STRATEGIES TO ENHANCE THE QUALITY AND SAFETY OF HOUSEHOLD DRINKING WATER IN BURAYU TOWN, OROMIA REGIONAL STATE, ETHIOPIA

By

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DEDICATION

I would like to dedicate this research work to my father and mother, my family member including spouse and children Alsen, Amen and Kena.

DECLARATION

I declare that this thesis which is entitled ***STRATEGIES TO ENHANCE THE QUALITY AND SAFETY OF HOUSEHOLD DRINKING WATER IN BURAYU TOWN, OROMIA REGIONAL STATE, ETHIOPIA*** *is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.*

I further declare that I submitted the thesis to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at UNISA for another qualification or at any other higher education institution.'

__________________ 21 June 2021

Signature Date

Kebede Eticha Gela

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ABSTRACT

The purpose of this research was to develop strategies to enhance the quality and safety of household drinking water (HDW) in Burayu town, Oromia regional state, Ethiopia and other similar settings.

Quantitative, non-interventional and cross-sectional research design and risk-based approach to HDW safety were employed. The data was collected from 265 households using an interview schedule and testing of water samples for faecal contamination indicators based on membrane filtration technique. Descriptive and explanatory methods which include bivariate and multiple logistic regression analysis were used to analyse the data.

The results revealed that 10.9% of all the sample households had low risk drinking water safety on combined water sample test and HDWI analysis. However, 57.0% of all the water samples, 82.1% of bottled water and 78.6% of the household treated drinking water samples using chlorine products were free of contamination indicators. Only 19.2% of the low risk HDW quality test results were aligned with the same risk level on the combined analysis.

Diarrhoea occurrence among under five years of age children was associated with lack of HDW safety risk perception (OR 2.8, 95% CI 1.3 -6.3), lack of latrine (OR 4.9, 95% CI 1.2 - 20.0) and regular cleaning of food utensils by the households (OR 4.0, 95% CI 1.2 -13.6).

Low risk HDW safety was associated with household water treatment (HWT) practices (AOR 12.6.0, 95%CI 1.2 – 125.0) and with low risk HDWI result having 58.0% (n=29) overlap on this risk level. Low risk microbial water quality findings were associated with bottled water (AOR 4.3, 95%CI 1.5 – 12.9) and HWT using chlorine products (AOR 3.2 95%CI 1.1 – 9.8), household's higher income (AOR 5.3 95% CI 1.4 – 20.2) and frequency of water container cleaning (AOR 2.6, 95% CI 2.5 – 5.1). This research further identified that HWT practices were associated with HDW safety risk perception that increased the practice by 72.0 % (AOR 0.28, 95% CI: 0.09–0.90) and with households' ability to conducting HWT (AOR 7.7 95%CI 3.7 -15.9).

In conclusion the safety of drinking water at household level is a big concern and comprehensive strategies are required to address the problem.

KEY CONCEPTS

Diarrhoea; drinking water quality and safety; drinking water treatment; hygiene; behaviour change; bottled water; risk-based approach; sanitation; safely managed drinking water, Ethiopia.

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LIST OF ABBREVIATIONS

AOR	Adjusted odd ratio
CI	Confidence interval
CLTS	Community led total sanitation
E.coli	Escherichia coli
EDHS	Ethiopia demographic and health survey
EHP	Environmental Health Project
FMoH	Federal ministry of health of Ethiopia
FMoWIE	Federal ministry of water, irrigation and energy
GDWQ	Guideline for drinking water quality
HBCC	Hygiene behaviour change communication
HDW	Household drinking water
HDWI	Household drinking water inspection
HSTP	Health sector transformation plan
HWTS	Household water treatment and safe storage
JMP	Joint monitoring program
NAS	National academy of sciences
OR	Odd ratio
OWNP	One WASH national program
PoU	Point of use
RANAS	Risk, attitude, norm, ability and self-regulation
SDG	Sustainable development goal
SEM	Socio-Ecological Model
SSA	sub-Saharan African
UNICEF	United Nations Children’s Fund
UNISA	University of South Africa
WQ	Water quality
WSP	Water safety plan
WASH	Water, sanitation and hygiene
WHO	World health organization

CHAPTER 1

ORIENTATION TO THE STUDY

1.1 INTRODUCTION

Adequate and safe drinking water, sanitation and hygiene (WASH) are essential for health, survival and wellbeing of people. However, these basic needs are far from reach for most of the world's poor population (John, Jain, Rahate & Labhasetwar 2014:725).

Public health problems related to inadequate WASH provision constitute a major disease burden in developing countries. In particular, diarrhoeal diseases are among the leading contributors to global child mortality, 20.0% of all deaths in children under five years of age. In low and middle-income countries (LMIC), 58.0% of the diarrhoeal morbidity and an estimated 842 000 deaths from diarrhoea each year globally is linked to inadequate WASH provision to the population (Pruss-Ustun, Wolf, Corvalán, Bos & Neira 2016:16). According to the UNICEF report, 60.0% of deaths due to diarrhoea in the world are attributed to unsafe WASH (UNICEF 2019).

Unsafe drinking water is a major risk factor for causing morbidity and mortality in the world (Eslami, Ghaffari, Barikbin & Fanaei 2018:40). Inadequate and unsafe drinking water supply related diarrhoeal diseases cause over 500,000 deaths each year and contributed to 9.1% of the global disease burden by 2015, primarily among children under five years of age in LMIC (Peletza, Kisiangania, Bonhama, Ronoha, Delairea, Kumpela, Marksb & Khushc 2018:907; Daniel, Diener, Pande, Jansen, Marks, Meierhofer, Bhatta &Rietveld 2019: 847).

Though global diarrheal disease incidence has reduced, linked to increased access to improved water sources, the burden among children under five years of age remains a concern (UNICEF & WHO 2016:5). Diarrheal outbreaks like cholera cause 3 to 5 million morbidities and 100,000 deaths every year across the world. The problem persists linked to the growing number of vulnerable people who do not have access to adequate WASH services. Lack of access to safe drinking water is the main risk to the disease among the cluster of risk factors. Contamination of drinking water and inefficient treatment are the path of diarrheal disease transmission including cholera (Lilje, Kessely & Mosler 2015:57).

Emerging issues related to human development, climate change, population growth and urbanization exert pressure on the availability and quality of water and associated disease risks (WHO GDWQ 2017:122, Li & Wu 2019:73, WHO 2019 online factsheet). Rapid urbanization in sub-Saharan African (SSA) countries has already led to a growing concern of sanitation condition, faecal contamination and risk of adverse health outcomes (Hurd, Hennink, Robb, Null, Peprah, Wellington, Yakubu & Moe 2017:300). According to the National Academy of Sciences (2018), 50.0% of the world population live in urban areas compared to less 15.0% in 1900.

Drinking water safety is incorporated into the Sustainable Development Goal (SDG) service level measurement for drinking water that involves the top service level, safely managed drinking water. The SDG baseline report indicates 29.0% of the global and 76.0% of the SSA population lack access to safely managed drinking water which is accessed on premises, free from contamination and available when needed. A total of 844 million people, which constitute 42.0% of the population in SSA, don’t have access to basic drinking water service (WHO/UNICEF 2017:10-23). Linked to these, the quality and safety of drinking water used by households is a big concern required to be addressed. Also the global trend analysis of drinking water service levels from 2000 to 2017 indicates that the target of reaching 100% safely managed drinking water services by 2030 is unlikely (Daniel, Sirait & Pande 2020:1). Hence, focus on ensuring the safety of drinking water at household level particularly in developing countries as an ‘interim approach’ is essential.

This research aimed to investigate the quality and safety of drinking water at household level and explore related determinant factors with a view to develop intervention strategies that contribute to addressing the safety of HDW at point of use (PoU).

1.2 BACKGROUND OF THE RESEARCH PROBLEM

An important and initial stage in a research process is defining the research problem. As described by Kothari and Garg (2019:22), it refers to difficulty experienced in the context of either theoretical or practical situations and requires a solution. Requirements for research problems include: existence of an individual or organization, the problem attributed, objective(s) to be attained, course of actions or alternatives towards the objective(s) and gap of clarity on the relative importance of different alternatives and the environment or context in which the problem pertains.

1.2.1 The source of the research problem

Low safety of drinking water in the world particularly in low- and middle-income countries is a big concern. The WHO global burden of diarrheal disease from inadequate WASH estimate report indicated that globally 26.0% of people drink water that is, at least occasionally, contaminated with faecal indicator bacteria and over 52.0% of the population in Africa expected to be exposed to contaminated drinking-water (WHO 2014:4).

According to the JMP report, one-fourth of the improved water sources have faecal contamination at the point of delivery (WHO & UNICEF 2017:2). And, an estimated 10% of improved drinking water sources are highly contaminated with faeces (Wolf, Hunter, Freeman, Cumming, Clasen, Bartram, Higgins, Johnson, Medlicott, Boisson & Pruss-Ustin, A. 2018:509).

In Ethiopia, the national drinking water quality (WQ) survey (2016) report indicated that limited proportion (14.0%) of the sample households (urban 37.4% and rural 8.4%) collect drinking water from low risk sources i.e. with no detectable Escherichia coli (E.coli) in the sample of water tested. As part of this, 36.4% (urban 15.9% and rural 41.6%) of households collected drinking water from sources categorized as very-high-risk in WQ (over 100 E.coli colonies count). The report also indicated that drinking water samples with low risk quality dropped to 5.6% (21.6% urban and 1.5 % rural) at PoU while the high-risk proportion increased the 36.4% to 48.0%. These suggest the general deterioration of the quality of drinking water between points of collection and use (CSAE 2016: 19-23).

However, the national survey report neither indicates the disparities that exist among different settings or households nor described the underlying factors influencing the quality and safety of HDW (UNICEF & WHO 2016:5). In order to address the problem, there is no dedicated national strategy on household drinking water safety. However, two national institutions responsible for drinking water safety i.e. Federal Ministry of Health (FMoH) and Federal Ministry of Water, Irrigation and Energy (FMoWIE) prepared broader strategies on National Hygiene and Environmental Health Strategy which include strategic objectives for safe drinking water from source to consumption and strategic framework on Climate Resilient Water Safety, through implementation of climate resilient water safety plan (CR-WSP), (FMoH 2016:16-17, FMoWIE 2015). While effective implementation of these strategies could help to address the safety of water at point of collection and use, a strategy on HDW safety is required to maintain and enhance the safety of drinking water at household level.

Drinking water related health problems like diarrhoeal diseases remain a persisting problem and cause of outbreaks in low- and middle-income countries. Analysis of evidence from 31 countries in SSA indicated 16.0% prevalence of diarrhoea in this region (Adedokun & Yaya 2020:3). In Ethiopia, a prevalence of 12.0% reported among under 5 years of age children over a 2 weeks period was reported. It accounts for 13.0% of the causes of deaths of the children (CSAE 2016:124,166). Evidence also indicated in 2013 diarrhoea caused over 38,500 children deaths every year in Ethiopia (GAVI 2013). In this research area, diarrheal illness is among the top five causes of morbidity among children under five years of age.

To address the prevailing problem of unsafe drinking water at PoU and diarrheal disease, water safety intervention across the water supply chain starting from the catchment and source to household level is being promoted. In this regard, households have a great role to ensure the safety of drinking water at point of use (Brown, Hamoudi, Jeuland & Turrini 2014:2).

Hence, this research is based on a premise that households' have a great role for ensuring the safety of drinking water at household level and their practices determine the safety of water at PoU. This is in particular relevant in the general context of low capacity in the implementation of drinking water safety intervention across the water supply system. The researcher is interested in application of risk based approach to investigate factors which are related with the safety of drinking water at household level and the behavioural factors that influence households' practice in relation to HDW safety as well as on application of risk-based approach to HDW safety and the association with diarrheal illness.

The researcher's professional experiences in drinking water safety including household water treatment and safe storage (HWTS) intervention, working in development and humanitarian contexts and engagement on national drinking WQ survey (2016) in Ethiopia created the interest to conduct a research on the topic.

1.2.2 Background to the research problem

WHO guideline for DWQ state that diseases related to contamination of drinking-water constitute a major burden on human health. Interventions to improve the quality of drinking water provide significant benefits to health (WHO GDWQ 2017:2). Improved water sources have been considered to protect contamination and a proxy measure of access to safe drinking water. However, growing body of evidences suggest that those sources do not assure the safety of water at point of delivery (Francis, Nagarajan, Sarkar, Mohan, Kang & Balraj. 2015:1; Seifert-Dähnn, Nesheim, Gosh, Dhawde, Ghadge and Wennberg 2017:1; Taylor, Khush, Peletz & Kumpel 2018:115).

Various factors across the water supply chain could introduce contamination and affect the safety of water. Water collected from improved sources could get contamination during transportation, storage and handling at household level. Intermittent supply of drinking water could also affect the quality and safety of drinking water (Falconi, Kulinkina, Mohan, Francis, Kattula, Sarkar, Ward, Kang, Balraj & Naumova 2017:29; Adane et al 2017: 2).

An estimated 309 million people worldwide experience interruption of water supplies and one third of urban water supplies in many low- and middle-income countries are frequently interrupted that could cause transmission of waterborne pathogens. Intermittent piped water supplies are a major problem in low- and middle-income countries including the slum areas of sub-Saharan Africa (Adane, Mengistie, Medhin, Kloos, & Mulat 2017: 1, 2).

The study conducted in rural Nepal indicated that increased contamination between the source and household storage was observed with 91.0% of stored water at home had E.coli (Daniel & Irvine 2015:59). Another study also indicated that most of the WQ deterioration, up to 30.0%, occurred during household storage (John et al 2014:725). Research conducted in Zambia indicates substantial microbial contamination HDW (Kinkese,Ndashe, Macwan, Toure,Kangwa, & Hang'ombe 2018: 63).

1.3 RESEARCH PROBLEM

The conventional and commonly used methodology of drinking WQ management which is based on end point testing of samples of drinking water for faecal microbial indicator and compliance monitoring has limitations which are described as "*too little too late*" to serve for public health protection.

Possible existence of other microbial hazards such as viruses and parasites in the environment and water treatment processes vary considerably from that of indicator bacteria. It was experienced that outbreaks of waterborne disease occurred regardless of compliance with the microbial guideline which is based on bacterial indicator organism. Thus, absence of faecal contamination indicator in a sample of water cannot guarantee safety of the water as some pathogens like cryptosporidium parvum are not easily inactivated on treatment. Enteric viruses and protozoa are more resistant to disinfection; consequently, the absence of E.coli does not necessarily suggest absence of these organisms. On the other hand, the result of the water sample test provides late and retrospective information which cannot help to prevent the risk of exposure to unsafe water (WHO QMRA 2016:1; WHO GDWQ 2017:65,149; CSAE 2016:19).

The quality of water could also vary in time depending on the condition of the water supply system and households practices, in which brief contamination events can escape detection on testing of samples of drinking water. Hence, there could be possible random and quick change in the quality of drinking water depending on the condition of the water supply system and its operation. For instance, increased water flow pressure could introduce or disseminate pathogens accumulated in sediments. Such short-term fluctuations on the quality of water can have high health risk to the user population. Also, water samples testing procedures have a drawback of taking time to get timely results for action (Eslami, et al 2018:40; WHO GDWQ 2017: 123).

In addition, regulatory requirements for monitoring drinking WQ through sample collection and testing on regular frequencies is found to be impractical or unreliable due to the cost, time and logistic implications in resource constrained settings (Taylor et al 2018:115; Peletz et al 2018:907). WQ monitoring practices are often conducted on testing of water samples from the point of collection rather than testing samples across water supply systems including PoU (FMoWIE 2015:19).

Studies also identified that the quality of drinking water is largely getting deteriorated than improved after collection from the source. For instance, a survey of drinking water (2016) quality in Ethiopia identified that 39.3% increase of the contamination was reported compared to 10.2% reduction in the contamination of drinking water at household level after collection from the source (CSAE 2016:27). This is due to contamination of the water during transportation, storage and handling at home. Though HWTS can improve the quality of drinking water at home, there is limited coverage of such practices and gaps in consistent and continued adoption of the practice by households. This undermines the potential outcome of the HWTS practices (Daniel et al 2019:847, Daniel 2020:2). In order to address these, there is a need for generating evidence regarding HDW safety practices and factors that determine the quality and safety of HDW (Francis et al 2015:1).

On the other hand, researches conducted on HWTS and related health outcomes i.e. on diarrhoea reduction found inconsistent findings. Open trial studies in low income settings found protective effects of the HWTS intervention while other controlled studies did not find association of drinking WQ with diarrheal disease incidence (Boisson, Stevenson, Shapiro, Kumar, Singh, Ward, Clasen 2013:2; Gruber et al 2014:1). The variation in the findings of the studies could be linked to the studies designs that applied the investigation of the association of drinking water safety and diarrhoea based on WQ testing results (WHO/UNICEF 2017:26).

The WHO WQ guidelines recommend a preventive, risk-based approach to drinking water safety management in order to proactively monitor and control critical risks in the water supply system from source to exposure or PoU (WHO QMRA 2016:1). JMP also recognizes a holistic risk management approach for ensuring the safety of drinking water (CSAE 2016:19). However, limited research has been conducted on risk-based approach to drinking water safety, primarily on HDW, and related outcome on diarrhoea.

Thus, this research employed a risk-based approach to investigate HDW safety using independent and combined analysis of the findings from risk assessments that involved drinking water sample testing and household drinking water inspection. The WHO GDWQ recognizes this approach as a reliable method for investigating and monitoring the safety of drinking water. Combined analysis helps to identify important causes and control measures of contamination particularly for HDW safety management. As microbial WQ testing for households is often impractical, household drinking water inspection (HDWI) risk assessment is an important strategy for HDW safety management (WHO/UNICEF 2017:38, 91). Risk assessment approaches are more feasible to assess risk at local settings or individual water supplies compared to epidemiological studies, which are applicable to large populations and incidence of health outcomes to provide sufficient statistical power (WHO QMRA 2016:3).

The other problem this research addressed is the paucity of evidence on investigating the outcome of drinking water service and other WASH exposure conditions on diarrhoeal disease prevalence have not been adequately investigated. The study conducted in Chad indicated that combined interventions of HWTS and hygiene could not enhance the outcome on diarrhoea (Lilje et al 2015:57-64). The WHO estimate of diarrheal disease related to inadequate WASH provision did not consider the effect of factors like intermittent supply of drinking water (Prüss-Ustün et al 2016:17).

Evidence has not been established regarding the outcome of safely managed drinking water in reducing diarrheal disease. Research reported the positive outcome of on-premise access to drinking water on diarrheal disease reduction (Wolf et al 2018:508). Thus, this research intended to explore the outcome of drinking water services and other WASH provisions on diarrhoea disease occurrence.

1.4 AIM OF THE STUDY

1.4.1 Research purpose

The purpose of this study was to develop strategies for enhancing the quality and safety of household drinking water (HDW) in the study area and other similar settings. This involved exploring factors which are associated with the safety of HDW and generating evidence to guide the development of the strategies.

1.4.2 Research objectives

The objectives of this research were to:

- Determine microbial safety of HDW using risk-based methodology
- Investigate the association of HDW safety risk levels with diarrhoea disease occurrence among children under five years of age
- Investigate the associations of WASH condition exposure scenarios including safely managed drinking water service with diarrheal disease occurrence
- Identify factors which are significantly associated with the safety of HDW
- Examine whether HDWI risk level correlate with the quality of HDW
- Develop strategies for enhancing the quality and safety of HDW

1.4.3 Research questions and hypotheses

This research aims to investigate the following questions which are relevant to the research problems:

- How is the microbial quality and safety of HDW in the study area?
- How is the association of HDW safety (risk levels) with diarrhoea occurrence? Are medium to high risk conditions of HDW safety associated with diarrhoea occurrence among children under five years of age?
- How is the association of WASH condition exposure scenarios with diarrheal disease occurrence? Do HDW safety and hygiene exposure risks associated with diarrhoea occur among children under five years of age?
- What factors determine or influence the quality and safety of HDW? Is the safety of HDW assured by households' treatment and storage practices?
- Does HDWI risk analysis relate with the quality of drinking water? Can HDWI variables predict the safety of HDW?
- What strategies can be developed to enhance the quality and safety of drinking water?

The hypotheses of this research, tentative solutions to the research questions based on the theoretical frame of the research (Bowling 2014:161-162), included:

- Diarrhoeal occurrence among children under five years of age is primarily associated with medium to high risk conditions of HDW safety
- Combined exposure to HDW safety and hygiene risks increase the occurrence of diarrhoeal among children under five years of age
- The safety of HDW is determined by households' treatment and storage practices which in turn is influenced by factors including households' risk perception, access to the technology options and contextual factor (household income)
- HDWI variables can predict the safety of HDW

1.5 SIGNIFICANCE OF THE STUDY

This study generates evidence regarding HDW quality and safety, related factors and strategies for assuring the safety of drinking water at household level. Thus, contribute to reduction of diarrhoea illness and other related health outcomes like nutrition among children under five years of age in the study area and similar settings.

This research also demonstrated application risk-based approach to drinking water safety, outcome on diarrheal disease prevalence and exploring factors influencing the safety of drinking water. Thus, the findings can help relevant sectors and professionals dealing with drinking water service delivery and surveillance for continuous improvement interventions.

The SDG has transitioned the water service ladder to include safely managed drinking water supply which consists of elements such as access, availability and safety of the water supply. The results of this study generated evidence on the health outcome of the service level that can be used for advocacy and promotion to ensure the drinking water service to the public.

1.6 CONCEPTUAL AND OPERATIONAL DEFINITIONS

Conceptual and operational definitions are required to describe the hypotheses i.e. all the concepts relevant to the study topic need to be defined and operational descriptions identified with the proxy measures of the concepts or method of measurement (Bowling 2014:162). The definitions of the concepts and operational descriptions relevant to this research are presented below:

Diarrhoea: is defined as three or more loose stools in a 24-hour period. Prevalence is the number of cases that exist at a given moment (Krickeberg, Hanh &Trong 2012:8). This study refers to diarrhoea occurrence among children under five years of age during the last two-week period of the data collection.

Drinking water quality: refers to the physical, chemical and microbial constituents of water used for human consumption. The most common and widespread health risk associated with drinking water is microbial contamination, the consequences of which mean that its control must always be of high importance (WHO GDWQ 2017:28). In this study, it refers to the microbial quality of water which is based on testing of indicator organism (E.coli / fecal coliform) and the findings are categorized by risk levels (low, medium and high).

Drinking water safety: According to the definition from Safeopedia - safety refers to a condition of being safe or protected. A condition where positive control of known hazards exists in an effort to achieve an acceptable degree of calculated risk such as a permissible exposure limit. As defined on the WHO guideline, safe water does not cause any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages (WHO/UNICEF 2017:1). UNICEF and the Ministry of drinking water and sanitation in India (MDWSI) (2013: 7) define it as the level of risk related to drinking WQ that serves as an indicator of how 'safe' the water is for consumption. This concept of risk level is applied in this research and involves the condition and practices at household to control the risk.

Household water treatment refers to treating water at home or PoU in other settings using technologies of a range of devices or methods (WHO GDWQ 2017:140a).

Household: comprises one or more people who occupy a housing unit or dwelling which can be a single detached house, town or row house, duplex, apartment or flat, mobile home, a group of rooms, a single room occupied as separate living quarters, a yurt, or a houseboat (McGregor 2016:5).

Strategy: is an activity or set of activities aimed at modifying a process, course of action or sequence of events in order to change one or several of their characteristics, such as performance or expected outcome. It describes a programme or policy designed to have an impact on an illness or disease in public health (WHO, Glossary of terms, WHO, 2004).

In this research, strategy refers to a list of key interventions that could have a considerable role for enhancing the safety of HDW.

Improved water sources are sources such as piped and non-piped supplies that have the potential to deliver safe water due to their nature of design and construction(WHO/UNICEF 2017:8).

Safely managed drinking water: is access to drinking water from an improved water source which is located on premises, available when needed and free from faecal and priority chemical contamination (WHO/UNICEF 2017:8).

Surface water sources are sources such as rivers and ponds which are highly exposed to contamination.

Unimproved water sources: are sources that are considered to be at risk from contamination. The WHO/UNICEF Joint Monitoring Programme (JMP) includes unprotected dug wells or springs, vendor-provided water, surface water, tanker-truck supply and bottled water within this category.

Bottled water: potable water obtained from approved underground water source, packaged in a container or bottles and presented for sale for human consumption or other uses (Yousaf & Chaudhry 2013:110).

1.6.1 Dependent and Independent variables

Variables are characteristics of units of the study which vary and take different values, categories and attributes on measurement. Variables that are the object of the study or part of the specified relationships are known as explanatory variables. These are classified as *dependent and independent*. Dependent variables are the expected outcome of the independent variables, which are the predictor or explanatory variables of the dependent variable (Straits & Singleton 2018:46-47; Bowling 2014:162). In this research while diarrhoea occurrence among children under five years of age and HDW safety are the primary dependant variables, other variables like drinking WQ and HWT practices were used as both independent and dependent variables.

The dependent variables for this research are:

- Diarrhoeal occurrence among children under five years of age during last two weeks period.
- HDW safety which is determined by combined analysis of water sample test for microbial indicator and HDWI results and the risk level classified as low, medium and high risk.

The independent variables include:

Drinking water quality – is the microbial quality of drinking water samples from households which is determined using faecal coliform indicator testing and the result is categorized as low, medium and high contamination risk levels.

Household drinking water inspection risk level – is determined by index-based measurement using ten relevant indicators to drinking water services and safety, hygiene and sanitation and the aggregated score is categorized by risk levels.

Water supply conditions - these involved elements of safely managed drinking water service which include water source, accessibility and availability.

Household water treatment - treatment practice, type of treatment method used, and efficiency of treatment practice by the households.

Household drinking water handling and storage practices - storage container, cleanliness of the container, storage capacity and duration.

Behavioural variables - these are elements of the RANAS behavioural model which include risk perception, attitude, social norm, ability and self-regulation. These variables are explained in the theoretical foundation section 1.7.

Household characteristics – these involve educational level and households' income.

1.7 THEORETICAL FOUNDATIONS OF THE STUDY

Theory is a set of interconnected concepts, definitions and propositions that explains situations by describing the relations among the concepts or variables. It condenses and organizes knowledge about the social world and explains how it works. It has assumptions, concepts, and explanations and frames how to investigate and think about a topic. It provides the researcher with concepts, basic assumptions and guidance to important questions. It also suggests ways to make sense of the data and making connections in order to see the broader significance of the findings. Good theory helps to clarify thinking, extend and deepen our understanding, and build knowledge over time. As Neuman noted, "theory is what helps researchers to see the forest instead of just a single tree" (Neuman 2014: 57-58, 86, Glanz 2019:0).

Assumptions are statements about the nature of things that we cannot observe or do not empirically evaluate. They are untested starting points or belief in a theory that is necessary in order to build a theoretical explanation. Theoretical concept – is an idea that is thought through, carefully defined, and made explicit in a theory. Concepts are the building blocks of theory and classified as concrete to abstract, simple or complex, variable (having values or quantities) and non-variable type. Explicitly defined concepts are required for conducting research and advancing knowledge (Neuman 2014: 57).Theories are also used to suggest effective ways to influence behaviour (Glanz 2019: 5).

The theory for this research is based on a faecal-oral ***disease transmission*** framework known as "F-diagram". This diagram was introduced by Wagner and Lanoix in 1958 to illustrate the pathways of faeces-based pathogens transfer from a person to a new host through fluid (water), food, finger (hand), flies, field and flood. The diseases spread when a susceptible person ingests a pathogen causing a disease, multiply inside the person and excreted with faeces to maintain the chain of transmission. (Daniel et al 2015:19, Reed & Scott 2014:4).

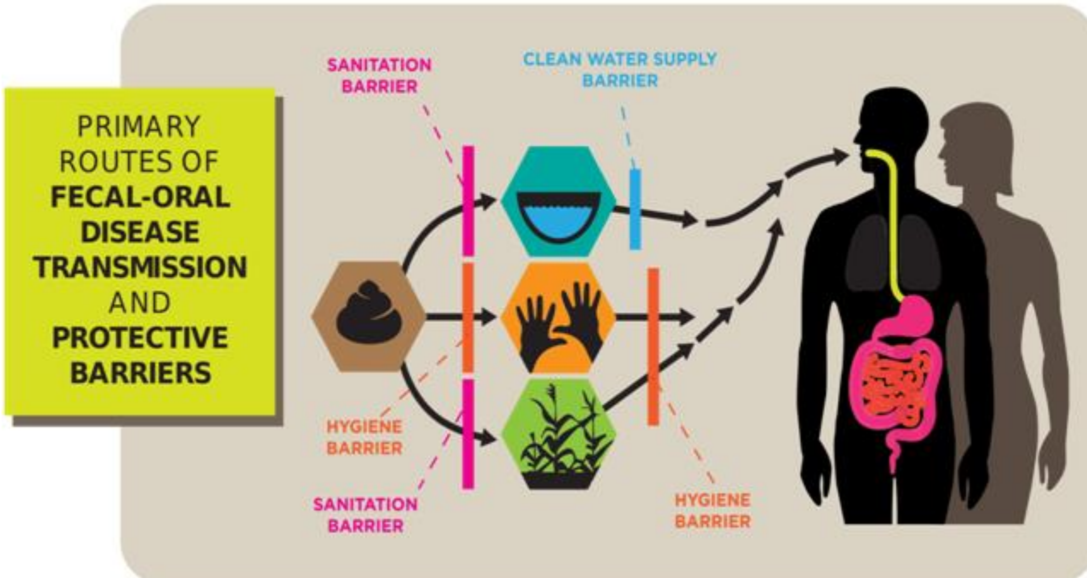


Figure 1.1 Faecal-oral disease transmission diagrams

The other theory used for this research to understand these factors which influence households' practices in relation to HDW safety was the individual psychological or behavioural model known as RANAS. These factors involve Risk perception, Attitudes, Normative factors, Ability, and Self-regulation or control (Seifert et al 2017:2).

Selection of models for understanding a particular behaviour is guided by its relevance (Ngigi & Busolo 2018:86). The RANAS model is advantageous in exploring WASH-related behavioural factors and to customize the RANAS construct to depict the linkages. It also describes socio-economic characteristics of people as a contextual factor influencing behaviour directly and indirectly through behavioural determinants(Daniel et al 2019:848).

Behavioural model - RANAS

Mosler and Contzen (2016:5) indicate Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) approach to systematic behaviour change as a method for measuring behavioural factors, assessing their influence on behaviour, designing tailored strategies that change behaviour and measuring the effectiveness of the interventions. The model is primarily developed for the WASH sector in developing countries and hence relevant to this research.

The model consists of four components: psychosocial factors (RANAS), behaviour change techniques (BCTs) i.e. type of intervention required for each of the factors, behavioural outcomes, and contextual factors which include social, physical and personal contexts (Mosler & Contzen 2016:7).

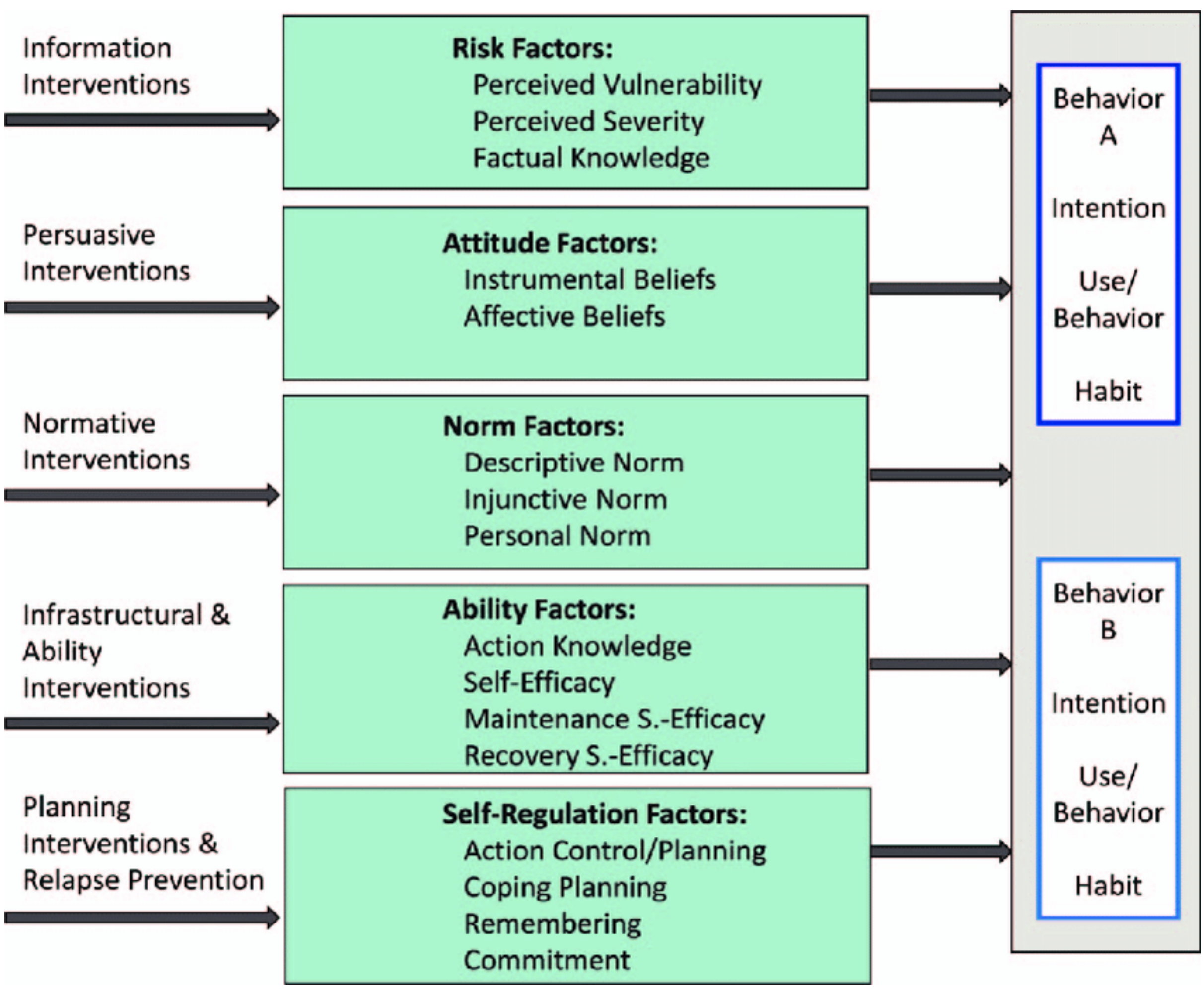


Figure 1.2: Elements of RANAS behavioural model

Psychosocial factors in the RANAS model are described below:

Risk factors- refers to respondents' knowledge and perception of risks, vulnerability and severity associated with use of unsafe drinking water.

Attitude factors-refers to respondents' positive or negative belief, feelings or opinions towards behaviours that ensure safe drinking water. These include beliefs regarding costs and benefits of the behaviour.

Norm factors - refers to the perceived social pressure and personal feeling towards the behaviour of HWTS for drinking water safety. This includes considering the behaviour as normal, approved or not in the community.

Ability factors - represents respondents' confidence in their ability to practice behaviours that ensures safe drinking water. These include their knowledge and perceived ability to organize, practice and continue the behaviour.

Self-regulation factors - refers to respondents' attempt to plan and self-monitor or evaluate a behaviour including managing conflicting goals and barriers, remembrance and commitment so that continuation and maintenance of the behaviour can be ensured.

The assumption is that combined psychosocial factors determine behavioural outcomes which include behaviour, intention, use, and habit. Behaviours are classified as desired (behaviour A) and competing behaviours (behaviour B), like use of safe drinking water vs use of unsafe drinking water. The psychosocial factors in turn are influenced by the contextual factors which include social (culture and social relations, laws and policies, economic conditions, information), physical (natural and built environment) and personal (socio-demographics such as age, sex, education and health of the individual) contexts.

