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Research Paper

Water quality suitability and sanitary inspection of hand-dug wells of Merawi Town, Ethiopia

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Abstract

In small towns of developing countries, because of unreliable piped water supply, households utilize water from private shallow wells, which can be easily contaminated. In this study, water quality suitability of hand-dug wells, which are the main alternative to the utility water provision in Merawi Town, and the risk of the sources to contamination were assessed. Samples from 14 wells were analyzed for 12 selected water quality parameters, and the overall water quality was judged using Weight Arithmetic Water Quality Index (WAWQI). Besides, sanitation practices of the town residents were evaluated through questionnaires administered to 386 householders and sanitary inspections of the sources were conducted using the World Health Organization form. Based on the results, temperature, electrical conductivity, total dissolved solids, chloride, nitrate, and magnesium were within the acceptable limit of drinking. However, all the water samples were bacteriologically contaminated. According to the WAWQI, only 14.29% of the samples waters were good for domestic use in both wet and dry seasons. From the sanitary inspection, 71.43% of the wells were at either high or very high risk of contamination; however, from the responses to the questionnaire, 57.3% of households do not treat the alternative sources. To overcome the bacteriological contamination and thus, the outbreak of diseases, short-term intervention, such as ensuring disinfection is compulsory. To achieve, the missing access to potable water, the utility needs to develop long-term goals. Generally, water quality analysis and sanitary inspection are complementary tools, which play the important purposes of ensuring water safety.

1. Introduction

Everyone has the right to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use (UN, 2010). However, WHO/UNICEF (2021) reported, one in four people, which is about two billion people, around the world lack safely managed drinking water. Groundwater, which is a major source of fresh water globally and which is mainly used for domestic purposes in developing countries, can be contaminated by both natural and man-made compounds. Naturally, it contains mineral ions and some impurities, even if it is unaffected by human activities. The types and concentrations of natural impurities depend on the nature of the geological formation through which the groundwater flows and the quality of the recharge water (Li et al., 2021; Sharma & Bhattacharya, 2017). However, human activities further exacerbate groundwater contamination, particularly in developing regions, by point sources such as waste disposal facilities, industrial pollution, on-site sanitation and many others, as well as non-point sources such as

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agricultural chemicals. In developing countries, the high rates of urbanization and population growth, poor accessibility and lack of legal status in urban slums drag back improvement of the sanitation level (Katukiza et al., 2012).

Groundwater contamination has a significant impact on human health, environmental quality, and socioeconomic development (Li et al., 2021). Diseases related to the use of contaminated groundwater can be caused by biological agents or by chemical substances. Microbial contamination of drinking-water as a result of contamination with human and animal excreta poses the greatest risk to drinking-water safety (WHO, 2022). Drinking water of unsafe levels of contaminants can cause health effects, such as gastrointestinal illness, nervous system or reproductive effects, and chronic diseases such as cancer. Chemicals from agricultural and industrial activities and open dump sites can also make drinking water unsafe and cause illnesses such as skin rashes, cancers, and other serious health problems (Conant & Fadem, 2012).

In developing countries, private family dug-wells are often poorly constructed (Oluwasanya, 2020) and they are rarely well-sealed against contamination, mainly due to lack of space and knowledge. Besides, latrines and garbage pits are dug close to dug wells (Mamert et al., 2021; Martinez-Santos et al., 2017). The pollutants released from the onsite sanitation systems are likely percolated into the surrounding groundwater sources and they may then affect health if the water is consumed.

In Ethiopia, 60 to 80 % of health problems are due to communicable diseases attributable to unsafe water supply, unhygienic and unsanitary waste disposal (Roba, 2017). A study on hand-dug wells in peri-urban areas of Bahir Dar city of Ethiopia indicated that chloride, total dissolved solids, conductivity, total hardness and nitrate were higher in the inner city than the outskirts (Goraw & Akoma, 2011). Another study, by which the hand-dug wells water quality of Debre Tabor town was investigated, showed that spatial and seasonal variations of the parameters were significant throughout the study area and total coliform and fecal coliform were detected in all the sampled groundwater wells (Adugnaw, 2021). Similar challenges are observed in Merawi town, where the utility water supply is irregular, mainly due to power interruption, pump failure and under estimated population during design. Thus, the town's residents commonly use hand-dug wells as alternative water source for domestic purposes. However, study has not been carried out on the suitability of the water quality of the wells for drinking purpose. The shallow wells are built on privately-owned plots with no proper consideration for potential negative impacts from nearby sanitation facilities, well protection, or other pollution sources. Poor wastewater and solid waste management, inadequate well construction and protection, waste disposal from livestock, and the presence of latrines nearby the wells may expose them to contamination.

