Seasonal Variations in Household Water Use, Microbiological Water Quality, and Challenges to the Provision of Adequate Drinking Water: A Case of Peri-urban and Informal Settlements of Hosanna Town, Southern Ethiopia

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ABSTRACT: Several studies have been conducted on household water use and microbial water quality globally. However, studies that considered seasonal variability of household water use and microbial water quality were limited. Therefore, this study investigated the seasonal variability of household water use, microbiological water quality, and challenges to the provision of adequate water in the peri-urban and informal settlements of Hosanna town, Southern Ethiopia. A longitudinal study was conducted on 288 households. The data was gathered using a pretested structured questionnaire, laboratory-analysis, interviews, storage-container inventories, focus group discussions, key-informant interviews, and an observational checklist. The data was analyzed using stepwise-multiple linear regression, bivariate and multivariable logistic regression, thematic-analysis, t-tests, and non-parametric-tests. Households were visited for 7 consecutive days during the dry and rainy seasons to account for changes in daily and seasonal variation of water use. 440 stored water and 12 source samples were analyzed for *E. coli* presence during dry and rainy seasons. The prevalence of stored water contamination with *E. coli* was 43.2% and 34.5% during the dry and rainy seasons, respectively. The per capita water consumption was 19.4 and 20.31 during the dry and rainy seasons, respectively. Piped water on-premises, small family size, volume, and number of water storage containers were significant predictors of per capita water consumption in both seasons. Piped water off-premises, storing water for more than 3 days, uncovered, and wide-mouthed water storage containers were significantly associated with the presence of *E. coli* in water in both seasons. Seasonal variability of household water use and microbiological water quality was statistically significant, which is a significant public health concern and needs intervention to enhance water quantity and quality to mitigate the risk of waterborne diseases. Findings also suggest seasonal monitoring of the safety of drinking water to ensure that the water is safe and healthy.

KEYWORDS: *E. coli*, Hosanna town, household water use, informal settlements, microbiological water quality, per capita water consumption, peri-urban, seasonal variability, Southern Ethiopia, water quantity

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Background

Access to safe drinking water remains a pressing issue, with an estimated 2 billion people lacking safely managed drinking water services worldwide.[1] Although 94% of the world population had access to improved drinking water sources, only 77% of the population had improved drinking water accessible on premises in 2020. In sub-Saharan Africa and Ethiopia, only 31% and 20% of the population had improved drinking water accessible on premises, respectively. Drinking water supply improvement with quality, quantity, and reliability is crucial for good health.[2] A systematic review indicated that the availability of enough quantities of water for consumption and hygiene is associated with water supply accessibility.[3] Evidence obtained from various studies also indicated that off-premises water access results in lower quantities and quality of water when compared to water sources located on premises.[4,5] Cairncross also discussed the concept of the water plateau, which describes the non-linear relationship between the quantity of water collected and the time or distance required to fetch water.[6] In general, as the time or distance increases, the quantity of water collected decreases. However, there is a point at which the quantity of water collected begins to plateau. The term water plateau is an important concept that helps us understand the difficulties of accessing water in developing countries and the effects of water interventions. Water access located off premises can also affect an individual's health adversely through lower water availability, reduced water quantity for hygiene, and increased contamination risks.[5]

In urban areas of Ethiopia, a significant improvement has been made in the coverage of improved water sources accessible on premises from 2000 to 2020. A recent report by WHO/UNICEF indicated that 75% of the urban population in Ethiopia had access to improved water sources accessible on premises in 2020.[1] The same report showed that only 13% of the population had access to safely managed drinking water services in Ethiopia. However, rapid population growth and informal peri-urban settlement have placed additional burdens on cities in sub–Saharan Africa, which struggle to adequately provide safe drinking water to residents, particularly in the informal peri-urban areas.[7] Evidence also indicated that piped water supply interruption was a big problem, particularly in slum areas of Addis Ababa.[8] According to a recent study, households residing in the peri-urban and informal settlements areas of the town had access to piped water located on and off premises.[9] However, the reliability of the water sources was a major challenge in the area. The details about peri-urban and informal settlements are discussed elsewhere.[9] The majority of households living in the peri-urban and informal settlements of the town has access to water sources located off premises, which is very inadequate and highly vulnerable to microbial contamination. Lack of access to household water connections increases exposure to waterborne pathogens due to contamination during collection, transport, or storage.[10] Households are also forced to store their drinking water for an extended time, thereby making the water vulnerable to microbial contamination. Evidence showed that consumption of fecally contaminated water was responsible for the occurrence of diarrhea.[11] Collecting water from off-premises water sources can also reduce the amount of water available in households.[4]

Seasonal changes are another crucial factor that affects water quality and the availability and consumption of water. A recent study discovered the quality of groundwater is affected by climatic factors, with better water quality observed during the dry season compared to the wet season. This finding highlights the significant impact of climatic factors on groundwater quality.[12] Evidence from Northwest China also showed that some parameters of Lake Sha exhibit seasonal variations.[13] Similarly, a study that assessed the microbiological quality of drinking water in Ethiopia showed that microbiological water quality at the point of use varies seasonally.[14] However, a different study that assessed groundwater quality found that the major ions analyzed in groundwater did not exhibit significant seasonal variations.[15] The study also verified that groundwater quality is influenced by various factors such as human activities, hydrogeological conditions, water-rock interactions, and rock weathering. The availability and consumption of domestic water can also vary seasonally.[16] Therefore, it is crucial to measure the quantity of water used for personal and domestic purposes to understand the impact of water quantity on human health.[17] Likewise, measuring the microbiological characteristics of water is an important way to ensure that the water is safe to drink and prevent water-related diseases.[18] Lack of sufficient access to safe water is responsible for several water-borne illnesses, such as diarrhea.[2] Inadequate water in terms of quantity and quality is also becoming a cause of various health problems in Hosanna town.[19] Hence, it is essential to comprehend the factors influencing the quantity and quality of water consumed in households.

Different studies have examined household water use and microbial water quality in different parts of the world.[11,20-25] However, studies that considered seasonal variability of household water use and microbial water quality and their determinant factors were limited, which makes it difficult to understand the full extent of water supply problems and develop effective interventions. Therefore, the objective of this study was to assess the seasonal variability of household water use, microbial water quality, and challenges to the provision of adequate water. It is believed that the result obtained from this study provides comprehensive data on household water use and microbiological water quality that can serve as a basis for designing an effective intervention to improve the quality and the quantity of water at the household and town level in the study area.

Method

Study area

The study was conducted in Hosanna town, the capital city of the Hadiya zone, located 232 km from Addis Ababa. The town has a population of 145 399 in 2021/22, of which 50.8% were males and 49.2% were females. It has a total of 6 urban kebeles, which is the lowest administrative structure in Ethiopia.[26] Households in the town obtain water from 2 water sources, which include piped and un-piped. However, the water supply was a critical problem in Hosanna town, particularly in the peri-urban and informal settlements.

