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Assessment of Pump-Based Drinking Water Quality Compliance with World Health Organization Standards in Central Gondar, Ethiopia

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Abstract

Access to quality water is critical for public health; however, Ethiopia is grappling with challenges stemming from inadequate infrastructure and limited resources. This study evaluated the quality of drinking water sourced from large and medium-sized pump-based systems in Central Gondar, comparing the findings against WHO water quality standards. Employing an explanatory mixed methods research design, 415 respondents were selected through systematic sampling. Data were gathered through surveys, focus groups, and key informant interviews, alongside experimental analyses conducted at sample sites.

The results indicated a low level of satisfaction with drinking water quality, with only 1.3% of householders reporting very high satisfaction and 18% expressing satisfaction. Regarding water treatment, a mere 0.26% of households were very satisfied, while 53% voiced dissatisfaction, underscoring concerns about the effectiveness of treatment methods. Additionally, approximately 55% of respondents rarely observed changes in water quality due to seasonal variations, reflecting a limited understanding of safety testing protocols.

Interestingly, 33.3% of respondents rated the WHO standards for drinking water quality as excellent, which was associated with a perception of a highly reliable water supply system. Experimental results revealed variability in calcium and magnesium levels, with the Dembia-3 sample showing the highest calcium concentration at 110 mg/L. Alarmingly, the Gondar-4 sample tested positive for fecal coliforms (3 colonies/100 mL) and total coliforms (15 colonies/100 mL), raising significant public health concerns.

In conclusion, the study highlights the urgent need for improvements in water quality management and emphasizes the importance of raising community awareness regarding water safety issues.

Keywords: Drinking water, Water quality, Satisfaction, WHO Standards, Pump-Based Systems, Central Gondar.

1. INTRODUCTION

Access to adequate, safe, and fresh drinking water is a fundamental necessity for human life. However, just 1% of this freshwater is accessible for human use, found in lakes, rivers, and groundwater. While water covers more than two-thirds of the Earth's surface, the majority of it is salty and unsuitable for consumption (Desalegn, 2021)

That is why freshwater resources make up only about 2.7% of the total water available on our planet (WHO, UNICEF, World Bank, 2022; Megersa, 2018; Mekuanint, 2021). According to WHO and UNICEF (2011), more than 75% of the planet is covered by the aquatic ecosystem, and the remaining 25% is a terrestrial ecosystem. From the total aquatic ecosystem, 97% is covered by the marine water bodies; the rest is covered by fresh water, which is the most exploited and important water body for humans.

Most of the available freshwater resources are inaccessible because they are in the hidden part of the hydrologic cycles (deep aquifers) and in glaciers (frozen in the polar ice) (WHO, UNICEF, World Bank, 2022). This report further noted that freshwater bodies, including rivers, lakes, reservoirs, ponds, and groundwater with a lower salt concentration, are important potential sources for use.

The WHO sets international norms and standards for drinking water quality (SDWQ) to protect public health and act as justification for national regulations and standards (WHO, 2017). These recommendations address microbial risk, chemical contaminants, and other factors that jeopardize water safety. Among the methods that have been supported by the WHO is the implementation of Water Safety Plans, which address risk management from catchment through consumer (WHO, 2017). The world water crisis must be tackled by a multi-pronged approach involving the establishment of infrastructure, effective water management, and continuous monitoring to ensure compliance with the established standards (WHO, 2021).

Currently, approximately one billion people in the developing world, including many in Africa, lack access to safe and adequate drinking water. Access to safely managed drinking water is not only a fundamental human right but also a crucial determinant of public health (United Nations, 2010). Despite this, millions across Africa are without reliable drinking water services, as highlighted by the World Health Organization (WHO, 2021).

Africa has the lowest water supply coverage in the world, with only 62% of the population having access to improved water sources. The situation is particularly awful in rural areas, where only 47% of the population has access to safe drinking water (Gebremichael et al., 2020). This deficiency makes rural communities especially vulnerable to poverty and disease, resulting in thousands of preventable deaths each year. Furthermore, the challenges of delivering quality water services extend beyond rural areas, impacting towns and cities throughout Africa (Gebremichael et al., 2020; Yirdaw et al., 2023). The combination of inadequate supply and ineffective delivery systems underlines the urgent need for comprehensive solutions to ensure safe drinking water for all.

Ethiopia faces substantial challenges in ensuring access to quality drinking water (World Bank, 2019). Despite efforts to improve water access, a large portion of the population still relies on unimproved sources, such as surface water and unprotected wells (UNICEF, 2020). In response to these challenges, the Ethiopian government has established national drinking water standards aligned with Sustainable Development Goal (SDG 6), which underscores the importance of safe water and sanitation (Federal Democratic Republic of Ethiopia, 2018). The Compulsory Ethiopian Standard for Drinking Water Specification outlines the physical, chemical, and bacteriological criteria that drinking water must meet (Ethiopian Standards Agency, 2019). However, a 2016 survey revealed that only a small percentage of Ethiopians utilized safely managed drinking water services, highlighting the urgent need for improvements in both water quality and access (WHO, 2021).

Furthermore, research indicates that many drinking water sources in Ethiopia are contaminated with E. coli and other harmful microorganisms, posing a serious threat to public health (Berhanu et al., 2018). Addressing these issues is critical for safeguarding the health and well-being of the Ethiopian population.

The Amhara Region faces major challenges related to poor water quality, particularly in rural areas (Abebe et al., 2020). A study assessing drinking water quality in rural Amhara found that the majority of water samples failed to meet national and international standards, exhibiting high levels of total and fecal coliforms (Hailu et al., 2019). In the Mecha district of Amhara, another study reported that most water samples exceeded WHO standards for turbidity, indicating the presence of suspended particles in the water (Tamiru et al., 2020). These water quality issues are exacerbated by factors such as agricultural runoff, sewage pollution, and insufficient water treatment facilities (Zelalem et al., 2018). Testing for water potability in the Amhara region revealed that groundwater is highly contaminated, with all samples exceeding the recommended limits for both total coliform and fecal coliform levels (Berhanu et al., 2018; Hailu et al., 2019).

However, similar studies have not been conducted in the Central Gondar district, which this study aims to address. Gebremichael, S., Yismaw, E., Tsegaw, B., and Shibeshi, A. (2020) prepared a study titled "Assessing the Socio-Demographic, Economic, and Water Source Types that Influence Households' Drinking Water Supply in Debre Tabor Town, Northwest Ethiopia." The study, published in MOJ Public Health, volume 9, issue 3, pages 63–73, discusses determinants of accessible and safe drinking water among households. The research investigates a range of socio-demographic and economic factors, in addition to alternative types of water sources, to analyze how they contribute to the supply of drinking water

Gondar, a historic city in the Amhara Region, faces major challenges in drinking quality water supply (Getachew et al., 2021).

The city's water supply primarily relies on the Angereb River Dam and treatment plant, supplemented by boreholes. However, the supply is often intermittent, especially during the dry season, forcing residents to choose unsafe water sources (Tadesse et al., 2020). This paper aims to identify these challenges to inform policy interventions.

Studies, including Getachew et al. (2021), have indicated that Gondar's drinking water sometimes exceeds WHO standards for turbidity, residual chlorine, total coliform, and fecal coliform. Addressing these issues with fresh data is crucial, as previous assessments have shown high rates of E. coli contamination in samples from protected wells, springs, and water lines (Girma et al., 2019; Tadesse et al., 2020). Yirdaw, G., Dessie, A., Azanaw, J., and Birhan, T. (2023) conducted a cross-sectional community-based study, "Latrine Utilization and its Associated Factors in Urban Slums Dwellers of Gondar City, Northwest Ethiopia." The research appeared in Environmental Health Insights, 17, 1–10, which examines the use of latrines among urban slums' residents and identifies the factors influencing this practice. The research highlights the significance of access to sanitation facilities and socio-economic, cultural, and environmental latrine use determinants for these communities, ultimately contributing to regional public health discussion and policy.

The results will be used to shape public health policy and enhance water accessibility within the area. More importantly, current conditions should be evaluated using recent data, which this paper aims to provide for policy considerations. In general, this study seeks to contribute to the understanding of current water quality supply by assessing drinking water from large and medium pump-based systems in Central Gondar, comparing compliance with the WHO quality water standards, and finally analyzing public health implications.