Water quality index (WQI), which is commonly used to get the general picture of water quality, as it reduces the number of parameters used in monitoring water quality to a simple expression to facilitate interpretation of data, was used in this study. The sanitation practices of the community were assessed using questionnaires administered to sampled households and the sanitary inspections were conducted around the wells, using key variables stated in the WHO form for this purpose. Thus, the focus of this study was to evaluate the quality of groundwater from hand-dung wells in Merawi town in terms the major physico-chemical and bacteriological parameters, to assess the sanitation practice of the town community and to relate the sanitary inspection to the water quality. If findings of the study are practically applied, they shall provide relevant information to the community and the utility, based on which susceptibility of water-quality-related risks shall be reduced and access to safe water supply will be guaranteed.

2. Materials and Methods

2.1 Study area description

Merawi town is found in West Gojjam Zone of Amhara National Regional State, which is in North-Western part of Ethiopia. The town is located at about 525 km from Ethiopia's capital city, Addis Ababa. It is situated at geographical coordinates of 11°24′25″ to 11°25′20″ N latitude and 37°8′40″ to 37°10′25″ E longitude, and at average elevation of 1901 m above sea level (Figure 1). Administrative boundary of the town covers 36 km^2 area and it is divided into 3 units (locally called kebeles). At present, the town is estimated to have a total population of 54,456.

Currently, access to piped drinking water supply service in Merawi town is limited, mainly because the water supply system is not upgraded to serve the rapidly growing population. The piped water supply service does not cover the entire town and the connected households receive intermittent supply. As alternative to utility water supply (through private piped connections, public stand pipes and private water vendors), the residents of the town rely on open sources such as water from untreated Bered River, Burka Spring and shallow hand-dug wells in their occupancy, for domestic uses (Dessalegn et al., 2013). The number of households having shallow hand-dug wells has been increasing, even though the quality for drinking is not yet approved.

2.2 Collection and analysis of water samples

The sampling was designed after a field survey, which led to the selection of a total of 14 representative sampling points (hand-dug wells). The wells were selected using stratified random sampling in which settlement patterns, which likely affect the sanitation risk were considered. Moreover, the dug wells shared by residents were purposively included and the sampling points were spatially distributed in all over the town area (Figure 1). The coordinates of the wells were determined by global positioning system (GPS) and the points were represented as S (for sample point) with subscripts 1 to 14. To assess seasonal variation of the water quality, sampling was done in both wet and dry seasons, from August 2022 to January 2023. During sample collection, standard procedures (Baird & Laura, 2017) were followed to ensure data quality and consistency. The water samples were collected in one-litre size high-density polyethylene (HDPE) bottles, which were well washed with distilled water and rinsed with the sample water to be taken for analysis before sampling. The samples were then filled completely in the container without leaving air space and then sealed securely and were labeled systematically. After the sampling, the bottles were stored in a cooler box, in which the samples were transported to laboratory on the same day of collection. The storage in the lab followed the required standard, that is, the source water was kept cool to below 10 ^{o}C, but was not allowed to freeze.

