of questionnaire distributed on socio-environmental factors affecting sources of drinking water, 145 (37.76%) agree that the environment for drinking water source is not sanitized, 124 (32.29%) agree that the water they drink is not clean, 128 (33.33%) agree they are not economically buoyant (poor), 185 (48.18%)

agree they are many in their household and 106 (27.60%) agree they are not educated. These figures are indications of the existing socio-environmental problems that affect the provision of potable water in Sabon Gari LGA. In an average at least 138 of the respondents agree to these existing socio-environmental factors.

People with high level of education and good economic status tend to maintain a good lifestyle as they are quite aware of the importance of personal hygiene, they tend to use every resources available to ensure a clean environment as such they are less prone to infection due to contamination. Most of them live in their personal houses where they can maintain good personal and environmental hygiene. Those who live in rented houses with many tenants are prone to infections as only one toilet might be available for all the tenants. It has been reported that close contact with infected person can transmit this pathogen (Tran *et al,* 2005). From Table 4.5, 33.33% and 27.60% agree that they have low economic income and low educational status respectively. This might explain the high exposure of *Salmonella typhi* to the inhabitant of Sabon Gari LGA.

People living in large household are vulnerable to contamination because they share almost everything in the household including drinking water. When someone with infection has a bowel movement, they may pass stools (faeces) that contain the *Salmonella typhi* bacteria. If they do not wash their hands properly after going to the toilet, they can contaminate any water they touch. If this is drunk by another person, they may also become infected. In parts of the world with poor levels of sanitation, infected human waste can contaminate the water supply. People who drink this contaminated water can develop typhoid fever.

Typhoid fever is associated with poor environmental and living conditions especially in economically poor countries among people with low income (Okome-Nkoumou *et al.,* 2000). In

the LGA studied, tapwater supply is not constant and waste disposal systems are poor. Toilet facilities are usually absent and nearby bushes are used for defecation, while domestic wastes are indiscriminately disposed of in the surroundings. Well water is more likely to be polluted in the wet season because the rains may wash debris and littered garbage into wells. Raised platform for wells may prevent pollution of well water (Musa, Shehu and Lukman, 2009).

In Table 4.5, 70.05% of the respondents agree that sources of drinking water are not clean and the environment for the sources of drinking water is not sanitized. This is a strong socio-environmental problem to the inhabitants of Sabon Gari LGA as Donald (2004), in his studies revealed that in region of the world where sanitation and garbage disposal are lacking, typhoid continue to destroy life. These factors are all the reason for the prevalence of typhoid fever in the study area.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS

The major sources of drinking water within Sabon Gari LGA are tapwater, well water, sachet water, and boreholes. Tapwater is the most consumed drinking water while sachet water is the most preferable.

The microbiological analysis of these sources of water indicates that some of the well water and boreholes are contaminated with *Salmonella typhi* C_3W (1.52×10^5 cfu/ml), M_1B (6.6×10^4 cfu/ml), G_2W (8.0×10^3 cfu/ml), G_2B (1.5×10^4 cfu/ml), G_3W (1.9×10^4 cfu/ml), G_3B (2.0×10^4 cfu/ml). The sachet water analysis shows no contaminant of *Salmonella typhi* (0 cfu/ml) and feacal coliform forming unit. The tapwater supply is also free of *Salmonella typhi* contrary to people's perception and contains no feacal colony forming unit indicating their potability at point of production.

The surveillance data collected from nearby hospitals revealed that the inhabitants of Sabon Gari LGA are exposed to *Salmonella typhi.* All the hospital data collected indicates the prevalence of *Salmonella typhi* in the Widal test conducted with respect to the total number of test conducted within each laboratory where samples are collected. The summary of all the hospital data collected (Table 5.1) indicate that there were 1332 cases of widal test conducted for all the 3 hospitals. Of this, 91% were significant cases and some might cause typhoid disease.

Analysis of variance (ANOVA) on *Salmonella typhi* count carried out for all the wards where samples are collected revealed that there were no significant differences on the *Salmonella typhi* detected in all the water samples.

There is a relationship between the prevalence of *Salmonella typhi* in drinking water and incidence of typhoid fever within the LGA. The results of microbiological analysis compliment

the result of incidence of typhoid within the LGA. Low income, education, poor hygiene, poor water supply and large household size are the socio-environmental factors that contribute to the prevalence of typhoid according to the responses from the inhabitants of the LGA.

