TES Trends in Environmental Sciences

OPEN ACCESS

Assessment of Physicochemical and Bacteriological Quality of Drinking Water from Source to Household Tap in Ayana Town, Western Ethiopia

Lamessa Fekeda and Kelbessa Gutema

Department of Environmental Science, College of Natural and Computational Sciences, Wallaga University, P.O. Box 395 Nekemte, Ethiopia

ABSTRACT

Background and Objective: Contamination and recontamination of drinking water is a persistent problem in developing countries like Ethiopia. The quality of drinking water in countries like Ethiopia is affected by both anthropogenic and natural causes. The objective of this study was to assess some selected physicochemical and bacteriological quality of spring drinking water from source to household tap in Ayana Town, Western Ethiopia. **Materials and Methods:** The 24 water samples were collected and analyzed for temperature, turbidity, color, pH, EC, TDS, TH, Ca, Mg, Fe, Mn, Cu, NO_3^-, SO_4^{2-}, PO_4^{3-}, fecal and total coliform counts. The experimental methods and procedures were set according to the international drinking water testing standards set by the American Public Health Association. A total of 17 drinking water quality parameters; 15 physicochemical and 2 biological indicators were analyzed in the laboratory to assess the quality of drinking water from source to household tap in Ayana Town. **Results:** The results revealed that the mean concentration of Mn in all sampling sites ranged from 0.45±0.11-0.97±0.23 mg/L, the pH value was in a range of 5.87±0.23-6.23±0.19 units and the mean fecal and total coliforms counts were in the ranges of 2.67±1.15-10.78±3.53 (CFU/100 mL) and 8.00±1.86-20.56±1.90 (CFU/100 mL), respectively. All the other parameters were observed to be within the permissible limits of the National Standards and World Health Organization Guidelines. **Conclusion:** The current study concluded that spring water is safe for drinking purposes after moderate treatment of Mn, pH, fecal and total coliforms.

KEYWORDS

Bacteriological parameters, fecal coliform, total coliform, physicochemical parameters, water source, water quality

INTRODUCTION

Water is one of the most important natural resources on earth. Access to safe water and basic sanitation is a worldwide need however, many of the world's population lack access to adequate and safe water[1]. In many households' priority is given to drinking and cooking purposes thus lack of access to water limits

https://doi.org/10.17311/tes.2025.31.44

Received: 12 Jul. 2024
Accepted: 15 Oct. 2024
Published: 01 Jan. 2025

sanitation and hygiene practices. Among many people living in rural areas, only one out of three people use safely managed drinking water services[2,3]. The basis for promoting safe drinking water in rural and urban communities in developing countries is the steadily high level of morbidity and mortality[3].

The Two-fifths of African countries lack access to improved water supply only 60.2% have access to improved drinking water sources and 36% have access to improved sanitation facilities[4]. In most urban and rural communities in developing countries particularly the Sub-Sahara Africa, surface water sources have been the most available sources of water used for domestic purposes. Water from these sources is contaminated with domestic, agricultural and industrial wastes and is likely to cause water-related diseases. Contaminated drinking water causes many diseases such as diarrhea, vomiting, gastroenteritis, dysentery and kidney problems[5].

Contamination and recontamination of drinking water is a persistent problem in developing countries like Ethiopia. The quality of drinking water in countries like Ethiopia is affected by both anthropogenic and natural causes. Ethiopia is one of the countries in the world with drinking water quality problems. It has one of the lowest coverages in Sub-Saharan countries with 42% for improved drinking water supply and 28% for improved sanitation[6]. As traditional water source users are highly vulnerable to waterborne diseases, there is a need to check drinking water quality to provide measures capable of diminishing the outbreak of water-related diseases. Communities' perception of quality also carries great weight in their drinking water safety[7].

Water contamination is the most widespread health risk in developing countries. The health and well-being of the population is directly affected by the coverage of water supply and sanitation[8]. Water quality and the risk of water-associated disease are serious public health concerns in many developing countries like Ethiopia. This is mainly due to a lack of subsequent water quality monitoring and a dearth of appropriate research and development for most of the towns in Ethiopia.

Several studies conducted in several rural and urban areas of Ethiopia on the bacteriological and physicochemical quality of drinking water revealed that the bacteriological and physicochemical parameters of different water sources had values beyond the maximum limit of WHO guidelines and Ethiopian compulsory standards[9,10]. They suggested the need for the appropriate intervention including awareness creation and improvement of existing infrastructures and conducting appropriate research.

The main problem of the study area is population growth due to informal settlements which in turn leads to environmental degradation, uncontrolled liquid and solid waste disposal and contamination of drinking water sources. In Ayana Town, one of the greatest challenges that the community faces is the shortage of drinking water supply and a lack of drinking water monitoring services. This study aimed to assess the physicochemical and bacteriological quality of drinking water from source to household tap in Ayana Town, Western Ethiopia. The results of the study were compared with national standards and international drinking water guidelines to determine its quality status concerning the threshold levels and to safeguard public health.

MATERIALS AND METHODS

Description of the study area: The study was conducted in Ayana Town, which is located in East Welega Zone, Oromia Regional State, Western Ethiopia. Ayana town is located in Gida Ayana District at about 112 km North of Nekemte City, which is located at 321 km from Addis Ababa to the West. Geologically Nekemte City is located at Longitude 36°36.000'E and Latitude 09°56.001'N. The study area is bounded by different districts: In East Kiramu, in West Limu, in South Guto Gida and in the North Amara Regional State. The climatic condition of the study area are temperatures ranging from 18-32°C, while rainfall ranges from 900-1400 mm as well as the elevation of the town ranging from 1400-2250 m above sea level. The demographic data of Ayana town reveals a total population of 25475 of which 12453 are male and 13022 female.