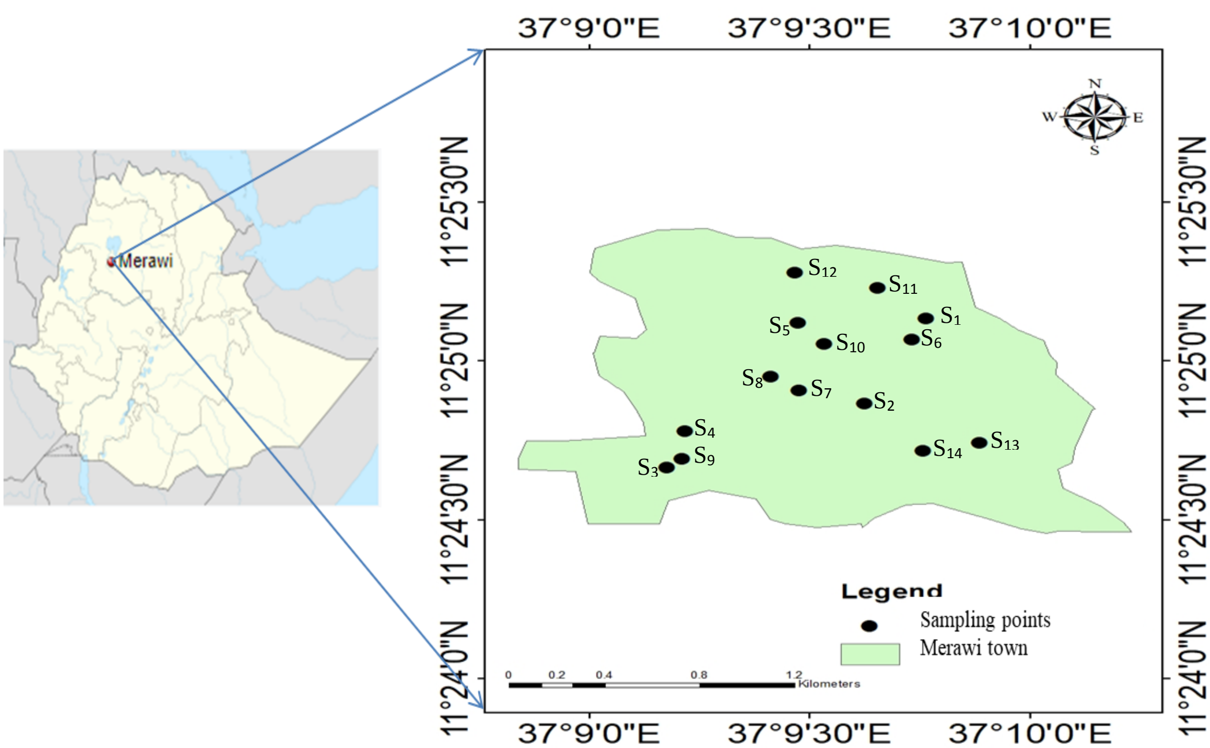

Figure 1: Location Map of the study area in Ethiopia and the sampling points (hand dug wells)

Then, the samples were analyzed within 24 hours of sampling by the standard method (Baird & Laura, 2017) for 12 selected physico-chemical and biological parameters; namely, pH, electrical conductivity (EC), Turbidity, total dissolved solids (TDS), temperature, calcium (Ca^{+2}), magnesium (Mg^{+2}), nitrate (NO_3^-), chloride (Cl^-), total hardness (TH), total and fecal coliforms. Parameters which are sensitive to alteration soon after sampling, namely temperature, pH, EC, turbidity, and TDS, were measured in-situ. The remaining parameters were analyzed in Bahir Dar University's water quality and treatment lab. pH, TDS, EC and temperature were measured using Aqua multi-parameter probe (AP 700) by inserting directly the instrument into the sample. Turbidity was measured using turbidimeter. In the laboratory, total hardness as $CaCO_3$, calcium, magnesium and chloride were determined by volumetric methods. Nitrate was determined using spectrophotometric method. Total and fecal coliforms were enumerated by membrane filtration technique following the Standard Method, in which (1) the sample was passed through a membrane filter with a pore size of 0.45 µm; (2) the filter was placed on an absorbent pad in a petri dish that was saturated with a culture medium that supports the growth of coliform bacteria; (4) the petri dish was incubated upside down for 24 h at the temperatures of 35 and 44.5°C for total coliforms and fecal coliforms, respectively; and (4) after incubation, coliform colonies on the filter were identified and counted (Forster & Pinedo, 2016). All the equipment used for the water quality analysis was calibrated before measurement according to the manufacturers' instruction and by using standard solutions. To improve the precision of estimates and to increase the trustworthiness of data, the analyses were done in triplicate and the average values were then taken.

2.3 Methods used to assess suitability of the source water for drinking

After data collection, the suitability of the wells water for domestic use was evaluated by comparing the values of the water quality parameters with those of the World Health Organization (WHO, 2022) and Ethiopian guideline (ES) values for drinking water. Moreover, based on the data of the water quality parameters collected from lab analysis, the WQI was calculated to determine the overall suitability of the wells water quality for domestic use. Currently, there are four commonly used water quality indices worldwide; namely, National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI), and Weight Arithmetic Water Quality Index (WAWQI) (Chidiac et al., 2023; Andinet & Yezina, 2023). In this study, the WAWQI was used as it is widely accepted (Lukhabi et al., 2023). The successful application of WAWQI for groundwater wells is confirmed (Patel eta al., 2023). The steps used to determine WQI, by WAWQI method (Chidiac et al., 2023) are:

Step 1: Proportionality constant "*K*" value is determined, using:

$$K = \frac{1}{\Sigma(1/Si)} \quad (1)$$

where S_i is standard permissible value of i^{th} parameter.