The study answered the question:

How does current drinking water quality, in relation to WHO standards, affect public health and respondent satisfaction, considering seasonal variations in the availability of water?

1.1 Conceptual framework of the study

This study assessed overall drinking water quality using multiple factors Bacteriological Indicators, chemical parameters, environmental factor, physical parameters, human impact and geographical factors were also considered to provide a comprehensive evaluation of water quality in the study area. All these factors combined give an overall picture of water quality in a given area (Figure 1).

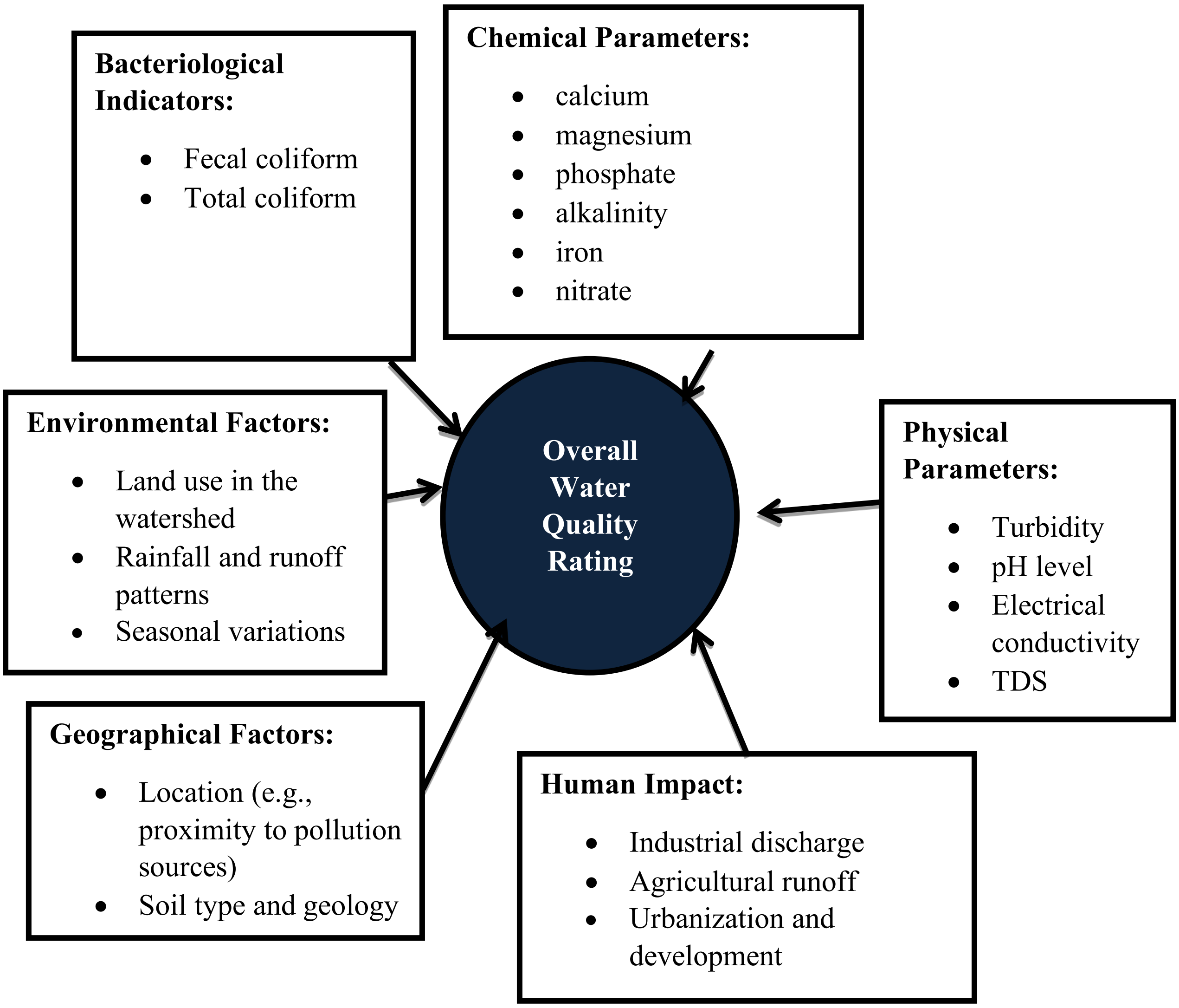

Figure 1. A schematic diagram showing the relationship between the overall water quality rating in the drinking water supply and several predictor variables

2. Description of the Study Area

2.1. Location

The study covers Wogera, Chilga, Koladiba, and Gondar city, all located in the Central Gondar Zone (see Figure 2). As shown in Figure 2, the absolute location of the study areas ranges from $11^{0}45'$ N and 37 $^{0}35'$ E. This zone is located in northwestern Ethiopia, extending along a ridge in the northern Ethiopian highlands. The rainfall pattern in Central Gondar is unimodal, including a single peak in July and August. Approximately 80% to 90% of the mean annual rainfall occurs during the main rainy season, known as *Kiremt*, which begins in June/July and continues until August/September. The annual rainfall in the study area can reach up to 1,151 mm. The agro-ecological zone is classified as *woinadega*, with a mean annual temperature ranging from 12.9°C to 26.4°C, a mean of 20°C. The topography comprises hilly and mountainous regions, as well as plains and valleys, with altitudes ranging from 708 to 3,077 meters above sea level. The soils in the area are varied, consisting of silt clay, sandy, sandy loam, silt loam, sandy clay, and silt clay loam (Nega et al., 2022).

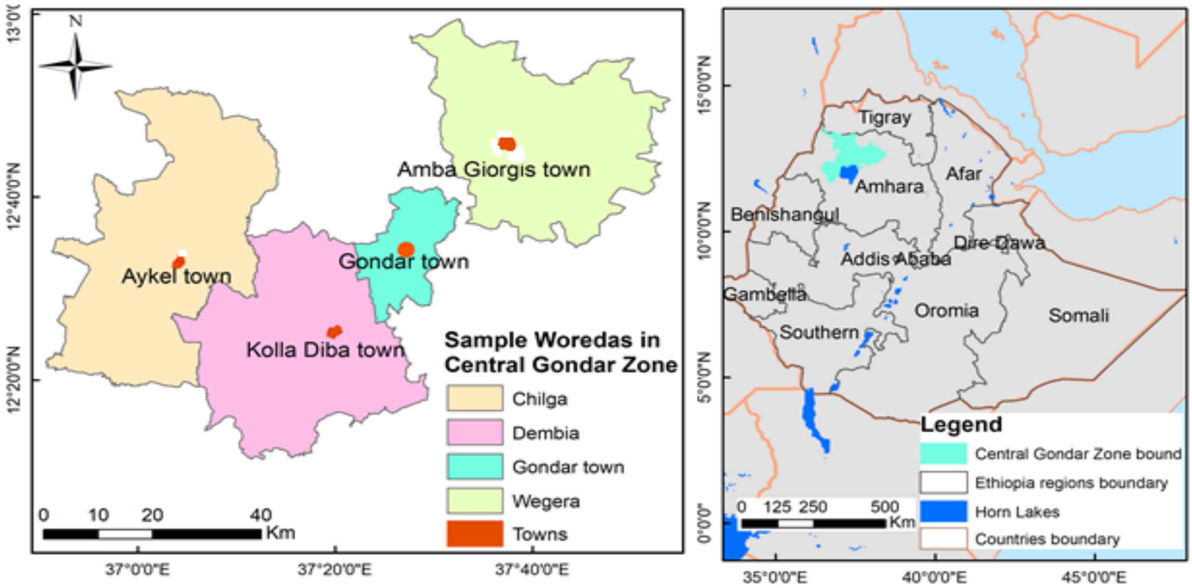

Figure 2. The location map of the study areas (Sources: Arc GIS)

2.2. Population of the Study Areas

According to the Ethiopian Statistics Service population projection, Gondar had a total population of 443,156, of whom 217,102 were men and 226,054 were women (ESS, 2023). According to the national census conducted by the Ethiopian Statistics Service (ESS, 2023) the total population for the study areas Chilga (291,046), Wogera (287,571), Dembia (353,907), Gondar city (443, 156) with a total population of 1,375,680.