Materials

Chemicals and reagents: Deionized water, distilled water, buffer Solutions (pH 4.01±0.02, 7.00±0.02 and 10.01±0.02 at 25°C), calcium and magnesium indicator solution, alkali solution for calcium and magnesium test, 1M Ethylene Diamine Tetra Acetic Acid (EDTA) solution, Egtazic Acid (EGTA) solution, chlorophosphonazo solution pillow, Comparative Dynamic Transcriptome Analysis (CDTA) reagent for ultra-low range hardness, membrane lauryl sulfate broth, HNO_3 and potassium chloride (0.01M KCl) and also ferrover iron, buffer-citrate type, sodium periodate, CuVer® copper, nitraver 5 nitrate, phosver 3 phosphate and sulfaver 4 reagent powder pillows.

Equipment: The DR/2400 portable spectrophotometer (Hach Company, 2002), laboratory incubator (DNP-9052A), mili pore, pH meter (Z-WAG-WE30020), portable microprocessor-based conductivity meter, portable microprocessor turbidity meter (WZS-200), sterilized sample bags, petri-dishes, a gridded membrane filter of 0.45 μm size, forceps, absorbent pad, pipet sterile 10-11 mL, beakers (100 and 200 mL), sample cell (10 and 25 mL), measuring cylinder of (10, 25, 50 and 100 mL) and glass bottles (2000 mL).

Research design and period: Laboratory-based research that utilizes a quantitative approach was conducted from January to March, 2020. The research was employed to assess the hysicochemical and bacteriological quality of the spring drinking water supply in Ayana town from the source to household tape. The 24 water samples were collected using sterilized bottles for the study and transported to the Nekemte water supply and sewerage service enterprise laboratory in small size ice cold box containing ice freezer packs for lab analysis. Total and fecal coliform counts were carried out by membrane ltration technique.

Duration and frequency of sample collection: To keep the validity of the data, samples were taken three times from each site in intervals of three weeks. The first round of samples was taken on January, 27, 2020, the second on February 18, 2020 and the third samples were taken on March 12, 2020. Totally 3 months were allocated for the collection of samples for laboratory analysis from January to March, 2020.

Sample collection and preservation: Glass bottles were used for sample collection which were previously washed and sterilized by steam sterilizer at 125°C. To avoid recontamination during sampling the glass bottles were rinsed several times with the water being sampled.

Before sample collection was carried out, the water pipe was opened for 2 min to allow the water to flow out and then water samples were collected in sterilized glass bottles of 2 L from the selected sampling site areas. For bacteriological analysis, two sterilized glass containers with a capacity of 120 mL were used to collect water samples and then each sample was labeled at the site and placed in an ice box that contains ice cubes. The collected samples were transported to the laboratory and kept at 4°C before the time of analyses.

Physicochemical and bacteriological analysis of samples: The water samples were analyzed in the Nekemte City Water Supply and Sewerage Service Enterprise Laboratory. The analyses of the samples were conducted by using standard methods of classical laboratory methods model of portable spectrophotometer. Details of the analytical methods for each parameter are discussed in Table 1.

Table 1: Analytical methods used for determinations of physicochemical parameter

No.	Parameter	Method used
1	Temperature	pH/Temperature meter
2	pH	pH/Temperature meter
3	Color	Platinum cobalt standard
4	Turbidity	Turbidity meter
5	Electrical conductivity (EC)	TDS/Conductivity meter
6	Total dissolved solids (TDS)	TDS/Conductivity meter
7	Nitrate (NO_3^-)	Cadmium reduction
8	Sulphate (SO_4^{2-})	Sulfaver 4
9	Phosphate (PO_4^{3-})	Phosver 3 (ascorbic acid)
10	Calcium (Ca)	Ca & Mg; Calmagite colorimetric
11	Magnesium (Mg)	Ca & Mg: Calmagite colorimetric
12	Copper (Cu)	Bicinchoninate
13	Manganese (Mn)	Periodate oxidation
14	Total iron (Fe)	FerroVer®
15	Total hardness (TH)	Ca & Mg; Chlorophosphonazo rapid liquid

Bacteriological analysis

Total and faecal coliform: Samples were analyzed using a standardized bacteriological analysis method to determine the degree of bacteriological contamination. All Samples were analyzed for the presence of indicator bacteria; fecal and total coliforms. Total and fecal coliform counts were carried out by membrane filtration technique[11]. The filtration apparatus and the Petri dishes were pre-sterilized in an autoclave at 135°C for 15 min.

A sterilized pad dispenser is aseptically used for introducing the growth absorbent pads into the base of Petri dishes and the growth pads dispensed at the base of the Petri dishes were saturated with the prepared Membrane Lauryl Sulphate Broth. Using sterilized forceps, a gridded membrane filter of 0.45 μm size was placed into the filtration apparatus Millipore.

A 100 mL of water samples were poured into the filtration apparatus (filter funnel) that was connected to the vacuum pump and it was pumped to suck so that the water pass through the membrane filter. After the water had been filtered, the vacuum pump was released and the membrane filter was taken from the filter funnel using sterilized forceps. The membrane filter was placed on the top of the absorbent pad which had been saturated with Membrane Lauryl Sulphate Broth. The Petri-dishes lid was replaced and it was labeled with sample type, number, date and time. The Petri dishes were placed in to the incubator for about 4 hrs at 37°C for resuscitation which can allow any physiologically stressed coliforms to be recovered before incubation. After 4 hrs of recovery, total coliforms were incubated at a temperature of 37°C for 24 hrs and fecal coliforms (thermo-tolerant coliforms) were incubated at 44°C for 24 hrs.

