Thesis for the Degree of Master of Science in Interdisciplinary Water Resource Management

Assessment of Pathways for Contamination of Drinking Water Linked to Sanitation Practices and Behavior at Household Level: A Case Study of Gulariya Municipality, Bardiya, Nepal

Dhirendra Kumar Shahi

2019-1-50-0007

Nepal Engineering College

Changunarayan, Bhaktapur

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Supervised by Prof. Sabitri K. Tripathi

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Interdisciplinary Water Resource Management

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Declaration

I hereby declare that this study entitled "Assessment of Pathways for Contamination of Drinking Water Linked to Sanitation Practices and Behavior at Household Level: A Case Study of Gulariya Municipality, Bardiya, Nepal" is based on my original work. Related works on the topic by other researchers have been duly acknowledged. I owe all the liabilities relating to the accuracy and authenticity of the data or any other information included hereunder.

Signature: Dhirendra

Name of the Student: Dhirendra Kumar Shahi

P.U. Registration Number: 2019-1-50-0007

Date: 15 march, 2023

Recommendation

This is to certify that this thesis entitled "Assessment of Pathways for Contamination of Drinking Water Linked to Sanitation Practices and Behavior at Household Level: A Case Study of Gulariya Municipality, Bardiya, Nepal" prepared and submitted by Dhirendra Kumar Shahi, was completed under my supervision in the partial fulfillment of the requirements of the Master of Science (M.Sc.) degree in Interdisciplinary Water Resources Management awarded by Pokhara University has been completed under my supervision. I recommend the same for acceptance by Pokhara University.

Signature:

Name of the Supervisor: Sabitri K. Tripathi

Designation: Professor

Date signed: March 15, 2023

Certificate

This thesis entitled "Assessment of Pathways for Contamination of Drinking Water Linked to Sanitation Practices and Behavior at Household Level: A Case Study of Gulariya Municipality, Bardiya, Nepal" prepared and submitted by Dhirendra Kumar Shahi has been examined by us and is accepted for the award of the degree of Master of Science (M.Sc.) in Interdisciplinary Water Resource Management by Pokhara University.

Dr. Dinesh Raj Manandhar External Examiner	.... Signature	15 March 2023 Date
Prof. Sabitri K. Tripathi Supervisor	.... Signature	March 15, 2023 Date
Prof. Dr. Thusitha Chandani Shahi Director, *nec* CPS Nepal Engineering College Center for Postgraduate Studies	.... Signature	March 15, 2023 Date

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Abstract

Faecal sludge contains excessive amounts of pathogens that have been expelled; these pathogens may also be hazardous to plants and soil, and they may also negatively affect the metabolism of soil microorganisms. Water is obtained from sources that are contaminated with faeces, collected in open or otherwise unprotected containers, and then kept in those same containers under an environment that may not be suitable for storing water. The main aim is to explore the pathways of contaminations of drinking water arising from sanitation practices and behavior at household level. There are three specific objectives: To assess the contamination of groundwater due to onsite sanitation system, To analyze contamination of drinking water from selected households focusing their behavioral practices from source to mouth, and to assess the socio-cultural barriers in managing water quality at household level. 50 water samples from the source, storage containers, and consumption vessels were examined throughout the dry and wet seasons after visiting a total of 33 households. *E.coli*, Nitrate and Temperature were used as a faecal contamination indicator to evaluate the water quality and also pH was used as an important parameter. For the 30 households, a survey of households was done. Additionally, focused group discussions and key informant interviews were conducted. 14 (42.42%) of the tested water samples taken from hand pumps in dry season were highly unsafe, 8 (24.24%), 7 (21.21%) and 4 (12.12%) of the hand pumps were low, intermediate and safe respectively. 29 (87.88%) of the tested water samples taken from hand pumps in wet season were highly unsafe. 3 (9.09%) and 1 (3.03%) of the pumps were low and safe respectively. The correlation between Nitrate and depth, Nitrate and distance from hand pump to septic tank and Nitrate and pH are not significantly different. Correlation between *E.coli* and depth, *E.coli* and distance from hand pump to septic tank and *E.coli* and pH are not significantly different. Relationship between contamination level of the water samples collected from the sources in dry and wet seasons is not significantly different. Water quality deteriorates from the source to the storage and from the storage to the consumption point when suitable water handling and procedures are not being used at the household level. Socio-cultural barriers such as lack of knowledge, inadequate infrastructure, and limited access to resources are the main obstacles to managing water quality. Implementing septic tanks with the sealed bottom is to prevent seepage to groundwater sources for water source protection. To improve the water quality, properly designing WSP and regularly monitoring, supervising it, conducting general awareness and training to the people relating to the sources, and addressing socio-cultural barriers to interaction about safe water.

Key words: Groundwater, *E.coli*, Nitrate, Hand pump, WSP, Dry Season, Wet Season

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Abbreviations/Acronyms

E. Coli	Escherichia Coliform
FGD	Focus Group Discussion
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
GoN	Government of Nepal
HHs	Households
KII	Key Informant Interviews
MPN	Most Probable Number
ODF	Open Defecation Free
PoU	Point of Use
PVC	Poly Vinyl Chloride
SDGs	Sustainable Development Goals
SDP	Sector Development Plan
SHWGs	Self Help Women Groups
SODIS	Solar Disinfection
SPSS	Statistical Package for Social Survey
UNICEF	United Nations Children’s Fund
WASH	Water Supply, Sanitation and Hygiene
WHO	World Health Organization
WSP	Water Safety Plan

CHAPTER 1
INTRODUCTION

1.1 Background

There are still 2.4 billion people without access to clean drinking water and 4.2 billion people without clean restrooms, with the majority of these individuals living in low and middle-income countries (UNICEF & WHO, 2019). The Sustainable Development Goals (SDGs) to increase food security, promote farmers' livelihoods, and minimize water resource pollution can all be aided by the connection between productive agricultural reuse and carefully managed sanitation. In order to optimize the benefits of reusing human waste, it is vital to address hazards to the public's health and the safety of sanitation employees, farmers, local communities, and produce consumers (WHO 2015). Inadequate Faecal Sludge Management (FSM) and proper sanitation are major concerns for Nepal. According to SDG 6, "Ensure availability and sustainable management of water and sanitation for all" has also been prioritized by the Government of Nepal (GoN) through the country's sectoral development plan (SDP), related policies and strategies. In order to achieve the WASH sector target by 2030, the Ministry of Water Supply has developed a long-term sector development plan by selecting priority areas for future interventions and a variety of thematic approaches. SDP is a framework for planning, implementing, coordinating, and monitoring all actions in the sector that is in accordance with the Sustainable Development Goals. The government has established goals to provide all citizens with basic WASH services by 2020, and to raise service levels (to a medium 50% and high 50%) by the end of 2030 (NPC, 2018).

Faecal sludge contains excessive amounts of pathogens that have been expelled; these pathogens may also be hazardous to plants and soil, and they may also negatively affect the metabolism of soil microorganisms. They can spread through the skin or the mouth by eating vegetables that have been contaminated (if Schistosomes and Hookworms) (Carr, 2001). As a result, waterborne illnesses and even deaths can cause which is a major concern. The various microbiological organisms that contaminate drinking water at various points, from source acquisition to distribution and consumption at the household level, are the main cause of water-borne diseases.

Diseases including Cholera, Typhoid, Diarrhea, Dysentery, Hepatitis A, etc. are spread due to contaminated water and poor sanitation practices. Unsanitary and improperly protected (open or poorly covered) water collection and storage vessels, as well as unclean activities in water fetching and use, can contribute to microbial contamination in stored water in households. Unsanitary water dispensing practices, such as using contaminated hands and dippers and failing to properly clean the vessels, cause the accumulation of sediments and pathogens in the vessels (Tambekar, et al., 2008). Faecal sludge management requires the safe end use or disposal of faecal sludge as well as its storage, collection, transportation, and treatment (Strande, 2014). Lacking a more effective method, faeces are improperly disposed of, endangering both human and environmental health. This is because faeces are dumped in open areas, downstream habitats, or neighboring areas (Blackett & Hawkins, 2017). Therefore, Faecal sludge management is a significant difficulty in many developing countries, particularly in those with rapidly urbanizing regions. Every day, tons of faecal sludge from toilets go untreated, which can be a serious issue and lead to many environmental and health hazards.

In the context of Nepal, water is obtained from sources that are contaminated with faeces, collected in open or otherwise unprotected containers, and then kept in those same containers under an environment that may not be suitable for storing water. For example, water stored in open vessels near livestock areas in the homestead or storage near the wastewater drain may increase the likelihood of water contamination. In such cases, the stored water is often heavily contaminated with faecal microbes and possesses high risks of infections and exposure to diseases. In addition, many urban and rural piped water supplies also have possibilities of contamination of faecal microbes due to such inherent deficiencies as poor source water quality, inadequate water treatment and distribution system, vulnerability to infiltration of faecal microbes and likely intrusion of sewage. Even piped water supplies of satisfactory microbial quality can pose risk to infectious diseases if the water gets contaminated due to unsanitary collection and storage conditions and water handling practices within the households. Considering these possibilities of contamination at different stages of water delivery system, the water collected and stored in the households for drinking and other domestic uses have high risk of getting contaminated, especially in the poor communities where sanitary practices in the households are often unsatisfactory and people lack awareness and appreciation for behavioral practices in water handling and use (Sobsey, et al., 2003). The focus on portable water and FSM is essential to achieve the goal of accessible and affordable safe water and sanitation for all.

1.2 Statement of the Problem

Water supply and sanitation sectors have seen significant investment and cooperation from national and international organizations, but Nepal still has a big problem to achieve clean water and safe hygiene. Additionally, clean water is vulnerable to environmental pollution and may be contaminated at any point along the supply chain, from the source to the point of use (PoU). Water contamination is considered to be directly impacted by personal hygiene, sanitation practices, and water handling behaviors. Even though there have been several initiatives to supply safe water until the point where the source water becomes contaminated, such as the installation of treatment plants, source conservation, and so on.

Gulariya Municipality is one of the municipalities that are urbanizing quite quickly. By 2030, Nepal aims to have at least 95% of its sanitation and water supply systems safely managed in order to meet SDG 6.2. Due to the large number of toilets being built at the time, faecal sludge control was a top priority for the municipality. The septic tanks/pits were constructed with very few cemented rings and desludging has been done by manually either themselves or private emptier. Faecal Sludge Treatment Plant (FSTP) constructed after ODF, is not functioning properly and there is a lack of adequate monitoring and regulating mechanisms for sludge management. Muslims, Madhesi, Dalits and Marginalized community in this municipality must facing obstacles to have equitable access to resources and lack of awareness (Tripathi, et al., 2021).

The quality and quantity of the water that people have access to directly affects their health and livelihood. People are more vulnerable to health risks when the water they use is unsafe. UNICEF (2020) generally plays essential roles in ensuring appropriate water quality at the point of use by their own behavioral practices of handling and using water. Faecal contamination is likely possible even within the house when drinking water is placed in open storage. It is well recognized that exposure to domestic and animal wastes as well as inappropriate management techniques are the main reasons of reduced water quality. This pattern has been confirmed by studies on water contamination in rural Sierra Leone, rural Honduras, South Africa, and Zimbabwe (Rufener , et al., 2010). Although in-house water contamination has negative impacts, its exact source is still unknown, and its impacts on people's health and wellbeing have not been properly researched. There has been no comparative study on water contamination at the household level, comparing water collected from contamination-free and contaminated sources. People's water handling behaviors and the possibility of water contamination due to unsanitary practices could be improved through education and awareness programs. Because of this, it is possible for two groups of people to have similar social and economic characteristics but have different levels of awareness concerning water handling and hygienic practices. *E.coli* and Nitrates are used as an indicator to determine the drinking water contamination for groundwater quality assessment and *E.coli* are used as an indicator to know the contamination due to handling and consumption behavior at household level in Gulariya Municipality.

In the previous study of Brown Gold project, it was found that the toilets in this municipality have septic tank/concrete rings unlined at the bottom and there is high risk of percolation of sludge from concrete rings to nearby groundwater where the soil is alluvial and water table is shallow which can be the major cause of water contamination (Tripathi, et al., 2022).

1.3 Research Questions

The following sets of research questions are identified for the purpose of developing the overall and specific research objectives.

- How does faecal sludge management impact water quality deterioration for domestic (drinking) purposes in Gulariya Municipality?
- How do the behavioral practices responsible for contamination of water from sources to mouth at the household level?
- How various socio-cultural barriers have influenced the water handling behavior in the study area?

1.4 Research Objectives

1.4.1 General Objectives

- To explore the pathways of contamination of drinking water arise from sanitation practices and behavior at household level.

1.4.2 Specific Objectives

- To assess the contamination of groundwater due to onsite sanitation system.
- To analyze contamination of drinking water from selected households focusing their behavioral practices from source to mouth.
- To assess the socio-cultural barriers in managing water quality at household level.

1.5 Significance of the Study

This study is important because Gulariya Municipality has currently unsafe faecal sludge management system. The outcome of the research will help find out the quality status of water sources for domestic purpose and current faecal sludge management (FSM) practices and to explore the possible measures to address for better and systematic ways for FSM and to make the water safe for drinking. With this study, it is expected that stakeholders will be involved in the planning and implementation of faecal sludge management and aware to make the drinking water safe.

In the context of existing water supply system in Gulariya Municipality, almost all of the households have been served by private hand pump where no mechanism of water quality monitoring and system of water treatment are in place and therefore these people have been in higher risk of possible health consequences from unmonitored water quality in this community. Therefore, this will help to address the possible contamination of water at the household level due to behavioral practices of handling water and uses for improving the supply of water services to the people in a systematic way and to examine how drinking water can be contaminated at various stages such as at source, during transportation, storage and Point of Use (PoU).

This study will be useful for getting a general understanding of the routes for drinking water contamination in this municipality and thus helps for practitioner, professional's researchers and policy makers for future planning and policy making for effective WASH implementation in the municipality.

1.6 Scope and Limitations of the Study

The scope of works includes field visit, focus group discussion (FGD), key informant interviews (KII) and analysis of data collected from these tools of inquiries to find out the relationship between groundwater contamination and faecal sludge management practices. The study has conducted in Gulariya Municipality which includes groundwater quality assessment, behavioral impact on quality of drinking water, hygiene practices and risk of contamination throughout the sanitation service chain.

However, this research also has some limitations. They are as follows:

- It's possible that a single water sample may not accurately reflect the whole water quality scenario.

- Within a same household, the pattern and behavior of water usage may vary from person to person as well as between various households.

CHAPTER 2
LITERATURE REVIEW

This chapter includes information from previous studies, their findings and associated information regarding water, water resources, FSM, water quality, groundwater contamination, water quality standards, FSM technologies, health risk and relevant information supportive for this study from around the world.

2.1 Route of Contamination

The faecal-oral route of pathogen transmission has been well described and includes a number of different pathways, including water, food, fingers, soil, and flies. However, it is unknown how important each pathway is in relation to the others. The burden of disease from diarrhea and other sanitation- and hygiene-related diseases can be reduced by providing access to safe water and sanitation facilities and by promoting good hygiene practices. Better sanitation facilities, such as latrines and flushing toilets, allow people to properly dispose of their waste, which can help prevent the spread of many diseases (CDC, 2019). It becomes very challenging to maintain safe water quality and conduct appropriate hygiene without adequate sanitation. For example, the possibility of the nearby water sources becoming contaminated with faeces is great if there are no latrines available in the community (Pruss et al., 2006). Even if people aren't defecating in the open, they might be utilizing a bucket or container of some kind that they will eventually have to empty manually. This could potentially offer a route via which faecal pollutants enter water supplies. The risk of faecal-oral transmission will also increase if the person emptying the container's hands are not adequately washed afterwards (Trevett, et al., 2005).

The disease-transmission mechanism for faecal-oral contaminants is shown in Figure 2.1 (World Bank, 2020).

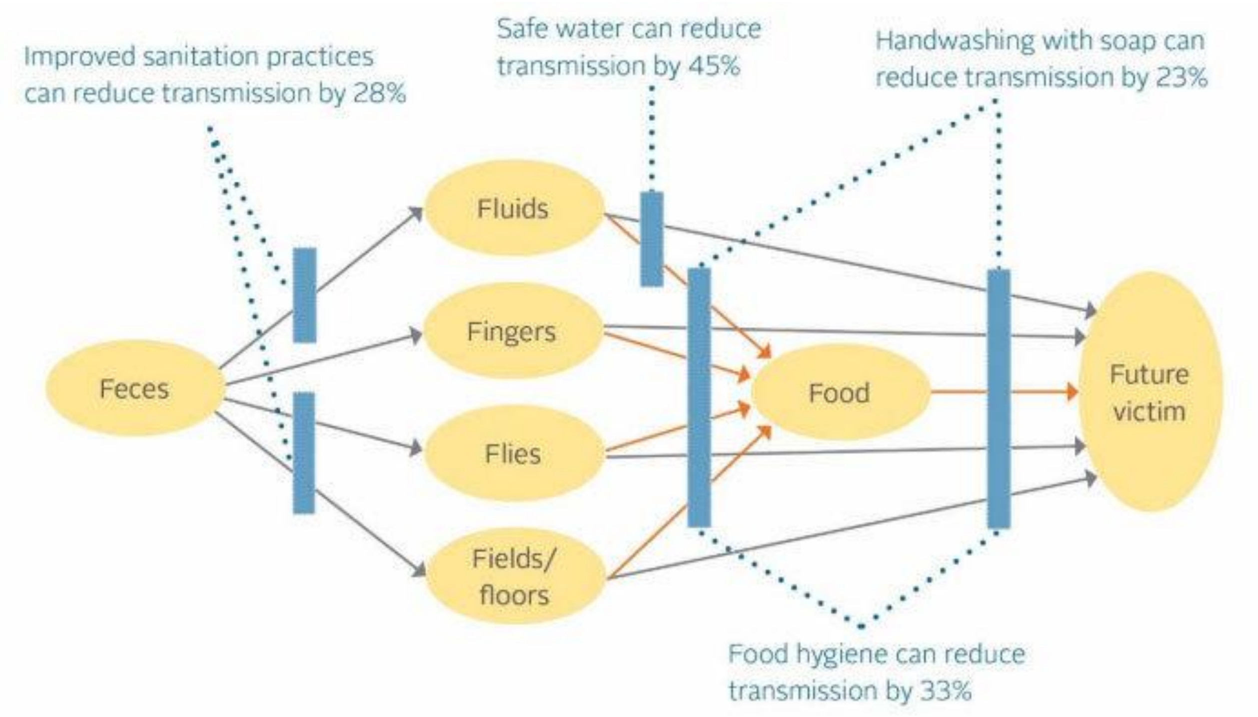


Figure 2.1 Pathways of Transmission of Pathogens Through the Faecal Oral Route and Percentage

(Teferi & Samuel, 2021)

2.2 Water Supply, Sanitation and Hygiene

For people to survive and maintain their health, it is essential to provide water, sanitation, and hygiene (WASH) services in sufficient quantities and of acceptable quality. Every day, thousands of children die or get sick due to inadequate access to safe water and sanitation services and poor hygiene practices. Without Water supply, Sanitation and Hygiene (WASH), sustainable development is impossible (UNICEF, 2011). Most of the populations in developing nations that are impacted by WASH issues are those that are extremely poor and typically live in rural or peri-urban areas. Lack of funding, insufficient financial resources, inadequate water supply and sanitation services, poor hygiene behaviors, and poor sanitation in public places, including hospitals, health centers, and schools, are some of the key issues that are to responsible for this situation.