Gondar is a historic city in the Amhara region of Ethiopia, renowned for its heritage. It was the capital city of Ethiopia during the 17th and 18th centuries, and some of its key points of interest include Fasil Ghebbi, a World Heritage Site. The medieval fortress complex includes palaces, churches, and a large swimming pool, depicting the unique architecture of the medieval Ethiopian period. It was founded by Emperor Fasilides in 1636, who commissioned most of its famous buildings. Gondar is also famous for the lively festivals, particularly Timkat (Epiphany), which is the celebration of Jesus' baptism in the Jordan River. The city is proud to possess many historic Orthodox churches with distinctive architectural designs and holy artwork. With the stunning backdrop of the Simien Mountains, Gondar offers stunning vistas and trekking and wildlife watching opportunities. The local economy is primarily agriculture-based, but tourism also plays a significant role because of its historical sites and natural landscape. Gondar as a whole is a stunning city showcasing Ethiopia's rich history and culture, and a good spot for tourists and historians alike.

3. Research Methodology

3.1. Research Philosophy

This study embraces a pragmatic philosophy, positing that the research question is the key factor in determining the appropriate research philosophy. This means that certain approaches might be more effective for addressing specific questions. According to Creswell (2014), mixed methods research involves collecting both quantitative and qualitative data, integrating these forms, and employing distinct designs that may incorporate various philosophical assumptions and theoretical frameworks. Therefore, this study utilized a pragmatic philosophy to gain these advantages.

3.2. Research Design

The study employed a concurrent mixed-methods research design, including both qualitative and quantitative research approaches. In this case, the quantitative data are first presented, followed by qualitative data. This design was chosen to show the strengths of each method, compensating for the weaknesses of the other. To effectively address the research questions and objectives, a mixed methods approach was essential. Socioeconomic and demographic data related to the drinking water quality of medium and large pump systems were collected and analyzed using quantitative and qualitative methods. In contrast, people's perceptions, attitudes, and opinions regarding the drinking water quality of large and medium-scale systems were collected and analyzed through qualitative methods.

3.3. Sampling Techniques and Sample Size Determination

This study employed both probability and non-probability sampling techniques. Multi-stage sampling was used to select respondents for the questionnaire. Initially, the Central Gondar administrative zone was purposively selected. Within this zone, Gondar city and three *woreda* (synonymous with district) towns (Aykel, Ambagiworgis, and Koladiba) were selected purposively (Figure 2).

The rationale for choosing these study areas includes: The selected areas face significant challenges related to drinking water quality, leading to ongoing grievances from beneficiaries. This necessitates a comprehensive study to identify the underlying issues.

The principal investigator and the supervisors have extensive experience with the drinking water supply problems in the selected areas, since their workplace is located within these areas. The distribution of drinking water is highly inadequate in these regions, indicating the need for research to inform policymakers. Last but not least, detailed studies are scarce regarding existing large and medium-scale pump-based projects in the selected sub-cities and towns, which further signifies this study.

Next, *Kebele* administrations (the lowest administrative unit in Ethiopia) were selected using simple random sampling techniques to ensure adequate representation for generalizations. Specifically, two *k*ebeles from Gondar city and three kebeles from the three *woreda* towns, as indicated below, were chosen randomly. The selected *kebeles* in Gondar city include: Azezo Sub-city *kebele* 19: 5,786 customers and Markie Sub-city *kebele* 18, 19: 9,337 customers. The selected *kebeles* from the three *woreda* towns include Aykel Town *kebele* 01: 1,210 customers, Amba Gergios Town *kebele* 01: 195 customers, and Koladiba Town *kebele* 03: 1,590 customers. The total sampling framework for the selected *kebeles* and sub-cities accounts for 18,118 customers.

Third, in determining the sample size to fill the questionnaire, Kothari's (2004) sample size formula was employed as shown below:

$$n = \frac{z^2.p.q.N}{e^2(N-1) + z^2 p.q}$$

Were,

n = sample size

z = value standard deviation at 95% confidence level (1.96)

p = sample proportion or result of pilot study (0.5),

q = 1 – p

N = number of total household population (18,118),

e = 5% error term

The total sample households, according to the formula, were about 377. However, because of the fear of missing data, the appropriate sample size was determined to be 415, an increment of 38 respondents. In relation to this, it is considered advisable to oversample by 10% - 20% in case there are non-response rates (Naing et al., 2006). However, 27 respondents did not correctly fill out the questionnaire and were excluded from the analysis. Finally, using a systematic sampling technique, 388 respondents were selected from a sampling frame obtained from each *kebele* administration of the selected *woreda* towns and sub-cities of Gondar City (see *Table 1*).

Table 1: Summary table in the selection of respondents proportionally

Kebele towns and sub-cities	**Total population (sampling frame)**	**The samples for the study**
Azezo sub-city kebele 19	5786	133
Maraki sub-city kebele 18	9337	213
Aykel town kebele 01	1210	28
Kolladeba town kebele 03	1590	36
Amba Georgis town kebeles 01	195	5
Total	18,118	415

Qualitative sampling

For qualitative sampling, the participants were selected using a purposive sampling technique. Accordingly, four water pump workers and four woreda water utility officers, four civil servants, and five kebeles administrators were selected as the key informants for the study. Additionally, four customers of male-headed households and four customers of female-headed households in each sample kebele's administration and sub-city were selected as key informants for the study. Besides, one focus group discussion (FGDs) in each woreda town and sub-city, with a total of five FGDs selected purposively. The FGD participants range from 6 to 8 members (Creswell, 2014). The composition of the FGD participants includes woreda water experts, civil servants, kebele administrators, water utility officers, and the customers/beneficiary households.

Laboratory Sampling

Stratified Composite Sampling

Stratified sampling is a technique that splits a population into subgroups (strata) by common traits and samples from each stratum (Cochran, 1977). Stratified Composite Sampling combines composite and stratified sampling methods. Composite sampling is a technique of combining several individual samples into one composite sample to reduce analytical costs (Helsel & Hirsch, 2002). The population is divided into five kebeles, from which ten users are randomly selected for water sampling to ensure representation. Samples from the Gondar kebele are combined into one, while the other three kebeles are treated separately. This method effectively assesses water quality across diverse groups, capturing the variations within the community. The benefits include comprehensive coverage of different strata, cost-effectiveness through reduced sample numbers, and increased precision by aggregating individual variances.

3.4. Data Sources and Data Collection Technique

This study utilized both primary and secondary data sources. Primary data sources included survey respondents, focus group discussion participants, and key informants. Secondary data sources comprised reports from the drinking water supply office, non-governmental organizations like WASH, regional project reports, CSA reports, and documents related to drinking water supply in the region. Data collection instruments included survey questionnaires, key informant interviews, focus group discussions, and direct observations.

***Survey Questionnaire*:** The questionnaire survey targets several key areas: socio-economic and demographic characteristics of respondents, community awareness of water quality, and water point protection. Data collection was done by the principal investigator, enumerators, and supervisors who can speak the local language. Interviews were scheduled at times convenient for respondents, such as Sundays and holy days, and were conducted near their homes, in offices, or around places of worship. A pilot survey was done with 40 respondents selected purposively. This helped to remove ambiguous and unclear words and to estimate the timeframe for the discussions.

Key Informant Interviews: The key informant interviews employed a non-directive, semi-structured format with some checklists, though these were not completely flexible. Interviews took place near the interviewees' homes, workplaces, or in churches and mosques, lasting between 60 and 120 minutes. Ethical standards were maintained by guaranteeing that informants were not obliged to continue if disinterested. Four key principles guided the interviews: allowing freedom of expression, attentive listening, maintaining a nonjudgmental attitude, and using a smartphone with consent to facilitate engagement and eye contact.

Focus Group Discussions (FGDs): FGDs are a key qualitative data collection method. Discussions focused on water quality related to small and medium-scale drinking water supply systems.

Checklists guided the discussions, allowing participants to share personal experiences and negotiate shared viewpoints. With the participant's consent, a smartphone was used to make eye contact with the interviewee. The principal investigator served as both moderator and facilitator, encouraging active participation and addressing potential dominance by certain individuals in the conversation.