Bacteria colonies were grown in specific blue and yellow colors in 24 hrs and counted using a magnified glass. Blue colonies were counted as *E. coli* and the red colonies were counted as fecal coliform[11].

Statistical analysis: Data were analyzed using SPSS software version 22 and Microsoft Excel 2007. Descriptive data were generated for all parameters and presented as Mean±Standard Deviation (Mean±SD). The results of the physicochemical and bacteriological parameters analyzed for all sampling sites were compared with CES, 2013 and 2011 and interpreted as acceptable or unacceptable. The mean variations in data between the sampled sites were analyzed using One-way ANOVA, $p \leq 0.05$ significant level. The measured values were correlated against each other to determine their statistical significance relation between physicochemical and bacteriological parameters using Pearson's correlation.

Quality assurance: Before the actual data collection and the actual analysis, a pretest was done in the laboratory by calibrating laboratory equipment, checking the expiry date of chemicals and reagents and preparing standard reagents for each test using samples to be taken from Nekemte City other than those included in the sample to that was ruled out measurement errors due to the measuring instruments and to have more reliable results.

RESULTS AND DISCUSSION

In this study, 24 water samples were collected from eight sites (S_1 = Source, S_2 = Reservoir, S_3 = Representative Bono/Public tap (01 Kebele), S_4 and S_5, respectively Private tap "a"&"b" (01 Kebele), S_6 = Representative Bono/Public tap (02 Kebele), S_7 and S_8, respectively private tap "a"&"b" (02 Kebele) of Ayana town in Gida Ayana district. A summary of the analyzed values (Mean±SD, n = 3) for the selected physicochemical and bacteriological parameters of spring drinking water samples were presented in Table 2, 3 and 4.

Some selected physical parameters: The selected physical parameters of the source to household tap of drinking water in Ayana town were analyzed and the results were tabulated as shown in Table 2. The analyzed parameters in this study were temperature, color, turbidity, electrical conductivity (EC) and total dissolved solids.

Temperature: The temperature of the drinking water samples was measured and tabulated in Table 2. The mean temperature values of the water samples taken at the time of collection were in the ranges of 19.39±0.80°C (S_7) to 20.73±0.73°C (S_5) and the values of all the sample sites were within the recommended range. The recorded temperature values were also similar to the result of a similar study conducted at Nekemte city[12]. The measured value of temperature in the entire site was not significantly different ($p = 0.168$) as shown in Table 2.

Color: Color is the measure of dissolved coloring compounds in water. Color intensity increases with an increase in pH[13]. Color in drinking water may be due to the presence of organic matter such as humic substances, metals such as iron and manganese, or highly colored industrial wastes. Colored water is not aesthetically acceptable to the public. Color affects the aesthetic quality of drinking water and indicates pollution.

The level of color positively correlated with turbidity and total suspended solid. It was also affected by the same factors that affect turbidity and total suspended solids. The color value of spring drinking water samples of the current study ranged from 4.33±1 PtCo (S_1) to 9.78±2.34 PtCo (S_5) which were lower than 15 and 22 PtCo. These measured values showed significant variations among water samples at all sample sites at ($p \leq 0.05$).

Turbidity: Turbidity is one of the important physical parameters that affect not only the quality of water but also other chemical and bacteriological parameters and the efficiency of water treatment plants. It also affects treatment processes with chlorine and reduces the pathogen removal efficiency[14]. It is the measure of the suspended particulate matter in a water body that interferes with the passage or dispersion of a beam of light through the water. The highest and lowest turbidity measurements recorded in the present study were 0.83±0.26 and 0.28±0.17 NTU, respectively. This value is within the permissible concentration limit. These measurements showed insignificant variations amongst water samples at all sample sites ($p \leq 0.05$). Since the town was located at a high altitude, the distribution systems would not be polluted by organic and inorganic matter. On the other hand, there are no factories around the town which pollute the spring drinking water. In comparison to other studies conducted in different sites, the turbidity recorded at the present study was less than the results recorded from Shambu towndrinking water

Table 2: Mean concentration values of physical parameters of the study area water samples

	Parameters with their results (Mean±SD units)				
Sampling sites	Temperature (°C)	Color (PtCo)	Turbidity (NTU)	EC (µs/cm)	TDS (mg/L)
Source					
S_1	19.78±1.42	4.33±1	0.61±0.1	50.56±4.03	46.65±0.89
Reservoir					
S_2	20.07±1.12	6.89±1.68	0.49±0.42	60.55±3.03	53.90±2.69
01 kebele					
S_3	20.46±0.74	6.78±1.35	0.28±0.17	62.78±1.92	55.87±1.71
S_4	20.36±0.48	5.33±1	0.83±0.26	64.00±1.53	56.96±1.36
S_5	20.73±0.73	9.78±2.34	0.59±0.37	65.33±1.45	58.14±1.30
02 Kebele					
S_6	20.52±0.74	7.67±1.34	0.56±0.06	62.78±2.34	55.38±1.46
S_7	19.39±0.80	6.11±0.84	0.40±0.02	64.67±0.88	57.55±0.78
S_8	20.37±0.56	4. 89±1.84	0.37±0.14	61.56±2.69	54.49±2.02
Standards					
WHO	<40	15	5	400	1000
CES	22		5	500	1000
F-value	0.773	4.608	1.593	11.278	14.791
ANOVA result					
p-value	0.618	0.005	0.208	0.000	0.000
Significance (p = 0.05)	Insignificant	Significant	Insignificant	Significant	Significant