1.7.1 Research paradigm

Paradigm is a theoretical perspective which consists of a set of assumptions that makes the foundation of a scientific enquiry (Bowling 2014:132). This research employed a positivist approach or philosophy through application of quantitative research methods. The approach assumes that conditions and human behaviour can be measurable and there is a single objective reality which can be ascertained using tools like survey and techniques of statistical analysis (Bowling, A. 2014:139-148).

Positivism considers social reality, comprises table and objective ‘hard’ facts so that value free research can precisely measure in the form of numbers and statistically test for causal theories. It applies a deductive process and emphasizes the principle of replication that repeated studies should produce closely related findings (Neuman 2014:50).

Accordingly, quantitative and systematic research design is employed for this research using an interview schedule to collect quantitative data on the study variables. The data were processed by statistical analysis to explore the association of the independent variables with the outcome variable. The objectivity of the evidences generated was ensured by controlling the source of biases and error throughout the study process.

1.7.2 Theoretical framework

Theoretical framework, also called theoretical system, is a very general theoretical system which contains assumptions, concepts, and specific social theories or forms of explanation. It is the synthesis of the thoughts in the field of study and basis for data analysis and interpretation of results. Often, researches seek evidence for one part of a theory within a framework (Neuman 2014:85).

The theoretical framework of this research which guide the explanation on the research problem and investigation of the research questions was based on the adaption of two models.

These are:

- Faecal-oral disease transmission pathway; and
- Behavioural model – Risk, Attitude, Norm , Ability, Self-regulation (RANAS)

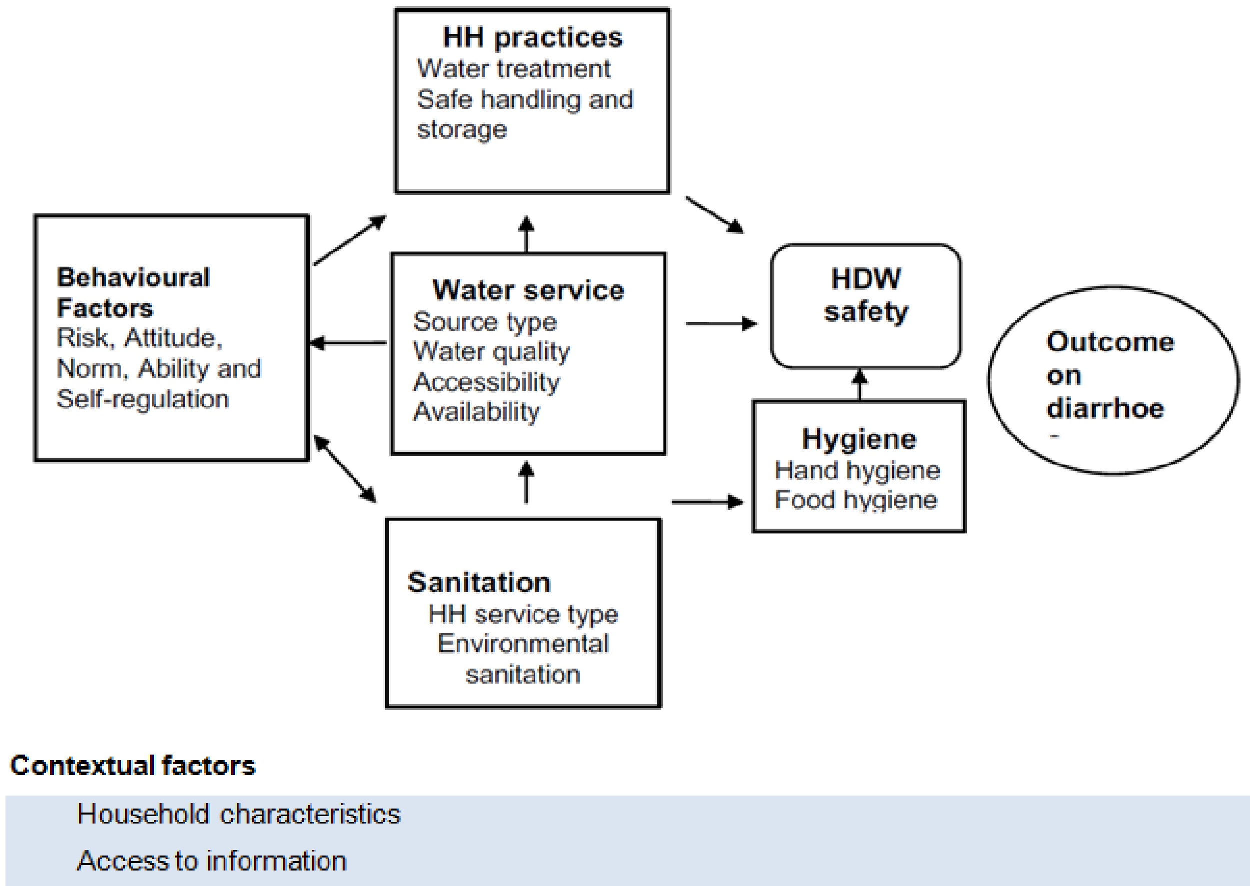


Figure 1.3: Theoretical Framework of HDW Safety

The WHO GDWQ (2017:118-120) indicates that an improvement in the quality and availability of water, excreta disposal and general hygiene are all important in reducing faecal–oral disease transmission. The relative contribution of these pathways to spread the disease could vary depending on pathogen, human behaviour and other context related factors including access to water, sanitation and hygiene (WASH) infrastructures. The WHO's recent estimate using comparative risk assessment (CRA) indicated a higher proportion of all cases of diarrhoea (34.0%) in LMIC which is linked to inadequate drinking water while sanitation and hygiene are attributed to 19.0% and 20% respectively. In combination, 58% of the diarrhoea morbidity is attributed to environmental risks which is primarily WASH (Pruss-Ustun et al 2016:16-17).

The newly adopted drinking water service of the SDG addresses three key elements of safely managed drinking water supply service which involve accessibility, availability and quality of the water provided to households (WHO/UNICEF 2017:24). Accessibility of water, in terms of premise level access or not, and availability in terms of regular supply could have linkage with the quality of water. Intermittent supplies, which are common in many developing countries, were found to have association with contamination (2017:57). The health outcome in terms of diarrhoea morbidity reduction of safely managed drinking water service has not well explored through research and this research included the analysis on this.

In relation to HDW safety practice, the uptake of water quality improvement interventions including HWTS often low by communities. A study conducted on drinking WQ intervention in rural Southern India indicated that lack of knowledge about health hazards associated with drinking unsafe water, low perceptions on water treatment, sense of protection from locally available water source, dislike to the taste or odor of treated water and a lack of support from male members of the household were important factors impeding acceptance and long term use of the intervention (Francis et al 2015:1). Applicable behavioural change intervention in this regard is essential.

A study in rural Nepal indicated that households' wrong perception on WQ is the main behavioural factor influencing HDW quality (Daniel et al 2015:59). Also, the study conducted in Chad on factors determining HWT practices identified that risk perception of diarrheal diseases, social norms, and perceived self-efficacy of households' were associated with the practice. Though many studies identified that HWTS improves the quality of drinking water, the coverage and adoption of this intervention is minimal, there is a demand for understanding factors which influence or hinder HWT practices. The study in Nepal indicated that individual socio-economic variables including education, wealth level, and HWT promotion are important drivers of HWT adoption. Also social norm, and ability to perform the behaviour were identified to be influential psychosocial conditions (Daniel et al 2019: 854). This research, so, applies the RANAS model that could help to bring these different factors including the contextual related in order to understand these factors playing role to the household practices.

Thus, this framework is based on propositions that:

- Unsafe drinking water is a primary risk factor for diarrhoea disease among children under five years of age and along with inadequate hygiene (hand and food hygiene) are the proximate pathways of diarrhoea transmission. Hence, interventions to ensure safety of HDW and hygiene have a magnificent outcome on diarrhoea disease reduction.
- The safety of drinking water is determined by factors which include drinking water supply service level, HWTS practice and hand hygiene.
- Drinking water supply service condition influences the quality and safety of HDW as well as the practice for home-based treatment by households.
- Households' HWTS practices are influenced by the behavioural factors (risk, attitude, norms, ability and self-regulation) of the household (Mosler & Contzen. 2016:5).
- Household's characteristics (like income, educational levels and access to information) influence HWTS practices through risk perception, attitude and ability factors.

1.8 RESEARCH METHODOLOGY AND DESIGN

1.8.1 Methodology and design

Gray, Grove & Sutherland (2017:85) have described research methodology as the type of the research selected to answer the research question and research design is the researcher's way of solving research questions in consideration of feasibility of various aspects. This research employed a quantitative, non-interventional, contextual, descriptive and explanatory cross-sectional design (details described in section 3.2). The research work involved two phases: the research planning and implementation phase and the strategy development phase. These phases are described below:

Phase I: Planning and implementation phase involved three stages of the research process: conceptualizing and planning phase, research designing phase and the empirical implementation phase.

Conceptualizing and planning stage which include presentation of the general context of the research topic, the research problem and questions and theoretical framework of the research. It also encompassed comprehensive review of literature which is relevant to the study topic and questions.

Research designing stage this involve planning on the sampling, data collection and analysis, validity and reliability as well as ethical considerations. During this stage, the researcher communicated with the regional health bureau to get approval of the research and informed the study area stakeholders (health and water offices) on the research project and its plan.

Empirical implementation stage is the actual data collection, analysis and report writing.

Phase II: Development of strategies to enhance the quality and safety of HDW phase. To develop the strategies, the socio-ecological model was used to identify required interventions at different levels from individual and household to society or national levels.

Details of the research design and strategies to HDW safety are indicated in Chapter 3.

1.8.2 Study setting and population

Study setting is the condition under which the research was conducted (Gray et al 2017:94). This research was conducted in the natural setting in Burayu town; a town annexed to Addis Ababa city and existing in Oromia regional state, Ethiopia. The town is managed by its municipality which also have service provider sectors including water supply and health offices.

All households in the study area, Burayu town, having children under five years of age were the source population for the study. Mothers or caregivers in the household were the respondents to the study questions.

1.8.3 Sampling and data collection

Cluster systematic sampling methods were used to identify a total of 265 samples or study units for the study. Data on the identified variables that are relevant to the research questions were collected using structured, close ended response options, and validated interview schedule. The respondents are assumed to reflect the conditions of their respective households accurately.

drinking water samples were collected from the sample households and their respective water sources and tested. The interviews were conducted with mothers of the children and complemented by observation of actual conditions related to drinking water treatment and storage conditions.

1.8.4 Data Analysis

The raw data were checked for quality, coded and entered using EpiData software and exported into the Statistical Package of Social Sciences (SPSS) version 23. The data was analysed using descriptive and analytical / explanatory methods which included correlation and binary logistic regression analysis. Statistical significance test of p value ≤ 0.05 will be used at 1df and 95% confidence interval.

1.8.5 Validity and Reliability

Validity and reliability of data collection tools are indispensable for generating realistic evidence in research. In this study, validity criteria which include content, criterion and construct validity were used for measuring the data collection instrument. Reliability in data collection was ensured through pre-testing of the interview schedule and review of the responses to assess the consistency of the responses. Also, adequate care was made during data entry and analysis (Kothari & Garg 2019:72). Qualified data collectors were recruited and adequately trained on the data collection process.

Details of the reliability and validity of the measurement including the internal and external validity of the study are presented in Chapter 3.

1.8.6 Ethical considerations

According to Bowling (2014: 182), all research can raise ethical issues and requires consent of relevant bodies to implement the research. Accordingly, ethical clearance was obtained from the research and ethical committee of Higher Degrees at the Department of Health Studies, University of South Africa (Annexure C). And, approval for conducting the study obtained from the regional health bureau to protect the rights of the study context (Annexure E).

In this research, adequate considerations were made to address ethical concerns starting with the design, preparation of the tool, data collection, processing and presentation. Appropriate ethical considerations in relation to the study participants, institutions and integrity of the research were addressed. The rights of the respondents were addressed through ensuring informed consent, privacy and addressing possible harm. Details of the ethical considerations on data collection are presented in Chapter 3.

1.9 SCOPE OF THE STUDY

The scope of this research covers studying the microbial quality and safety of HDW as well as other elements of WASH (hygiene and sanitation) at household level including studying on the behavioural factors associated with HWT and thus HDW quality and safety. This research does not extend to investigating factors across the water supply chain from source to point of delivery to the households. However, these elements were addressed on the literature review and strategy development sections.

1.10 STRUCTURE OF THE DISSERTATION

This study report is organized into seven chapters, each of which are described below:

Chapter 1: Orientation of the study – this section contains the general background of the study topic including the research problem, rationale, objectives and research questions. Relevant conceptual and operational definitions, theoretical framework and overview of the research design and methods are also presented in this chapter.

Chapter 2: Literature review – in this section relevant and contemporary evidences from literatures that are relevant to the to the study topic are presented.

Chapter 3: Research design and method – this section contains detailed plans, techniques and procedures to implement the research including the study area and population, sampling and data collection, analysis, quality assurance (reliability and validation) and ethical considerations are addressed.

Chapter 4: Analysis and findings.
Chapter 5: Discussion of the findings.
Chapter 6: Summary, conclusion and recommendations.
Chapter 7: Development of strategies to enhance the quality and safety of HDW.

1.11 CONCLUSION

This chapter presented an introduction part which is relevant to the research topic, the research problem, purpose, objectives and significance of the research as well as the research questions and main hypothesis. Also, it contained conceptual and operational definitions of the key concepts which are relevant to the research topic and the theoretical foundation and framework of the research. In addition, overview of the research design and methods for this research including ethical considerations are included in this chapter. The next chapter presents details of the literature review in detail.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Literature review is the primary and essential step in conducting research. It involves historical succession and integrative review and summarizes the state of knowledge on the topic including the arguments and distinctions between the research findings. Also, it helps the researcher to conduct self-study review to demonstrate familiarity with a subject area (Neuman 2014:126, Straits & Singleton 2018:517-518).

For this research, review of literature relevant to the research topic was conducted in order to describe the theoretical contexts of the study problems, assess existing information, knowledge and present key findings of relevant studies. The review also indicates how this research fits with the previous studies and builds on the broader body of knowledge including theoretical and methodological background.

The review was focused to topics which are pertinent to the research problem and questions including descriptions of the theoretical aspects and findings from other researches which have relevance to the purpose and objectives of this research. The sources for the review included books, guidelines and articles from different journals.

The topics of the review included:

- Background of WASH with a focus on the state drinking water service at global, regional and national levels
- WASH related health outcomes
- Focal-oral disease transmission and diarrheal diseases causative agents
- Prevention and control of diarrheal disease
- Drinking water supply and SDGs service level
- Risk based approach to drinking water safety, water safety plan and the elements
- Water quality parameters, indicator organisms and testing methods

- Household water treatment (HWT) and safe storage
- HWT technologies and selection parameters
- WHO scheme of technologies evaluation
- Monitoring and evaluation of HWTS program
- Behavioural change theories and models including RANAS approach and socio-ecological model
- WASH services in Ethiopia

2.2 WATER, SANITATION AND HYGIENE

2.2.1 Introduction

WASH involves access to safe water supply, safe disposal of human faeces and hygiene including hand washing and food hygiene practices (Seifert et al 2017: 2). The United Nations General Assembly (2010) recognized water and sanitation as human rights and required for the full enjoyment of life and all human rights. Everyone has the right to adequate, safe, physically accessible, continuous available, acceptable, and affordable water for personal and domestic use (UNICEF 2016:1).

WASH conditions have direct linkage with public health. Contaminated water and poor sanitation provide the path for transmission of diarrhoeal diseases including cholera, dysentery, typhoid; polio and hepatitis A. Inadequate WASH in health care facilities (HCFs) affect the health of patients, staff and visitors. A total of 15.0% of patients in health care facilities develop an infection during their stay in the facilities. WASH in school also affects the health of students and teachers, often the cause of school absenteeism. Also, WASH has linkages with socio-economic conditions. For instance, improved access to safe drinking water means that women and children will have less time spent on water collection that will be used for productive engagements. Reduced health risk to children provides better school attendance (WHO 2019 online fact sheet).

The SDG is more ambitious in addressing WASH through including safely managed service levels for drinking water and sanitation. Regardless of the considerable progress during the MDG period, still three out of ten people used contaminated drinking water by 2017 (Daniel et al 2020:1). According to the WHO/UNICEF progress update report (2019: 7-9), 71.0% and 45.0% of the global population had access to safely managed drinking water and sanitation services by 2017 respectively. A total of 90.0% of the population worldwide used at least a basic service and 2 billion people use faecal contaminated drinking water. However, there are big inequalities by geography, socio-cultural and economic aspects. The state in SSA countries is considerably low where 27.0% and 18.0% had access to these service levels respectively. Regarding hand hygiene, existing data indicates that 60.0% of the global and 25.0% of the SSA countries had access to hand washing facilities at home with soap and water. The WHO fact sheet (2019) also indicated that half of the global population will experience water stress by 2025.

As indicated in section 2.8 of this research report, the state of drinking water service in Ethiopia is that 13.0% of the population (urban 37.0% and rural 5.0%) had access to safely managed drinking water and 14.0% of households (urban 37.0% and rural 8.0%) collect water from sources having low risk in quality test results. Over half of households in urban areas reported that water had been unavailable at some time during the previous two weeks or insufficient during the preceding month (CSAE 2016:9). In this research study area (town), these gaps in the service remain applicable and even worsening due to the imbalance in the service delivery in relation to the extensive expansion and growth of the population in the town including informal settlements.

2.3 WASH RELATED HEALTH OUTCOME

Inadequate provision of WASH is recognized as a key risk factor for diarrhoea and other health outcomes including infectious diseases, nutritional status and non-health effects (Wolf et al 2018:509). Low access to WASH is the main cause of faecal-oral disease transmission including diarrheal diseases including cholera and outbreaks that cause the second cause of death of children under five years of age in SSA countries. Diarrhoeal diseases and intestinal worms (environmental enteropathy) cause malnourishment and stunting of children. WASH interventions are critical for saving life in emergency contexts, which is demanded by a growing number of populations since the last decade. WASH conditions are also associated with diseases like malaria, polio and neglected tropical diseases (NTDs) such as trachoma, guinea worm and schistosomiasis. WASH in health care facilities and schools also have considerable linkage with health and educational outcomes (UNICEF 2016:1-2).

Diarrheal diseases mainly impacting children under two years of age account for 72.0 % deaths in these groups (Francis et al 2015:2). According to UNICEF (2019), 60% of deaths due to diarrhoea in the world are attributed to unsafe WASH. Diarrhoea is the underlying cause for 54.0% of deaths of children under five years of age from malnutrition. Every child in developing countries experiences four to five episodes of diarrhoea that cause below weight - for - age and lead to risk of malnutrition and impaired development (EHP 2004:3).

Globally 8.0% of the averted death of children is linked to WASH interventions in 2017 (UNICEF 2019). In Ethiopia, remarkable achievements in child mortality and reaching the millennium development goal (MDG) for child survival was possible through interventions which include nutrition, WASH, oral rehydration salt (ORS) and introduction of the Hib vaccine. An estimated 13.0% of child mortality averted due to the interventions in WASH (Doherty, Rohde, Besada, Kerber, Manda, Loveday, Nsibande, Daviaud, Kinney, Zembe, Leon, Rudan, Degefie & Sanders 2016: 5). Thus, progresses in WASH services including the safety of drinking water are critical for child health improvement in the country.

2.3.1 Water related diseases

Water related diseases constitute a major cause of morbidity and mortality across the globe. The diseases in this classification are classified into four (National Academy of Sciences 2018, Daniel 2015:19) as presented below:

Water-borne disease

Waterborne diseases are diseases that spread through drinking of contaminated water or eating food prepared with water contaminated by human or animal faeces or urine containing pathogens. These diseases commonly cause diarrhoea such as typhoid, cholera, dysentery, gastroenteritis, and hepatitis. Inhalation of contaminated water aerosols also cause a disease known as Legionnaires' disease (Legionella pneumonia), caused by Legionella bacteria (National Academy of Sciences, Engineering and Medicine 2020:12, Jagai, Naumova & Fefferman 2011:716).

Presence of these pathogens in drinking water in small numbers often causes disease and difficult to predict outbreak of waterborne diseases as even the undetectable level of contamination can cause high risk of contamination. Ecological, meteorological and climate changes influence the incidence and transmission of the diseases. Environmental stressors affect the risk to vulnerable populations. The effects of meteorological factors vary with climatic and geographic areas like seasonal peak of cryptosporidiosis infection during the warmer and wetter months in tropics (Jagai, Naumova & Fefferman 2011:721).

According to WHO (2017:1), the population at greatest risk of waterborne disease are: infants and children, people with low immunity and elderly people who live in unsanitary conditions. Recent systematic review study report indicated that an improvement in microbiological quality of drinking water reduces diarrhoea diseases morbidity by 31.0% (Adane et al 2017: 2).

Water borne diseases are caused by bacteria, virus and protozoa pathogens. The common species of the pathogens causing disease risk include Shigella, Salmonella, Vibrio cholerae, Campylobacter species and Yersinia enterocolitica bacteria. The other categories are Hepatitis A and E virus, Rota virus and Entamoeba histolytica, Cryptosporidium and Giardia lamblia protozal parasites (Yousaf & Chaudhry 2013:111). These diseases are prevalence in Ethiopia and the study area including the occurrence of cholera outbreak, often reported as acute watery diarrhoea (AWD).

These enteric diseases are most severe in children under 5 years of age manifesting as acute diarrhoea and often requiring hospitalization. In adults, diarrhoea episodes are often less severe, and resolves without serious medical care (Ayoade, Fayemi, Daramola, Osho, Oyejide, Adenodi & Anazodo 2013: 97).

Water-washed diseases

Water-washed diseases are caused by poor personal hygiene linked to inadequate availability of water. The diseases include dysentery, trachoma, yaws, conjunctivitis, scabies and other skin infections.

Water-based diseases

These are diseases that transmit through aquatic vectors, intermediate organisms, such as worms that can penetrate the skin when contaminated water is used for cleaning or bathing. Diseases in this category include Guinea worm and Schistosomiasis.

Water-related insect vector diseases

These are diseases that spread by insects that depend on water such as mosquitoes and black flies which breed in or near stagnant water. The diseases include malaria, filariasis, dengue fever, yellow fever, and river blindness.

2.4 FAECAL-ORAL DISEASE TRANSMISSION

Major proportion, more than 80.0%, of diarrhoeal diseases is transmitted through faecal-oral route through waterborne infections, contaminated food, hands, surfaces and objects (EHP2004:1). The transmission pathway of diarrhoea depends on the causative agent or pathogen, type of WASH infrastructure used by the households and human behaviour related hygiene practices. Poor sanitation and hygiene conditions can cause food contamination and inappropriate disposal of excreta and sewage can cause contamination of both surface and groundwater. Also, pathogens in animal excreta can contaminate drinking water sources. Higher proportion of diarrheal transmission (34.0%) is linked to drinking water while sanitation and hygiene constitute 19% and 20% respectively (Prüss-Ustün et al 2016:16).

Disease outbreaks are often linked to inadequate treatment of water supplies, and poor management of drinking water distribution including cross-connections, contamination during storage, low water pressure and intermittent supply (WHO, 2017:117). Use of unimproved drinking water sources constitutes major public health risk (Joshua et al 2018:1).

2.4.1 Causative agents of diarrhoeal disease

According to WHO (2017:118-120), infectious diseases that are transmitted by drinking water are caused by bacteria, viruses and protozoa as well as helminths and parasites. List of bacterial diseases that can be transmitted through faecal contaminated drinking water include Escherichia coli (diarrhoeagenic), E.coli O157, mycobacterium avium, salmonella typhi (different species), shigella, vibrio cholerae O1 and O139. Similarly, viral diseases associated with contaminated drinking water include rotaviruses, hepatitis A and E virus as well as protozoal agents like E. histolytica, giardia intestinalis and cryptosporidium.

Rotavirus is the common viral responsible for severe diarrhoea among children and Norovirus is also another viral agent of importance. Bacterial origin includes several strains of E.coli, Shigella, Salmonella, Campylobacter and Vibrio cholerae. Entamoeba histolytica is the main protozoal cause of diarrhoeal disease (Krickeberg et al 2012:47-48). It was reported that Rotavirus is responsible for two thirds of the deaths due to diarrhoea among children in Ethiopia (GAVI 2013).

Pipe water systems can cause growth of bacterial infectious agents like legionella pneumophila and maintain the life cycle of helminths agent dracunculus medinensis that transmit through drinking water. These disease-causing agents are mainly transmitted through consumption of water containing the agents. Parasitic diseases like Schistosomiasis are transmitted by contact with water (WHO, 2017:118-120).

These causative agents are the target in dealing with HDW safety and are applicable to this research.

2.4.2 Prevention and control of diarrhoeal diseases

Considerable progress has been made in recent decades to minimize the impact of diarrhoea particularly among children through case management using oral rehydration therapy. However, the incidence of diarrhoea and related health outcomes remain a major problem in developing countries. This can be addressed through basic hygiene improvement interventions that can ensure two third reductions of diarrhoea incidence among children (EHP 2004:1).

Hygiene improvement framework is a comprehensive approach to preventing diarrhoea through three key intervention domains aimed to bring change at household level. These include access to water and sanitation i.e. hardware aspect, hygiene promotion to influence hygiene behaviour and strengthening the enabling environment to ensure sustainability (EHP 2004:9). These interventions help to prevent diarrhoea through breaking the transmission pathways. Assurance of the quality and availability of drinking water for households, provision of adequate sanitation and promotion of hygiene behaviours including hand hygiene, cleanliness of utensils and food hygiene are the key measures.

WASH practices and HWTS interventions bring varying protective effects on diarrhoea (Seifert et al 2017: 2). Adequate WASH provisions can avert 58.0% of the diarrheal morbidity in LMIC (Pruss-Ustun et al 2016:16). Other sources indicated that WASH interventions can deter up to 95 % of diarrheal deaths among children under five years of age in high-burden countries. Hand washing, proper excreta disposal and improved WQ are the effective interventions in their order to reduce diarrheal risk (Francis et al 2015:2).

Controlled field trial studies results indicated that the HWTS intervention resulted in 42.0% reduction of the diarrheal disease compared to the control group. Use of different technologies could help remove pathogens effectively but often reports of health outcome studies overestimate the benefits of HWT as a result of methodological challenges including possible bias in use of non-blinded studies in assessing the health outcomes. Meta-analysis study findings also indicated that hand washing with soap alone can reduce diarrhoea incidence by over 40.0% (EHP 2004:9).Risk based management of drinking water service like WSP is also helpful for avoiding waterborne outbreaks (WHO, 2017:117-120; WHO 2014:5; UNICEF 2019).

Recent meta-analysis findings on the impact of WASH interventions on childhood diarrhoea disease indicated that HWT using effective water filtering devices reduce risk by 61.0% (RR = 0.39; 95% CI: 0.32, 0.48), on premise access to quality drinking water reduces the risk by up to 75% (RR = 0.25 (0.09, 0.67) and continuous availability of drinking water supply reduces the risk by 36% (RR 0.64 (0.42, 0.98). However, sanitation intervention without provision of improved drinking water could reduce the risk by only 25% (RR = 0.75 95%CI 0.63, 0.88) (Wolf et al 2018:508).

The inconsistent results reported in relation to the outcome of different WASH intervention elements could be linked to the different diarrheal transmission pathways, depending on the context, resulting in different degrees of effect (Kumie 2020:268). In this research, a theoretical framework which presents the associations of WASH elements with the outcome (diarrhoea), in consideration of HDW safety and hygiene as proximate factors and the underlying factors which could determine the household’s practices with focus to the HDW safety including the RANAS behavioural model element was used. Also, a risk analysis based on the condition of key WASH elements for the households and analysis of different exposure risk scenarios were made in order to assess the association with diarrhoea as an outcome.

This research tried to investigate the outcome of HDW safety, household inspection result, HWTS, and other elements of WASH including hygiene and sanitation conditions of the households in consideration of different exposure scenarios and risk categorization of the household. Also, factors influencing household’s practices were investigated.

2.4.3 Drinking water supply

Safe drinking water is a fundamental human need and right. It is an essential prerequisite for improving the living standard of people. Though most of the earth's surface is covered with water, a limited proportion (2.5%) of it is fresh water i.e. does not contain significant levels of dissolved minerals or salt while 2/3 of the water is frozen in ice caps and glaciers. Also, only 1.0% of the water on the earth (3.0% of the freshwater) is accessible for use but unevenly distributed (National Academy of Sciences 2018, Dinka 2018:163-165).

While some countries in the globe are classified as a water-stressed country, other countries have adequate freshwater resources. The scarcity of water in the world is progressively increasing due to the growing demand for supply linked to population growth and pollution of water resources (Dinka 2018:163).

There are five key parameters of water supply: quantity, quality, accessibility, reliability, and cost. An individual requires access to a minimum of 20 to 50 litres of safe drinking water for drinking, food preparation, and hygiene purposes (NAS 2018, Dinka 2018:163, 168). Accessibility of drinking water sources involve the distance travelled and time taken for water collection and an optimum access of 20 litres per person in a day from improved source at a distance of one kilometre from home (Yousaf & Chaudhry 2013:110). Time to collect water has a linkage with meeting basic per capita need of 15-25 litres drinking water as travel over 30 minutes deter meeting the need (Hygiene improvement framework 2010:17).

Key facts related to drinking water supply:

- 5000 children die each day due to diarrhoea
- 443 million schooldays are lost due to water related diseases
- 700 million people live below the water-stress threshold in 43 countries
- Women and girls in developing countries walk an average of 6 kilometres per day to fetch water
- 2 in 3 people who lack access to clean water survive on less than 2 USD per day

- 10 million refugees and 25 million internally displaced peoples (IDPs) require drinking water services

Source: National Academy of Sciences (2018), online source

The sources of drinking water are broadly categorized as ground water such as spring water which are important sources of water supply and surface water sources like river, pond, and lakes which constitute a small percentage of the Earth's water but regularly replenished through the hydrological cycle. It is essential to protect and manage these sources and the distribution system for optimal availability and use (NAS 2018).

2.4.3.1 *Challenges in drinking water supply*

As described by the National Academy of Sciences (2018 online source), major problems related to drinking water supply service include: contamination and pollution, inadequate distribution system, lack of reliable and sustainable system, climate change and disasters, poverty, demography and competitive use of water.

Contamination and pollution

The available fresh waters are being polluted by anthropogenic factors and are reducing the availability of potable water (Chalchisa, Megersa & Beyene 2017:1). Most fresh water sources are contaminated or polluted by point or nonpoint sources including untreated human waste including excreta and refuse, industrial waste, pesticides, and other pollutants or by natural causes such as Arsenic and Fluoride. Health effects of these range from short term to long term impact like cancer. Microbial contamination is the common and widespread health risk associated with drinking-water (WHO WQDG 2017:27).

Biofilms, sediments and corrosion products may harbour pathogenic microorganisms introduced into the water supply system. They could be hidden in the sediments or embedded in the biofilm and in tubercles, there is possibility of release of the pathogens during repairs and cleaning operations or flooding. The pathogens survival depends on their nature, microbial activity in the biofilm and environmental factors. Some of the pathogenic bacterial species may multiply if favourable conditions, such as appropriate water temperature and nutrients are present. Bacterial pathogens such as *Helicobacter pylori*, enterotoxigenic *E. coli, Salmonella typhimurium, Campylobacter* and *Pseudomonas* species, mycobacteria can persist within biofilms, as well *Legionella* and amoebae. Viruses and protozoa are obligate parasites and require a human or animal host to multiply. If they enter water supply system, they can only survive for a limited period (except some viruses); the infective dose for human hosts is likely to be reached only if large accumulations occur within system deposits in the instances of cross-connections, backflow or intrusion contaminants through pipe openings. Health effects linked to long term survival of pathogens within a distribution system have not been reported, however, organisms like *Legionella* can cause health concern to people (Bonadonna, Briancesco, Della Libera, Paradiso & Semproni 2012:1; Li & Wu 2019:74).

Inadequate distribution system

Inadequate distribution systems mainly affect the rural and urban slum areas. Most rural populations depend on natural sources of water and need to travel long distances every day to collect water. This causes many children and women to be deprived of educational and economic opportunities that contribute to the vicious cycle of poverty. Urban areas that are poor in slum areas are obliged to use water from private sources with an increased price. In other places, water distribution systems are poorly maintained and exposed to breakage and leakage that cause loss of water and introduce contaminants.

Lack of reliable and sustainable system

Lack of reliable water supply is a growing problem affecting the global population. Population growth is impacting on water resources by surpassing the replenish rate and increased use for agriculture competes the need for domestic use. Water supplies are affected by human and environmental pressures and seasonal variability also causes the supply to be unreliable. Surface water sources are highly vulnerable to variability of precipitation.

Climate change and disasters

An increase in the earth's temperature, 0.74 degree over the past century, has an impact on water with varying effect across geographic locations; highest in arid areas, decreased precipitation in most subtropical areas and an increase of precipitation in other places. It influences the seasonal variation and causes many sources of fresh water to be lost. Rising sea levels cause swamp coastal groundwater aquifer blackish and unfit for consumption. It can also worsen seasonal variability in water supply and climate trends such as El Nino and La Nino, fluctuations in the Pacific's ocean-atmosphere system notably influence weather patterns with opposite effects. Natural and human made disasters often impact on water infrastructure, causing damage and contamination to water supplies. Displacements of people and refugees linked to disasters create new demand for drinking water supply. Also, conflicts over water resources in arid and drought affected areas cause damage to water infrastructure (NAS online source 2018).

In countries like Ethiopia, climate variations and diverse demographic settings, both climate change induced drought and flood affect the quantity and quality of water. Many of the WASH facilities are not resilient to climate change effects (FDRE MWIE 2015:11).

Poverty

Access to improved and safely managed drinking water supply and sanitation is the lowest in poor countries. Use of unsafe drinking water sources is impacting on the health and socio-economic conditions that contribute to the chain of poverty. Also, the cost of using improved water sources is higher in these countries as most of the households, mainly the slum and per-urban areas, is out of reach of the distribution system and obliged to use private sources which cost 5-10 times higher than those other households which have access to the supply.

Demography

Population growth, urbanization and increased drive of people living in cities and urban than rural areas primarily in Africa and Asia is a big challenge to achieving the goal in water supply. Urban expansion is occurring where there is no municipal distribution system and slum areas where there is a poor sanitation system. Also, linked to industrial and agricultural growth, unsafely managed waste, chemicals and agricultural runoff causes pollution to water resources.

Competitive use of water

Global consumption of water by sectors involves agriculture which consumes an estimated 70.0% of the freshwater, industry including commercial and ecological uses 22.0% and domestic use 8.0%. Efficiency use in water stress or arid areas is highly essential through appropriate water management plans (National Academy of Sciences 2018).

There is inequality in access to access to drinking water across the world. While developed countries and some segments of the population are highly benefited from access to utility services, a considerable number of households do not have access to piped water to yard level. As such, varieties of water sources like communal water points; dug wells and hand pumps are used by the households (John et al 2014:726).

2.4.4 SDG drinking water service levels

According to SDG water supply, service levels are categorized into five for monitoring WASH in the 2030 agenda: safely managed, basic, limited, unimproved and surface water sources (WHO/UNICEF 2017:8).

Safely managed drinking water, access to drinking water from an improved water source which is located on premises, available when needed and free from faecal and priority chemical contamination, is the top service level of drinking water ladder used for global monitoring.

Figure 2.1: SDG WASH service levels

Improved sources include piped water, boreholes or tubewells, protected dug wells, protected springs, rainwater, and packaged or delivered water.

Basic access: is access to drinking water from an improved water source within 30 minutes or less round trips. The remaining levels include limited service, access to improved sources that take beyond 30 minutes for collection; unimproved access to unimproved water sources and surface water access like the use of river and ponds.