Hosanna town lies approximately between the latitude 7° 30′ 00″ to 7° 35′ 00″ North and the longitude 37° 49′ 00″ to 37° 53′ 00″ East. Its altitude ranges from 2400 meters above sea level at the Bale-Wold Church to 2200 meters above sea level at Tekle-Haymanot Church.[27] The yearly average rainfall of the town ranges from 920.4 mm to 1436.5 mm, and the highest rainfall occurs between July and September. The town has a mean annual temperature of 17.1°C. The maximum temperature is experienced between January and March, whereas the lowest temperature is between July and September. The town is found in the Woina-Dega agro-climatic zone. The town's geology is diverse. The hillsides and valleys are composed of mostly igneous and metamorphic rocks, while the plain part of the town is characterized by sedimentary rock. The soil in the hillsides and valleys of the town is lithosol, while the plain part of the town has vertisol soil with poor drainage and infiltration rate.[28] The map of the study area is presented in Figure 1.[9]

Study design

A longitudinal study was conducted to explore the seasonal variability of household water use and microbial water quality. The study design involved collecting data on water consumption and microbiological water quality from the same individuals during both the dry and rainy seasons. This method can offer a more precise picture of changes over time and can help to identify factors that contribute to changes in water consumption and microbiological water quality. Additionally, a qualitative study was also conducted to examine the challenges

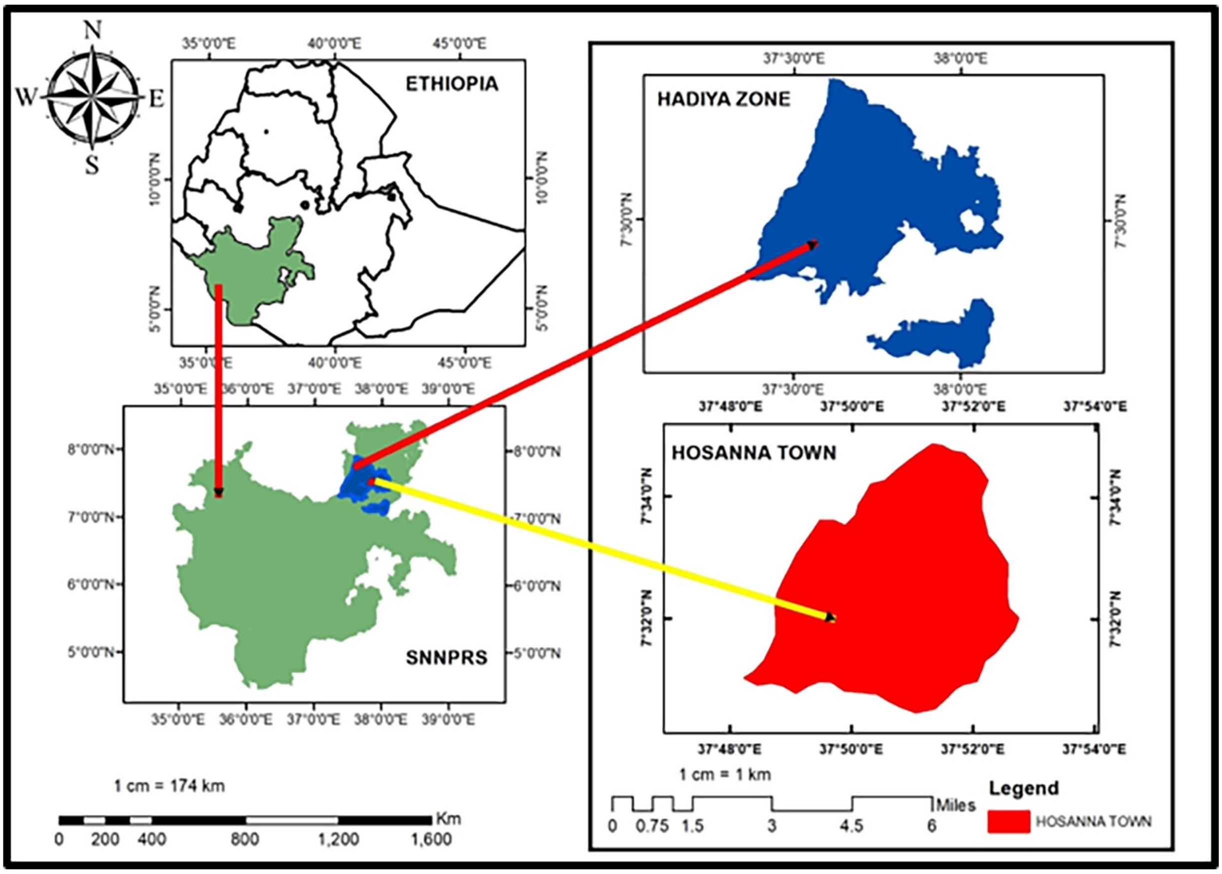

Figure 1. Map of the study area.

to the provision of adequate drinking water and its implications on childhood diarrhea. The study collected qualitative data on the challenges to the provision of adequate drinking water through focus group discussions and key informant interviews.

Sample size determination and selection of study households

A cohort study sample size calculation formula using Epi-info software was used to calculate the study sample size. The statistical assumptions, which include risk ratio = 1.56,[29] percentage outcome in an unexposed group = 37.5%,[30] the ratio of unexposed/exposed groups = 1:1; $\alpha = 0.05\%$ (95% CI), and desired power = 90%, were considered to calculate the sample size. Considering a 15% follow-up loss, the total sample size of the study was 292. Three focus group discussions and 6 key informant interviews were also conducted to collect qualitative data. Qualitative data was collected on lived experiences of people regarding water quantity and quality issues and their implications on childhood diarrhea. These issues include water accessibility, major problems associated with primary water sources, challenges faced when accessing water, water shortage and coping strategies, and the role of government and community participation in water supply projects. The study was conducted in 3 purposely selected kebeles; Bobicho, Sech-Duna, and Jelo-Naremo kebeles. A randomly selected 288 households participated in the study. The details about sample size determination and sampling techniques are discussed elsewhere.[9]

Inclusion and exclusion criteria

Households connected with improved water sources located on premises were considered as unexposed groups, whereas households connected with improved water sources located off premises were considered as exposed groups. Off-premises refers to the water sources located outside the living areas, whereas on-premises refers to the water sources located inside the user's dwelling, plot, or yard. Those households who had an interest in being involved and were able to explain the problem frankly participated in the qualitative study. In all cases, the households living in the peri-urban and informal settlement areas who fulfill inclusion criteria were involved in the study. The study excluded households with less than 6 months of stay in the selected kebeles and households lacking improved water sources located either on or off premises. The study also excluded households with known mental health problems to avoid causing further anxiety to households and also because such households might also provide inaccurate information.

Data collection tools and collection strategy

Various data collection tools were used for this study, including a pretested structured questionnaire, an observational checklist, a questionnaire for the daily water consumption data collection, water storage container inventories, interviews, and laboratory analysis. The observation checklist was used to assess the covering of drinking water, cleanliness of water storage container, mouth size of a water storage container, presence of garbage in the living area, level of water changes in water storage containers, water withdrawal method, the size and number of different storage containers, types of water sources, and availability of handwashing facilities and soap. The qualitative data was also collected using focus group discussions (FGDs) and key informant interviews (KIIs). The data was collected by 12 trained health professionals, which was checked timely for consistency and lack of any errors.