2.2.1 Water Safety Plan

Water Safety Plan (WSP) is the most effective means of ensuring the safety of drinking water supply through the use of a comprehensive risk assessment and risk management approaches (WHO, 2008). WSP is also a proactive effort to reduce risks and prevent contamination before water reaches the consumers which can be achieved by shifting management to a holistic risk-based approach that covers the water production, abstraction and distribution, from the catchment to the consumers (WHO and IWA, 2010).

The WSP approach allows for appropriate institutions to work together making informed decisions relating to the strategic, financial, operational and legal aspects of drinking water quality management. Such stakeholder cooperation that is an implicit part of WSP, for example, facilitates the identification of appropriate barriers to contamination that does not overly focus on expensive treatment processes, rather considers a range of options that may result to improving the raw water quality and maintenance of post treatment water quality delivered to the consumers (WHO and IWA, 2010).

The objectives of a water safety plan are to ensure safe drinking water through good water supply practices that involve (WHO, 2010):

i. Prevention of contamination of water at the source,
ii. Treatment of water to reduce or remove contamination to the extent necessary to meet the water quality targets, and
iii. Preventing re-contamination during storage, distribution and handling of drinking water.

2.3 Hygiene Behavior

Hygiene is the science of preserving and promoting the health of both the individual and the community and embraces personal, domestic and community hygiene. Hygiene, in more specific terms, refers to procedures or activities used to reduce microbial contamination on environmental sites and surfaces, etc., in order to prevent the spread of infectious disease (Larsen , 2003). The public health perception of hygiene emphasizes cleanliness of water, food, and the environment, whereas the popular perception is primarily concerned with dirt avoidance, germ killing, and bathroom and hospital cleanliness. Recently, hygiene has been emphasized as the "most economically sustainable prevention strategy" (Stanwell-Smith , 2007). Hygiene refers to a variety of actions, all of which should act as barriers to the spread of biological contamination. While hygiene practices are essential in the prevention of infectious disease, they also serve other purposes. Among these is the desire to create order and beauty, as well as to demonstrate respect for social morality (Curtis, et al., 1993). Barriers primarily fall into two categories: The purpose of primary barriers is to stop infections from entering the environment after defecation. This can be achieved by utilizing clean restrooms, disposing of human waste safely, and washing hands after using the restroom. Practices that prevent faecal germs that have gotten into the environment from reaching a new host are considered the second type of barrier. It involves a variety of behavior: washing hands with soap and water on a regular basis, covering food and water tanks, maintaining cleanliness in the household, controlling flies, etc. (Graf, et al., 2008). Drinking water must be handled carefully to prevent recontamination throughout collection, transportation, storage, and usage. According to WHO recommendations, hygiene education programs initiatives should include behaviors related to water storage, water collection, and drinking (drawing water from the storage container). Hygiene behaviors related with water collection, storage, and drinking can be compiled as following Table 2.1.

Table 2.1 Hygiene Behaviors Related with Water Collection, Storage and Point of Use (PoU) (WHO)

Water Collection	**Water Storage**	**Consumption**
Drinking-water should be collected in clean vessels without coming into contact with hands and other materials. Water should be transported in a covered container.	Water should be stored in vessels that are covered and regularly cleaned. Drinking-water should be stored in a separate container from other domestic water wherever possible.	Drinking-water should be taken from the storage vessel in such a way that hands, cups, or other objects should not contaminate the water.

2.3.1 Household Water Treatment

There are several quick, easy, and economical household water treatment techniques that provide adequate water purification without being expensive. Use of various types of water filters, boiling water, chlorination, and solar disinfection (SODIS) are some of the most common methods for treatment of water at the household level.

2.4 Onsite Sanitation System and Groundwater Contamination

The two most popular types of on-site sanitation systems are septic tanks and pit latrines. Septic tanks have issues like sludge disposal and routine cleaning. 2.1 billion People use toilets attached to septic tanks that are not safely emptied or other systems that release raw sewage into open drains or surface water bodies in urban areas where both household and communal toilets are more common (WHO, 2017). Septic tank effluent disposal can result in unpleasant odors, mosquito breeding grounds, and health risks. The main cause of ground water pollution is leachate from onsite sewage systems (ARGOSS, 2001). The threat is brought about by the chemical contaminants and pathogenic germs that are emitted from these onsite sanitation systems and are filtered into the nearby groundwater sources through the soil. When onsite sanitation and ground water supplies are spread out closely together, this threat is more serious in areas of dense population. Water must be preserved because there is a lack of drinking water in almost all peri-urban areas. Pathogen and nitrate contamination of drinking water are two serious public health issues frequently associated with onsite systems (Hammoud, et al., 2018).

The depth to the water table, the distance between the groundwater source and the on-site sanitation system, the hydro-geological and soil conditions of the surrounding environment, and the level of groundwater contamination all have an impact to the ground water. In addition to the above mentioned factors, onsite sanitation systems, solid waste landfills, livestock manure storage, and wastewater pit leaks also contribute to ground water pollution (Banks, et al., 2002).The settlement's highest population and pit latrine density were correlated with the highest groundwater nitrate concentrations (Lewis, et al., 1980). The majority of researchers use chloride, nitrate, and faecal coli forms as the indicator parameters to evaluate the effectiveness of onsite sanitation systems (Lewis, et al., 1980; Lawrence, et al., 2001). Because of inadequate monitoring, the degree of groundwater contamination is poorly understood in many developing countries. Therefore, it is crucial to check the water quality of groundwater.

2.5 Socio-Cultural Barriers

Madhesi, Muslims, Dalit Communities, and other disadvantaged (very poor, landless) groups are the most vulnerable in this municipality from a sanitation point of view (GSF, 2013). These groups, which are primarily ultra-poor, are among the lowest socioeconomic classes in society. Most sanitation-related activities, such as handling trash, whether it is faeces or other waste, cleaning, managing graves, sweeping, etc., have traditionally been considered Dalit people's livelihoods and occupations, and they are still performed in both formal and informal systems. Dalits, Terai, and Muslims who are urban poor in this municipality face numerous obstacles to obtaining resources in an adequate way. Their condition for accessing proper sanitation services and practices is made worse by their lack of awareness and traditional cultural barriers. For adequate access to resources, services, as well as workplace safety and wellbeing, differentiated positive discrimination must be implemented (Tripathi, et al., 2021).

The study area has constructed toilets in the pursuit of ODF free zone. Prior to this, the people used to go to nearby forest and rivers for defecation. This was a huge problem for the women who used to make the defecation journey before the sun rose. Now, with the advent and installation of toilets at the homestead, it is much easier for the family members as they, especially female members of the family, are not compelled to wake up early and make their ways to forest. Prior to this, there was improper management of faecal sludge in the area as the local people go to forest and water bodies to defecate which has higher chances of water contamination (Tharu, 2022).

Faecal Sludge Treatment Plant in Gulariya

The goal of the FSTP in Gulariya was to effectively treat and manage FS in Nepal's Mid-Western region. The capacity of this treatment facility is 3 m^3 per day. By processing FS, this treatment facility produces two by-products: compost and wastewater.

CHAPTER 3
MEHODOLOGY

3.1 Study Area

The Gulariya Municipality is situated in Nepal's south-western region. The Headquarter and Municipality of Gulariya are located in Bardiya District in the Lumbini Province of Nepal. It is located in the Terai region's plains near the Indian border in Bahraich District, in the Indian state of Uttar Pradesh.

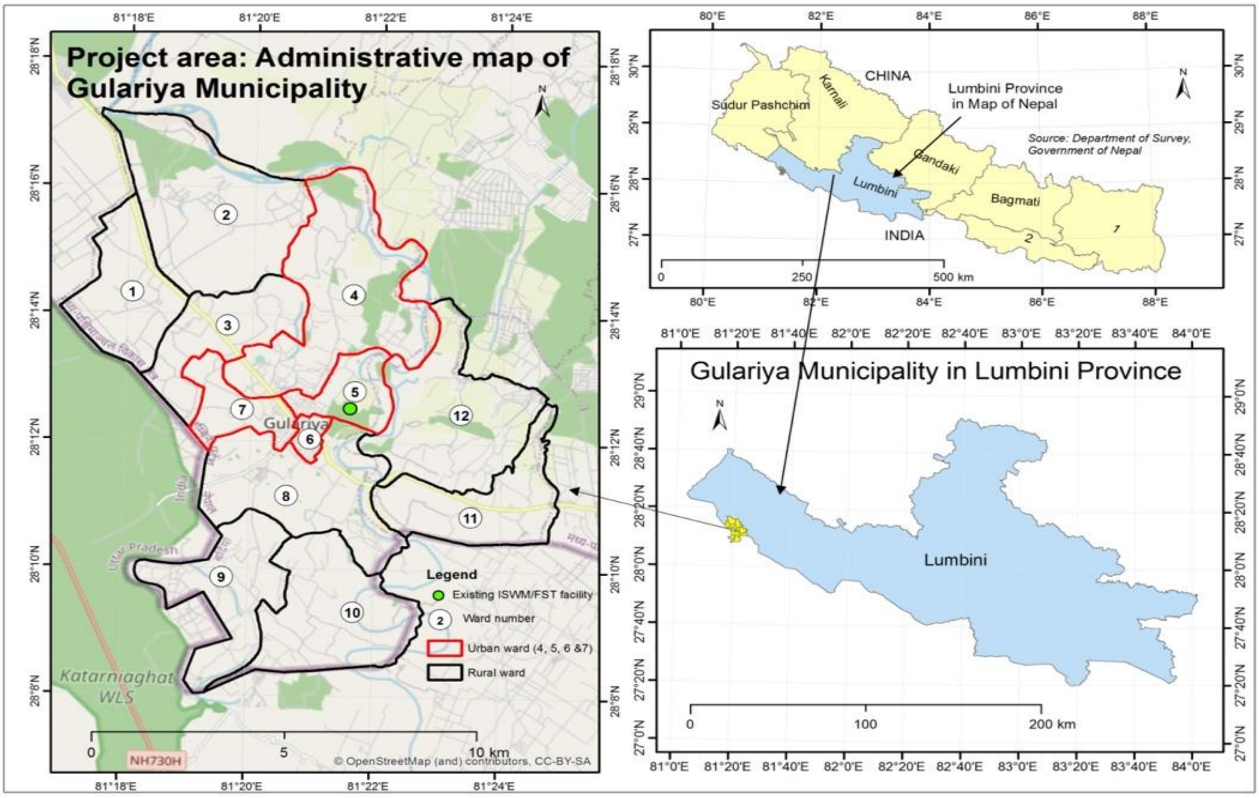


Figure 3.1 Study Location (Gulariya Municipality)

(Municipality Profile, 2019)

Gulariya, which is located approximately 35 kilometers to the west of Nepalgunj City, was established as a municipality in 1995 and underwent reorganization in 2015 at the direction of the federal government. There are 12 wards within this municipality. Out of the 12 wards, 4 (the 4, 5, 6, and 7) are located in urban areas, while the remaining 8 are in rural areas. Gulariya Municipality is located in the terai plain of Nepal, where summer temperatures can reach 40°C and winter temperatures can reach 6–7°C. According to the census carried out by Gulariya Municipality and it shows that there are 71,991 total populations, including 36,972 males and 35,019 females living in 13,831 households (Municipality Profile, 2019).

The Gulariya Municipality is a multicultural location where many different languages are spoken. For the older residents of the area, Awadhi and Tharu are their native tongues. The majority of the district's population often speaks these languages, which are also simple to understand. People from hilly (migrated people) and terai (native people) regions coexist in the municipality, which is a heterogeneous community.

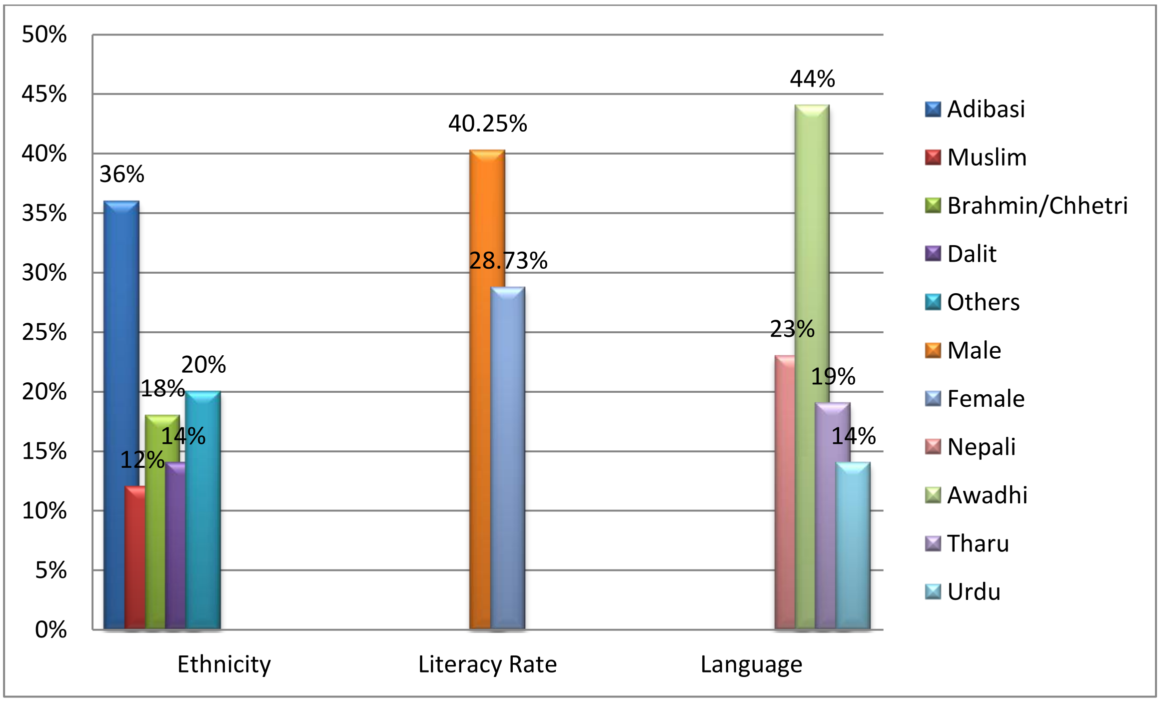


Figure 3.2 Demographic Profile of Gulariya Municipality

(Municipality Profile, 2019)

Water contamination has increased significantly as a result of inadequate faecal sludge management, insufficient faecal sludge management mechanisms, and inoperable treatment plants (Tripathi, et al., 2021).

The municipality's management of solid waste and faeces is insufficient. Due to inadequate garbage collection services, a lack of public knowledge, and technical incompetence, open burning activities and incorrect disposal of mixed solid waste have become the trend in the municipality. Although trash treatment facilities are already present in the municipality, a number of issues arise when the infrastructures are used (Tripathi, et al., 2021).

3.2 Research Approach and Design

For this study, a case study approach was used. To achieve the objectives of the research, a variety of inquiry techniques were used to gather data from various sources.

3.2.1 Literature Review

The analysis of drinking water quality, its practices and FSM and studies from across the nation, as well as comparative international practices were done. This process, which was carried out throughout the study time, would support the discussion by giving the research findings which will be more supportive or may invalidate the research findings. Priority in the effort was given to literature that has been published in journals in the last 20 years by prominent researchers.

3.2.2 Site Visit

The main objectives of site visit are to collect data on water quality, sanitation practices, field observation and interaction with the stakeholders. Preliminary site visit was made to the research area. To establish a relationship with locals and relevant stakeholders was another goal of the site visit. Before beginning the field observation, the checklist must be prepared.

3.2.3 Household Survey

Household survey was conducted by administering semi-structured questionnaire in selected households in the Gulariya Municipality. The questions were focused to assessing the FSM practice at the household level, to understand the knowledge on FSM, the behavioral practices relating to water handling, storage and use at the household level and the health and livelihood consequences resulting from water contamination. The questionnaire contained relevant questions such as socio-economic attributes of the households, practices of water collection, storage and use, sanitary practices at the household level and health consequences that are known to have occurred in the households in the past. The questions relating to behavioral practices of water handling was focused to inquiries on the source of water accessed, practices of water transport, and types of containers used in water fetching and storage, water-treatment methods, personal hygiene and cleaning of utensils. In obtaining information relating to behavioral practices of water handling, the female members were included in the inquiry because they are the one directly involved in water related tasks including collection, transportation, and storage of water at the household level (Bhattarai, 2012).

3.2.4 Key Informant Interviews

Various individuals from a variety of institutions, including the municipality, ward offices, local leaders, political leaders, and Self Help Women Groups (SHWGs), with positions of assigned responsibility was interviewed for this tool. The main objective of the KII was to evaluate participants' understanding of FSM and its impacts on water resources, current FSM practices, about the present situation of hygiene, sanitation and water supply and about the WASH intervention programs in that area. The goal of the KII with government representatives was primarily to identify and understand the legislative processes that were currently in place, local level policies, and future plans for FSM in the municipality. Similar to this, the aim of KII with FSM practitioners shall be to gain insight into the method and practice of FSM, particularly with regard to the collection, transportation, and disposal of FS, as well as to assess knowledge of FSM policy, rules, and regulations. Based on the snowball sampling approach, the informant shall be chosen. A series of established checklists will make this easier.

3.2.5 Field Observation

The field observation involved recording each family member's function and behavior with regard to collecting, transporting, storing, and consumption of water as well as maintaining the cleanliness of the utensils used during collecting and storing water as well as ensuring overall hygiene in the household. To reflect various socioeconomic classes, castes, occupations, levels of education, and levels of awareness, different houses for behavioral observation was identified. Each family member, who varied in age and gender were observed in the households for their behavioral patterns.