3.5. Method of Data Analysis

Quantitative and qualitative data analysis techniques were utilized in this study. The analysis of qualitative data began concurrently with data collection, distinguishing it from quantitative methods, which typically adhere to more rigid protocols. The qualitative data analysis followed the six-step approach outlined by Braun and Clarke (2006). The first step involved familiarizing oneself with the data through careful reading, note-taking, and highlighting key statements. In the second step, initial codes were generated to categorize the data. Related codes were then grouped into potential themes in the third step. The fourth step involved reviewing and refining these themes for clarity and coherence. In the fifth step, the final themes were defined and named, encapsulating the core findings. The final step consisted of synthesizing and writing up the findings, presenting a clear narrative of the insights gained from the qualitative analysis. Accordingly, the themes emerging from the analysis include: Water quality concerns and environmental Influences, community awareness about water quality, water quality assessment, socioeconomic factors, and satisfaction. The quantitative data analysis, on the other hand, involves the processes of tabulating and summarizing empirical and numerical data to describe or generalize ideas about the population based on the sample. Upon completion of data collection, the data were coded, cleaned, and entered into statistical software (SPSS version 20 and transformed to STATA version 17). Descriptive and inferential data analysis methods were employed for the study.

Descriptive statistics summarize data using tables, percentages, and frequencies. Inferential statistics, such as the Chi-square test, were employed to show associations between variables.

In addition to quantitative and qualitative data analysis methods, this study incorporated laboratory-based water quality testing analysis conducted by the Gondar City Water Supply and Sewerage Service Drinking Water Quality Control Case Team. Four water samples coded Dembia-3, Chilga-2, Gondar-4, and Ambageorgis-1 were analyzed for physical, chemical, and bacteriological parameters. The physical parameters included turbidity, pH, temperature, conductivity, and total dissolved solids (TDS).

Chemical parameters assessed were calcium, magnesium, alkalinity, iron, nitrate, and phosphate. Bacteriological analysis focused on fecal and total coliforms. The units of measurement were turbidity in UNT, conductivity in μS/cm, and all chemical parameters in mg/L. These samples were selected to represent different water sources within Gondar city and its surrounding areas, aligning with the study's focus on large and medium pump-based systems.

4. Results and Discussion

4.1 Results

4.1.1. Demographic and Socio-Economic Characteristics of Respondents

Demographic and socio-economic characteristics of respondents are vital to assess drinking water quality from large and medium pump-based systems. As shown in Table 2, the age breakdown revealed that the largest number, about 40% of the respondents, were between 29 and 39 years old. Furthermore, the lowest number of respondents, about 4%, was found in the age group above 61 years. This implies that a larger number of respondents have good awareness regarding the issue of drinking water quality.

Among respondents, nearly half, 188 (48.45%), were female, and one-fourth (25%) of respondents have a secondary or higher educational level, while those who cannot read and write account for 5.9%. This implies that this group has good awareness of the quality of drinking water and protects drinking water from any contamination, like animal waste, field defecation, and the like.

Regarding marital status, the majority of the respondents (83%) were married, indicating that marriage is stable in the study areas. The lower percentage of categories of family size is between 1 and 3 (19.1%), whereas the larger family size has a range of 4-6 (33%) (see Table 2). The average family size of the respondents was about 6, with an STD of 3.321. Moreover, regarding occupation, respondents who were occupied in a temporary job and not employed account for about 36% and 41%, respectively; however, self-employed and permanent job account for 12% and 11%, respectively (Table 2).

Table 2: Demographic and socioeconomic characteristics of the study respondents

Variables	Categories	Freq.	%
Age (years)	18-28	52	13.40
	29-39	159	40.98
	40-50	108	27.84
	51-61	53	13.66
	>61	16	4.12
Total		**388**	**100**
Sex	Male	200	51.55
	Female	188	48.45
Total		**388**	**100**
Marital status	Married	322	82.99
	Unmarried	66	17.01
Total		**388**	**100**
Educational status	Unable to read and write	23	5.93
	Able to read & write	89	22.94
	Primary school	177	45.62
	Secondary school & above	99	25.52
Total		**388**	**100**
Occupation status	Self-employed	48	12.37
	Permanent job	44	11.34
	Temporary job	139	35.82
	Not employed	157	40.46
Total		**388**	**100**
Family size	1-3	74	19.07
	4-6	128	32.99
	7-9	94	24.23
	≥10	92	23.71
Total		**388**	**100**

4.1.2. The Status of the Current Drinking Water Quality of the Respondents

This study revealed that satisfaction with drinking water quality is very low in the study area, with only 1.3% and 18% householders rated as very satisfied and satisfied, respectively. It was also noted that approximately 32% and 8% were dissatisfied and very dissatisfied, respectively, with the quality of the drinking water (Table 3).

The study revealed that satisfaction with drinking water quality is notably low in the study area, with only 1.3% of households reporting being very satisfied and 18% satisfied. Likewise, about 32% of households expressed dissatisfaction, and 8% were very dissatisfied with the quality of drinking water. The remaining 40% of respondents reported a neutral stance (see Table 4 for details). The reliability of safety drinking water in Central Gondar is very low, evidenced by only three (0.77%) being very reliable and 49(12%) reported reliable to the safety of the drinking water, while approximately 40% of households report unreliable. About 11% of participants believed the current treatment method is ineffective in ensuring the safety of the drinking water. The experiences of seeking information on water quality standards are very low, only 0.26%and 14% participants were very frequently and frequently.

The findings regarding current water treatment in Central Gondar indicate very low community satisfaction, with only 0.26% of households reporting being very satisfied, and about 11% satisfied with the treatment results. A majority of households expressed dissatisfaction (53%), while approximately 36% remained neutral toward the effectiveness of water treatment. Regarding water quality testing frequency, merely 0.26% and 10% of participants believed that water should be tested very frequently and frequently to ensure safety. This overwhelmingly suggests that most participants think water quality testing is needed only rarely and very rarely, highlighting a significant lack of awareness about the importance of regular water quality testing. Furthermore, participants' understanding of WHO drinking water quality standards revealed that only 2% had excellent knowledge, 23% had good understanding, and about half (52%) possessed a fair understanding.

This data reflects a knowledge gap that could contribute to the low confidence and limited expectations about water treatment efficacy and safety monitoring within the community.

Table 3: The current status of quality **drinking water** in the study area

Variables	Categories	Freq.	%	Mean	SD	Min	Max
Satisfaction with the quality of drinking water	Very satisfied	5	1.29				
	Satisfied	70	18.04				
	Neutral	156	40.21				
	Dissatisfied	125	32.22				
	Very dissatisfied	32	8.25				
Total		**388**	**100**	**3.28**	**0.89**	**1**	**5**
Reliability of the water supply system to providing safe water	Very reliable	3	0.77				
	Reliable	49	12.63				
	Neutral	146	37.63				
Total	Unreliable	153	39.43				
	Very unreliable	37	9.54				
		388	**100**	**3.44**	**0.85**	**1**	**5**
Issue with water quality	Never	6	1.55				
	Rarely	41	11.08				
	Occasionally	543	39.69				
	Frequently	150	38.66				
Total	Very frequently	35	9.02				
		388	**100**	**3.42**	**0.86**	**1**	**5**

Believing the current treatment method ensures safe	Very effective Effective Neutral Ineffective Very ineffective	15 213 105 44 11	3.87 54.90 27.06 11.34 2.84				
Total		**388**	**100**	**2.54**	**0.85**	**1**	**5**
Ability to afford safe drinking water	Excellent Good Fair Poor Very poor	66 34 133 126 29	17.07 8.76 34.28 32.47 7.47				
Total		**388**	**100**	**3.04**	**1.18**	**1**	**5**
Feel that socio-economic status affects their equal access **Total**	Never Rarely Some times Often Very often	11 85 199 75 15 **388**	2.84 21.93 51.29 20.10 3.87 **100**	**3.00**	**0.83**	**1**	**5**
Understanding of WHO standards for water quality	Excellent Good Average Poor Very poor	9 88 200 79 12 **388**	2.32 22.68 51.55 20.36 3.09 **100**	**2.99**	**0.81**	**1**	**5**
Total							
Seek information about water quality standards	Very frequent Frequent Occasionally Rarely Very rarely	1 53 143 147 44	0.26 13.66 36.86 37.89 11.34				
Total		**388**	**100**	**3.46**	**0.87**	**1**	**5**
Change the water quality related to seasonal change	Never Rarely Some times Often Very often	3 44 144 153 44	0.77 11.37 37.21 39.53 11.37				
Total		**388**	**100**	**3.49**	**0.85**	**1**	**5**
Satisfied with the result of water treatment	Very satisfied Satisfied Neutral Unsatisfied Very unsatisfied	1 41 140 156 50	0.26 10.57 36.08 40.21 12.89				
Total		**388**	**100**	**3.54**	**0.85**	**1**	**5**
Confident to the quality of drinking water	Very confident Confident Moderately confident Slightly confident Not confident	3 37 160 147 41	0.77 9.54 41.24 37.89 10.57				
Total		**388**	**100**	**3.48**	**0.836**	**1**	**5**