Measuring household water consumption during the dry and rainy seasons

The quantity of water was measured from May 9 to 15/2022, and August 22 to 28/2022, during the dry and rainy seasons, respectively. In most parts of the country, the dry season begins from October to May, while the rainy season begins from June to August. The quantity of water used for various domestic purposes was estimated using a mixed-method, which includes a questionnaire for the daily water consumption data collection, storage container inventories, observation, and interviews. Several studies have used only questionnaires[21,22,31] or in combination with other methods to estimate water use.[16,20,32] Although the questionnaire is the most commonly used method in developing countries, it is highly subject to reporting and recall biases.[17] Hence, a mixed method was used to minimize the limitations associated with questionnaire and generate reliable water use data. In this case, the other 3 methods were combined with a questionnaire in a way that complements the questionnaire and produces complementary information. The final total amount of water consumed by households was obtained by summing up the amount of water used daily, which was obtained from the questionnaire, and the amount of water used directly from taps, which was obtained from interviews. In this study, the other methods are designed in a way that complements the questionnaire and does not generate different results. Households were visited for 7 consecutive days during the dry and rainy seasons to account for changes in the daily and seasonal variation of household water use. A 24-hour recall period was considered for estimating household water use. Evidence from a systematic review showed that measurements of unmetered water use should consider the day-to-day and seasonal variation of water use for reliable results.[17] It also indicated that a 24 or fewer hours recall period has to be considered for reliable water use estimation.

During water use measurements, both the amount of water collected for use and the amount of water consumed for different household activities were considered. The quantity of water collected by households connected with piped water off premises was estimated by considering factors such as the number of person-trips per day made for the collection and the amount of water collected per trip by the person. Hence, the total amount of water collected was determined by multiplying the amount of water carried per trip by the person by the reported number of trips. For households connected to piped water on premises, the quantity of water collected from their tap was estimated by considering factors, which include the number of times they filled storage containers and the amount of water in liters filled storage containers per time. The amount of water used directly from taps was estimated by multiplying the duration of time households directly used water by the water flow rate in liters. The water flow rate in liters per minute was measured on the field in 3 sampled households, and then average results were used to estimate directly used water.

Storage container inventory was also carried out to estimate the volume of water collected and consumed at household levels. The storage container inventory involves identifying the size and number of different storage containers in which households store water and the frequency of water collection. Besides, pictures of water storage containers of different types and their equivalent volume were used, which can be used to estimate the volume of water storage vessels in households. Furthermore, the data collectors were trained to estimate the size of the water storage vessel and the level of water change in the water storage vessel using a tape meter when they visited households during seven consecutive days in both the dry and rainy seasons.

Water sample collection and microbial analysis during the dry and rainy seasons

The microbiological water quality analysis was conducted from May 17 to 31/2022, and August 2 to 17/2022, during the dry and rainy seasons, respectively. Totally, 440 water samples from water storage containers and 12 water samples from the point of collection and storage reservoir were collected during the dry and rainy seasons for *E. coli* analysis. Besides, physicochemical parameters such as pH, turbidity, and temperature were analyzed. Temperature and pH were measured using the Pocket pH Sensor, while turbidity was measured using a Photometer (Model 9300). *E. coli* was used for assessing the microbiological quality of water as it indicates recent fecal contamination.[33,34] Water sampling, handling, and processing were conducted according to World Health Organization (WHO) and American Public Health Association (APHA) guidelines on water handling and processing.[35,36] The microbiological water quality analysis was conducted at the Southern Region Health Bureau Public Health Laboratory, Hosanna Branch. The water samples collected from the sources and point of use were analyzed for *E. coli* using standard methods of membrane filtration technique.[35-37] A 200 ml water sample was collected using a sterile Whirl-Pak bag, which contains 5 drops of sodium thiosulfate to neutralize the effect of any chlorine present in the sampled water. All collected water samples were immediately stored in a cold box containing ice packs, and transported to the laboratory, and analyzed within 4 hours of collection.

A carefully measured 100 ml of water was filtered aseptically through a sterile membrane filter of 0.45 µm pore size. All the retained *E. coli* bacteria on the membrane filter was transferred to the Petri dish containing an absorbent pad, which was saturated with M-Lauryl Sulfate Broth. Then, the Petri dish was incubated for 4 hours at 30°C followed by 14 hours at 44°C. Finally, the bacterial growth on solid media in colony form was counted and described in standard methods cited by WHO and APHA.[35,36] *E. coli* is represented by yellow colonies and therefore counted and expressed in numbers of colony-forming units (CFU) per 100ml of the water sample.

Challenges to the provision of drinking water and its implication on childhood diarrhea

Qualitative data was collected on challenges to the provision of drinking water and its implication on childhood diarrhea. In order to gain insights into the challenges of providing drinking water, 3 focus group discussions (FGDs) were conducted in 3 kebeles. Each FGDs consisted of 8 households that were representative of the target population. The households were selected purposely by considering sex, age, and interest to maintain diversity among the participants. In addition, 6 key informants were interviewed, including 1 local leader, 1 higher official on water supply, and 3 health extension workers from the selected kebeles. The key informants were selected purposely based on their firsthand knowledge of the challenges of providing drinking water and their ability to explain these challenges. The focus group discussions and key informant interviews were led by trained moderators using a discussion guide, which contains 8 open-ended questions that allow participants to share their thoughts and opinions. These methods were used to investigate the difficulties of ensuring sufficient drinking water, the inadequacy of water supply, and their implications on childhood diarrhea. Some of the issues raised in the open-ended questions include water accessibility, adequacy of water supply, major problems associated with their primary water sources, community member's participation in the planning of the water supply project, government effort in the provision of adequate water, the main barriers to the provision of adequate water at the household level, water shortage and its implication on childhood diarrhea and their suggestion in improving the existing water supply system. Finally, results obtained from FGDs and KIIs were audio recorded for thematic analysis.

Study variables

Dependent variables. The dependent variables of the study were microbiological water quality and daily average per capita water consumption, which was measured in *E. coli* number per 100 ml of water (CFU/100ml) and liters (L/C/D), respectively. A binary code was created for the microbiological quality of stored drinking water to identify factors associated with fecal contamination of water. No (1) indicates the absence of *E. coli* in drinking water (Not contaminated with *E. coli*), and Yes (2) indicates the presence of *E. coli* in drinking water (Contaminated with *E. coli*).

Independent variables. The potential explanatory variables predicting the 2 outcomes of the study were identified from the literature review. The independent variables that could predict the per capita water consumption variables include type of water sources, sex of household head, educational level of mothers and household head, household family size, monthly household income, number of under-five children, volume of water storage containers, number of water storage containers, duration of water storage, and rainwater harvesting and using. The explanatory variables that could predict contamination of drinking water with *E. coli* include type of water sources, monthly household income, duration of water storage, types of sanitation facilities, availability of handwashing facilities, covering of water storage containers, water withdrawal method from the water storage containers, frequency of cleaning water storage containers, mouth size of water storage containers, solid waste disposal practice, and educational level of mothers.