Limited access: is drinking water from an improved source for which collection time exceeds 30 minutes for a round trip, including queuing

Unimproved access: is drinking water from an unprotected dug well or unprotected spring

Surface water: is drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal.

2.5 SAFE DRINKING WATER FRAMEWORK

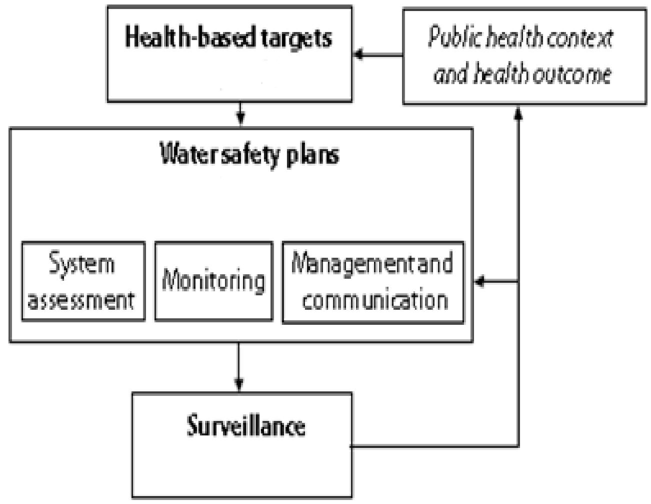
Safe drinking water is water that does not present risk to health over a lifetime of consumption (WHO GDWQ 2017:1). It is water that is safe for drinking, food preparation, personal hygiene and washing. The safety is determined by the extent to which potential hazardous events are controlled in the supply chain and the water is free from faecal contamination.

Monitoring of drinking WQ as a final product in the water supply production process has been the practice over the past decades. However, this method is recognized to have limitations in terms of managing risks to the public health and can't serve as preventive management tool (Van den Berga, Friederichsa, Versteegha, Smeetsb & Roda Husma 2019:1). Microbial quality of water often varies rapidly and over a wide range. An increase in pathogen concentration over a brief duration may heighten disease risks and trigger outbreaks of waterborne disease. Besides, by the time microbial contamination is detected, people may have been exposed to the risk. Hence, end-product testing cannot be reliable to determine the microbial safety of drinking water (WHO 2017:4).

In some cases, good quality water delivery can happen while the water supply system might have operational inconsistencies that could cause varying incidents to the system including leakages, introduction of contaminants, improper operational methods and incomplete treatment processes. Thus, the approach to drinking water safety has shifted to a preventative risk assessment and management across the water supply chain from the catchment to consumer level, known as water safety plan (WSP) (Van den Berga et al 2019:1; Eslami et al 2018:40; WHO QMRA 2016:1).

According to the WHO (GDWQ 2017:19), the basic and essential requirement to ensure the safety of drinking water is the implementation of a framework which involves three key domains indicated below:

- Health based targets – which involve health outcome target, water quality targets, performance targets, and specified technology targets to be set at national level
- Implementation of water safety plan (WSP)
- Independent surveillance by regulatory body



Adapted from revised WHO GDWQ 2017

Figure 2.2: Framework for safe drinking water

2.5.1 Water safety plan (WSP)

WSP is a plan aimed to ensure the safety of drinking water through application of a comprehensive risk assessment and risk management approach across water supply system from catchment to consumer level (GDWQ 2017:20). WSP comprehensive approach for sustainable service delivery is through the application of preventive and risk-based intervention and potential of integrating climate change resilience intervention.

The safety of drinking water depends on a series of factors across the supply system including quality of source water, effectiveness of treatment practices, reliability and integrity of engineered infrastructure, distribution system where there is potential of microbial introduction in the pipes, storage and handling at home or point of use. Hazards can potentially compromise the quality of the water at each stage in the production and delivery of drinking water (Bonadonna et al 2012:1; Li & Wu 2019:74).

And the millennium water alliance report (2014:23) indicated that all water sources in the country are considered to have substantial risks of contamination, including urban piped water supplies and protected rural water supplies linked to potential contamination across the water supply chain or irregular supply. In rural areas and small towns where drinking water is directly supplied from different sources without adequate treatment, the quality of the water from the source is critical. Sanitation condition, climate, season, hydrology, water–rock interactions and land cover including forest and grassland are some of the factors related with the water source quality (Li & Wu 2019:74).

The WHO GDWQ (2017:45) states WSP as the most effective means of consistently ensuring the safety of a drinking water supply. The objective is to supply water of a quality that meets health-based targets and its success is assessed through surveillance and control. It involves three key elements:

- System assessment in order to determine if drinking-water supply system from the source to the point of consumption can deliver water of a quality that meets the health-based targets
- Operational monitoring of the control measures that are of importance in securing drinking-water safety in order to ensure that drinking water system is operating properly. The aim is to assess control measures i.e an action that identified during the system assessment and serves to reduce or eliminate contamination
- Management plans, document the system assessment and monitoring plans and describe action needs to be taken during normal and incident operational conditions including upgrade and improvement, documentation and communication. The purpose is to document and communicate all information regarding the management of drinking WQ and safety.

WSP evolved on the concepts and approaches of sanitary inspection, multiple-barrier and hazard assessment and critical control points (HACCP). Main objectives of WSP are preventing or minimizing contamination to drinking water sources, remove or reduce contamination that might have occurred through treatment options, to the level of not becoming a risk to the public health and prevent contamination during storage, distribution and handling at home. Interventions to improve water safety start with protecting the source water; treating water at the point of distribution, collection, or consumption; and ensuring that treated water is safely stored at home in regularly cleaned and covered containers(WHO, 2017:45-46). Hence, interventions to ensure drinking water safety across water supply systems (source to tap) and at households or PoU are essential for ensuring the safety of drinking water.

The aim is to ensure water entering a drinking water distribution system should be safe to drink, without additional treatment, once it has reached the initial consumer connection. Hence, the management of distribution systems basically involves maintaining WQ, and reducing the risk of contamination and deterioration of quality across the path. However, often the distribution systems have a complex set of pipes, pumps, valves and tanks that cause the risk detection a problem (Bonadonna et al 2012:9). The study conducted in Ghana indicated a deterioration in drinking water piped quality between treatment outlet and use by household, linked to low-pressure situations in the intermittent distribution system and unhygienic storage practices at home such as storing water in open containers and dipping unwashed hands into the water supply (Renwick 2013:3).

A well managed distribution system is an important barrier to protect drinking-water from contamination. Evidences indicated that inadequate management of drinking-water distribution systems has led to outbreaks of illness in both developed and developing countries. Common problems include cross-connections and back-siphonage, burst or leakage, contamination during storage, poor practices in maintenance, pressure fluctuations and leaching from pipe work. Intermittent supplies causes loss of pressure and backflow through cross-connections and ingress through faults and breaks in distribution systems (WHO 2014:6-7).

An intermittent piped water supply, which is lack of continuous flow of water to customer homes or public taps, is common in developing countries. It is caused by caused by either or some combinations of scarcity of source water, scarcity of treatment capacity, irregularity of electricity to pump water, prevailing leakage and population growth. This can lead to contamination of the supplies due to back-pressure conditions in the system which can be created when the water in the piped network is at a lower pressure than the surrounding water such as rainwater, sewage spills, latrine drainage, etc. hence, small leaks in the piped network allows the water (contaminated) to infiltrate. Also, intermittent supplies of water causes the user to store water as much as they can and this further exacerbate the problem of the intermittent supply. Moreover, water storage can also lead to water contamination through unsafe storage practices (Renwick 2013:12).

WSP was first adopted by the WHO in 1999 as the Stockholm Framework and then incorporated into the third edition of WHO GDWQ which included the framework for safe drinking water and the international water association (IWA) Bonn charter of safe drinking water in 2004. In 2009, IWA and WHO produced a WSP implementation guideline which comprises of five processes and ten steps (Van den Berga et al 2019:1; Eslami et al 2018:40; WHO QMRA 2016:1,GDWQ 2017:48, WHO 2014:12-13). These are:

1. Preparation and launching CR-WSP including assemble a team - a group responsible to implement WSP (Step 1). It is important to engaging senior management, and securing financial, defining the roles and responsibilities of the individuals on the team and resource support and define the time frame to develop WSP

2. System assessment, identify hazards at every step of the supply chain
   - System description (Step 2) is the first task of the team to fully describe the water supply system in order to support the subsequent risk assessment process which involve gathering information on the system; preparing a flow chart from source to consumer and including the elements; inspecting the system to verify that the flow chart is accurate; and identifying potential water quality problems.
   - Hazard and risk analysis (Step 3)
   - Control measure, identify control measures for every risk (Step4)
   - Improvement planning (Step 5)
3. Monitoring
   - Operational (Step6)
   - Verification, confirming the monitoring indicators (Step7)

4. Management and communication, including supporting programmes (Step 8-9)
5. Review and improve CRWSP (Step 10)

A number of benefits have been reported from countries implementing WSP (IWA/WHO 2017:10). These include:

- Improved system management, managerial and operational procedures at water supplies
- Improved WQ through compliance with regulations
- Improvements in operations and management, institutional knowledge and awareness
- Improved monitoring such as operational and verification and surveillance
- Increased promotion and knowledge sharing of WSP
- Improved record keeping and data collection at water supplies
- Increased capacity building and training within the water supplies that ensured improved awareness, knowledge and understanding among staff of water supplies
- Improved communication and collaboration within water supplies and with other stakeholders.

The IWA/WHO (2017:5,9) review report indicates that WSP implementation is on rise across the globe, highest in the South-East Asia region while the progress in Africa is low. WSP auditing, an independent and systematic check of a WSP through internal or external, formal or informal ways, to confirm its completeness, adequate implementation in practice and effectiveness, was put as a requirement by some of the countries on their WSP policies or regulations but few countries implemented it per the set frequency.

In Ethiopia, a national framework for CR WSPs was formally adopted and guidance documents CR WSPs for urban and rural systems prepared. By 2016, a total of twelve water supply schemes started the implementation and there was a plan for scaling it up.

The effectiveness of WSP implementation in developing country is another challenge linked to the capacity and commitment of the water supply utilities as well as the complexity of pipe water supply system in some of the urban areas. This has implication in terms of the safety of drinking water provided to the public. In such condition, interventions to enhance the quality and safety of drinking water at household level is critical in order to put the final barrier to contamination as well as maintaining or preventing deterioration of the quality. Efforts to implement WSP with incremental improvement approach helps to ensure improvement in the safety of drinking water supplied to households and influence the need for HWT.

2.5.2 Water quality parameters

The quality of drinking water can be assessed in terms of microbial, physical, chemical, and radiological composition of the water. Major contents of water that have considerable public health implication are the faecal microbial pathogens, arsenic, and fluoride chemicals (Daniel et al 2015:20). According to WHO (WHO WQDG 2017:75), essential parameters of drinking WQ include E. coli, faecal (thermotolerant) coliforms, residual chlorine, PH and turbidity.

Ethiopian standards authority (ESA) drinking water specification indicates three drinking WQ parameters namely physical, bacteriological and chemical, the standards and test methods. The standard is that any treated water should not contain faecal and other coliform organisms on testing using appropriate methods (ESA 2013:6).

2.5.3 Indicator organisms

Direct testing of microbial agents in drinking water has not been possible given the advance of technologies. Also, it is impractical to test all pathogens that can be present in water in relation to the time, cost and complexity (UNEP & WHO 1996:1). As such, indicator organisms existing in faeces are used to assess microbial quality of water and the level of contamination.

According to WHO GDWQ (2017:148-149), selection of the most appropriate faecal indicator bacteria is guided by the characteristics which include: universally availability in animals and humans’ faeces in large numbers, easily detection by simple testing methods, persist in water in the same way as faecal pathogen, can respond to the water treatment process in the same way to faecal pathogens, do not multiply in natural water and must not be pathogens themselves.

There are three categories of such indicator organisms. These are coliform bacteria groups which include Escherichia coli (E.coli), thermotolerant coliform (also known as faecal coliform), and total coliform. While E.coli is an important parameter for drinking WQ monitoring, thermotolerant coliforms are alternative to E.coli, and both exist in high numbers in contaminated water. They are a good measure of potential health risks from bacterial pathogens. They relate with the biological and physicochemical properties of the different groups of pathogens in terms of their ability to survive in the environment and their response to water treatment processes. The guideline value is that these indicators must not be detected in any 100 ml of drinking water or treated water entering or in a distribution system. However, these indicator organisms have limitations to serve as indicators for enteric viruses and protozoa, which are resistant to some of the treatment methods. They correlate less with viral risks, protozoa and toxic algae. Viruses and protozoa can survive longer in the environment than do faecal bacteria and have a higher degree of resistance to disinfection (Bonadonna et al 2012:1-2; WHO GDWQ 2017:148-149). Thus, absence of coliforms in water, particularly in treated water sample, may not rule out the water is free of all the pathogens.

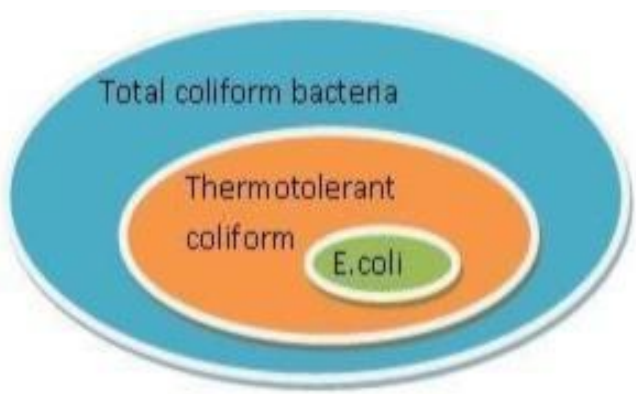


Figure 2.3: Layout of Faecal Indicator bacteria

Coliform bacteria are indicators of sanitary quality of water and food. They are abundant in faeces of warm-blooded animals and also exist in aquatic environments, soil, and vegetation (Hygiene improvement framework 2010:ii)

Total coliform - are a large group of different types of bacteria, gram-negative, rod-shaped bacteria that share several characteristics and are mostly harmless. These bacteria naturally exist in the environment on vegetation, soil, human and animal faeces particularly in tropical countries and their presence may or may not indicate faecal contamination. Hence, it is not recommended as an indicator for faecal contamination of drinking water water. On testing, they are grown in or on a medium containing lactose, at 35 or 37 °C and provisionally identified with the production of acid and gas on the fermentation of lactose (Daniel et al 2015:21; UNEP & WHO 1996:1).

Thermotolerant coliform refers to coliform including non-faecal origin but their presence in drinking water primarily indicates faecal contamination. They grow at 44 or 44.5 °C and ferment lactose to produce acid and gas. Often, over 95% of the thermotolerant coliform in drinking water are E.coli. E.coli is the most specific indicator of faecal contamination, definitive proof of faecal contamination while thermotolerant coliform is also considered as surrogate indicators. E.coli testing is based on growth on a media containing lactose, at 44 or 44.5 °C and provisionally identified by the production of acid and gas on fermentation of lactose. A faecal streptococcus is also evidence of faecal contamination. They likely persist in the environment and are resistant to drying. On testing they grow on a medium containing sodium azide, at 37-44 °C (Gruber et al 2014:1, UNEP & WHO 1996:2).
E.coli, sub-group of thermotolerant coliform, member of the family Enterobacteriaceae and genus Escherichia, is a gram-negative, facultative anaerobic, rod-shaped bacteria. It is widely found in the lower intestine of endothermic organisms (both human and animal) and constitute about 1 percent of the total faecal bacterial flora of humans. Most of them are non-detrimental, however, some pathogenic E.coli like E. coli 0157:H7 is harmful and potentially causes fatal haemolytic uraemic syndrome, bacteraemia and meningitis. Its presence in water is a strong signal of recent faecal contamination from human and animal origin and provides evidence of faecal contamination of water. Also, signalling the potential presence of other bacteria, viruses, and protozoa, thus the water is considered unsafe for consumption (Kinkese et al 2018:64; Daniel et al 2015:21, Hygiene improvement framework 2010:37).

The national survey findings in Ethiopia indicated that there was 55.0% overlap of the E.coli and thermotolerant coliform test results in samples of water from households. Most of the overlap (47.4%) was seen on highly contaminated water (over 100 coliform colony count). The thermotolerant coliform concentration count was higher (78%) on highly contaminated water compared to E.coli (51.6%) (CSAE 2016:30).

2.5.4 Testing methods

The common methods used for testing of drinking water microbial quality through isolation of indicator organisms from water are the membrane-filtration (MF) and the multiple-tube or most probable number (MPN) methods. As bacteria in water is not present individually, but in colonies associated with particulate matter therefore the colonies are counted in testing.

MF method provides a direct count of total coliforms and thermotolerant coliform that exists in a sample of water. A volume of drinking water is measured, often 100 ml, and filtered, using vacuum, and a cellulose acetate membrane with uniform pore with a diameter of 0.45 μm. The retained bacteria on the membrane is then placed on an appropriate selective medium in a sterile container and incubated at the required temperature. On contaminated water, colonies will be developed. The method is not applicable to water samples which have high suspended material. In this case, a small sample could be diluted so that there's a sufficient volume to filter across the full surface of the membrane. It is assumed that each bacterium, attached to a particle in water will grow into a single colony, known as colony forming unit (cfu) and the result present as cfu per volume of water (UNEP and WHO 1996:14).

2.5.5 Drinking water quality monitoring and surveillance

Routine monitoring of quality of water is key element of water supply management but not enough to protect public health. This is based on the detection of indicator organisms that are surrogate markers of contamination. However, such monitoring can trigger a corrective action or public health response only after a problem has occurred and affected the finished product. The testing procedure take some time between sampling and obtaining the result including the time for the incubation requirement of up to 48 hours, and adverse results could further take time to identify the problem. Also, microbial quality of water could markedly be variable in time and a single test only represents a snapshot of the system. Hence, these cause the consumers to use contaminated or unsafe drinking water (Bonadonna et al 2012:1-2).

Also there are operational challenges to conduct the testing as frequent as possible for monitoring purposes. These necessitate the need for focusing on monitoring the hazards conditions or practices with the aim to manage the risk. As such, the role of routine monitoring lie in verifying the components of the water supply system are operating correctly and compliances with specific requirements. Thus, the scientific community proposed a new approach that can link monitoring frequency of finished water and sanitary surveys, as complementary activities (Bonadonna et al 2012:1-2).

And, this research is based on application of combined analysis of WQ test and household drinking water inspection for investigating HDW safety and the linkages between the results analyzed.

The WHO definition of surveillance of drinking water quality is the continuous and vigilant public health assessment and review of the safety and acceptability of drinking-water supplies. Surveillance contributes to the protection of public health by promoting improvement of the quality, quantity, accessibility, coverage i.e. populations with reliable access, affordability and continuity of drinking-water supplies. It requires a systematic programme of surveys, which may include auditing, analysis, sanitary inspection and institutional and community aspects. It should cover the whole of the drinking-water system, including sources and activities in the catchment, transmission infrastructure, treatment plants, storage reservoirs and distribution systems. The role for conducing this belong to the authority assigned, often the health sector regulatory agency, than the service supplier (WHO 2017:9).

This research also highlights the need to conduct surveillance of HDW safety.

2.6 HOUSEHOLD WATER TREATMENT AND SAFE STORAGE

2.6.1 Introduction

HWTS is an essential public health intervention for improving the quality of drinking-water and related health outcome particularly for the vulnerable population who rely on unsafe water sources and where the pipe water supply system is unreliable. It is also considered as an interim solution for the majority of the population not accessing safe, piped and reliable water sources in developing countries (WHO GDWQ 2017:141, Gruber, Ercumen & Colford 2014:1, WHO GDWQ 2017:141, WHO/UNICEF 2012: 1).

Studies which include controlled field trial results indicated that considerable reduction of diarrheal morbidity, ranging from 38 % to 45%, can be achieved by HWTS depending on water source type and when effective methods are used correctly and consistently (Pruss-Ustun, A. et al 2016:17, UNICEF & WHO 2016:2, EHP 2004:9). In SSA, majority of the countries support HWTS through integration with health programs. However, there is a limited coverage of such practices by most of the households and lack of consistent and incorrect use of HWT by households undermines the potential health benefit. There are also challenges of limited monitoring and evaluation of HWTS interventions; poor coordination among the stakeholders; and lack of regulation. Addressing these constraints could determines the effectiveness of HWTS program (WHO 2014: 5-9; Daniel et al 2019:847).

HWTS, while an essential and universal applicable intervention, is of particular importance to vulnerable populations in order to reduce the risk of infection and related health outcome. Thus, promotion of HWTS helps for its effective application through creating the awareness and skill among households and addressing related behavioural factors (Solomon et al 2020:2).

In Ethiopia, promotion of HWT historical related to response to emergencies including diarrheal disease outbreak which later was also linked with other programs like nutrition and HIV/AIDs disease response.

2.6.2 Factors influencing HDW safety

A case study on variations of drinking WQ influenced by seasons and household Interventions indicated that the quality of water at point of consumption is influenced by factors across the supply chain. These include the conditions of watershed and raw water source, seasonal variations, municipal treatment system and PoU treatment and storage practices. The study suggests the need for further study to quantify different factors which determines the variations in drinking WQ at household level (Seifert et al 2017: 14). Population density, type of latrines, and protection condition of wells has an effect on the microbiological quality of water. Also, seasons can make variation to the quality of the water, which causes increased contamination to the water during wet seasons (Seifert et al 2017: 2). Intermittent supply of drinking water is other factor influencing the quality of water delivered to households (Renwick 2013:25).

Household practices are the other critical aspect in relation to HDW safety. Evidence indicated that reduction or deterioration of WQ in household storage linked to unhygienic practices including lack of hand washing and use of dippers to collect water from storage containers (John et al 2014: 719; Renwick 2013:25). However, other studies indicated the importance of a few days of home storage in improving the physical and microbiological quality of water through a process which include sedimentation, equalization and devitalisation (Ayoade et al 2013:98).

In Ethiopia, the problem of intermittent pipe water supply and home storage in tanks and reservoirs is common in order to ensure the need for short or extended duration use; however, this is linked with increased contamination of the water due to the loss of disinfectant residual, bacteria re-growth, poor turnover, and extended detention time. The study conducted in Ethiopia, Jimma town, indicated that all water samples collected from household storage tanks were positive for total coliforms and faecal coliforms and the level of microbial contamination increased from before entering the storage reservoir to after leaving the tank (Chalchisa et al 2017:1-2).

This research has addressed the need for further evidence with regard to the factors which influence HDW safety. This includes investigating the effect of drinking water service, household practices and related behavioural factors. Risk classification of households was highlighted to conduct the research.

2.6.3 HWT technologies and parameters of choice

HWT technologies involve a variety of devices and methods used for treating water at home or PoU in other settings. The technologies used to treat water collected from the sources including unsafe piped water is by removing or inactivating microbial pathogens. HWT should be linked with safe storage to minimize post treatment contamination. Some of the technologies are not effective in removing all the categories of pathogens in drinking water (WHO GDWQ 2017:140a - 141).

TABLE 2.1: LISTS OF HWT TECHNOLOGIES AND METHODS

Technologies by treatment process	Description
Chemical disinfection *Free chlorine disinfection*	Turbidity and chlorine demanding solutes inhibit this process; free chlorine x time product predicts efficiency Not effective against Cryptosporidium oocysts
Solar disinfection *Solar disinfection (solar UV radiation + thermal effects)*	Varies depending on oxygenation, sunlight intensity, exposure time, temperature, turbidity and size of water vessel (depth of water)
Thermal (heat) disinfection *Boiling*	Treatment to reduce spores (vegetative cells) by boiling must ensure sufficient temperature and time
UV light using lamps *UV irradiation*	Excessive turbidity and certain dissolved species inhibit process; effectiveness depends on dose, which varies with intensity, exposure time, UV wavelength
Membrane, porous ceramic or composite filtration *Porous ceramic filtration*	Varies with pore size, flow rate, filter medium and inclusion of augmentation with silver or other chemical agents
Membrane filtration *(microfiltration, ultrafiltration, nano-filtration, reverse osmosis)*	Varies with membrane pore size, integrity of filter medium and filter seals, and resistance to chemical and biological (“grow-through”) degradation

Fibre and fabric filtration *e.g. sari cloth filtration*	Particle or plankton association increases removal of microbes
Granular media filtration	
Household-level intermittently operated slow sand filtration	Varies with filter maturity, operating conditions, flow rate, grain size and filter bed contact time
Rapid granular, diatomaceous earth, biomass and fossil fuel–based filters	Varies considerably with media size and properties, flow rate and operating conditions
Combined methods	
Flocculation plus disinfection systems e.g. commercial powder sachets or tablets	Applies multi-barrier approach
Sedimentation *Simple sedimentation*	Effective due to settling of particle and large microbes; varies with storage time and the number of particulates in the water

Adapted from WHO 2011, evaluating household water treatment options

The choice of appropriate HWT technologies and products need to consider parameters which include: effectiveness in removing the pathogens, simplicity for operation and maintenance, robust and reliable, affordable for households, and accepted by the local community. Microbial performance and technologies certified by national regulatory authority should be the focus in technology selection decision making.

2.6.4 WHO scheme of technologies evaluation

The performances of these treatment options vary in removing three categories of microbes (bacteria, virus and protozoa). In order to evaluate and classify the technologies with their performances, WHO established a scheme for independent evaluation of the technologies. Three tier performance levels were identified which include comprehensive performing Star 3 and 2 and targeted protection Star 1). The evaluation criteria for the technologies are indicated in the below table (WHO 2019:4).

TABLE 2.2 THE EVALUATION CRITERIA FOR THE TECHNOLOGIES

Performance classification	Bacteria (log_{10} reduction required)	Viruses (log_{10} reduction required)	Protozoa (log_{10} reduction required)	Interpretation (assuming correct and consistent use)
★★★	≥ 4	≥ 5	≥ 4	Comprehensive protection (very high pathogen removal)
★★	≥ 2	≥ 3	≥ 2	Comprehensive protection (high pathogen removal)
★	Meets at least 2-star (★★) criteria for two classes of pathogens			Targeted protection
–	Fails to meet WHO performance criteria			Little or no protection

log 2=99.0%, log 3=99.9%, log 2=99.99%, log 5=99.999%

According to the phase I and II evaluation, a number of technologies do not provide sufficient protections to the health of users.

2.6.5 Monitoring and evaluation of HWTS program

In order to ensure effectiveness of HWTS through addressing the gaps in incorrect and inconsistent use of HWTS and encourage the uptake of interventions, WHO/UNICEF (2012) developed a harmonized tool kit for monitoring and evaluation (M&E) which include key indicators. It involves presentation of commonly tested water quality parameters (turbidity, free and total chlorine residual, E.coli, and faecal coliforms and arsenic and fluoride. Also describes step-by-step guidance to conduct the M&E (WHO/UNICEF toolkit 2013:7).

2.7 BEHAVIOURAL CHANGE THEORIES AND MODELS

2.7.1 Introduction

Application of theories, models or frameworks, often used interchangeably, have a key role in implementation science i.e. scientific study of methods to ensure systematic uptake of research findings to improve the quality and effectiveness of service delivery. They help to guide the process of development of implementation strategies (known as process models); to understand factors influencing implementation outcome and evaluation of implementation. Many implementation strategies fail because of lack of explicit rationale or theories. While different theories have overlapping roles with regards to the above indicated functions, process models in particular recognize a temporal sequence of implementation of strategies(Nelson 2015:1-2).

Application of behavioural theories or frameworks in behaviour change implementation sciences can result in improved behavioural outcomes. Many years of research and programme interventions in WASH have enabled application of different models which are broad or focused to specific behaviour or settings. However, use of these models in WASH intervention design and assessment is limited. A review study indicated that the models are focused to individual-level behavioural determinants and did not consider the role of physical and natural environment or a broader ecological aspect that put individual behaviours within a multi-level causal framework and other models consider psychological aspects of factors related to behaviour change as a boarder multilevel approach. So, understanding WASH behaviours within the context is essential for designing interventions that create and sustain the desired behaviours (Dreibelbis, Winch, Leontsini, Hulland, Ram, Unicomb & Luby 2015:2, 5).

Behavioural Change Communication (BCC) is a systematic process of formative research and behaviour analysis, communication planning, implementation, monitoring and evaluation. It is an interactive process to understand and design promotional strategy based on different theories. BCC has a key role to influence adoption of new behaviour, avoid negative or harmful behaviours to health and to change or modify existing behaviours (Ngigi & Busolo 2018:85-86).

Behaviour change can be influenced by a range of factors including personal, social, environmental and structural variables which act in varying combinations and strengths to influence behaviour. Personal factors are the common element and intrinsic to individuals. It comprises of the level of individual knowledge, awareness or the belief in the ability to change or practice habit and behaviour. Factors like awareness, knowledge and attitude are often neither adequate nor robust by themselves to influence behaviour. Social factors such as community norm and interpersonal influences have a strong role to influence individual behaviour (Ngigi & Busolo 2018:86).

In consideration of the broad factors influencing behaviour, different theories and models of behaviour change with varying perspectives were developed to guide the understanding of peoples' behaviour. Models are used to discover behaviours and related factors while the theories of change describe how behaviour change could occur. However, there are limitations with the models that could simplify the case and snub the details of behaviour (Ngigi & Busolo 2018:86).

In WASH sector, the focus of researches until mid 2000 was on addressing technologies which could effectively remove pathogens from the environment. However, during last decade there is a shift as practitioners, policymakers, and researchers began to realise that figuring out what to give people wasn't sufficient (hard ware) and needed to consider how it could be given (promotional approach). Hence, a wider variety of intervention mechanisms began to be studied. The biggest move has been the focus on studying psychosocial triggering mechanisms, these approaches that leverage social pressure, emotional cues, and other psychological triggers. The prominent one in this regard is the community-led total sanitation (CLTS), which originated in Bangladesh and spread across the globe (Chirgwin 2018).

In application to this research, two of the models used for assessing households' behaviour with regards to HWT and for designing intervention strategy are reviewed below:

2.7.2 RANAS approach to behaviour change

RANAS approach to systematic behaviour change was developed by experts at EAWAG, Swiss Federal Institute of Aquatic Science and Technology, for measuring behavioural factors, designing and evaluating behaviour change strategies in WASH sector. It is based on a premise that behaviour change relates with people's mindsets and multitude of factors influence behaviour. Also, the approach is based on environmental and health psychology which investigate techniques of behaviour change. It targets and intervenes on these factors which influence a specific behaviour in a specific population.

The model has four components: psychosocial factors including risk, attitude, norm, ability and self-regulation, behaviour change techniques (BCTs), behavioural outcomes and contextual factors. Its systematic application involves four phases including identifying potential behavioural factors, measuring these factors and determining the significant factors, identifying corresponding behaviour change techniques (BCTs) and developing intervention strategies, finally implementing and evaluating the strategies (Mosler, H & Contzen N. 2016:4-7).

The RANAS model is one of the commonly used in WASH research and interventions. The model links intervention strategies with each of the identified factor domains like awareness creation interventions with risk factors, persuasion with attitudinal factors; access and enabling interventions with ability factors (Dreibelbis et al 2015: 5). The relevance of this model is discussed in theoretical framework section (1.7.2) of this study.

2.7.3 Socio-ecological model

Social ecological model (SEM) applies a system approach to understand factors influencing behaviour and to design effective programs. This model recognizes the relationship between individuals and their environment determines people's behaviour. The framework highlights multiple stages of Influence including individual, interpersonal, organizational, community and public policy (Glanz 2015:18). At the base of the model is an individual that involves their knowledge, beliefs, attitudes and skills. The next level is interpersonal which refers to the influences from family, friends and other influential people.

This model provides a framework to see an individual's environment at different levels, from the household and community and institutions responsible to provide support as well as the policy context. It highlights that individuals' behaviours are linked to social influences, and the physical environment (UNICEF and MDWSI 2013:14).

A communication model developed by Figueroa and Kincaid for water treatment and safe storage practices indicates that interventions influence behavioural outcomes through a set of multi-level intermediary outcomes. Individual-level outcomes include cognitive elements, emotional factors, and social interactions and household factors include income, time allocation and decision-making practices. At community level, community action and resources, community cohesion, and leadership are the factors (Dreibelbis et al 2015:5).

There is a need to strengthen such multilevel intervention in Ethiopia and other parts of the world in order to bring concrete change to communities and households in HDW safety as well hygiene and sanitation.

2.8 WASH SERVICES IN ETHIOPIA

The national survey result indicated that a total of 13.0% of the population (urban 37.0% and rural 5.0%) and 51.0% in Addis Ababa city had access to safely managed drinking water and 14% of households (urban 37.0% and rural 8.0%), collected water from low risk supplies on the water sample testing while 36.6 percent collected from very-high-risk supplies. However, best quality of water at source was reported from the capital city, Addis Ababa, where 85.0% of the water sources samples at point of collection were low risk on the quality testing. This is 46.4% in large towns, 14.1% in small towns and worse in rural areas (8.4 percent low-risk). Also, nationally, 42.0% of the drinking water quality test for samples collected from piped water into premise was low risk. Water from improved sources had about 10 times better quality (20.0% low-risk) than the water collected from unimproved sources (2.2% low-risk). Furthermore there is regional disparity of the water quality from the sources that the southern region had the lowest finding with 7.2% low risk (CSAE 2016:9, 22).

Over 75 percent of the population usually use improved water sources during rainy and dry seasons. A total of 35.0% of the population use unimproved water sources and there is high variation by residence as 43.0% of the population in rural and 3% in the urban uses unimproved water sources. Appropriate household water treatment (HWT) is practiced by 7% (12.0% in urban areas) of the households. Accessibility of the population to water sources (basic service) as measured by the time taken to collect water in 30 minutes or less was 74 % while 18.4% used a source located on the premises. The time burden of water collection is higher for residents of rural areas. However, availability of water when needed and sufficiency of drinking water, was lower in urban areas. In urban area, over half of households reported that water had been unavailable at some time during the previous two weeks or insufficient during the preceding month (CSAE 2016:9-10).

Regarding sanitation the state of the provision is low and solid progress has not been made over time. Basic sanitation, improved latrine for households which is not shared, has just increased from 3.0% (1.0% in rural and 15.0% in urban) in 2000 to 7.0% (4.0% in rural and 18.0% in urban) in 2015. However, open defecation (OD), practice has decreased from 80.0% in 2000 to 27.0% in 2015. And only 1.0% of the population had hand washing facilities with soap and water at home by 2015 (WHO & UNICEF 2017:80). This not different in this research area and the finding of the research have helped to generate evidence in this regard.

National plan

Ethiopia's Second Growth and Transformation (GTP2) Plan for the Water Supply and Sanitation Sub-Sector (2015/16 – 2019/20), defines the following goals for water accessibility and availability:

- Provide rural access to water supply that sets a minimum service level of 25 liters per capita per day (l/c/day) within 1 km from the water delivery point for 85 percent of the rural population, 20.0% of whom are reached by a piped system.

- Provide urban access to water supply with a minimum service level of 100 liters per capita per day (l/c/day) for category-1 towns/cities, 80 l/c/day for category-2, 60 l/c/day for category-3, 50 l/c/day for category-4 up to the premises, and 40 l/c/day for category-5 towns/cities within 250 m, with a piped system for 75 percent of the urban population l/c/day (CSAE 2016:3).

2.8.1 One WASH national program

One WASH national program (OWNP), is a sector wide approach launched in 2013 with the objectives to achieving universal access to water, sanitation and hygiene services in Ethiopia. It is a model of addressing the gap in the WASH programme delivery to a transforming approach through coordinated and harmonized planning, financing, implementation and monitoring. It is based on partnership and alignment in the WASH programme implementation with the objective of achieving one plan, one budget and one report in the country. The programme has three pillars (creating enabling environment, optimizing availability and use of resources and capacity development) and four intervention areas including rural and pastoral WASH, Urban WASH, Institutional WASH and programme management. Phase I (2013-2015) of the project was reviewed and indicated considerable achievements and phase II (2016-2020) is under implementation (Wilson, Faris, Getaneh & Admasu 2018:10).