3.2.6 Focus Group Discussion

The focus group discussion was conducted from the community inclusive of all the people representing different ethnicities and socio-economical status groups. The FGDs were focused on the current practices of faecal sludge management at the households and community level, the initiation at the local levels from ward offices and Gulariya Municipality, the initiation by the community in upholding the sanitation status in the study area. One of the basic objectives of arranging the FGD was to verify the information collected from the questionnaires on the knowledge, attitude and behavioral practices and on the issues relating to faecal sludge management, hygiene and sanitation. Sanitation workers from Gulariya Municipality were another group with whom the challenges on faecal sludge management was discussed. These were facilitated with a set of predetermined checklist.

3.2.7 Water Quality Sampling

Water quality sampling was carried out to assess the current water quality status of groundwater sources that were used for drinking purpose as well as stored water. Water samples were collected from the household's water sources specially the hand pumps. The sample water criteria which includes:

- Ward wise coverage
- Marginality
- Inclusion
- Types of water source (municipality/private)
- Private/Public
- Distance from septic tank

Water quality was analyzed for two different sets of parameters – physico-chemical and microbial parameters. Pocket Colorimeter and pH meter were used to test chemical parameters i.e. Nitrate and pH respectively. MPN Test Kit were used to test microbiological parameters i.e. *E.coli* were tested.

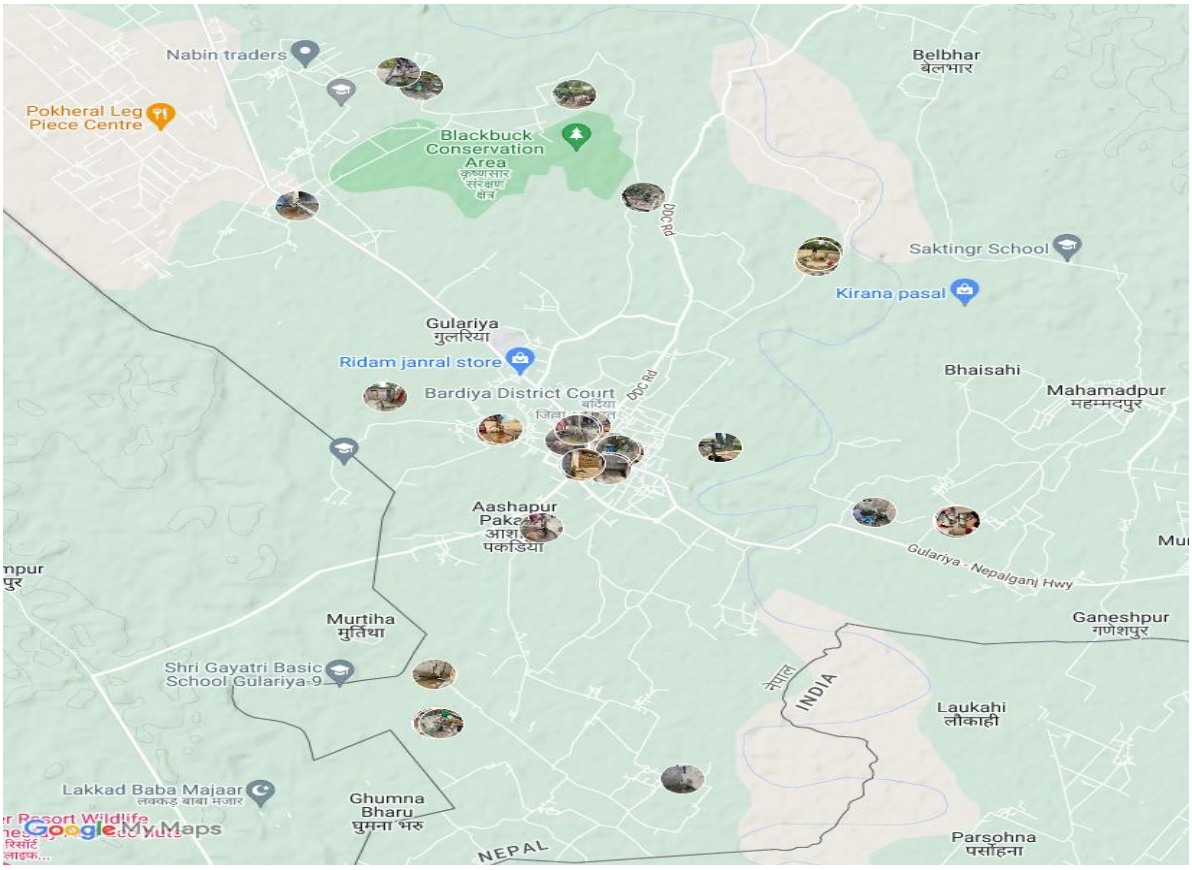


Figure 3.3 Google Maps used to plot geo-tagged photos of the sites visited

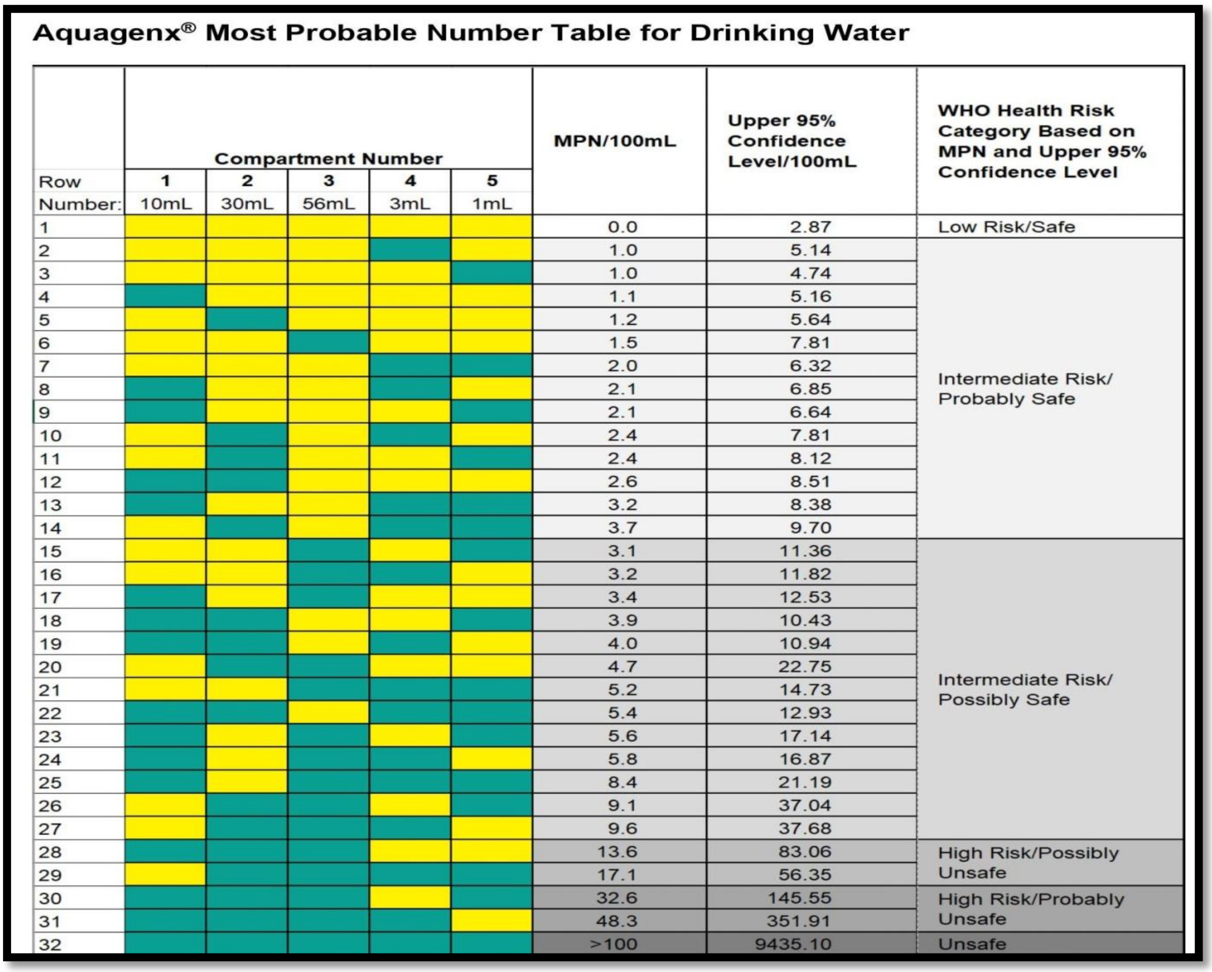
In the Gulariya municipality, about 97.06% of population have hand pump for the source of drinking water and for other household works like cooking, bathing, washing dishes as well as for animal husbandry. So, for different needs, hand pump water is fetched and used for many productive works in the households. And this water is collected by all the family members with different vessels like mug, jug, bucket, gallon, and drum. The water sample for testing was collected with Whirl-Pak Thio-Bag by sterilizing the hand pump water. The collected 100ml sample in the Whirl-Pak Thio-Bag was mixed with Aquagenx growth medium and dissolved the growth medium in the sample by swirl and squeezing. After that slowly poured the sample from the Thio-Bag into Aquagenx Compartment Bag and rub top of bag and sides of bag together to open for sample run into each compartment. Then slowly poured sample into bag while gently tilted and squeezed bag to distributed sample among five compartments. After that, rolled down Whirl-Pak seal at top of Compartment Bag and fasten shut and attached plastic seal clip across Compartment Bag to prevent water from leaking out of compartments. And left in the dark room for 24 hrs at the room temperature covering with thick clothe. This sample was taken the reading after 24 hrs and measured the level by using UV ray light. The UV ray light was used to determine the color of the sample according to the following criteria:

- Yellow compartment with and without UV light exposure is negative for *E.coli* and total coliforms.
- Yellow compartment with blue fluorescence under UV light is positive for total coliforms.
- Blue compartment in ambient light is positive for *E.coli* and total coliforms.

So that the MPN value was known to know the exact value of *E.coli* recording based on multiple colors. The microbiological results were divided into risk categories for easier interpretation (WHO, 2011).

Likewise, for value of nitrate, 10 ml of sample was collected .The water sample was mixed with free nitrate powder pillow and mixed for 20 second to dissolve the reagent by shaking in the small bottle of 10 ml. One hour later, the sample was tested in pocket colorimeter and the value of nitrate was noted.

Again, the pH value was also taken by using pH meter.



Aquagenx® Most Probable Number Table for Drinking Water

Row Number:	Compartment Number 1 10mL	2 30mL	3 56mL	4 3mL	5 1mL	MPN/100mL	Upper 95% Confidence Level/100mL	WHO Health Risk Category Based on MPN and Upper 95% Confidence Level
1						0.0	2.87	Low Risk/Safe
2						1.0	5.14	Intermediate Risk/ Probably Safe
3						1.0	4.74	
4						1.1	5.16	
5						1.2	5.64	
6						1.5	7.81	
7						2.0	6.32	
8						2.1	6.85	
9						2.1	6.64	
10						2.4	7.81	
11						2.4	8.12	
12						2.6	8.51	
13						3.2	8.38	
14						3.7	9.70	
15						3.1	11.36	Intermediate Risk/ Possibly Safe
16						3.2	11.82	
17						3.4	12.53	
18						3.9	10.43	
19						4.0	10.94	
20						4.7	22.75	
21						5.2	14.73	
22						5.4	12.93	
23						5.6	17.14	
24						5.8	16.87	
25						8.4	21.19	
26						9.1	37.04	
27						9.6	37.68	
28						13.6	83.06	High Risk/Possibly Unsafe
29						17.1	56.35	
30						32.6	145.55	High Risk/Probably Unsafe
31						48.3	351.91	
32						>100	9435.10	Unsafe

Figure 3.4 E.coli Matrix (www.aquagenx.com)

Figure 3.5 Sample Collection and Water Quality Testing

Recommended Incubation Periods at Ambient Temperature Conditions:

35-37 °C: Incubate 20 hours

31-34 ℃: Incubate 24-30 hours

25-30 ℃: Incubate 40-48 hours

Below 25 ℃: Incubate in a portable at 35-37 ℃ for 24 hours or put in or near another heat source for up to 48 hours, depending on the temperature.

Over 40 ℃: Some total coliforms will be inhibited, and the results may not be accurate for total coliforms (LLC, 2013).

3.3 Sample Size

A sample was collected from above population, for sample it can be calculated

Based on the following formula (Israel, 1992)

Where, n = Sample Size

z = 1.96 for 95% Confidence Level

p = 0.5, q=0.5, e = Margin of error, using 7% error margin

For N= 53,578,

n=1.96^2*0.5x0.5/0.07^2 = 196

For finite population:

$$n = \frac{n}{1+\frac{n-1}{population\ size}} = \frac{196}{1+\frac{196-1}{53578}} = 195.29 \approx 195$$

n=195

For N=53,578, number of samples is 196.

Therefore, the sample size for the research was taken as 195.

A total of 195 Samples will be collected from Gularya Municipality to obtain the results of the study.

Proportionate stratification was used to distribute the total sample size over different strata proportionately. Strata sample sizes were calculated using the following equation (Stat Trek, 2021).

n_i = (Ni/N)*n……………………..… (1)

Where n_i is the sample size for strata "i", N is the total population size, and n is the total sample size.

Table 3.1 Ward wise Sample Collection Strategy according to Population of each ward of Gulariya Municipality

S.N.	Ward	Population	Number of Sample
1	2	5650	20
2	4	9077	34
3	5	4335	16
4	6	4400	16
5	7	4400	16
6	8	6439	23
7	9	7101	26
8	10	6012	22
9	12	6164	22
Total		53578	195

The selection of the households/public points were done to include various classes, castes, education, households of different socio economic condition, family size, types of water sources and sanitation systems.

Total 33 sites were visited, took 50 water samples and conducted 30 household questionnaires in 09 Wards (out of total of 12 wards). Wards were selected to cover both urban (n=4) and rural (n=5) Wards. Both private hand pumps and public hand pumps/ municipality pipe water supply were selected for study. Similarly, stored water and treated water were also sampled from the households covering more than 1224 people in the municipality.

3.4 Data Analysis

The data collection based on the four specific objectives were sorted and analyzed to obtain the results of the study. The data obtained from different tools of inquiries were managed and analyzed using Aqua Reader (version 4), Most Probable Number (MPN) Test Kit, pH meter and Pocket Colorimeter.

Data analysis of two different categories (quantitative and qualitative) was based on the data obtained. The data obtained from household survey, water quality testing was quantitative data thus for these data MS excel was used for data analysis whereas data collected from KII, literature review and secondary data source was qualitative data and thus these data was analyzed based on the content analysis concept. IBM Statistical Package for Social Survey (SPSS) was used to handle and evaluate the data gathered from various techniques of inquiry. Cross tabulating data and counting the frequency of the observed phenomena was also part of the investigation. To compare across different categories of households, the mean and variance of the observation was calculated as needed. Qualitative data was analyzed by retrieving common information and difference in information.

It is necessary to arrange the data in some logical and concise order as most of them were obtained from primary and secondary sources. Both qualitative and quantitative information were tabulated. While qualitative information was explained in detail using qualitative measures. Quantitative measures were processed through statistical measures. Line diagram, bar diagram, pie chart, table, boxes etc are shown wherever possible. The secondary data and the primary data are used to analysis the relation between Ecoli contamination of water sources in the wet season and the dry season by using SPSS.

3.4.1 Laboratory Analysis

Water sample from three different points namely hand pump water, municipal supply water and storage water was collected and analyzed.

The water sample was transported to the laboratory for analysis of necessary parameters i.e. *E. coli*, Nitrate, Temperature and pH.

3.4.2 Qualitative and Quantitative Data Analysis

Data and information collected using the above- mentioned tools of inquiry was compared to and contrasted with data and information about a scenario taken from the literature. To fulfill the study objectives, qualitative data was gathered via KII, literature reviews, policy and legal document reviews, and other secondary data sources. Qualitative and quantitative approaches were the two types of tools used in FSM and drinking water contamination. In qualitative measuring procedures, householders generally participate as informants, interacting directly or indirectly with researchers and communicating their viewpoints through their own words and conceptions, for as in focus group discussions (Rousseau, 1990). The different ideas, views, perceptions of interviewer from the interviews taken from the survey determine the qualitative data which helps to know the exact social scenario of the concerned area. As a result, through qualitative measurement, detailed information can be gathered in the focal group's own language.

Quantitative techniques on the other hand, use procedures that are typically highly standardized and calibrated, such as highly organized interviews, surveys and questionnaires, and Q-sorts, to quantitatively assess (Wreathall, 1995). From this Quantitative survey, different types of numerical data from primary or secondary sources are obtained and used for different processes to obtain the new results for the demand of the study.