Step 2: Quality rating scale for i^{th} parameter (Q_i) is calculated, using:

$$Q_i = 100\left[\frac{(Vi-Vio)}{(Si-Vio)}\right] \quad (2)$$

where V_i is estimated value of the i^{th} parameter of the given sampling station, *vio* is ideal value of this parameter in pure water and *Si* is standard permissible value of the i^{th} parameter.

Step 3: The unit weight for the each water quality parameter is determined by

$$W_i = \left(\frac{k}{si}\right) \quad (3)$$

Step 4: WQI is determined, using,

$$WQI = \frac{\Sigma(Wi * Qi)}{\Sigma Wi} \quad (4)$$

After determining WQI values, the water was rated as excellent, good, poor, very poor and unfit for drinking for WQI range of 0-25, 26-50, 51-75, 76-100 and greater than 100, respectively (Chidiac et al., 2023).

2.4 Sanitation practice

Questionnaire survey was administered to households to assess the sanitation practice. The survey participants were fully informed about the purpose of the survey and confidentiality and anonymity were guaranteed. The questionnaire mainly considered the sanitation facilities used and wastewater and solid waste disposal practiced by the town residents. Both closed and open- ended questions were included and the respondents were communicated in the local language, Amharic. To assess the sanitation practice, probability sampling technique was employed as it gives for every sample household equal chance of being contacted. Only household heads of over 18 years of age and who were willing to participate in the study were considered. To determine the sample size of households, the technique developed by Yamane (1967), assuming 95% confidence level and 5% confidence interval, was applied. The formula is:

$$n = \frac{N}{1+Ne^2} \tag{5}$$

where n is number of sample households, N is total number of households (11,782) and e is precision level (0.05). The total number of households contacted, along with the sample size for each kebele are given in Table 1.

Table 1: The sample size of the three kebeles (admin units) of the town

Kebele	Number of Households	Sample Size
1	3,989	131
2	3,452	113
3	4,341	142
Total	11,782	386

2.5 Sanitary inspection

The susceptibility of the wells to contamination was evaluated using sanitary inspection forms, which are standardized field checklists that support the assessment and management of risks within drinking-water supply systems (WHO, 1997). The forms pose a number of basic observational questions that help identifying risk factors, and prompt appropriate action to safeguard public health. All sanitary inspection questions required a "yes" or "no" answer, in which a "yes" response indicated the presence of the risk under observation. Each water source was evaluated using the form and received a sanitary risk score of zero to ten, where zero indicates that none of the evaluated sanitary risk factors are present at the source and a ten confirms presence of all. Categories are assigned as low risk (0-2), intermediate risk (3-5), high risk (6-8) and very high risk (9-10), as established WHO scoring criteria. Physicochemical characteristics of the wells were not reflected by the Risk of Contamination (RoC) scores. RoC can be used to select appropriate remedial action to improve water quality. Perfect correlation is neither expected nor desired between sanitary inspections and microbial water quality analyses (Kelly *et al*., 2021). However, the use of both tools helps to pinpoint prospects to enhance the effective application of each.

2.6 Statistical data analysis method

The Statistical Package for Social Sciences (SPSS) version 26 was used for analysis of variance (significant tests), frequency, and percentages and to compute the mean values. The one-way analysis of variance (ANOVA) was used to determine whether there were any statistically significant differences between the means of the dry and rainy seasons' variables.

3. Results and Discussion

3.1 The hand-dug wells water quality

Table 2 shows the concentration of major water quality parameters of the hand-dug wells water, as the crucial feature describing its suitability for drinking purpose. Higher mean TDS value was recorded in the dry season, which may be associated with evaporation and the absence of a dilution effect, while the lower values during the wet season are assumed to be due to dilution from rainfall (El Adnani et al., 2020). The TDS values of all the samples were within the acceptable limits of both WHO and Ethiopian standards, showing low content of soluble salts in the groundwater samples with good palatability and no threat of objectionable effect on household appliances. Similar to the TDS values, the EC of all the wells samples were within the allowable limit in both dry and wet seasons. However, 42.9% the samples had turbidity higher than the WHO and ES permissible limits of 5 NTU. This may be due to particles, from the waste and surrounding land, are washed into the wells.

