COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

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ASSESSMENT OF THE BACTERIOLOGICAL CONTAMINATION OF DRINKING WATER FROM SOURCE TO POINT-OF-USE IN HABRU DISTRICT, NORTH WOLLO, ETHIOPIA

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THESIS APPROVAL SHEET

As members of the Board of Examiners of the final Msc. open defense, We certify that we have read, examine and evaluated the thesis prepared by Habib Alemu Legesse, entitled "Assessment of Th**e** Bacteriological Contamination of Drinking Water from Source to Point-of-use in Habru district, North Wollo, Ethiopia", this is to certify that the thesis has been accepted in partial fulfillment of the requirement for Master of Science Degree in Applied Microbiology.

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AUTHOR DECLARATION

By my signature below, Declare and affirm that this thesis entitled "Assessment of Th**e** Bacteriological Contamination of Drinking Water from Source to Point-of-use in Habru District, North Wollo, Ethiopia" is my original work. I also seriously declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Habib Alemu Legesse	______________	____________
Name of Student	Signature	Date

BIOGRAPHICAL SKETCHE

The author was born on July 12, 1995 G.C in Shiwa village, Mekaneselam Town, Ethiopia. He attended his elementary education at Abu kebele (011), for his secondary education, he attended Mekaneselam High School and Mekaneselam General Preparatory School. In 2018 G.C, the author graduated with a Bachelor of Science degree in veterinary science from Bahir Dar University. His academic journey reflects a strong passion for microbiology and environmental health, inspiring him to further his studies. The author is currently advancing his expertise in Applied Microbiology at Woldia University. His research interests focus on bacteriological water quality from sources to point-of-use and its implications for applying public health and sustainable environmental practices. This work aims to address challenges in water pollutants and the management of drinking water quality from source to point-of-use.

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ABBREVATIONS

APHA……………………………..American Public Health Association

CFU………………………………..Colony Forming Units

E.coli……………………………….*..Escherichia coli*

FC/TTC……………………………...Fecal/Thermotolerant coliform

FDRE, MoH……………………….Federal Democratic Republic of Ethiopia, Ministry of Health

FDRE, MoWR……………………....Federal Democratic Republic of Ethiopia, Ministry of Water Resources

GIS…………………………………...Geographic Information System

MF…………………………………...Membrane Filtration

NGO………………………………......Nongovernmental organization

PPS…………………………………...Probability Proportional to Size

PS……………………………………..Protected Spring

PT……………………………………..Public Tap

PW……………………………………Protected Well

SARC………………………………..Sirika Agricultural Research Center

SAS…………………………………..Stastiscal Analysis Software

SPSS…………………………………..Stastiscal Product and Service Solution

TDS……………………………………Total Dissolved Solid

TNTC…………………………….......Too Numerous To Count

US……………………………………..Unprotected Spring

WHO…………………………………World Health Organization

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ABSTRACT

Drinking water in rural areas is often vulnerable to microbial contamination due to inadequate protection at the source, poor hygiene practices during water collection, and improper household water handling. In Ethiopia, fecal contamination of drinking water is a major public health concern and contributes significantly to child and elderly mortality. This study aimed to assess the bacteriological quality of drinking water from source to point-of-use and to evaluate sanitary risk factors and water handling practice in Habru district, North Wollo. A cross-sectional study was conducted from February to June 2024. A descriptive statics and ANOVA were used to analyze collected data. A total of 36 source water samples and 243 household water samples were collected and analyzed for bacteriological quality, using the membrane filtration technique. Sanitary survey and structured interviews were also conducted to assess risk factors and hygiene practices. The study found that drinking water sources with high sanitary risk scores, such as the unprotected spring at Awera, showed significantly higher bacterial contamination, while protected springs at Libso and Kule had lower contamination levels. Among 81 interviewed households, 64.1% reported hand washing during water collection, 73.4% rinsed their water collection containers, 92.6% used covered storage vessels, and 69.0% drew water by dipping method, which increases the risk of post-collection contamination. Laboratory analysis revealed that most water sources were contaminated with TC (counts ranged from 0-112CFU/100mL) and FC (counts ranged from 0-100CFU/100mL). All household water samples (100%) of tested positive for TC/ FC. The contamination was attributed to inadequate source protection, poor water handling. Contributing factors to unsafe household water practices included low educational status, limited income, large family size. Therefore, to improve water quality, protection of water sources and safe handling at households will be taken as a solution.

Keywords: Drinking water, Fecal coliform, Household water storage, Membrane filtration, Total coliform

1 INTRODUCTION

1.1 Background of the Study

Access to safe drinking water is a fundamental human right and critical determinant of public health globally (World Health Organization [WHO], 2022). Safe water is defined as meeting established standards for physical, chemical, and, crucially, microbiological quality to prevent waterborne disease transmission (WHO, 2022). Despite this, billions of people, primarily in developing regions, still lack access to safely managed water services, sanitation, and hygiene (WASH), creating a persistent global health challenge (WHO, 2022).

Ethiopia exemplifies this challenge. While access has improved, significant disparities persist, particularly in rural areas. Recent estimates indicate that a substantial portion of the rural population still relies on unimproved water sources or faces contamination risks even with improved sources (WHO & UNICEF, 2023). This limited access to safe water, compounded by sanitation and hygiene challenges, contributes heavily to Ethiopia's burden of waterborne diseases, which remain a leading cause of morbidity, particularly among children, imposing considerable economic and social costs (Beyene et al., 2015; Dessalegn et al., 2014).

Microbial contamination, primarily from faecal sources, poses the most widespread and immediate risk to drinking water safety in such contexts (WHO, 2022). Pathogens enter water bodies through inadequate sanitation, poor waste management, and agricultural runoff. Once introduced, contamination can occur or worsen at multiple points: at the source itself, during collection, during transport, due to inadequate storage at the household level (point-of-use), or through unhygienic handling practices (Sobsey, 2002; WHO, 2017). Thermotolerant coliforms (TTC) and *Escherichia coli (E. coli)* serve as internationally accepted faecal indicator bacteria (FIB) because their presence reliably signals faecal contamination and potential pathogen presence, providing a practical measure of bacteriological water safety (WHO, 2022). The WHO guideline stipulates that FIB, specifically E. coli or TTC, should not be detectable in any 100 ml sample of water intended for drinking (WHO, 2022).

Within Ethiopia, rural communities are disproportionately affected. They often depend on unprotected springs, rivers, or poorly constructed shallow wells (Abera et al., 2011; UNDP Ethiopia, 2018). While source protection is the most effective barrier (Amenu et al., 2013), studies consistently show that contamination frequently occurs after water is collected. Deterioration of water quality during transport, storage in unsanitary or uncovered containers, and drawing water via dipping (introducing hands or utensils) are major pathways for secondary contamination at the household level (Tadesse et al., 2010; Dessalegn et al., 2014; Ersado, 2016). Studies in various Ethiopian settings (e.g., Dessalegn et al., 2014; Seid, 2003; work cited as Tadesse et al., 2010) document prevalent unsafe water handling practices, confirming this post-collection risk.

Habru District, located in the North Wollo Zone, typifies the rural Ethiopian context concerning water access and safety challenges. Characterized by both surface water (rivers like Weraba) and groundwater potential (Habru Woreda Administration, personal communication, 2023), the district nonetheless struggles to provide adequate, safe water schemes to all kebeles. Consequently, communities may rely on unprotected sources or face challenges in maintaining the safety of water from protected sources throughout the supply chain. Furthermore, anecdotal evidence and localized surveys suggest prevalent unsafe household water storage and handling practices within the district (Habru Woreda Health Office, unpublished data, 2023). While the contamination risks from source to point-of-use are well-documented nationally, there is a critical lack of district-specific, systematic evidence mapping the extent and primary points of microbial contamination along this pathway within Habru. Understanding where and how contamination occurs specifically in Habru is essential for designing targeted, effective interventions to safeguard drinking water and improve public health outcomes for its population.

1.2 Statement of the Problem

Ensuring access to safe drinking water remains a critical global public health challenge, particularly in developing nations like Ethiopia (Amenu, 2013). Microbial contamination during transport, storage, and handling significantly degrades water quality between source and point-of-use (POU), even when sourced from protected supplies (WHO, 2017; Trevett et al., 2004). This secondary contamination is frequently linked to unsanitary storage containers and unhygienic water-drawing practices (Kausar et al., 2012).

In Ethiopia, unsafe water, sanitation, and hygiene (WASH) conditions are a leading risk factor for disease burden (Ameya et al., 2018), contributing substantially to diarrheal morbidity (WHO, 2017). Studies confirm widespread fecal contamination in diverse Ethiopian water sources, including protected springs and wells (Mebratu, 2007; Atnafu, 2006), demonstrating that infrastructure improvements alone do not guarantee safe water at consumption.

Despite this recognized risk of post-source contamination, no systematic assessment has evaluated the bacteriological quality of drinking water along the entire pathway from source through storage to use within Habru District, North Wollo. Preliminary observations indicate reliance on potentially unprotected sources (e.g., springs, dug wells) and unsafe household water handling practices (Habru Woreda Health Office, personal communication, October 15, 2023). Consequently, the specific points and extent of microbial contamination across Habru's water chain remain unknown, hindering effective interventions to safeguard water safety for the district's rural population.

This study therefore aims to: determine the bacteriological quality (Total Coliforms and Fecal Coliforms) of drinking water at source, storage container, and point-of-use stages; and assess household water handling practices in Habru District, North Wollo Zone.

1.3 Research Questions

The Study was planned to answer the following basic questions.

1. What is the difference in *E. coli*, concentration (CFU/100ml) between drinking water sources and point-of-use (household storage) in Habru District, North Wollo, Ethiopia?
2. To what extent do protected water sources in Habru District, align with the WHO *E. coli………* standard (0 CFU/100ml)?
3. What proportion of household water collection vessels in Habru District, exhibit detectable *E. coli*……… contamination (>1 CFU/100ml)?

4. To what extent does *E. coli*……. concentration increase in household-stored water versus source water over 24–72 hrs relative to the WHO standard (0 CFU/100ml) in Habru District?

1.4 Objectives of the Study

1.4.1 General objective

The general objectives of the study were to:

- Assess the level and variation of bacteriological contamination in drinking water from the source to the point-of-use within Habru District, North Wollo, Ethiopia.