Water quality should be tested to ensure safety	Very frequent Frequent Occasionally Rarely Very rarely	1 37 150 153 49	0.26 9.54 38.66 38.92 12.63				
Total		**388**	**100**	**3.54**	**0.84**	**1**	**5**

4.1.3. The–Influence of Seasonal Changes on Drinking Water Quality: Timing for Testing

Table 4 revealed important associations between seasonal changes and the perceived frequency of water quality testing necessary to ensure safe drinking water. Approximately 55% of respondents reported that they rarely observed changes in water quality related to seasonal variations, which reflects a limited understanding of when water should be tested to maintain safety. This lack of awareness suggests a critical knowledge gap, as understanding how seasonal factors affect water quality can empower households to take protective measures such as boiling water and maintaining the cleanliness of water sources. Conversely, approximately 55% of respondents who believed water quality should be tested only occasionally also tended to perceive seasonal changes as infrequent or rarely indicators for water quality fluctuation. Only a very small proportion, about 2.3% and 12%, reported that water quality should be tested very frequently and frequently, directly linked to varying often and often seasonal changes impacting water quality. A chi-square test was conducted to assess the statistical association between perceptions of seasonal water quality changes and the frequency with which water quality should be tested to ensure safety. The result demonstrated a strong and significant association (χ^2 = 26.6881, p = 0.045, df = 16), indicating that perception of seasonal water quality changes is significantly related to beliefs about the appropriate frequency of testing.

Table 4: The association of water quality change related to seasonal changes in the frequency of water testing

Water quality related to Seasonal change		The frequency of water testing					Total
		Very frequently	Frequently	Occasionally	Rarely	very rarely	
Never	*Freq*	0	0	0	2	0	2
	%	0.0	0.0	0.0	100.0	100	100
Rarely	*Freq.*	1	2	24	12	5	44
	%	2.3	4.6	54.6	27.3	11.4	100
Sometimes	*Freq.*	0	16	55	50	23	144
	%	0.0	11.1	38.2	34.7	15.9	100
Often	*Freq.*	0	18	50	67	18	153
	%	0	11.7	32.6	43.8	11.7	100
Very often	*Freq.*	1	1	20	20	3	44
	%	2.3	2.3	45.6	45.6	6.8	100
Total	*Freq.*	2	37	149	151	49	388
	%	0.77	9.6	38.5	39.0	12.6	100

4.1.4. Compare compliance with the WHO Standards for Water Quality

The laboratory Results presented in **Table 6**, the chemical analysis of the water samples indicated that

Dembia-3 has the highest level of calcium (110 mg/L), which is of value in water hardness and can also be a suitable indicator of geological impacts in the area. Alternatively, Chilga-2 has a significantly lower level of calcium (8 mg/L), suggesting that there are few geological sources of calcium or other sources of water.

Calcium is vital to aquatic life, and it encourages suitable levels that maintain biological processes.

The magnesium concentrations vary, with Ambageorgois-1 having the highest (40 mg/L) and Dembia-3 having the lowest (52 mg/L). Magnesium plays a very crucial role in aquatic plants' photosynthesis and can potentially influence the general health of freshwater ecosystems.

The levels of alkalinity range from 83 mg/L in Dembia-3 to 126 mg/L in Ambageorgois-1. Higher alkalinity indicates the capacity of water to neutralize acids, which is essential for a steady pH and the maintenance of aquatic life. The variations may differ due to variations in watershed characteristics and land use management.

All the locations have 0.00 mg/L of iron concentration, which implies that iron contamination is not a problem at these sites. Iron is largely needed in minute traces but can turn out to be problematic if found at high concentrations, affecting the quality and palatability of water.

Nitrate concentration is much higher in Chilga-2 (6.93 mg/L) and Gondar-4 (0.21 mg/L) while low in concentration in Ambageorgois-1 (0.00 mg/L). High concentrations of nitrate could be due to agricultural runoff or percolation of wastewater, which are dangerous to human health as well as aquatic organisms. It is necessary to monitor and regulate the concentration of nitrate in these fields.

The highest concentrations of phosphate are found in Gondar-4 (11.6 mg/L) and Ambageorgois-1 (10.94 mg/L), while Dembia-3 is quite low (7.23 mg/L). High phosphate concentrations can lead to eutrophication, which promotes the growth of algae that deplete oxygen and kill aquatic life. Phosphates can also signify the presence of fertilizer or other human sources' runoff.

The geochemical survey reflects significant variation in water quality at the sampling points, which may be attributed to local geology, land use, and man-made factors.

Frequent monitoring should be done to establish the safety and wholesomeness of drinking water, with more priority being accorded to nitrates and phosphates, as they are responsible for short- and long-term health hazards to humans and aquatic organisms. Further investigation into the source of these chemicals and their possible effect on the environment will be essential to effective water management.

Table 6: Chemical analysis results

Sample sites	**Chemical analysis**					
	Calcium	Magnesium	Alkalinity	Iron	Nitrate	Phosphate
Dembia-3	110	52	83	0.00	0.00	7.23
Chilga-2	8	24	108	0.00	6.93	6.93
Gondar-4	44	22	89.6	0.00	0.21	11.6
Ambageorgois- 1	38	40	126	0.00	0.00	10.94

Based on the **Physical analysis results** of Table 7, the following can be concluded regarding the quality of the water in the sample points:

Turbidity is an important indicator of water quality. Low turbidity (0-2 NTU) is associated with good quality, while higher turbidity may indicate pollution or sedimentation. Turbidity of Chilga-2 can be investigated further to identify the source of particulates.

pH values at the sampling points fall within an internationally accepted drinking water range (6.5 to 8.5). Gondar-4's higher pH, however, may indicate alkalinity influencing mineral solubility and nutrient bioavailability. Closely regulated are pH values to ensure that these are not harmful to aquatic life and human health.

Temperatures are reasonably consistent at all four stations, which is good for maintaining balanced aquatic ecosystems. Temperature affects dissolved oxygen levels and can regulate the metabolic process of aquatic organisms.

Ongoing monitoring is necessary, particularly during the transitional periods. Conductivity refers to the measure of dissolved ions in water. Conductivity is highest in Gondar-4, suggesting a higher concentration of dissolved solids, perhaps as a result of pollution or minerals. Lower conductivity in Chilga-2 could mean cleaner water. Understanding these levels helps establish general water quality.

TDS readings inform us regarding the overall quality and purity of the water. Chilga-2 has a significantly lower TDS than other sites, implying that it is the least mineralized and potentially the purest. Higher TDS readings at other locations may need more study to identify the potential sources of contamination or mineralization.

Generally, the physical analysis demonstrates that while the majority of sites have good water quality, some sites, particularly Gondar-4 and Chilga-2, require special attention due to their turbidity, conductivity, and TDS. Constant monitoring and further testing can avoid negative changes in water quality and guarantee the safety of drinking, and maintain good ecosystem health.

Table 7: Physical analysis results

Sample sites	Physical analysis				
	Turbidity	PH	Temp (^0C)	Conductivity	TDS
Dembia-3	0	7.28	16.3	136	182.6
Chilga-2	4	7.31	16.9	61.6	44.4
Gondar-4	2	8.1	17.1	190.7	104.8
Ambageorgois-1	0	7.14	16	147.2	79.6

From a bacteriological perspective, as illustrated in **Table 8,** the analysis revealed concerning results.

Dembia-3 has no fecal coliform or total coliform bacteria detection, and this indicates that the water quality is excellent as far as bacteriological pollution is concerned. This suggests good sanitation practices and minimal pollution, meaning it is safe to drink and for recreational use.