Table 2: The water quality parameters of the hand dug wells in both dry and wet seasons

Parameter	Wet season			Dry season			Standard values	
	Mean	Max.	Min.	Mean	Max.	Min.	WHO	ES
Temperature	19.62	21.94	18.06	22.28	24.95	20.82	15-25	-
pH	6.74	7.32	5.81	7.35	7.82	6.83	6.5-8.5	6.5-8.5
EC	364.55	728.50	145.70	379.17	735.20	161.80	1000	1000
TDS	207.50	397.40	105.30	224.60	412.40	88.01	500-1000	1000
Turbidity	7.35	28.56	1.30	6.87	24.20	1.21	<5	<5
Ca^{+2}	22.80	84.00	3.27	29.56	92.70	4.15	75	75
Mg^{+2}	18.07	28.00	3.09	25.54	39.20	7.40	50	50
NO_3^-	3.52	4.51	1.77	2.56	3.89	0.36	50	50
Cl^-	33.65	51.60	2.13	29.55	48.00	1.60	250	250
TH	90.35	298.00	20.00	114.07	321.00	45.00	300	300
FC	51.92	98	11	30	61	5	Nil	Nil
TC	93.71	167	36	50.5	93	16	Nil	Nil

Note: All units are in mg/l except for conductivity (μs/cm), temperature (°C), turbidity (NTU), total coliform and fecal coliform (CFU/100ml) and pH (non- dimensional).

The turbidity values were marginally higher in the wet season than the dry season. High levels of turbidity may lead to staining of materials, fittings and clothes exposed during washing, in addition to interfering with the effectiveness of treatment processes.

The pH of the water rises during the dry season while it is lower in the wet season. The wet season pH varied from 5.81- 7.32. The mean pH values in both dry and wet seasons were found to be within the recommended limits (WHO, 2022). The slightly acidic concentration at S11 was possibly associated with domestic waste. pH control is necessary to ensure satisfactory water disinfection; otherwise, the concentration in drinking water itself does not cause health concern. On the other hand, even though the temperature of the groundwater in the wet season was lower than in the dry season, all the sampled groundwater temperatures were within the allowable limit that they are safe for consumption in this regard.

The concentration of calcium was slightly lower in the wet season, due to increased water level of wells and/or due to dissolution of aquifer minerals with rainwater. However, in some of the samples it was above the WHO allowable limit of 75 mg/l for both seasons, likely due to the respective geologic formation. Calcium occurs in water mainly due to the presence of limestone, gypsum and dolomite minerals. However, concentrations of magnesium in all sampled dug wells water were within the WHO permissible limit of 50 mg/l for drinking purpose. On the other hand, higher content of nitrate was detected during rainy season, which could be due to anthropogenic factors such as the use of fertilizers for agriculture, resulting in leaching of nitrate through porous soil into groundwater. Similarly, chloride concentration is higher in the wet season, which could again be due to the application of fertilizers, or solid wastes and domestic sewage. However, in all the sample wells both nitrate and chloride concentrations were within the WHO allowable limit of 50 and 250 mg/l, respectively, in both seasons.

The study area showed soft to very hard water, as 35.71% (5 of the 14) of the samples water were soft as the TH as $CaCO_3$ was less than 75 mg/l. 42.85 % (6 wells) and 14.28 % had moderately high and hard classes of hardness, respectively. In the dry season, at a well, hardness was found to be above the permissible limit of 300 mg/l set by the standards. Hardness of groundwater mainly depends on presence of dissolved calcium and magnesium salts; thus, the higher hardness might be caused by weathering of calcium-containing minerals. Hardness of water increase in dry season as concentrations of salts increase due to higher evaporation.

In all the wells water samples, fecal coliforms were detected in both seasons. Fecal contamination can arise from sources such as leaking septic tanks, contaminated storm drains, agricultural runoff and infiltration of animal fecal matter. The presence of fecal coliform in a water sample often indicates recent fecal contamination, underlining a greater risk that pathogens are present. Similarly, significant number of total coliforms was detected in all the samples. Similarly, Ndububa & Idowu (2015) conducted a study in Nigeria on sanitary risk assessment of 20 domestic hand-dug wells and found all the wells to be tested positive to total coliform count and at various levels of risk. Proper well location, construction, and maintenance are key factors in reducing well vulnerability to bacterial contamination. The present study results are also similar with the study conducted in Ghana, in which total coliform counts in the wet season were higher than that of the dry season (Samuel et al., 2016). Contaminated drinking water causes a health problem and leads to water-borne diseases.

Figure 2 shows the WQI values of the sample hand-dug wells in the study area. The results of the calculated WQI in wet season showed 71.42% of the wells to be either poor or very poor in quality and 14.29 % were completely unsuitable for drinking. Only two, out of the 14, wells were good for drinking as per the WQI values in both seasons. In dry season also, only two wells were rated as good, the remaining being poor to unsuitable for drinking.