Data analysis

Water quantity and microbiological water quality data were summarized using descriptive statistics such as percentage, range, standard deviation, and mean. Factors associated with the per capita water consumption were identified using a stepwise multiple linear regression analysis. A paired sample t-test was used to observe the difference in mean per capita water consumption between the dry and rainy seasons. The differences in mean per capita water consumption between households connected with piped water on and off-premises were also checked using an independent sample t-test. Binary and multivariable logistic regression was conducted to identify factors associated with microbial contamination of drinking water. The adjusted odds ratios (AOR) were used to interpret the result of the logistic regressions instead of crude odds ratios (OR) because they take into account the effects of other variables that may be associated with the outcome variable. A Wilcoxon signed-rank test was used to observe the seasonal variation of microbiological water quality at the point of use. A non-parametric Mann-Whitney U-test was also used to observe the differences in microbiological water quality between households connected with piped water on and off-premises. The multicollinearity among independent variables was checked using VIF values before undertaking the regression analysis. The fitness of the bivariate and multivariable logistic regression model was checked using the Hosmer-Lemeshow statistics and log-likelihood ratio *P*-value, respectively. All assumptions of stepwise multiple linear regression were also checked before starting the analysis. Data that failed to meet the assumption of multiple linear regressions was transformed into logarithmic to meet the assumption. Assumption also checked for t-test before starting the analysis. Generally, a *P*-value less than .05 was considered statistically significant. All quantitative data was analyzed using STATA 14 software. The qualitative data obtained from 3 focus group discussions and key informant interviews was summarized by developing themes. The data was audio-recorded, translated from Amharic to English, and then thematically analyzed following a 6-step analysis process.[38]

Results

Household socio-economic and water-related factors

Of the total sample size (n = 292), 288 households participated with a 98.6% response rate. Four households did not participate in the study due to loss to follow up. The majority of the heads of households (62.5%) and mothers (55.2%) had access to secondary school and above education level. The head of household is a person who is recognized by the members of the household as the one who provides the basic necessities of life and as the head of the household. The Protestant religion was the dominant religion in the study area. Of the total households, 77.8% of the households were Protestants (Table 1). The median monthly income of the household was 78.7 US dollars.

Water consumption during the dry and rainy seasons

The study households were visited for 7 consecutive days during the dry and rainy seasons to measure the daily and seasonal variation of household water use. Household water use refers to the quantity of water used inside and outside the home, which includes water used for drinking, handwashing, cooking, washing clothes, cleaning, other domestic purposes, and excluding water used for agricultural purposes. The average per capita water consumption was 19.4 and 20.31 during the dry and rainy seasons, respectively. The average per capita water consumption was calculated by adding the daily water consumption values of the seven consecutive days and dividing the sum by the number of days and then by the number of individuals living in the households. A higher per capita water consumption was obtained during the rainy season compared to the dry season. The daily per capita water consumption was calculated to be less than 201 for 52.1% and 45.5% of the studied households during the dry and rainy seasons, respectively.

Physicochemical and bacteriological quality of water sources and point of use water during the dry and rainy seasons

All water samples collected from water storage reservoirs (n = 6) and the point of water collection (n = 6) during the dry and rainy seasons were negative for *E. coli* (Supplemental Table 1). This means that *E. coli* is absent or not detectable in the sampled water, which makes the water safe and healthy for human consumption.

Table 1. Household socio-economic and water-related factors.

VARIABLES	CATEGORY	NUMBER OF PARTICIPANTS (%)
Sex of household head	Female	23 (8)
	Male	265 (92)
Educational status of household head	< Secondary school	108 (37.5)
	Secondary school and above	180 (62.5)
Education level of Mothers	< Secondary school	129 (44.8)
	Secondary school and above	159 (55.2)
Household family size	2-4	95 (33)
	5-6	134 (46.5)
	⩾7	59 (20.5)
Religion	Protestant	224 (77.8)
	Orthodox Christian	43 (14.9)
	Other religions	21 (7.3)
Average monthly HH income	<61.63 USD	137 (47.6)
	61.63-150.17 USD	119 (41.3)
	>150.17 USD	32 (11.1)
Observed water sources	Piped water on premises	144 (50.0)
	Piped water off premises	144 (50.0)
Sanitation facilities	Improved	155 (53.8)
	Unimproved	126 (43.8)
	No facility	7 (2.4)
Presence of soap near handwashing facilities	Yes	49 (17)
	No	138 (47.9)
	No handwashing facilities	101 (35.1)

The average exchange rate of 1 USD = 51.9425 ETB (Ethiopian Birr) in 2022.

A total of 440 water samples were also collected from randomly selected households during the dry and rainy seasons and analyzed for the presence of *E. coli* in water. The result revealed that the prevalence of contamination of drinking water with *E. coli* was 43.2% (95% CI = 36.6%-49.8%) and 34.5% (95% CI = 28.2%-40.9%) during the dry and rainy seasons, respectively. The *E. coli* counts ranged from 0 to 310 CFU/100ml and 0 to 284 CFU/100ml during the dry and rainy seasons, respectively. The mean *E. coli* counts were 14.7 and 8.3 CFU/100ml during the dry and rainy seasons, respectively. The risk levels for drinking

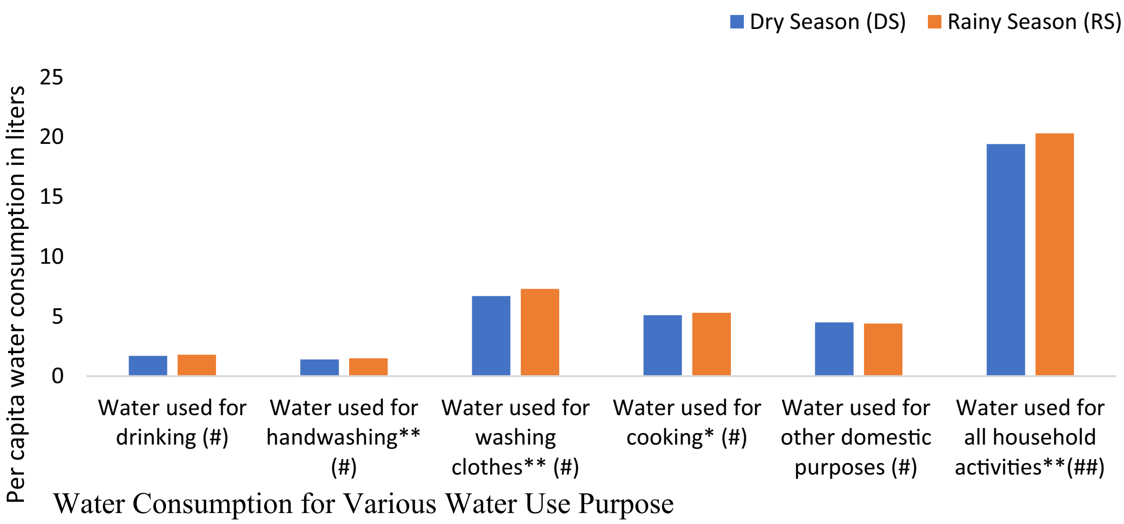

Figure 2. Seasonal variation in per capita water consumption for various water use purpose.
*Significant at *P*-value < .01; **Significant at *P*-value < .001. (#)—Self-reported. (##)—Self-reported + Field measurement (Water flow rate in liters per minute) + Measuring the level of water changes in the water storage vessel using a tape meter. Water used for drinking: DS (95% CI = 1.72–1.78), RS (95% CI = 1.72–1.79), *P*-value (2-tailed), .3597. Water used for handwashing: DS (95% CI = 1.35-1.43); RS (95% CI = 1.48-1.57), *P*-value (2-tailed), < .001. Water used for washing clothes: DS (95% CI = 6.17-7.16), RS (95% CI = 6.83-7.83), *P*-value (2-tailed), < .001. Water used for cooking: DS (95% CI = 4.96-5.29), RS (95% CI = 5.09-5.43), *P*-value (2-tailed), .0018. Water used for other dome. purposes: DS (95% CI = 4.36-4.64), RS (95% CI = 4.30-4.59), *P*-value (2-tailed), .1828. Water used for all HH activities: DS (95% CI = 18.81–20.05), RS (95% CI = 19.69–20.94), *P*-value (2-tailed), < .001.