In Chilga-2, even though fecal coliform is zero, the presence of 5 total coliform colonies per 100ml is a concern. Total coliforms can be present naturally in the environment, but their presence is a sign that the water is capable of being contaminated. The origin needs to be determined with monitoring and other analyses in order to safeguard water safety.

Gondar-4 shows the presence of fecal and total coliform bacteria, raising serious questions about water quality. The detection of fecal coliform indicates potential fecal contamination, which is unsafe for health. The total coliform level is also higher, meaning that the water is not safe for drinking without processing. There is a need for immediate action, including repetition of the test and taking protective measures.

Similar to Dembia-3, Ambageorgios-1 does not contain detectable fecal coliform or total coliform bacteria concentrations. This is an indication of good quality and safety for use, suggesting good water source management.

The bacteriological test reveals significant variations in water quality among the sample sites. Dembia-3 and Ambageorgios-1 possess better water quality, while Chilga-2 has a few problems that require action. Gondar-4 poses a serious threat since it holds both fecal and total coliform bacteria. The areas require remediation immediately and constant monitoring to ensure public health protection, as well as a safe drinking water supply at all the sites.

Table 8: Bacteriological analysis results

Sample sites	Bacteriological analysis		
	Fecal Coliform	Total coliform	Rem
Dembia-3	Nil	Nil	
Chilga-2	Nil	5 colony /100ml	
Gondar-4	3 colony /100ml	15 colony /100ml	
Ambageorgois-1	Nil	Nil	

Figure 3 illustrates respondents' perceptions of the WHO water quality standards.

The results indicate that a significant majority, comprising 51.6% of respondents, reported an average level of understanding regarding these standards. This suggests that while many individuals are aware of the guidelines, their comprehension may not be deep enough to fully grasp their implications for drinking water safety. In contrast, approximately 25% of respondents expressed a good to excellent understanding of WHO guidelines related to drinking water quality. This subset of the population demonstrates a more informed awareness, which is crucial for advocating safe water practices and influencing community health initiatives. The disparity in understanding highlights an important area for potential educational outreach. Enhancing knowledge of WHO standards could empower more individuals to recognize the importance of water quality and advocate for improvements in their local water supply systems. Overall, these findings underscore the need for targeted educational programs to elevate public understanding of water quality standards and their significance for health and safety.

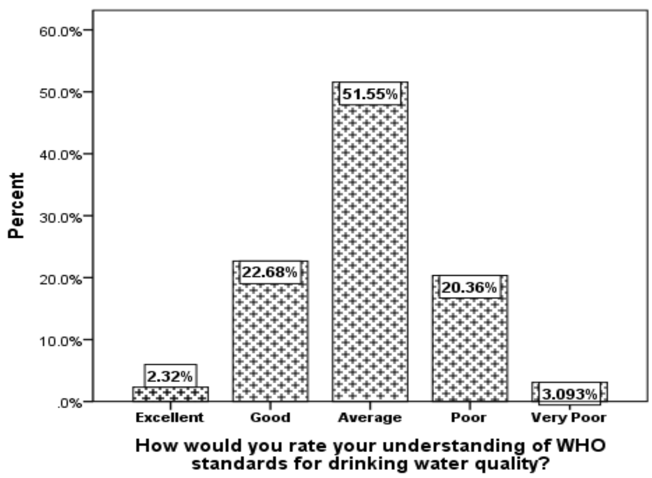

Figure 3: Understanding of WHO standards for drinking water quality

Figure 4 presents the relationship between respondents' understanding of WHO standards for drinking water quality and the perceived reliability of their safe water supply system. The findings revealed that 33.3% of respondents rated the WHO standards for drinking water quality as excellent, correlating with a perception of a very reliable water supply system. In contrast, the majority of respondents (61.2%) rated the WHO standards as average, indicating a belief that the reliability of the quality of their drinking water supply is generally reliable. However, it is noteworthy that 54.1% of respondents rated the WHO standards as average, while simultaneously deeming the quality of their safe drinking water supply as very unreliable. This discrepancy highlights a concerning gap between awareness of established standards and the actual reliability of the water supply, suggesting that while respondents may recognize the importance of WHO guidelines, they experience significant challenges in accessing consistently safe drinking water.

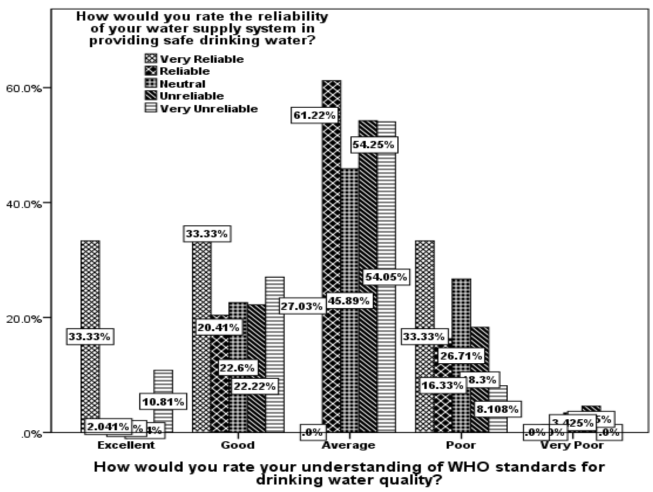

Figure 4: The relationship between understanding WHO standards for drinking water quality and the reliability of the drinking quality water supply system

Figure 5 presents an analysis of the reliability of the water supply system as perceived by customers regarding their access to drinking water. The results indicate that only approximately 13% of respondents considered their drinking water supply to be reliable, with less than 1% rating it as very reliable. This suggests a significant lack of confidence in the water supply system among the majority of users. Conversely, nearly 50% of respondents classified the water supply as either unreliable or very unreliable. This substantial percentage highlights critical concerns regarding the consistency and quality of drinking water available to the community. The findings underscore the urgent need for improvements in the water supply infrastructure and management to enhance public trust and ensure safe drinking water access for all residents.

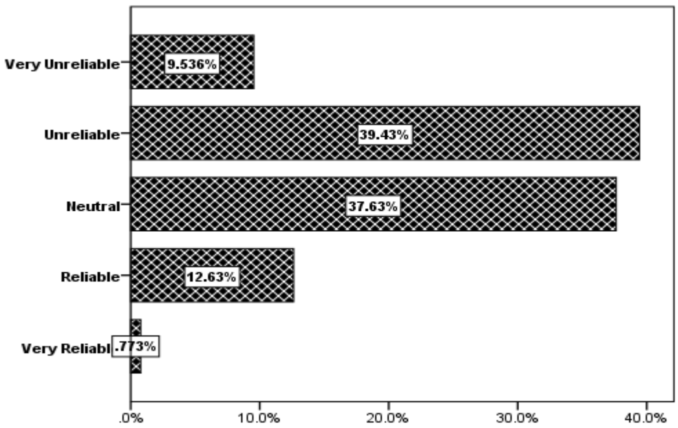

Figure 5: Rating the reliability of water supply in providing safe drinking water

4.1.5. Satisfaction Levels in Drinking Water Supply and Socio-Economic and Demographic Variables: Chi-square test analysis

The associations between the level of satisfaction in drinking water quality and socio-economic and demographic variables were examined using the chi-square test (Table 5). Variables such as educational level, marital status, employment status, and access to information about water quality showed significant associations with satisfaction regarding drinking water quality. Specifically, descriptive statistics indicate that households with primary education (15%) and those with secondary education or higher (27%) reported satisfaction with their drinking water quality. The relationship between educational level and satisfaction was both strong and statistically significant (χ^2 = 67.689, p = 0.000). Likewise, married households demonstrated higher satisfaction levels, with 61(18.9%) expressing satisfaction with drinking water quality. Marital status also showed a significant association with level of satisfaction in drinking water quality (χ^2=18.24, p=0.002**).

Self-employed and permanent households showed higher levels of satisfaction with drinking water quality, with 20.8% and 18.2% expressing satisfaction, respectively. These satisfaction levels are notably higher compared to those holding temporary jobs or being unemployed. The association between employment status and satisfaction with drinking water quality was statistically significant (χ^2 = 21.68, p = 0.040*). Furthermore, the belief that water quality should be regularly tested to ensure safety was strongly correlated with satisfaction levels (χ^2 = 46.21, p = 0.000**). Accessing information about water quality standards was also significantly linked to higher satisfaction with drinking water quality.