S_1: Source, S_2: Reservoir, S_3: Representative bono/Public tap (01 Kebele), S_4: Private Tap "a" (01 Kebele), S_5:Private Tap "b" (01 Kebele), S_6: Representative bono/Public tap (02 Kebele), S_7: Private Tap "a" (02 Kebele) and S_8: Private Tap "b" (02 Kebele) water samples

samples (1.26-4.23 NTU), at Gedeo Zone, Ethiopia recorded turbidity values of 3.78-40.2 NTU and within the range recorded in Nekemte town drinking water from source to household tap connection (0.1±0.05-1.7±0.80 NTU) reported in Nekemte[9]. High turbidity values affect the clarity of the water and reduce the depth to which light can penetrate. It has also been an indication of poor filtration process of water supplies. Particulate matter can protect microorganisms from the effect of disinfection and can stimulate bacterial growth. High turbidity can interfere with disinfection and provide a medium for microbial growth[15].

Electrical conductivity (EC): The ability of a solution to conduct an electrical current is governed by the migration of ions and is dependent on the nature and numbers of the ionic species in that solution. This property is electrical conductivity. It is a useful tool to assess the purity of water. The maximum acceptable value for electrical conductivity (EC) is 400 μS/cm while the EC of the collected and analyzed samples ranged from 50.56±4.03-65.33±1.45 μS/cm. This showed that the EC values of all water samples were within permissible limits of guidelines and the spring drinking water samples of the current study are safe in terms of EC.

Across the sampling sites, the values of EC did not differ significantly at (ANOVA, $p<0.05$). The recorded value was lower than the ranges from 179.3-201, 80-248.96, 63.96-300.37 μS/cm and within 58.25±3.5-74.2±3.05 μS/cm which were recorded in Wondo Genet Campus[16].

Total dissolved solids: Total Dissolved Solids (TDS) can be taken as an indicator for the general water quality because it directly affects the aesthetic value of the water by increasing turbidity. High concentrations of TDS limit the suitability of water as a drinking source and irrigation supply. In the present study, the range of TDS of analyzed water samples varied between 46.65±0.89-58.14±1.30 mg/L as shown in Table 2. All TDS values were below the maximum acceptable concentration of CES and WHO (1000 mg/L) and low compared to other similar studies results reported in Wondo Genet Campus[16], in the Ankober District of Amhara Region. The highest TDS value observed at S_5 indicates that the water samples were more mineralized than the other water sample sites.

Statistical results from ANOVA ($p<0.05$) show that the mean concentration of TDS was significantly varied among all the sites (Table 2). Therefore, all the spring water samples of the current study were potable in terms of total dissolved solids.

Selected chemical parameters: Some selected chemical parameters of the present study were metals like Calcium, Magnesium, Iron, Manganese and Copper; pH, Total hardness and anions like Nitrate, Sulphate and Phosphate and their respective values were tabulated in Table 3.

pH of water: The pH is a measure of the hydrogen ion concentration in water. It is a simple parameter but extremely important since most of the chemical reactions in aquatic environment are controlled by it. In the present study, the pH value ranges between 5.87±0.23 units (S_3) to 6.23±0.19 units (S_2) and all the water samples analyzed have pH values lower than the safe limit of 6.5 to 8.5 values[17]. Thus, all the water samples were slightly acidic which tends to be corrosive to plumbing and faucets. The result of the present study was lower than that of the result of the study conducted in Wondo Genet Campus[16], Ethiopia. In the present study, the pH value was significantly different from each sample site ($p\leq 0.05$) as tabulated in Table 3.

Calcium (Ca): The calcium level recorded in the entire sampling points of the spring drinking water samples ranged from 0.08±0.07 mg/L (S_2) to 0.18±0.06 mg/L (S_3 & S_5) and the values recorded were below the average value concentration level of calcium in tape water 6.8-135 mg/L[18,19,20]. The result of the present study was lower when compared to the result of the study conducted at Wondo Genet Campus[16], Ethiopia. The mean calcium values of the water samples measured at the selected sampling sites were not significantly different ($p\leq 0.05$) across the selected sites of the current study (Table 3).

Table 3: Mean concentration values of chemical parameters of the present study

		Parameters with their results (Mean±SD mg/L except pH)									
Sampling sites		pH units	Ca	Mg	Fe	Mn	Cu	NO_3^-	SO_4^{2-}	PO_4^{3-}	TH
Source	6.12±0.30	6.12±0.30	0.09±0.06	2.42±0.12	0.18±0.02	0.47±0.12	0.27±0.09	1.39±0.81	0.89±0.19	3.44±0.47	2.51±0.17
Reservoir	6.23±0.19	6.23±0.19	0.08±0.07	2.37±0.16	0.12±0.09	0.69±0.14	0.29±0.09	1.82±0.54	1.22±0.69	2.48±0.49	2.45±0.13
01 kebele	5.87±0.23	5.87±0.23	0.18±0.06	2.17±0.35	0.1±0.04	0.97±0.23	0.17±0.05	1.00±0.76	1.56±0.20	2.88±0.46	2.35±0.40
	6.17±0.27	6.17±0.27	0.14±0.04	2.14±0.06	0.06±0.04	0.97±0.14	0.34±0.11	1.62±0.61	2.00±0	2.36±0.52	2.28±0.10
	5.98±0.34	5.98±0.34	0.18±0.05	2.55±0.36	0.16±0.09	0.63±0.17	0.34±0.03	0.65±0.56	1.00±0.33	1.36±0.08	2.73±0.41
02 kebele	5.89±0.03	5.89±0.03	0.15±0.08	2.62±0.26	0.13±0.07	0.56±0.15	0.19±0.02	0.30±0.08	1.44±0.20	1.09±0.09	2.78±0.34
	6.07±0.04	6.07±0.04	0.12±0.03	2.45±0.23	0.10±0.07	0.45±0.11	0.24±0.05	1.71±0.75	2.33±0.34	1.27±0.15	2.57±0.28
	6.06±0.24	6.06±0.24	0.13±0	2.63±0.53	0.11±0.07	0.54±0.15	0.2±0.01	1.76±0.27	2.33±0.34	0.51±0.41	2.76±0.53
Standards	6.5-8.5	6.5-8.5	75	50	0.3	0.4	2	50	250	5	300
	6.5-8.5	6.5-8.5	75	50	0.3	0.5	2	50	250		500
ANOVA result	0.94	0.94	1.276	1.236	1.331	5.128	3.196	2.715	8.394	19.917	1.015
	0.504	0.504	0.322	0.34	0.299	0.003	0.026	0.046	0	0	0.457
Significance (p = 0.05)		Insignificant	Insignificant	Insignificant	Insignificant	Significant	Significant	Significant	Significant	Significant	Insignificant