water contaminated with fecal coliform were categorized into low risk (<1), medium risk (1-10), high risk (11-100), and very high risk (>100).[34] The result indicated that 21.8% and 14.1% of the household stored water were categorized under high-risk and above level during the dry and rainy seasons, respectively (Supplemental Table 2). The pH value of the water collected from water storage reservoirs and the point of water collection ranged from 7.2 to 7.6 and 7.5 to 7.6 during the dry and rainy seasons, respectively. The mean pH value of stored water for dry (7.76) and rainy (7.53) seasons was found in the safe drinking water range (6.5-8.5). The study also found that the difference in pH, turbidity, and temperature of stored water between the dry and rainy seasons was statistically significant (*P*-value < .001). Additionally, there was a statistically significant seasonal variation in the temperature of water collected from the point of collection (*P*-value < .05). In contrast, there were no statistically significant seasonal variations in pH and turbidity of water collected from storage reservoirs and the point of collection.

Per capita water consumption and prevalence of microbial water contamination among households connected with piped water on and off premises during the dry and rainy seasons

The households connected with piped water on premises had better per capita water consumption in both seasons. The mean per capita water consumption for households connected with piped water on premises was 23.1 and 23.61 during the dry and rainy seasons, respectively. On the other hand, the mean per capita water consumption for households connected with piped water off premises was 15.8 and 17.01 during the dry and rainy seasons, respectively (Supplemental Table 3). An independent sample test was also conducted to observe the difference in mean per capita water consumption between the 2 groups. The result indicated that the difference in the mean per capita water consumption between households connected with piped water on and off-premises during both the dry and rainy seasons was statistically significant (*P*-value < .001).

The result also revealed that the prevalence of contamination of drinking water with *E. coli* was higher in households lacking piped water on premises than in households connected with piped water on premises during the dry and rainy seasons (Supplemental Table 4). A non-parametric Mann-Whitney U-test was used to observe the difference in *E. coli* counts in drinking water between the 2 groups in both seasons. This method was used due to the non-normal distribution of the bacteriological water quality data. The Mann-Whitney U-test indicated that the *E. coli* counts in water for households connected with piped water off premises during the dry and rainy seasons were statistically significantly higher than the *E. coli* counts in water for households connected with piped water on premises during both seasons (*P*-value < .001).

Seasonal variability of per capita water consumption and microbial quality of stored water

A paired sample *t*-test was used to observe the seasonal variability of per capita water consumption for various water use purposes. The result revealed that the difference in mean per capita water consumption for all household activities between the dry (19.41, 95% CI = 18.81-20.05) and rainy seasons (20.31, 95% CI = 19.69-20.94) was statistically significant at a *P*-value less than .001. Likewise, the paired sample t-test showed that the difference in mean per capita water consumption for handwashing, washing clothes, and cooking between the dry and rainy seasons was statistically significant (Figure 2).

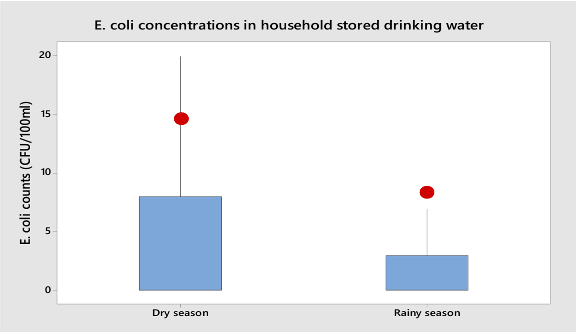

Figure 3. Seasonal variability of *E. coli* concentration in household stored drinking water (CFU/100 ml). A blue graph represents *E. coli* loads, and a red circle represents the mean *E. coli* value.

However, the difference in mean per capita water consumption for drinking and for other domestic purposes between the dry and rainy seasons was not statistically significant. The seasonal variation in the bacteriological quality of household stored water was checked using a non-parametric Wilcoxon signed-rank test. This method was used due to the non-normal distribution of the bacteriological water quality data. A Wilcoxon signed-rank test indicated that the *E. coli* counts in water during the dry season were statistically significantly higher than in the rainy season at a *P*-value less than .001 (Figure 3).

Factors associated with the microbial quality of stored water during the dry and rainy seasons

Eleven independent variables which could predict contamination of drinking water with *E. coli* during the dry and rainy seasons were identified. This includes types of water sources, duration of water storage, types of sanitation facility, availability of handwashing facilities, covering of water storage containers, water withdrawal method from the water storage containers, frequency of cleaning water storage containers, mouth size of water storage containers, solid waste disposal practice, monthly household income, and educational level of mothers. The bivariate analysis indicated that 6 variables, which include types of water sources, duration of water storage, availability of handwashing facilities, covering of water storage containers, water withdrawal method from the water storage containers, and mouth size of water storage containers were significantly associated with the presence of *E. coli* in drinking water during the dry season. However, the multivariable logistic regression verified that piped water off premises (AOR = 4.50; 95% CI = 1.88- 10.75), storing water for more than 3 days (AOR = 2.78; 95% CI = 1.35-5.72), uncovering of water storage containers (AOR = 2.41; 95% CI = 1.12-5.18), and wide-mouthed water storage containers (AOR = 4.38; 95% CI = 1.56-12.33) were significantly associated with the presence of *E. coli* in drinking water (Table 2).

Of those 11 variables considered in the bivariate analysis, 5 variables, which include the types of water sources, duration of water storage, covering of water storage containers, mouth size of water storage containers, and water withdrawal method from the water storage containers were significantly associated with the presence of *E. coli* in drinking water during the rainy season. On the other hand, the multivariable logistic regression showed that piped water off premises (AOR = 2.86; 95% CI = 1.24-6.58), storing water for more than 3 days (AOR = 2.26; 95% CI = 1.09- 4.69), uncovering of water storage containers (AOR = 2.91; 95% CI = 1.34- 6.34), wide-mouthed water storage containers (AOR = 12.06; 95% CI = 3.05- 47.62) and mother's with less than secondary school education level (AOR = 2.17; 95% CI = 1.07- 4.41) were significantly associated with the presence of *E. coli* in drinking water (Table 3).

Predictors of per capita water consumption during the dry and rainy seasons

A stepwise multiple linear regression model was used to identify predictors of the per capita water consumption. Around 10 variables for the dry season and 11 variables for the rainy season were identified from the literature that could predict the per capita water consumption in each season. However, 3 variables that failed to meet the assumptions of linear regression were excluded from the analysis. This includes the number of under-five children, monthly household income, and sex of household head. The data on the volume of water storage vessels and family size was log-transformed to meet the assumptions of linear regressions. Then, a stepwise multiple linear regression was conducted with 7 and 8 independent variables for the dry and rainy seasons, respectively. Both the dry and rainy seasons models were significant at a *P*-value less than .001. The final model for the dry season included the types of water sources, family size, volume of water storage vessels, and number of water storage containers to predict per capita water consumption.