The implications of the results suggest that improving education, employment stability, and access to information about water quality can significantly enhance satisfaction with drinking water. This underscores the importance of socio-economic empowerment and public awareness campaigns to boost confidence and trust in water safety, ultimately promoting better water management and public health outcomes.

Table 5: The associations between levels of satisfaction in drinking water quality and demographic and socio-economic variables

Variables	Level of satisfaction in drinking water quality (%)					X^2	p-value
	Very satisfied	**Satisfied**	**Neutral**	**Dissatisfied**	**Very dissatisfied**		
Age of the household head						12.50	0.781
18-28	1(1.9)	11(21.2)	17(32.7)	17(32.7)	6(11.5)		
29-39	1(0.6)	27(16.9)	74(46.5)	47(29.6)	6(11.5)		
40-50	1(0.9)	22(20.4)	38(35.2)	36(33.3)	10(6.3)		
51-61	1(0.9)	7(13.2)	21(39.6)	19(35.8)	11(10.5)		
>61	1(6.3)	3(18.7)	66(37.5)	6(37.5	0(0.0)		
Sex of household head							
Female	2(1.1)	33(17.6)	83(44.2)	57(30.2)	13(6.9)	2.79	0.590
Male	3(1.5)	37(18.50	73(36.5)	68(34.0)	19(9.5)		
Educational level							
Unable to read and write	4(17.4)	3(13.0)	7(30.4)	8(34.8)	1(4.4)	67.68	0.000***
Able to write and read	1(1.1)	13(14.6)	37(41.6)	30(33.7)	8(8.9)		
Primary	0(0.0)	27(15.3)	80(45.2)	61(34.4)	9(5.1)		
Secondary and above	0(0.0)	27(27.3)	32(32)	26(26.7)	14(14.1)		
Income level of respondents							
High	4(2.4)	31(18.2)	72(42.4)	49(28.8)	14(8.3)	7.920	0.441
Middle	0(0.0)	27(16.9)	66(41.3)	56(35.0)	11(6.9)		
Low	1(1.7)	12(10.7)	18(31.0)	20(34.5)	7(12.1)		
Marital status						18.24	0.002***
Married Unmarried	2(0.6) 3(4.6)	61(18.9) 9(13.6)	126(39.2) 30(45.5)	106(32.9) 19(28.8)	27(8.4) 5(27.4)		
Employment status of households							
Self-employee	3(6.3)	10(20.8)	18(37.5)	15(31.3)	2(4.2)	21.68	0.041**
Permanent	1(2.2)	8(18.2)	18(40.9)	17(38.6)	0(0.0)		
Temporary	0(0.0)	21(15.1)	60(43.2)	41(29.5)	17(22.2)		
Not employe	1(0.6)	31(19.7)	60(38.2)	52(33.1)	13(8.3)		
Frequent water testing to ensure safety							
Very freq.	0(0.0)	0(0.0)	1(100)	0(0.0)	0(0.0)		
Frequently	1(2.7)	2(5.4)	23(62.2)	8(21.6)	3(8.1)	46.21	0.000***
occasionally	1(0.7)	26(17.3)	50(33.3)	68(45.3)	5(3.3)		
Rarely	3(1.9)	29(19.2)	71(47.0)	33(21.8)	15(9.9)		
Very rarely	0(0.0)	13(26.5)	11(22.5)1	6(32.6)	9(18.4)		
The reliability of the drinking water supply							
Very reliable	0(0.0)	1(33.3)	1(33.3)	0(0.0)	1(33.3)	26.00	0.054*
Reliable	1(2.0)	10(20.4)	26(53.1)	8(16.3)	4(8.2)		
Neutral	0(0.0)	24(16.4)	50(34.3)	57(39.0)	15(10.3)		
Unreliable	1(2.7)	12(32.4)	13(35.1)	11(29.7)	0(0.0)		

How often do you seek information about water quality standards?							
Very frq.	0(0.0)	0(0.0)	0(0.0)	1(100)	0(0.0)	29.63	0.020**
Frequently	4(7.6)	9(16.9)	16(30.2)	22(41.5)	2(3.7)		
Occasionally	1(0.7)	31(21.7)	56(39.2)	45(31.5)	10(6.9)		
Rarely	0(0.0)	22(14.9)	66(44.9)	44(29.6)	15(10.2)		
Very rarely	0(0.0)	8(18.2)	18(40.2)	13(29.6)	5(11.4)		

Key: * =Significant at 10%, **=Significant at 5%, ***=Significant at 1%

4.1.6. Interpretation of the Qualitative Results

The qualitative component of this study explored factors affecting drinking water quality from large and medium pump-based systems in Central Gondar, Ethiopia. Interviews and focus group discussions involved 15 participants, including water utility managers, community representatives, and key informants (11 males, 4 females, mean age 43.2 years). Thematic analysis revealed key themes that enhance and complement the quantitative findings, as outlined below:

Water Quality Concerns and Environmental Influences

This theme captures persistent worries related to microbial contamination (notably fecal coliform and E. coli), turbidity, and chemical pollutants exceeding WHO and national standards, particularly in Gondar and Chilga. Environmental factors such as seasonal rainfall variations, land use changes, and pollution from agricultural runoff were highlighted as crucial determinants of water quality fluctuations. In this regard, a water quality expert emphasized microbiological testing as critical for ensuring safe drinking water as follows;

The findings from the Key Informant Interviews (KII) indicate that community members recognize seasonal changes and pollution negatively impact the reliability of water sources. This shows the need for continuous water quality monitoring and adaptive strategies.

> *A 47-year-old Utility manager. According to my experience, there is a noticeable dissatisfaction with water quality and infrequent testing practices in the area where I am working. I suggested that there is a pressing need for strategies that enhance community engagement and encourage more residents to participate more (Utility manager, from Gondar, January 2025).*

Community Awareness

Knowledge gaps about WHO water quality standards, water safety, and the importance of frequent testing emerged as a significant barrier to community confidence and participation. While some participants possessed good awareness, many exhibited limited understanding of drinking water safety protocols.

In this regard,

> *A 39-year-old key informant indicated his opinion in the following ways:*
>
> *I received reliable information and open updates from water providers greatly strengthened trust and helped me better understand water quality issues. In turn, this supports me in better service delivery and community ownership of water safety. I recommend that enhancing educational outreach and communication strategies is essential to empower communities to engage meaningfully with water safety efforts (Key informant from Ambagiworgis kebele 01, January 2025).*

Water Quality Assessment

The qualitative findings from this theme stated that water quality was a central concern for consumers, with several indicators highlighted as essential:

> *As a 50-year water quality expert in the Gondar city water and sewerage office, I understand the*

importance of conducting microbiological tests, such as E. coli analysis and turbidity testing, to ensure we give our community safe drinking water. (key informants from Gondar /January 2025).

As a 35-year-old expert, I noticed the presence of harmful chemicals, which indicates a critical need for regular checking to ensure public health. (a key informant from Abagiworgis/January 2025)

Similarly, a 47-year-old expert from Chilga highlighted the recurring presence of harmful chemical and bacterial contaminants, stressed the necessity of continuous and rigorous monitoring to mitigate health risks. This expert stated, "I always start by checking turbidity and E. coli levels," reflecting adherence to international WHO standards in water quality evaluation. (key informants in Chilga keble 03/January 2025)

Socioeconomic Factors and Satisfaction

The qualitative findings underscore the significant influence of socioeconomic status on access to safe water and satisfaction with water supply services. Those with stable income sources reported improved satisfaction, likely related to better ability to afford safe water and knowledge of water quality standards. Participants noted challenges linked to the affordability of safe water, reinforcing the need for policies ensuring equitable access as follows;

As a 48-year-old respondent, I feel that stable work and a higher level of education play a substantial role in achieving greater satisfaction. This probably reflects a higher economic ability to pay for safe drinking water and an enhanced perception of the standards and practices regarding water quality. (key informants from Koladiba/January 2025)

Having worked as a 39-year-old utility manager in Gondar, I strongly believe that bridging the socioeconomic disparities is core not only to individual contentment but also to community involvement and effective water management. (key informants from Gondar/January 2025)

The qualitative analysis explored key themes that emerged around persistent water quality concerns, including microbial contamination and chemical pollutants exacerbated by environmental changes. Knowledge gaps about water safety standards and the need for more frequent testing were identified as barriers to community trust and participation. Water quality assessment emphasized the critical role of microbiological and chemical monitoring aligned with WHO standards. These themes deepen understanding of the complex challenges affecting water quality and service satisfaction in the region.