TH: Total hardness

Magnesium (Mg): The values of magnesium recorded were slightly the same, but maximum at S_8 (2.63±0.53 mg/L) and minimum at S_4 (2.14±0.06 mg/L) which was below the maximum acceptable concentrations of 50 mg/L. The level of magnesium in all the water samples is very low which makes the water good for drinking and domestic uses. In this study, the measured mean concentration of magnesium was very low compared to the result of the study in Arba Minch[21], Ethiopia. The mean concentration of magnesium in the studied area does not vary significantly ($p \leq 0.05$) across the selected sites (Table 3).

Total iron (Fe): Iron is an essential element for almost all living organisms as it participates in a wide variety of metabolic processes, but in excessive amounts, it can lead to tissue damage[22]. Source to household tap connection of spring water from the sampling areas had low values of iron concentration ranging from 0.06±0.04 mg/L (S_4) to 0.18±0.02 mg/L. The Fe concentration in the entire site was less than the maximum acceptable limit of 0.3 mg/L. The low content of iron recorded in this study was due to low or no rock contents that have high iron concentrations around the sites. When compared with other research findings the result of the current study is lower than that of the result of the study in Nekemte City[9].

Statistical ANOVA result ($p \leq 0.05$) shows that the mean concentration of Fe among the sampling site was not significantly different (Table 3). In this study, all spring water samples of the current study were safe for drinking and other purposes in terms of iron concentration.

Manganese (Mn): The mean manganese concentration of the spring drinking water samples of the current study ranges from the minimum value of 0.45±0.11 mg/L (S_7) to a maximum value of 0.97±0.23 mg/L (S_3). The recorded value was higher than the maximum acceptable concentration limit of 0.45 mg/L[19]. In this study, the water source was found to be unsafe for drinking in terms of manganese concentration. At levels exceeding 0.15 mg/L, manganese stains plumbing fixtures and laundry and causes undesirable tastes in beverages. From ANOVA results ($p \leq 0.05$) it was observed that the concentration of manganese varied significantly among the sampling sites (Table 3).

Copper (Cu): The source for the presence of copper in the water can be from agricultural chemicals of copper compounds, corrosion of copper-containing alloys in pipefitting may introduce measurable amounts of copper into water in a pipe system. The concentration of copper in the water sample under the study ranges from a minimum of 0.17±0.05 mg/L (S_3) to a maximum of 0.34±0.03 mg/L (S_5). None of the sites of the spring water samples analyzed for Cu shows above the recommended limit of 1.3 mg/L[20]. This shows that the concentration in the water was generally low. Across the sampling sites, the concentration of Cu was differing significantly (ANOVA, $p \leq 0.05$), as in Table 3. Considering the guideline, the spring water samples can be considered wholesome concerning copper content. This implies the source-to-house connection of spring water of the current study may be safe from this contamination.

Nitrate (NO_{3-}): In this study, the measured nitrate ion concentration was in the range of 0.30±0.08-1.82±0.54 mg/L with the lowest record of 0.30±0.08 mg/L from S_6 and the highest record 1.82±0.54 mg/L from S_2. This may be due to the absence of over-leaching of nitrate-containing organic wastes and agricultural fertilizers in the nearby agricultural fields. Therefore, nitrate measurements of the water from the source to the household connection were much less than the recommended limit of 50 mg/L in drinking water. The nitrate mean concentration values of spring water samples of the current study were within the ranges 0.3-38 mg/L and lower than 1.42-4.97 and 18.03-20.17 mg/L reported in Nekemte City[9] and in Wondo Genet Campus[16]. The mean concentration of nitrate in the studied area varied significantly ($p \leq 0.05$) across the selected sites (Table 3).

Sulphate (SO_4^{2-}): Drinking water from the sampling areas generally had low SO_4^{2-} concentrations ranging from 0.89±0.19 mg/L (S_1) to 2.33±0.34 mg/L (S_7 and S_8). These all values were within the acceptable maximum contaminant limits (250 mg/L). The sulfate content of spring water samples of the study area was within the range of 0 to 3 mg/L and below the detectable level to 3.6 mg/L reported in Wondo Genet Campus[16] and lower than the range 16±3-25±1 mg/L studied in Nekemte Town[9], Oromia, Ethiopia. Statistical data analysis indicates that the mean concentration of sulfates differed significantly ($p \leq 0.05$) among the sites of the current study (Table 3).