1.4.2 Specific objective

The specific objectives of the study were to:

- Assess the bacteriological quality of drinking water sources in selected Habru District kebeles.
- Compare contamination levels between source and corresponding point-of-use and changes of contamination during collection, storage and to evaluate the sanitary risk score of drinking water sources in the study area.
- Analyze the impact of water handling and storage practices on water quality.

1.5 Significance of the Study

This study provides critical data on bacteriological contamination levels from source to point-of-use in Habru District, identifying specific contamination points and contributing factors (e.g., handling, storage, source sanitation). It directly informs the Habru District Environmental Health Program and relevant bureaus (Water, Health) for targeted interventions. Serving as the first baseline assessment in this area, it fills a knowledge gap and aids stakeholders (NGOs, policymakers, community organizations) in improving rural water safety and monitoring progress.

1.6 Scope and Limitation of the Study

The study focused on the bacteriological quality of drinking water in nine rural kebeles of Habru District, analyzing samples from the source to household level, including collection and storage practices.

Due to various reasons, the following limitations were compromised. Drinking water quality analyses usually cover the sources, reservoir (disinfection point), point-of-use, and the storage container. In this study, however, samples were not taken from the reservoir which would have been better to evaluate the appropriate TDS. The Sampling of drinking water at household level and source water were limited to few selected sites, and parameters were analyzed after sample were transported for 4 hours, this might has effect on the exact results and researcher has budget shortages in order to test more parameter such as physico chemical and seasonal variation of water quality. Moreover, self-administered questionnaires usually could be biased.

2 LITERATURE REVIEW

2.1 Human Health and Water Quality

Water quality is fundamentally linked to drinking water safety, hygiene, sanitation, and consequently, human health (World Health Organization [WHO], 2017). In many developing countries, water supplies are frequently unsafe for human consumption (Birhanu, 2017). Contaminated drinking water is a primary transmission route for pathogenic microorganisms causing diarrheal diseases (WHO, 2022a), including cholera, bacillary dysentery, *enterohemorrhagic E. coli* infection, shigellosis, typhoid fever, cryptosporidiosis, hepatitis A and E, and giardiasis. Waterborne disease outbreak typically arise from source contamination, treatment system failures, distribution system contamination, or the use of untreated water (WHO, 2022a). Improved sanitation can reduce diarrheal disease incidence by 32%, while hygiene education and hand washing promotion can achieve a 45% reduction (WHO, 2015). Household water treatment methods, such as point-of-use chlorination, can also reduce diarrheal diseases by 35–39% (WHO, 2011).

Although natural microorganisms exist in water, the most significant health-related pollutants originate from domestic and industrial wastes. These pollutants include pathogenic bacteria, viruses, and parasites capable of causing disease in humans and animals (Sood et al., 2008). Human and animal wastes are primary sources of bacterial contamination in drinking water, entering supplies via runoff from feedlots and pastures, or seepage from septic tanks and sewage facilities into inadequately protected wells (Brian, 2002; Sood et al., 2008). Global concern over drinking water quality is increasing, driven primarily by contamination with pathogens and potentially toxic chemicals (WHO, 2005). Effective water quality management is therefore essential to mitigate disease outbreaks stemming from polluted water (Birhanu, 2017).

The predominant health risk associated with drinking water is fecal contamination from human or animal sources, which can harbor pathogenic microorganisms. Consumption of water contaminated with human and animal excreta poses the greatest public health risk, though other exposure routes can be significant (Cotruvo, 2017). Direct monitoring of pathogens (bacteria, viruses, protozoa) is often complex, costly, and time-consuming. Consequently, water quality monitoring typically relies on detecting indicator organisms that signal potential fecal contamination. Commonly used bacteriological indicators include total coliforms (TC), thermotolerant (fecal) coliforms (TTC), *Escherichia coli, and Enterococcus spp.* (American Public Health Association [APHA], 1998; WHO, 2022b).

An effective indicator organism for inferring the presence of pathogens should: be universally present in large numbers in human and animal feces; not multiply in natural waters; persist in water similarly to fecal pathogens; be present in higher numbers than fecal pathogens; respond to treatment processes similarly to fecal pathogens; and be detectable by simple, inexpensive methods (WHO, 2008).

The Membrane Filter (MF) technique is widely used to enumerate fecal coliform bacteria in water. The MF consists of a small, circular cellulose acetate membrane that retains bacteria on its surface while allowing water to pass through its pores. Surface tension draws culture media up through the pores to nourish and stimulate bacterial growth on the membrane surface. A major limitation of the MF technique is its reduced effectiveness with water samples containing high levels of suspended solids (Mckinney, 2004).

2.2 Total Coliforms (TC)

Total coliforms are aerobic or facultatively anaerobic, Gram-negative, non-spore-forming, rod-shaped bacteria that ferment lactose to produce acid and gas within 24–48 hours at 35°C. Their ability to grow in natural waters, the lack of consistent correlation with pathogen numbers, and the detection of non-fecal strains limit their reliability as general water quality indicators. Nevertheless, they are commonly used as presumptive indicators of possible fecal contamination. The group includes bacteria of fecal origin (e.g., *E. coli*) and environmental species (e.g., *Klebsiella* spp., *Citrobacter* spp., *Serratia* spp., *Enterobacter* spp.) found in nutrient-rich water, soil, decaying vegetation, and drinking water with elevated nutrient levels (WHO, 2022b). The recommended test for TC enumeration is membrane filtration using m-Endo agar LES, incubated at 35–37°C for 24 hours, producing colonies with a characteristic golden-green metallic sheen (Irshad, 2011).

2.3 Fecal (Thermotolerant) Coliforms (FC)

Fecal coliforms (FC), or thermotolerant coliforms, are a subset of the TC group distinguished by their ability to grow at 44.5°C. Many countries have adopted FC as indicators within their water quality standards, often recommending them for evaluating microbiological quality. FC are more specifically associated with the gastrointestinal tract of warm-blooded animals than total coliforms and generally show a strong correlation with fecal contamination from these sources (APHA, 1998; WHO, 2022b). They are present in virtually all warm-blooded animals, including humans, typically in numbers far exceeding pathogens. However, the FC group includes some species (e.g., *Klebsiella* spp., *Enterobacter* spp., *Citrobacter* spp.) that are not exclusively of fecal origin (Irshad, 2011).

2.3. Source Water Supplies

The World Health Organization (WHO) classifies source water supplies as either improved or unimproved (WHO, 2022c). Improved sources include public taps/standpipes, piped household connections, boreholes or tube wells, protected dug wells, protected springs, and rainwater collection. Unimproved sources include unprotected dug wells, unprotected springs, water provided by carts or tanker-trucks, surface water (rivers, dams, lakes, ponds, streams, canals, irrigation channels), and bottled/sachet water (if secondary use involves another unimproved source) (WHO, 2022c).

Studies in Ethiopia highlight variability in source water quality. In Jimma Zone, Oromia, 40% of protected well samples had bacterial counts below 10 CFU/100ml, and 26.67% were free of fecal coliforms. For protected springs, 60% were free of fecal coliforms, and 46.67% had TTC counts <10 CFU/100ml (Yasin et al., 2015a). In Dire Dawa, 83.34% of samples from protected wells tested positive for indicator bacteria (Amenu et al., 2013). Another study found spring samples and 29.2% of tap samples had high TC loads, while 81.4% of supplies met WHO and Ethiopian Standards for FC (Abera et al., 2014). Unprotected sources in Jimma Zone were universally positive for TC and FC, with FC detected in 80% of all samples (Yasin et al., 2015b). A study in North Gondar found educational status significantly associated with fecal coliform presence in drinking water sources (Getachew et al., 2018).

2.4. Water Handling Practice

Water handling practices significantly impact drinking water safety at the point of use. Various containers are used for collection and storage in developing countries, including clay pots, metal buckets, plastic jerricans, bottles, and tanks (United Nations Children's Fund [UNICEF], 2008). Key factors for safe household water include clean collection and storage practices and the choice of container (WHO, 2022d). Containers should be clean (ideally cleaned with detergent or chlorine), covered to prevent contamination, and water should be poured out rather than dipped to avoid contact with hands; scoops, if used, must be clean and stored within the covered container (Ahmed, 2017).

Studies in Ethiopia demonstrate common practices: In South Wollo, 73.4% of households rinsed collection containers, 92.7% covered storage vessels, but 72% drew water by dipping (Ahmed, 2017). In Dire Dawa's Adada village, jerricans (59.37%) and clay pots (40.63%) were common; 93.75% withdrew water by dipping (Amenu, 2013). In Tehuledere, Amhara, clay pots (54.7%) and jerricans (44.7%) were used; 92.7% covered containers, but 72% drew water by dipping (Seid, 2003). In Jimma Zone, 70.4% dipped water, with 52.2% using handle less cups (Ahmed, 2017).

Safe source water does not guarantee safe consumption, as contamination frequently occurs during collection, transport, storage, and drawing in the home (UNICEF, 2008; Ahmed, 2017). Numerous studies show that inadequate storage conditions and vulnerable containers contribute to increased microbial contamination compared to the source. Research in Northeast Thailand indicated a higher risk of fecal coliform ingestion from household cross-contamination than from source pollution, with mean counts significantly higher in stored water than in well water (Ahmed, 2017).

Factors affecting bacteriological quality include water storage/handling practices, hygiene practices, and water treatment. Sociodemographic factors (e.g., sex, age, marital status, occupation, education) indirectly and directly influence these practices and treatments (Cohen et al., 2015) (Figure 1).