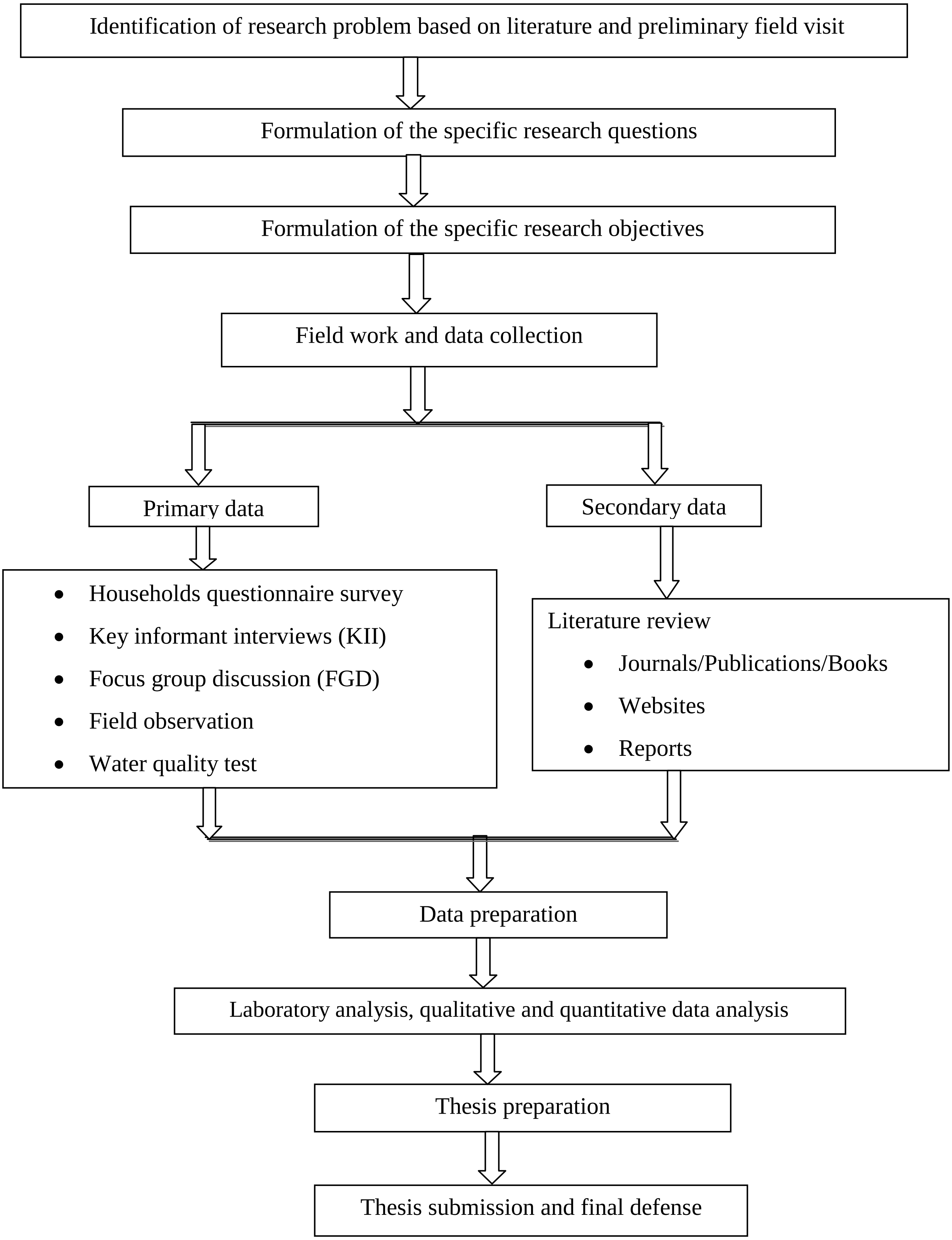
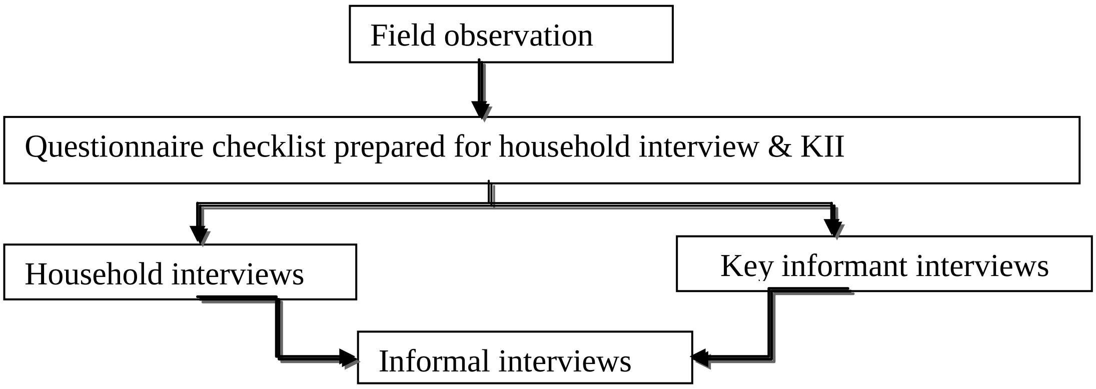
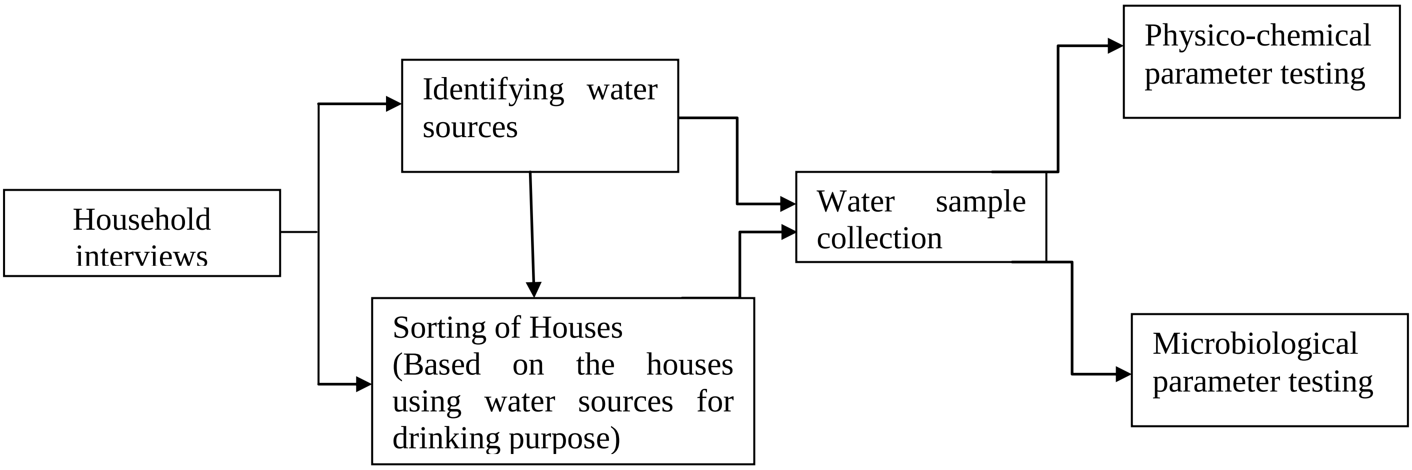


Figure 3.6 Research Framework

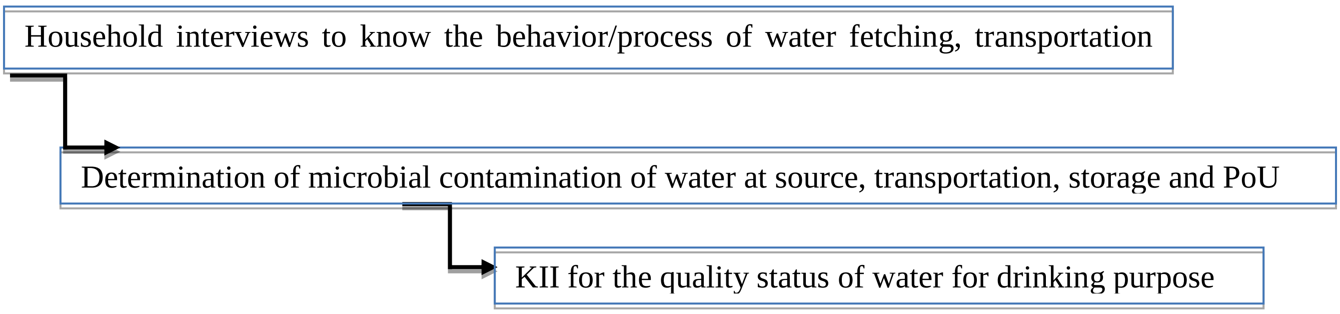
Research Objective 1 - To explore the pathways of contamination of drinking water arise from sanitation practices and behavior at household level.



Research Objective 2 - To assess the contamination of groundwater due to onsite sanitation system.



Research Objective 3 - To analyze contamination of drinking water from selected households focusing their behavioral practices from source to mouth.



Research Objective 4-To assess the socio cultural barriers in managing water quality at household level.

Interview about situation of hygiene, sanitation and water supply and about the WASH intervention programs in that area

→ Key informant interviews with Municipality about water quality and FSM practices

Table 3.2 Research Matrix

Research Objectives	**Variables**	**Tools of Inquiry**	**Analysis Method**	**Expected Outcome**
To explore the pathways of contamination of drinking water arise from sanitation practices and behavior at household level.	Practices, Number of households with on-site sanitation. Toilet condition-water availability, soap.	Field observation, household interviews, KII, FGD	Statistics Description (pie chart, table, bar diagram) and Correlation	The status of faecal sludge management and drinking water contamination in Gulariya Municipality
To assess the contamination of groundwater due to onsite sanitation system.	Water Quality Test results (*E.coli*, Nitrates, Temperature, pH)	Water quality test using Aqua Reader, MPN Test Kits, Pocket Colorimeter (for Nitrates), pH meter	Paired T test and Percentage	Status of shallow groundwater quality used for drinking purposes

To analyze contamination of drinking water from selected households focusing their behavioral practices from source to mouth.	Collection, transportation, storage and consumption of water, Factors related to FSM i.e. containment, emptying, transport, treatment, reuse/disposal	Field observation, Household interviews, FGD, KII	Analysis Emptying frequency/facility practices and Capacity of septic tank	Status of water quality(bacterial contamination) at each stage, status of behavioral practices
To assess the socio cultural barriers in managing water quality at household level.	Social norms, Cultural values, Cultural Beliefs, Cultural Attitudes, Social Beliefs	Field observation, Key Informant Interview	Qualitative Analysis	Status of Social norms and value, Sanitation service chain gap identification

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Overview

The results of the study are presented in this chapter based on the detailed methodology addressed in the preceding chapter. Three types of statistical analysis are applied in this study to analyse the collected data. These are descriptive statistics used to demonstrate the demographic data, MPN kit test, Nitrate test and screening and scoring qualitative measure of behavioural changes taken from literature review.

4.2 Survey Statistics

The research population is the households who live in Gulariya Municipality in Nepal. This study targeted all the family in these areas due to the nature of questions assessing the quality of water for everyone commitment to safe drinking water. In order to maximize the response rate, two methods of data collection have been employed in this study including in-person and delegation method. Also, the in-person method of data collection was implemented through visiting sites and conducting meetings and interviews with household's members either in-group or individually. The second method involved the delegation of data collection by KII.

4.3 Demographic Variables

Demographic variables in this study are the control variables collected from the responding households to deliver a broader look into the research outcomes. Eleven control variables are collected from responding households including gender, age, education, family size, economic status, ethnicity, numbers of children below five years, live stocks at households, occupations, and type of houses and location of houses.

4.3.1 Gender

The majority of respondents that participated in the survey were male, with very limited number of female respondents. Male respondents were 24 in number (72.73%) and there were only 9 female respondents (27.27%). This shows that, generally males are more interested to involve in the survey which may be because they are more educated than female in the municipality (male (56.12%) / female (43.88%)).

4.3.2 Age

Age is the fourth demographic variable in the study. The respondents were in the age category from under 25 years with a total number of responses of 5 (15.15%). Also, a total of 6 respondents (18.18%) were in the age category from 26 to 35 years. Age category from 36 to 45 years had a total of 6 respondents (18.18%) and the numbers of respondents who are 46 to 55 years old came to 8 respondents (24.24.%). Lastly, the number of respondents who are older than 56 years old is very small, with 8 respondents (24.24%) and that is justified because the study targeted for experienced peoples preferably elder than 40 years.

4.3.3 Demographic and Socio-economic Data

The socio-economic characteristics of the households included in the documentation and analysis of behavioral practices in household level water handling is provided at the outset so that incidences of water contamination could be related with the socio-economic profile of the households included in the study. Among 33 households included in the study, 9 Hhs have the family members 1-5, 14 (6-10), 3 (11-15) and 7 (above 15). Children below 5 years of age were in 28 households (84.85%). In 27 households (81.82%), the person involved in water handling and management was female and in the remaining 6 households (18.18%), it was male. 39.39% of the sample population was from Muslim community. Similarly, Brahmin and Chhetri were 15.15% each, Tharu were 12.12%, Dhobi, Dalit and Madhesi were 6.06% each. Out of the total household sample, the percent of poor, medium and rich households were 75.76%, 24.24% and 0.00% respectively. The classification of the different economic class was done by considering five different factors namely monthly income, own house or rent type of house, location of house and income diversification. The information on these factors was collected by the help of questionnaire survey and observation. Also, of the total respondents, 60.61% of them were illiterate. Similarly, 18.18% had education below secondary level, 18.18% had higher secondary level education and 3.03% were graduates as shown in Table 4.1.

Table 4.1 Demographic and Socio-economic Data

Attributes		**No. of Hhs (%)**
Caste/ Ethnicity	Brahmin/Chhetri	5 (15.15%)
	Adibasi	13 (39.39%)
	Tharu	4 (12.12%)
	Muslim	5 (15.15%)
	Dalit	2 (6.06%)
	Dhobi	2 (6.06%)
	Madhesi	2 (6.06%)
Family Size (No. of family members/Hh)	1-10	23 (69.69%)
	10-20	5 (15.15%)
	>20	5 (15.15%)
No of Hhs with children below 5 years of age	Yes	28 (84.85%)
	No	5 (15.15%)
Economic Status of the family	Poor	25 (75.76%)
	Medium	8 (24.24%)
	Rich	0 (0.00%)
No of Hhs with livestock at Homestead	Yes	23 (69.69%)
	No	10 (30.30%)
Gender role in the water management level	Male Manager	6 (18.18%)
	Female Manager	27 (81.82%)
Educational attainment of the water manager	Illiterate	20 (60.61%)
	Secondary Level	6 (18.18%)
	Higher Secondary	6 (18.18%)
	Graduate	1 (3.03%)

4.4 Sources of Water

The major water source for drinking water at Gulariya Municipality, were Tube wells/ Hand pumps. As per the data collected, 97.06% of water sources are used the water from tube wells/hand pumps; remaining 2.94% of them used water from municipality water supply system. Following are the type of sources of water:

i. Tube well/ hand pump → Public (4)
→ Private (29)

ii. Piped Municipality Water supply- 1

There were two types of tube wells or hand pumps according to ownership: Public and Private. 87.88% of tube wells/ hand pumps used at households were private, and remaining 12.12% of them were public according to the sampled data.

4.5 Water Quality at the Source

In Gulariya Municipality, drinking-water supplies are obtained from the underground aquifers. Altogether 66 samples (hand pump water sample) were collected to test the quality of water for dry and wet season. From table 4.2, 14 (42.42%) of the tested water samples taken from hand pumps in dry season were highly unsafe >100 (MPN per 100ml), 8 (24.24%), 7 (21.21%) and 4 (12.12%) of the pumps were low (1-10), intermediate (11-100) and safe (0) MPN per 100ml respectively.

From table 4.2, 29 (87.88%) of the tested water samples taken from hand pumps in wet season were highly unsafe >100 (MPN per 100ml), 3 (9.09%), 1 (3.03%) and 0 (0.00%) of the pumps were low (1-10), safe (0) and intermediate (11-100) MPN per 100ml respectively.

Data shows that *E.coli* contaminations in water sources in Gulariya Municipality were found 87.88% and 96.99% during the dry season and the wet season respectively; UNICEF (2020) states that *E.coli* contamination in water sources, on other hand, was found 75.30% overall in Nepal where as 82.6% in Lumbini Province.

Table 4.2 Water Quality at the Source

E.coli **(MPN/100ml)**		**Source of water**		**Total**
		Dry Season	Wet Season	
Present	Low(1-10)	8(24.24%)	3(9.09%)	11(16.67%)
	Intermediate(11-100)	7(21.21%)	0(0.00%)	7(10.61%)
	High(>100)	14(42.42%)	29(87.88%)	43(65.15%)
Absent	Safe(0)	4(12.12%)	1(3.03%)	5(7.58%)
Total	N	33	33	33
	%	100	100	100

4.5.1 Presence of *E.coli* with respect to Depth of Water Sources and Distance from Septic Tank

In order to determine how these septic tanks have affected the adjacent water sources that the households use for drinking, one of the study's goals was to achieve this. Water source contamination is significantly influenced by how far the water sources are from the septic tank. Between the septic tank and the water source, there should be at least 30 meters of horizontal space (Sphere Project, 2011). As a result, the distance between each household's water source and its corresponding septic tank was also measured. 39.39% of the water sources (13 sources) are located at a distance above 15 m from the septic tank in the surveyed households, 10 water sources (30.30%) are located within 5-10 m of distance from the septic tanks and 6 (18.18%) water sources are located at 10-15 m and 4 (12.12%) water source are located at 0-5 m (Table 4.3). Few people in the business core region have municipal water taps, and 100% household respondents in the study area had hand pumps.

In this study, to evaluate the quality of the water sources being used by the households, a set of WHO Guidelines for Drinking Water Quality was employed. Out of 33 respondents, 87.88% respondents' results for presence of *E.coli* were positive within 24 hours. The water quality analysis was carried out in the month June/September (Dry and Wet season) 2022. According to the procedures included in the MPN test kit, the presence and absence of coliform for 24 hours were determined. A correlation coefficient was determined between the coliform contamination and the depth of the water sources. Normally, the septic tank is 1.52 m (5 ft) depth, with no cementing materials lining the bottom layer. For 24-hour incubation, the correlation between the depth and the coliform is also slightly stronger but still not statistically significant. According to the National Drinking Water Quality Standard, it has been determined that the water is contaminated in various sources, making it unsafe to consume without treating it. In recent years, the frequency of infectious diseases had reduced in the community. In the past, they used to spend approximately NRs. 1000 per month on medical expenses. Water related diseases for example: Diarrhea and dysentery were more common in the past and it is now significantly reduced. They believed that it might be as a result of using toilets rather than open defecation and drinking water that has been treated using a bio-sand filter (FGD/KII).

Table 4.3 Percentage of Households with E.coli and Nitrates present in the Study Area

Distance of source to septic tanks	**Number of Households (nos.)**	**Households having *E.coli* presence in their source**		**Households having Nitrate presence in their source**	
		N	%	N	%
0 to 5 meters	4	4	12.12	2	6.06
5 to 10 meters	10	9	27.27	3	9.09
10 to 15 meters	6	6	15.15	1	3.03
Above 15 meters	13	11	33.33	5	15.15
Total	33	29	87.88	11	33.33

Nitrate concentrations were higher in wells at all distances from septic tanks during the dry season compared to the wet season (Table 4.4). The hand pumps located 0 to 5 m from septic tanks contained average concentrations of nitrates is 5.53 mg/l in the dry season while 0.65 mg/l in the wet season. Between 5 to 10 m from septic tanks contained average concentrations of nitrates is 4.26 mg/l in dry season and 0.94 mg/l in wet season. (10 to 15) m and (above 15 m) from septic tanks contained average concentrations of nitrates are 3.28 mg/l and 3.50 mg/l respectively in dry season. In other hand, they are 0.14 mg/l and 1.32 mg/l respectively in wet season.

In general, low concentrations were measured in the wet seasons and high concentrations during the dry seasons. There may be high percolation rate in dry season because in wet season there is chance of swipe away of the sludge due to flood water. Therefore, it is assumed that there are more nitrates in dry season than in wet season. Kacaroglu & Gunay (1997) also observed seasonal fluctuations in nitrate concentration (10–200 mg/l) in groundwater samples from the wells. It is observed that all surveyed water sources are contaminated with *E.coli* which are situated 0 to >15 meters from the septic tanks. This might be the indication of percolation of FS from septic tank into the groundwater.