Phosphate (PO_4^{3-}): The concentration of phosphate in the studied area from source to household tap of spring drinking water samples varies from 0.51±0.41 mg/L (S_8) to 3.44±0.47 mg/L (S_1). In the entire site, the concentration of phosphate is below the maximum acceptable limit of 5 mg/L. The phosphate concentration was slightly higher than 0.24-0.86 mg/L and 0.35±0.20-1.0±0.30 mg/L reported in Nekemte City[9], studied in Oromia, Ethiopia of a similar study from source to household tap. The mean concentration of phosphate differed significantly ($p \leq 0.05$) among the sites (Table 3). High concentration of phosphate in water bodies is an indication of pollution and is largely responsible for eutrophication. Phosphates are not toxic to people or animals unless they are present at very high levels. In the case of phosphate concentration, the current study is safe for drinking and other purposes.

Total hardness (TH): Water hardness is mainly contributed by bicarbonates, carbonates, sulfates and chlorides of calcium and magnesium. The principal hardness-causing ions are calcium and magnesium. The acceptable limit of total hardness is 300 mg/L whereas the maximum limit is 600 mg/L[23]. The hardness of analyzed water samples varied from 2.28±0.10 (S_4) to 2.78±0.34 mg/L as $CaCO_3$ (S_6) and the measured values of total hardness from spring drinking water of the present study were within the acceptable limit values of the national standard and WHO (500 mg/L) guideline. In similar studies, the lower and higher values of total hardness recorded were 40 and 215 mg/L in the Ankober District[24,25].

Bacteriological parameters: For water to be potable, it must be free of pathogenic contaminants. An important indicator of water quality is the number of bacteria present in the water. Though it would be difficult to determine the presence of all bacteria in a sample, certain types of microorganisms can serve as indicators of pollution. Chief among these are the coliform bacteria, which survive better and longer and are easier to detect than other pathogens[24].

The result of bacteriological analysis indicated that the spring water sources from the source to the household tap connection were found to be positive for fecal coliform and total coliforms (Table 4)[26]. The mean fecal coliform counts ranged from 2.67±1.15-10.78±3.53 (CFU/100 mL) with the lowest and the highest range corresponding to samples from the S_3 and S_7 sample sites, respectively. The mean total coliform counts ranged from 8.00±1.86-20.56±1.90 (CFU/100 mL) with the lowest and the highest range corresponding to samples from S_5 and S_7, respectively (Table 2). Since 0 CFU/100 mL counts are required in drinking water, both fecal and total coliform counts in the current study were above the required values. The mean values of fecal and total coliform counts in the source (10.44; 18.78) are more contaminated than that of Reservoir (4.78; 10.45), 02 Kebele (7.41; 14.96) and 01 Kebele (3.11; 9.89) in CFU/100 mL, respectively. To compare the fecal and total coliform counts contamination across the kebeles (household) of the private tap and bono; in the case of 01 Kebele, the private tap is more contaminated than the Bono but in the case of 02 kebele, the private tap is less contaminated than the Bono.

Similar research findings[18,19] reported the values of Fecal and total coliform counts in Munesa District, Arsi Zone, Oromia; in Ankober district, Amhara region by Alemnew and Seyoum, 2020 and in Nekemte City, Oromia, Ethiopia, respectively the ranges of (2±1.93 to 22±2.74 CFU/100 mL, 3±2.36 to

Table 4: Mean concentration values of bacteriological parameters of Ayana town water samples

	Results (Mean±SD CFU/100 mL)	
Sampling sites	Fecal coliforms	Total coliforms
Source		
S_1	10.44±2.59	18.78±0.69
Reservoir		
S_2	4.78±2.14	10.45±3.89
01 kebele		
S_3	2.67±1.15	9.89±3.86
S_4	3.89±1.95	11.78±6.88
S_5	2.78±0.51	8.00±1.86
02 Kebele		
S_6	7.45±4.02	16.33±4
S_7	10.78±3.53	20.56±1.90
S_8	4.00±2.34	8.00±0.88
Standards		
WHO	0	0
CES	0	0
ANOVA result		
F-value	5.125	5.702
p-value	0.003	0.002
Significance ($p \leq 0.05$)	Significant	Significant

CFU: Colony forming unit, S_1: Source, S_2: Reservoir, S_3: Representative bono/Public tap (02 Kebele), S_4: Private tap "a" (01 Kebele), S_5: Private tap"b" (01 Kebele), S_6: Representative bono/Public tap (02 Kebele), S_7: Private tap "a" (02 Kebele) and S_8: Private tap "b" (02 Kebele) water samples

30±5.01 CFU/100 mL), (0 to 1 CFU/100 mL, 0 to 147 CFU/100 mL) and (0 to 22.5±0.8 CFU/100 mL, 14±6.4 to 95±2.8 CFU/100 mL) in the same source to household tap connection of drinking water samples. In this study, significant differences ($p<0.05$) within and among water samples were detected for the fecal and total coliform counts (Table 4).

Pearson correlation: The strength of the association between two continuous parameters is measured using a correlation coefficient. The most commonly used measure of correlation is Pearson's "r". It is also called the linear correlation coefficient because "r" measures the linear association between two variables[25]. The data were statistically computed using a correlation coefficient to indicate the sufficiency of one variable to predict the other. Pearson's correlation coefficient is usually signified by r (rho) and can take values from -1.0 to 1.0. Where -1.0 is a perfect negative correlation, 0.0 is no correlation and 1.0 is a perfect positive correlation. The variables having coefficient value (r) >0.5 or <-0.5 are considered significant. The correlation matrix is given in the Table 5.