The dry season model indicated that piped water on premises (Coef. = 4.99, *P*-value < .001), volume of water storage vessels (Coef. = 3.05, *P*-value < .001), and number of water storage containers (Coef. = 0.44, *P*-value < .05) were statistically significantly associated with increased per capita water consumption. However, family size was associated negatively with per capita water consumption (Coef. = −6.63, *P*-value < .001). Similarly, the rainy season model also showed that piped water on premises (Coef. = 3.94, *P*-value < .001), volume of water storage vessels (Coef. = 2.39, *P*-value < .003), and number of water storage containers (Coef. = 0.78, *P*-value < .001) were statistically significantly associated with increased per capita water consumption (Table 4). On the other hand, family size was associated negatively with per capita water consumption (Coef. = −7.00, *P*-value < .001).

Challenges to the provision of drinking water and its implication on childhood diarrhea

The study involved 24 households in 3 focus group discussions in the selected kebeles. All participants in the focus group discussion and key informant interviews believed that the provision of drinking water was insufficient, particularly

Table 2. Factors associated with the bacteriological quality of stored drinking water during the dry season.

VARIABLES	CATEGORY	CONTAMINATION OF WATER WITH *E. COLI* (DRY SEASON)		OR (95% CI), *P*-VALUE	AOR (95% CI), *P*-VALUE
		YES	NO		
Water sources	Piped water on premises	28	82	1	1
	Piped water off premises	67	43	4.56(2.57-8.11), <.001***	4.50(1.88-10.75), .001**
Duration of water storage	⩽3 d	26	72	1	1
	>3 d	69	53	3.61(2.03-6.40), <.001***	2.78(1.35-5.72), .006**
Mouth size of WSC	Narrow mouthed	9	45	1	1
	Wide and narrow	35	63	2.78(1.22-6.35), .015**	4.38(1.56-12.33),.005**
	Wide mouthed	51	17	15 (6.09-37.00), <.001***	18.72(4.90-71.52), <.001***
Water withdrawal method	Pouring	27	72	1	1
	Dipping	68	53	3.42(1.94-6.05), <.001***	0.45(0.17-1.18), .103
Is the WSC covered?	No	71	68	2.48(1.39-4.44), .002**	2.41(1.12-5.18), .024*
	Yes	24	57	1	1
Frequency of cleaning WSC	More than once a week	38	49	1	1
	Weekly	28	59	0.61(0.33-1.14), 0.119	0.38(0.16-0.87), 0.022*
	Above weekly	29	17	2.20(1.06-4.58), .035*	0.76(0.27-2.12), .602
Sanitation facility	Unimproved	49	50	1.60(0.93-2.74), .088	0.68(0.32-1.46), .321
	Improved	46	75	1	1
Availability of HWF?	No	44	31	2.62(1.48-4.64), .001**	1.42(0.61-3.33), .420
	Yes	51	94	1	1
Monthly HH income	Low	51	51	1	1
	Middle	34	57	0.60(0.34-1.06), .078	0.73(0.32-1.63), .438
	High	10	17	0.59(0.25-1.41), .233	0.80(0.25-2.54), .703

Abbreviations: 1, reference category; OR, crude odds ratio; AOR, adjusted odds ratio; HWF, handwashing facilities; WSC, water storage containers.
All variables with a *P*-value < .25 in the bivariate logistic regression analysis were included in the multivariable logistic regression analysis.
*—Significant at *P*-value < .05. **—Significant at *P*-value < .01. ***—Significant at *P*-value < .001.

in the peri-urban and informal settlement areas of the town. Due to inadequate water supply, a large number of people were compelled to use unsafe water, which increased health risks in the area. One FGD participant explained that;

> "Access to piped water supply was very low in our area. While even the rural villages get enough water, people who live in the peri-urban areas of the town do not get enough water. Due to insufficient piped water supply in the area, we are forced to use unprotected springs and unsafe water. For this reason, the health of our children and ourselves are deteriorating." (Women, 35, Bobicho kebele)

The FGD result indicated that the major problems associated with the primary water sources were failure of public taps to provide water service at regular hours, lack of water from the main water sources, break-down of public taps, and slow repair. The result also revealed that private piped water coverage was low in the peri-urban informal settlement areas, and all participants believed that the reason is the area where they live is illegal. Most participants also indicated that community participation in planning and implementing water supply projects was poor. One key informant noted that;

Table 3. Factors associated with the bacteriological quality of stored drinking water during the rainy season.

VARIABLES	CATEGORY	CONTAMINATION OF WATER WITH *E. COLI* (RAINY SEASON)		OR (95% CI), *P*-VALUE	AOR (95% CI), *P*-VALUE
		YES	NO		
Water sources	Piped water on premises	23	87	1	1
	Piped water off premises	53	57	3.52 (1.94-6.36), <.001***	2.86 (1.24-6.58), .013*
Duration of water storage	⩽3 d	20	78	1	1
	>3 d	56	66	3.31(1.80-6.07), <.001***	2.26 (1.09-4.69), .029*
Mouth size of WSCz	Narrow mouthed	8	46	1	1
	Wide and narrow	23	75	1.76 (0.73-4.27), .209	2.26 (0.77-6.60), .138
	Wide mouthed	45	23	11.25 (4.56-27.76), <.001***	12.06 (3.05-47.62), <.001***
Water withdrawal method	Pouring	18	81	1	1
	Dipping	58	63	4.14 (2.22-7.72), <.001***	0.70 (0.26-1.90), .481
Is the WSC covered?	No	61	78	3.44 (1.79-6.61), <.001***	2.91(1.34-6.34), .007**
	Yes	15	66	1	1
Frequency of cleaning WSC	More than once a week	27	60	1	1
	Weekly	27	60	1(0.52-1.90), 1.000	0.94 (0.42-2.09), .883
	Above weekly	22	24	2.04 (0.98-4.25), .058	0.93 (0.35-2.43), .876
Mother's education level	< Secondary school	40	57	1.70 (0.97-2.97), .065	2.17 (1.07-4.41),.032*
	⩾ Secondary school	36	87	1	1
Availability of HWF?	No	32	43	1.71(0.96-3.05), .070	0.68(0.30-1.54), .358
	Yes	44	101	1	1

Abbreviations: 1, reference category; OR, crude odds ratio; AOR, adjusted odds ratio; HWF, handwashing facilities; WSC, water storage containers.
All variables with a *P*-value < .25 in the bivariate logistic regression analysis were included in the multivariable logistic regression analysis.
*—Significant at *P*-value < .05. **—Significant at *P*-value < .01. ***—Significant at *P*-value < .001.

> "The community is willing to participate in any activities to improve the water supply in our area. The community, including me, with whatever is necessary, including financially. We are willing to cooperate vigorously. However, due to the lack of a government body to coordinate with us, our participation has been low so far. Additionally, we are also experiencing a shortage of water." (Man, 48, Bobicho Kebele)

The results of the FGD indicated that the government's efforts to provide water were insufficient.