2.8.2 Climate resilient water safety plan

The Ministry of Water, Irrigation and Energy of Ethiopia worked with the WHO country office to prepare a national strategic framework on climate resilient water safety. Though Ethiopia has made good progress in access to drinking water coverage to the population, the need to provide higher service levels including the quality of water remains a gap. The causes identified for this include ongoing population growth, un-functionality of water schemes due to limited operation and maintenance capacities, contamination and pollution of water sources from various sources and effects of climate change. Thus, the CR-WSP aimed to address these challenges (FMoWIE 2015:18-19).

2.9 CONCLUSION

In this chapter, review of literature relevant to the research problem and questions were addressed. It includes background to WASH, drinking water and SDG service levels, related health outcomes, theoretical framework for the study on diarrheal disease transmission pathways, prevention and control. The argument between existing literature and objectives of this research including risk based approach to drinking water safety and description on the problem statement with reference to this research area context were addressed. Also, WQ parameters and microbial testing methods, HWTS and treatment technologies and WHO scheme for evaluation of the technologies. In addition, review of the behavioural change models including RANAS, SEM and brief review of WASH program in Ethiopia included.

CHAPTER 3

RESEARCH DESIGN AND METHOD

3.1 INTRODUCTION

This chapter presents the overarching details related to the research design and methods employed for this research. It involves description of the type of research design, the study setting, population and sampling method, study variables, data collection plan and tools, quality assurance, data analysis and ethical considerations. Also it involves the HDW safety strategy development and dissemination approach.

3.2 RESEARCH DESIGN

The research design employed for this research was *quantitative*, *non interventional* and *descriptive cross-sectional* research design. In relation to this, specific research designs used for this research including the information from literatures are presented below:

Research design has been defined as a set of logical steps taken by the researcher to answer the research questions (Brink et al 2012:217). Burns et al (2013:195) defined research design as a blueprint for conducting a study with maximum control over factors that may interfere with the validity of the findings. It is the overall plan, conceptual structure or strategy, within which a research is conducted for addressing a research question, including the specifications for enhancing the integrity of the study. It is the researcher's choice of the best way in which to answer a research question in consideration of various details of the research process including the methods to be employed. It outlines what the researcher does in a research process including a clear statement of the research problem, population to be studied and blueprint of methods and techniques for collection, measurement and analysis of data (Polit and Beck 2017:273; Kothari and Garg 2019: 29-31). Research design helps to provide collection of relevant data with optimum resources depending on the purpose or objective of the research (explorative, descriptive, diagnostic or experimental). Selection and details of research design needs to consider the time, cost, and means of obtaining the information and its justification (Kothari & Garg 2019: 29-31).

There are three main research designs which are quantitative, qualitative and mixed types. These are not discrete and thus should not be considered mutually exclusive with rigid boundaries (Creswell & Creswell 2018:3). According to Punch (2011:63) four main ideas in research design: strategy, conceptual framework (presented in chapter 1 for this research), question of who or what will be studied (sampling) and tool and procedure to be used for collecting and analysing empirical materials. The strategy is the logic, rationale, or set of idea of how the research intends to address the research questions that may involve doing comparisons. In quantitative research, the strategy could be experimental, quasi experimental or non-experimental types. Depending on the extent of the researcher intervening the research situation against doing it naturally, the design can be described as extreme interventionist to non-interventionist.

This research design was non-interventional as it was conducted in the natural context without any manipulation to the study subject or households.

3.2.1 Quantitative research

This research employed quantitative design as the data collection tool was designed in such a way quantitative or countable data that used to measure the condition of the household and water quality and safety were collected. This enable to generate data which is empirical, measured and observed, and helps to generate results in magnitude, relationship between variables and understand the associations between the variables (Gray et al 2017:83).

It applies a positivism approach and follows a linear research path, precise measurement of variables and testing of hypotheses that are linked to general causal explanation (Neuman 2014:107). This is also referred to as rigor, which implies deductions are perfectly reasoned, and decisions are based on scientific method. It depends on application of proper research design, high degree of accuracy and consistency in measurement (Gray et al 2017:91).

3.2.2 Survey research

This research employed quantitative *survey research* to systematically gather data on the relevant variables from sample study units. So that generalized description and explanation on the research questions which involve describing household drinking water safety, the association with diarrhoea occurrence and factors influencing HDW safety can be made.

Survey research is quantitative social research through systematic interview of many people using the same questions, organizing and analysing the responses to describe and examine the relationships among the measures. Its features involve choosing many respondent people using probabilistic sampling methods, uses systematic questionnaire or interview procedures and responses are numerically coded and analysed (Neuman 2014:107; Straits&Singleton2018:203).

It develops within positivism and follows deductive approaches, which start with theoretical research problems and employ empirical measures and data analysis. Variables can be measured to produce quantitative data and use statistics to test causal relationship (Neuman 2014:192-193).

3.2.3 Cross sectional survey design

This research was conducted using cross sectional and contextual design. This enabled to gather data regarding the dependent and independent variables at the same point in time from representative sample households without regard to their status on the dependant / outcome and independent. This helps to determine the magnitude or burden of diarrhoeal disease among the target children and conduct analysis of associations among variables. The consideration or assumption here is that there is logical time interval (induction period) between the independent variables (considered customary to the households) with the outcome variables (Rothman, Greenland & Lash 2008:97, 300). It is also a feasible design given the available time and other resource for conducting this research.

Survey research which applied cross-sectional study design implies the data on the sample households was collected at some point in time. There are two distinctions of cross-sectional survey designs (contextual and social network designs) based on the influence of social contexts and interpersonal relations on individual behaviour. Social network design focuses on interpersonal relationships and interactions among social actors and requires interviewing every person in the study population (Straits & Singleton 2018: 209).

3.2.4 Descriptive, explanatory and contextual research

This research applied descriptive, explanatory and contextual types in order to explicitly describe the findings of the research area based on the data generated from systematically selected sample households and the data was analyzed to explore the relationship between the variables that enable answering the research questions.

According to Straits and Singleton (2018:68) a research could be conducted for three purposes. These are describing a situation or particular group precisely and accurately (descriptive), to examine and test relationships among variables (explanatory or analytical) and to explore phenomena and get insight (exploratory).

Descriptive research aims to explore and describe a situation focused on isolated variables in real life situations. It is conducted in order to address lack of evidence or limited knowledge regarding a phenomenon.

Explanatory research aims to test relationships and seeks to explain why the relationship occurs in terms of cause and effect. It also describes a broader scope focused to description of the relationships among variables (Straits&Singleton2018:68). Both these research types require a design which is rigid or structured and adequately addresses the accuracy, sources of bias and reliability of data (Kothari & Garg 2019:31, Gray et al 2017:86).

This research employed descriptive and explanatory types in order to generate evidence on household drinking water safety and factors through application of risk-based measurement using composite measure of HDW safety. To the best of the researcher, there has not been a research that used this method. Also, the relationship of the variables with the outcome of interest: diarrhoea disease occurrence, drinking WQ and safety of drinking water and HWT practice were examined.

Contextual design

According to Straits and Singleton (2018: 209), contextual design takes enough sample cases or study units within a particular group or contexts to describe the characteristics of those contexts. This design was applied for the research through identifying systematically selected study samples from randomly selected settings or contexts (clusters) in the study area.

3.3 RESEARCH METHODS

Kothari and Garg (2019:6-7) define research methods as methods and techniques that are used in performing research operations including data collection, analysis and verification of the result. They are the specific ways the researcher selects to conduct the study within the chosen design. Accordingly, the methods used for this research are presented below:

3.3.1 Study setting

This research was conducted in Burayu town which exists in a special zone of Oromia regional state, Ethiopia. The town is situated in proximity or connected to Addis Ababa (Finfinne) city, the capital for the region and the country, in the West direction at 9º02’30’’North Latitude and 38º03’30’’- 38º41’30’’ East Longitude with 1920-meters elevation(Figure 3.1). The special zone was created in 2008, encompassing 8 towns including Holeta, Sabata, Galan, Dukam, LagaTafo-LagaDishi, Sandafa, Sululta, the peri-urban and rural areas surrounding Addis Ababa city.

The town was established in 1953 and the population increased markedly over time from 4,138 in 1984, 10,027 in 1994 to 100,200 by 2010 and 156,463 people in 2016 (data from town health office). In fact, the current population of the town is unknown due to the considerable influx of the people to the town, and progressive expansion of the town primarily through informal settlement (Bekele, Asfaw & Jafri 2014:10).

Burayu has a town administration, municipality and six administrative units (kebeles) which are subdivided by clusters. Burayu town water supply utility is responsible for provision and management of the supply. Gefersa water dam, one of the sources of drinking water supply for the capital, Addis Ababa city, is located in Burayu town administration catchment, however, did not benefit the town residents.

Due to the proximity of the towns to the national capital and better opportunities of economic activities, there is high immigration of people from different parts of the country causing progressive population growth, urbanization, industrialization and peri-urban expansion in the zone (Tadesse & Imana 2017:4). These put considerable strain in service provision including water supply for the people.

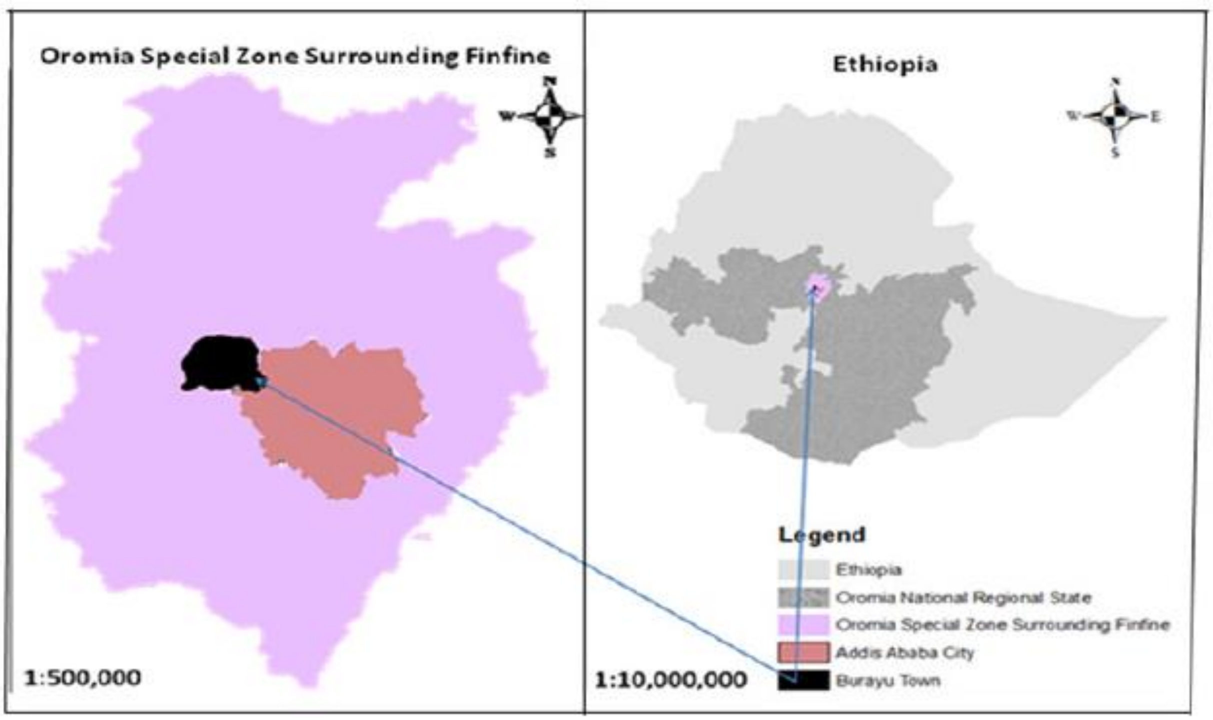


Figure 3.1: Burayu town map in Oromia region, Ethiopia

Source: Map from Oromia Regional State, Bureau of Finance and Economic Development, 2012

3.3.2 Study and target population

The study population or universe includes all the items which are under consideration of a research. It can be defined through identifying the *target population i.e.* the research generalizing population, through determining inclusion criteria and *sampling frame*, i.e. set of all cases from which the sample is selected (Kothari & Garg 2019:13, Strait & Singleton 2018;107).

All the residents of Burayu town, estimated to be a total of 15,000 households, dwelling in six administrative units or kebeles (administrative areas) of the town constitute the study population of this research. Each kebele are subdivided into clusters or villages that have 15 - 20 clusters. Households who had under five years of age children were the target or source population for the study. Households were the study unity of the research i.e. entities under the study on which the descriptions of this research were based (Straits & Singleton 2018: 43).

Inclusion and exclusion criteria

Households with children under five years of age and mothers or caregivers above the age of 18 years were included in the sample and household who did not have children under five years of age were excluded.

3.3.3 Sample size

This refers to the number of samples needed for the study. Adequate samples are required in consideration of desired precision (degree of variability or error in sample estimate, known as standard error), type of sampling design, heterogeneity of the population, data analysis breakdown to be made and available resources (Straits& Singleton 2018;132).

A single proportion estimation formula for infinite population was used to determine the sample size for the study. Optimum sample size is required for a study to manage sampling error (smaller standard error). However, it should be large enough to provide a confidence interval of desired width. Conditions which determine sample size include: nature of the population, proposed number of classes to be formed for the study, nature of the study (whether intensive and continuous vs general), sampling method, desired accuracy and confidence level as well as other considerations like time, cost etc. A commonly used determination method is based on the desired precision of estimation (Kothari &Garg 2019:162-167).

Below were the considerations made to determine the sample size:

$$n = \frac{(Z\alpha /2)^2 * P (1- P)}{d^2}$$

n is the minimum sample size

The level of precisions required for the determination considered:

- The proportion of households in urban with low risk drinking water at PoU is 21.6% (CSAE 2016: 19-23).
- Confidence level of 95% (Z) and level of significance of 5% (α)
- Sampling error or accepted margin within 5% of the true level i.e. 0.05 (D)

Accordingly, the determined sample size was 265 households. This is also comparable with a finite population formula using the estimated 15,000 households in the town.

3.3.4 Sampling procedure

The process of selecting representative items (sample) to estimate population parameters is known as sampling *technique*. The plan which indicates how the sample is to be selected and the number of units in the sample (size) is *sample design,* and it should be reliable and appropriate for a given study (Kothari et al 2019:52-54). In order to address or reduce possible error i.e. sampling error and control systematic bias (measured by precision for a given sample size and sampling design), that could arise on sampling, appropriate sampling design was selected. (Kothari & Garg 2019:52-54).

This research employed *cluster sampling methods.* Cluster sampling is a method of selecting samples by grouping the population based on different distinctions like geographic area and selects the study samples from randomly sampled clusters. It is applicable where the complete list of the population is not available (Straits & Singleton 2018:121).

The steps used to select the sample units included identifying the sampling frame (list of clusters or villages in each of the administrative units or kebeles), and random selection of one cluster or (village) from each of the six kebeles of the town (Figure 3.2). From the selected clusters, a total of 265 households who had children under five years of age were included into the study samples using proportional allocation method.

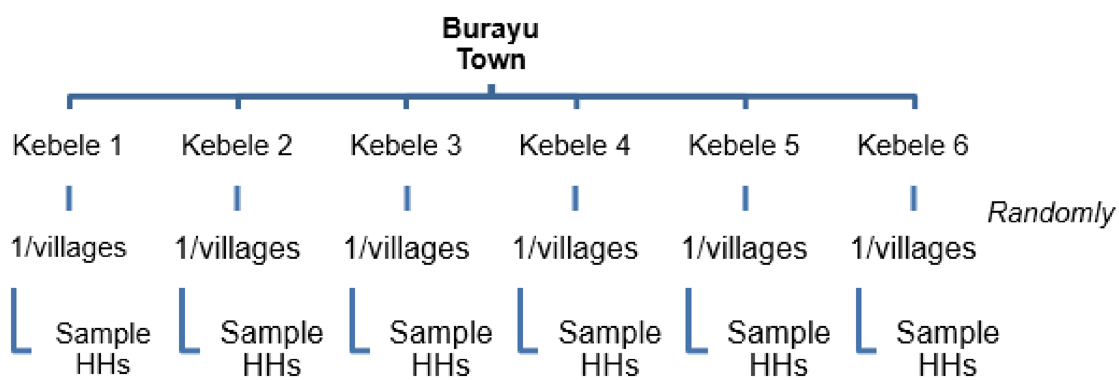


Figure 3.2: Sampling procedure in Burayu town

TABLE 3.1: NAME OF THE KEBELE, SELECTED CLUSTER AND SAMPLE SIZE

Kebele	Cluster	Sample size
Burayu Keta	Mugar 1	45
MelkaGefersa	Melka 2	44
GefersaNono	Tsebela 2	45
Leku Keta	Kule 9	44
GefersaBurayu	Lole 1	43
GefersaGuje	Silki	44

3.3.5 Data collection instrument development and processes

Straits and Singleton (2018:74) describe a measurement process initiates with the formulation of the research questions, hypotheses and contains the concepts or variables of the study. It involves describing the abstract and empirical meaning of these concepts. There are four stages of the measurement process that applied in this research:

Conceptualization– refers to understanding the concepts related to the study. It is an initial step in measurement to develop and clarify the concepts embedded in the research questions and hypotheses with a theoretical definition that directs search for appropriate measures of concepts. Concepts have two aspects in relation to measurement i.e. single category or multiple categories and measurement assumes the possibility to assign different values or categories to the study units. Thus, concepts that have varying characteristics (referred as variables) are measured. In this study, conceptual definitions of concepts have been provided in chapter one of the study. This will help users to understand the strategies and its concepts better.

Operationalizing – refers to providing operational definition to the concepts constructed as variables. The definition describes research operations that specify the values or categories of a variable. As many operational definitions can be prepared for a given variable, the researcher needs to choose the one which soundly relates or fits the concept of the study. Also, considering the research strategy, practicality and characteristics that describe nature and quality of information generated by the operational definitions such as the level of measurement, reliability and validity (Straits & Singleton 2018:75-77, 83-84, 102). In this study, operational definitions of concepts have been provided in chapter one of the study. The process helps to make the concepts more contextual and applicable in the study.

Selection of indicators – (empirical representations) is the other important step in the measurement process for developing operational definitions. Indicators are specific questions, scales or other devices by which the variables of the study are measured. As a perfect measure (indicator) of a concept is a challenge due to errors of classification and inability to capture all the meaning of a concept, different alternatives i.e. more than one indicator, should be considered depending on the nature of the concept. This allows stability to the scores and improves validity (Straits & Singleton 2018:77; Kothari 2019:73). In this research, ten selected indicators were used for HDWI and more than one indicator used to measure each of the RANAS behavioural variables.

The fourth stage is **formation of index**, in which several dimensions of a concept or different measurements of a dimension combine to produce a single index, as is the case used to operationalize a complex concept. Such overall index provides better measurement than single indicator (Kothari &Garg 2019:73).Also, as Straits and Singleton (2018:77) indicate, indicators are combined to form a new variable. In this research, the findings of the HDWI and behavioural variable indicators were combined to measure these variables.

Further details of the variables and indicators for each of the variables are presented below in section development and testing of data collection instruments.

Data collection approach and method

The researcher developed an interview schedule and drinking water sample collection form to collect primary data from the sample households. This research used primary data that was collected using two methods: self-report interview and drinking water samples collection and testing. The respondents were primarily mothers and some caregivers were also respondents to the sample households. The interview was complemented by observation of the actual condition and practices as applicable in order to validate the response.

Trained and capable enumerators who can interpret the questions of the interview schedule were used to conduct the interview and register the responses from the respondents. Measured operations (un-manipulated) were used in order to measure existing values of the variables (Straits & Singleton 2018: 80-81).

The data collection approach and methods used included:

- Verbal report by the respondents using aself-report interview tool
- Testing of drinking water samples using Membrane Filtration (MF) technique
- Composite measures of variables under the behavioural study used by combining responses to relate the variable under study like risk perception, attitude etc
- Observation of HDWI questions to verify the verbal reports

Characteristics of the data collection instrument

Self-report interview tool used for this research was filled by trained enumerators who ask and record the response (verbal or self-report) from the respondents. It has advantages of reducing non-response and to collect more accurate and timely data. However, there could be an element of interviewer bias and requires honest and competent enumerators (Kothari & Garg 2019:100-101).

Structured interview refers to preparing all the questions ahead of data collection and ask the respondents in the same order and the interviewer is restricted in introductory remark and follow up questions (Straits&Singleton2018:205).It also refers to close ended questions that consist of response options for the respondent (Neuman 2014:2014).

Development and testing of data collection instrument

The development of the data collection tool for this research was based on the study questions and theoretical framework for the study. Elements of the safely managed drinking water and theoretical framework for this study including the behavioural model were used to identify the study variables and indicators.

The key concepts of the research and related variables were identified as dependent and independent variables. These variables are presented in Chapter 1- under operational definition. Relevant indicators and questions for each of the variables were identified using literature review. Straits and Singleton (2018:255) described that questions that were used on previous research are the important raw materials available for researchers.

As indicated below (figure 3.3), the process for the development of the study tool(Straits & Singleton 2018:74-77, 83-84):

Figure 3.3: Processes for the development of the study tool

The list of indicators and questions used for this research are presented below:

Dependent variable

This research had two major dependent variables which included:

- Diarrhoeal occurrence during last two-week period among children of under five years age
- Household drinking water safety as determined by combined analysis of HDWI and WQ test results and the result presented in risk categories as low, medium and high risk
- The quality of samples of drinking water from household determined using testing for thermotolerant coliform in colony count per 100 ml. The result is then categorized in risk score as: low, medium and high contamination.

Independent variables

The independent variables for this research included the following:

A. Water source:

- Type of source (improved, unimproved including unprotected dug well and spring, and surface water source such as river and pond)
- Accessibility in terms of point of collection, yard or outside home, time taken to collect
- Availability: regular access to the water source and amount of water used per day

B. Household water treatment:

- HWT practice
- Correct and consistent use of HWT by the households
- Type of treatment method used by the households (boiling, chemical disinfection, solar disinfection, membrane and ceramic filtration)

C. HDW handling and storage:

- Type of storage container used (plastic jerican, bucket, size, ceramic)
- Condition of storage container (type, opening, cover, cleanliness)
- Storage and duration of storage before use
- Adequacy of household storage container
- Availability of water reservoir tank

D. Household drinking water inspection

Ten selected indicators were used to conduct HDW inspection. These involve drinking water service, household water treatment and safe storage (HWTS), hygiene and sanitation conditions of the households. The indicators which have relevance and potential linkage with HDW safety were selected based on literature review. The findings for each of the households categorized and presented as low, medium and high risk. Each of the indicators considered to have equal weight.

The ten indicators and questions used for the HDWI included:

- Access to improved water source
- Access to improved water sources on premise
- Availability of water from the sources when needed
- Diarrhoea risk perception related to unsafe water
- Appropriate use of HWT
- Consistent use of HWT
- Safe storage and handling practice at home
- Duration of water storage over 3 days at home
- Use of basic latrine

- Availability of hand washing station for household

E. Behavioural variables

Each variable of the behavioural elements was assessed using more than one statement having five response options. The respondents indicated their response based on the extent of their agreement to the statement in a range of strongly agreed, neutral or non-attitudinal, disagree and strongly agree and score range of 5 to 1. The questions for each of the behavioural variables are indicated below:

TABLE 3.2 QUESTIONS OF THE BEHAVIOURAL VARIABLES

Psychosocial factors	Questions
Risk perception	Knowledge ▪ The safety of the drinking water from the source is often unreliable for health ▪ Physically clear water is not necessarily safe to drink ▪ Intermittent supply of water can affect quality and safety of drinking water ▪ Vulnerably ▪ There is high risk of getting diarrhoea from unsafe water ▪ Physically clear water is not sign of safe drinking water ▪ Severity ▪ Children under five-year age are highly affected by unsafe drinking water ▪ Diarrhoeal illness is a prevalent among children <5
Attitude	▪ Household water treatment can improve the safety of drinking water ▪ The cost of household water treatment is manageable ▪ Safe storage and handling of drinking water at home helps to maintain the safety of drinking water
Norm	▪ Household water treatment is common practice among the community ▪ HWT is prestigious behaviour ▪ People important to the household expect always to treat water provided to children ▪ The respondent personally feel household water treatment is highly important
Ability	▪ Household water treatment can improve the quality and safety of drinking water ▪ The cost of household water treatment is affordable ▪ Safe storage and handling of drinking water at home helps to prevent and maintain the safety of drinking water ▪ The taste and odour of household treated water is acceptable
Self-regulation	▪ The household clean the filter regularly as required or make stock of chlorine chemical or remember to boil for daily use ▪ The household can do consistent HWT ▪ The household have commitment (priority) for HWT

F. Hygiene and sanitation

Variables considered in relation to hygiene and sanitation for this research included:

- Availability of hand washing station for the households
- Hand washing practice for six critical moments
- Availability of basic latrine for the households
- Provision of hot and well-cooked food for children
- Availability of refrigerator for the households
- Cleaning practice of food utensils using detergent

G. Households' demographic and socioeconomic characteristic

The questions include family size, number of children under five years of age , age of the children under five years of age and respondent, educational level of the mother, monthly net income and access to information sources.

Measurement of behavioural variables

Behavioural variables which include Attitude, Risk perception, Norm, Ability and Self-regulation (RANAS) were measured using Likert scale and composite measures (more than one indicator) for each of the variables that helped to enhance the precision of the measurement. The Likert scale has five response options that generate ordinal data to measure the behaviour variables for each of the sample study units or households. The measurement scales were in a range of 1 (for strongly disagree) and 5 (for strongly agree) responses. It was first developed by Rensis Likert in the 1930s to measure attitude using ordinal measure. Scales are commonly used to measure individual feeling or thinking (Neuman 2014:155).

Measurement scale used

These variables for this research were primarily the categorical (nominal/ordinal) type and the level of measurement included mainly nominal and ordinal measures. Bowling (2014:166-167) describes four types of scales that generate varying levels of data:

nominal, ordinal, ratio and interval data types. Selection of the appropriate scale for a given research is guided by the required type of statistical analysis and satisfaction of relevant acceptability criteria such as nature of the variable (physical, behavioural etc), ability to measure the variable and if the scores enable to correlate with other variables (Bowling 2014:166-167).

A measurement scale that produces quantitative value and can adequately differentiate among the respondents is the preferred for having powerful statistical analysis. Nominal or categorical data are simply numbers used for classification, grouping or coding of measurements into discrete categories. Such data does not have unit or intervals that have equal or ranking measures and can’t be added or averaged. Ordinal data are those measurements or observations which are grouped and ranked like Likert scale. Ordinal data also can’t be averaged or arithmetically manipulated, however, it is common practice to use parametric statistics for ordinal data with the assumption of equal intervals between categories and calculate average and use multivariable statistics. Interval data are similar to ordinal data, but the group rank is considered to have equal interval or the distance between any two numbers on the scale are of known size. Ratio is similar to interval data with zero starting point (Bowling 2014:166-169).

Interview questions designing

The questions were prepared in consideration of the principles for effective writing which include keeping clear, simple and considering respondents’ perspective and heterogeneity. Effort was made to avoid ambiguous and confusing questions and make the response categories exhaustive, mutually exclusive and balanced. Also, attention was given to address questions that have social desirability, knowledge testing concerns and require recall of the respondents. The questions were organized with logical flow considering order and context effects, different sections with introductory briefing and skip to questions guide where appropriate(Neuman 2014:195-208).

Pilot study was conducted on a sample of households (on 5% of the study sample) in order to test the reliability of the tool on a population having similar characteristics to the study population. The respondents used in the pilot study were not included in the final study. Pilot study helped to assess if the data collection tool serves for the designed purpose or revision was sought. Uni-dimensionality of the measurement, i.e. all items on a scale or index fit together or measure a single construct, was assessed using Cronbach alpha that range 1 for perfect score to zero (Neuman 2014:151).

Data collection process

The research data was collected in November 2019 over a two weeks period. The data collection process involved training of data collectors, pretesting, conducting interviews, collection of water samples and testing.

1. Training of data collectors or enumerators

Inadequate training of the interviewers is associated with interviewer errors and extensive training contributes to better quality of the data. The training may involve topics which include introduction to the study and interviewing skills and responsibilities; thoroughly familiarizing the interviewers with the data collection tool and; practical exercise (Straits&Singleton2018:228).

In this research a total of ten enumerators, who are University graduates, have data collection experience and able to speak more than one language which are applicable in the study area, were recruited and adequately trained for two days on the data collection including familiarizing them with the interview schedule questions, techniques of interviewing and representative drinking water sample collection.

2. Pretesting

Pretesting and piloting of the data collection tool was conducted with a view to assess and improve the validity and reliability of the measurement for this research. This involved testing of how the enumerators understand and present the questions to the respondents, assess the understanding and engagement of the respondents and identify problems. All the enumerators applied pretesting of data collection in a cluster which was outside of the clusters where the actual data collection conducted. Review and reflections on the pretesting experiences and filled tools were made with required feedback and revision to the tool.

3. Conducting the interview

Visits to the sample households were made and the interview conducted in a room where privacy can be assured. The interview took a maximum of 30 minutes per the households and additional 10 minutes for drinking water sample collection. The researcher conducted daily supervision and review of the collected data. Completed questionnaires were collected and stored safely in the researcher's office under lock and key.

Main contents of the training included general interviewing skills, procedures and techniques required for the data collection and ethical requirements for the study. The trainees were familiarized with the study purposes, objectives and data collection tool including specific questions of the tool. They did practice the interview process in a role play method. The sampling plan and eligible respondents presented and well addressed through discussion.

4. Drinking water sample collection and testing

Water samples were collected from the sample households into sterile polyethylene water sampling bags and the households requested to provide a glass of drinking water sample that they can provide to children under five years of age. The water samples were coded to have same identification with the interview schedule of the household and transported to the testing laboratory (Kale Hiwot church development program) in Addis Ababa city in an ice box within 2 to 4 hours after the samples collection. The samples were collected on a daily basis of the data collection period (November 2019).

Testing for faecal contamination indicator bacteria (thermotolerant coliform) were conducted using membrane filtration technique (described in literature review section 2.5.4). Experienced WQ experts supported the testing based on the standard procedure and strict application of quality assurance measures including disinfection and sterilization of materials like filtration apparatus (using formaldehyde gas produced on burning methanol), media plate and laboratory surfaces. A sample of 100 ml water was filtered through the membrane filter and put on a media plate consisting of lauryl sulphate broth, prepared using distilled water, and incubated for 24 hours at 44.5 degree Celsius (UNEP and WHO 1996:16). The result as identified by yellow colour colonies that were counted and registered as thermotolerant coliform cfu in 100 ml for each of the samples per the code provided in advance of the testing. Finally, the plates with grown bacteria were disinfected with concentrated chlorine solution and disposed of safely.

3.3.6 Reliability and validity of data collection process

The quality of data can be appraised by the reliability and validity of the data collection methods. Measurement or non-sampling error could arise in the data collection process related to inefficiency of data collector, interviewer bias and non-response. Hence, measurements should be precise and unambiguous in research (Kothari & Garg 2019:54, 71-72).

Reliability– refers to the stability and consistency of an operational definition or measurement tool. It is the dependability and reproducibility of the data collection tool. Also refers to the degree to which the tool measures the same item without *random error* and with repeatability. It is addressed in consideration of the sources of variations in this research (as indicated below) and pilot testing of the data collection.

Validity - is an important criterion in conducting a research and it refers to the goodness of fit between an operational definition and the concept. It indicates the truthfulness or the degree to which the data collection instrument measures what it is supposed to measure. It is also the measure of the extent to which the difference found with the measuring tool reflects true difference among those being tested. Valid measurement tools are continuously reliable (Straits & Singleton2018:102; Bowling 2014:170-172; Kothari & Garg 2019:70-71).

A complete valid measure reflects only true differences which imply it is free of *systematic* and *random errors*. Such reliable measures could also be free of random error but may reflect true differences and/or systematic errors. There are different types of validity measurement which include face, content, criterion and construct validity (Bowling 2014: 174-175; Neuman 2014:143; Kothari & Garg 2019:70-71; Gray et al 2017:578). Each of these approaches was addressed to test the validity of the measurement methods.

Face validity is a basic kind of validity that is judged by the scientific community if the indicators can measure the construct. In this research, this was verified on the basis that a theoretical framework and model with related indicators which are familiar in the scientific studies were adapted. Also, pertinent study variables were identified and used for the development of the data collection tool.

Content validity is a judgement whether full content of a definition is represented in a measure. It refers to the extent to which the content of the data collection instrument appears logical to examine comprehensively the full scope of the characteristics or domain intended to be measured and provides adequate coverage of the topic under study. In this research, the content validity was ensured through detailed review of relevant literature to define the concepts, identify and adapt relevant indicators that represent or address the operational definition of the study variables and elements of the research framework. The multiple indicators or questions used for measuring variables like HDWI and behavioural variables such as risk perception and attitude helped to enhance the content validity of the measurement in order to measure existing conditions.

Criterion validity refers to relation of the measure with another criterion measure, accepted as valid (gold standard) or if recognized proxy measure was used. Two types of criterion validity are: concurrent validity (measuring what it intends to measure) and predictive validity (ability of the data collection instrument to predict future changes in the variables). Qualities of criterion include relevancy of the measure, being free from bias which include data collection from the subject in similar way, ensure reliability and availability of the information sought. In this research concurrent validity was addressed through application of standard method and procedures in testing of the water samples for E.coli and other recognized proxy measures of HDW safety practices were used.

Construct validity is corroboration that the data collection instrument is measuring the underlying concept or theoretical construct it purports to measure, involves examining the fit between the conceptual and operational definitions of a variable. It includes convergent (scale should correlate with similar variables) and discriminant or divergent (scale should not correlate with dissimilar variables) types. Other measures of the data collection instrument include *precision* (the ability of the data collection instrument to detect small changes of an attribute); *sensitivity* (proportion of actual cases who score positive on a measurement) and *specificity* (probability of correlate identifying non-affected).

In this research, the method of investigation of the dependent variable (HDW safety) that involves combined analysis of HDWI and water sample testing results is considered to address construct (convergent) validity of the measurement. Pilot testing of the tool was conducted before the actual data collection to address the validity and reliability of the measurement (Neuman 2014:141, 157).

Sources of variations in measurement

There are three sources of variations in any measurement. One of these is the true difference which accounts for most of the variation of measurements to the study unit and this can be assured by perfect operational definition that ensure valid measurement. Other possible sources of variations are due to systemic and random errors. Systematic *error* relates to systematic influence on the process of measurement or the concept being measured that creates constant bias in one direction (no effect on reliability). This is mainly linked to respondents' reactions to participating in researches that cause reactive measurement and socially desirable effects. *Random error* is related to temporary chances that cause variations in unpredictable direction and affect reliability due to various reasons such as transitory variations in coding, respondent or investigator fatigue etc. The difficulty here is determining what parts of the observed value are due to either of these sources of variation (Straits & Singleton2018: 90-91).

Kothari and Garg (2019:54, 71-72) also describe four major sources of error in data collection or measurement that could affect the reliability and validity of the study. These are: respondent, situation or setting under which the data collection is conducted, measurer or data collector and data collection instrument used. Accordingly, actions taken to address these sources of errors in this research are described below:

Respondents

The respondents were well informed of the purpose of the research and engaged in order to ensure their commitment and genuine response. This helped to address possible negative feelings or not ready to admit their ignorance and this may lead to interview 'guesses' addressed. Also, for addressing reluctance in admitting their ignorance and interview of guesses that could contaminate the results. (Kothari & Garg 2019:54, 71-72). Self-report of the respondents may differ from their actual condition or practices (Neuman 2014:193).

Data collectors

Inefficiency of data collector, interviewer bias behaviour and style of interviewer on data collection have considerable influence (Kothari & Garg 2019:54, 71-72). Possible sources of variations in data collection due to fatigue of the data collector were addressed by limiting the number of households visited every day. Also, the duration of data collection was limited to minimize possible fatigue to the respondents. Possible burden to data collectors was addressed by limiting the number of the interview schedule to be filled on a daily basis to manageable quantities.