From Pearson's correlation coefficient matrix shown in Table 5, it was observed that the correlation of Mg with (r = 0.986) and EC with TDS (r = 0.976) had a very high positive correlation. Again Ca with temperature (r = 0.558), color with EC and TDS, respectively (r = 0.540 and r = 0.524), Mg with Fe (r = 0.548), total hardness with Ca and Fe, respectively (r = 0.599 and r = 0.577) and fecal with total coliform counts (r = 0.836) are pairs strongly positively correlated and fecal coliform with temperature and Ca (r = -0.706 and r = -0.520), phosphate with EC (r = -0.527), Mn with Mg, total hardness and Fe, respectively (r = -0.635, r = -0.588 and r = -0.555) are pairs negatively correlated significantly at 99% confidence level. Whereas Fe with temperature (r = 0.434), Ca with EC and Mg, respectively (r = 0.411 and r = 0.482 are pairs positively correlated and total coliform count with temperature and Mn (r = -0.432 and r = -0.414), phosphate with TDS, Mg, sulfate and total hardness, respectively (r = -0.498, r = -0.411, r = -0.409 and r = -0.426) are pairs negatively correlated significantly at 95% confidence level. All the rest physicochemical parameters of the current study showed weak correlations against each other.

Table 5: Pearson's correlation matrix between physicochemical and bacteriological parameters of Ayana town spring drinking water samples

	Temp.	pH	Color	Turb.	EC	TDS	Ca	Mg	Fe	Mn	Cu	NO_3^-	SO_4^{2-}	PO_4^{3-}	TH	FC	TC
Temp.	1																
pH	0.233	1															
Color	0.097	-0.201	1														
Turb.	0.262	0.227	-0.037	1													
EC	0.210	0.004	0.540**	-0.140	1												
TDS	0.111	-0.060	0.524**	-0.135	0.976**	1											
Ca	0.558**	0.259	0.328	0.009	0.411*	0.371	1										
Mg	0.265	0.326	0.267	0.087	0.092	0.060	0.482*	1									
Fe	0.434*	0.358	0.064	0.261	-0.279	-0.273	0.339	0.548**	1								
Mn	0.073	-0.279	0.188	0.097	0.291	0.266	-0.105	-0.635**	-0.555**	1							
Cu	-0.108	0.209	0.099	0.255	0.130	0.150	-0.078	-0.095	-0.078	0.117	1						
NO_3^-	-0.004	0.191	0.114	0.244	0.079	0.128	0.313	0.281	0.115	-0.136	0.078	1					
SO_{42}^-	0.147	0.100	-0.325	0.013	0.356	0.353	0.233	0.118	-0.227	-0.054	-0.337	0.303	1				
PO_{43}^-	-0.137	0.064	-0.241	0.113	-0.527**	-0.498*	-0.372	-0.411*	0.098	0.381	0.077	-0.042	-0.409*	1			
TH	0.350	0.321	0.305	0.092	0.149	0.114	0.599**	0.986**	0.577**	-0.588**	-0.113	0.311	0.130	-0.426*	1		
FC	-0.706**	-0.049	-0.226	-0.120	-0.354	-0.320	-0.520**	-0.089	-0.102	-0.386	-0.085	-0.108	-0.086	0.094	-0.178	1	
TC	-0.432*	0.128	-0.185	-0.125	-0.260	-0.252	-0.262	-0.006	0.111	-0.414*	-0.163	-0.007	-0.009	0.088	-0.034	0.836**	1

**: Correlation is significant at the 0.01 level (2-tailed) and *: Correlation is significant at the 0.05 level (2-tailed)

CONCLUSION

The analyzed physicochemical parameters were observed to be within the permissible ranges of national standards and WHO guidelines except Mn and pH. The analyzed biological parameters were not complying either with national standards or WHO guidelines. The presence of fecal and total coliforms in the water samples demonstrates the potential presence of pathogenic organisms, the high values of Mn in the water samples can cause metallic odor and taste and the low content of pH in the samples tends to be corrosive to plumbing and faucets. Thus, the findings of this study concluded that moderate treatment of the water for Mn, pH and microbiological contaminants is required to use the water for drinking purposes.

SIGNIFICANCE STATEMENT

The purpose of this study was to assess some selected physicochemical and bacteriological parameters of drinking water like temperature, turbidity, color, pH, EC, TDS, TH, Ca, Mg, Fe, Mn, Cu, NO_3^{-}, SO_4^{2-} and PO_4^{3-}, fecal and total coliforms from source to household tap. The results of the study revealed that average values for selected physico-chemical parameters were found within the acceptable limit of Ethiopian and WHO standards, except Mn, pH and indicator bacteria. The presence of indicator bacteria in water samples demonstrates the presence of pathogenic organisms that would be a threat to water users. Hence, it can be suggested that regular monitoring of water sources can improve the quality of drinking water in the study area.