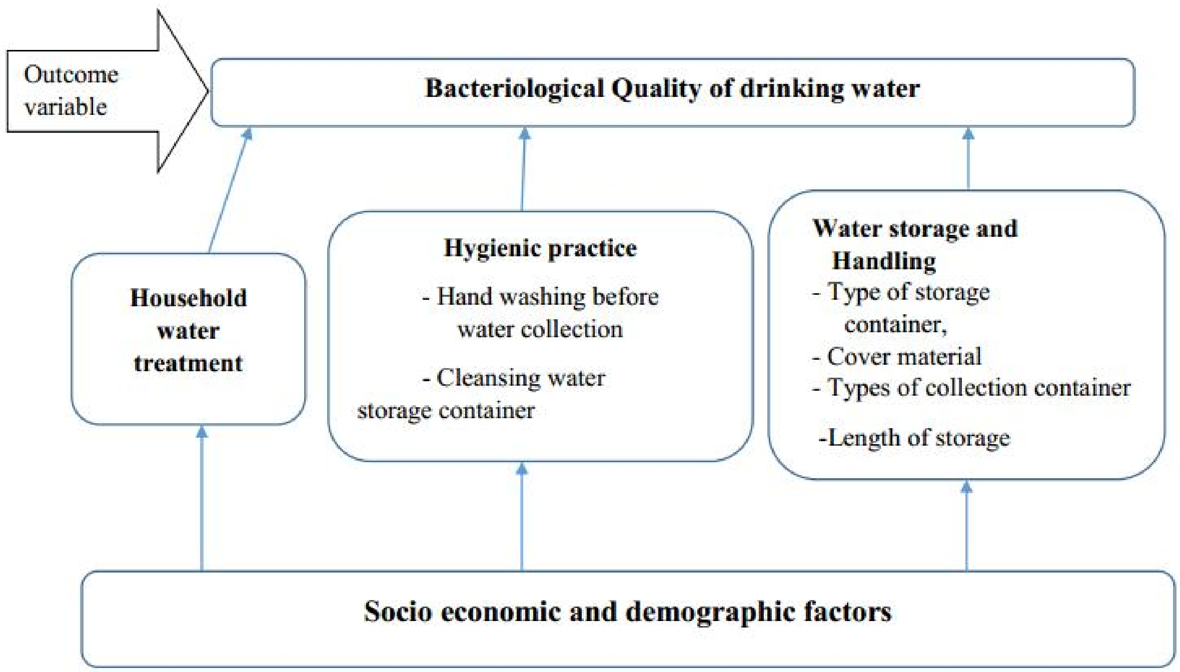

Figure 1 Conceptual frame work of bacteriological quality of drinking water

Source: (Cohen, Tao et al.2015).

2.5. WHO and Ethiopian Standards of Drinking Water Quality

Water safety gained prominence on the international agenda following the 1972 UN Conference on the Human Environment in Stockholm. The WHO Guidelines for Drinking-water Quality (GDWQ) advocate protecting public health through Water Safety Plans (WSPs) (WHO, 2022e).

2.5.1. Maximum Permissible Level

The maximum permissible level is a critical threshold; exceeding it renders water unfit for drinking and domestic use due to probable health hazards.

WHO risk categories based on thermotolerant coliform counts per 100ml are (Michael, 2006; Meseret, 2012; WHO, 2022e):

Table 1.Water Quality Risk Categories Based on Thermotolerant Coliform Counts

Count per 100 ml	Risk Category	Risk Score	Description
0	Conformity	A	In conformity with WHO
1 – 10	Low	B	Low risk
11 – 100	Intermediate	C	Intermediate risk
101 – 1000	High	D	High risk
>1000	Very High	E	Very high risk

The Ethiopian Standard (ES) specifies the following bacteriological requirements for treated drinking water (Ministry of Health [Ethiopia], 2011):

Table 2.Ethiopian Bacteriological Standards for Safe Drinking Water

Organism	Maximum permissible level	Testing method
Total viable count/100ml	Must not be detectable	ES ISO 483
Fecal *streptococci*/100ml	Must not be detectable	ES ISO7899-1 ES ISO7899-2
Coliform organisms/100ml	Must not be detectable	ES ISO 9308-1
E. coli/100ml	Must not be detectable	ES ISO 9308-1 ES ISO 9308-2

Source: Ministry of Health [Ethiopia]. (2011). National drinking water quality monitoring and surveillance strategy. Addis Ababa.

3 MATERIALS AND METHODS

3.1 Description of the Study Area

This study was conducted in selected rural kebeles of Habru District, situated within the North Wollo Administrative Zone of the Amhara National Regional State, Ethiopia. Geographically, the district is located approximately between 11°30' and 12°00' North latitude and 39°30' and 40°00' East longitude (Habru WoARD, 2016), with an average elevation of 1500 meters above sea level (masl) (SARC, 2015). Habru District shares borders with the Mille River to the south (separating it from South Wollo), Gubalafto Woreda to the west, the Alawuha River to the north (separating it from Kobo Woreda), and the Afar Regional State to the east (Habru WoARD, 2016). The administrative center is Mersa town, located 491 km northeast of Addis Ababa and 30 km south of Woldia, the zonal capital (Habru WoARD, 2016). The district encompasses a total area of 1,239.79 km² (123,979 hectares), administratively divided into 36 rural kebeles and 3 sub-urban kebeles (Habru WoARD, 2016).

Climatically, the district experiences a mean annual maximum temperature of 28.5°C and a mean annual minimum temperature of 15°C (SARC, 2015). Rainfall is characterized as erratic, with an annual average of approximately 300 mm, but varying considerably, sometimes ranging between 600 mm and 1200 mm (SARC, 2015).

Based on projections from the 2007 national census conducted by the Central Statistical Agency (CSA), the district's total population in 2016/17 was estimated at 235,347, reflecting a 22.1% increase since 2007 (CSA, 2013). This population comprised 118,088 males and 117,259 females. The projected urban population was 37,659, representing 16% of the district's total population and indicating a 74.34% increase in the urban population since 2007 (CSA, 2013).

The rural economy of Habru District is predominantly based on mixed crop-livestock farming systems, characterized by traditional practices (Habru WoARD, 2016). Major cultivated crops include teff (Eragrostis tef) and sorghum (Sorghum bicolor) (Habru WoARD, 2016). Livestock production primarily involves cattle, goats, and camels (Habru WoARD, 2016).

Agriculture faces challenges related to unreliable rainfall patterns and other factors, impacting productivity (Habru WoARD, 2016).

The primary drinking water sources for domestic use in the district include public taps, protected springs, unprotected springs, protected hand-dug wells, unprotected hand-dug wells, and protected hand pumps (boreholes) (Habru WoARD, 2016). Among these, unprotected springs and wells are frequently reported as major sources, particularly in rural areas (Habru WoARD, 2016). Common challenges identified in the nine study sites include inadequate access to clean drinking water, insufficient water for agricultural and household activities, and a lack of sufficient sanitary facilities (Habru WoARD, 2016).

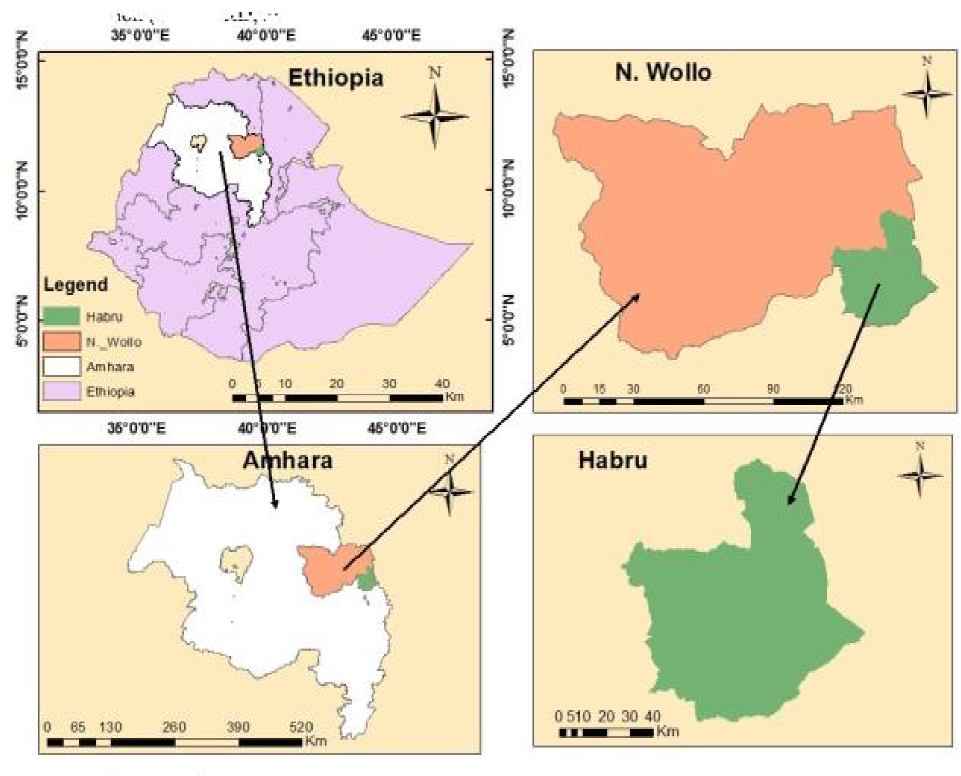

Figure 2 Map of the Study Area

Source; GIS map (2017) of Agricultural Center in Habru district.

3.2 Study Design

A community-based cross-sectional study design was employed to assess bacteriological contamination levels in household drinking water at point-of-use, evaluate water handling practices, and assess sanitary conditions around source water points in selected rural kebeles of Habru District. Data collection occurred from February 2024 to June 2024.

3.3 Source and Study Population

The source population comprised all households within the 36 rural kebeles of Habru District. The study population consisted of households (N ≈ 4230) systematically selected from nine randomly chosen rural kebeles.

3.4 Inclusion and Exclusion Criteria

Households were included if at least one adult member (≥18 years) had resided there for a minimum of six months prior to the study. Households were excluded if no adult member was available, willing, or able (e.g., due to critical illness or severe mental impairment hindering communication) to participate during the data collection period.

3.5 Sample size Determination

The initial sample size was calculated using Cochran's formula for single population proportion (Cochran, 1977) with the assumptions: 95% confidence level (Z = 1.96), 5% margin of error (d = 0.05), expected proportion (p) of 0.5 (due to absence of prior local studies), and a 10% adjustment for non-response:

$$n_0 = \frac{z2\alpha / 2p\,(1 - p)}{d^2}$$

n_0 = population size

Z = 95% confidence limit (z-value at $\alpha = 0.05$ is 1.96)

P (population proportion) = 0.5, 1-P = 0.5

D = Marginal error or degree of accuracy = 0.05

Then, $n_0 = 384$

Adjustment for non-response: $n = n_0 / (1 - \text{non-response rate}) = 384/ 0.90 \approx 427$.