Table 4.4 Mean Nitrate Concentrations in Hand pump at Various Distance from Septic Tanks

Distance of source to septic tanks	**Number of Households (nos.)**	**Households having Nitrate presence in Dry Season**		**Households having Nitrate presence in Wet Season**	
		N	mg/l	N	mg/l
0 to 5 meters	4	4 (12.12%)	5.53	2 (6.06%)	0.65
5 to 10 meters	10	8 (24.24%)	4.26	8 (24.24%)	0.94
10 to 15 meters	6	6 (18.18%)	3.28	2 (6.06%)	0.14
Above 15 meters	13	11 (33.33%)	3.50	7 (21.21%)	1.32
Total	33	29 (87.88%)	16.57	19 (57.58%)	3.05

In contrast, 67% of sources have depth of hand pump 50 ft (15.24 m) and 33 % have below 15.24 m (50 ft) depth. 18 out of 33 water sources being used for the domestic purposes are located at a depth of 10- 15 m, whereas 11 out of 33 water source lie within a depth of above 15 m, 3 out of 33 water source lie at a depth of 5- 10 m and 1 out of 33 water source lie at a depth of 0-5 m.

Table 4.5 Relation between E.coli and Nitrate with Depth of Sources

Depth of source	**Number of Households (nos.)**	**Households having *E.coli* presence in their source**		**Households having Nitrate presence in their source**	
		N	%	N	%
0 to 5 meters	1	0	0.00	0	0.00
5 to 10 meters	3	2	6.06	1	3.03
10 to 15 meters	18	16	48.49	12	36.36
Above 15 meters	11	10	30.30	4	12.12

Total	33	28	84.85	17	51.52

The hand pumps depth between 5 to 10 m contained average concentrations of nitrates is 4.1 mg/l in the dry season while 0.8 mg/l in the wet season. The depth of 10 to 15 m contained average concentrations of nitrates is 3.28 mg/l in dry season and 1.03 mg/l in wet season. The depth of above 15 m and (0 to 5 m) contained average concentrations of nitrates are 2.82 mg/l and 0.00 mg/l respectively in dry season. In other hand, they are 0.79 mg/l and 0.00 mg/l respectively in wet season. There may be high percolation rate in dry season because in wet season there is chance of swipe away of the sludge due to flood water. Therefore, it is assumed that there are more nitrates in dry season than in wet season.

Table 4.6 Mean Nitrate Concentrations in Hand pumps at Various Depths

Depth of the well	**Number of Households (nos.)**	**Households having Nitrate presence in Dry Season**		**Households having Nitrate presence in Wet Season**	
		N	mg/l	N	mg/l
0 to 5 meters	1	0 (0.00%)	0	0 (0.00%)	0
5 to 10 meters	3	3(9.09%)	4.1	1 (3.03%)	0.8
10 to 15 meters	18	15 (45.46%)	3.82	12 (36.36%)	1.03
Above 15 meters	11	9 (27.27%)	2.82	6 (18.18%)	0.79
Total	33	27 (81.82%)		20 (60.61%)	

4.5.2 Correlation of the Parameters

The most preferred indicator organism for analyzing the microbiological quality of wastewater is *Escherichia coliform* bacteria (Young & Thackston, 1999). *E.coli* was selected as the faecal coliform because it is a more accurate indicator of faecal contamination (Cabral, 2010; Jamieson et al., 2002).

Hypothesis

The relationship between water contamination level of the water samples collected from the sources for different parameters at significant level $\alpha = 0.05$.

Null hypothesis (Ho): There is no significant relationship between contamination level of the water samples collected from the sources for different parameters (*E.coli*, Nitrate, Temperature and pH).

Alternate hypothesis (H1): There is significant difference between contamination level of the water samples collected from the sources for different parameters (*E.coli*, Nitrate, Temperature and pH).

Table 4.7 Correlation of the Parameters

Description	No of samples	Co. of correlation	P-value	Remarks
Correlation between *E.coli* and depth of the hand pump	50	0.18	0.22	Ho rejected ($P<0.05$)
Correlation between *E.coli* and distance from the hand pump to septic tank	50	0.042	0.78	Ho rejected ($P<0.05$)
Correlation between Nitrate and depth of the hand pump	50	-0.145	0.32	Ho rejected ($P<0.05$)
Correlation between Nitrate and distance from the hand pump to septic tank	50	0.14	0.34	Ho rejected ($P<0.05$)
Correlation between *E.coli* and pH	50	0.087	0.544	Ho rejected ($P<0.05$)
Correlation between Nitrate and pH	50	-0.113	0.428	Ho rejected ($P<0.05$)
Correlation between *E.coli* and Temperature	50	-0.034	0.816	Ho rejected ($P<0.05$)
Correlation between Nitrate and Temperature	50	0.229	0.110	Ho rejected ($P<0.05$)

Remarks: From correlation test, since $p \leq 0.05$ is less than our chosen significance level $\alpha = 0.05$, the null hypothesis is accepted, and conclude that contamination level of the water samples collected from the sources for different parameters is different.

From correlation test, since $p \leq 0.05$ is more than our chosen significance level $\alpha = 0.05$, the null hypothesis is rejected, and conclude that contamination level of the water samples collected from the sources for different parameters is not different.

From the Table 4.7, the significant values of *E.coli* and depth of the hand pump, *E.coli* and distance from hand pump to septic tank, *E.coli* and pH and *E.coli* and Temperature are 0.22, 0.78, 0.544 and 0.816 respectively. Since $p \leq 0.05$ is more than our chosen significance level $\alpha = 0.05$, the null hypothesis is rejected, and conclude that correlation between *E.coli* and depth, *E.coli* and distance from hand pump to septic tank, *E.coli* and pH and *E.coli* and temperature are not significant different.

From the Table 4.7, the significant values of Nitrate and depth of the hand pump, Nitrate and distance from hand pump to septic tank, Nitrate and pH and Nitrate and Temperature are 0.32, 0.34, 0.428 and 0.110 respectively. Since $p \leq 0.05$ is more than our chosen significance level $\alpha = 0.05$, the null hypothesis is rejected, and conclude that correlation between Nitrate and depth, Nitrate and distance from hand pump to septic tank, Nitrate and pH and Nitrate and Temperature are not significant different.

From the source to the households and storage, the Water Temperature and *E.coli* levels increased. There is a chance for microbial growth because Temperatures were found to be between 34°C and 36°C in all sources and storage types (35 out of 50 water samples tested). This is particularly significant considering that this threshold level has been linked to an increase in microbial growth (Fransolet, et al., 1985).

4.6 Effect of Seasonal Variations on Water Contamination Level

Climate is a classification of the seasonal weather that can be clearly divided into dry and wet seasons. In this study, the dry and wet seasons were represented by the months of May to August and September to November respectively. In contrast to the wet season, which includes most of the region's average rainfall and higher temperatures, the dry season is characterized by low rainfall and temperatures (Mc Mahan, 2006).

4.6.1 Comparison between the Parameters of Wet and Dry Seasons

In comparison to the dry season, more *E.coli* counts were found during the wet season (Fig 4.1). The higher detection of *E.coli* during the wet season was linked to the rainy season's favorable microbial conditions (Makuwa, et al., 2022).

Nitrate concentrations were found to be low in the wet seasons and high in the dry seasons. Lee, et al., (2003) stated that, the researchers examined the properties of nitrate in groundwater in relation to rainfall patterns. In comparison to the dry season, the nitrate concentrations were lower during the wet season.

During the wet season, the pH value of the sample was 6.05, while during the dry season, it was 7.05. The results show that the dry season is slightly alkaline and the wet season is slightly acidic. As the rainfall increases, the pH decreases. The reason for the pH decrease that occurs during the rainy season is the increase in organic matter brought on by rainfall, which causes a decrease in dissolved oxygen (DO) by means of organic dehydration (Anhwange, et al., 2012).

4.6.2 Testing Research Hypothesis

Testing the study hypothesis is the last step of statistical analysis in this research.

To determine the present scenario of water contamination level of the water samples collected from the sources in dry and wet seasons is main objective. The hypothesis is tested from the Independent t-test using IBM SPSS software.

Hypothesis

The relationship between water contamination level of the water samples collected from the sources in dry and wet seasons at significant level $\alpha = 0.05$.

Null hypothesis (Ho): There is no significant relationship between contamination level of the water samples collected from the sources in dry and wet seasons.

Alternate hypothesis (H1): There is significant difference between contamination level of the water samples collected from the sources in dry and wet seasons.

Table 4.8 Independent Samples Test of Three Parameters

Parameter	**Dry Season**		**Wet Season**		**Statistical Analysis (t-test) Unpaired**	
	Number of sample	Mean	Number of sample	Mean	P value	Significantly different (p<0.05)
E.coli (MPN/100ml)	50	4309.62	50	8512.60	0.032	Yes
Nitrate (mg/l)	50	4.054	50	0.720	0.000	Yes
pH	50	7.05	50	6.05	0.224	No

Remarks: From independent t test, since $p \leq 0.05$ is less than our chosen significance level α = 0.05, the null hypothesis is rejected, and conclude that relationship between contamination level of the water samples collected from the sources in dry and wet seasons is different.

From the Table 4.8, the significant values of *E.coli* and Nitrate are 0.032 and 0.00 respectively. Since $p \leq 0.05$ is less than our chosen significance level $\alpha = 0.05$, the null hypothesis is rejected, and conclude that relationship between contamination level of the water samples collected from the sources in dry and wet seasons is significantly different.
From independent t test, since $p < 0.05$ is greater than our chosen significance level $\alpha = 0.05$, the null hypothesis is accepted, and conclude that relationship between contamination level of the water samples collected from the sources in dry and wet seasons is not different.

From the Table 4.8, the significant value of pH is 0.224. Since $p < 0.05$ is greater than our chosen significance level $\alpha = 0.05$, the null hypothesis is accepted, and conclude that relationship between contamination level of the water samples collected from the sources in dry and wet seasons is not significant different.

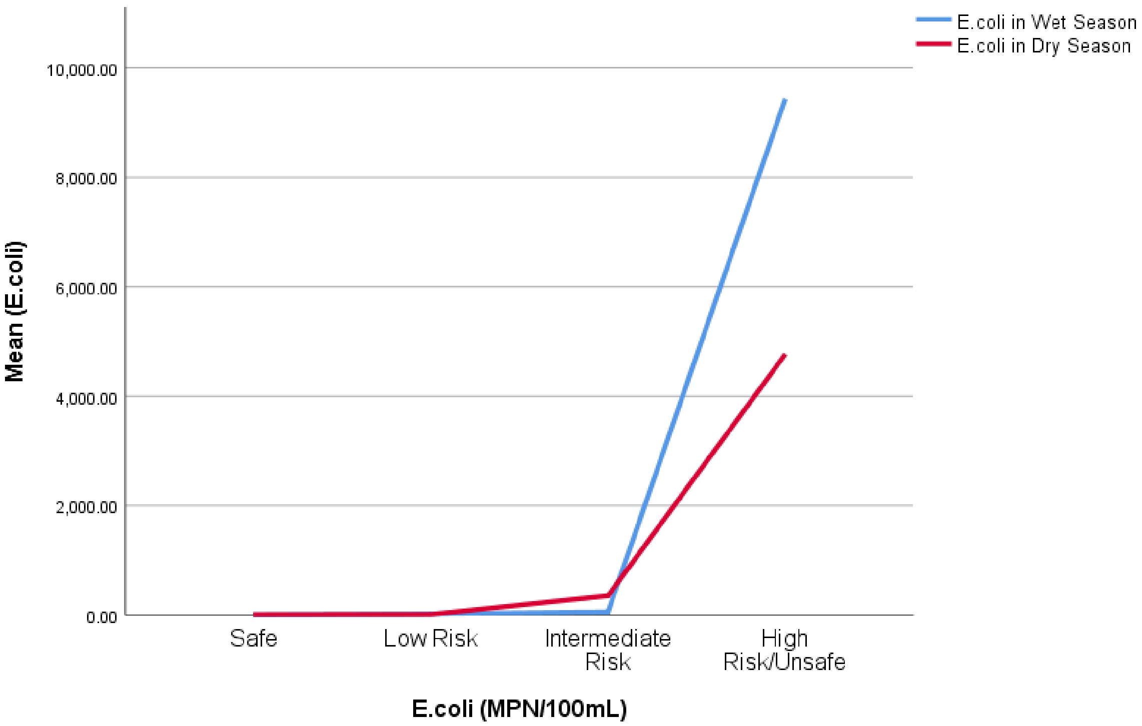


Figure 4.1 Contamination of E.coli in Dry Season and Wet Season

4.7 Practices of Water Handling

The practices for handling water, including collecting and transporting the water needed for daily needs from the source, storing the water, practicing water treatment at the household level, and analyzing the respondent households' water consumption and hygiene practices.

4.7.1 Water Collection and Transportation

The households were observed using a variety of water vessels to collect and transport their daily water demands from the source either from public or private water taps. While carrying water from the sources to home, 36% of the respondents covered the mouth of the vessel with lid while 64% of the respondents transport with vessel uncovered. In the study area, a variety of vessels were used to transfer water from the sources. These vessels were Bucket, Metal Vessel, Gallon, and Others (Bottle, Jar, etc.). "***Gagri***" is a metallic barrel used for transporting water, and the others are non-metallic containers.

Figure 4.2 Different Vessels used for Collection, Transportation and Storage of Drinking Water

Some of the houses used all or some of them used two or three of the above mentioned type of vessels to carry water from source to home as shown in the figure 4.3 below.

Majority (45%) of the households used plastic bucket to collect and transport water. As many as (33%) of the households used narrow neck vessels made of brass or copper, locally called ***'gagri'***, of 12-20 liters capacity, to collect and transport the needed volume of water from the public/private taps to the homestead.

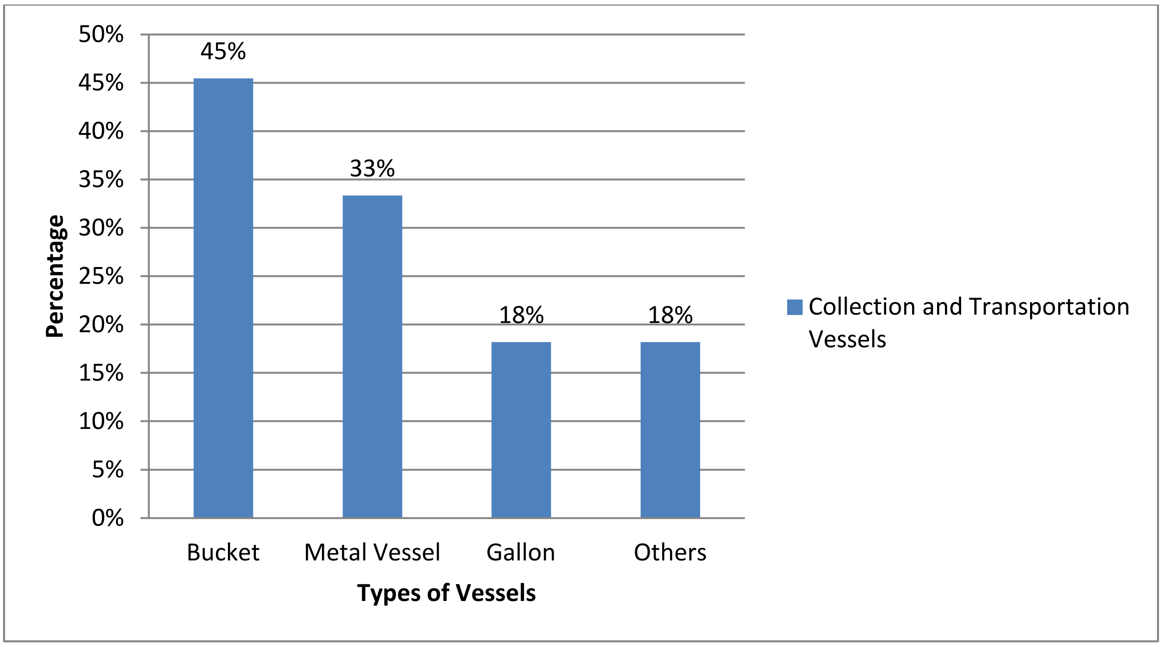


Figure 4.3 Types of Water Collection and Transportation Vessels used in Households

When the practices of transporting water in lidded or un-lidded vessels was inquired, in majority (63.64%) of the households the person(s) responsible for fetching water from the source were found not covering the mouth of the vessels while transporting water from the source to homestead where as in 36.36% of the households the mouth of the vessels was kept covered. Thus the uncovered vessels can also be the one of the reason for the contamination of water at the time of transportation which leads to contamination at the storage as well.

Table 4.9 Practice of Covering the Water Vessels in Transportation

Vessels covered/ not covered		**No. of *E.coli* (MPN/100ml)**			**Total**
		Low	Intermediate	high	
Yes	N	1	2	9	12
	%	3.03	6.06	27.27	36.36
NO	N	0	1	20	21
	%	0.00	3.03	60.61	63.64

4.7.2 Storage

In order to store water inside the household, households adopted a variety of techniques. The water that was transported from the source to the household was either kept in the same container or poured into a separate container meant to meet the daily water requirements of the households. But transferring water to another container for storage was common practices. In 15.15% of the households, the practice of mixing the freshly collected drinking water in the previous day's water in the storage container was found common, while 84.85% of households stored the collected water after completely emptying the previous day's collection. The vessels used for the storage of water also differed with the households. Use of narrow neck metallic vessels (*gagri*) of brass or copper for storage of water was noted (33.3%) of the households while 69.7% of the households used plastic buckets for the storage of water (Table- 4.10). Other (36.4%) of the households was found using clay pots or bottles to store water.

Table 4.10 Types of Storage Vessels used by the Sample Households

Types of Vessels	No. of Households	Percentage
Bucket	23	69.7%
Metal Jar	11	33.3%
Bottle	9	27.3%
Clay pot	3	9.1%

4.7.3 Treatment

In the study area, various water treatment practices were observed among the households. In this study, these treatment procedures were referred to as point of use (PoU) water treatment methods. These practices ranged from the simplest practice of boiling water or solar disinfection (SODIS) through the application of various types of water filters. Water treatment methods of some forms were found being used by as many as 81.8% of the households while 18.2% of the households were not practicing any water treatment method. The methods of water treatment used in the households were ceramic/sand filters (66.7%), boiling (12.1%) and solar disinfection (24.2%) as shown in figure 4.4. The most popular water treatment method among households was the use of ceramic bio sand filters, though local development organizations are promoting SODIS as an alternative.