The maximum WQI of 284.99 at a well in wet season was likely due to particles from the municipal waste and dungs from the surrounding land are washed into the well or leaching into groundwater. Even though coliforms were detected in all the 14 wells, two of the wells water was rated as 'good water quality' by the WQI technique. WQI is a technique of rating the overall or general suitability of water for domestic use. Thus, the application of WQI alone to measure the drinking water quality is barely sufficient. In the WQI rating, 'good water quality' means that the water quality is protected with a minor degree of threat that it may need to be treated before use for drinking.

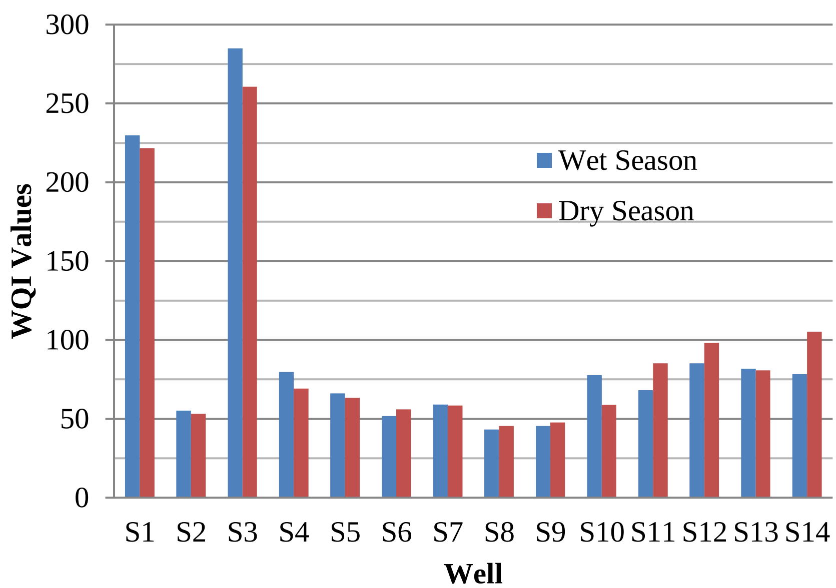

Figure 2: The WQI of the hand-dug wells

Thus, the compliance of the individual parameters with the standards should also be considered based on the required priority; making it free of pathogenic organisms takes the prior attention. Meseret (2022) reported 'excellent water quality' even though coliforms were detected in the study.

3.2 Sanitation practice

3.2.1 Drinking water sources and treatment methods

The questionnaire survey showed that almost all the households of the town are connected to piped water supply (Table 3). However, due to the serious water supply system problems, the community relies on various alternative sources. The majority of them use hand-dug wells (60.9%) and the other main alternative source is spring water. 40% of the hand-dug wells water users depend on this alternative source for drinking purpose. However, the 60% use the water for other domestic purposes, such as for cooking and washing.

The findings of this study also showed that only 42.7% of the respondents treat the alternative water sources before use for domestic purpose, by chemical addition, filtration, and boiling, in proportion of 67.9, 17.6 and 14.5%, respectively.

Similar study in Wolaita Sodo town (Ethiopia) indicated, the most dominant type of water treatment methods used to be disinfection (using chemicals like chlorine, aqua-tabs, and other locally manufactured water disinfectants or chlorine stock preparations) (Amha & Ashenafi, 2016). Some drinking water contaminants can harm human health, but cannot be tasted, smelled, or seen in drinking water. Thus, private well owners had better take actions to keep their drinking water safe by properly protecting the wells.

3.2.2 Sanitation facilities and solid waste management practices

Considering the sanitation facilities, out of the total contacted households (N = 386), 96.6% have access to some type of latrine (Table 4). 45.8% of the households empty their pits using mechanical emptying and 54.2% of them dig new hole when the pit has been filled and there is no practice of emptying pit manually. Based on the responses to the questionnaires, majority of sanitation facilities were unlined. The town does not have sewerage system to collect wastes; thus, and only 2.3% use septic tank. The 96.6 % sanitation facilities coverage was higher than the 2016 government estimate of urban sanitation coverage of 88%, which includes both improved and unimproved sanitation facilities (World Bank, 2018). As pit latrines and groundwater resources are mainly used in low-income nations, there is concern that pit latrines may create human and ecological health problems linked with microbiological.