4.1.7. Evaluate Public Health Implications

The detection of fecal coliforms in Gondar samples poses a great risk of waterborne diseases. The communities utilizing this water source may experience outbreaks of waterborne diseases such as cholera, dysentery, and gastroenteritis, particularly in vulnerable groups, which are children, the elderly, and those with compromised immunity.

Total coliforms in Gondar and Chilga indicate possible fecal contamination routes, thus making outbreaks of disease more likely to take place. If not corrected, this can lead to large-scale illness, overwhelming local health facilities and resources.

Phosphite levels exceeding WHO standards portend potential health effects of chronic exposure. While acute toxicity is expected to be minimal, chronic exposure to elevated levels of phosphite has been shown to bring about developmental and reproductive issues, as well as toxic effects on aquatic life, which can have further-reaching effects on local food sources.

Pregnant women, infants, the elderly, and individuals with underlying health conditions are most likely to suffer adverse health effects from contaminated water. These populations require special attention to safeguard and ensure their safety. Higher cases of waterborne illnesses may result in increased health expenses for households and the local healthcare system. This can impose a financial burden on individuals and the state, taking away funds from other important health programs. Consequences of water contamination can erode public trust in local water utilities and government. Such distrust can lead to poor adherence to public health warnings and poor participation in community health activities, thereby contributing to health risk. It is important that community education about the risks of drinking contaminated water takes place. Public health announcements should promote the utilization of safe water measures such as boiling water, filtration systems, and the potential health impacts of contaminants. Ongoing monitoring of water quality and health outcomes is required to identify trends and new emerging health issues. This will aid in the formulation of targeted public health policy and interventions that will reduce the burden of waterborne disease.

4.2. Discussion

This study elucidates a markedly low level of overall satisfaction concerning drinking water quality among households in Central Gondar. Specifically, only 1.3% of respondents expressed delight, while 18% reported satisfaction; conversely, approximately 32% of participants were dissatisfied, and 8% were very dissatisfied, with around 40% remaining neutral. These findings underscore persistent challenges in water service quality, notwithstanding the existence of a pump-based water supply infrastructure. The elevated levels of dissatisfaction suggest that a majority of households perceive the quality of their drinking water as inadequate or unsafe. Furthermore, a noteworthy proportion of neutral respondents (40%) may exhibit uncertainty regarding water quality, potentially attributable to a lack of knowledge or variability within water sources.

These findings resonate with previous research conducted in North Gondar (Mengesha et al., 2004), South Gondar (Alemayehu et al., 2023), and Gondar Town, which identified intermittent supply and insufficient service coverage as enduring issues adversely affecting residents' perceptions of water satisfaction (Abebe, 2018). This study's observations regarding low satisfaction levels, despite infrastructure investments, suggest that the mere presence of infrastructure is insufficient without reliable service provision and quality assurance. Additionally, studies compiled in the Ethiopia Socioeconomic Survey offer valuable insights into various dimensions of the country's socioeconomic landscape (JMP, 2016).

A significant number of households rated their water supply as unreliable or very unreliable in terms of safety for consumption, corroborating findings from urban Ethiopian studies (Muluken et al., 2021) and research conducted in Gondar (Abebe, 2018).

The investigation into the relationship between household satisfaction and drinking water quality in the Central Gondar zone examined relevant socio-demographic factors, including educational attainment, marital status, employment status, frequency of water quality testing, and access to information regarding water quality.

Chi-square analyses revealed statistically significant associations between satisfaction levels and these independent variables. Notably, households led by individuals with higher educational levels, particularly those possessing secondary education or higher, reported greater satisfaction with drinking water quality. This observation aligns with extant literature from Ethiopia and broader African contexts (Muluken et al., 2021; Assefa et al., 2018). It is plausible that education heightens awareness regarding water quality standards and influences expectations, leading educated individuals to either implement better water treatment methods at home or advocate for enhanced services, thus resulting in higher satisfaction rates.

Married households demonstrated higher satisfaction levels, a finding corroborated by urban Ethiopian studies (Anbesaw, 2018). The rationale may lie in the shared responsibilities associated with water collection and household management among married couples, coupled with the stability and resource management that a marital partnership affords, leading to improved perceptions of water quality.

Employment status emerged as a critical determinant of satisfaction, with self-employed and permanently employed individuals reporting higher levels of satisfaction compared to those in temporary or unemployed statuses. This finding is supported by research conducted in Kenya and Tanzania (Mason et al., 2013; Nyanza et al., 2021) as well as a study in Central Gondar (Muluken et al., 2021). One plausible explanation is that stable employment provides households with enhanced incomes, thereby increasing access to water quality information and resources known to enhance satisfaction. Furthermore, higher satisfaction levels among self-employed individuals may indicate a greater capacity to afford safe drinking water.

The frequency of seeking information regarding water quality standards significantly affected satisfaction levels. This result is consistent with international evidence (Brocklehurst & Slaymaker, 2015; Asghari et al., 2023).

Households that recognized the necessity of regular water quality testing for ensuring safe drinking water exhibited higher satisfaction levels, thus indicating that awareness and knowledge empower consumers to assess and potentially demand improved services. Ultimately, transparency in information and accessibility play a direct role in influencing consumer satisfaction (Brocklehurst & Slaymaker, 2015; Asghari et al., 2023).

5. Conclusion

The investigation into the quality of drinking water in Central Gondar reveals significant deficiencies, characterized by low satisfaction rates and consequential public health risks stemming from microbial contamination. These findings underscore an urgent necessity for enhancements in water supply infrastructure, as well as initiatives aimed at raising awareness regarding water safety standards. Addressing the socioeconomic disparities that impede access to safe drinking water is essential for promoting public health and ensuring equitable access for all community members.

The study's results indicate a pressing demand for improvements in drinking water quality within Central Gondar. The evident dissatisfaction among respondents highlights critical shortcomings within the existing water supply systems, compounded by gaps in public understanding and engagement concerning water quality standards. The detection of fecal and total coliform bacteria in various water samples poses a significant health risk that requires immediate intervention.

Furthermore, socioeconomic disparities greatly influence public perceptions of water quality and access to safe drinking water. Fostering awareness within the community about water safety practices and ensuring universal access to clean water are pivotal for enhancing public health outcomes.

6. Recommendations

1. Public Education Campaigns: Implement comprehensive public education initiatives to elevate understanding of WHO water quality standards and the importance of regular water testing. These campaigns should reach a wide audience to maximize engagement and participation.

2. Improved Water Infrastructure: Allocate resources to enhance the water supply system infrastructure, thus ensuring the delivery of safe and secure drinking water. This effort should include regular maintenance checks and surveillance to preempt contamination.

3. Community Involvement: Actively involve the community in water management programs. By integrating residents into monitoring practices and decision-making processes, a sense of responsibility and ownership regarding water safety can be fostered.

4. Periodic Monitoring and Testing: Establish standardized procedures for routine water quality testing to promptly identify contaminants. This protocol should encompass both microbiological and chemical analyses, alongside transparent reporting mechanisms to inform the community of findings.

5. Overcoming Socioeconomic Challenges: Formulate policies aimed at reducing socioeconomic disparities that hinder access to clean drinking water. Potential strategies may include offering subsidies to low-income households to make water treatment options more affordable.

6. Building Health Systems: Enhance the capacity of local health centers to effectively respond to

outbreaks of waterborne diseases and provide appropriate care and support to vulnerable populations.

By addressing these areas, we can work toward improving water quality and health metrics, ultimately fostering a healthier and more equitable community in Central Gondar.

7. Declarations

Ethical Declaration: This study received ethical approval from University of Gondar College of social since and humanities department of development and environment management studies Ethics Committee reference number DEMS/61/2025

Consent to Publish: All participants involved in this study provided informed consent for publication.

No Funding Declaration: The authors confirm that this research did not receive any funding.

Data Availability Statement: The data that support the findings of this study can be obtained from the corresponding author upon reasonable request.

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