Given the finite source population size (N ≈ 4230 households identified during piloting), Yamane's formula (Yamane, 1967) was applied for final adjustment:

$n\_final = N / (1 + N*(e^2)) = 4230 / (1 + 4230*(0.05^2)) \approx 352.5$ (where e = margin of error = 0.05). Considering logistical feasibility and rounding, a final target sample size of 360 households was set.

3.6 Sampling Technique

The study employed a multi-stage sampling approach to select participating kebeles, households, and water sources. In the first stage, nine rural kebeles (representing 25% of the district's 36 rural kebeles) were selected using simple random sampling. The selected kebeles were Goffacho, Mehalaba, Molekise, Abiwotfre, Libso, Chekorsa, Awera, Kule, and Jara. The target sample size of 360 households, determined in section 3.5, was then allocated to these nine kebeles proportionally based on the number of households in each kebele, using Probability Proportional to Size (PPS) allocation. This ensured kebeles with larger populations contributed more households to the sample.

Within each selected kebele, households were systematically sampled from official kebele administration lists. A sampling interval (k) was calculated for each kebele based on its allocated household sample size and total household count, and households were selected at regular intervals (e.g., every k^{th} household) starting from a random point on the list.

For water source assessment, the four most frequently utilized source types within each selected kebele (protected well, protected spring, unprotected spring, and public tap) were first identified. Subsequently, one functional source of each identified type was randomly selected within each kebele for sampling. This yielded a total of 36 source water samples (9 kebeles × 4 source types).

Finally, for bacteriological analysis of household stored water, a subset of the systematically selected households within each kebele was sampled. Water samples were collected from the storage vessels of every 4^{th} household selected in the systematic household sample list for each kebele. This approach facilitated the collection of household water samples aligned with the broader household survey while ensuring manageable laboratory workload.

3.7 Water Sampling Procedure

Water samples were collected following standardized aseptic techniques for both source and household points. Source water samples (100ml) were collected directly from the point of discharge (e.g., tap outlet, spring eye, well bucket) into pre-sterilized 100ml polyethylene bottles, adhering to established protocols (APHA et al., 2017; WHO, 2022a). Household drinking water samples (100ml) were collected from the main storage vessel within the home. This was done either by using a pre-sterilized dipper to transfer water into a pre-sterilized polyethylene bottle or, where applicable, by aseptically collecting water directly from the vessel's spout into the bottle (APHA et al., 2017). Immediately after collection, all samples were clearly labelled and placed in a dark cooler containing ice pack to maintain a temperature of approximately 4°C during transport. Samples were transported promptly to the microbiology laboratory at Woldia University for analysis.

Upon arrival at the laboratory, samples were processed within 4 hours of collection. Bacteriological analysis was performed using the membrane filtration method as described in Standard Methods (APHA et al., 2017). To ensure the validity of results and monitor potential contamination introduced during sampling or handling, stringent quality control measures were implemented. Specifically, one field blank (sterile distilled water) was processed identically to the actual water samples for every batch of 20 samples collected. In total, 36 water samples were collected from the identified sources across the nine kebeles, and 243 water samples were collected from household storage vessels for bacteriological analysis.

3.8 Data Collection Tools and Procedures

Data collection employed multiple tools administered by trained personnel. A structured household questionnaire, administered face-to-face by trained enumerators, was used to gather information from one adult respondent (≥18 years) per selected household. The questionnaire covered key domains including socio-demographic characteristics, water collection methods, transport practices, storage container types and handling, point-of-use treatment, and general water handling behaviors. This instrument was developed in English, drawing upon WHO core questions for drinking water, sanitation, and hygiene in household surveys (WHO, 2022b) and relevant literature. To ensure clarity and cultural appropriateness, the questionnaire underwent translation into Amharic (the local language), pre-testing, back-translation into English to check consistency, and final refinement.

Sanitary conditions around the selected water sources were assessed using an observational checklist. This checklist was adapted from WHO sanitary inspection forms tailored to specific source types (e.g., springs, wells, taps) (WHO, 2022c). The checklist included items such as evidence of animal access, presence of drainage, structural integrity, and visible fecal contamination near the source. Sanitary risk scores derived from these observations were categorized according to WHO guidelines: 0-2 indicated Low risk, 3-5 indicated Intermediate risk, 6-8 indicated High risk, and 9-10 indicated Very High risk (WHO, 2022c). Standardized water sampling record forms were used to document essential metadata for each collected water sample, including precise location, date, time, source type, container type observed at the household, and sample identification code.

3.9 Variables

3.9.1 Dependent variable

The dependent variable was water quality, quantified by counts of total coliform (TC) and fecal coliform (FC) per 100-milliliter sample (reported as colony-forming unit, CFU/100mL).

3.9.2 Independent variable

Independent variables included three categories: socioeconomic/demographic characteristics of respondents, sanitary conditions of drinking water sources, and household water handling practices.

3.10 Bacteriological Analysis

3.10.1 Membrane filter technique

Bacteriological water quality, specifically total coliform (TC) and fecal coliform (FC) concentrations, was analyzed using the membrane filtration (MF) technique according to

Standard Methods 9222 (APHA et al., 2017). This method determines the degree of fecal contamination by quantifying indicator bacteria.

Each water sample was homogenized by vigorous shaking for a minimum of 30 seconds immediately prior to analysis. A measured 100mL aliquot (or an appropriate dilution prepared with sterile phosphate-buffered dilution water; APHA et al., 2017) was filtered through a sterile, 0.45-µm pore size, grid-marked membrane filter housed within a filter funnel assembly connected to a vacuum source. The funnel walls were rinsed with 20-30mL of additional sterile dilution blank to ensure complete transfer of bacteria to the membrane. After filtration, the vacuum was disengaged, the funnel was unlocked and removed, and the membrane filter was aseptically transferred using sterile flamed forceps onto the surface of a solidified, selective culture medium. To avoid air entrapment, the membrane was placed with a rolling motion.

Total Coliform Analysis: Membranes were placed on m-Endo agar LES (APHA et al., 2017). Petri dishes were inverted and incubated at 35.0°C ± 0.5°C for 22-24 hours within a humidified chamber.

Fecal Coliform Analysis: Membranes were placed on m-FC agar (APHA et al., 2017). Petri dishes were inverted and incubated in a water bath at 44.5°C ± 0.2°C for 22-24 hours.

Following incubation, colonies exhibiting characteristic morphology were enumerated. For TC on m-Endo agar, typical colonies appear red or pink with a metallic (gold-green) sheen (APHA et al., 2017). For FC on m-FC agar, typical colonies are blue (APHA et al., 2017). Colonies were counted using a binocular dissecting microscope (10-15x magnification) with an oblique light source. Counts were recorded as colony-forming units (CFU) per 100mL of sample. Quality control measures, including analysis of sterile dilution blanks (negative controls) and laboratory-fortified blanks (positive controls), were performed concurrently with each sample batch to ensure method validity (APHA et al., 2017).

3.10.2 Multiple tube method

The multiple tube fermentation technique was used to quantify total coliforms (TC) and fecal coliforms (FC) following Standard Methods 9221 (APHA et al., 2017). Serial dilutions of samples were inoculated into lauryl tryptose broth with Durham tubes. After 24-48 hours incubation at 35°C ± 0.5°C, gas production indicated presumptive TC presence. Positive tubes were confirmed using brilliant green lactose bile broth incubated at 35°C ± 0.5°C for 48 hours (APHA et al., 2017). For FC confirmation, positive tubes were subcultured in EC broth and incubated at 44.5°C ± 0.2°C for 24 hours. Results were interpreted using Most Probable Number (MPN) tables (APHA et al., 2017). Escherichia coli was confirmed by growth on eosin methylene blue agar.

3.10.3 Membrane Filter Calculation

Colony counts were calculated according to Standard Methods 9222 (APHA et al., 2017). For reliable quantification, total coliform (TC) counts were considered valid within the range of 20 to 80 colonies per membrane filter, while fecal coliform (FC) counts required 20 to 60 colonies per filter. Final concentrations were expressed as colony-forming units per 100 milliliters (CFU/100mL), calculated using the formula: (Number of colonies counted × 100) / Volume of sample filtered (in milliliters). Based on the resulting CFU/100mL values, samples were classified into risk categories: concentrations below 1 CFU/100mL were classified as 'Excellent' quality (WHO, 2022); values between 1 and 10 CFU/100mL were deemed 'Acceptable' per Ethiopian national standards (FDRE MoWR, 2005); counts ranging from 11 to 50 CFU/100mL were categorized as 'Unacceptable' (FDRE MoWR, 2005); and samples exceeding 50 CFU/100mL were classified as 'Grossly polluted' (WHO, 2022).

3.11 Operational Definition

Good water handling practices: Performance of ≥3 key behaviors: rinsing collection containers, using covered storage, pouring (not dipping), handwashing before collection, or point-of-use treatment (Abebe & Dejene, 2015; WHO, 2022).

Household: Co-residing individuals acknowledging one head, sharing housekeeping (CSA, 2013).

Hand washing: Mechanical removal of pathogens using soap and running water (Getnet et al., 2017).

Critical hand washing times: Before food handling/after defecation (Getnet et al., 2017).

Contamination risk levels:

- High: Sanitary risk score 8–12 (Howard, 2002)
- Medium: Score 5–7 (Howard, 2002)
- Low: Score 1–4 (Howard, 2002)

Household water treatment: Point-of-use pathogen reduction methods (Alemeshet et al., 2018).

Waterborne diseases: Illnesses caused by fecal-oral pathogen transmission (e.g., cholera, typhoid, hepatitis A) (WHO, 2017).

3.12 Data Quality Control

Enumerators received 3-day training including pretesting with 5% of the sample size in a comparable kebele *(*sub district) excluded from the main study. Supervisors verified completeness before data entry.

3.13 Data Processing and Analysis

Data were analyzed in SPSS 28.0 (IBM Corp., 2021). Descriptive statistics summarized frequencies. Water quality results were compared against WHO (2022) and FDRE MoWR (2005) standards. After confirming normality (Shapiro-Wilk test) and homogeneity of variance (Levene's test), ANOVA with Tukey post-hoc testing identified spatial differences ($\alpha=0.05$).