One FGD participant noted that;

> "The government's efforts to improve the existing water supply problems were insufficient. Additionally, the right to access water has been denied to us just because the place where we live is illegal." (Women, 27, Sech-Duna Kebele)

On the contrary to the above FGD participant, 1 key informant from Hosanna town water supply enterprise noted that: -

> "Our office provides drinking water to all areas in the town, even in peri-urban and informal settlement areas. However, due to the water shortage, we are making it available in shifts. In general, we cannot say that the water supply is sufficient, but great efforts are being made to improve the water supply. Additionally, due to water scarcity, there are places where we have not been able to provide water even in shifts, especially the communities living in the peri-urban and informal settlement areas." (Higher official, HTWSE)

According to both FGD and KII participants, the inadequate provision of safe water has led to various water-related diseases, including diarrhea in the area. One FGD participant noted that;

Table 4. Stepwise multiple linear regression for identifying predictors of per capita water consumption during the dry and rainy seasons.

SEASON	VARIABLES	NO. OF OBS.	COEFF.	95% CI, *P*-VALUE
Dry season	Piped water on premises	288	4.99	3.98-6.01, <.001***
	Family size (log)		−6.63	−7.91-(−5.36), <.001***
	Volume of water storage vessels (log)		3.05	1.59-4.50, <.001***
	Number of water storage containers		0.44	.06-.81, .022*
Rainy season	Piped water on premises	288	3.94	2.84-5.05, <.001***
	Family size (log)		−7.00	−8.39-(−5.61), <.001***
	Number of water storage containers		0.78	.38 -1.19, <.001***
	Volume of water storage vessels (log)		2.39	.81-3.97, .003**

Mother's education level, education status of the head of household, and duration of water storage did not significantly contribute to the dry season model were excluded from the analysis.
Mother's education level, education status of the head of household, duration of water storage, and rainwater harvesting and using did not significantly contribute to the rainy season model were excluded from the analysis.
In both seasons the Model *P*-value is significant at *P*-value < .001.
*Significant at *P*-value < .05. **Significant at *P*-value < .01. ***Significant at *P*-value < .001.

> "In our kebele, especially in the peripheral area where we live, the water supply has not been paid attention to, so it has had a great impact on our health. The lack of adequate water supply in our area has made it difficult for us to maintain our personal hygiene. For this reason, the number of people suffering from diarrhea and other water-related diseases in our kebele was very high." (Man,42, Bobicho Kebele)

In line with the above FGD participant, 1 key informant participant also noted that: -

> There are a lot of water supply problems in the kebele where I work. As my work is on children and mothers, I am seeing how the lack of adequate water is affecting health. The community had to travel long distances to obtain water and use unsafe water sources due to insufficient water supply. As a result, children are frequently affected by diarrhea. (Health extension worker, Jelo-Naremo Kebele)

All participants in the FGD and KII suggested that government bodies should take the initiative to involve community members in the planning and implementation of the water supply project. This could improve the provision of adequate and safe water for the community. Participants also suggested several measures to improve the existing water supply, such as repairing non-functional public taps quickly, building new public taps at a reasonable distance, and developing unimproved water sources.

Discussion

The findings showed that the seasonal variation in per capita water consumption was statistically significant. This is consistent with findings obtained from Sierra Leone and Ghana.[16,31] A higher per capita water consumption during the rainy season in the study area could be associated with the availability of alternative water sources such as rainwater. The average per capita water consumption during the dry (19.41) and rainy seasons (20.31) was lower than the findings in Benin, Ghana, and Sierra Leone.[16,31,39] This could be associated with the inadequacy of water supply, socioeconomic condition, culture, lifestyles, and climate condition of the study area. A statistically significant difference in mean per capita water consumption was also observed between the households connected with piped water on and off-premises during the dry and rainy seasons. In both seasons, households having piped water on premises had a better per capita water consumption compared to households lacking piped water on premises. Generally, the result revealed that the per capita water consumption for a large number of households in both seasons was below 201 per day, which failed to meet the minimum per capita water consumption Howard et al recommends. Howard et al recommend the minimum per capita water consumption compromising personal and domestic hygiene is 201 per day.[40] Lack of adequate water for domestic and personal hygiene could make households highly vulnerable to water-related diseases, including diarrhea.

The study attempted to determine what factors influence the amount of water people consume in both the dry and rainy seasons. A stepwise multiple linear regression identified piped water on premises, family size, number of water storage containers, and volume of water storage vessels as significant predictors of water consumption in both seasons. However, the importance of each factor varied depending on whether it was the dry or rainy season. Having piped water on premises has increased the per capita water consumption in both seasons. Households having piped water on premises had 5 and 4 times more per capita water consumption than households lacking piped water on premises during the dry and rainy seasons, respectively. Other studies also found that having piped water on premises was associated with better per capita water consumption.[4,5] The accessibility of water on premises might require less effort to collect large amounts of water and also encourage more water use, which might increase their per capita water consumption. This is in agreement with the findings obtained from a systematic review.[5] The increase in the number and volume of water storage containers was also associated with an increased per capita water consumption in both seasons. A 1 unit increase in the volume of water storage vessels was associated with an average increase of 0.03 and 0.021 in per capita water consumption during the dry and rainy seasons, respectively. Likewise, a 1 unit increase in the number of water storage containers was associated with an average increase of 0.44 and 0.781 in per capita water consumption during the dry and rainy seasons, respectively. This could be due to an increase in the number and volume of water storage containers, which might increase the ability of households to store more water and simultaneously consume more water. This is consistent with the findings obtained from Ghana.[31] The household family size has an inverse relationship with the per capita water consumption in both seasons. Households with a larger family size had a lower per capita water consumption compared to a smaller family size. A 1 unit increase in family size was associated with an average decrease of 0.071 in per capita water consumption in both seasons. This finding is consistent with studies conducted in Ghana, Iran, China, and the Middle East.[22,31,41,42] This is because water used for various domestic purposes such as cooking, house cleaning, yard cleaning is relatively independent of family sizes.[22,31,41]

Although the water sample collected from the storage reservoir and point of water collection was free from contamination, household stored water was significantly contaminated with *E. coli* during the dry and rainy seasons. The prevalence of drinking water contamination with *E. coli* was 43.2% and 34.5% during the dry and rainy seasons, respectively. This microbial contamination of water might increase the risk of water-related diseases. The high prevalence of fecal contamination in this study could be due to poor water handling practices during collection, transport, and storage. Besides, inadequate access to piped water on premises, poor household water treatment practices, longer duration of water storage, and mouth sizes of water storage containers could also have effects on the level of microbial water contamination. On the other hand, the prevalence of fecal contamination of water in both the dry and rainy seasons was lower than other studies conducted in the Dessie Zuria district (66.0%), North Gonder Zone (72.6%), and Jimma Zone (80.0%).[23-25] The disparity could be associated with the sources of water, where in this study, all study households relied on improved water sources while in the other studies relied on both improved and unimproved water sources. Besides, water handling practices, study setting, and sanitation might contribute to fecal contamination of water.