5.2 CONCLUSION

It can be concluded at this point that the major sources of water within Sabon Gari LGA are tapwater and sachet water. At point of production sachet water and tapwater are free of *Salmonella typhi* therefore, potable for drinking. Some of the drinking water within this LGA is contaminated with *Salmonella typhi* (C_3W, M_1B, G_2W, G_2B, G_3W, G_3B) while some of the drinking water is free of this microorganism and suitable for drinking (C_1B, G_1B, M_2B, M_3B, and all the tapwater and sachet water). The presence of *Salmonella typhi* in the water samples can be attributed to the unhygienic conditions of the environment where drinking water is being collected and there are possible contaminations of drinking water from municipal and household wastes.

The inhabitants of Sabon Gari LGA are exposed to *Salmonella typhi* and it can be traced to some of the drinking water consumed. Drinking water within this LGA transmit *Salmonella typhi* either directly from the water source or from the container used in fetching or drinking. The prevalence of typhoid among the inhabitant of this LGA cannot be seen as an epidemic, this can be attributed to the fact that the drinking water in the LGA is not grossly contaminated with *Salmonella typhi* and the level of hygiene is not too bad as some of the inhabitant have taken some measures to curtail the rate of contamination and pollution. Lack of education, poor hygiene, economic constrain, overcrowdings and lack of access to clean water are the common socio-environmental factors that promotes the occurrence of typhoid in Sabon Gari LGA.

5.3 RECOMMENDATIONS

People should be discouraged from buying sachet water on the street. Isolation of sources of drinking water from human activities that have the possibilities of contaminating it is an important step to take when protecting drinking water. Another line of action is to prevent pollution activities in the areas which may be a source of infection. This means defining areas where sewage sludge should not be applied, exercising strict control over discharge of sewage effluent and agricultural wastes and the location of sites for the dumping of garbage and toxic wastes.

Sources of groundwater such as wells and boreholes should be sited and constructed so as to be protected from surface drainage where all kinds of waste finds their way into it easily.

Drinking water should be adequately treated before being consumed. Long time storage should be discouraged for drinking water of any kind as they create favorable condition for microorganism growth and causes undesirable changes in water quality. The environment should be kept clean as they prevent contamination. Maintaining personal hygiene will also go a long way in preventing self infection with *Salmonella typhi*.

There is need for further research on the role of food in transmission of typhoid disease within this LGA. Typhoid fever is an acute illness associated with fever caused by *Salmonella typhi.* This is because the bacteria are deposited in water or food by human carrier and are then spread to other people in the area. The incidence of typhoid fever in Sabon Gari LGA is markedly growing therefore, proper care need to be taken.

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Appendix 1

DEPARTMENT OF GEOGRAPHY
AHMADU BELLO UNIVERSITY, SAMARU-ZARIA
QUESTIONNAIRE FOR THE INHABITANT OF SABON GARI, ZARIA

Questionnaire on evaluation of *Salmonella typhi* in Drinking Water Within Sabon Gari L.G.A., Zaria, Kaduna State.

Dear Respondent,

I am a student of Geography undertaking a research project to determine the quality of water with regard to the presence of *Salmonella typhi* in drinking water, also to know the kind of water consumed mostly (tap water, sachet water, boreholes, and well water), and how often are the inhabitant of this region diagnosed of typhoid disease. To this end I kindly request that you complete the following short questionnaire regarding your habit, preference, health condition (in respect to typhoid disease) and attitudes towards drinking water. It should take no longer than 10min of your time. Your response is of utmost importance to me.

Please answer the following questions by crossing (x) the relevant block or writing down your answer in the space provided.

Section A – Background information

This section of the questionnaire refers to background or biographical information. Although I am aware of the sensitivity of the questions in this section, the information will allow me to compare groups of respondents. Once again, I assure you that your response will remain anonymous. Your co-operation is appreciated.

1. Gender

Male	1
Female	2

4. How would you describe your economic status?

Poor	1
Below average	2
Average	3
Above average	4
Affluent	5

5. Your highest educational qualification?

Primary	1
Secondary	2
Tertiary	3
Post-graduate	4
No formal education	5

6. How would you describe the area in which you are residing?

Urban	1
Rural	2

7. Size of your household, i.e. the number of people including yourself, who live in your household/dwelling for at least three months of the year.

Live alone	1
2	2
3	3
4	4
5 or 6	5
More than 6	6

Section B

This section of the questionnaire explores your habits, health (in respect to typhoid disease), and preferences, if any, with regard to the drinking water consumed.

8. Please indicate which one of the following types of water you consume most. (Mark one option only in each of the columns.)