3.14 Ethics

Ethical clearance was obtained from the institutional ethical clearance review committee of Woldia University. After thoroughly discussing the ultimate purpose and method of the study, a written consent was obtained from all respondents. The privacy and confidentiality were maintained during the interview. Participation in the study was based on willingness and the participants had the full right not to participate.

4 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Sociodemographic characteristics and Association with water handling

A 100% response rate was achieved through complete participation of all 81 targeted households. The mean respondent age was documented as 28.00 years (±3.3 SD). Females constituted 76.5% of participants, a distribution consistent with national trends in water management responsibilities (CSA, 2017). Marital status analysis indicated 61.7% were married. Occupational categorization revealed 35.8% were farmers, 13.6% merchants, 12.3% government employees, and 38.3% engaged in other occupations. Educational attainment was distributed as follows: 32.1% had received no formal education, 38.3% attained primary education, and 29.6% achieved high school or higher qualifications.

Key household patterns were observed: 61.7% contained ≤5 family members, while 59.3% reported monthly incomes ≤ ETB 2000. Significant associations with water handling practices were identified. Safe water handling was practiced by 87.5% of respondents with high school education or above, contrasting with 42.3% among those without formal education (*p*<0.001). Similarly, 90.9% of higher-income households (>ETB 2000/month) demonstrated safe handling versus 28.6% of low-income households (≤ETB 500/month) ($p<0.001$). Smaller households (≤5 members) exhibited safer practices (74.0%) compared to larger households (>5 members, 61.3%; $p=0.032$).

These findings align with Fenet (2016), confirming education and income as significant predictors of water safety behaviors. The association between smaller household size and improved practices was consistent with Matusala (2020). Collectively, educational access, economic capacity, and family structure were established as key determinants of water handling quality in Habru District.

Table 3 Association Between Sociodemographic characteristics and water handling practices in rural Habru district, North Wollo Zone, Ethiopia, February 2024 (n=81).

Variable	Category	Frequency	Water handling	
			Good	Poor
Age	18-24	38	20	18
	25-29	25	15	10
	30-34	7	5	2
	35-39	4	2	2
	.>40	7	5	2
Sex	Male	19	10	9
	Female	62	32	30
Educational level	No formal education	26	11	15
	Primary	31	19	12
	High school and above	24	21	4
Occupation	Government employee	10	7	3
	Farmer	29	16	13
	Merchant	11	10	3
	Others	31	17	14
Marital status	Married	50	25	25
	Single	28	18	10
	Divorced and Widowed	3		1
Family size	≤5	50	37	13
	>5	31	19	12
Income per month	500	7	2	5
	501-1000	9	4	5
	1001-1500	6	3	3
	1501-2000	26	16	10
	>2000	33	30	3

4.1.2 Water handling practice

Concerning water collection and storage Practices, water collection was primarily conducted using jerricans (94.6%), while clay pots were used by 5.4% of households. Storage containers were covered in 92.6% of cases but left uncovered in 7.4%. Water was transferred by dipping in 69.0% of households and pouring in 31.0% (Table 4).

Regarding hygienic practices, collection containers were rinsed by 73.4% of households, and hands were washed before water collection by 64.1%. Storage containers were regularly washed before use by 72.5%. These results indicate moderate awareness of hygienic practices, though critical gaps persisted.

Utensil Storage and Treatment Methods: Drinking cups were placed on the floor (45.8%), tables/shelves (26.6%), walls (8.9%), storage covers (12.5%), or inside containers (6.3%). This aligns with findings from Tehuledere, where 73.4% stored utensils non-hygienically (Seid, 2003). Most households (60.0%) stored water for ≤1 day. Water treatment was applied by 66.5% of households; settling (44.4%), boiling (7.4%), chlorine (9.9%), and filtering (4.9%) were the primary methods.

Regarding hand washing and contamination Risks: Hand washing after toilet use was reported by 74.1% of respondents. However, only 38.8% had dedicated hand washing stations with soap and water, a higher rate than Kola Diba (soap use: 46.1%; Yimam, 2013), though methodologies differed. Risk assessment categorized households as high (40.5%), medium (29.5%), or low (30.0%) risk, likely due to inadequate hygiene awareness and unsafe practices (e.g., floor-level utensil storage). These practices may exacerbate fecal contamination of drinking water.

Table 4 Household water handling practices in rural Habru district, North Wollo Zone, Ethiopia, February 2024 (n=81).

Variable	Number	Percent
Type of water collection container		
Clay pot	4	5.4
Jerricans	77	94.6
Presence of cover for water storage container		
Yes	75	92.6
No	6	7.4
Wash water storage container before washing		
Yes	59	72.5
No	22	27.5
Hand washing practices before water collection		
Yes	52	64.1
No	29	35.9
Collection container rinsing/washing		
Yes	59	73.4
No	22	26.6
Transfer of water from storage vessel		
Pouring	25	31.0

Dipping	56	69.0
Frequency of water collection		
Every other day	3	3.1
Once per day	24	29.7
Twice a day	44	54.2
More than twice	10	13.0
Duration of water storage at household		
A day and less	49	60.0
More than a day	32	40.0
Type of water storage container		
Clay pot	30	37.3
Jerricans	51	62.7
Placement of water drawing utensils		
Tables and/or shelves	22	26.6
Storage cover	10	12.5
Inside the container	5	6.3
Hang on wall	7	8.9
Floor	37	45.8
Types of household water treatment		
Boiling	6	7.4
filtering	4	4.4
Chlorine	8	10
Allowing water to settle	36	44.4
No treatment	27	33.5
Wash hands after visiting a toilet		
Yes	60	74.1
No	21	25.9
A place for washing hands with water and with cleaning agent		
Yes	31	38.8
No	50	61.2
Latrine availability	18	21.8

4.1.3 Source-level contamination

Of 36 water sources, 25.0% (n=9) were classified as excellent (Class A: 0 CFU/100ml), 25.0% (n=9) as acceptable (Class B: ≤10 CFU/100ml), 33.3% (n=12) as low quality (Class C), and 16.7% (n=6) as grossly polluted (Class D) per WHO standards (WHO, 2022). Total coliform (TC) or fecal coliform (FC) contamination was detected in 66.7% of sources (Table 5). The highest TC counts were recorded at Awera unprotected spring (112 CFU), Molekise protected well (100 CFU), and Jara unprotected spring (97 CFU). Elevated contamination was strongly associated with very high sanitary risk scores at Awera unprotected spring (score 9) and Molekise protected well (score 8), whereas protected springs in Libso and Kule exhibited minimal risk (score 1).

Mean TC counts were highest in unprotected springs (61 CFU) and protected wells (60 CFU), exceeding levels reported in Bahir Dar (mean: 35.5 CFU; Getnet, 2008). This disparity may reflect inadequate source protection, observed unsanitary overflow, and animal waste discharge in Habru district—a pattern consistent with rural Ethiopian communities (Desalegn et al., 2014). Notably, contamination rates were lower than in Yubdo-Legebatu (max: 1447 CFU; Birhanu, 2008), likely due to differences in source infrastructure.

Among 243 household samples, 67.5% were classified as high-risk for contamination, though no samples exceeded 100 CFU (Annex 1). This high-risk prevalence underscores vulnerability to waterborne diseases (e.g., cholera, typhoid) despite moderate CFU counts, aligning with poor handling practices identified in Section 4.1.2.

Adequately protected sources (e.g., Libso public tap: 0 CFU, score 2) demonstrated superior bacteriological quality. Conversely, infrastructure deterioration and poor site selection—evidenced at Molekise protected well (100 TC, score 8)—were identified as critical contamination pathways. These findings emphasize that source protection alone is insufficient without maintenance and user hygiene (Abebe & Dejene, 2015).

Table 5 Bacteriological and sanitary risk analysis of drinking source water supplies in rural Habru district, North Wollo Zone, Ethiopia, February 2024.

		CFU/ 100ml of water			
Study site	Sources	TC	FC	Water quality Grade	Sanitary risk score
Goffacho	Protected well	35	40	C	7
	Protected spring	49	50	B	2
	Public tap	0	0	A	2
	Unprotected spring	90	87	D	7
Awera	Protected well	100	80	D	7
	Protected spring	79	0	A	2
	Public tap	79	0	B	3
	Unprotected spring	112	89	D	9
Kule	Protected well	0	31	C	5
	Protected spring	0	0	A	1

	Public tap	70	0	B	4
	Unprotected spring	64	5	C	4
Jara	Protected well	76	35	D	6
	Protected spring	0	78	C	5
	Public tap	0	0	A	2
	Unprotected spring	97	91	C	4
Mehalaba	Protected well	52	0	C	3
	Protected spring	84	88	C	5
	Public tap	0	54	B	2
	Unprotected spring	82	0	B	2
Molekise	Protected well	100	95	D	8
	Protected spring	96	99	D	7
	Public tap	0	0	A	2
	Unprotected spring	0	0	A	2
Libso	Protected well	32	37	C	4
	Protected spring	0	0	A	1
	Public tap	0	0	A	3
	Unprotected spring	46	73	B	3
Chekorsa	Protected well	76	80	C	5
	Protected spring	0	0	B	3
	Public tap	0	0	A	2
	Unprotected spring	90	99	C	5
Abiwotfre	Protected well	0	50	B	3
	Protected spring	34	62	C	5
	Public tap	29	78	C	5
	Unprotected spring	49	0	B	2

4.1.4 Analysis of variance among TC and FC in all water samples

Significant differences in mean total coliform (TC) and fecal coliform (FC) counts across water sampling points were assessed using ANOVA at $\alpha=0.05$. Four primary groups were evaluated: protected wells (PW), protected springs (PS), public taps (PT), and unprotected springs (US), with samples collected at source, collection vessels, storage, and point-of-use ($n=144$).

A statistically significant difference in mean TC counts was observed between sites ($F=18.39$, $df=4$, $p<0.01$) (Table 6). The highest mean TC contamination was identified in unprotected springs (61 CFU/100ml) and protected wells (60 CFU/100ml), while public taps demonstrated the lowest (20 CFU/100ml). This variation aligns with sanitary survey data showing frequent livestock access and use of unclean drawing utensils at high-contamination sites.