A statistically significant seasonal difference in microbial contamination of stored water was observed. The water contamination with *E. coli* at the point of use in the dry season was significantly higher than in the rainy season. This finding is in line with evidence obtained from South Africa, which showed higher levels of microbial contamination of stored water during the dry season than in the rainy season.[43] The study finding is also in contrast with evidence obtained from Addis Ababa, which found higher microbial contamination of stored water during the rainy season.[14] The high prevalence of fecal contamination of water during the dry season could be associated with poor hygienic practices and longer duration of water storage due to critical water shortages during the dry season than in the rainy season. Furthermore, households might use unsafe alternative water sources during water supply interruption and when they face water shortage, which is very common in the dry season. This could cross-contaminate the water storage containers and water collected from their water sources, thereby increasing the risk of microbial contamination of water in the household during the dry season. The prevalence of drinking water contamination with *E. coli* was higher in households connected with piped water off premises than in households connected with piped water off premises during the dry and rainy seasons. This finding is in line with evidence obtained from Vietnam and the systematic review.[4,5] This might be associated with households who lack piped water on premises were expected to collect water outside their compound, which could increase the risk of microbial contamination of water due to poor water handling during collection, transportation, and storage. The majority of households who lacked piped water on premises collect water using Jerry cans and transport it to home by carrying it on their head or backs. The findings also indicated that more than 94% of households store their water inside their home or kitchen. Storing water for an extended period of time combined with unsafe storage could increase the risk of microbial contamination, which is supported by different studies.[23,44]

Various factors were associated with microbial contamination of stored water in the study area. The multivariate analysis indicated that the piped water off-premises, storing water for more than 3 days, uncovering of water storage containers, and the wide-mouthed water storage containers were significantly associated with the presence of *E. coli* in drinking water in both the dry and rainy seasons. Households with piped water off premises were 4.5 and 2.8 times more likely to have *E. coli* in their drinking water compared to households with piped water on premises during the dry and rainy seasons, respectively. Similarly, storing water for more than 3 days was 2.8 and 2 times more likely to increase the *E. coli* count in water compared to households who store water for a lower number of days during the dry and rainy seasons, respectively. The result is in line with findings obtained from Dessie Zuria District, which indicated that water stored for more than 3 days and uncovered water storage containers were significantly associated with the presence of fecal coliform in water.[23] The majority of households (75.5%) in the study area use either wide-mouthed or wide-and narrow-mouthed water storage containers for storing water, which could increase the risk of microbial contamination. This is because wide-mouthed water storage containers provide a large surface area for microbial attachment and are also more likely to be left open, which allows microbes to enter the water storage containers more easily. Besides, wide-mouthed water storage containers are typically larger in size and store water for a longer time, which could increase the risk of contamination. This is in line with the findings obtained from El Paso, Texas.[44] The study also indicated that mothers with less than a secondary school education level were another important predictor of contamination of household stored water in the rainy season. Mothers with less than a secondary school education level were 2 times more likely to have *E. coli* in their drinking water compared to mothers with secondary school and above education levels during the rainy season.

The study showed that the microbiological quality of stored water can be affected by per capita water consumption. The study found that the prevalence of microbial contamination of drinking water was high during the dry season when per capita water consumption was lower, and lower during the rainy season when per capita water consumption was higher. These results suggest that a lower per capita water consumption during the dry season might reduce hygienic practices, which could play a role in increasing the microbial contamination of drinking water. Conversely, increased per capita water use during the rainy season could improve hygienic practices, which may help lower the microbial contamination of drinking water. This is consistent with other findings, which revealed that reduced water availability can lead to poor hygienic practices.[40,45,46] Moreover, reduced availability of drinking water during the dry season might force households to use unsafe water, which contributes to an increase in microbial contamination of drinking water.

The town's drinking water provision was insufficient, particularly in the peri-urban and informal settlement areas. This was due to several factors, including poor investment in water infrastructure, lack of local community participation, unreliability of water sources, access inequality, breakdown in water distribution systems, and slow repair. The majority of the households in the selected study area were also lacking piped water on premises, which could be associated with the lack of land tenure rights and spatial factors. A review paper also indicated that economic, spatial, social, institutional, political, and informational factors were barriers to water infrastructure development in urban informal settlements in low-income and middle-income countries.[47]

Limitation of the Study

Despite the strength of the study, which measured seasonal variability of household water use and microbial water quality, the study had a few limitations. There are cases where households might wash their clothes outside their compound, which could underestimate the average per capita water consumption. Besides, very few households collected water from their water sources and used it for backyard farming, which was excluded from the analysis that might underestimate the average per capita water consumption. For households connected with piped water on premises, the quantity of water used directly from running taps was estimated using self-reported data on the duration of time in minutes of water used directly. This could be associated with recall bias that could affect the average per capita water consumption. Although the study has measured the bacteriological quality of water at the point of use, storage reservoir, and point of water collection, there could be other confounding factors that could affect the current level of microbial water contamination in the household. The confounding factors that could affect the current associations, which include leakage and microbial contamination in the distribution system, have to be further investigated. Therefore, sampling water from a household's private tap and water distribution systems has to be considered to have a full picture of the microbial contamination problems in the study area. Furthermore, although we have confirmed that the sampled water from households was from their primary sources, alternative unsafe water sources could be used during water supply interruption that could contaminate water storage containers as well as stored water collected from their main water sources. This might affect the level of microbial water contamination at the household level.

Conclusion

This study investigated the seasonal variation in household water use and microbiological water quality and their determinant factors. It also highlighted the challenges faced in providing adequate drinking water. The main conclusions are as follows:

- The findings revealed that the difference in per capita water consumption and microbial contamination of stored water between the dry and rainy seasons was statistically significant. A higher per capita water consumption was observed during the rainy season. Despite an improvement in per capita water consumption during the rainy season, the per capita water consumption for many households in both seasons was below 20 liters. This might lead to poor personal and domestic hygiene that could increase the risk of water-related diseases. Lack of enough water could also force households to use unsafe water, which might affect their health and well-being. The findings also showed that the microbial contamination of water in the dry season was significantly higher than in the rainy season.
- The probability of *E. coli* contamination in households with piped water on premises is lower than in households with piped water off premises in both the dry and rainy seasons. Piped water off premises, storing water for more than three days, uncovering of water storage containers, and wide-mouthed water storage containers were significantly associated with the presence of *E. coli* in drinking

water in both seasons. The findings also confirmed that households having piped water on premises had the highest per capita water consumption in both seasons. The per capita water consumption was positively correlated with piped water on premises, volume of water storage vessels, and number of water storage containers in both seasons, while family size was negatively correlated.

- The study recommends taking measures to enhance the quantity and microbiological quality of water to mitigate the risk of waterborne diseases. More investment in water infrastructures, including private and public taps, is also highly recommended to improve the quantity of water delivered to households. The findings also suggest seasonal monitoring of the safety of drinking water throughout all stages of water production, distribution, and use to ensure that the water is safe and healthy. A proper measure also has to be considered to reduce the level of microbial contamination at the point of use, which includes education on hygiene, safe water handling and storage, and household water treatment.

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Authors Contribution

All authors contributed equally to conceptualization, methodology, investigation, data curation, formal analysis, validation, writing review and editing. Besides, AAA contributed to writing the original draft.

Ethical Consideration

The study was approved by National Research Ethics Review Committee, Ethiopia (Ref.No.7/2-150/ M 259/35). A study permit was obtained from Hosanna town administration office and selected kebeles. A written consent was also taken from all study households.

Data Availability Statement

Data will be made available on reasonable request.

Supplemental Material

Supplemental material for this article is available online.

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