	Used most	Preferred
Sachet water	1	1
Tap water	2	2
Well water	3	3
boreholes	4	4
others	5	5

9. What is the most important reason for using the type of water specifies in question 8. (Mark one option only.)

It is more safer	1
It is the most readily available	2
The place where I work/study/live provide the most used type	3
Other (specify)	4

10. If the type of water consume most often differ from the one you prefer most, what is the most important reason for this discrepancy? (Mark one option only)
If there is no discrepancy, please go to the next question.

My prefer is not safe for consumption	1
It is not readily available	2
The place where I work/study/live does not provide the preferred type	3
Other (specify)	4

11. This question is for those who sometimes or often consume tap water, borehole or well water. How do you consume the water?

		Tap water	Boreholes	Well water
I allow it to decant before consumption	1			
I boil it before consumption	2			
I chlorinate the water before consumption	3			
Consume directly without any of the three above	4			
Other (specify)	5			

12. How would you rate the quality of water you drink?
(Mark one option only in each columns.)

	Poor	Very poor	Good	Very good	Fair
Sachet water	1	2	3	4	5
Tap water	1	2	3	4	5
Boreholes	1	2	3	4	5
Well water	1	2	3	4	5

13. How would you rate the sanitary state of your environment with regards to source of drinking water?

	Poor	Very poor	Good	Very good	Fair
Sanitary level of source of water	1	2	3	4	5

14. How often are you diagnosed/fall sick of typhoid disease?

	Never	Rarely	Often	Always
Typhoid disease	1	2	3	4

15. If the option you tick in question 14 above indicate you fall sick of typhoid disease, do you consider the water you consumed to be the cause of typhoid disease?
If it does not indicate, please go to the next question (16).

Yes	1
No	2

16. Do you consider yourself to be safe from disease regarding the water you consumed?

Yes	1
No	2

Section C

This section explores your attitude and perceptions regarding water consumption.

To what extent do you agree with each of the following statements? Please indicate your answer using the following 5-point scale where:

1. = Strongly disagree
2. = Disagree
3. = Neutral
4. = Agree
5. = Strongly agree

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
17. Drinking water increases my risk of getting typhoid.	1	2	3	4	5
18. I prefer drinking sachet water	1	2	3	4	5
19. I prefer drinking tap water	1	2	3	4	5
20. I prefer drinking borehole water	1	2	3	4	5
21. I prefer drinking well water	1	2	3	4	5
22. I drink sachet water because it is safer	1	2	3	4	5
23. I drink tap water because it is safer	1	2	3	4	5
24. I drink borehole water because it is safer	1	2	3	4	5
25. I drink well water because it is safer	1	2	3	4	5
26. I feel safe with the type of water I consumed	1	2	3	4	5
27. I don't have access to safe drinking water	1	2	3	4	5
28. The sanitary environment in respect to source of drinking water is not sanitized	1	2	3	4	5

Thank you for your co-operation in completing this questionnaire.

Appendix 2

Table 3.1: List of packaged water companies within Sabon Gari L.G.A

S/N	Names	Wards	S/N	Names	Wards	S/N	Names	Wards
1	Jericom Water	Dogarawa	31	Nasuka Water	Hanwa	61	Basaco Water	Hanwa
2	Jovick Water	Ckikaji	32	Zabi Water	Zabi	62	Bol-Mac Water	Chikaji
3	Desanco Water	Hanwa	33	Hanwa Water	Hanwa	63	Aderems Water	A. Gabas
4	Ojjida Water	Jushi	34	Salwa Water	Muchia	64	Kemdal Water	Chikaji
5	Akogba Water	Muchia	35	Fersco Water	A. Gabas	65	Gimbiya Water	Hanwa
6	Nasara Water	Hanwa	36	Simi Water	Muchia	66	Guru Water	Zabi
7	Fansa Water	Hanwa	37	Shimak Water	A. Gabas	67	Ollan Water	A. Gabas
8	Emasol Water	A. Gabas	38	San Water	A. Gabas	68	Zubby Water	
9	Laydav Water	Jushi	39	Shobos Water	A. Gabas	69	Isam Water	
10	E.M.D Water	Hanwa	40	Dan Arewa Water	Chikaji			
11	Nasiba Water	A. Gabas	41	Santex Water				
12	Aqua Divine Water	Chikaji	42	Sabo Water	Muchia			
13	Fahad Water	Hanwa	43	Naib Water	A. Gabas			
14	First Value Water	Hanwa	44	De-Effisy Water	Zabi			
15	Inem Water	Hanwa	45	Empire Water	A. Gabas			
16	Himan Water	Chikaji	46	B-Best Water	Chikaji			
17	Baruch Water	Basawa	47	Lolayo Water	A. Bomo			
18	De Concord Water	A. Gabas	48	Dansil Water	Basawa			
19	Dogarawa Water	Dogarawa	49	NAPRI Water	A. Bomo			
20	Annur Water	A. Gabas	50	De Nas Water	Zabi			
21	Co-operate Water	Dogarawa	51	H.R Water	A. Gabas			
22	Aishat Water	A. Gabas	52	Ausbliss Water	A. Gabas			
23	Sadom VIP Water	A. Gabas	53	Akuakuul Water	Basawa			
24	Pariso Water	Hanwa	54	Nazib Water	A. Gabas			
25	Ammer Water	Basawa	55	New Era Water	A. Gabas			
26	Crown Mayor Wtaer	Basawa	56	Life Span Water	Basawa			
27	IBM Water	A. Bomo	57	Ras Water	Hanwa			
28	Shika Water	A. Bomo	58	Ashwal Water	Hanwa			
29	Dinson Water	Zabi	59	Kassa Water	A. Gabas			
30	Sunpat Water	Hanwa	60	Marvic Water	Hanwa			