Table 3: Main water source, alternative source and household water treatment practices

Variables	Category	Frequency	Percent
Main water source	Piped water supplied by the utility	383	99.2
	Spring water	3	0.8
Alternative water source	Hand-dug well	235	60.9
	Spring water	145	37.6
	Surface water, such as river and pond	6	1.5
Treatment Methods	Chlorine/water guard/aqua tab	262	67.9
	Water filter (bio sand/ceramic)	68	17.6
	Boiling	56	14.5

Table 4: Sanitation Facilities of the sample population

Sanitation Facilities	Frequency	Percent
Flash/pour flash	55	14.25
Ventilated improved Pit latrine	38	9.84
with slab	232	60.10
without slab	48	12.44
No access to latrine	13	3.37
Total	386	100

The solid waste management practice showed, 276 (71.5%) of the households get the solid waste collected by the service provider, 74 (19.17%) burn after gathering, 26 (6.74%) dump in a garbage pit (bury) and 10 (2.59%) convert the solid waste to compost. The solid waste which is collected by the service providers is transported to an open dump site.

From the relative location of the toilets with respect to the hand-dug wells, the specified standard is violated. Pit latrines generally lack the physical barrier, such as concrete, between stored excreta and soil and/or groundwater. Liquids leach from the pit and pass to the unsaturated soil zone. Subsequently, the liquids from the pit enter the groundwater where they may lead to its pollution (Graham & Polizzotto, 2013). Similarly, precipitation that infiltrates in the solid wastes disposed on open land mixes with the liquids already trapped in the crevices of the waste and leach compounds from the solid waste. In this research, it is clear that disease-causing organisms are present in the sampled groundwater stations, possibly due to leakage from wastewater produced by onsite sanitation systems, primarily pit latrines and septic tanks.

3.3 Sanitary inspection

The level of the sanitary risk noted at the water sources was determined based on the cumulative sum of the risk factors and it is shown in Figure 3. Close to three-fourth of the water sources had either a very high or high sanitary risk score for coliform contamination and only one of the 14 wells had a low sanitary risk score. None of the hand-dug wells had a risk score of zero.

Table 5 shows sanitary assessment of the hand-dug wells. The relationships between risk factors and the indicator bacteria were evaluated by Chi-Square test. Five sanitary risk factors of the hand-dug wells, namely, uphill latrine, other sources of pollution, concrete floor less than 1 m, cracks in the concrete floor, and rope bucket exposed had significant association with the presence of coliform ($p<0.05$).

Similar research in Gedeo zone (Ethiopia) showed sanitary survey results of 31, 49.8 and 18.2% of water sources with high, medium and low-risk level, respectively (Zemachu et al., 2021). The results of the sanitary survey indicated that the wells were at risk of contamination with bacteria. Spatially higher risk of contamination were observed in northern and south east areas and the low risk of contamination was observed in the south west areas of the town.

The common sources of pollution identified were presence of animal excreta and rubbish within a radius of 10 m from wells. There is poor drainage; causing stagnant water within 2 m, as 13 of the 14 wells inspected lacked the appropriate drainage. 42.85% of the wells with their ropes knotted to buckets used for drawing are normally left at points around the wells that are likely to be contaminated. Thus, the most common risk for the wells was absence of drainage, followed by the inadequate well lining.

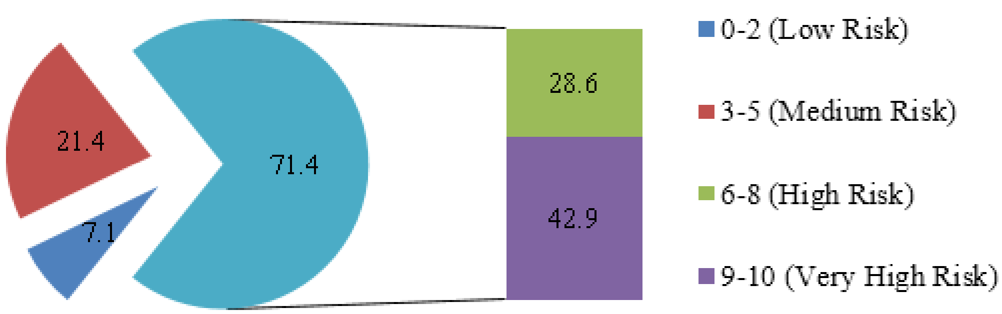

Figure 3: Contamination risk score and level of the water sources in percentage

Table 5: Sanitary assessment of hand-dug wells with the association between coliform and sanitary risk factors checklist of the hand-dug wells (p-value)