Data collection instrument

These potential factors which influence the measurement linked to data collection instrument were addressed on the development of the study tool as presented in the section 3.3.5.3. With regard to HDW testing, samples of water were collected in similar way from the households and put into sterile containers and tested within four hours of collection to enable valid measurement of the sample. Quality assurance of the testing was made by including a blank sterile water sample for testing on daily basis during the data collection period.

3.3.7 Ethical considerations on data collection

Ethics is about identifying the boundaries between what is right, moral and what is not that guides behaviours and decisions in life. Research ethics helps to address concerns, dilemmas and conflicts that arise over the proper way of doing a study. A researcher must balance the value of pursuing knowledge and keeping the rights of research participants and the potential benefits with the costs (Neuman 2014:69).

Ethical issues related to conducting a research cover a range of concerns across research design, the study subjects and data collectors or enumerators. The guiding principles include avoiding harm to the respondents, ensuring their informed consent and privacy, protecting and securing the generated data (Bowling 2014:183).Straits and Singleton (2018:483) have indicated four important areas of ethical concerns to human subjects which include: informed consent, privacy, deception and harm. Gray et al (2017:273) described guidelines for protecting the rights of human subjects based on four ethical principles: autonomy, justice, beneficence and non-maleficence. These rights which require protection in research include right to self-determination, right to privacy, right to anonymity and confidentiality, right to fair treatment or justice and right to protection from discomfort and harm.

In this research, appropriate ethical concerns which were addressed in relation to the study participants, institutions and integrity of the research are presented below:

A. Right of the participants

The participant in this research refers to the respondent mothers or caregivers of a household who were interviewed for the study. The ethical considerations made for ensuring the right of the respondents included ensuring informed consent, self-determination, privacy and addressing possible harm to them.

Informed consent

It implies the study subjects understand that their participation is *voluntary,* and they are given adequate information about the research to make informed decisions whether to participate. The participants should not be coerced to participate in the study. Basic contents of the informed consent letter include description of the research purpose, potential risk and benefits to the study units and how privacy can be assured (Straits & Singleton2018:486-487).

Accordingly, respondents' consent was taken after reading the purpose of the research, the research processes and informing on the data protection aspect. The respondents were informed of their right to participate or refuse, and that confidentiality of their responses was maintained. Assurance made that the data provided by them will be solely used for the intended purpose of the research. A letter of participant informed consent was attached to each of the schedules in order to confirm the consent is taken before proceeding to data collection.

Self-determination

It is consideration of humans as autonomous agents based on the ethical principle of respect for persons. It can be violated through coercion, covert data collection, deception i.e. misinforming the study purpose (Gray 2017:273-274). In this research, there were no elements of these that violate the right of the respondents to be used in the data collection. Respondents were well informed about the research before they were asked to provide consent and told that they can withdraw at any stage of the interview. They were also informed that they could answer questions that they wanted to respond to.

Privacy

Privacy of the respondents was protected by ensuring *anonymity* i.e. not linking respondents' identity with their response and *confidentiality* by holding the responses from the respondents secrete(Gray et al 2017:286).Respondents were allowed to self-decide when, where, to whom and to what extent their attitude, belief and behaviour can be shared (Straits & Singleton2018:493). The setting in which the interview was conducted was arranged in such a way that privacy can be assured.

The collected data on a daily basis was compiled by the investigator and kept in a secure place. Respondent identifying information (name) was removed on data entry but a code was used. Minimal risks that might create inconveniences to the respondents like the time period the interview took was communicated. They were also informed of the possibility to cease the interview at any stage of the data collection or ask to skip questions they didn't want to respond to. The interview schedule was designed in such a way it makes the least burden to the respondents. They were also informed of the contact details of the investigator in case of need.

The training for the data collectors involved topics on ethical concerns and the data collection process including essential skills in interpersonal communications and need to provide important or ethically appropriate feedback at the end of data collection.

Beneficence

Refer to striving to do good for the respondents and protection from discomfort and harm i.e. non-maleficence (Gray et al 2017:290). Harm to the study subjects in social research often include personal (humiliation or embarrassment), psychological (loss of self-esteem) and social (affecting trust in others) (Straits & Singleton2018:484). Possible minimal risks to the respondents related to the interview were addressed through making the interview schedule tool precise, well organized and took short duration. The interview was also conducted at a convenient time for respondents.

Justice

This was addressed through proper selection of the research participated households based on the sampling and set inclusion and exclusion criteria.

B. Rights of institution

Relevant institutional rights secured for this research included: ethical clearance from the research and ethical committee of higher degrees at the department of health studies, University of South Africa. Permission letter to conduct the research was obtained. The support letter from the regional health bureau provided to Burayu town health and water offices to inform them on the research and facilitate their cooperation in the data collection process.

C. Scientific integrity of the research

Scientific progress depends on the trustworthiness of the findings from many researchers (Straits&Singleton2018:481). Hence, the researcher committed to maintaining the scientific integrity by being honest and accurate in conducting the research and reporting the findings. The validity of the study in the research processes was addressed and all references used for this study were properly acknowledged and cited.

3.3.8 Data management and analysis

The data management process was started with the development of a list of variables including the exact wording of each question for easy reference (Curtis & Drennan 2013:380). Data management was done by following a data preparation process guided by the analysis plan, which was set up in advance of data collection. It involves checking the filled questionnaire, coding, data entry, data cleaning and missing data (Kothari & Garg 2019:114). The collected data was examined for completeness, accuracy, error or omissions and quality at time of data collection and later before data entry. The data sheets were kept in a safe place for easy retrieval and use. Details of the data management interventions are described below:

3.3.8.1 Data coding

According to Kothari and Garg (2019:115-116), coding is required for efficient analysis. It is the process of assigning numerals or other symbols to response options to the variable questions in order to put them into limited, appropriate, exhaustive and mutually exclusive categories each having a unique concept. The data needs to be classified according to common attributes (called statistics of attributes data) and classes i.e. class interval (statistics of variable data) in order to assess pertinent relationships. In this research, the codes for most of the response options were identified on the data collection tool while the rest were coded during data entry. HDW risk levels were categorised and coded into three (low, medium and high) based on the findings and categorization plan. During data analysis, the data was also transformed through recoding and computing variables.

3.3.8.2 Data entry and cleaning

The collected data was entered into SPSS version 26 by the researcher. Data cleaning started while entering the data into the prepared form on SPSS. Simple descriptive frequencies were run after data entry to check quality and completeness. Cross-tabulation of variables was done to check for logical errors (Curtis & Drennan 2013:380). Data editing, cleaning and modification was conducted as required in order to improve the quality, accuracy, consistency, completeness and consistency of the data.

3.3.8.3 Missing data

The review of cases and case entry often reveals missing information. The missing data in all the variables was analysed to determine whether they adversely impacted the results or not (Curtis & Drennan 2013:380).

3.3.8.4 Data analysis

Data analysis is a computation of indices or measures along with searching for patterns of relationship that exist among the groups. It involves estimating the values of unknown parameters of the population and testing hypotheses for drawing inferences. There are descriptive and inferential or analytical (explanatory) types of analysis as well as correlation and causal or regression analysis (Kothari & Garg 2019:126). It requires converting the raw data into a suitable form for the required analysis and this determines the result of the analysis.

Computer-based data analysis

The researcher analysed the data using SPSS version 26 through application of descriptive and analytical statistics. The methods of data analysis included univariate statistics for one variable analysis using frequency distribution, percentage and statistics of central tendency and dispersion. Bivariate statistics for analysis of association of two variables including contingency table, correlations and test of differences between group proportions and; multivariate analysis for measurement of the effect of one variable on the outcome using multiple regression, logistic regression and multiple discriminant analysis (Bowling 2014:360).

In this research, univariate, bivariate analysis using chi-square test and logistic regression analysis was used. These are appropriate due to non-parametric measurements used by the research which included categorizing the risk levels of safety and quality of drinking water and other dependent variables. The results presented in frequencies, cross tabulation table and graphs. The results of the analysis of the associations between variables presented in crude and adjusted odd ratios, using statistical significance test p-value at 0.05. Independent variables which were significant at p-value 0.05 on bivariate chi-square test was considered for multiple regression analysis to analyse the association with the outcome of interests. Since non-parametric measurements used to categorize the risk levels of safety and quality of drinking water, the method of analysis used include chi-square, odds ratios and logistic regression models (WHO GDWQ 2017:91).

The results of HDW samples testing and sanitary inspection was categorised into three risk levels (low, medium and high risk). Negative result for 100 ml sample test for EC was considered as low risk, while 100 and above positive count for EC was considered as high risk. Similarly, the number of negative responses (which were unmet) to household inspection questions was used to set risk categories.

Drinking water test result

Based on the samples test result, risk categorization was conducted per table adapted from WHO GDWQ (WHO 2017:92):

TABLE 3.3: RISK CLASSIFICATION BASED ON DRINKING WATER TESTING AND HDW INSPECTION RESULTS

Households inspection (met)	CFU EC/100 ml	Risk classification
8–10	<1	Low risk
6–7	1 – 10	Medium risk
4–5	11 – 100	High risk
0 –3	>100	Very High risk

Combined risk analysis using the findings of drinking water sample testing and HDW inspection, which is applicable to HDW safety assessment, conducted using ten selected variables. The WHO guideline for drinking water quality (GDWQ) indicates the relevance of combined analysis of sanitary inspection and WQ data in assessing HDW management systems. This helps to determine important causes and control measures of contamination (WHO 2017:91). The table below depicts how the risk categories on the combined analysis are made.

TABLE 3.4: COMBINED ANALYSIS OF MICROBIAL TESTING AND HDW INSPECTION RESULTS

		Household inspection risk score			
		0-2	3-5	6-8	9-10
classification (colony count/100ml)	<1				
	1-10				
	11-100				
	>100				

1	2	3	4

Adapted from WHO GDWQ 2017: 92

1-low risk, 2-medium risk, 3-high risk, 4-very high risk

The findings for the measures of behavioural variables using Likert scale add up to produce an index for each of the variables and study units. The total result is then categorized as low, medium or high for a given variable. For instance, if the attitude indicators are five questions, each with five scale measures, then the total possible result range is 5 – 25. Thus, results above 15 may be considered as high (favourable attitude), exact 15 as neutral and below 15 as unfavourable attitude finding for the study unit (household).

Similarly, HDWI indicators response score was added to determine the HDW risk level as low, medium and high risk. This also applies to safe handling and storage variables in which the responses to the related indicators were combined to produce a composite measure (index). In this research, some of the indicators of HDWI variables were independently analysed to assess their associations or correlations with the dependent variable and this created multiple tests and checking in relation to the hypothesis.

As hypothesis testing on survey research infer temporal order and association, it is required to consider alternative explanations (control variables), which are not part of some specified relationship and hence controlled or prevented from varying during course of observation or analysis (Neuman 2014 :193; Straits & Singleton 2018: 48). Hence, in this research such variables were ruled out or kept constant in regression analysis. Statistical significance test at p-value ≤ 0.05 was used to rule out the effect of chance on the analysis of association between variables. Different indicators of the same concept such as the households inspection indicators were analysed separately in order to yield different evidence or cross checks of the hypothesis (Straits & Singleton2018: 78).

The fourth step in the measurement process is formation of an index, in which several dimensions of a concept or different measurements of a dimension combine to produce a single index. Such an overall index provides better measurement than a single indicator (Kothari & Garg 2019:73). As indicated by Straits and Singleton (2018:77), indicators are combined to form a new variable, as is the case to operationalize a complex concept. In this research, behavioural variables (RANAS) were analysed by aggregating the data of different indicators of the same concept (like attitude).

The aggregated results then categorized as:

- Low/neutral vs high risk perception related to drinking water safety
- Negative/neutral vs positive attitude related to drinking WQ and safety interventions
- Unsupportive/neutral vs supportive norm related to HDW safety interventions
- Unable/neutral vs capable for HDW safety interventions
- Uncomplying / uncommitted / neutral vs comply/committed to drinking water safety interventions

3.4 INTERNAL AND EXTERNAL VALIDITY OF THE STUDY

Appraisal of the findings of a research depends on three aspects. These are measurement validity, internal and external validity of a study. Valid measurements correspond adequately with the theoretical concepts and the operational definitions of the variables and measures what intended to be measured (Straits & Singleton 2018:147).

The threats to reliability and validity of the study relate to data collection instrument design and scaling, biases and errors that can be introduced in the research processes including conceptualization of research idea, design, sampling and processing that leads to systematic deviations from the true value (Bowling 2014:179).Straits and Singleton (2018:215) also describe Rober Groove's '*total error perspective*' that involve four interrelated errors: coverage error which is the difference between the target population and the sampling frame, sampling error(the difference between a population value and a sample estimate), non-response error i.e. difference in the characteristics of those who choose to respond and who refuse, and measurement error i.e. inaccurate responses linked to the respondent, interviewer and data processing.

In this research, actions that help to enhance the reliability and validity of the study were addressed in the design, sampling, the study tools development, data collection and analysis stages. Internal and external validity aspects of this research are discussed below:

Internal validity refers to the extent to which a study design allows control over these factors which influence the result of the study. It is about addressing possible errors internal to the design of the study (Bowling 2014: 179).

In this research, internal validity was addressed across the study design and implementation stages including synthesis of the theoretical framework, identification of relevant study variables and operational definitions, development of the data collection tool, preparation for the data collection including training of the enumerators and pretesting, and data analysis through use of appropriate methods including use of multiple regression to control of confounding variables. Water sample testing procedures were strictly followed to avoid contamination.

External validity refers to generalizability of the findings of the study to broader context and population (Neuman 2014:147).This was addressed through probability sampling method using cluster sampling method and providing focus to the internal validity of the study. The interview schedule method of data collection helped to reduce the non-response as the interviewer visited each of the homes of the sample household and established good rapport with the respondents and assured informed participation (Straits & Singleton 2018:217).

3.5 STRATEGY DEVELOPMENT AND DISSEMINATION METHOD

This research employed a socio-ecological model (SEM) for developing the strategies for HDW safety promotion. The model helps to develop the strategies by considering the essential intervention needs at different levels in order to bring the desired outcomes at individual and household level. The findings of this research and review of literature have informed the strategies development. According to Glanz (2016), successful strategies in public health are based on understanding of behaviours and the context in which they occur. Also noted interventions based on apparent theoretical foundation are effective.

As noted by Ngigi & Busolo (2018:85), communication strategies which implements message dissemination need to consider accessible communication channels to the targeted audience including interpersonal and media channels, segregating the audiences, messages and materials pre-testing in order to influence towards the desired behaviour.

Thus, the developed strategy will be disseminated to the targeted audiences and stakeholders through different mechanisms including publication and through presentations on different forums. Most importantly the study area will be shared with printed and soft copies of the research and intervention strategies for use.

3.6 CONCLUSION

This research design and method chapter indicated the type of the research design used in the research which is quantitative, non-interventional cross-sectional design including descriptive, explanatory and contextual research type. The research methods which include the study setting, study and target population, sample size and sampling procedure are presented. Also, data collection approach including data collection instrument development, testing, data collection process and data management including analysis are indicated. Most importantly the aspects to ensure the reliability, validity and ethical considerations are presented. The following chapter presents the data analysis and presentation of the findings.

CHAPTER 4

ANALYSIS AND PRESENTATION OF FINDINGS

4.1 SOCIOECONOMIC CHARACTERISTICS

Out of the total 265 respondents from 6 clusters of the research area, 85.0% (n=225) of them were under 35 years of age and 72.8% (n=193) had one child under five years of age while the rest 26.1% (n=69) had two and 1.1% (n=3) had three under five children. A total of 66.8% (n=177) of the households had 5 and less family members and the remaining households had 6 and above family members. Most of the households in two clusters i.e. Tsebela 2 (80.0%, n=36) and Silki (90.9%, n=40) had 5 and less family members. However, households in Mugar1 (51.1%, n=23) and Kule9 (47.7%, n=21) had 6 and above family members and these differences are statistically significant. The table below indicates the percentage within the group.

TABLE 4.1: TOTAL FAMILY SIZE IN EACH OF THE CLUSTERS OF THE STUDY AREA (N=265)

Total family size		Village						Total
		Mugar 1	Kule 9	Lole 1	Malka 2	Tsebela 2	Silki	
1-5	Count	22	23	30	26	36	40	177
	% within Village	48.9%	52.3%	69.8%	59.1%	**80.0%**	**90.90%**	**66.8%**
6-11	Count	23	21	13	18	9	4	88
	% within Village	**51.1%**	**47.7%**	30.2%	40.9%	20.0%	9.1%	33.2%

Out of the total 261 respondents 76.6% (n=200) of them attended primary to secondary level education while 10.2% (n=27) were uneducated and 12.9% (n=34) of them had certificate and above educational qualification.

Out of the total 239 respondents 60.3% (n=144) earn monthly income of less 3000 ETB and 79.1% (n=189) of them earn 5000 and less ETB in a month. From the total of 125 respondents in three clusters: Malka2, Tsebela and Silki, 93.6% (n=117) of the households earn 5000 ETB and less monthly income.

TABLE 4.2: MONTHLY INCOME OF THE HOUSEHOLDS IN ETHIOPIAN BIRR (N=239)

Income less 5000		Village						Total
		Mugar 1	Kule 9	Lole 1	Malka 2	Tsebela 2	Silki	
Less 5000	Count	18	27	27	41	39	37	189
	% within Village	43.9%	73.0%	75.0%	**93.2%**	**90.7%**	**97.4%**	**79.1%**
Over 5000	Count	23	10	9	3	4	1	50
	% within Village	**56.1%**	**27.0%**	**25.0%**	6.8%	9.3%	2.6%	20.9%

4.2 DIARRHOEA PREVALENCE

Out of the total 265 sample households, 11.3% (n=30) of the households reported diarrhoea among under five children during the last two weeks period. The prevalence in Mugar 1 cluster was 6.7% (n=3) and 13.6% (n=6) in Lole1 cluster. The proportion of 30.0% (n=9) of the diarrhoea occurrence on the date of the interview was reported. The prevalence of diarrhoea did not show significant difference among the clusters of the study area. Also, 3.4% (n=9) diarrhoea occurrence among over five years old family members during the last two weeks period reported.

4.3 DRINKING WATER QUALITY AND SAFETY

4.3.1 Drinking water sample test result

More than half (57.0%, n=151) of the household sample test results were free from faecal contamination indicators and thus low risk. The remaining test results were medium risk (29.4%, n=78) and high to very high risk (13.6%, n=36). In Kule 9 of the total 44 households, 77.3% (n=34) of them had low risk test result of the water samples while 25.0% (n=11) of the samples test result in two clusters (Lole 1 and Melka 2) were high to very high risk.

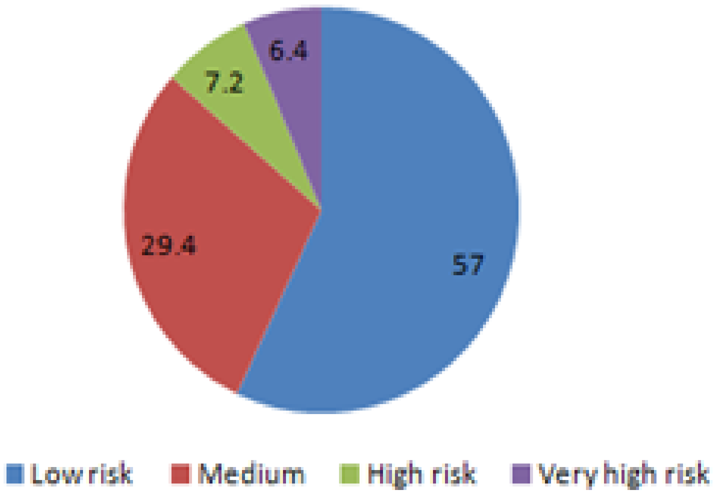


Figure 4.1: Drinking water test result in percentage (N=265)

Most of the bottled water (82.1%, n= 32), 62.5% (n=5) of the tap water sample and 60.3% (n=35) of the treated water samples were low risk. Also 94.8% (n=92) of the water samples from HWT and bottled water sources were low to medium risk. On the other hand, 40.0% (n=2) of the water samples from the reservoir tank were at high risk.

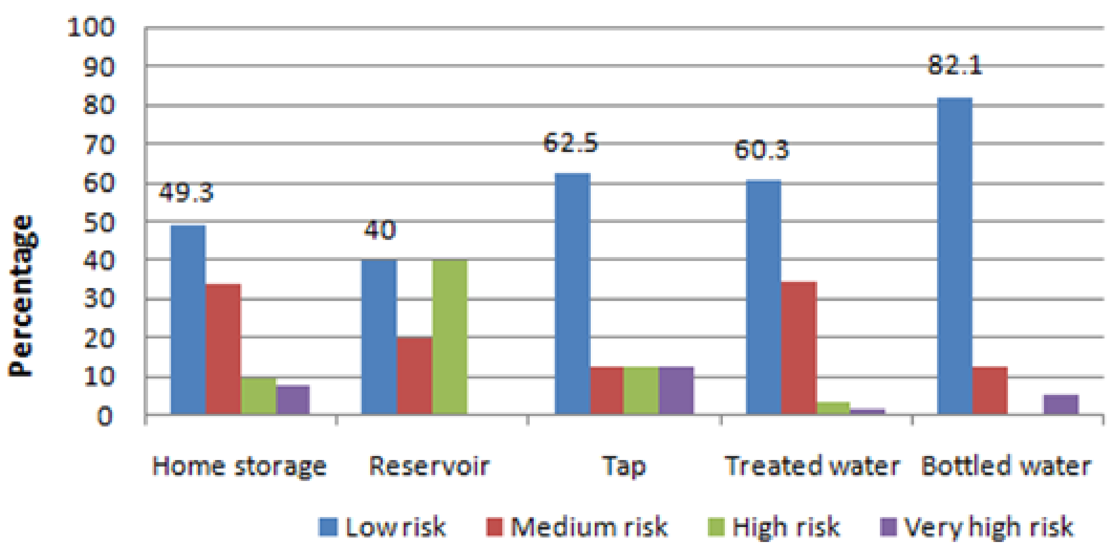


Figure 4.2: HDW test result by source of the water sample (N=262)

In Kule 9 cluster, 77.3% (n=34) of the water samples were low risk. In this cluster, majority of the samples (47.7%, n=21) were from bottled water while the rest were from home storage (29.5%, n=13) and home treated water (22.7%, n=10). In Tsebela 2 cluster, 64.4% (n=29) were low risk and the samples were mostly from home storage (75.6%, n-34).

However, in Malka2 cluster 25.0% (n=11) of the samples result were high to very high risk result where most of the sample were from home storage (52.4%, n=22).

TABLE 4.3: HDW QUALITY TEST RISK LEVELS BY THE CLUSTERS OF THE STUDY AREA (N=265)

Household sample result cat		**Village**						**Total**
		Mugar 1	Kule 9	Lole 1	Malka 2	Tsebela 2	Silki	
Low risk	Count	27	34	18	19	29	24	151
	% within Village	60.0%	**77.3%**	41.9%	43.2%	64.4%	54.5%	**57.0%**
Medium risk	Count	17	8	14	14	13	12	78
	% within Village	37.8%	18.2%	32.6%	31.8%	28.9%	27.3%	29.4%
High risk	Count	1	0	4	7	1	6	19
	% within Village	2.2%	0.0%	9.3%	**15.9%**	2.2%	13.6%	7.2%
Very high risk	Count	0	2	7	4	2	2	17
	% within Village	0.0%	4.5%	**16.3%**	**9.1%**	4.4%	4.5%	**6.4%**

TABLE 4.4: HDW QUALITY TEST RISK LEVEL BY SAMPLE SOURCES (N=262)

HDW quality risk category		**Source of water sample at households**					**Total**
		Home storage	Reservoir	Tap	Treated water container	Bottled water	
Low to medium	Count	126	3	6	55	37	227
	% within source of water	82.9%	60.0%	75.0%	**94.8%**	**94.9%**	86.6%
High to very high	Count	26	2	2	3	2	35
	% within source of water	17.1%	40.0%	25.0%	5.2%	5.1%	13.4%

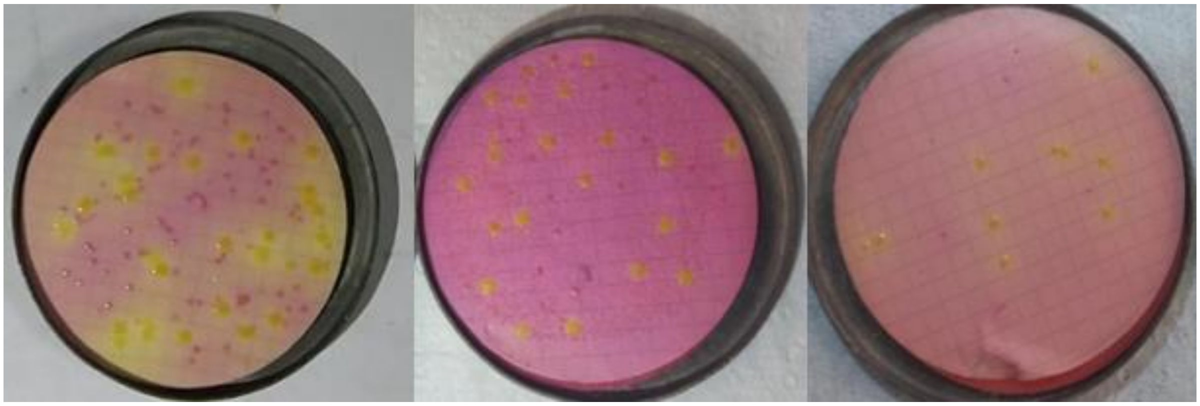


Figure 4:3: Sample of the thermotolerant coliform colonies test results

4.3.2 Household drinking water inspection result

The HDWI result indicates that 18.9% of all sample households (265) had low risk scores i.e. met at least eight of the ten inspection indicators, and 34.0% of the households had medium risk (met six to seven of the ten indicators). The remaining 36.2% and 10.9% of the HDWI result categorized as high and very high risk respectively. Low risk result of HDWI is higher in Mugar1 cluster (48.9%, n=22) while 79.6%, n=35) of households in Silki cluster had high to very high-risk inspection result.

TABLE 4.5: HDW INSPECTION RISK LEVELS BY THE CLUSTERS OF THE STUDY AREA (N=265)

Households inspection risk category		Clusters						Total
		Mugar 1	Kule 9	Lole 1	Malka 2	Tsebela 2	Silki	
low	Count	22	3	7	8	10	0	50
	% within Village	48.9%	6.8%	16.3%	18.2%	22.2%	0.0%	18.9%
medium	Count	16	18	23	13	11	9	90
	% within Village	35.6%	40.9%	53.5%	29.5%	24.4%	20.5%	34.0%
high	Count	7	19	11	19	21	19	96
	% within Village	15.6%	43.2%	25.6%	43.2%	46.7%	43.2%	36.2%
v.high	Count	0	4	2	4	3	16	29
	% within Village	0.0%	9.1%	4.7%	9.1%	6.7%	36.4%	10.9%

Though most of the households had access to improved water sources, a limited proportion had regular supply from the source (9.8%, n=26). HWT practice and hand washing facilities coverage for the households were also inadequate.

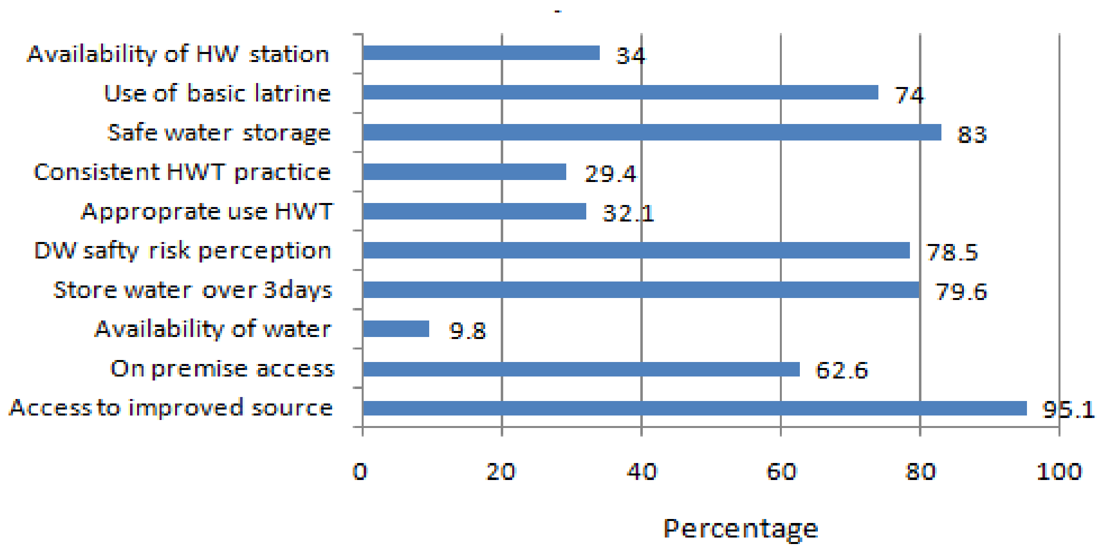


Figure 4.4: HDW inspection results (N=265)

4.3.3 Combined household water safety result

A proportion of 10.9% of all the sample households had low risk drinking water safety on the combined water test and drinking water inspection results. The remaining 37.0%, 35.1% and 17.0% of the households had medium, high and very high-risk results of HDW safety result respectively.

There is a significant difference of the drinking water safety results among the clusters of the study area. The proportion of 26.7% (n=12) of the households in the Mugar1 cluster had low HDW safety risk on the combined analysis. In the Silki cluster most of the households (81.8%, n=36) had high to very high risk of drinking water safety.

The proportion of 19.2% (n=29) of the low risk and 55.1% (n=43) medium risk HDW quality test samples were found low and medium risk on the combined HDW safety risk classification respectively. Also, 45.7% (n=69) of the high and very high risk results of HDW safety on the combined analysis were found to be low risk on the quality test result.

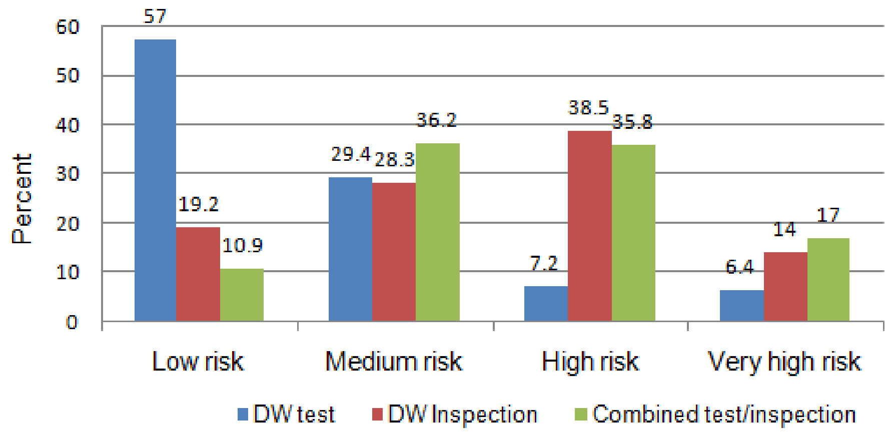


Figure 4.5: Combined drinking water test and inspection result (N=265)

TABLE 4.6: COMBINED HDW SAFETY AND HDW INSPECTION RISK LEVELS (N=265)

HDW quality risk category	Combine test and inspection result				**Total**
	Low	Medium	High	V. high	
Low risk	**32 (100.0%)**	42 (53.2%)	55 (53.9%	22 (42.3%	151 (**57.0%**)
Medium risk	0	**37 (46.8%)**	31 (30.4%	10 (19.2%	78 (29.4%)
High risk	0	0	**16 (15.7%)**	3 (5.8%)	19 (7.2%)
Very high risk	0	0	0	**17 (32.7%)**	17 (6.4%)

TABLE 4.7: COMBINED HDW SAFETY LEVELS BY THE CLUSTERS (N=265)

HDW safety risk category		**Village**						**Total**
		Mugar 1	Kule 9	Lole 1	Malka 2	Tsebela 2	Silki	
Low	Count	12	1	6	4	6	0	29
	% within Village	**26.7%**	2.3%	14.0%	9.1%	13.3%	0.0%	10.9%
Medium	Count	25	19	18	12	14	8	96
	% within Village	55.6%	43.2%	41.9%	27.3%	31.1%	18.2%	36.2%
high	Count	8	18	10	20	20	19	95
	% within Village	17.8%	40.9%	23.3%	**45.5%**	**44.4%**	**43.2%**	35.8%
v.high	Count	0	6	9	8	5	17	45
	% within Village	0.0%	13.6%	20.9%	18.2%	11.1%	38.6%	17.0%

TABLE 4.8: COMBINED HDW SAFETY AND QUALITY TEST RESULT OVERLAPs (N=265)

HDW test results		Combined result				Total
		Low	Medium	High	V. high	
Low (negative)	Count	32	42	55	22	151
	% within Comb recode	100.0 %	53.2%	53.9%	42.3%	57.0%
Medium to very high (positive)	Count	0	37	47	30	114
	% within Comb recode	0.0%	46.8%	46.1%	57.7%	43.0%

There is significant association between HDWI and the combined HDW safety analysis results. The proportion of 58.0% (n=29) of the analysis results were matched on low risk whereas 36.0% (n=18) of the low risk results of the inspection were medium risk on the combined analysis. And there were 86.7% match on medium risk, 90.6% match on high risk (the remaining proportion were very high risk on the combined) and 100% match on very high-risk results. However, 85% of the high to very high-risk findings of the inspection found to be low to medium risk on the quality test result.

Also, HDW sample test results are significantly associated with the combined analysis of HDW safety result to predict high and very high-risk results of combined drinking water safety. A proportion of 84.2% of high risk on sample test were high risk on combined analysis while the remaining 15.8% were very high risk on combined result. Similar to the inspection result there was 100% match on very high-risk results of the test and combined analysis. However, low risk testing results were poorly matched with the combined analysis as 51.0% of the low risk result testing results were found to be high to very high risk on the combined analysis.

4.4 ACCESS TO WATER SUPPLY

Most of the households' main source of water was pipe water at premise level (61.5%, n=163) and 27.5% (n=73) access piped water sources outside a premise. The remaining households access drinking water from protected spring (4.9%, n=13) and trucked (4.2%, n=11) sources. On premise access of water was higher in Lole E1 (86.0%) and Tsebela2 (80.0%) clusters. Only 18.2% of the households in Kule9 and 29.5% of households in Silki clusters had access to water on premise. The proportion of 25% of the households in Kule9 depends on trucked water purchase.