Similarly, a significant difference in mean FC counts was detected ($F=20.37$, $df=4$, $p<0.01$) (Table 6). Protected wells exhibited the highest mean FC counts (50 CFU/100ml), followed by unprotected springs (51 CFU/100ml). These results are consistent with reports of open defecation near water sources and absent perimeter fencing (100% of households grazed livestock near sources).

A marked increase in contamination was noted between sources and households. While 75% of sources (27/36) were TC/FC-positive, 100% of household samples (243/243) tested positive. A separate ANOVA confirmed significantly higher mean TC/FC counts at household points (storage/use) compared to sources ($p<0.05$), attributable to poor handling practices during collection and storage. Specifically, 87.5% of fecally contaminated household cups originated from safe sources, and 22.5% of point-use samples exceeded source contamination levels.

The pervasive contamination of protected springs (55.5% FC-positive) contrasts with lower rates in South Wello (75% TC-positive; Atnafu, 2006) but aligns with Farta woreda, where 83.3% of protected springs exceeded WHO guidelines (Kassie & Hayelom, 2017).

Household samples were categorized as low-risk (23%) or intermediate-risk (72%) for FC. This gradient—combined with 100% contamination prevalence—confirms high vulnerability to waterborne diseases (e.g., cholera, typhoid), necessitating interventions at collection, storage, and use stages.

Table 6 ANOVA of TC and FC among source and household water samples.

Parameter	Groups	Sum of Square	Mean Square	DF	F value	P value
TC	Between groups (combined)	1782549	445637.3	4	18.39	< 0.01
	With in groups	3368331.4	24232.6	139		
	Total	5150880.4	469869.9	143		
FC	Between groups (combined)	1576673	394168.3	4	20.37	< 0.01
	Within groups	2689705.6	19350.4	139		
	Total	4266378.6	413518.7	143		

DF= degree of freedom, TC= total coliform, FC= fecal coliform

4.1.5 Household-level contamination

After samples from collection vessels (n=81) exhibited mean total coliform (TC: 53 CFU/100ml) and fecal coliform (FC: 50 CFU/100ml) counts exceeding the WHO low-risk threshold of ≤10 CFU/100ml (WHO, 2022). A significant association was observed between container rinsing and reduced TC contamination, with rinsed containers demonstrating higher proportions of low-risk samples (39/59 ≤10 CFU) compared to non-rinsed containers (8/22 ≤10 CFU; $p<0.05$). Similarly, hand washing prior to collection was associated with lower contamination levels (hand washers: 18/34 ≤10 TC CFU vs. non-hand washers: 9/29 ≤10 TC CFU; $p<0.05$). Clay pots were found to have significantly lower contamination than jerricans (3/4 vs. 25/77 ≤10 TC CFU; $p<0.05$), attributed to their ease of cleaning. These findings are consistent with research from Tehuledere Woreda, where inadequate rinsing and hand hygiene were linked to elevated contamination (Seid, 2003).

Table 7 Contamination level of total coliform and fecal coliform counts from collection vessel by water handling practice (n=81).

Variables	TC counts 100ml		FC counts 100ml		P value
	≤ 10	>10	≤ 10	>10	
Collection container rinsing					<0.05
Yes	39	20	40	19	
No	8	14	9	13	
Hand washing practice when collecting water					<0.05
Yes	18	34	20	32	
No	9	20	12	17	
Type of collection container					<0.05
Clay Pots	3	1	3	1	
Jerricans	25	52	30	47	

Further contamination escalation was documented at storage (mean TC: 55 CFU; FC: 65 CFU). Significant risk reduction was associated with: 1) water treatment (37/54 ≤10 TC CFU in treated vs. 8/27 in untreated; $p<0.05$), 2) shorter storage duration (≤1 day: 19/49 ≤10 TC CFU vs. >1 day: 19/32 ≤10 TC CFU; $p<0.05$), and 3) elevated utensil placement (16/22 ≤10 TC CFU on tables/shelves vs. 11/36 on floors; $p<0.05$). Contrary to collection-phase results, jerricans outperformed clay pots during storage (36/53 vs. 7/30 ≤10 TC CFU; $p<0.05$), aligning with studies from Tamale, Ghana highlighting jerricans' superior contamination resistance (Daniel, 2013).

Table 8 Contamination level of TC and FC counts from storage conditions by water handling practice (n=81).

Storage condition	TC counts per 100ml		FC counts per 100ml		P value
	≤10	>10	≤10	>10	
Transfer of water from storage vessel					<0.05
Pouring	16	9	13	10	
Dipping	15	40	16	40	
Placement of drawing utensils					<0.05
Table	16	6	12	11	
Floor	11	25	10	27	
Duration of water storage at household					<0.05
A day and less	19	30	20	29	
More than a day	19	13	17	15	
Type of water storage container					<0.05
Clay pot	23	7	20	10	
Jerricans	15	36	15	36	
Household water treatment usage					<0.05
Treatment	37	17	31	23	
No Treatment	8	19	10	17	

Peak contamination occurred at point-of-use (mean TC: 71 CFU; FC: 64 CFU), with only 12.5% of samples meeting WHO low-risk standards. Significant contamination reduction was achieved through pouring (16/25 ≤10 TC CFU) versus dipping (15/56 ≤10 TC CFU; $p<0.05$) and non-floor utensil storage (15/28 ≤10 FC CFU on tables vs. 13/37 on floors; $p<0.05$). Critically, 30% of contaminated point-of-use samples originated from bacteriologically safe sources (Annex 1), confirming substantial post-collection degradation.

A progressive contamination increase was evidenced across handling stages: 82.5% of collection vessels and 87.5% of point-of-use samples exceeded WHO safety thresholds despite source quality. Primary contamination vectors included dipping practices (introducing hand-borne pathogens), floor-level utensil storage, and inadequate pretreatment. These practices collectively elevate intermediate/high-risk exposure to waterborne diseases (e.g., cholera, typhoid) (WHO, 2017), particularly where 30% of safe-source water became contaminated during household handling. This demonstrates that infrastructure improvements alone are insufficient without concurrent hygiene behavior interventions.

Table 9 Contamination level of TC and FC counts from point-of-use by water handling practice (n=81).

Variables	TC counts per 100 ml		FC counts per 100 ml		P value
	≤10	>10	≤10	>10	
Water transferred from storage vessel					<0.05
Pouring	16	9	18	7	
Dipping	15	41	20	36	
Placement of drawing utensils					<0.05
Table	16	6	15	7	
Floor	11	26	13	24	

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Water safety in Habru District is critically compromised by both contaminations of sources and poor household handling practices, leading to universal contamination of water at the point-of-use. Key determinants include low education/income levels, larger household size, inadequate source protection/maintenance, and unsafe practices during collection (e.g., lack of rinsing/hand washing), storage (e.g., long duration, floor placement), and use (e.g., dipping). Contamination escalates significantly from source to point-of-use, with 30% of safe-source water becoming contaminated in households.

5.2 Recommendation

To improve the quality of drinking water in rural areas of Habru district:

- Targeted Hygiene Education: Implement community-based programs focusing on:
    - Mandatory container rinsing and hand washing before water collection.
    - Safe water drawing (pouring, not dipping) and use of designated clean cups.
    - Proper storage: using jerricans, treating water (e.g., chlorination, boiling), storing for ≥1 day, and keeping containers elevated off floors.
- Source Infrastructure Improvement & Maintenance:
    - Prioritize rehabilitation of high-risk sources (e.g., Awera spring, Molekise well) based on sanitary risk scores.
    - Enforce strict protection measures (e.g., fencing, diversion ditches) for springs and wells, particularly preventing livestock access and surface runoff.
    - Establish regular maintenance schedules for protected sources (springs, wells, and taps).
- Promotion of Optimal Containers:
    - Encourage clay pots for water *collection* due to ease of cleaning.

    - Promote jerricans for water *storage* due to better contamination resistance.
- Socioeconomic Support:
    - Integrate water safety messaging into broader poverty reduction and adult education initiatives to address the strong link between low income/education and unsafe practices.
    - Explore subsidies for affordable water treatment products (e.g., chlorine tablets) for low-income households.
- Strengthen Surveillance & Community Engagement:
    - Establish simple, community-led water quality monitoring (e.g., using H2S vials).
    - Form water safety committees to promote maintenance, monitor practices, and sustain behavior change.

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7 ANNEXS

Annex 7.1 Table show bacteriological analysis of drinking water from source to household

		At source		Collection vessel		Storage		Consumption point	
Study site	Sources	TC	FC	TC	FC	TC	FC	TC	FC
Goffacho	Protected well	35	40	32	79	0	80	62	99
	Protected spring	49	50	27	67	0	51	43	32
	Public tap	0	0	8	0	9	0	6	21
	Unprotected spring	90	87	60	12	24	31	42	35
	H5			73	41	0	10	0	36
	H6			12	40	6	9	43	79
	H7			0	47	31	35	25	27
	H8			25	81	20	32	19	68
	H9			31	23	16	12	26	0
Awera	Protected well	100	80	66	36	38	39	31	41
	Protected spring	79	0	49	58	32	0	29	80
	Public tap	79	0	60	0	0	8	11	0
	Unprotected spring	112	89	8	0	51	42	65	64
	H5			7	21	20	32	41	50
	H6			12	9	5	3	23	19
	H7			8	6	30	35	25	27
	H8			0	8	20	65	40	31
	H9			31	23	16	12	26	18
Kule	Protected well	0	31	0	11	20	0	31	20
	Protected spring	0	0	54	21	44	59	26	0
	Public tap	70	0	10	7	11	0	13	61
	Unprotected spring	64	5	89	14	9	0	60	54
	H5			14	21	20	12	41	50
	H6			0	9	0	7	21	19
	H7			8	6	30	35	25	27
	H8			4	8	0	6	64	71
	H9			31	20	16	12	26	78
Jara	Protected well	76	35	6	16	10	0	32	81
	Protected spring	0	78	9	6	34	19	31	0
	Public tap	0	0	10	0	0	7	11	63
	Unprotected	97	91	23	14	51	42	65	44