Appendix 3

Table 3.2: List of Sabon Gari Local Hospitals, Clinics and Primary Health Care

Clinics			
S/N	**Health Facilities**	**Wards**	**Who Manage The Facilities**
1	Aviation Clinics	Basawa	F.G
2	MRS Clinic Barrack	Basawa	F.G
3	Leather Research Clinic	Basawa	F.G
4	Savanna Clinic	Bomo	Private
5	Maternity Marhaba Clinic	Dogarawa	Private
6	Alpha Clinic	Hanwa	Private
7	Hakuri Clinic	Chikaji	Private
8	Victory Maternity Clinic	Chikaji	Private
9	MIMIT Sabon Gari	Chikaji	Private
10	Abdulrahman Clinic	Jushi	Private
11	Alheri Clinic	Jushi	Private
12	May Fair Clinic	Jushi	Private
13	Kanawa Clinic	Jushi	Private
14	Hakuri Clinic	Jushi	Private
15	Hauwa Kulu Maternity Home	Muchia	Private
16	Al-Ummah Clinic	Muchia	Private
17	Sick Bay ABU	Samaru	F.G
Hospitals			
1	Midway Hospital	Dogarawa	Private
2	Mumy Hospital	Hanwa	Private
3	Imani Hospital	Hanwa	Private
4	Salama Hospital	Hanwa	Private
5	Limi Hospital	Hanwa	Private
6	Al-Madinah Hospital	Hanwa	Private
7	Nana Hospital	Hanwa	Private
8	C H C ABUTH S/Gari	Chikaji	F.G
9	Elite International Hospital	Chikaji	Private
10	Joysam Hospital	Jushi	Private
11	Jama'a Hospital	Samaru	Private
12	Sauki Hospital	Samaru	Private
13	Salisu Hospital	Samaru	Private
14	Jocee Hospital	Anguwan Gabas	Private
15	Ladiya Hospital	Anguwan Gabas	Private
16	Sunshine Hospital	Anguwan Gabas	Private
17	General Hospital Major Abdullahi	Chikaji	State
18	General Hospital Shika	Bomo	F.G
19	Saidu Dange Hospital	Chikaji	F.G

Primary Health Care			
1	P.H.C Basawa	Basawa	L.G
2	P.H.C Palladan	Basawa	L.G
3	P.H.C Anguwan Rimi	Basawa	L.G
4	P.H.C Hayin Dogo	Bomo	L.G
5	P.H.C Bomo	Bomo	L.G
6	P.H.C Kwariwaren Manu	Bomo	L.G
7	P.H.C Chikaji	Chikaji	L.G
8	P.H.C Sakadadi	Dogarawa	L.G
9	P.H.C Dogarawa	Dogarawa	L.G
10	P.H.C Gwanda	Dogarawa	L.G
11	P.H.C Zangon Danbarrno	Dogarawa	L.G
12	P.H.C Hanwa	Hanwa	L.G
13	P.H.C Jama'a	Jama'a	L.G
14	P.H.C Abdu Kwari	Jushi	L.G
15	P.H.C Anguwan Kudu	Jushi	L.G
16	P.H.C Anguwan Mal. Sule	Jushi	L.G
17	P.H.C Madugu Muchia	Muchia	L.G
18	P.H.C Kwata	Muchia	L.G
19	P.H.C Samaru	Samaru	L.G
20	P.H.C Anguwan Jaba	Anguwan Gabas	L.G
21	P.H.C Zabi	Zabi	L.G
22	P.H.C Hayin Ojo	Zabi	L.G
23	P.H.C Shika Dam	Zabi	L.G
24	P.H.C Almajirai H/C M/Gwanda	Zabi	L.G