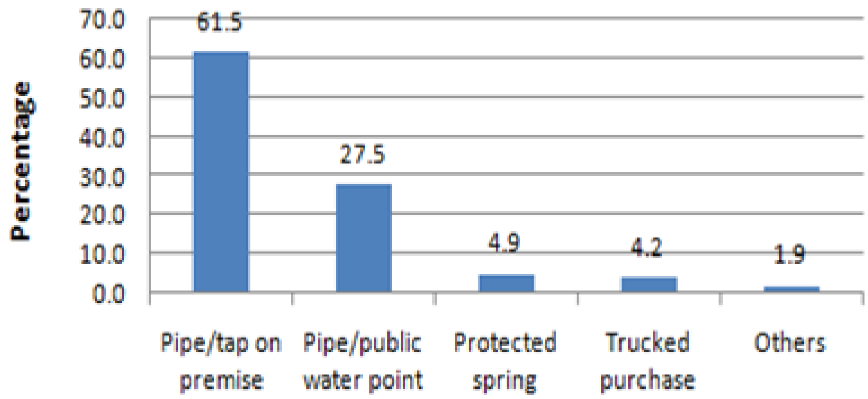


Figure 4.6: Main source of water for households (N=265)

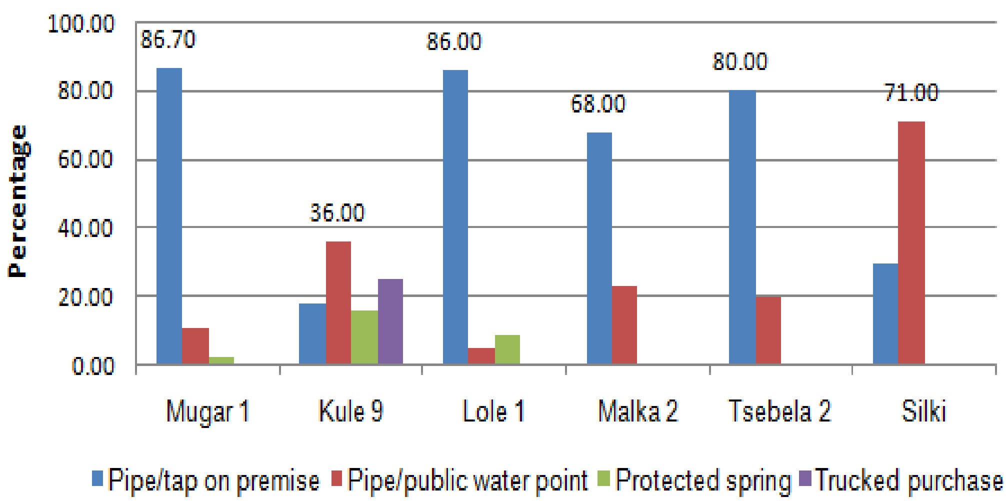


Figure 4.7: Main water source for the households in different clusters (N=265)

With regard to daily per capita, 67.3% and 47.9% of all the households use less than 15 litres and 10 litres or less respectively without significant difference among the clusters. Also 5.3% of the households use five and less litre per person per day. Safely managed drinking water coverage is very low as only 1.9% of the households access water from improved water sources regularly and have no faecal contamination at point of use.

Availability of water from the source

A total of 90.2% of all the households experienced irregular availability of the water from the sources. Most of the households (67.9%, n=180) experience water supply interruption over a week to a month. The better supply case is in the Lole1 cluster where 65.0% of the household experience the interruption for duration of less a week and 50.0% of households experience the interruption for 1-2 days in a week. Also in the Silki cluster, 87.8% of households experience water interruption from the source for a duration of less than a week. In the Melka2 cluster, 25% of the households had regular availability of water from the source.

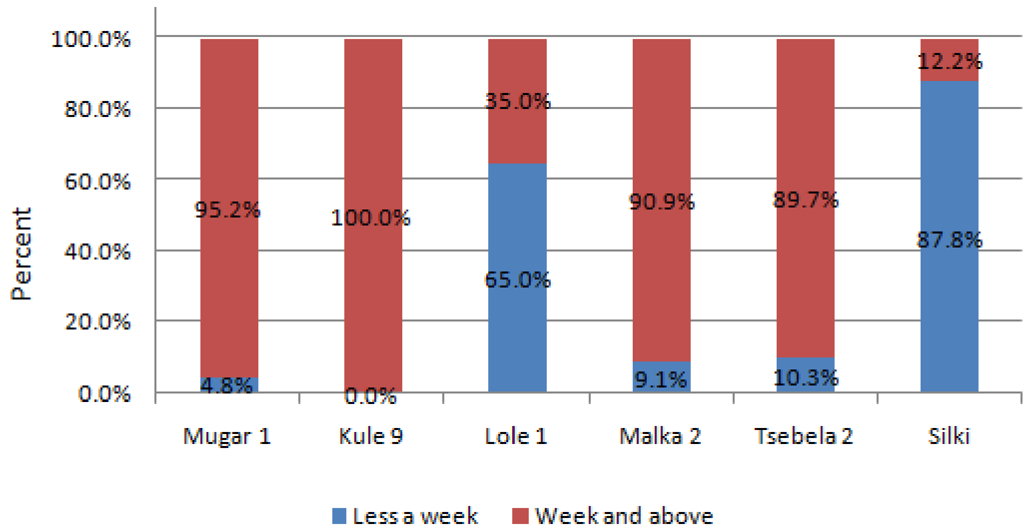


Figure 4.8: Duration of Water Interruption by the clusters of the study area (N=221)

Time to collect water

A total of 11.3% of the households and 38.6% of households in Kule 9 cluster took over 30 minutes round trips for water collection travel including queuing time. The quantity of water used on a daily basis by households was 50 litres or less for 42.6% of the households while 15.6% of the households used 100 and above litres of water in a day.

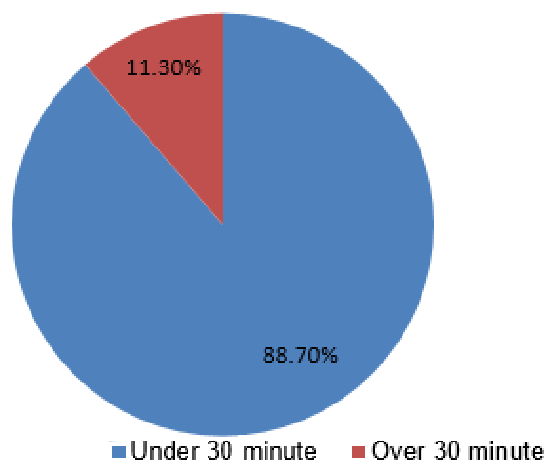


Figure 4.9: Time to collect water from sources (N=265)

Water storage

Use of home storage containers and reservoir tanks were commonly used to cope with the prevailing interruption of the water from the sources. Some of the households (34.5%) have water reservoir tanks which serve for storing water for more than two weeks and above period for 57.3% of these households. There is a significant difference among the clusters on the use of reservoirs which is 71.1% in the Mugar1 cluster and only 6.8% in the Silki cluster. The proportion of 36.7% of the reservoirs had the capacity to hold 2000 or above litres of water.

A total of 66.4% of the households reported adequate water storage containers, which is higher (69.3%) in those households having on premise level water access. Those households who have on premise level access to water had a significant adequate water storage container (73.2%) compared to those who don’t have on premise access (56.5%).

Most of the households (79.6%) store water for a period of over three days. This is associated with the availability of adequate water storage containers for the households. The proportion of water storage over three days is higher (87.5%) among households who have adequate containers compared to those who reported that they don’t have adequate water storage containers (64.0%).

Bottle water use

Out of the total 263 households 68.1% of the households had bottled water use experience and 36.7% of these households used bottled water (which is 62.9% in Kule9 cluster) on a daily basis for drinking purposes. Most of them provide the water for children under five years of age (59.0%) while the remaining households use it for all family members. Also, 28.0% of the households use bottled water occasionally, on a weekly or monthly basis and 13.6% use it when stored water finishes.

The bottled water is used by all family members (77.3%) and some households provide only for children under five years of age (22.7%). The proportion of 36.7% of the households reported daily use of bottled water for drinking purposes, primarily in the Kule9 cluster (62.9%).

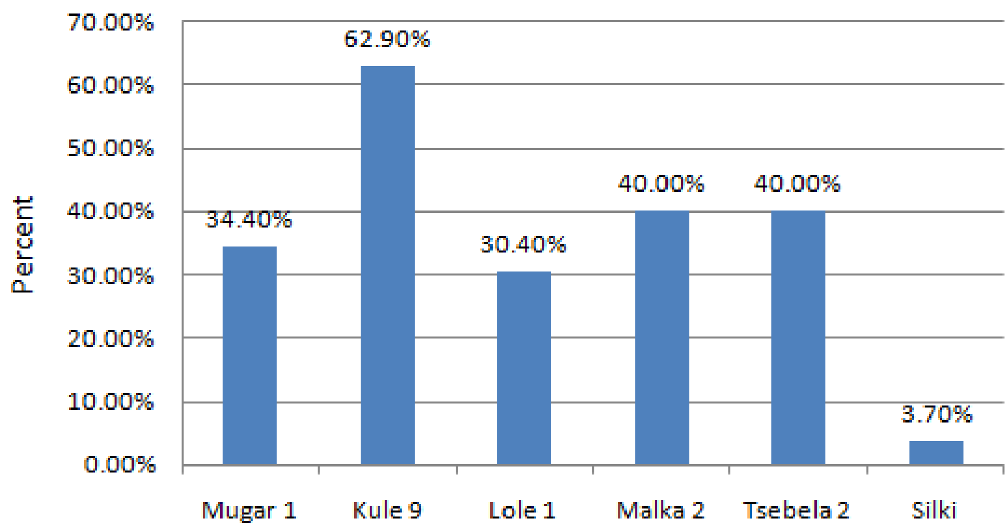


Figure 4.10: Daily bottled water use by the clusters of the study area (N=65)

The use of bottled water on a daily basis is significantly associated with a lack of regular supply of water from the source. Those households which experience interruption of water from the source for more than a week were 10 times more likely to use bottled water (OR 10.7, 95% CI 3.1 – 36.9) than those households which experience the interruption for less than a week. Also, daily bottled water use is significantly associated with the household monthly income that households which earn above 5000 ETB are 4 times more likely to use bottled water on a daily basis (OR 4.0, 95%CI 1.9-8.7) thank those who earn 5000 or below ETB.

TABLE 4.9: FREQUENCY OF WATER INTERRUPTION (N=265)

Frequency of bottled water use		**Frequency of water interruption**		**Total**
		Less a week	Week and above	
Weekly and above	Count	36	56	92
	% within frequency of water interruption	92.3%	52.8%	63.4%
Daily	Count	3	50	53
	% within frequency of water interruption	7.7%	**47.2%**	36.6%

P value – 0.001, x2-19.1, OR 10.7 (3.1 – 36.9)

TABLE 4.10: FREQUENCY OF BOTTLED WATER USE BY INCOME CATEGORY (N=159)

Frequency of bottled water use		Households Income cat5000		Total
		5000 and less	5000 and above	
Occasional	Count	85	14	99
	% within Income	70.2%	36.8%	62.3%
Daily	Count	36	24	60
	% within households Income	29.8%	**63.2%**	37.7%

P value – 0.001, x2-13.7, OR 4.0 (1.9-8.7)

4.5 HOUSEHOLD WATER TREATMENT AND SAFE STORAGE

HWT is practiced by 31.3% (n=83) of the households, and 27.9% that is 90.0% of these practice HWT consistently. HWT practices vary significantly among the clusters which was 55.6% in Mugar1 and 9.1% Silki cluster. The methods of treatment used include filtration (39.8%), chemical disinfectant (33.7%) and boiling (26.5%). Most of the households (91.2%) practice HWT for over six months while the rest use it for six months or less. Also, 45% of the households used HWT for over two years and 78.3% of the households purchased the treatment products from the local market.

Also 22.2% of the households had experience of HWT but interrupted due to various reasons. These include perception of considering the source is safe, lack of attention or awareness, dislike of the taste of the water, difficult to treat all the time, lack of time and use during rainy seasons. Some of them resorted to use of bottled water.

The proportion of 65% of the drinking water sample test result in HWT practicing households was low risk and 30.1% was medium risk, with no significant difference by the method of treatment used. However, the proportion of low risk test results among the households using chemical disinfectant was 78.6%. The proportion of low and medium risk among the households using boiling was 50.0% and 45.5 % respectively.

4.6 SAFE STORAGE

A total of 58.9% of the households, particularly in Tsebela2 cluster (90.5%), reported use of water stored for a week and above duration. The proportion of 83.0% of the households had safe storage of water i.e. clean container with a narrow opening and cover.

The storage containers of the households visually observed to be clean for 82.9 % and cover were 98.4% of the households. The containers in the households with a narrow opening were reported to be 55.5%, wide opening 16.2% and both types at 28.3%. Frequency of proper cleaning of the container every week and less was reported by 25.3% of the households while most of the households (74.6%) clean every week or above period and whenever they collect water from the sources. The type of containers were plastic jerican (42.0%) and both plastic jerican and buckets (31.2%). Also 67.1% of the households reported lack of adequate water storage container.

4.7 HYGIENE AND SANITATION

The total of 95.8% of the households had latrine and 74.0% of the households had basic latrine. The type of latrine include: pit latrine with concrete slab (47.5%), flush toilet with septic tank (20.1%), ventilated improved latrine (7.5%), pit latrine without slab (19.2%) and communal shared latrines (2.8%). The proportion of 29.4% of the households had latrine and hand washing facilities.

Use of a flush toilet with a septic tank is significantly associated with households income and educational level. However, adjusting for educational level, household income was found to be significantly associated with those households which earn over 9000 ETB which are 3.9 times more likely to have flush toilets with septic tanks than those households which earn below the stated amount.

TABLE 4.11: USE OF FLUSH LATRINE WITH SEPTIC TANK BY HOUSEHOLD SOCIOECONOMIC

Variable	Flush latrine with septic tank	X2	OR (95% CI)	AoR (95% CI)
Monthly households Income (over 9000 ETB)	11 (45.0%)	13.1	4.6 (1.7 - 11.8)**	3.9 (1.5 - 10.4)**
Educational level (secondary and above)	35 (28.0%)	10.1	2.8 (1.5 – 5.6)	-

A total of 34% of the households have hand washing stations with significant disparities among the clusters (66.7% in Mugar 1 and 11.4% in Silki clusters). Some of the household's respondents (42.2%) are able to describe essential five to six hand washing moments while 16.3% of the household's respondents describe just one to two moments of hand washing with soap and water. There is a significant variation among the clusters that 75.6% of the households in Mugar1and 18.2% in Silki clusters are able to describe essential five to six hand washing moments. Regular child hand washing before meal and after defecation was reported by 52.8% and 47.7% of the households respectively.

Most of the respondents (77.8%) reported access to information related to household water safety from media (50.9%) and face to face communications (36.3%) of workers in the sector. Access to both these sources was reported by 12.3% of the respondents. Majority of the respondents (97.0%) considered the information from these sources valuable and preferred face to face communication (58.1%) while the media source was chosen by 29.8% of the respondents.

Regarding food hygiene, 92.4% of the households use cooked food consistently and 48.7% have refrigerators. There is a significant difference among the cluster as 77.8% of Mogar1 and 9.3% of Silki clusters had refrigerators. Cleaning of utensils, on a daily basis, using detergents was reported by 93.4% of the respondents.

4.8 FINDINGS OF THE BEHAVIOURAL VARIABLES

4.8.1 Risk perception

The aggregated risk perception indicators result indicate that 78.5% (n=208) of the respondents had high risk perception. A total of 80% (n=212) of the respondents perceive that the safety of drinking water from the source is often unreliable (there who agree and strongly agreed to the statement) and physical clear appearance of water can't be a sign of safety. Similarly, 85.2% of the respondents notice that intermittent supply could affect the safety of water and 82.2% of the respondents perceive water borne diarrhoea is prevalent in the community. Also, high risk of diarrhoea related to unsafe water was perceived by 90.2% of the respondents.

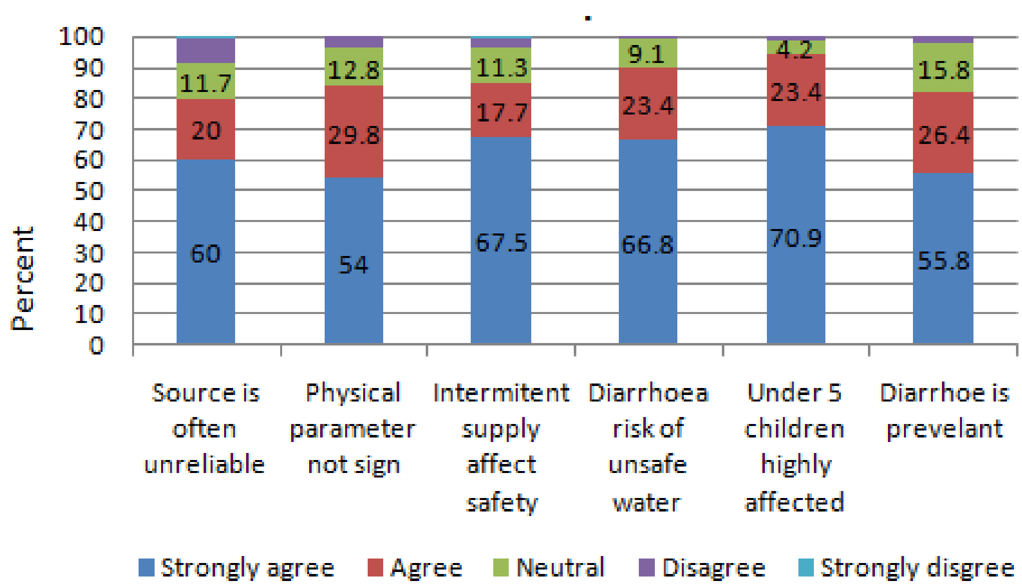


Figure 4.11: Risk perception related to DW safety (N=265)

4.8.2 Attitude

The proportion of 41.9% of the households had positive attitude aggregated scores related to HDW safety practices. The proportion of 83.8% of the respondents' believe that HWT can improve the quality and safety of water, however, 40.4% consider that the cost of HWT is affordable and 24.2% regard it unaffordable while the remaining respondents were neutral. Also, the proportion of 31.3% of the respondents considered the taste and odour of household treated water unacceptable.

Bivariate analysis results indicated that aggregated positive attitude related to HWT practices was significantly associated (p-value <0.01) with the secondary and above educational status of the respondents (AOR 2.35, 95%CI: 1.42 – 3.40).

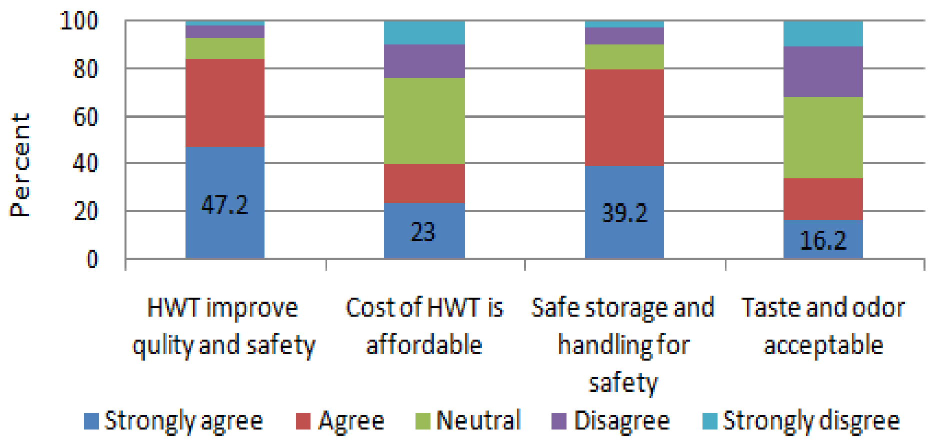


Figure 4.12: Attitude related to DW safety practices

4.8.3 Social norm

The proportion of 34.9% of the households had an aggregated score of social norm acceptance of practices related to HDW safety. A total of 34.3% of the respondents consider that HWT is not common practice in the community, though 74.0% of the respondents personally value HWT.

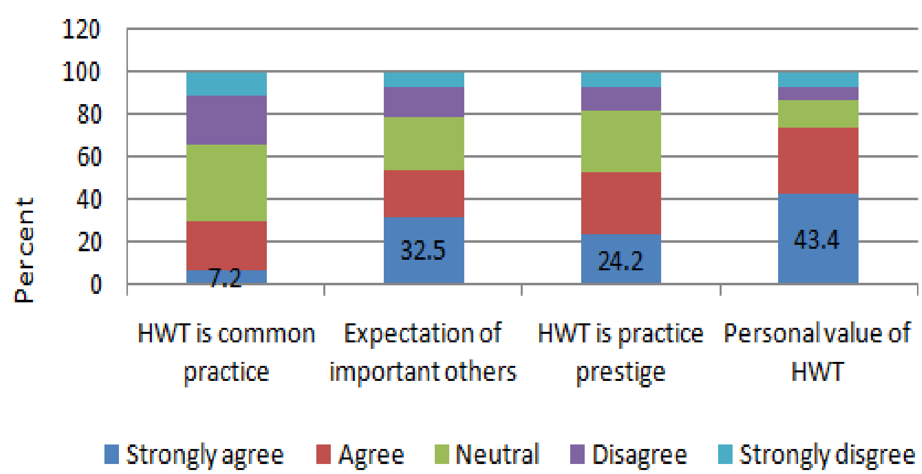


Figure 4.13: Social norm related to drinking water safety practices

4.8.4 Ability factor

The proportion of 37.5% of the households had aggregated ability scores related to HDW safety practices. A proportion of 53.9% of the respondents feel that they have good knowledge of HWT and 60.7% also feel they have good knowledge of safe storage. However, 36.2% of the respondents don't feel able to practice HWT continually due to different barriers.

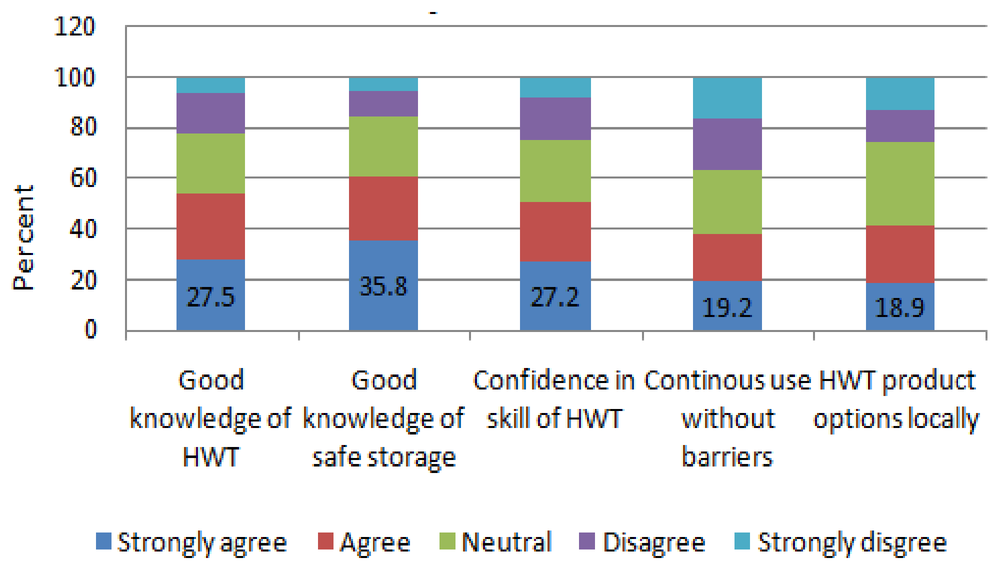


Figure 4.14: Ability related to drinking water safety practices

4.8.5 Self-regulation factor

The proportion of 71.9% of the households who practice HWT had an aggregated score for self-regulation related to HDW safety practices. This involved 80.9% of households who reported that they can consistently use of HWT, 66.3% doing regular cleaning of HWT filters or keeping stock of chemical treatment products and 78.6% of the households had commitment for HWT.

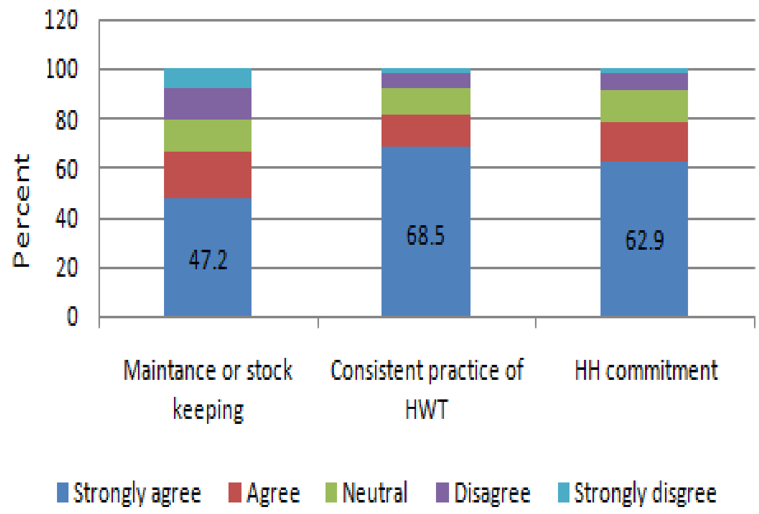


Figure 4.15: Self-regulation related to drinking water safety practices

4.9 LOGISTIC REGRESSION ANALYSIS

4.9.1 Factors related to diarrhoea among under five children

The occurrence of diarrhoea during the last two periods among children under five years of age did not show significant association with the HDW safety risk level on the combined and independent analysis of HDW sample test and inspection results. However, diarrhoea was less reported (6.9%, n=2) in households with low risk combined HDW safety result compared those households with medium to very high risk (119%, n=28). Also, it was less reported (6.1%, n=3) in households with low risk HDWI result compared those households with medium to very high risk HDWI result (12.6%, n=27). There was a significant association with lack of household latrine (36.4%), hygiene practice in terms of cleaning of food utensils (31.3%) and lack of risk perception related drinking water safety (21.1%).

Households who don't have latrine are 4.9 times more likely to contract diarrhoea (OR 4.9, 95% CI 1.2 -20.0) than those who have household latrine. Households who don't practice daily cleansing of food utensils using detergent are 4.0 times more likely to contract diarrhoea (OR 4.0, 95% CI 1.2 -13.6) than those who do not practice daily cleansing of food utensils using detergents. Also, households who had low to neutral risk perception related to HDW safety were 2.8 times more likely to experience diarrhoea (OR 2.8, 95% CI 1.3 -6.3) than those household who have high risk perception related to drinking water safety.

All households who have safely managed drinking water supply did not report diarrhoea, however, was not statistically significant. Daily use of bottled water for drinking was not found to be associated with reduction of diarrhoea prevalence, rather the prevalence of diarrhoea among those groups was high (16.9%).

TABLE 4.12: BINARY AND MULTIPLE LOGISTIC REGRESSION ANALYSIS OF VARIABLES ASSOCIATED WITH DIARRHOEA OCCURRENCE

Variable	Diarrhoea prevalence	X2	OR (95% CI)	AoR (95% CI)
Lack of latrine for household	4 (36.4%)	7.2	5.0 (1.3-18.5)**	4.9 (1.2 -20.0)*
Lack of daily food utensils cleaning using detergent	5 (31.3%)	6.9	4.2 (1.3-13.2)**	4.0 (1.2-13.6)*
Drinking water safety risk perception (low to neutral)	12 (21.1%)	6.9	2.8 (1.3-6.3)**	3.2(1.3 -7.7)*

*P-value <0.05 **P-value <0.01

4.9.2 HDW safety and the associations

4.9.2.1 *HDW safety on combined sample test and inspection*

According to multiple logistic regression analysis conducted, low risk HDW safety on the combined analysis of the test and inspection results was statistically associated with HWT practice that 31.8% of the households had low risk. Households practicing HWT were 12.6 times more likely to have low risk HDW safety (OR 12.6.0, 95%CI 1.2 – 125.0) than those households which did not practice it.

However, on bivariate analysis, it was significantly associated with many variables including on premise access to drinking water, water storage at home over 3 days, use of latrine, availability of hand washing facility. Also, it was associated with households' income of over 5000 ETB.

Low to medium of HDW safety was statistically associated with on premise access to water (59.6%), HDW safety risk perception (57.7%), HWT practice (90.6%), safe storage practice

(90.6%), use of basic latrine (54.1%) and had a hand washing station (80.0%). It was more likely among households which had on premise access to water (OR 16.9, 95%CI 2.3 – 20.8), high risk perception related drinking water safety (OR 11.0, 95%CI 2.9 – 119.0), practice HWT(OR 100.0, 95%CI 8.4 – 1000.0), safe storage (OR 12.3, 95%CI 3.1 – 50.0), use of basic latrine (OR 5.0, 95%CI 1.6 – 15.0), had a hand washing station (OR 19.2, 95%CI 6.3 – 58.8) than those households which did not meet those variables.

TABLE 4.13: BINARY AND MULTIPLE LOGISTIC REGRESSION ANALYSIS OF VARIABLES ASSOCIATED WITH LOW RISK HDW SAFETY

Variable	HDW safety risk (Low)	X2	OR (95% CI)	AoR (95% CI)
Access to water on premise	29 (17.5%)	19.4	0.58 (0.52 – 0.65)**	-
Home storage over 3 days	29 (13.7%)	8.3	0.77 (0.72 -0.83)**	-
HDW safety risk perception (high)	29 (13.9%)	8.9	0.76 (0.71 -0.82)**	
HWT practice	27 (31.8%)	55.6	44.0 (9.6–180.0)**	12.6 (1.2–125.0)*
Households treated and bottled	22 (22.7%)	21.1	6.6 (2.7 – 16.2)**	
Consistent HWT practice	25 (32.1%)	50.5	21.7 (7.2 – 67.0)**	-
Safe storage practice	29 (13.2%)	6.7	0.81 (0.76 – 0.86)**	-
Use of basic latrine	26 (13.3%)	4.2	3.4 (1.0 – 11.5)*	-
Availability of functional Hand washing facility	20 (22.2%)	17.8	5.3 (2.3 – 12.1)*	-
Household income (5000 & above)	10 (20.0%)	6.1	2.9 (1.2 – 6.9)*	

*P-value <0.05 **P-value <0.01

TABLE 4.14: BINARY AND MULTIPLE LOGISTIC REGRESSION ANALYSIS OF VARIABLES ASSOCIATED WITH LOW TO MEDIUM RISK HDW SAFETY

Variable	HDW safety risk (Low to medium)	X2	OR (95% CI)	AoR (95% CI)
Water on premise	99 (59.6%)	27.7	4.1 (2.4 – 7.1)**	6.9 (2.3–20.8)**
Home storage over 3 days	116 (55.0%)	25.3	6.1 (2.8-13.2)**	-
Risk perception (high)	120 (57.7%)	42.9	14.1 (5.4-37.0)**	11.0 (2.9–119.0)**
HWT practice	77 (90.6%)	94.6	26.3 (11.9 – 58.8)**	100 (8.4 – 1000)**
Consistent HWT practice	69 (88.5%)	75.6	17.8 (8.4 – 38.4)**	-
Safe storage practice	118 (53.6%)	21.7	6.3 (2.7 – 14.7)**	12.3 (3.1–50.0)**
Use of basic latrine	106 (54.1%)	4.2	3.1 (1.7 – 5.6)**	5.0 (1.6–15.0)**
Availability of functional hand washing facility	72 (80.0%)	58.9	5.3 (5.0 – 16.9)**	19.2 (6.3–58.8)**
Household Income (9000 & above)	15 (75.0%)	6.9	3.7 (1.3 – 10.7)*	-

*P-value <0.05 **P-value <0.01

4.9.2.2 Drinking water test result

Low risk (free of thermotolerant coliform) drinking water samples test result was associated with bottled water sample (82.1%), HWT using chlorine products (78.6%), household income (85.0%), frequency of proper water container cleaning(72.7%) and lack of regular availability of water (59.4%).

Bottled water samples and HWT using chlorine products were 4.3 (AOR 95%CI 1.5 – 12.9) and 3.2 times (AOR 95%CI 1.1 – 9.8) more likely to be low risk on testing compared to combined samples from other sources (home storage, HWT, reservoir and taps) and those households who did practice HWT using chlorine products respectively. Households with monthly income of 9000 and above were 5.3 times (AOR 95% CI 1.4 – 20.2) more likely to have a low risk water sample compared to households with less than that amount of income. Households who clean their water container for less than a week frequency were 2.6 (AOR 95% CI 2.5 – 5.1) times more likely to have low risk HDW sample test results compared to cleaning frequency of a week and above. The unexpected results was households who lack regular supply from the source were 4.3 (AOR 95% CI 1.5 – 11.9) times more likely to have low risk HDW sample test results compared to those who have regular supply.

No significant associations of the drinking water sample test and HDWI results were found. However, low to medium risk (free of thermotolerant coliform) HDW samples test result was associated with low to medium risk HDWI result. All the households (100%) with low to medium risk HDWI result were found to have low to medium risk sample test result. Similarly, all the high to very high-risk samples test results were from households having high to very high HDWI results and constituted 25.7% among these households. These associations are statistically significant with a p-value less than 0.01.

TABLE 4.15: BINARY AND MULTIPLE LOGISTIC REGRESSION ANALYSIS OF VARIABLES ASSOCIATED WITH LOW RISK HDW SAMPLE TEST RESULT

Variable	Low risk	X2	OR (95% CI)	AoR (95% CI)
Bottled water sample	32 (82.1%)	11.8	4.1 (1.8-9.8)**	4.3 (1.5 -12.9)**
Household treated and bottled	67 (69.1%)	9.3	2.3 (1.3-3.8)*	-
HWT using chlorine	22 (78.6%)	5.9	3.07 (1.2 – 7.8)*	3.2 (1.1 -9.8)*
Frequency of container cleaning (less a week)	48 (72.7%)	8.9	2.5 (1.4 – 4.6)**	2.5 (1.3 – 5.1)**
Household monthly income (9000 and above)	17 (85.0%)	7.4	4.9 (1.4 – 17.3)**	5.3 (1.4 – 20.2)*

Lack of regular availability of water from the source	142 (59.4%)	5.9	2.8 (1.2-6.5)**	4.3 (1.5–11.9)**

*P-value <0.05 **P-value <0.01

On binary regression analysis, low to medium risk HDW samples test results were associated with HWT practice and samples of water from bottled and household treated water sources combined. On multiple logistic regression analysis, bottled and HWT sample sources were 76.0% higher to be low to medium risk (AOR 0.24, 95%CI 0.05 – 1.0). A total of 94.5% of the water samples from these were low to medium risk.

TABLE 4.16: BINARY AND MULTIPLE LOGISTIC REGRESSION ANALYSIS OF VARIABLES ASSOCIATED WITH LOW TO MEDIUM RISK HDW SAMPLE TEST

Variable	Low to medium risk	X2	OR (95%CI)	AoR (95% CI)
Bottled and HWT samples	92 (94.5%)	8.9	0.25 (0.1 – 0.65)**	0.24 (0.05 – 1.0)*
HWT practice	80 (94.1%)	6.3	0.3 (0.11 – 0.81)**	-
HWT samples	55 (94.8%)	4.3	3.4 (1.0 – 11.6)**	-

4.9.2.3 *HDW inspection risk and the associations*

Low risk HDWI results are significantly associated with access to water on premise (29.5%), HWT practices (56.5%), consistent HWT (57.7%), availability of household basic latrine (23.5%) and hand washing station (37.8%). Respondents' educational level (secondary and above) was also associated with the low risk HDWI on binary logistic regression analysis.

TABLE 4.17: BINARY AND MULTIPLE LOGISTIC REGRESSION ANALYSIS OF VARIABLES ASSOCIATED WITH LOW TO MEDIUM RISK HDWI SCORE

Variable	Low to medium HDWI result	X2	OR (95% CI)	AoR (95% CI)
Access to water on premise	49 (29.5%)	32.9	41.0 (5.6–302.7)**	1182.6 (30.0- 4657.0)**
Risk perception	50 (57.7%)	16.8	1.4 (1.25 –1.47)**	-
HWT practice	48 (56.5%)	115.6	115.5 (26.9– 496.2)**	122.8 (5.1- 2934.5)**
Consistent HWT practice	45 (57.7%)	108.8	49.6 (18.3– 134.3)**	44.5 (1.8-1090.5)*
Household safe storage practice	50 (22.7%)	12.6	1.3 (1.2– 1.4)**	-
Availability of households basic latrine	46 (23.5%)	10.4	5.1 (1.7– 14.4)**	78.0 (4.9- 1246.7)**
Availability of functional hand washing facility	34 (37.8%)	31.8	6.0 (3.1– 11.8)**	64.2 (4.1- 995.6)**
Educational level (Secondary and above)	34 (25.8%)	8.5	2.6 (1.4 -5.1)**	-

The distinctions of households that had low to medium risk HDWI result also included access to water on premise (79.2%), HDW safety risk perception (57.7%), HWT practices (90.6%), safe storage practice (53.6%), availability of household basic latrine (54.1%) and hand washing station (80.0%).