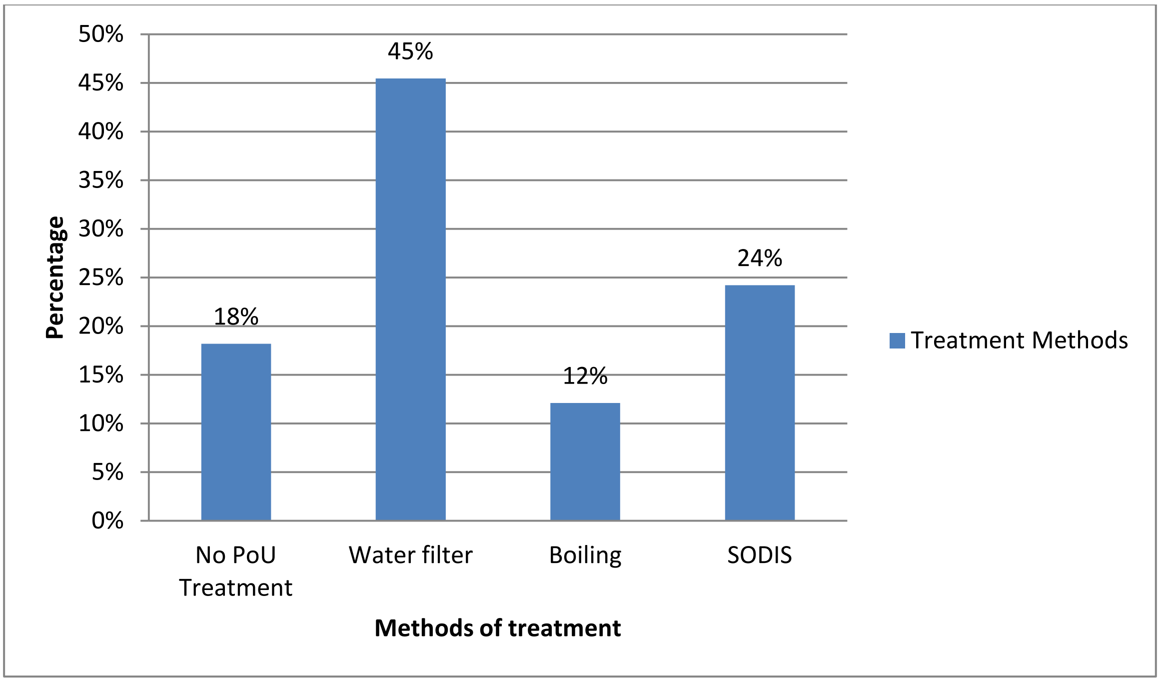


Figure 4.4 Households with different Types of Water Treatment Practices

4.7.4 Water used for Drinking Purpose

To meet the drinking needs, the family members in the households were observed consuming small amounts of water several times throughout the day in vessels of various sizes, either directly from the storage containers or after some types of treatment. The containers are steel glasses or various-sized plastic bottles. In 36.36% of the households the family members were found consuming water in glasses of different sizes while use of plastic bottles was noted in 60.61% of the households. In remaining 3% of the households, use of cups made of clay or ceramic was found being used to consume water.

The process of drawing water from storage containers and storing it in drinking vessels is a crucial aspect of water consumption. In 78.95% of the households, the family members were observed accessing water either by pouring it into a consumption vessel or by dipping it into storage containers to scoop out the necessary amounts. The remaining 21.05% of the households were found to using an extraction receptacle of some kind to extract water from the storage vessel. 15 of the households used short-handled jugs while 4 households used long-handled receptacles to prevent hands from coming into direct contact with the water kept in the storage vessel. The family members of these households used extraction receptacles to draw water from the storage vessel, especially from buckets.

4.8 Assessing Microbial Contamination of Water

It was found that it is important to establish the microbiological quality of water at the source and at the system that supplied the households included in the study for evaluating the drinking water quality at the household level and any potential contamination caused by behavioral practices in water handling in the study area.

Table 4.11 Microbial Contamination of Water at Water Supply System

Water Supply System	**No. of Samples (Households)**	***E.coli* (MPN/100ml)**			
		Safe (0)	Low (1-10)	Intermediate (11-100)	High (>100)
Hand Pump	33	1	0	1	31
MWSS	3	0	0	0	3

As mentioned previously, this study focused on two water supply systems in the Gulariya Municipality, including a Tube well/Hand pump that served 33 of the 33 sample households and a municipal drinking water supply that served three sample households. In the Tube well/Hand pump system, microbial water quality at the source, treatment points and storage water were analyzed. The obtained results of water quality analysis at water supply system are presented in Table 4.11.

4.9 Sanitation and Hygiene Practices and its Impact on Water Quality

Sanitation and hygiene behavior of the family members is a very important factor responsible for contamination of water at the household level. These behaviors include practice of hand hygiene and cleaning of utensils used in transportation, storage and consumption. Of the 33 respondents included in the study, only 14 (42.42%) of them said that they wash their hand with soap or ash before collecting water. The frequency of cleaning the vessels used for collection and transportation of water from the source to homestead differed with the household. While in majority (69.70%) of the household the utensils for collection and transportation of water was found to be cleaned daily, the frequency of cleaning of the utensils in 21.21% of the households was at the interval of 2-3 days and as long as 4-5 days in remaining 9.09% of the households. The Combination of infrequent washing of hands and water utensils is known to increase the likelihood of water contamination. The combination of responses on frequency of cleaning of water utensils and hand hygiene obtained among the households in the study area are presented in Table 4.12.When the respondents were inquired on practice of defecation and hand hygiene with soap after defecation, all of them reported that they use private latrines and they wash their hands after defecation with soap or ash.

Table 4.12 Practice of Cleaning of Water Vessels and Hand Hygiene in the Study Area

Frequency of washing the vessels	**Percentage (%)**	**Hand Hygiene with soap before collecting water**		**Total**
		Yes	No	
Daily	23 (69.70%)	10 (30.30%)	13 (39.39%)	23 (69.70%)
2-3 days	7 (21.21%)	2 (6.06%)	5 (15.15%)	7 (21.21%)
4-5 days	3 (9.09%)	2 (6.06%)	1 (3.03%)	3 (9.09%)

4.9.1 Hand Hygiene

Hand hygiene is the vital behavior of human being to stay healthy. It is one of the key of personal hygiene. A person can be protected from various diseases simply by washing their hands properly. In the question asked when do you wash your hands with the options given every time when it is dirty, after using toilet, before preparing food, before eating food, after toileting children, before fetching water and before drinking water, respondents answer had variations from 2 in some options to 33 in others as shown in Figure 4.5. Not only, is hand hygiene important it is vital also for number of times such as after using toilet and before eating food to remain healthy.

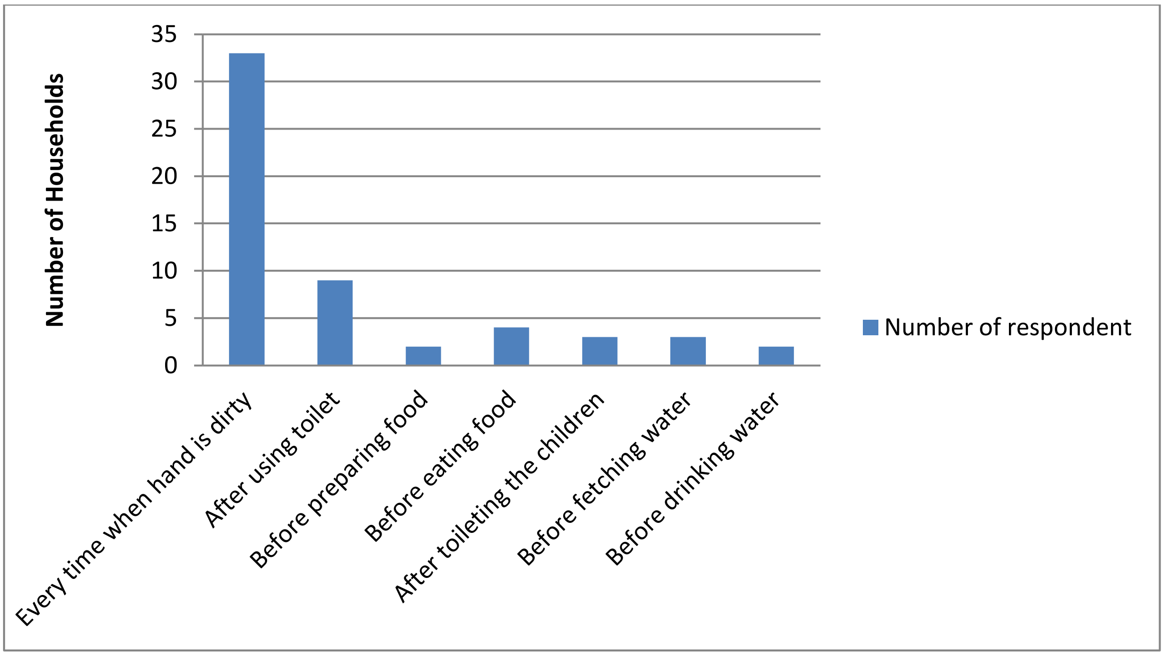


Figure 4.5 Hand Hygiene Habit

At the crucial times like after using toilet and before eating the trend of hand hygiene with soap was low in the municipality. That meant they handle water with the dirty hands and that ultimately leads to contamination of water at the households either at the time of storage or at the point of use.

Though hand hygiene is good healthy living practice, just simply washing hand with water is not very much protective, it requires proper hand hygiene with soap (Husain, 2015). Though majority of the surveyed hhs practices hand hygiene, the question is do they regularly wash their hands? The result showed that the hand hygiene frequency in Gulariya municipality is higher (94%). This is the result of the awareness level of importance of hand hygiene. But still the respondents are yet to know about the importance of the hand hygiene with soap. So, though they wash their hands with water it still has the chance to contaminate the water while, fetching or cooking food, while taking out water in the cup or jug from the container to drink and at many other points.

People were asked what might be the keys to remain healthy and to have good personal hygiene. Most of the respondents (81.82%) answered that safe drinking water is the main key to remain healthy. Similarly clean hands were the second key for the respondents to remain healthy. This shows that the people in both of the settlements have knowledge of the importance of drinking water and the clean hands for the healthy life.

Table 4.13 Keys to Remain Healthy

Keys to Remain Healthy	Number of Households	Percentage of Households
Bathing Everyday	7	21.21%
Clean drinking water	27	81.82%
Clean environment	8	24.24%
Clean hands	20	60.61%
Others (Good Food)	4	12.12%

4.9.2 Sanitation

Contained septic tank is one of the steps in sanitation service chain which need to be constructed in order to minimize the contamination of water sources whether it is surface or groundwater. 21 (64%) out of 33 respondent households have simple toilet i.e. with the concrete rings placed in the dug hole, 10 out of 33 (30 %) surveyed household's toilets are connected to a septic tank, 2 out of 33 (6%) household toilets generate biogas. The number of various types of toilets observed in the household questionnaire visit is shown in Table 4.14. Amongst those households (64 % of the households) who have concrete rings, 76% has 3 to 4 concrete rings. The concrete rings' size is 0.3 meter height and 0.91 meter diameter. 10 (30.30%) houses have septic tanks have open bottom. The bottom of all the existing septic tanks lack proper cement lining. This could act as a potential source of leakages to the groundwater. Since it is a low lying area, frequent flooding during the monsoon season poses a serious threat to these toilets and is expressed by the local people. The overarching of the sludge from the septic tank can pollute the water sources during the monsoon season.

From Table 4.14, for sanitation facilities with pit latrines 20 (60.61%) of the water samples were found highly unsafe and 3 (9.09%) of the water samples were found at low risk. In contrast, 9

(27.27%) and 1 (3.03%) water samples was highly unsafe and safe respectively for sanitation facilities with septic tanks.

Data shows that *E.coli* contaminations from sanitation facilities in Gulariya Municipality were found 96.97%; UNICEF (2020) states that *E.coli* contamination from sanitation facilities on other hand was found 79.20% overall in Nepal where as 83.4% in Lumbini Province.

Table 4.14 Sanitation Facilities with respect to Groundwater Contamination with E.coli

***E.coli* (MPN/100ml)**		**Sanitation Facilities**		**Total**
		Pit Latrine	Septic Tank	
Present	Low	3 (9.09%)	0 (0.00%)	3 (9.09%)
	Intermediate	0 (0.00%)	0 (0.00%)	0 (0.00%)
	High	20 (60.61%)	9 (27.27%)	29 (87.88%)
Absent	Safe	0 (0.00%)	1 (3.03%)	1 (3.03%)
Total		23 (69.70%)	10 (30.30%)	33 (100%)

4.10 Changes in the Microbial Water Quality at the Household Level

For all the households included in the study, the source of drinking water is public or private taps, either from municipal water supply system or from the tube well/hand pump. The water obtained from the source taps is subjected to different levels of risks of contamination depending closely on the water handling and use behavior at the household level. This section discusses the changes in the levels of bacterial contamination in the water at different stages of water handling and use at the household level observed in the study area. The Terai Plain in Gulariya has alluvial soils. This particular soil type has a higher water percolation rate. Gulariya's groundwater table varies from 6 to 12 meters (20 to 40 feet), which makes it highly vulnerable to contamination (Tripathi, et al., 2021).

4.10.1 Changes in the Contamination Level from Source to Storage

The changes in the number of *E.coli* from the source tap to storage at the households in the two water supply systems is presented in Table- 4.15. Any increase in the *E.coli* count in storage is due to possible contamination during transportation of water from the source tap to storage vessel and during storage at the household level. As discussed in the previous section the households were using different kinds of transportation vessels in transporting water from the source tap to homestead storage vessels and practice during transportation was either keeping the mouth of the transportation vessels covered or open. Therefore, in noting down the changes in the *E.coli* count from the source to storage the effect of the practice of covering the mouth of the transportation vessel was also taken into account. Table 4.15 shows that out of 33 samples of hand pumps collected, 3 were found safe at the source; however during the transportation and storage process, the remaining 3 samples were further found contaminated with *E.coli*. It means all 33 samples after storage found *E.coli* contamination. Similarly, all pipeline supplied water at the source was contaminated with *E.coli* and after analyzing the same sample when stored, it was again found all contaminated with *E.coli*.

Table 4.15 Changes in the Contamination Level from Source to Storage

Water Supply System	**No. of Households**	***E.coli* (MPN/100ml)**			
		Source		**Storage**	
		Safe	Unsafe	Safe	Unsafe
Hand Pump	33	3	30	0	33
MWSS	3	0	3	0	3

The result indicates that pathogen free water at the source is not a guarantee for safe. The sanitation practices also have impact in the water quality at the source.

4.10.2 Storage Vessel and Risk of Contamination

The practice of storage of water at homes and the kinds of storage vessels used in storing water among the households in the study area has been discussed in the previous section. This section looks into the effect of kinds of storage vessels on likely contamination of water noted among the households in the study area. The risk level of water in storage based on the *E.coli* counts in the water stored in different kinds of storage vessels observed in the study area is presented in Table-4.16. This revealed different levels of risk associated to different vessels in storage of water at homes. It was however not possible to identify the kind of the storage vessel that was most effective in terms of lowering the risk of bacterial contamination during storage. Two factors, which are likely to affect contamination of water during storage and relate to the behavioral practices in water handling, are use of kinds of storage vessels and the duration of storage. In attempt to look into the effect of the storage vessels on likely contamination of water in storage, the risk levels associated to different kinds of storage vessels were compared (Table- 4.16). This revealed different storage vessels have different levels of risks of contamination of *E.coli* during storage with higher level of risk associated to such storage vessels as plastic and metallic buckets and clay pots.

Data shows that *E.coli* contaminations in stored drinking water in Gulariya Municipality were found 96.97%; UNICEF (2020) states that *E.coli* contamination in stored drinking water on other hand was found 85.10% overall in Nepal where as 90.9% in Lumbini Province.

Table 4.16 Risk Level of Water in Storage as Affected by Types of Storage Vessels

Types of storage vessels		**No. of *E.coli* in storage vessels**
Plastic	N	18
	%	54.55
Metal, Clay, Wood, Ceramic or Glass	N	11
	%	33.33
Other vessels materials	N	4
	%	12.12

From the Table 4.17, for the vessel kept above waist height, 8 (24.24%) of the water samples were found highly unsafe for drinking water from the sources, 1 (3.03%) and 1 (3.03%) of the water samples was found low and intermediately unsafe for drinking water from the sources respectively. For the vessel kept below waist height, 21 (63.64%) of the water samples was shown that they were highly unsafe to drink water taken from the sources, and 2 (6.06%) of the samples were depicted that they were intermediately unsafe. 80% of the sample of the vessel kept above waist height were highly contaminated and 91.30% of the sample of the vessel kept below waist height, in other hand were highly contaminated.

The Table 4.17 showed that the samples kept above waist height were less contaminated than the samples kept below waist height. It was concluded that the drinking waters were stored above waist height to prevent from contamination.

Table 4.17 The Vessel kept above Waist Height

Vessel kept above waist height		**No. of *E.coli* (MPN/100ml)**			**Total**
		Low	Intermediate	High	
Yes	N	1	1	8	10
	%	3.03	3.03	24.24	30.30
No	N	0	2	21	23
	%	0.00	6.06	63.64	69.70

From the Table 4.18, for a sign of dirt on the vessels or containers, 15 (45.46%) of the water samples were found highly unsafe for drinking water from the sources, and 2 (6.06%) of the water samples was found intermediately unsafe for drinking water from the sources. For no sign of dirt on the vessels or containers, 14 (42.42%) of the water samples was shown that they were highly unsafe to drink water taken from the sources, and 1 (3.03%) and 1 (3.03%) of the samples were depicted that they were low and intermediately unsafe respectively.

Table 4.18 Any Sign of Dirt on the Vessels or Containers

Any sign of dirt on the vessels or containers.		**Presence of *E.coli* (MPN/100ml)**
Yes	N	17
	%	51.52
NO	N	16
	%	48.48

The Table 4.18 showed that the samples of sign of dirt on the vessels or containers were 51.52% contaminated and the samples of no sign of dirt on the vessels or containers are 48.48%.

4.10.3 Methods of Water Extraction and Risk of Contamination

The effect of the types of the storage vessels and contamination risk of water, household water management practices are also likely to impair the drinking water quality. Higher level of contamination of coliform was detected in those cases where a serving utensil was used. Significant difference was seen in contamination levels between households where the family members dip their fingers while extracting water and the households where the family members pour water out of the storage container as shown in Table 4.19. This may be connected to the fact that serving utensils could not fit through the openings of vessels with narrow mouths. Studies that investigated the possibility of transferring faecal contamination into stored drinking water by dipping water extraction receptacles in storage containers came up with similar findings (Copeland, et al., 2009; Trevett, et al., 2004). However, in cases when the source water itself had a higher amount of faecal contamination, there was no significant difference in the contamination level between narrow and wide mouthed storage containers. This observation was also made in earlier studies that examined how storage vessels affected the contamination of stored water (Jensen, et al., 2002). Improving household treatment and storage methods may not result in a quantitative improvement in water quality when the source water is of poor quality. Wide opening storage containers generally contain higher levels of E. coli contamination than narrow necked storage containers, which is mostly due to die-off effects brought on by increased heat exposure (Barcina, et al., 1986). This could not be observed in this study because this study did not look into the changes in the number of coliform in storage at different periods and the effects of environmental conditions thereto. Contrary to the findings of this study, studies completed by (Copeland, et al., 2009) and (Trevett, et al., 2004) suggested that the types of storage container may not be major determinant in controlling the likely contamination in storage.