REFERENCES

1. Tsega, N., S. Sahile, M. Kibret and B. Abera, 2013. Bacteriological and physico-chemical quality of drinking water sources in a rural community of Ethiopia. Afr. Health Sci., 13: 1156-1161.
2. Grady, C.A., S.C. Weng and E.R. Blatchley, 2014. Global Potable Water: Current Status, Critical Problems, and Future Perspectives. In: Potable Water: Emerging Global Problems and Solutions, Younos, T. and C.A. Grady (Eds.), Springer, Cham, Switzerland, ISBN: 978-3-319-06563-2, pp: 37-59.
3. Sebsibe, I., B. Degaga, G. Feye and T. Tekle, 2021. Bacteriological and physical quality of fiche drinking water from households and reservoirs, Oromia, Ethiopia. Water Pract. Technol., 16: 924-934.
4. Sila, O.N., 2019. Physico-chemical and bacteriological quality of water sources in rural settings, a case study of Kenya, Africa. Sci. Afr., Vol. 2. 10.1016/j.sciaf.2018.e00018.
5. Yilkal, E., F. Zewge and B.S. Chandravanshi, 2019. Assessment of the quality of bottled water marketed in Addis Ababa, Ethiopia. Bull. Chem. Soc. Ethiop., 33: 21-41.
6. Belay, D.G. and Z. Andualem, 2024. Correction: Limited access to improved drinking water, unimproved drinking water, and toilet facilities among households in Ethiopia: Spatial and mixed effect analysis. PLoS ONE, Vol. 19. 10.1371/journal.pone.0303771.
7. de França Doria, M., 2010. Factors influencing public perception of drinking water quality. Water Policy, 12: 1-19.
8. Ameya, G., O. Zewdie, A. Mussema, A. Amante and B. Asmera, 2018. Bacteriological quality of drinking water obtained from main sources, reservoirs and consumers' tap in Arba Minch Town, Southern Ethiopia. Afr. J. Microbiol. Res., 12: 567-573.
9. Tadesse, M., D. Tsegaye and G. Girma, 2018. Assessment of the level of some physico-chemical parameters and heavy metals of Rebu River in Oromia Region, Ethiopia. MOJ Biol. Med., 3: 99-118.
10. Yasin, M., T. Ketema and K. Bacha, 2015. Physico-chemical and bacteriological quality of drinking water of different sources, Jimma Zone, Southwest Ethiopia. BMC Res. Notes, Vol. 8. 10.1186/s13104-015-1376-5.
11. Tambi, A., U. Brighu and A.B. Gupta, 2023. Methods for detection and enumeration of coliforms in drinking water: A review. Water Supply, 23: 4047-4058.
12. Duressa, G., F. Assefa and M. Jida, 2019. Assessment of bacteriological and physicochemical quality of drinking water from source to household tap connection in Nekemte, Oromia, Ethiopia. J. Environ. Public Health, Vol. 2019. 10.1155/2019/2129792.

13. Meride, Y. and B. Ayenew, 2016. Drinking water quality assessment and its effects on residents health in Wondo Genet Campus, Ethiopia. Environ. Syst. Res., Vol. 5. 10.1186/s40068-016-0053-6.
14. Léziart, T., P.M.D. de la Rochere, R. Cheswick, P. Jarvis and A. Nocker, 2019. Effect of turbidity on water disinfection by chlorination with the emphasis on humic acids and chalk. Environ. Technol., 40: 1734-1743.
15. Farrell, C., F. Hassard, B. Jefferson, T. Leziart, A. Nocker and P. Jarvis, 2018. Turbidity composition and the relationship with microbial attachment and UV inactivation efficacy. Sci. Total Environ., 624: 638-647.
16. Mohammadpour, A., E. Gharehchahi, M.A. Gharaghani, E. Shahsavani and M. Golaki *et al*., 2024. Assessment of drinking water quality and identifying pollution sources in a chromite mining region. J. Hazard. Mater., Vol. 480. 10.1016/j.jhazmat.2024.136050.
17. Arhin, E., J.D. Osei, P.A. Anima, P. Damoah-Afari and L.L. Yevugah, 2023. The pH of drinking water and its human health implications: A case of surrounding communities in the Dormaa Central Municipality of Ghana. J. Healthcare Treat. Dev., 4: 15-26.
18. Cormick, G., M. Lombarte, N. Minckas, A. Porta and A. Rigalli *et al*., 2020. Contribution of calcium in drinking water from a South American country to dietary calcium intake. BMC Res. Notes, Vol. 13. 10.1186/s13104-020-05308-7.
19. van Wendel de Joode, B., B. Barbeau, M.F. Bouchard, A.M. Mora and Å. Skytt *et al*., 2016. Manganese concentrations in drinking water from villages near banana plantations with aerial mancozeb spraying in Costa Rica: Results from the infants' environmental health study (ISA). Environ. Pollut., 215: 247-257.
20. Manne, R., M.M.R.M. Kumaradoss, R.S.R. Iska, A. Devarajan and N. Mekala, 2022. Water quality and risk assessment of copper content in drinking water stored in copper container. Appl. Water Sci., Vol. 12. 10.1007/s13201-021-01542-x.
21. Reda, A.H., 2015. Assessment of physicochemical quality of spring water in Arbaminch, Ethiopia. J. Environ. Anal. Chem., Vol. 2. 10.4172/2380-2391.1000157.
22. Abbaspour, N., R. Hurrell and R. Kelishadi, 2014. Review on iron and its importance for human health. J. Res. Med. Sci., 19: 164-174.
23. Tiwari, D. and R. Bajpai, 2012. Assessment of water quality in terms of total hardness and iron of some freshwater resources of kanpur and its suburbs. Nat. Environ. Pollut. Technol., 11: 235-238.
24. Shar, A.H., Y.F. Kazi, M. Zardari and I.H. Soomro, 2007. Enumeration of total and faecal coliform bacteria in drinking water of Khairpur City, Sindh, Pakistan. Bangladesh J. Microbiol., 24: 163-165.
25. Kassegne, A.B. and S. Leta, 2020. Assessment of physicochemical and bacteriological water quality of drinking water in Ankober District, Amhara Region, Ethiopia. Cogent Environ. Sci., Vol. 6. 10.1080/23311843.2020.1791461.
26. Khan, T.A., 2011. Trace elements in the drinking water and their possible health effects in Aligarh City, India. J. Water Resour. Prot., 3: 522-530.