TABLE 4.18: BINARY AND MULTIPLE LOGISTIC REGRESSION ANALYSIS OF VARIABLES ASSOCIATED WITH LOW TO MEDIUM RISK HDWI SCORE

Variable	Low to medium HDWI result	X2	OR (95% CI)	AoR (95% CI)
Access to water on premise	99 (79.2%)	27.7	4.1 (2.4-7.1)**	6.9 (2.3-20.8)**
Duration of water store (Over 3 days)	116 (92.8%)	25.3	6.1 (2.8-13.2)**	-
HDW safety risk perception	120 (57.7%)	42.9	14.2 (5.4 - 39.9)**	10.9 (2.9-41.7)**

HWT practice	77 (90.6%)	7.4	4.9 (11.9–58.8)**	100 (8.4- 1000)**
Consistent HWT practice	69 (88.5%)	75.6	17.9 (8.4–38.4)**	-
Household safe storage practice	118 (53.6%)	21.7	6.3 (2.7– 14.7)**	12.3 (3.13-50.0)**
Availability of household basic latrine	106 (54.1%)	14.4	3.1 (1.7– 5.6)**	29.7 (1.6- 15.6)**
Availability of functional hand washing facility	72 (80.0%)	21.7	9.2 (5.0– 16.9)**	19.2 (6.3- 58.8)**
Monthly income (Over 9000 ETB)	15 (75.0%)	6.9	3.8 (1.3-7.1)**	-

4.9.3 Behavioural and other factors associated with HWTS

Behavioural variables that are statistically associated with the HWT practice were risk perception related to HDW safety (38.9%) and ability to conduct HWT (64.6%) which include knowledge and skill of HWT, correct and continuous use and able to get treatment options locally.

High risk perception related HDW safety increased HWT practice by 72.0 % (AOR 0.28, 95% CI: 0.09–0.90) and households with high ability to conducting HWT were 7.7 more likely to practice HWT (AOR 7.7 95%CI 3.7 -15.9) than those households which responded with low to neutral ability for HWT practice.

On bivariate analysis, ability to conduct HWT practices was significantly associated with consistent HWT practices which increases the practice by 86.0% (AOR 0.14, 95%CI: 0.03 - 0.65).

TABLE 4.19: BINARY AND MULTIPLE LOGISTIC REGRESSION ANALYSIS OF BEHAVIOURAL VARIABLES ASSOCIATED WITH HWT PRACTICE

Variable	HWT (yes)	X2	OR (95% CI)	AoR (95% CI)
Risk perception (high)	81 (38.9%)	20.9	8.5 (2.9–22.6)**	0.28 (0.09–0.9)**
Attitude (positive)	52 (46.8%)	19.1	3.2 (1.9–5.5)**	-
Norm (accepted)	58 (55.8%)	43.6	6.2 (3.5 - 10.9)**	-
Ability (capable)	64 (64.6%)	76.4	12.5 (6.8– 23.2)**	7.7 (3.7 – 15.9)**

** P value < 0.01

Safe storage practice

Safe storage practice of households was significantly associated with the availability of adequate water containers for a household (87.5%) and educational level of the respondents (90.2%). Households which had adequate water storage containers and educational levels of secondary and above were 2.4 times (AOR 2.4, 95% CI 1.3 – 4.5) and 2.9 times (AOR 2.9, 95% CI 1.3 – 5.2) more likely to practice safe storage respectively than the other groups.

TABLE 4.20: BINARY AND MULTIPLE LOGISTIC REGRESSION ANALYSIS OF BEHAVIOURAL VARIABLES ASSOCIATED WITH SAFE STORAGE PRACTICE

Variable	Safe storage (yes)	X2	OR (95% CI)	AOR (95% CI)
Risk perception (high)	178 (85.6%)	4.5	2.1 (1.1 – 4.3)*	-
Availability of adequate container	154 (87.5%)	7.4	2.4 (1.3 – 4.5)**	2.3 (1.2 – 4.5)*
Education (secondary and above)	119 (90.2%)	9.3	2.9 (1.4–5.8)**	- 2.6 (1.3 – 5.2)**-

4.10 CONCLUSION

This research on the data analysis and presentations presented descriptive results with regards to socioeconomic characteristics of the study participants, two weeks diarrhoea prevalence among children under five years of age and the result of drinking water safety including the independent and combined results of drinking WQ and HDW inspection. Also, access to drinking water, HWTS practices and findings of the behaviour variables on RANAS were presented. Bivariate and multiple logistic regression analysis to investigate the associations between the outcome and independent variables results presented.

CHAPTER 5

DISCUSSION

The discussion chapter of this research aimed to review key findings of the study, examine the associations between the variables and conduct literature control of the findings using other study findings including the anomalies. Also, some of the shortcomings of the research are presented (Straits & Singleton 2018; 520).

5.1 DIARRHOEA AND ASSOCIATED FACTORS

In this research the prevalence of diarrhoea disease in the study area was comparable to the national EDHS report in 2016 which identified 12.0% prevalence of diarrhoea (CSAE 2016:124,166). In SSA countries, diarrhoea prevalence is reported to be 16% which includes a range of 10.8% in Benin and South Africa, 21.9% in Burundi, 22.4% in Uganda to 24.8% in Liberia (Adedokun & Yaya 2020:3).

The focus of this study was on the application of a risk-based approach to drinking water safety and explores the associations with diarrhoeal disease occurrence among children. This study could not establish a statistically significant association in this regard. However, households with low risk to HDW safety and HDWI results had few diarrhoea cases. This could be due to the small number of diarrhoea cases identified related to the study sample size (power of the study) and other factors might determine the occurrence of the disease.

This study found significant association of the diarrhoea occurrence with lack of latrine and daily washing of food utensils using detergents by the households. Also, low risk perception of the respondents related to drinking water safety associated with increased occurrence of diarrhoea. The study conducted in Sebeta town, Ethiopia also indicated that households who had improved latrine type, availability of household hand washing station and mothers good awareness of the causes of diarrhoea were associated with less childhood diarrheal compared to the other households (Idris 2014:133). According to the study in Ethiopia, a reduction of 36.0% incidence of diarrhoea was observed in households which practiced HWT using chemical disinfectant or chlorine compared to the control households (Solomon et al 2020:1).

Other studies indicated that improvement in quality of water, continuous provision of water to households, safe storage and handling practices are identified as preventive measures of diarrhoea. A systematic review study indicated that improvements in microbiological quality of water reduce the risk of diarrhoea-related morbidity by 31.0%. A significant reduction (73.0%) of diarrhoea reported on intervention that shifted intermittent supply into continuous provision. Also, safe water storage, handling and HWT practices were found to reduce diarrhoea by 25.0% - 85.0% (Adane et al 2017: 2). A controlled trial research in Diredawa town, Eastern Ethiopia found that 36.0% reduction in incidence of diarrhoea was observed in households with HWT using chlorine intervention (Solomon et al 2020:1). In this research, widespread interruption of drinking water supply probably caused lack of disparity among the households in relation to diarrhoea outcome.

In this research diarrhoea report was less among households who used chemical disinfection, though statistically insignificant, compared to those households who reported HWT using boiling and filtration. The WHO evidence also indicated poor outcome of HWT on diarrhoea reduction using boiling method linked to possible recontamination (WHO 2014:5). All households who have safely managed drinking water supply did not report diarrhoea, however was not statistically significant. Daily use of bottled water for drinking was not associated with the reduction of diarrhoea. Shortage of water which could impact on hygiene practices could have influenced diarrhoea occurrence among these households. Most of the households who were using bottled water on a daily basis were those who had limited access to water supply. Also, households who used HWT for duration of over six months reported less diarrhoea cases, but not statistically validated. This could support the evidences that adherence to HWT ensure positive health outcome.

The study conducted in a slum area of Addis Ababa city indicated that E.coli contaminated household stored water, use of vessels that lacked handle to dip water into storage containers were independently associated with diarrhoea occurrence in the household. A study also indicated a 73.0% reduction in diarrhoea after the change from intermittent to continuous water supplies (Adane et al 2017: 12).

Socio-economic and child related characterises could also determine diarrheal illness among children. Household’s wealth and income, residence, material education, age of children and mothers, immunization and nutritional status of children and birth weight are some of the factors. Also, the extent of access to information influences the risk to the disease. Review of the data in SSA indicated that morbidity from diarrhoea was found high among the poor (with odds of occurrence of diarrhoea increased by 21-28%) and mothers who don’t have education (14% increases in the odd occurrence). Children aged of 1 to 2 years were more likely to experience diarrhoea (69.0%) compared to older age children. Children of mothers whose age is 15-24 years are 47% more likely to have diarrhoea compared to those mothers aged 35 years and above (Adedokun & Yaya 2020:2,6).These multiple factors could be the reasons influencing the findings of research on WASH and drinking water safety in relation to diarrheal morbidity.

5.2 ACCESS TO DRINKING WATER

Although most of the households had premise level or yard connection to the pipe water system (61.5%), there was a critical problem of interruption of the supply from the source. Hence, most of the households depend on purchase of trucked water, bottled water and storage of water as the supply obtained. Hence, safely managed drinking water coverage is critically low (1.9%) compared to the JMP report of 38.0% in urban areas (WHO/UNICEF 2019:93).

The proportion of 11.3% of the households took over 30 minutes to collect water, particularly in one cluster (Kule9) many of the households (38.3%) took them the stated time. Compared to the national average access to premise level improved water source access (77.0%) and to safely managed drinking water in urban areas (37.0%), the status in Burayu town is very low (1.9%) (CSAE 2016:9). This is primarily due to lack of regular supply of water from the sources. The study conducted in a similar urban setting, Sebeta town, indicated that 39.6% of the households had yard connections of pipe water supply and 18.0% of the households took more than 30 minutes to collect drinking water (Idris 2014:90).

5.3 DRINKING WATER SAFETY AND RELATED FACTORS

Though drinking WQ test result indicated over half of the households were low risk, 10.9% of the households had low risk HDW safety on combined analysis of the test and inspection results. Despite low household inspection score related to the gaps in the water supply and safety practices, the test result indicated a higher proportion of low risk in quality. Only 19.2% of the low risk HDW quality test samples were matched with low risk HDW safety result on the combined analysis. Conversely, 45.7% the high and very high risk HDW safety results on the combined analysis were found low risk on the WQ test result. This could be due to the reason that most of the households use bottled water and access water from other sources including trucked supplies, which could be free of the contamination indicator. And this finding highlights the considerable gaps in HDW safety indicators.

Lack of associations between the water sample test and household inspection results could be linked to the above reasons including use of bottled water and other factors like household income which was found associated with low risk WQ test result on this study, but not part of the inspection variable. So, other factors which are not part of the inspection played a role in the quality of the water test result.

5.4 FACTORS ASSOCIATED WITH DRINKING WATER QUALITY

According to this study, more than half (57.0%) HDW samples quality test results were free from faecal contamination i.e. low risk. Compared to the 2016 national drinking WQ survey low risk drinking WQ result (21.6% in urban areas) (CSAE 2016:9), the risk in the study area was better. This could be due to the HWT practices and bottled water use in the town.

Low risk WQ was associated with bottled water samples, HWT practice using chlorine products, higher household income and water container cleaning practice. For instance in one of the research area cluster (Kule9), where most of the water samples (70.4%) were from bottled and home treated water, 77.3% of the samples were low risk. Household's income association with low risk WQ test results could be due to the prevailing use of bottled water by those households, as identified by this research.

Low risk WQ also associated with lack of regular availability of water from the source for more than a week which is the case for most of the households (67.9%). This could be due to the reason that those households who don't have regular supply of the water were relying on other sources like purchase of trucked and bottled water and tap water collection from the locations (like from capital city) which may have better quality and the water samples for the test could also be from these sources. For instance, 32 of the 39 households (82.1%) who provided water sample for the testing from bottled water in use and 8 out of 11 households (72.7%) who reported trucked water purchase as their main water sources had low risk test of the sample.

Also, most of the households which experience the interruption of the supply were relying on water storage in tanks and reservoirs. In this research finding, households which use stored water of less 3 days duration had better low risk (61.1%) water quality test result than these households who stored water for over 3 days, 55.9% low risk test result, though the difference was not statistically significant. Longer storage of water could expose to contamination linked to unsafe storage practices. In Tsebela 2 cluster of this research area, where most of the water samples were from home storage (75.6%), 64.4% of the samples were low risk. However, in Malka2 cluster 25.0% of the samples were high to very high risk result category where most of the sample was from home storage.

The study conducted in Nigeria indicated that a significant reduction in bacteria load on home water storage for a period of 2 to 7 days and suggest this is a viable method of HWT (Ayoade et al 2013: 96). Thus, the effect of home water storage in tanks and reservoirs on the WQ and related factors require further investigation.

No significant associations of the low risk HDW quality test and HDWI risk levels were found. The results of the inspection variables like access to improved water source, regular availability of water from the source, drinking water safety risk perception, safe water storage and duration of storage and use of basic latrine are similar among most of the households. Also, HWT practice was not associated with low risk WQ result. These could make a lack of disparity among the households and the correlation between the inspection and quality test result. This explanation could also be supported by the finding that drinking WQ test results were associated with other variables which are not part of the inspection variable like use of bottled water, HWT using chlorine product and frequency of water container cleaning. Hence, further research in the application of HDWI and the linkages with the household drinking water sample test result are required.

5.5 BOTTLED WATER USE AND THE QUALITY

The use of bottled water is increasing globally linked to water scarcity, lack of reliance and preference for water sources including tap water by people and concerns of disease risks (Juba & Tanyanyiwa 2018:239).This study also indicated that majority of the households (67.5%) had bottled water use experience and some of these use it on daily basis (36.7%) primarily linked to intermittent supply of water from the source, mainly supply interruption over a week. Also, use of the bottled water is associated with households' higher income (5000 birr and above) compared to lower income category households.

The study conducted in Harare indicated people had a perception that bottled water is better in quality and taste than tap water (Juba & Tanyanyiwa2018:243).The study conducted in Belgium, where the people have access to safe tap water, indicated supportive social norm and the like of taste are the reasons for widespread use of bottled water (Geerts, Vandermoere,Winckel, Halet, Joos, Steen, Meenen,Blust, Borreg_an-Ochando & Vlaeminck 2020:1).

Regarding the quality, this study identified that 18.9% of the bottled water samples had faecal contamination. The national survey report in Ethiopia indicated that 53.0% of the bottled water samples were low risk (CSAE 2016:23). Other studies also indicated that bottled water is not free from contamination. The study conducted in Pakistan indicated that 8.3% of the sample had total coliform (Yousaf & Chaudhry 2013:110).Because of the gap with the bottled water safety and lack of compliance to national quality and safety standards, countries like Zimbabwe banned some brands of bottled water. The problem includes contamination, unsuitable packaging and wrong labelling (Juba&Tanyanyiwa2018:239). Thus, regulation and monitoring of the quality and safety of bottled water is essential.

5.6 HWTS AND RELATED FACTORS

The coverage of HWT practice (31.3%) in the study area was considerably higher than the national report in 2016 for urban areas (12.0%). Also, reported consistent HWT practice (90.0%) was good. The three commonly used methods of treatment used by the households included: filtration (39.8%), chemical disinfection (33.7%), and boiling (26.5%). However, the Millennium water alliance (MWA) report (2014:8) indicated that boiling is the primary method of HWT in the country followed by treatment using chlorine products which is considered to have low adherence.

The use of filtration and boiling were not significantly associated with low risk WQ test results. This raises a question on the effectiveness of different treatment methods. Evidence indicated that boiling can improve quality of drinking water but can't ensure risk free and may not be reliable for WQ improvement intervention. Its outcome depends on correct practice. Post treatment contamination during storage is also a concern. There are also some barriers to its application, as was seen particularly in SSA. However, boiling is the most commonly used method of HWT globally, contributing to negative environmental impact on use of fossil fuel energy for boiling and related health outcomes from indoor air pollution. It is also considered costly and time-consuming practice(Samir, Sodha, Menon, Trivedi, Ati, Figueroa, Ainslie, Wannemuehler, Quick 2011:577, 583; Cohen, Pillarisetti, Luo, Zhang, Li, Zhong, Zhu, Colford, Smith, Ray & Tao 2020:1-2).

In this research, HWT was associated with the households' risk perception related to HDW safety and ability to conduct HWT which was also associated with the consistent HWT practice. This includes knowledge and skill for correct and continuous use and access to the treatment products locally. Other research conducted in the peri-urban area of Indonesia indicated that socioeconomic conditions like mother's education are associated with regular use of HWT. These mothers had a more positive attitude and confidence for

HWT practice. Also, self-regulation related to addressing barriers to HWT helped to ensure regular practice (Daniel et al 2020:1). Positive attitude for HWT was also associated with the respondent's education level in this research. The study in Nepal indicated that individual socio-economic variables including education, wealth level, and HWT promotion are important drivers of HWT adoption. Also, social norm and ability to perform the behaviour were identified to be influential psychosocial conditions (Daniel et al 2019: 854).

In this research lack of adherence to HWT practice related to household's perception of considering the source is safe, lack of attention or awareness, dislike of the taste of the water, difficult to treat all the time, lack of time and season. The millennium water alliance report (2014: 21), also indicated the problem of low adherence in Ethiopia and other countries, due to similar reasons mentioned above. And reported training and follow-up on HWT intervention project helped to address this problem.

5.7 LIMITATIONS OF THE STUDY

The limitations related to this study also relate the study methodologies which include:

- Risk categorization of the HDW safety and HDWI results of this research were not based on established evidence as there is no literature in this regard. However, the WHO DWQG (2017:92.) guidance on classification of drinking water test and inspection results as well as the combined results was used.

- Equal weight for each of the HDWI variables was given while their linkage with the quality and safety of drinking water could vary. These may influence the accuracy in the validity of the findings.

- The research was conducted in the dry season and the results may not fully represent the condition in the wet season. This may influence the generalization of some of the findings. Seasonal variations of WQ have been reported depending on the source of the water used by households and related factors influencing the quality such as volume of water, frequency of rainfall events, storm run-off, evaporation and sources of pollution (Edokpayi, Rogawski, Kahler, Hill, Reynolds, Nyathi, Smith, Odiyo, Samie, Bessong& Dillingham 2018:2).

- The responses to the interview questions depend on the respondents self-report which may not be accurate due to guess and requiring recall like questions on income, quantity of water used in a day, regularity of cleaning of water storage containers.

- The variables and questions used to measure HDW safety through inspection and HWT behaviour using RANAS indicators were not standard but prepared by the researcher based on literature review (Mosler & Contzen 2016:24), considering relevant indicators like water source type, HWTS practice, risk perception and attitude related to HDW safety practices.

- Testing for residual chlorine of the water sample or related remedial measure to neutralize any content was not conducted and this may affect the result of the test for expected few number of the samples.

5.8 CONCLUSION

This chapter five discussion reviewed the key findings of the research with regards to diarrhoea occurrence and factors associated with the diarrhoea occurrence, HDW safety and HWT. Explanations provided to the findings regarding lack of expected associations and in relation to the contexts in the study area. Literature control was applied through comparing with other research reports and limitations of the research were indicated.

CHAPTER 6

STRATEGIES TO ENHANCE HOUSEHOLD DRINKING WATER QUALITY AND SAFETY

6.1 INTRODUCTION

The development of the strategies is based on the findings of the research, review of literature and application of socio-ecological models. Multiple factors influence HDW safety and broader strategies are required to promote the safety of HDW. Hence, the purpose of this strategy is to indicate comprehensive and risk-based interventions that enable sustained use of safe drinking water at household level.

The theoretical framework of this research (Figure 1.1) indicates that the safety of HDW is determined by three key elements: drinking water service level, HWTS and hand hygiene. HWTS is further influenced by RANAS and contextual factors of the household like educational status and income level of households. The quality and safety of drinking water is also influenced by household and environmental sanitation conditions and application of safe drinking water framework which involve risk based drinking water supply management approach i.e. WSP and surveillance.

Hence, selection of a framework for development of strategies for HDW safety is based on consideration of these elements that can be addressed at different levels of the system.

6.2 FRAMEWORK OF THE STRATEGY

Socio-ecological models are adapted to serve as a framework for development of the strategies to enhance the safety of HDW. Accordingly, four levels of influence are considered for the development of intervention strategies for enhancing the quality and safety of HDW. These include Household, Community, Institution and Society target interventions. Household level refers to individual level factors determining the safety of drinking water such as cognitive characteristics of households such as awareness, knowledge, attitude, belief, and skill. The next levels of the framework are the community, institution and society (national and sub-national) which are the social and environmental influences on households characteristics and practices.

Three key intervention domains that apply to the different levels of the framework are identified for ensuring the safety of HDW, that are also in line with the hygiene improvement framework (EHP 2004:9). These include:

- Hygiene behavioural change communication (HBCC)
- Water and sanitation service delivery
- Addressing the enabling environment

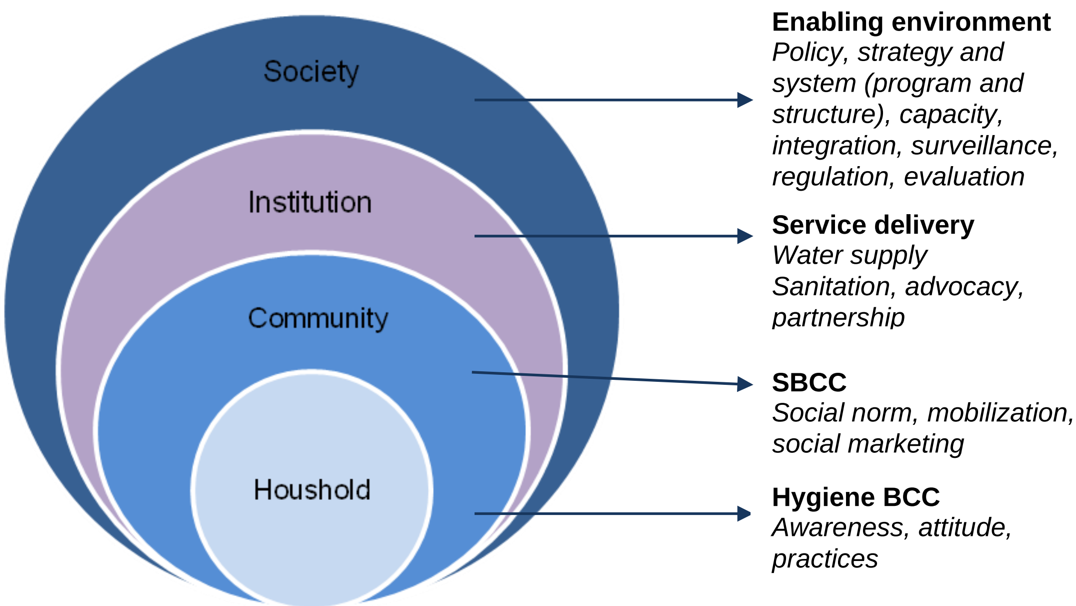


Figure 6.1: Socio-ecological model to HDW safety

This model is also used by MDWS of India as a framework of drinking water advocacy and communication strategy (2013 – 2022) (UNICEF & MDWSI 2013:13). The concepts in its application include:

- Multiple levels factors affect human behaviour and its of utmost importance to understand and address barriers and constraints to behaviour change at these levels
- Effectiveness depends on interventions including communication at all the levels

6.3 HYGIENE BEHAVIOUR CHANGE COMMUNICATION (HBCC)

This involves interventions that aimed at engaging and influencing behaviour of households and communities in relation to safe drinking water. HBCC refers to application of BCC approaches and principles for promotion of hygiene practices in water and sanitation. The aim is to create awareness and risk perception, demand, favourable attitude and skill required for HDW safety.

The targeted behaviours to promote involve: HWTS practice, use of improved water sources, hand hygiene and latrine facility. The RANAS model behaviour change techniques as applicable to each of the behavioural factors serve to suggest required interventions (Mosler & Contzen 2016:7-8). Accordingly, the HBCC interventions types need to include: information, persuasive, normative, infrastructural and ability and maintenance or sustaining interventions. Accoutring to this research, media and interpersonal communication are the main sources of information.

Essential to ensure communication and facilitating community engagement are central elements of the interventions. The communication methods include interpersonal communication through home visits by promoters, discussion with the community members, use of media and social platforms and information, education and communication (IEC) materials which include prints like posters, banners, stickers and use of audio-visuals to transmit messages and demonstrate HWT practices including presenting case stories, drama and messaging using jingle songs.

Focus should be given to each of the behaviour for a targeted population (women, men, vulnerable community or people etc). Discussion with the targeted population group and households helps to create awareness, to understand their perception, thinking and existing practices, the gaps and factors influencing the behaviour thereby for addressing potential barriers and solutions. Also, it is essential to consider contextual factors and external conditions that facilitate or hinder the desired behaviour. According to Mosler & Contzen (2016:17), three contexts include: social context like addressing access to products and services including information, economic condition of the community and households; physical context which include environmental and technical aspects and personal context.

Engagement of the community in drinking water safety promotion is essential. Inadequate drinking water management relates to lack of community involvement and ownership in interventions (UNICEF & MDWSI 2013:9). Studies indicated that inadequately engaging and messaging to the people resulted in incorrect and inconsistent HWT practice and low reduction in childhood diarrhoea. Engaging people helps to understand the contextual factors including appropriate HWT technologies including consideration of source water characteristics. Also allows the people to make informed selection of the technologies (WHO 2019:4, 7).

Often the communication efforts by service providers are related to disease outbreaks and the promotion of HWT products by companies. The government and stakeholders' needs to ensure the public get adequate awareness and skill related to drinking water safety and related practices. Also train community WASH committees and hygiene promoters.

At community level, social BCC (SBCC) aims to create a supportive environment which includes promotion of collective measures including social norm, mobilization of the community for drinking water safety, improved sanitation and hygiene conditions and social marketing of HWT technologies are some of the needs.

6.3.1 Household water treatment and safe storage (HWTS)

HWTS interventions that create awareness and skill for correct and consistent use of effective treatment methods is the strategy being promoted during recent years in order to take the problem of safe water supply at PoU (Ayoade et al 2013: 98). HWT intervention has the potential to fill the service gap where access to improved and piped water sources is not ensured, resulting in positive health impacts in developing countries as a barrier to waterborne infectious disease due to source water contamination like surface water, unprotected wells etc.

HWT could be generally applicable to all households who access drinking water from improved, unimproved or surface water sources. However, the outcome could be high for the population using high risk drinking water sources. Many piped water supplies are microbiologically unsafe due to post-collection and post treatment contamination during distribution, and HWT technologies helps to overcome this widespread problem. However, some piped water supplies may have residual chlorine that prevent possible post treatment contamination. If unprotected sources are the only option as sources of drinking water, the focus should be to improve WQ at PoU. Hence, the use of appropriate treatment methods or products should be risk based. Different appropriate treatment technologies can be promoted, and the users are able to get the opportunity to be trained on the options including informing the pros and cons of the options. Similar treatment technologies can also be used by travellers in areas where the drinking WQ is uncertain.

According to this research and other research findings, promotional interventions to increase risk perception and positive attitude related to HDW safety awareness and practices, ability for HWT correct and consistent practice, promoting self-regulation and creating social norm are required.

For effective of HWTS program, promotional interventions to enable the engagement and support of the stakeholders, establish coordination mechanism, creating adequate awareness, demand creation and skill for correct and consistent use by households, monitoring and evaluation of the program, technologies evaluation and regulation are required.

Some of the key communication messages of HDW safety promotion include:

- Safe drinking water is critical for the health and development of children
- Households have a great role for ensuring the safety of HDW before consumption
- Correct and consistent use of effective HWT products and solutions can enhance the safety of HDW
- Safe handling and storage of drinking water
- Regular hand hygiene practices helps to prevent contamination of HDW
- Regular cleaning of water collection and storage container

6.3.2 Hand hygiene

Hand washing practice at essential moments is required for diarrhoea prevention and protection of drinking water safety. This research indicated that availability of hand washing stations was associated with low to medium risk HDW safety.

The global initiative for hand hygiene for all could be an entry point to facilitate promotion of hand hygiene for households. The initiative requires three kinds of activities to be part of country roadmap to achieve universal access to hand hygiene (WHO & UNICEF 2020). These are:

- **Political leadership** to embed a culture of hygiene across all levels of government and society;
- **Policy action** to strengthen the enabling environment for hand hygiene programming, including the five building blocks promoted by Sanitation and Water for All (SWA) i.e policies and strategies, institutional arrangements, financing, planning, monitoring and review and capacity development; and
- **Sustainable, inclusive programming at scale** to increase supply and demand for hand hygiene. This involves supplying hand hygiene and other hygiene products and services; and promoting hand hygiene including behaviour change intervention

6.3.3 Sanitation

Interventions ensuring access to basic and safely managed sanitation services are the primary need to break the chain of faecal-oral infections as part of multi-barrier approach (Reed & Scott 2014:4). Lack of latrine for households is a factor associated with occurrence of diarrhoea children in this research. Also, low-medium HDW safety was associated with use of basic latrine.

Ethiopia is among the countries which made the largest reduction in open defecation (OD) practice in the world. This was primarily possible though Implementation of CLTS approach (WHO/UNICEF 20019:14). However, still over 21.0% of the population practice OD, mainly in rural areas and sustaining the achievements and further progress for elimination of OD are the concerns. Also, there is a need to improve the sanitation service to safely manage the level and progress to the SDG.

6.4 INSTITUTIONAL SERVICE DELIVERY

- Creating access to safe and reliable drinking water supply, sanitation and hygiene services are a critical demand and in attainment of the SDG. According to this research, lack of regular supply from the sources is a major problem in the study area. Also, access to drinking water supply at premise level was associated with low to medium HDW safety.

- Effort should be made to address the inequalities by geographic, socio-cultural and economic conditions including the disparities in between rural – urban areas and in towns/cities to reach people living in low-income, slum, informal settlements WHO 2019 factsheet).

6.4.1 Addressing SDG WASH service level

Intervention towards reaching the SDG 6.1 for drinking water by 2030, *achieve universal and equitable access to safe and affordable drinking water for all*. The intervention needs to ensure progressive improvement across the service ladder (Figure 7.2) (WHO/UNICEF 2017:7-8).

SERVICE LEVEL	DEFINITION
SAFELY MANAGED	Drinking water from an improved water source that is located on premises, available when needed and free from faecal and priority chemical contamination
BASIC	Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing
LIMITED	Drinking water from an improved source for which collection time exceeds 30 minutes for a round trip, including queuing
UNIMPROVED	Drinking water from an unprotected dug well or unprotected spring
SURFACE WATER	Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal

Source: JMP WHO/UNICEF 2017

Figure 6.2: SDG drinking water service ladder

The SDG 6.2 sanitation service aims to - *achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations* (Figure 7.3). Improved facilities are flues/pour to piped sewer piped systems, septic tanks, pit latrines, ventilated improved pit latrines, composting toilets or pit latrines with slab (WHO/UNICEF 2017:7-8).

SERVICE LEVEL	DEFINITION
SAFELY MANAGED	Use of improved facilities that are not shared with other households and where excreta are safely disposed of in situ or transported and treated offsite
BASIC	Use of improved facilities that are not shared with other households
LIMITED	Use of improved facilities shared between two or more households
UNIMPROVED	Use of pit latrines without a slab or platform, hanging latrines or bucket latrines
OPEN DEFECATION	Disposal of human faeces in fields, forests, bushes, open bodies of water, beaches or other open spaces, or with solid waste

Source: JMP WHO/UNICEF 2017

Figure 6.3: SGD sanitation service ladder

Also, hygiene has three service ladders based on availability of hand washing facility: basic, limited and no facility. The facility can be fixed or mobile and includes a sink with tap water, back with a tap or tippy tap (WHO/UNICEF 2017:9).

SERVICE LEVEL	DEFINITION
BASIC	Availability of a hand washing facility on premises with soap and water
LIMITED	Availability of a hand washing facility on premises without soap and water
NO FACILITY	No hand washing facility on premises with soap and water

Source: JMP WHO/UNICEF 2017

Figure 6.4: SDG hygiene service ladder

6.4.2 Implementation of water safety plan

Risk-based management approach through application of WSP helps to enable prevention of contamination and provision of low risk and reliable supply for households. It ensures effective means of providing consistent and acceptable safe drinking-water supplies through the use of a comprehensive risk assessment and risk management approach that applies to all steps of a water supply from catchment through treatment and distribution system. Its effective implementation helps to develop consumer confidence on the safety of water and influence the need for HWT (WHO 2014:10).

While the water service provider or water utilities play the lead role for WSP implementation, the intervention also requires multi-sector intervention to address the safety of drinking water across the catchment and source. Major source of contamination is faecal contamination related to poor or inadequate sanitation conditions. Also inadequate management of urban, industrial, and agricultural wastewater is a big concern to contamination and chemical pollution to water sources (WHO 2019 factsheet).

There is a need to promote and develop the capacity for the implementation of the WSP at scale through the leadership of the sector responsible for drinking water supply.

6.4.3 Sanitation chain and community led total sanitation (CLTS)

Progress on the sanitation service level can be made through application of sanitation management chain through promoting and use of a range of technologies and systems for containment to re-use and disposal of human excreta (UNICEF 2016:27). This intervention in particular is required in urban areas.

Figure 7.5: Sanitation management chain

Source: UNICEF

Figure 6.5: Sanitation management chain

UNICEF’s context specific sanitation improvement strategies are valid. These include creating demand in high open defecation (OD), provision of supplies where there is low open defecation but high unimproved sanitation coverage and financing support where there is low open defecation but high improved. Also, highlight addressing specific challenges to high water table areas and land tenure issues (UNICEF 2016:29).

The CLTS approach is essential for creating an OD free community which is common in rural areas. In locations where latrines are not available, this approach has been found useful in changing people's behaviours and stop open defecation. The approach tries to achieve behaviour change in mainly rural people by a process of "triggering", leading to spontaneous and long-term abandonment of open defecation practices. For this different methods that enable disgusting of the practice by the community are used. The term "triggering" is central to the CLTS process, which refers to ways of igniting community interest in ending open defecation, usually by building simple toilets, such as pit latrines. CLTS involves actions leading to increased self-respect and pride in one's community. It also involves shame and disgust about one's own open defecation behaviours. CLTS takes an approach to rural sanitation that works without hardware subsidies and that facilitates communities to recognize the problem of OD and take collective action to clean up and become "OD free" (Galvin 2015:9).

6.5 ENABLING ENVIRONMENT

Upstream measures which include preparing appropriate policy of drinking water services and safety, strategic plan for drinking water safety program, program for HDW safety including promotion of HWTS, monitoring, surveillance and evaluation are essential. Also, need for establishing a system or institutional arrangement for the implementation and capacity building. Governance policies are essential to ensure commitments and required measures be taken in relation to creating access to safe drinking water and safety of drinking water supply (Li & Wu 2019:75).

The strategy needs to define program goals, objectives, targets and activities related to the proposed intervention domains. Also state the guiding principles, implementation approach that is based on risk-based management processes, and monitoring, evaluation and regulation needs. It is essential to ensure integration of HDW safety intervention with relevant health programs including WASH, nutrition and child health programs in order to optimising efficiency and effectiveness.

Established or strengthened systems which include structure and human resources for drinking water safety implementation is required at different levels of relevant government sectors responsible for the program and partners working on drinking water safety programs. Also capacity development to the system is required. In Ethiopia, some of the challenges in HDW safety intervention relate to lack of trained professionals at different levels, staff turnover, weak monitoring and information management system (UNICEF & WHO 2016: 2, 5). Development of training modules and guidance related drinking water safety interventions is essential.

The other needs are creating access to HWT technologies and products as well as financing mechanisms for HDW safety and sanitation improvement in order to address the barrier in this regard to households. While disinfectants like chlorine products can be obtained in some of local pharmacies, there is a need to create more access through establishing social marketing centres for different options.

6.5.1 Goal and objectives of the strategies

The goal of the strategies is to contribute to SDGs improved health outcomes for the people in particular to children and other vulnerable population groups through control of diarrheal diseases and prevention of outbreaks. The overall objective is to ensure the safety of drinking water at household level.