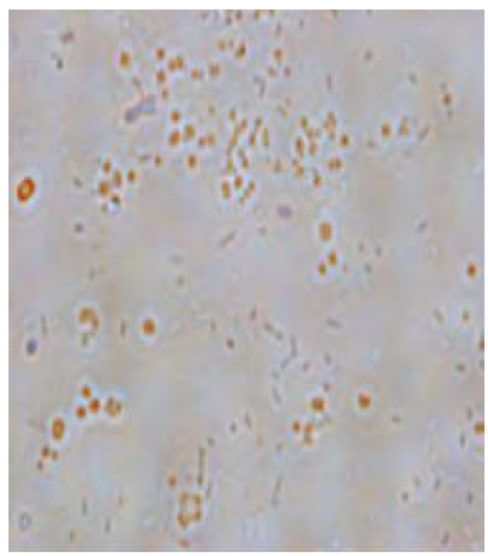
	spring								
	H5			4	1	10	12	14	30
	H6			12	9	5	7	73	19
	H7			8	6	30	35	25	27
	H8			12	8	20	65	40	31
	H9			31	23	16	12	26	18
Mehalaba	Protected well	52	0	0	6	0	3	31	51
	Protected spring	84	88	9	20	30	49	26	0
	Public tap	0	54	10	0	0	8	11	62
	Unprotected spring	82	0	23	14	51	42	65	34
	H5			11	21	10	12	40	50
	H6			12	9	5	9	23	79
	H7			8	12	13	10	85	27
	H8			4	8	20	19	32	40
	H9			31	23	16	12	26	18
Molekise	Protected well	100	95	60	16	7	0	71	21
	Protected spring	96	99	5	0	13	19	26	0
	Public tap	0	0	6	0	0	23	11	13
	Unprotected spring	0	0	2	14	12	12	21	34
	H5			14	21	20	12	41	50
	H6			1	0	5	9	23	19
	H7			8	6	30	35	25	57
	H8			12	8	20	54	20	61
	H9			31	23	16	12	26	38
Libso	Protected well	32	37	6	16	18	0	31	21
	Protected spring	0	0	0	21	34	19	26	0
	Public tap	0	0	10	7	0	8	0	13
	Unprotected spring	46	73	23	14	51	42	65	34
	H5			14	21	20	12	41	50
	H6			12	9	5	4	23	19
	H7			8	6	30	35	25	27
	H8			24	8	20	65	40	31
	H9			31	23	16	12	26	18
Chekorsa	Protected well	76	80	0	16	14	0	31	21
	Protected spring	79	0	9	21	34	19	26	20
	Public tap	0	0	10	7	8	80	11	0
	Unprotected spring	90	99	23	14	51	40	52	34
	H5			19	0	10	12	11	60
	H6			0	6	0	8	23	19
	H7			8	6	30	35	55	77
	H8			13	8	20	65	50	71
	H9			0	13	16	12	66	18

Abiwotfre	Protected well	0	50	6	5	6	0	31	21
	Protected spring	34	62	31	11	34	19	86	90
	Public tap	29	78	10	0	13	0	0	73
	Unprotected spring	49	0	0	14	19	32	55	84
	H5			44	29	20	12	41	50
	H6			72	9	0	31	23	99
	H7			88	66	30	35	25	77
	H8			6	0	20	65	40	31
	H9			31	63	16	12	66	78

H= household

Annex 7.2 Photos

A   B

C   D

A= spring water, B= public tap water, C= compound microscope manipulating and observing the features of TC $ FC, D= microscopic features of TC

Annex 7.3 Participant Information Sheet

7.3.1 Information sheet English version

My name is ______________________________. I am working as data collector for the study being conducted in this community by Habib Alemu, who is studying his Master's degree at Woldia University College of Natural and computational Sciences. I kindly request you to lend me your attention to explain you about the study and being selected as the study participant.

The study title: Assessment of The Bacteriological Quality of Drinking water from Source to point-of-use in Habru district, northern Ethiopia.

Purpose of the study: the findings of this study can be of a paramount importance for Habru district water supply and sewerage authority and health office to plan intervention programs to improve the drinking water quality. Moreover, the aim of this study is to write a thesis as a partial requirement for the fulfillment of a Master's program in Applied Microbiology for the principal investigator.

Procedure and duration: i will be interviewing you using questionnaire to provide me with pertinent data that is helpful for the study. There are different questions to answer where i will fill the questionnaire by interviewing you and drinking water sample will be analyzed by filtration method. The interview and water sample analysis will take about 20 minutes, so i kindly request you to spare me this time for the interview.

Risks and benefits: the risk of being participated in this study is minimal, but only taking few minutes from your time. There would not be any direct payment for participating in this study. However, the findings from this research may reveal important information for Habru district Water Supply and Sewerage Authority, Health Office and government planners.

Confidentiality: the data you will provide us will be confidential. There will be no information that will identify you in particular. The findings of the study will be general for the study population and will not reflect anything particular of individual person. The questionnaire will be coded to exclude showing names. No reference will be made in oral or written reports that could link participants to the research.

Rights: participation in this study is voluntary. You have the right to declare to participate or not in this study. If you decide to participate, you have the right to withdraw from the study at any time and this will not label you for any loss of benefit, which you otherwise are entitled. You do not have to answer any question that you do not want to answer. Contact address: if there, are any questions or enquires any time about the study or the procedures, please contact: Habib Alemu:

Mobile number (+251)-935-423-938 Email Address: abuyehya123456@gmail.com.

7.3.2 Information sheet Amharic version

የተሳታፉ መረጃ ገጽ እና የፍቃደኛነት ቅፅ

ጤና ይስጥልኝ እንደምን አደርሽ/ዋልሽ? ስሜ ___________________ይባላል:: የመጣሁት ከዚሁ ሲሆን የወልድያ ዩኒቨርስቲ የማስተርስ ተማሪ በሆኑት በአቶ ሀቢብ አለሙ አማካኝነት ለሚካሄደው የመጠጥ ውሃ ንጽህና ጥናት መረጃ በመሰብሰብ ላይ ከሚገኙ መረጃ ሰብሳቢዎች መካከል አንዱ ነኝ:: እርስዎ/አንቺ ከዚህ በታች የሚነበበውን የጥናቱን መግለጫ ተገንዝበው ፈቃደኛ ከሆኑ መረጃ በመስጠት የዚሁ ጥናት ተሳታፊ እንዲሆኑ ሳይንሳዊ በሆነ መንገድ ተመርጠዋል፡፡

የጥናቱ ርዕስ፡ በሀብሩ ወረዳ የገጠር የመጠጥ ውሃ ንጽህና ከጀርም (ተዋህስያን) አንጻር ከመነሻ እስከ መኖሪያ ቤት ያለውን ሁኔታ በሚመለከት፡፡

የጥናቱ አላማ፡ ይህ ጥናት ለ ሀብሩ ወረዳ ውሃና ፍሳሽ ባለስልጣን እንዲሁም ለ ሀብሩ ወረዳ ጤና ቢሮ የገጠር የመጠጥ ውሃ ንፅህናን ለማሻሻል ለሚሰሩ እቅዶች እንደ አንድ ግብአት ሆኖ ያገለግላል፡፡ ከዚያም በበለጠ ለተማሪው የማስተረስ ትምህርት (Msc in Applied Microbiology) የማሙያ ጽሁፉን ለማዘጋጀት ይረዳል፡፡

ጥናቱ የሚወስደው ጊዜና ቅደም ተከተል፡ ጥናቱ እስከ 20 ደቂቃ የሚወስድ ሲሆን መጀመሪያ በቃለ መጠየቅ እና የመጠጥ ውሃ ናሙና በመውሰድ ይሆናል፡፡ በቃለ መጠየቁ ጊዜ የምትሰጡን ምላሽ ለጥናታችን መሰረታዊ ስለሆነ በትኩረት እነድትከታተሉን በትህትና እጠይቃለሁ፡፡

የጥናቱ ጉዳት እና የጥናቱ ጥቅም ፡ በጥናቱ ተሳታፊ በመሆናችሁ የሚደርስባችሁ ምንም አይነት ጉዳት የለም:: የተወሰነ ጊዜን ከማባከን ውጪ፡፡ ተሳታፊዋ በመሳተፉ የምታገኘው ምንም አይነት ክፊያ የለም:: ነገር ግን ከዚህ ጥናት የሚገኘው ውጤት የችግሩ መንስኤዎችን በመለየት በውሃ ብክለት ከሚመጡ ችግሮች ለመቆጣጠር እንድዲቻል የትኩረት አቅጣጫ ይጠቁማል እና በ ወረዳ ወደ ፊት ለሚጠኑ ተመሳሳይ ጥናቶች እንደ መነሻ ግብዓት ሆኖ ያገለግላል:: የጥናቱ ውጤት ለ ሀብሩ ወረዳ ውሃና ፍሳሽ ባለስልጣን እነዲሁም ለ ሀብሩ ወረዳ ጤና ቢሮ ይገለጻል፡፡ ከዚህም በላይ በዋናነት ለማስተርስ ዱግሪ መመረቂያ የማሟያ ጥናታዊ ጽሁፍ ለማዘጋጀት ነው፡፡

የጥናቱ ተሳታፊ መብቶች: በዚህ ጥናት መሳተፊም ሆነ አለመሳተፍ ሙሉ መብት አለዎት:: በመሳተፍ ላይ ያሉ በማንኛውም ሰዓት ማቋረጥ ይችላሉ፤ ከጥያቄዎች ውስጥ ለመመለስ የማይፈልጉትን ጥያቄ መተው ይችላሉ:: ጥያቄ ካለብዎት በማንኛውም ሰዓት መጠየቅ ይቻላሉ፡፡

የጥናቱ ሚስጥራዊነት: የሚሰጡን መረጃ ሚስጥራዊነት የሚጠበቅ ሲሆን እንደ ግለሰብ ተለይቶ የሚወሰድ መረጃ የለም።የጥናቱ ውጤት የህብረተሰቡን አጠቃላይ ሁኔታ እንጂ የአንድን ግለሰብ ምንም ነገር አያንጸባርቅም። የተሳታፊዎችን ስም ላለማሳየት ለመጠይቆቻችን የራሳችን ቁጥር ስጥተናቸዋል ። የጥናት ተሳታፊዎችን ከምርምሩ ጋር በማጣቀስ የሚሰጥ የቃልም ይሁን የጹሁፍ ሪፖርት የለም። ጥያቄ

ANNEX 7.4 CONSENT FORM

7.4.1 Consent form English version

I have read/ was read to me the participant information sheet. I have clearly understood the purpose of the research, the procedures, the risks and benefits, issues to confidentiality, the rights of participating and contact address for any queries. I have been given the opportunity to ask questions for things that may have been unclear. I was informed that I have the right to stop the study at any time or not to answer any question that I do not want. Therefore, I declare my voluntary consent to participate in this study with my initials (signature) as indicated below.