From Table 4.19, for used types of extraction utensils with small handled jugs 45.46% of the water samples were found *E.coli* contamination. While used types of extraction utensil with the tap, by pouring, and long handled jugs were 24.24%, 18.18% and 12.12% respectively found *E.coli* contamination.

Table 4.19 Water Extraction Methods and E.coli Contamination Risk

Types of Extraction Utensil Used		**Presence of *E.coli* (MPN/100ml)**
Not used (Pour)	N	6
	%	18.18
Small handled jug	N	15
	%	45.46
Large handled jug	N	4
	%	12.12
Tap	N	8
	%	24.24

4.10.4 Vessels used for Drinking Water and Risk of Contamination

The possibilities of contamination resulting from the use of different kinds of consumption vessels, the risk level of contamination of faecal coliform associated with different kinds of consumption vessels used among the households were analyzed (Table 4.20). The analysis revealed high risk of contamination of faecal coliform in steel glasses and plastic bottles as compared to ceramic cups, probably due to improper cleaning and therefore formation of bio-film in the inner lining of the consumption vessel (Momba, et al., 2003).

Table 4.20 Effect of Different Types of Consumption Vessels on Faecal Coliform

Types of Consumption Vessel		**Risk Level by number of *E.coli***			**Total**
		<1 No risk	1-10 Low risk	>10 High risk	
Steel glass	N	1	1	8	10
	%	3.03	3.03	24.24	30.30
Mud glass	N	0	1	5	6
	%	0.00	3.03	15.15	18.18
Plastic bottle	N	0	2	15	17
	%	0.00	6.06	45.46	51.52

4.10.5 Tracing Water Contamination through Socio-economic and Cultural Lenses

The sanitation and hygiene practices and behavior of the households are known to be dependent on the socio-economic characteristics. Therefore, the level of contamination in drinking water is expected to be different among different categories of households. In this study influence of three important socio-economic attributes- family size, income level and educational attainment were analyzed to look into the likelihood of water contamination resulting from differences in these attributes across the studied households. The possible effects of the stated socio-economic attributes on water contamination, as noted in the study area, are discussed in this section.

4.11 Water Borne Diseases

Water borne diseases are the major causes of the health hazards in the developing countries. The respondents were asked about water borne diseases. They had idea about various diseases that is diarrhea, dysentery, typhoid, cholera, worms, eye infection and jaundice which are caused by water. Figure 4.6 shows that respondents are more aware of all the diseases. 32 respondents in the municipality answered that they had suffered by diarrhea, 11 respondent suffered by dysentery, 11 respondent suffered by jaundice, 10 suffered by typhoid and 8 suffered by eye infection. Most of the respondents were aware about all the above water born diseases mentioned. So, the data shows that the people in the Gulariya municipality are more aware of the water borne diseases which may be due to the exposure to various intervention programs by governments/NGOs in this municipality. Data shows that, there are 18–20% water-related diseases, reduced from 48% before ODF (KII, municipality).

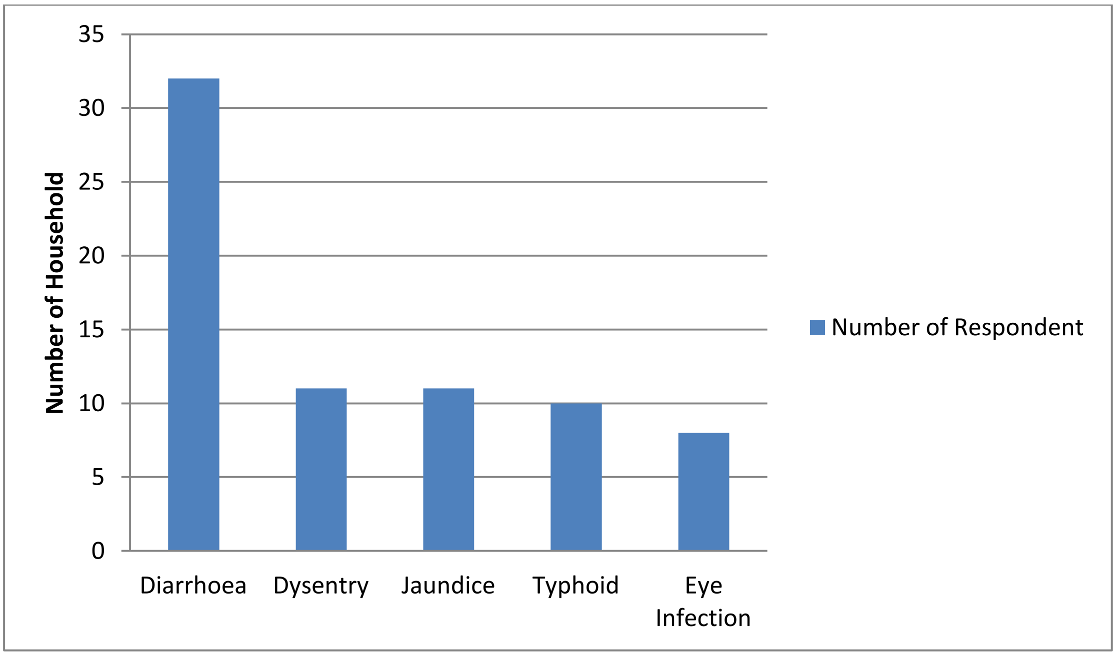


Figure 4.6 Knowledge of Various Water Borne Diseases

Though they were aware that water can cause many diseases, some of them were the victims of the water born diseases. The most pronounced disease was diarrhea in the settlements. Other diseases like jaundice and dysentery were also reported by the people as shown in the Table 4.21.

Data shows that out of 33 samples of hand pumps collected, 30 were found contaminated with *E.coli* and the remaining 3 samples were found safe at the source. The occurrence of water-related diseases has been found at a high rate in households. Mainly 96.97% suffered from diarrhea whereas 33.33% suffered from jaundice and dysentery each, 30.30% suffered from typhoid and 24.24% suffered from an eye infection. While the household whose source was found safe, they were also suffered from water-related diseases like diarrhea and typhoid. It means the occurrence of water-related diseases in the household justifies the *E.coli* contamination.

Table 4.21 Occurrence of Water Related Diseases

Types of Water-related Disease		Household suffered from Diseases
Diarrhoea	N	32
	%	96.97
Typhoid	N	10
	%	30.30
Dysentery	N	11
	%	33.33
Jaundice	N	11
	%	33.33
Eye Infection	N	8
	%	24.24
Total	N	72
	%	100

Due to the lack of proper sanitation facility, the pandemic had occurred in the settlements before three years ago. The participants in the focus group discussion revealed that typhoid, diarrhea and the jaundice were the main diseases that occurred during the period of pandemic. That incident of pandemic affected almost all of the households of the settlement. It was because of the improper sanitation habit, lack of drainage system in the settlement and the drinking of water without any kind of treatment.

While cross tabulating the houses with the age under 5 and the occurrences of disease 63.64% of the houses with the children suffered with some kind of water borne diseases.

Table 4.22 Water Disease in the Children under Age Five

Below children under Age 5		**Disease**		**Total**
		Yes	No	
Yes	N	12	9	21
	%	36.36	27.27	63.64
No	N	7	5	12
	%	21.22	15.15	36.36
Total	N	19	14	33
	%	57.58	42.42	100

This supported the fact that the children are the one who are vulnerable to the water borne disease at first in the family.

4.12 Socio-cultural Barriers

The socio-cultural barriers to water contamination are complex and can vary greatly from one region to another. Generally, these barriers can be divided into two categories: cultural norms and beliefs and economic incentives. Cultural norms and beliefs often play a role in water contamination, as people may be unwilling to change their practices or even recognize the need for change. Additionally, cultural beliefs can lead to a lack of awareness of the health risks associated with water contamination and the importance of water conservation. Economic incentives can also play a role in water contamination. For example, in areas where access to clean and safe water is limited, people may resort to using contaminated water sources to meet their needs, due to the low cost. As such, providing economic incentives, such as subsidies or tax credits, to encourage the use of safe water sources can be an effective way to reduce water contamination.

4.12.1 Types of Houses

For different types of houses, out of the 33 households included in the study, in 15 (45.46%) has one stored *kaccha* houses (thatched/mud houses) while two stored *kachha* houses and two stored *pakka* houses (cemented houses) was 21.21% and 15.15% respectively. In other hands, one stored *pakka* houses and more than two stored *pakka* houses were found 9.09% each.

Table 4.23 Types of Houses

Type of Houses		**Presence of *E.coli* (MPN/100ml)**
One-stored *kaccha*	N	15
	%	45.46
two-stored *kaccha*	N	7
	%	21.21
One-stored *pakka*	N	3
	%	9.09
two-stored *pakka*	N	5
	%	15.15
More than two-stored *pakka*	N	3
	%	9.09

This Table 4.23 shows that more conscious efforts made by the households of one-stored *pakka* and more than two-stored *pakka* in limiting the contamination level of water in storage and consumption than one-stored *kaccha*, two-stored *kaccha* and two-stored *pakka*. The poorer groups of households face a higher risk of bacterial contamination of water during storage and consumption due to insufficient access to sanitation and hygiene practices as well as a lack of information and awareness.

4.12.2 Gender Role in the Water Management Level

Gender roles considered in this study were those played by men and women in water management heads of households. The Table 4.24 show that 81.82% of women as a wife and heads of households are more involved in the water management while 18.18% of men as a heads of households involved in water management. The results show that women predominate in the decisions on the water management level. In the study area, 72.73% of water sample were highly unsafe as a women manager in the water management level while 15.15% of water sample were highly unsafe as a men manager in the water management level which may be because female population in this municipality have lower literacy rate (43.88%) than male (56.12%) and thus lack of knowledge and awareness.

Table 4.24 Gender Role in the Water Management

Gender Role in the Water Management Level		**Presence of *E.coli* (MPN/100ml)**
Female Manager	N	27
	%	81.82
Male Manager	N	6
	%	18.18

4.12.3 Educational Attainment of the Water Manager

In this study risk level of bacterial contamination in water was compared across the households with different levels of educational attainment, as shown in Table 4.25. The observation in this table show that positive effect of level of educational attainment of the family members involved in water handling in reducing the risk of bacterial contamination in drinking water from the source to the point of use. 54.55% of respondents were found to have a significant level of risk of bacterial contamination, particularly those with uneducated family members handling water or those with illiterate. In houses whose family members who handled water had higher levels of education such as secondary level, higher secondary and graduate level was 18.18%, 15.15%, and 0.00% respectively.

Table 4.25 Risk of Bacterial Contamination of Drinking Water in Relation to Educational Attainment

***E.coli* (MPN/100ml)**		**Education Attainment**				**Total**
		Illiterate	Secondary Level	Higher Secondary	Graduate	
Present	Low(1-10)	2(6.06%)	0(0.00%)	1(3.03%)	0(0.00%)	3(9.09%)
	Intermediate(11-100)	0(0.00%)	0(0.00%)	0(0.00%)	0(0.00%)	0(0.00%)
	High(>100)	18(54.55%)	6(18.18%)	5(15.15%)	0(0.00%)	29(87.88%)
Absent	Safe(0)	0(0.00%)	0(0.00%)	0(0.00%)	1(3.03%)	1(3.03%)
Total	N	20	6	6	1	33
	%	60.61	18.18	18.18	3.03	100

4.13 Transmission Pathways of Contamination of Drinking Water in Gulariya Municipality: Research Finding

The transmission pathway of pollution starts from the groundwater contamination due to the septic tanks with the unsealed bottom. So, the water sources have already been highly contaminated. In the processes of collection and transportation, the contamination level increases due to improper hand hygiene with soap or sanitizer, or detergent at the time of collection and opened mouth vessels at the time of transportation. During the storage period, the vessel kept outdoors, below waist height, easily accessible to animals or birds, and uncovered mouth deteriorates the water quality. As the stored water consumed or used, it is be also contaminated because of the extraction of water from the vessels without using extraction receptacles. Overall, contamination level of water in each stage from contaminated sources to mouth has gradually increased.

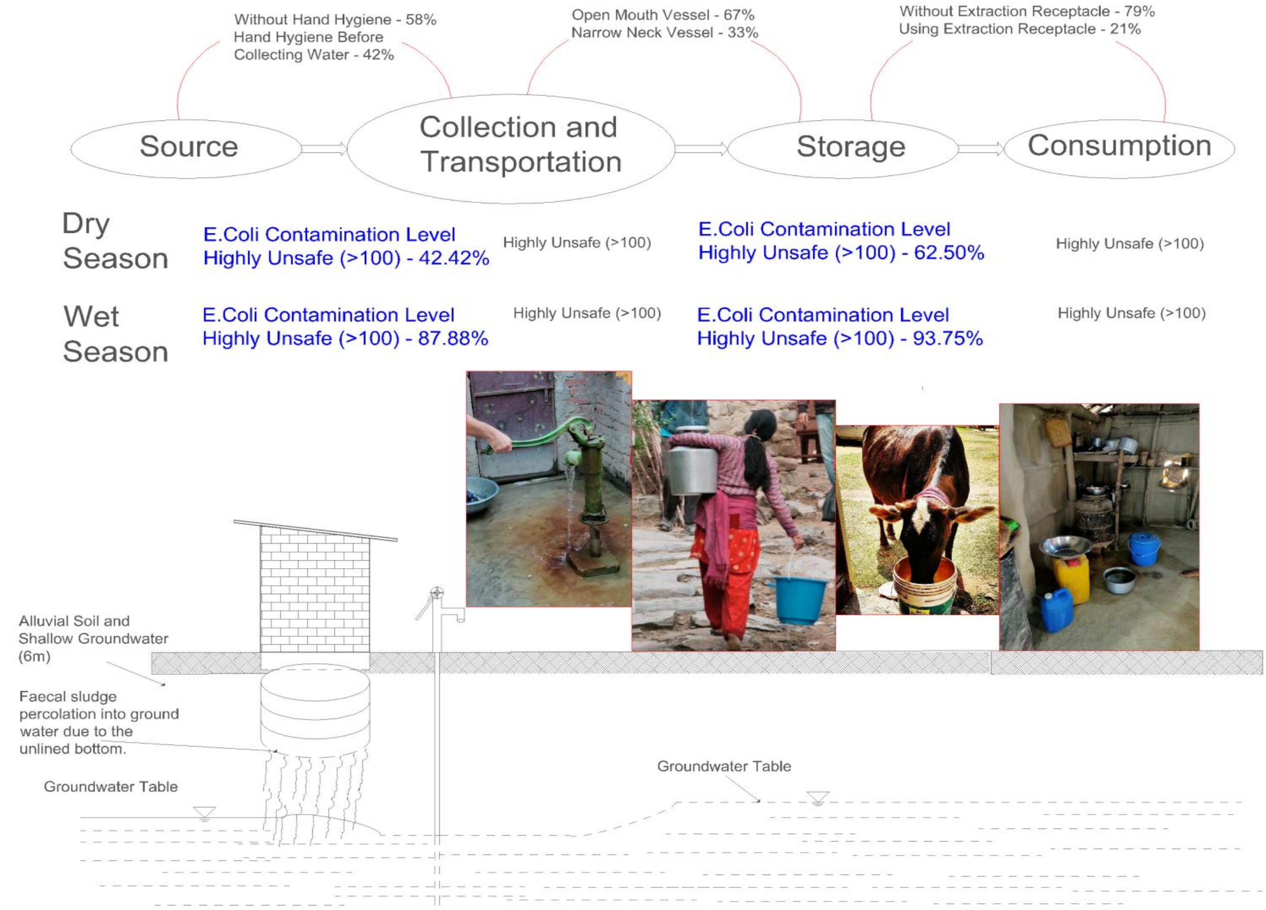


Figure 4.7 Diagrammatically showing The Transmission Pathways of Contamination of Drinking Water of Gulariya Municipality

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study was conducted in selected wards of Gulariya Municipality to explore the pathways of pollution of drinking water arises from sanitation practices and behavior, to assess the contamination of ground water due to onsite sanitation system thereby contributing for behavioral practices from source to mouth in the study area. The study also aimed to examine the contribution of socio-cultural barriers in managing water quality for domestic purposes in the study area.

Gulariya's groundwater is particularly contaminant-prone at shallow depths (6 m) due to its alluvial soil type. Groundwater contamination is caused by 95% of on-site septic tanks/pits that are not sealed at the bottom. Data show that 15% of septic tanks are not drained since its construction, indicating groundwater percolation. In addition to septic tank percolation, 86% of the population disposes of or retains FS in the soil rather of transporting it to the FSTP. Moreover, only 8% of FS is sent to FSTP (Tripathi, et al., 2021). Seasonal variations were demonstrated to have significant influences on the detection of indicator parameters. The higher *E.coli* (88%) detection rates during the wet season were linked to the season's favorable environment for bacteria than dry season (42%). Water-borne diseases frequently have significant effects on the community. The most frequently recurring diseases were diarrhea (88%) and dysentery (85%), along with typhoid, jaundice, eye infection, worms, and skin problems. Even utilizing soap and water after defecating was observed in very few populations whenever it related to sanitary practices. It was found that the settlement had a significant prevalence of water-borne diseases. Even though the occurrence of water-borne diseases was significant, it was observed that many people were unaware of the diseases causes. No adaptation strategies were adopted by the dominant population.

Various water handling procedures and the application of PoU treatment determines the microbiological quality of drinking water inside the house. Water quality decreases from the source to the consumption point when suitable water handling procedures and PoU treatment are not practiced or not appropriately performed at the household level. It was found that in most of the households people did not washed their hand with soap before collecting the drinking water and most of them washed their water handling vessels in daily basis without using any detergent. The combination of the practice of hand hygiene at the time of collection of water and frequency of cleaning of collection and storage vessel was found to affect the level of contamination of water. Also, the drinking water was observed to be stored under unsanitary conditions, i.e. in containers lacking of lids and in the same vicinity as livestock.

The study also shows that socio-cultural barriers such as lack of knowledge, inadequate infrastructure, and limited access to resources are the main obstacles to managing water quality at the household level. 59% of the peoples are engage in farming, 15% are in business and 26% do labor work. 61% are uneducated and are deprived from awareness of sanitation practice and they also belong to very low economic group. Mainly they have agriculture as a source of income. So, they sanitation cannot fall under their priority (Tharu, 2022). 82% of women are involved in the water management role than (18%) of men. The results show that women predominate in the decisions on the water management level.