Specific objectives need to include: :

- Scaling up HWTS coverage
- Ensuring access to safe and reliable sources of drinking water
- Enable proper and frequent hand washing behaviour of the people at critical moments
- Provision of basic and safely managed sanitation for households

6.5.2 Guiding principles

Priority setting – interventions need to focus reaching vulnerable populations including children, mothers in emergencies and outbreaks and peoples who rely on unreliable or unimproved drinking water sources, affected by water borne diseases and outbreak and other disasters (WHO 2019:3).

Risk based approach: the safety of drinking water can be enhanced through multi-barrier intervention (WHO GDWQ 2017:4). This involves interventions in the water supply system (WSP) including ensuring availability of safe supply and household level intervention.

Program integration – strengthening HDW safety intervention within WASH programs and other programs like health and nutrition is essential to optimize the outcome. Integrated WASH and health interventions like nutrition optimize the outcome and effectiveness in reducing related diseases (Reed and Scott 2014:3). Evidence from countries indicated that package of services including antenatal and child health care services ensured improvement on HWT and uptake of the services (WHO/UNICEF toolkit 2013:6).

6.5.3 Implementation approach

In order to implement risk-based management of HDW safety, or surveillance and response system, for a community or population in a defined location, an adapted WSP approach is suggested. That is application of step wise processes which involve preparation, assessment and analysis, hazard or gap identification, risk analysis and improvement planning, implementation and finally review and re-assess (GDWQ 2017:48).

During the initial preparatory stage, a team involving relevant sectors, community members and partners is established; training provided to the team and preparation for the assessment. Baseline and post intervention assessment can be conducted using the HDWI tool which involves an appropriate list of variables and key indicators through household interviews and observations. While the variables used in this research are relevant, it is also important to consider other variables like regular use of bottled water, type of HWT technology used, duration of drinking water interruption from the source and frequency of water container cleaning.

Also, it is important to include HDW sample testing for bacteriological (coliform indicators), essential chemicals and physical testing (residual chlorine and turbidity) on the assessments. The assessment process may also engage the people with qualitative methods like focused group discussion, key informant interviews, and review of secondary data including related morbidity data.

Analyses of the data to be conducted to generate evidence with regards to the state of HDW safety in risk levels, identify the gaps and make risk analysis that enables prioritization for intervention in consideration of the potential outcome. Thus, prepare an improvement plan with a detailed action plan. Progress monitoring of the safety of HDW using HDWI tools which involve key indicators and variables is required in order to track the progress and operational challenges.

6.5.4 Monitoring, evaluation and regulation

The JMP report indicated that the big challenge to monitoring safely managed drinking water is lack of representative data on WQ from countries (WHO & UNICEF 2019:77). However, monitoring information helps to provide status of drinking WQ and safety which is required for decisions to improve interventions (Li & Wu 2019:73). Hence, monitoring and evaluation of key indicators related to input, process, output and outcome of the intervention domains (HBCC including HWTS, service delivery and enabling interventions) needs to be conducted on an ongoing basis.

It is important to create the capacity and system for HDW safety practices and risk monitoring and reporting. HDW safety program intervention assessment data can be used to feed into the reporting system. Key monitoring indicators include:

- Proportion of urban and rural households with safely managed drinking water service (include access on premise, low risk WQ and regular availability from the source)
- Proportion of households (urban and rural) with low risk drinking WQ to faecal contamination indicator
- Proportion of households (urban and rural) with low risk HDWI result
- Proportion of households with low risk combined drinking WQ and HDW inspection
- Proportion of households practicing HWTS including knowledge and practices in correct, consistent and continuing use, treatment technologies or methods used. (*Detail HWTS indicators are presented on WHO toolkit, 2012*).

Also, scaling up the implementation of WSP and creating auditing and reporting systems is critical for enhancing safety of drinking water sources. And strengthening regulation of drinking water safety including HWT technologies is another important need.

6.6 CONCLUSION

This chapter on the strategies for enhancing HDW quality and safety presented the theoretical framework of the strategy which is based on the socio-ecological model, consisting of four levels of intervention: Household, Community, Institution and Society. Three key intervention domains that apply to the different levels: HBCC including promotion on HWTS, hygiene and sanitation, WASH service delivery which includes implementation of WSP and addressing the enabling environment. Also, the goals and objectives of the strategies, guiding principles, monitoring approach and monitoring, evaluation and regulation aspects of drinking water safety were indicated.

CHAPTER 7

SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 SUMMARY OF THE RESEARCH FINDINGS

Summaries of the research findings in relation to the proposed questions of the study are presented below:

HDW quality and safety

Limited proportion of the households had low risk HDW safety on the combined WQ test and inspection results. Despite the finding that over half of the households had low risk WQ result, the decrease in the safety is linked to the gaps on the HDWI variables including water supply and safety practices.

Low risk HDW quality testing results poorly matched with the HDW safety result which was based on the combined analysis of the WQ test and HDWI. For instance only 19.2 % of the HDW quality tests were low risk on the combined analysis. Hence, HDW safety result using the combined analysis presumes more amplified risk than the quality test. However, high risk test result could be a predictor of HDW safety. Also, more than half of the low risk HDWI results were matched significantly with the low risk HDW safety results and hence it can better serve to predict the risk in HDW safety compared to the quality test result. Low risk HDWI results were associated with access to water on premise, HWT and consistent practices, availability of household basic latrine and hand washing station. Households with high risk inspection result could be low risk on the household water sample test result. So, HDWI using selected key indicators depending on the context helps for monitoring purpose.

Diarrhoea occurrence and associated factors

There was no significant association of diarrhoea and HDW safety risk levels established with this evidence. However, few cases of diarrhoea reported among households with low risk HDW safety and HDWI results. The small number of diarrhoea cases linked to the study sample size and other factors could determine diarrhoea occurrence. It was associated with lack of latrine and daily washing of food utensils as well as low risk perception of the respondents related to drinking water safety.

Factors associated with HDW safety

Low risk HDW safety was statistically associated with HWT practice and low risk HDWI result. And, low risk microbial WQ test result was associated with bottled water, HWT using chlorine products, households' higher income, frequency of water container cleaning and lack of availability of water from the source for more than a week. Use of bottled water was associated with higher income of the households.

There were no associations found between the water sample test and household inspection results. This could be due to the finding that other factors which were not part of the inspection like use of bottled water by the households and access water from other sources (the capital city), HWT using chlorine products, higher households income, water container cleaning had the role for low WQ test result. Households' income is also associated with low risk WQ result and regular use of bottled water by the households. The effect of home water storage practices on water quality requires further investigation.

HWTS and associated factors

Close to one third of the households practice HWT using filtration, chemical disinfection and boiling by order. However, the improvement in the quality of water was not significantly associated with the practice, except use of chlorine products for the treatment. This creates concern on the effectiveness of the technologies used. HWTS practice was associated with behavioural variables risk perception related to HDW safety and ability to conduct HWTS which involve knowledge and skill of HWT, correct and continuous use and able to get treatment options locally.

Strategies to enhance the quality and safety of HDW

Strategies for enhancing HDW quality and safety should involve multi-level interventions based on the SEM model which involve household, community, institutional and society level interventions. Three key intervention domains include HBCC including promotion on HWTS, hygiene and sanitation, WASH service delivery and addressing the enabling environment.

7.2 CONCLUSIONS AND RECOMMENDATIONS

The safety of drinking water at PoU is a big concern and multiple factors influence the safety including water supply service conditions, risk perception and practices of households, HWT ability of the households for HWT, hygiene and sanitation conditions, and socio-economic status of households. Hence, interventions aimed at addressing these factors are essential to enhance the safety of HDW in the study area and other similar settings across the globe.

Thus, based on the findings, the researcher makes the following recommendations related to required interventions and further research areas.

7.2.1 Recommendations related to key interventions

The recommendations regarding essential interventions are presented under changing behaviour, ensuring access to safe drinking water and strengthening the enabling condition including HDW safety monitoring, surveillance and response system.

Behaviour change communications (BCC)

BCC on HDW safety is required in order to create awareness on drinking water safety and related health benefits including health of children under five years of age, HWTS practices, hygiene and use of improved latrine facility by households. Households should be involved in using the strategies. Hand washing should be reinforced at an early age with the help of the family members.

Ensuring access to safe and reliable drinking water services

Service providers should be committed to provision of WASH services including capacity building intervention. The community members and all families should be taught and mobilised regarding the importance of ensuring that the water is collected from reliable and safe sources to avoid the use of contaminated water. Government and other stakeholders need to ensure service delivery for creating access to basic and safely managed drinking water.

Strengthening enabling condition including HDW safety monitoring, surveillance and response system

National level priority should be provided for development of strategy and system of HDW safety implementation. Developing the capacity for human resources for HDW safety promotion and quality monitoring is essential. The country should always make use of health environmental officers in monitoring HDW and ensure that water for human consumption is always clean and not contaminated. The human resource distribution and availability of health environmental officers require attention. The placement of health environmental officers from *woredas* should be based on population and community level activities. Health environmental officers need to attend meetings, training and community level activities, to understand what is happening at community level and to make their services well known.

Developed strategies should be made available to the stakeholders engaged in drinking water service delivery and safety promoters at all levels and community members engaged in the use of the strategies.

7.2.2 Further research areas

The researcher recommends below listed further research areas to be conducted:

- Application of risk-based approach to HDW safety and the association with diarrheal disease incidence and prevalence among children
- Correlations of HDWI and microbial quality of drinking water at point of use
- Outcome of safely managed drinking water service level on diarrhoea incidence
- The effect of home storage using different storage containers and reservoir for a varying duration on the quality of water
- Effectiveness of different HWT technologies and solutions on drinking water microbial quality and safety including related factors influencing the performance

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Annexures

Annexure A – Self-report questionnaire

STRATEGIES TO ENHANCE THE QUALITY AND SAFETY OF HOUSEHOLD DRINKING WATER IN BURAYU TOWN, OROMIA REGION, ETHIOPIA

HOUSEHOLD DATA COLLECTION: INTERVIEW SCHEDULE

HOUSEHOLD IDENTIFICATION

Kebele of residence	
Village/cluster	
Household code	
Date of interview (Day/Month/Year)	
Time interview started (hr:min)	
Name and signature of interviewer	

1. **SOCIO-DEMOGRAPHIC CHARACTERISTICS**

No	Question	Response
1.1	Total family size (number)	___________
1.2	Number of under five children	___________
1.3	Age of the under-five children	___________ (Months)
1.4	Age of the respondent	___________ (Year)
1.5	Educational level of the respondent	Uneducated………. …............. 1 Primary education (1-8) ………. 2 Secondary education (9-12)……3 Certificate......................4 Diploma…………………5 Degree………………..…6 Masters and above……7
1.6	Monthly net income of the household (ETB)	---------------- ETB
1.7	Have you ever received information on water safety and household water treatment and safe storage?	Yes…….1 No………2 (If no skip to 2.1)
1.8	What was the source of information? (More than one response is possible)	Face to face (HWs)……….1 Media sources…………….2 Print materials …………….3 Other (specify) ……………
1.9	Was the information useful?	Yes…….1 No………2
1.10	What source you prefer to receive the information	Face to face (HWs)……….1 Media sources…………….2 Print materials …………….3

		Other (specify) ……………

2. **DIARRHOEA MORBIDITY**

No	Question	Response	Skip note
2.1	Do children under 5 years in your family have diarrhoea illness during the last 14 days?	Yes…….1 (Specify if more than one child) No………2	If 2 skip to #2.3
2.2	Do children under 5 years of age have diarrhoea today?	Yes…….1 No………2	
2.3	Does a person over 5 years in your family have diarrhoea illness during the last 14 days?	Yes…….1 (Specify if more than one person) No………2	

3. **WATER SUPPLY**

No	Question	Response	Skip note
3.1	What is the main source of drinking for the household?	Pipe water/Tap on premise....1 Pipe water/public point………2 Protected well on premise ….3 Unprotect. well on premise…4 Surface water ………. 5 Other (Specify)…………6	If 1 skip to 3.3
3.2	If the source is outside the compound, how long takes to collect water (round trip and queuing time)	-------------- minutes	
3.3	Do you get water from the source regularly (no interruption) every day?	Yes…….1 No………2	If 1 skip to #3.5
3.4	If not, how frequent is the interruption?	Half day per week…….1 1 day per week ……….2 2 day / per week ….3 3 days per week………4 Other (specify)……….	
3.5	Daily quantity of water used (litres) by the household	----------- litres	
3.6	Do you have a water storage reservoir?	Yes ….1 No…….2	
3.7	Capacity of the reservoir	________ litres	
3.8	How long does the reservoir serve to provide water for the family if supply interrupts?	__________ (hours or days)	
3.9	How frequently does the reservoir get cleaned?	_______ (weeks or month)	
3.10	Do the household have experience of using bottled water?	Yes ….1 No…….2	If 2, skip to part 4.1
3.11	How often do you use bottled water	……… (daily, weekly…	

		monthly)	
3.12	Who uses bottled water?	All member use……………1 Children under five years….2 Other (Specify)………………	

4. HOUSEHOLD WATER TREATMENT AND STORAGE

No	Question	Response	Skip note
Ask sample of drinking provided to a child for drinking - pour into Whirl Pak bag			
4.1	Where does the sample of water come from?	Home storage……….1 Reservoir tank……….2 Direct from tap……….3 Filter/treated water container.4 Other (specify)………..5	If 3 skip to # 4.10
4.2	Did you do anything to treat the water after collection?	Yes…….1 No………2	If 2 skip to # 4.10
4.3	What did you do? (Treatment method practiced) Observation – kindly ask the respondent to show you the treatment method being used	Boiling ………. 1 Solar treatment (SODIS).……2 Chemical disinfectant ….3 Combined flock/disinfectant…………4 Ceramic filtration (Tulip) ……5 Membrane filtration ………. 6 Other (specify)…………7	Write name of the filter use ……………
4.4	Does the household consistently (daily) practice household water treatment?	Yes…….1 No………2	
4.5	When started to practice household water treatment?	_____ months ago (_____ weeks ago)	
4.6	Who uses the treated drinking water?	Children under 5 only….1 All family member….2 Other (specify)……………	
4.7	Do you feel any benefit of the HWT? If yes, what is/are the benefits felt	Reduced diarrhoea among family member….1 Reduced diarrhoea on children…2 Enjoy reliable safe water…3 Reduced medical cost …4 Other (specify)…………	
4.8	Where did (do) you purchase the treatment product?	Local shop….1 Shop in Addis Ababa city….2 Other (specify)……………	
4.9	How much is your expense for the treatment method so far?	-----ETB	Skip to #13
4.10	Have you used HWT in the past?	Yes…….1 No………2	If 2, skip to 4.13
4.11	When did you practiced HWT last time	_______ day or week ago	

4.12	Why did you stop the treatment?	______________________	
4.13	If home storage used, how long the water stored at home (period since collected)?	___ minutes (____hours) No storage _____	If no storage skip to 4.22
4.14	Type of home storage container used? Observation – kindly ask to see the storage type	Plastic jerrycan …......... 1 Plastic bucket ………. 2 Ceramic ………… 3 Other (specify)	
4.15	Kind of the container opening? (Observe)	Narrow opening…….1 Wide opening ………2	
4.16	Does the container have usable cover?	Yes…….1 No………2	
4.18	Does the container have cleanliness? (observe)	Yes…….1 No………2	
4.19	How frequently does the water container be cleaned properly? (observe the cleanliness)	Every day ….1 Every second day….2 Twice in a week….3 One in a week…4	
4.20	How long does the stored water stay before all used?	…. ….(hours or days)	
4.21	Does the household have an adequate water storage container at home?	Yes…….1 No………2	

5. BEHAVIOURAL FACTORS

Direction: There are five behavioural variables each of them having more than one statement. The questions are responded using five response options to indicate the extent of the respondents' agreement to the questions. There is also an option for neutral response for no opinion or not sure responses. Kindly respond for each question accordingly.

Response code

Strongly agree	*Agree*	*Neutral or no opinion*	*Disagree*	*Strongly disagree*
5	*4*	*3*	*2*	*1*

No	**Question**	**Response code**
5.1	**Risk Perception**	
5.1.1	The safety of drinking water from the source is often unreliable for health	
5.1.2	Physically clear water is not sign of safe drinking water	
5.1.3	Intermittent supply of water can affect quality and safety of drinking	

	water	
5.1.4	There is high risk of getting diarrhoea from unsafe water	
5.1.5	Children under 5-year health are highly affected by unsafe drinking water	
5.1.6	Diarrheal illness due to unsafe water consumption is a prevalent among children <5	
5.2	**Attitude**	
5.2.1	Household water treatment can improve the quality and safety of drinking water	
5.2.2	The cost of household water treatment is affordable	
5.2.3	Safe storage and handling of drinking water at home helps to prevent and maintain the safety of drinking water	
5.2.4	The taste and odour of household treated water is acceptable	
5.3	**Norm**	
5.3.1	Household water treatment is common practice of the households in the community	
5.3.2	People who are important to you expect you should always treat drinking water provided to your children under five years age	
5.3.3	Household water treatment is a practice of prestige	
5.3.4	You personally feel household water treatment is highly important	
5.4	**Ability**	
5.4.1	The respondent have good knowledge of household water treatment practice including treatment options	
5.4.2	The respondent have good knowledge of safe storage and handling of drinking water at home	
5.4.3	The respondent are confident of own skill for correct use of household water treatment option	
5.4.4	The respondent can practice household water treatment continually (extended period), have no barrier (like access to the product, cost…)	
5.4.5	The household water treatment options are locally available	
5.5	**Self-regulation**	
5.5.1	The household clean the filter regularly as required or make stock of chlorine chemical or remember to boil (use SODIS) for daily use	
5.5.2	The household can conduct consistent (for daily use) treatment of drinking water at home	
5.5.3	The household have commitment (priority) for household treatment practice	

6. HOUSEHOLD HYGIENE AND SANITATION CONDITION

No	Question	Response
6.1	**Hygiene and sanitation facility**	
6.1.1	Does the household have a functional hand washing station? (*observe - water and soap*)	Yes………..1 No………….2
6.1.2	Ask the critical moments to wash hand with water and	

	soap Does the household mention these six critical moments of hand washing? 1. *Before eating food,* 2. *After eating food,* 3. *After going to toilet* 4. *Before preparing food* 5. *Before feeding children* 6. *After cleaning child defecated*	____ of the six moments mentioned
6.1.3	Do the children under five wash their hands with soap every time before meals?	Rarely wash hand…….1 Sometime wash hand….2 Always wash hand…….3 Other (specify)…………………
6.1.4	Do the children under five wash their hands with soap every time after latrine use?	Rarely wash hand…….1 Sometime wash hand….2 Always wash hand…….3 Other (specify)…………………….
6.1.5	Does the household have a toilet facility?	Yes…….1 No………2
6.1.5	What is the type of the toilet?	Pit latrine without concrete slab…1 Pit latrine with concrete slab…….2 Ventilated improved pit latrine…. 3 Shared latrine with neighbour ……4 Flush toilet connected to septic/storage tank…….5 Other (specify)……………….
6.2	**Food hygiene**	
6.2.1	Does children provided hot and well-cooked food (including sauce or wax, milk, meat) every day	Yes always………..1 Yes, most of the time ….2 Sometime (hot and raw)….2 Other (specify)………………
6.2.2	Does the household use a refrigerator?	Yes……….1 No………….2
6.2.3	Do food utensils be cleaned daily using detergents?	Yes……….1 No………….2

7. HOUSEHOLDDRINKING WATER INSPECTION (*to be filled by interviewer*)

No.	Questions	Yes	No
7.1	Does the household have access to improved water sources? *Improved sources include piped water, protected well and spring*		
7.2	Does the household get water on premise?		
7.3	Households water storage duration over three days		
7.4	Drinking water safety risk perception		
7.5	Does the household consider diarrheal illness linked to unsafe water consumption is a prevalent and severe among children under 5 years of age		
7.6	Does the household practice appropriate household water treatment?		
7.7	Does the household practice appropriate household water treatment consistently during the last two weeks?		
7.8	Does the household have a safe water storage container (clean and narrow opening with cover)?		
7.9	Does the households use basic latrine? (Latrine for the household with concrete slab)		
7.10	Does the household have a functional hand washing facility (observe)? *Functional - facility with water and soap in place*		

2 WATER SAMPLE IDENTIFICATION

Description	Source sample	Household sample
Sample code		
Time of collection		
Time of testing		
Test result - thermotolerant coliform /100 ml		

The interview ended, thank you for your response to the questions!

Annexure B – Participant information note and informed consent form

Title of the study - Strategies to Enhance the Quality and Safety of Household Drinking Water in Burayu Town, Oromia Region, Ethiopia

Name(s) and affiliation(s) of researcher(s):
Kebede Eticha Gela, UNISA, Addis Ababa Ethiopia

Why the research? In order to develop strategies that enhances the quality and safety of drinking water in Burayu town and other similar settings of the country

What will happen during the study? The study involves data collection through interviews of sample households that are selected systematically. The interviewer reads the interview schedule for the respondents (mother having children under fiveyears age). Drinking water samples used by households which are provided to children will be collected and tested. There is no right or wrong answer of the responses from the respondents. The duration for the interview takes a maximum of 45 minutes.

Will anyone know what you respond to? Nobody will know or identify your response, but the data will be submitted to the researcher.

What are the possible gains and harm to you? The study may or may not have any direct benefit for you at the moment, but the findings of the research will be used for developing that will help to improve the health of the community. There is no envisaged harm to the respondents participating in this research.

Can respondents withdraw from the interview? You are free to interrupt the response to the interview of the study at any time even after you have provided informed consent, which is attached to this information note.

Contacts If you have any concerns, you may send an electronic mail (e- mail) or phone the researcher:

Researcher: Mr Kebede Eticha Gela (Name of Researcher)
Phone - 0911411416, E-mail: *keticha.ke@gmail.com*

PARTICIPANT INFORMED CONSENT LETTER

(Introduction and consent)

Dear Participant,

Greetings!

My name is ………………. . A research is being conducted on household water safety as part of a Doctorate Degree fulfilment by candidate Kebede Eticha Gela, at University of South Africa (UNISA).

The purpose of the study is to develop strategies to enhance household drinking water quality and safety for Burayu town and other similar settings. The objectives of the study include investigating the quality and safety of water at household and its association with diarrheal disease occurrence as well as exploring factors which are related with the quality and safety of drinking water.

Your household is selected as part of the sample household for the data collection purpose. This is, therefore, to kindly request your willingness and permission to participate in the study and provide appropriate responses to the interview questions and provide samples of drinking water for testing. The questions are related to household socio-demographic characteristics, diarrhoea morbidity, water supply and related household level practices, hygiene and sanitation condition of the household. Your responses are used only for this study purpose and kept confidential. Personal identification information will not be used at any of the research processes.

Your commitment to the study is very crucial to generate reliable and valid data for the research. You can have full control on the data collection process including requests to understand the questions and decide not to respond or interrupt the interview whenever you want to do so. The interview will take a maximum of 30 minutes to complete the questionnaire.

Thank you for your time and interest in cooperating. Kindly ask if you have any questions.

Do you have any questions that you want to ask about the study?

Are you willing to participate? I agree to participate in this study: Yes □ No □

May I begin the interview now?

Name and signature of interviewer: ____________________ Date: ___/___/_________

Annexure C – Ethical clearance letter from the University

RESEARCH ETHICS COMMITTEE: DEPARTMENT OF HEALTH STUDIES

REC-012714-039 (NHERC)

6 December 2017

HSHDC/805/2017
Kebede Eticha Gela
Student No.:6194-691-5
Supervisor: Prof LV Monareng Qualification: D Litt et Phil Joint Supervisor:

Dear Kebede Eticha Gela

Decision: Ethics Approval

Name: Kebede Eticha Gela

Proposal: Strategies to enhance the quality and safety of household drinking water in Burayu Town, Oromia Region, Ethiopia

Qualification: **DPCHS04**

Thank you for the application for research ethics approval from the Research Ethics Committee: Department of Health Studies, for the above mentioned research. Final approval is granted from 6 December 2017 to 6 December 2022

The application was reviewed in compliance with the Unisa Policy on Research Ethics by the Research Ethics Committee: Department of Health Studies on. 6 December 2017

The proposed research may now commence with the proviso that:

1) *The researcher/s will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.*

2) *Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the Research Ethics Review Committee, Department of Health Studies. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*

3) *The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.*

4) *[Stipulate any reporting requirements if applicable].*

Note:

The reference numbers [top middle and right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the Research Ethics Committee: Department of Health Studies.

Kind regards,

Prof J.E. Maritz

Prof JE Maritz
CHAIRPERSON
maritje@unisa.ac.za

For Prof MM Moleki
ACADEMIC CHAIRPERSON
molekmm@unisa.ac.za

Prof A Phillips
DEAN COLLEGE OF HUMAN SCIENCES

Annexure D – Letter of permission request from UNISA, Addis Ababa office

UNISA university of south africa

22 MAY, 2019

UNISA-ET/KA/ST/29/22-05-19

Oromia Regional Health Bureau

<u>Addis Ababa</u>

Dear Madam/Sir,

The University of South Africa (UNISA) extends warm greetings. By this letter, we want to confirm that Mr. Kebede Eticha Gela (student number 61946915) is a doctoral student in the Department of Health Studies at UNISA. Currently, he is at the stage of data collection on his PhD research entitled "***Strategies to enhance the quality and safety of household drinking water in Burayu Town, Oromia Region, Ethiopia***".

This is therefore to kindly request you to assist the student in any way that you can. Attached, please find the ethical clearance that he has secured from the Department of Health Studies.We would like to thank you in advance for all the assistance that you will provide to the student.

Sincerely,

Dr Tsige GebreMeskel Aberra

Director

UNISA REGIONAL LEARNING CENTRE
PO BOX 13836 ADDIS ABABA ETHIOPIA
TEL +251-114-350141
+251-114-350078
FAX +251-114-351243
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University of South Africa
Regional Learning Center
P.O. Box: 13836, Addis Ababa, Ethiopia
Telephone: +251 11 435 2244 / +251 11 435 0078

Annexure E – Letter of permission to conduct the study

BIIROO EEGUMSA FAYYAA OROMIYAA | **OROMIA HEALTH BUREAU**

የኦሮሚያ ጤና ጥበቃ ቢሮ

Ref No/ቁጥር: BEFO/HRTF-4/1-16/128
Date/ቀን 4/10/2011

Waaj/E/F/Bul/Mag/Buraayyuu tiif
Buraayyuu

Waaj/Bishaan/Dhug/Mag/Buraayyuu tiif
Buraayyuu

Dhimmi: Xalayaa Deeggarsaa Ilaala.

Akkuma beekamu Biiroon Keenya Ogeyyii, dhabbile akkasumas namoota qorannoo geggessuuf propozaala dhiyeffatan propoozaala isaanii madaaluun akkasumas iddo biratti ilaalchisani fudhatama argatan (approved) dhiyeffatan,propoozaala isaanii ilaaluudhaan waraqa deggersa ni kenna. Haaluma kanaan mata duree'' **Strategies to enhance the quality and safety of household drinking water in Burayu Town, Oromia Region, Ethiopia''** jedhamu irratti **''Obbo Kabbadee Itichaa''** Magaalaa keessan keessatti qorannoo geggessuuf propoozaala isaanii koree "Health Research Ethical Review Commite" Biiroo keenyatti dhiyeffatani jiru. Haaluma kanaan koreen "Health Research Ethical Review Committee" Biiroo keenyaa piropoozaala kana ilaaluun mirkanecssee qorannoon kun akka hojii irra oolu murteessee jira. Kanaafuu, hojji qorannoo kana irratti deggersa barbaachisa ta`e gootaniifii, hordoftan jechaa,

''**Obbo''Kabbadee Itichaa''**qorannoon kun qacceffamee eerga xumuramee booda firii isaa koppii tokko BEFO tiif akka galii godhan galagalcha xalayaa kanaan isaan beeksifna.

Anis, '' **Obbo Kabbadee Itichaa''** wayitti qorannoon kun qaaceffame xumuramu firii isaa koppii tokko BEFO tiif galii gochuuf mallattoo kootiin nimirkanessa.

Nagaa wajjin!

Mallattoo_______________
Maqaa **''Kabbadee Itichaa''**
Bilbila_______________
G/G
'' **Kabbadee Itichaa**' tiif
Finfinnee

Tessoo: Tel: +251-11-371-72-77, Fax: +251-11-371-72-27 Box. 24341 E-mail: ohbhead@telecom.net.et Address: ADDIS ABABA/FINFINNE-ETHIOPIA

Annexure F – Curriculum Vitae

Curriculum Vitae
Kebede Eticha Gela
Mobile: 251-911-411416, Addis Ababa, Ethiopia
Email: ketichа.ke@gmail.com; k_eticha@yahoo.com

Personal Profile	
Nationality	Ethiopian
Sex	Male
Profession	Public Health
Date of Birth	August 1974
Education	
2017-2021	**PhD in Public health candidate at UNISA** *Thesis: Strategies to enhance the quality and safety of household drinking water*
2007	**Master of Public Health,** Addis Ababa University, Ethiopia *Thesis: prevalence and Determinants of Child malnutrition, posted here*
2000	**BSc, Environmental Health,** Jimma University, Ethiopia
Summary of Biography	
	Have Master Degree in Public health from Addis Ababa University and BSC in Environmental health and over 18 years work experience working for INGO, UN agency and Government health sector. Worked for UNICEF regional office for East and Southern Africa (ESARO) as WASH/IPC consultant during 2020/2021. Before that worked for the Carter Centre as Behavioural ***Change Communications (BCC) Campaign Manager*** for Guinea Worm Eradication. The work involved Program management, Implementation, Capacity building, and Partnership. Prior to that worked for ***WHO Ethiopia Country office*** during 2015-18 as National Professional Officer for Health and Environment program, providing technical assistance to Ministry of health and Ministry of water in WASH and environmental health program. Also worked for ***Oxfam America***, Horn of Africa Regional Office, for seven years (2008 – 2015) as Public Health Specialist for humanitarian program. Working on need assessment, early warning surveillance, support partners in proposal development, response and grant management. Expertise and Skills: have reliable skill and expertise in technical expertise of Public health, program design, project and grant management, capacity building, team work, monitoring and evaluation. LinkedIn profile here

Professional Experience	
January – December 2020	**WASH and IPC consultant** **UNICEF, ESARO** **Major Duties and Responsibilities** ▪ Provide support to regional IPC working group in response to Covid 19 pandemic including country response review, adapting tools and training materials ▪ Support regional IPC/WASH working group in response to Coivd-19 ▪ Adapt and review WASH assessment and monitoring tools ▪ Adapt and prepare guidance document and training modules, sample here ▪ Provide technical support to countries in the region, sample here ▪ Engage in virtual review and feedback to countries on WASH/IPC team ▪ Lead review of the UNICEF WASH and youth engagement project in three East Africa countries (Somalia, South Sudan and Ethiopia) **Major Accomplishments** **WASH and Youth project** ▪ Prepared country project review plan and tool ▪ Conducted the project review in three East Africa countries (Somali, South Sudan and Ethiopia) ▪ Preparing three countries WASH and youth engagement project review and overall learning note **IPC/WASH regional technical and country support in the context of Covid 19** ▪ **Regional IPC working group** - Supported and facilitated regional IPC WG meetings on weekly basis, review of meeting minutes and action points - Engaging on countries IPC deep dive IPC capacity and performance review - Conducting bilateral call with selected countries in the regions to follow-up on IPC implementation and providing technical guidance and support ▪ **Adaptation and review of tools** - Review and input to health care facilities IPC score card and WASH/IPC FIT - Preparing community IPC/WASH community score card ▪ **Assessment of health care facilities** - Provided risk based approach to IPC/WASH FIT webinar sessions for Ethiopia UNICEF and WASH cluster partners focal persons in the context of Covid 19. - Supported planning and implementation of an assessment of WASH/IPC in 65 facilities in non-formal settlement in Kenya working with UNICEF country team, through providing training for the data collectors, conducted risk analysis of the assessment data and prepared learning note of the assessment experience , here

01/06/2018 -31/08/2019	▪ **Capacity development** - Worked on development of training catalog on IPC/WASH in the context of Covid19, link here - Worked on development of IPC WASH training modules for learning management system (LMS) - Organizing virtual training session with countries (Ethiopia, Kenya) ▪ Contributed to a research paper on drivers to health workers infections to Covid 19 in region by making initial draft concept of the paper, data analysis and review and submitted for publication
1/10/2015 - 31/03/2018	**Program Manager - Behavior Change Communication (BCC)** **The Carter Center, Ethiopia** **Organization Type: INGO** **Major Duties and Responsibilities** ▪ **Program management -** lead BCC campaign for Guinea worm disease (NTD) eradication working closely with KYNE BCC Team to intensify national awareness creation and community engagement activities. ▪ Facilitating developing and implementation of **evidence driven BCC strategy** though conducing formative studies to understand the context, existing awareness and perception, practices, communication channels, enablers/barriers, and identifying key messages for the communication and IEC material development (*End-to-end process*) ▪ Facilitating **development of communication materials** – working with creative agencies to produce print and audio materials including posters, billboards, PSA, radio drama and key message, jingle and campaign song. Ensure proper dissemination and monitoring and print materials, ensure proper distribution and monitoring ▪ **Program Implementation** - providing effective oversight, to ensure that work plans are coordinated and executed in a timely manner. Promoting community and media engagement, organizing campaign events and advocacy sessions. ▪ **Capacity building** - training to local officers, supervisors and government stakeholders through developing guideline and training manual ▪ **Managing program staff and budget** including contracts with media and creative agencies ▪ **Partnership** – working with partners and stakeholders including Ethiopia Dracunculosis Eradication program (EDEP) members, national and regional media, private sectors ▪ Conducting periodic field supervision, monitoring and reporting, formative assessments and audience feedback research. **National Professional Officer, Public Health and Environment**

	World health organization, Ethiopia country office **Organization Type: UN Agency** **Major Duties and Responsibilities** ▪ Providing technical assistance and capacity building support to Ministry of health and stakeholders in Environmental Health programs including water safety, WASH and IPC in health care facilities and WASH monitoring. Supporting strategy and guidance materials development focused to preventive risk management approach ▪ Strengthen national capacity in household water treatment and Safe storage (HWTS) implementation and strengthening regulation of household water treatment (HWT) technologies. ▪ Promotion of WASH in health care facilities through supporting government's Clean and Safe health facilities (CASH) program including documentation of the program, track implementation and lessons. ▪ Collaboration, networking and contribute to national and global discussion, and events/conferences, establish linkage with national regulatory bodies and support activities of WHO network of drinking water regulators. ▪ Support the activities of WHO/UNICEF Joint Monitoring Program (JMP) on water and sanitation

Annexure G – Turnitin originality report

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	Kebede Gela
Assignment title:	Revision 2
Submission title:	Final thesis revised excluding the re...
File name:	Thesis_Final_31_January_2021_61...
File size:	2.65M
Page count:	170
Word count:	41,242
Character count:	227,564
Submission date:	31-Jan-2021 10:15PM (UTC+0200)
Submission ID:	1498287408

Annexure H – Letter from language editor

ROSEMARY'S PROOFREADING
& EDITING SERVICES

+27 83 215 6445
Rosemarys.pes@gmail.com
1 Richards drive
Midrand, 1684

02 FEBRUARY 2021

To whom it may concern

RE: LANGUAGE AND TECHNICAL EDITING

This letter serves as confirmation that the thesis titled "STRATEGIES TO ENHANCE THE QUALITY AND SAFETY OF HOUSEHOLD DRINKING WATER IN BURAYU TOWN, OROMIA REGIONAL STATE, ETHIOPIA" by KEBEDE ETICHA GELA, a PhD candidate, student number 61946915 was edited by Rosemary's Proofreading & Editing Services.

Kind Regards

R MALULEKE (LANGUAGE EDITOR)