Sanitary risk factors	Hand-dug wells		P-value			
			Wet Season		Dry Season	
	No	%	FC	TC	FC	TC
Latrine within 10 m	6	42.86	0.546	0.358	0.706	0.560
Latrine on higher ground	5	35.71	0.003	0.004	0.001	0.001
Other sources of pollution within 10 m	7	50.00	0.003	0.007	0.004	0.004
Drainage absent or blocked	13	92.86	0.278	0.237	0.288	0.270
Faulty drainage channel	13	92.86	0.278	0.237	0.288	0.270
Concrete floor less than 1m	8	57.14	0.004	0.006	0.004	0.010
Cracks in the concrete floor	9	64.29	0.018	0.01	0.012	0.010
Well-lining inadequately sealed	12	85.71	0.267	0.298	0.227	0.354
Inadequate headwall (parapet)	9	64.29	0.278	0.153	0.196	0.129
Exposed rope bucket	6	42.86	0.002	0.001	0.001	0.001

The contamination of all the 14 samples with coliform is mainly because the poor sanitary condition of source water increases the risk of contamination. Zemachu et al. (2021) also showed that the presence of a latrine in uphill of the water sources was associated with fecal coliform contamination and rope used to fetch water was associated with fecal contamination of dug well. The use of manually operated rope and bucket system to collect water from the sources is considered unsafe because the water retuning back during the extraction may result into increased contaminations (Pantaleo, 2019). In this study, latrines presence within 10 m was not associated with coliform. Similarly, Kirubel (2015) showed that latrine proximity had no significant relationship with both *E. coli* and Enterococci contamination. Generally, in agreement with Gnimadi et al. (2024), it is crucial to promote hand-dug well sitting, construction and maintenance standards to ensure that the wells are properly built and protected from possible contamination sources.

4. Conclusions

In order to determine the safety of hand-dug-wells water, which is used as a substitute of the intermittent utility source of drinking in Merawi Town, water quality parameters were compared with WHO and Ethiopian standard values. From the physico-chemical analysis results, EC, TDS, Cl^-, NO_3^-, and Mg^{+2} were within acceptable limit of drinking water quality in both dry and wet seasons. However, temperature, turbidity, Ca^{+2} and TH need monitoring at some of the wells. From the bacteriological analyses, all of the sampled wells did not meet standards for drinking purpose. Most of the parameters showed seasonal variation of concentration. Based on the WQI, 85.71 % of the wells were categorized as poor to unsuitable for drinking. However, 57.3% of the households do not treat the alternative water source. Thus, the community is susceptible to waterborne diseases. The improper well construction, poor sanitation facility condition and absence of proper waste disposal practices of the community likely polluted the groundwater source. In the study area, pit latrines are common sanitation facility, even though majority of them are unlined and thus may have a direct impact on the groundwater quality. Thus, all of the hand-dug wells are at risk of contamination.

Based on the bacteriological contamination, the community is susceptible to waterborne diseases; thus, short-term solutions of mitigating the risks are needed. The fact that a significant percentage of the community does not treat their water combined with the bacteriological contamination of the wells, calls for immediate interventions such as interventions such as temporary water treatment solutions. The community should be advised not to use the hand-dug wells water for drinking, at least without boiling. These are critical in preventing outbreaks of waterborne diseases. Moreover, given that nearly 86% of the wells are classified as poor to unsuitable, majority of the residents lack access to potable water, which poses potential health crises. Thus, as a long-term solution, the utility needs to consider making water available regularly and thus improving the missing access to safe drinking water. If that will be the case, the value of sanitary inspection will not be limited to predicting risks to water quality, but also informing the utility the requirement of a robust strategy to protect water safety. Thus, sanitary inspection and water quality analysis are complementary tools, which play the important purposes of ensuring water safety.

It is also necessary to improve the condition of available infrastructures, such as lining wells, improving overall well construction, and providing access to safe sanitation facilities. For this, it is paramount importance for the local government and community members to collaborate. The utility may provide the required technical expertise and guideline and by doing so it plays the crucial role in ensuring sustainable water safety. Besides, locally functioning NGOs may play the role of funding for infrastructure improvement. Broadly, policy changes with regard to awareness creation, making available well-construction guidelines and mandatory activities of local government are needed.

Although there is practically useful knowledge arrived at as findings of this study, it should be stated that the study is not free from the common limitations to well-water quality analysis, such as sampling and lab analysis techniques. Moreover, parameters such as heavy metals were not studied. For further study, it is recommended to consider heavy metals and longer duration of study.

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