Name and signature of the participant: ______________________

Signature of data collector: ______________Date: ____________

7.4.2 Consent form Amharic version

የፈቃደኝነት መጠየቂያ ቅጽእኔ ____የጥናቱ መግለጫ ተነቦልኝ/ አንብቤ የጥናቱ አላማ፥ ጉዳት፥ ጥቅም እና ከእኔ የሚወሰደው መረጃ ምስጥራዊነቱ እንደሚጠበቅ ተገንዝቤ እና ካልፈለግሁኝ በማንኛውም ሰዓት ከጥናቱ ማቋረጥ እንደምችል አውቀ የጥናቱ ተሳታፊ ለመሆን ፈቃደኛ መሆኔን አረጋግጣለሁ፡፡

የመጠይቁ መለያ ቁጥር____

የተሳታፊ ፊርማ____

የመረጃ ሰብሳቢ ፊርማ______________________________ ቀን___________________________

ጥናቱን የሚያጠናው አድራሻ ሞባይል 0935423938 ኢሜል abuyehya123456@gmail.com.

Annex 7.5 Questionnaire

7.5.1 English version questionnaire

Woldia University, College of natural and computational Sciences, Department of Biology. Questionnaire for demographic characteristics, water handling practice among households and assessment of bacteriological quality of drinking water from source to point-of-use in Habru district, Northern Wollo Zone, Ethiopia, 2024.

Household Identification

Date of interview: ____/ _____/ ____ Time started:

Region: ____________________ Zone: ______________ Woreda: _________________

Kebele ______________________ House number: _______ Participant code: __________

Name of data collector ________ Date ____________ Signature__________

Name of Supervisor __________ Date ____________ Signature__________

Questions and coding categories

Part I Socio-economic and demographic characteristics

1. Age of the respondents in year _________

2. Sex of respondent

    1. Male
    2. Female

3. Educational level of the respondent.

    1. No formal education
    2. Primary
    3. Secondary and above

4. Marital status

    1. Single
    2. Married
    3. Divorced
    4. Widowed
    5. Others (specify) ___________

Part II Household water storage and handling practice

1. Types of collection container (observe)

    1. Clay pots

    2. Jerricans

    3. Other/ specify

2. Do you regularly wash your water containers before water collection?

    1. Yes

    2. No

3. For how long do you store drinking water ______________Days?

    1. A day and less

    2. More than one day

4. Type of water storage container

    1. Jerricans

    2. Clay pots

    5. Other specify _______

5. Does it have a cover? (Observe)

    1. Yes

    2. No

6. Occupation of respondents

    1. Merchant

    2. Government employee

    3. Daily laborer

    4. Unemployed/not working/ Pensioned

    5. Other specify___________

7. Family size

    1. ≤5

    2. <0.05

8. Income of the family in birr

    1. <500 5. >2000

    2. 501-1000

    3. 1001-1500

4. 1501-200054

9. How often do you wash the storage container?

1. Daily ____
2. Every 3 days
3. Weekly
4. Every 15 days
5. Never

10. Does the storage containers accessible to children?

1. Yes
2. No

11. Where do you regularly place cups used for drinking?

1. On the floor
2. Place prepared for it
3. On the water container
4. Other specify ___________

Part III Hygienic practice

1. Do you wash your hands before water collection?

1. Yes
2. No

2. Do you wash your hand after visiting a toilet?

1. Yes
2. No

3. If yes to Q2 do you use a soap to wash your hands?

1. Yes
2. No

4. Is there a place for washing hands? (Observe)

1. Yes
2. No

5. Is the water available? (Observe)

1. Yes
2. No

6. Is there any soap or cleaning agent like ash? (Observe)

    1. Yes
    2. No

Part IV: Household water treatment

1. Does the family/household use any water treatment?

    1. Yes
    2. No

2. If Yes to above question, which method

    1. Chlorine/ Weha agar
    2. Strain it through a cloth
    3. Let it stand and settle
    4. Boiling
    5. Others specify __________

7.5.2 Questionnaire Amharic version

የአማርኛ መጠይቅ ይህ መጠየቅ በሀብሩ ወረዳ የገጠር የመጠጥ ውሃ ንጽህና ከጀርም (ተዋህስያን) አንጻር ከ መነሻ እስከ መኖሪያ ቤት ያለውን ሌዩነት እና የመጠጥ ውሀ አቅርቦት ሁኔታ በሚመለከት የተዘጋጀ መጠይቅ ነው፡፡

የቤተሰብ መለያ መጠየቅ፡

የተጠየቀበት ቀን: _____/ ______/ _____ መጠይቅ የተጀመረበት ሰዓት:

ክልል: ______________________ ዞን: ________________ ወረዳ: __________________

ቀበሌ: ________________________ የቤት ቁጥር: ________ የተሳታፊ ኮድ: ____________

መረጃ ሰብሳቢው ስም________________ ቀን ______________ ፊርማ____________________

የተቆጣጣሪው ስም___________________ ቀን ______________ ፊርማ____________________

ክፍል አንድ፡- የማህበራዊ እና ኢኮኖሚያዊ ሁኔታ

የጥያቄ ምርጫ

1. ዕድሜዎ ስንት ነው? __________

2. የተሳታፊ ፆታ

    1. ወንድ
    2. ሴት

3. የት/ት ደረጃዎ ስንት ነው?

    1. መደበኛ ያልተማረ

2. አንደኛ ደረጃ

4. ሁለተኛ ደረጃ ያጠናቀቀ እና ከዚያ በላይ

4. የጋብቻ ሁኔታ

1. ያላገቡ

2. ያገቡ

3. ፍቺ የፈፀሙ

4. ባል የሞተባት

5. ሌላ ካለ ይጥቀሱ ____________

ክፍል ሁለት፡ የመጠጥ ውሀ አቅርቦት ሁኔታ በሚመለከት

1. የዉሃ መቅጃ እቃ አይነት

1. የሸክላ እቃ

2. ጀሪካን

3. ባልዲ

4. ሌላ ካለ ይጥቀሱ__________

2. ውሃ የሚቀዳበትን እቃ በየጊዜው ከመቅዳት በፍት ታጥባላችሁ?

1. አዎን

2. አይደለም

3. ለምን ያህል ጊዜ የመጠጥ ውሃን ታስቀምጣላችሁ? _________(ቀናት)

4. የመጠጥ ውሃን በምን ውስጥ ታስቀምጣላችሁ?

1. ጀሪካን

2. ባልድ

3. እንስራ

4. ሌላ ካለ ይጥቀሱ_______

5. በጉብኝቱ ወቅት የመጠጥ ውሃ ማጠራቀሚያው ክዳን አለው? (በምልከታ)

1. አዎን

2. አይደለም

6. መደበኛ ስራዎ ምንድ ነው?

1. ንግድ

2. መንግስት ሰራተኛ

3. የቀን/የጉልበት ሠራተኛ

4. ሥራ-አጥ / እየሰራ አይዮሆም (ጡረተኛ)

5. ሌላ ካለ ይጥቀሱ___________

7. የቤተሰብ ብዛት

≤5

>5

8. የቤተሰብ ገብ መጠን

5 <500

5. >2000

501-1000

1001-1500

1501-2000

9. በምን ያህል ጊዜ የውሃ ማጠራቀሚያችሁን ታጥባላችሁ?

1. በየቀኑ

2. በየሦስት ቀኑ

3. በየሳምንቱ

4. በየአስራ አምስት ቀኑ

5. በጭራሽ

6. ሌላ ካለ ይጥቀሱ __________

10. የመጠጥ ውሃ ማጠራቀሚያውን ሌጆች ይደርሱበታል?

1. አዎን

2. አይደለም

11. የውሃ መጠጫ የት ታስቀምጣላችሁ?

1. በወለል ላይ

2. ለውሃ መጠጫ ማስቀመጫ በተዘጋጀ ቦታ

3. በውሃ ማጠራቀሚያው ላይ

4. ሌላ ካለ ይጥቀሱ _____________

ክፍል ሶስት፡ የግል ንፅህና አጠባበቅ

1. ውሃ ከመቅዳትዎ በፍት እጅዎን ይታጠባሉ?

1. አዎን

2. አይደለም

2. ከመፀዳጃ ቤት መልስ እጅዎን ይታጠባሉ?

1. አዎን

2. አይደለም

3. የሚታጠቡ ከሆነ ሳሙና ይጠቀማሉ?

1. አዎን

2. አይደለም

4. ህፃናትን ከመመገቦ በፊት እጅዎን ይታጠባሉ?

1. አዎን

2. አይደለም

5. የሚታጠቡ ከሆነ ሳሙና ይጠቀማሉ?

1. አዎን

2. አይደለም

6. በግቢው ውስጥ የእጅ መታጠቢያ ቦታ አሉ? (በምልከታ)

1. አዎን

2. አይደለም

7. ካለ የእጅ መታጠቢያው ውሃ አለው? (በምልከታ)

1. አዎን

2. አይደለም

8. ሳሙና ወይም ሌሎች ፅዳትን መጠበቂያዎች እንደ አመድ፣ አሸዋ አለ? (በምልከታ)

1. አዎን

2. አይደለም

ክፍል አራት፡- የመጠጥ ውሃ ህክምና

1. የሚጠቀሙ ከሆነ የትኛውን መንገድ ይጠቀማሉ?

1. ክሎሪን በመጨመር

2. በንፁህ ጨርቅ በማጥለል

3. ለተወሰነ ጊዜ አስቀምጦ በማዝቀጥ

4. በማፍ የቤት ውስጥ የመጠጥ ውሃ ህክምና

2. በቤት ውስጥ የመጠጥ ውሃ ህክምና ይጠቀማሉ?

1. አዎን

2. አይደለም