5.2 Recommendations

- Local Government should focus on the construction of septic tanks/pits with standard design (i.e. containment) especially the sealed bottom to prevent seepage to groundwater sources for water source protection and the design is to be introduced in the upcoming building bylaws edition. Similarly, they should be proper mechanism to be developed to aware people about the constructed FSTP and its benefit to the health and the environment so that it will be functional and safe sanitation chain will be attained.
- Water Safety Plan (WSP) should be prepared for municipal water supply system (MWSS), Gulariya as soon as possible to ensure safe drinking water through good water supply practices. The local WASH groups should be proactive to implement WASH services in the municipality effectively. For example: D-WASH-CC, M-WASH-CC, W-WASH-CC, T-WASH-CC and S-WASH-CC.
- The government and development partners need to provide proper training, orientation and awareness to local peoples and stakeholders (regulators, farmers, local government employees, landowners and industry representatives and sanitation workers).
- The women water management at the household level should be given proper training regarding safe water management, hand hygiene and good sanitation practices.
- It is suggested to promote and increase awareness among general public on need and importance of safe water, sanitation practices and behavior and water quality testing at household level. And also suggested to ensure safe and sustainable water use, the participation of community members in decision-making process access to education and

information and the provision of adequate resources. Improving water quality at the household level requires a multi-sectoral, interdisciplinary approach to address socio-cultural barriers.

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APPENDICES

Appendix I: Questionnaire for the household survey

General information:

Name	
Ward number	
Age	
Sex	Male ☐ Female ☐
Caste	Bhramin ☐ Chhetri ☐ Janajati ☐ Socially Marginalized ☐ Madhesi ☐ Muslim ☐ Others ☐
Education	Illiterate ☐ Primary Education ☐ Higher secondary Education ☐ Graduate ☐ University Level ☐
Occupation	Agriculture ☐ Service ☐ Business ☐ Others ☐ Foreign Employment ☐
House type	Mud House ☐ Concrete ☐ Wooden ☐ Others ☐
Household Head	Male ☐ Female ☐ Others ☐
House Ownership	Own ☐ Rented ☐
Ground Water Source	Hand Pump ☐ Dug Well ☐ Municipal water supply ☐
Depth of Hand Pump / Well	
Family Size(Nos.)	

Sanitation facilities

1. How many toilets do you have in the house?

2. What kind of toilet facility do members of your household usually use?

1- Flush/pour flush
2- Ventilated improved pit latrine (VIP)
3- Composting toilet
4- Pit latrine with slab
5- Pit latrine without slab/open pit
6- No facilities/bush/field (Open Defecation)
7- Shared
8- Other toilet facility

3. If Flush / Pour Flush, Where does it flush to?

Pit Latrine (   )
Septic Tank (   )
Elsewhere (   )
Unknown (   )

4. In your opinion what is the condition of water resources of your community/area?
a. Good
b. Not Good
c. Don't know

5. How you know about your water quality?

6. While storing the drinking water in your house, do you mix the freshly collected water with previously stored water of earlier day?

a. Yes   b. No

<u>Personal Hygiene and Behavior</u>

7. When do you wash your hands?
1.Every time when hand is dirty
2.After using toilet
3.Before preparing food
4.Before eating food
5.After toileting the children
6.Before fetching water
7.Before drinking water
8.Other

8. Hand Hygiene with soap before collecting water?
1. Yes   2. No

9. Why it is important to wash your hands?
1-To remove dirt
2-To protect from diseases
3-To remove bad smell from hands
4-Others

10. What is the most important thing, in your opinion to remain healthy?

1- Bathing Everyday
2-Clean drinking water
3-Clean environment
4-Clean hands
5-Others

11. Do you have live stock at your home?

1. Yes   2. No

12. If Yes, Which one(s)?
1-Cows and Buffalos

2- Pig, Ducks and Chickens
3-Dogs and Cat
4-Goat
5-Others

13. What are the diseases you know about by drinking contaminated water?

1-Diarrhea
2-Typhoid
3-Dysentry
4-Jaundice Worms
5-Eye infection
6-Others

14. What do you do when somebody get sick at your home?

1-Visit dhami/jhakree
2-Hospital/Health center
3-Self medication

15. How frequently have you experienced visiting doctor due to above mentioned water induced diseases in last year?

1-Once a year
2-Twice a year
3-More than twice
4-No visit

16. How much money you spent in medicine yearly?

Water Source

17. Where do you get your drinking water?

1- Hand pump/ Tube well
2- Sand filter/ R.O filter
3- Piped water (into dwelling)
4- Public tap or standpipe
5- Bottled water
6- Other (specify)

18. How far is the source of water from your household?

1- (<100 m)

2- (100-500m)

3- (>500 m)

19. On average, have you fetched water from this source during the last month?

1- Twice a day
2- Daily

3- 2 days
4- Weekly
5- Don't know

20. Do you drink water directly from the source?
1. Yes 2. No

21. What type of container/device do you collect the water with?

1- Plastic
2- Metal, Clay, Wood, Ceramic/glass
3- Other vessel material

Water Storage

22. Is the source of the water stored within the compound?
1. Yes 2. No

23. Where do you store your drinking water?
1- Small container (e.g. 20litre jerry can/pot or smaller)
2- Larger container (larger than 20 liter and, up to 100 liters in size)
3- Tank (larger than 100 liters)
4- Water stored in containers bought at a shop
5- Other (specify)
6- Don't know

24. When was this container (used to store drinking water in the home) last cleaned?

1- Today
2- Yesterday
3- In the last week
4- In the last month
5- Longer than this
6- Never

25. What was used to clean the container?

1- Water only
2- Water and detergent
3- Water and abrasive (cloth, net or sand)
4- Water and Ash
5- Water and Mud
6- Water, detergent and abrasive (cloth, net or sand)
7- Other (specify)

26. Which part of the container was cleaned?
1- Inside
2- Outside
3- Lid

4- All parts
5- Don't know

27. Is the vessel accessible to animals or birds?
1. Yes 2. No

28. Is the vessel kept above waist height?
1. Yes 2. No

29. Does the vessel has a lid and is it covered?
1. Yes 2. No

30. Are there signs of dirt on the container?
1. Yes 2. No

31. Is the water container kept indoors?
1. Yes 2. No

32. If indoors, where?

1- Kitchen
2- Bedroom
3- Living (sitting) room
4- Other (specify)

33. What types of storage vessels?

1-Bucket
2-Metal Jar
3-Bottle
4-Clay pot
5-Others

34. How does the respondent take water from the vessel?

1- Cup with handle
2- Cup without handle
3- Jug
4- Inclined Jerrycan
5- Dipper (with long handle)
6- Tap
7- Other (specify)

Water Treatment

35. What did you do to make the water safer to drink?

Boil ( )

Add Bleach/Chlorine/Water guard ( )

Add a water coagulant (e.g. alum) ( )

Strain through a cloth/Sieve ( )

Use water Filter (composite/sand/ceramic etc.) (   )

Solar disinfection (   )

Let it stand to settle (   )

Other (specify) (   )

None   (   )

Cultural Barrier

36. Do all ethnic groups can use the same tap?

1. Yes   2. No

If No, from where does the other specified groups collect water from? Specify the source.

37. Have you ever tested the quality of drinking water?

1. Yes   2. No

If Yes, when did you test the water?

38. Who is responsible for fetching water?

1. Male   2. Female

39. Where do you dispose the liquid waste from your house?

1-Nearby pit
2-Pubic sewerage
3-Open drain
4-Kitchen garden
5-Directly into the river

Socio-Economic

40. How many members are there in your family?

1- Male
2-Female
3-Children

41. What is the major occupation of the family?

1-Farmer
2-Business
3-Employ

42. How many children are there in this family who are below 5 years of age?

43. How many sources of income are there for this family?

1- One
2- Two
3- Three
4- More than Three

44. Economic Status of the family?

1-Poor
2-Medium
3-Rich

45. Is this your own house or are you living in rent?

1-Own
2-Rent

46. In case the house is of your own, what is the type of the house?

1-one story kachha house
2-two story kachha house
3-one story pakka house
4-two story pakka house
5-more than two story pakka house

47. Where is the house located at?

1-Market
2-Close to market
3-Away from market
4-Squatter

Diseases

48. Methods of Water Extraction on Contamination in Storage Vessel

1-Not used (Pour)
2-Small handled jug
3-Large handled jug
4-Tap (Direct)

49. Which kind of water-related disease in your community in the last 5 years?

1-Diarrhoea
2-Typhoid
3-Dysentery
4-Eye infection
5-Jaundice

50. Educational attainment of the water manager?

1-Illeterate
2-S.L.C.
3-Higher Secondary

4-Graduate

51. What traditional beliefs and practices relate to the collection, storage and use of water ?

Appendix II: Checklist

List of KII conducted during field visit in Gulariya Municipality

S.N.	Name	Title	Address
1	Mr. Shabir Khan	Service holder	Mainapokhar, Badaiyatal Rural Municipality
2	Mr. Mukund Sharma	Social Development Officer	Gulariya Municipality
3	Mr. Tihar B. Chaudhary	Badghar	Samjhana tole, Balapur, Ward No. 5
4	Mr. Hari Ram Bhurji	Supervisor	Sanitary workers at FSTP

1. What is the source of drinking water?
2. Where do you dispose the liquid waste from household level?

Nearby pit	Public sewerage	Open drain
Kitchen garden	Directly into the river	

3. What are the overall sanitation practices in the municipality?
4. Is there any FS treatment plant in the municipality?
5. Will people be interested to have FSTP in or nearby their locality/community?
6. In your opinion what is the condition of water resources of your community/area?
   a. Good
   b. Not Good
   c. Don't know
7. What is the major problem or difficulties faced while operating the treatment plan?
8. What kind of trainings or awareness activities do you think is required in addition to the previous awareness program?

List of FGD conducted during field visit in Gulariya Municipality

S.N.	Name	Address
1	Sanitary workers	FSTP
2	Squatter settlement(now they have land with sanitation facility)	Dipendranagar Tole
3	Muslim community(Women)	Purano VDC Tole, Ward No. 6
4	Tharu community	Balapur, Ward No. 5
5	Urban Business group	Ward No. 6
6	Madhesi community	Ward No.7, Kotharipur, Krisnashar Tole
7	Dalit Basti(Settlement)	Taruwa, Ward No. 2

1. What is the major problem or issue of this community relating to the drinking water?
2. Have you suffered from water borne diseases like diarrhea, typhoid and jaundice? How often?
3. What is the most important thing, in your opinion to remain healthy?

   1- Bathing Everyday
   2-Clean drinking water
   3-Clean environment
   4-Clean hands
   5-Others

4. Where do you dispose the liquid waste from your house?

   1-Nearby pit
   2-Pubic sewerage
   3-Open drain
   4-Kitchen garden
   5-Directly into the river

5. What traditional beliefs and practices relate to the collection, storage and use of water?
6. What kind of trainings or awareness activities do you think is required in addition to the previous awareness program?

Appendix III: List of Respondents from Water Quality Test

S	Name of House Owner	Ward No.	Source of Water(Well / Hand pump)	Depth of the Source(ft)	Distance from Septic Tank(ft)	*E.Coli* (MPN/100ml)		pH
						Dry	Wet	
1	Jokhan Gaddi	12	Hand pump	35	97	>100	>100	6.74
2	Health post/ Mohammad	12	Hand pump	25	26	>100	>100	7.08
3	Tharu community forest user group/ Kaliprassad Chaudhary/Badghar	5	Hand pump	125	101	1.5	>100	7.13
4	Khusi Ram Tharu	5	Hand pump	40	25	0	>100	6.85
5	Chhabi Narayan Tharu	5	Hand pump	80	64	1.5	>100	7
6	Rupa Sharma Bajagain	6	Municipal Water Supply			>100	>100	6.71
7	Parbati Rokaya	6	Hand pump	35	15	>100	>100	6.84
8	Rupa Sharma Bajagain	6	Hand pump	55	64	4.7	4.7	6.7
9	Handpump Street	2	Hand pump	40	18	>100	>100	6.82
10	Dewan Damai/landless people	2	Hand pump	30	41	>100	>100	7.19
11	Jaikali Damai	2	Hand pump	135	46	>100	>100	6.82
12	Min Prasad Subedi	2	Hand pump	40	21	48.3	>100	6.88
13	Ram Prasad Tharu	4	Hand pump	35	57	13.6	>100	7.2
14	Rajesh Yadav	7	Hand pump	35	105	1.2	2.4	6.73
15	Khusnuma Khan	6	Hand pump	40	11	0	>100	6.78
16	Sabia Began	6	Hand pump	40	20	48.3	>100	6.71
17	Jamsed Ahamad	6	Hand pump	35	110	5.2	>100	6.75
18	jawahirlal Gupta/ Private shop	6	Hand pump	35	26	3.7	0	6.86
19	Satya Narayan Baniya	6	Hand pump	90	27	>100	>100	6.97
20	FSTP	5	Hand pump	115	15	32.6	>100	7.23

21	Jagmohan Godiya	9	Hand pump	35	36	9.6	>100	6.97
22	Chabilal Lodh	9	Hand pump	45	37	0	>100	6.99
23	Nanda Shahi	9	Hand pump	45	82	2.6	>100	6.97
24	Santosh Bahadur Shahi	9	Hand pump	55	73	>100	>100	6.9
25	Nashim Ahamad	10	Hand pump	50	45	>100	>100	6.68
26	Pampha Lodh	8	Hand pump	50	58	13.6	>100	6.69
27	Gaurishankar Temple	6	Hand pump	35	85	48.3	>100	6.87
28	Suraj Parajuli	5	Hand pump	50	90	0	>100	6.76
29	Asgar Ali Hazzam	7	Hand pump	40	32	1.1	>100	6.73
30	Muktiyar Dhobi	5	Hand pump	50	28	3.4	>100	6.79
31	Baliman Burathoki	7	Hand pump	45	55	4.7	>100	7.13
32	Mahabood Ali Dhobi	7	Hand pump	35	24	>100	>100	6.98
33	Gulam Sabbir Haluwai	7	Hand pump	30	12	1.5	9.6	6.74

Appendix IV: Water Quality Results

E.Coli

Correlation between *E.Coli* and Depth of the Well

Correlations			
		Upper 95% Comfidence level/100mL	Depth of the well
Upper 95% Comfidence level/100mL	Pearson Correlation	1	.179
	Sig. (2-tailed)		.210
	N	50	50
Depth of the well	Pearson Correlation	.179	1
	Sig. (2-tailed)	.210	
	N	50	50

Correlation between *E.Coli* and Distance between the Hand pump to Septic Tank

Correlations			
		E.coli	Distance
E.coli	Pearson Correlation	1	.042
	Sig. (2-tailed)		.773
	N	50	50
Distance	Pearson Correlation	.042	1
	Sig. (2-tailed)	.773	
	N	50	50

T- Test

Paired Samples Correlations				
		N	Correlation	Sig.
Pair 1	Upper 95% Comfidence level/100mL & Upper 95% Comfidence level/100mL	50	.300	.032

Paired Samples Test							
E.Coli for Dry and Wet season	Paired Differences				t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			

					Lower	Upper			
Pair 1	Upper 95% Comfidence level/100mL - Upper 95% Comfidence level/100mL	4202.97569	4695.36606	657.48276	2882.38270	5523.56867	6.393	50	.000

Nitrate

Correlation between Nitrate and Depth of the Well

Correlations			
		Depth of well	Nitrate (NO3)
Depth of well	Pearson Correlation	1	-.145
	Sig. (2-tailed)		.315
	N	50	50
Nitrate (NO3)	Pearson Correlation	-.145	1
	Sig. (2-tailed)	.315	
	N	50	50

Correlation between Nitrate and Distance between the Hand pump to Septic Tank

Correlations			
		Nitrate (NO3)	Distance
Nitrate (NO3)	Pearson Correlation	1	.137
	Sig. (2-tailed)		.343
	N	50	50
Distance	Pearson Correlation	.137	1
	Sig. (2-tailed)	.343	
	N	50	50

T-Test

Paired Samples Correlations				
		N	Correlation	Sig.
Pair 1	Nitrate (NO3) & Nitrate for 1st data	50	.521	.000

Paired Samples Test				
Nitrate for Dry and	Paired Differences	t	df	Sig. (2-

Wet season		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				tailed)
					Lower	Upper			
Pair 1	Nitrate (NO3) - Nitrate for dry	-3.3340	2.7366	.3870	-4.1117	-2.5563	-8.615	50	.000

pH

Correlation between pH and *E.coli*

Correlations

		pH	Upper 95% Comfidence level/100mL
pH	Pearson Correlation	1	.087
	Sig. (2-tailed)		.544
	N	50	50
Upper 95% Comfidence level/100mL	Pearson Correlation	.087	1
	Sig. (2-tailed)	.544	
	N	50	50

Correlation between pH and Nitrate

Correlations

		pH	Nitrate (NO3)
pH	Pearson Correlation	1	-.113
	Sig. (2-tailed)		.428
	N	50	50
Nitrate (NO3)	Pearson Correlation	-.113	1
	Sig. (2-tailed)	.428	
	N	50	50

T-Test

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	pH & pH for dry	50	-.173	.224

Paired Samples Test									
pH for Dry and Wet season		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	pH - pH for dry	-1.00078	.52823	.07397	-1.14935	-.85222	-13.530	50	.000

Temperature

Correlation between Temperature and *E.coli*

Correlations

		Temperature (°C)	Upper 95% Confidence level/100mL
Temperature (°C)	Pearson Correlation	1	-.034
	Sig. (2-tailed)		.816
	N	50	50
Upper 95% Confidence level/100mL	Pearson Correlation	-.034	1
	Sig. (2-tailed)	.816	
	N	50	50

Correlation between Temperature and Nitrate

Correlations

		Temperature (°C)	Nitrate (NO3)
Temperature (°C)	Pearson Correlation	1	.229
	Sig. (2-tailed)		.110
	N	50	50
Nitrate (NO3)	Pearson Correlation	.229	1
	Sig. (2-tailed)	.110	
	N	50	50

Appendix V

Photographs

	
Interviewing on HHs Survey	Interviewing on HHs Survey
	
Taking Water Sample from Hand pump	Taking Water Sample from storage vessel
	
Taking Water Sample from R.O. Filter	Taking Water Sample from Bio-sand Filter

Taking Water Sample from Storage Vessel

Focus Group Discussion

Measuring pH value from pH meter

Water Quality Testing using MPN Test Kit

Water Quality Testing using Aqua Reader Version 4.0

Water Quality Testing using Pocket Colorimeter (for Nitrate)