SINET: Ethiop. J. Sci., 46(3): 271-282, 2023 ISSN: 0379–2897 (PRINT)

eISSN: 2520–7997

Date received: 12 July 2023; Date revised: 19 February 2024; Date accepted: 25 February 2024
DOI: https://dx.doi.org/10.4314/sinet.v46i3.4

Assessment of Drinking Water Quality from Source to Household Storage Containers in Kachisi town, West Shewa, Ethiopia

Gazahagn Kebache[1], Alemayehu Negassa[1], Dagim Jirata[2*]

[1] Department of Biology, College of Natural and Computational Sciences, Ambo University, Ambo, Ethiopia.

[2] Department of Microbial, Cellular and Molecular Biology, College of Natural and Computational Sciences, Addis Ababa University, Addis Ababa, Ethiopia. E-mail : dagimj@yahoo.com

ABSTRACT: A wide range of human and natural processes affect the quality of fresh waters and diseases related to contamination of drinking water constitute a major burden on human health. Thus, this study was conducted to assess the quality of drinking water supplied to Kachisi town using selected physicochemical and bacteriological parameters. A total of 60 water samples in triplicate were collected from boreholes, water reservoirs, household taps and storage containers in the households between October, 2019 and February, 2020. The physiochemical parameters were measured using HACH HQ440d multi meter and portable digital spectrophotometer (DR/6000) according to HACH instruction and bacteriological parameters were analyzed using the membrane filtration technique. The study results indicated that temperature and pH of the water samples were in the range of 18.77 ^{0}C and 21.4 ^{0}C, and 7.05 and 7.73, respectively. Total dissolved solids fell between 93 mg/l and116 mg/l while electrical conductivity records ranged between 185µS/cm and 232 µS/cm. The concentrations of Iron, nitrate and phosphate were in the range between 0.01-0.26 mg/l, 2.20-5.72 mg/l and 0.12-0.76 mg/l, respectively. Total Coliforms loadalso varied from 1CFU/100ml to 2CFU/100ml in samples collected from boreholes and reservoirs, from 1CFU/100ml to 12CFU/100ml in tap water samples and from 6CFU/100ml to 22CFU/100ml in samples from storage containers in the households. Fecal Coliform was negative in the water samples collected from boreholes, reservoirs and household taps while it was detected in 25% of the samples collected from household storage containers in the rangeof 3CFU/100ml to 5CFU/100ml. The detection of Total Coliforms in all water samples and Faecal Coliforms in some of the household containers samples might be attributed to absence of disinfection, lack of regular supervision of the system, poor water management and lack of safe water storage and handling practices.

Keywords: Coliforms, Ethiopia, Kachisi town, physicochemical parameters, water quality

INTRODUCTION

Safe drinking water and basic sanitation is basic need and right for every human being (Gundry *et al.*, 2006).Though, safe water is a precondition for health and development and it is still inaccessible to hundreds of millions of people in the developing world (UNICEF, 2008). Access to water and sanitation is essential in breaking the cycle of poverty since it improves public health, capacity towork, and school attendance (CAWST, 2009). Drinking water must be free from organisms that are capable of causing diseases and from minerals and organic substances that could have adverse physiological effects (WHO, 2006). Research results also indicate that drinking water should be aesthetically acceptable; free from apparent turbidity, color, and odor and from any objectionable taste (Temsgen Eliku.and Hameed, 2015), and should also have a reasonable temperature. Water that meets these requirements is considered potable water. Potable water is safe to drink, pleasant to taste, and can be used for domestic purposes (Chatterjee, 1998).According to WHO (2011a), more than 80% of human diseases worldwide are caused by unsafe water supply and inadequate sanitation practices. Furthermore, more than 88% of global diarrheal diseases are water-borne infections resulting from the consumption of unsafe and contaminated water (Gundry *et al.*, 2006).

Research findings identified that, every year, more people die from the consequences of unsafe water than from all forms of violence, including war (BirhanuFurgassa, 2016). Water drawn from protected sources may be contaminated by the time it is consumed in households (UNICEF, 2008). Chemical contamination of water supplies, both naturally occurring and from pollution is a very serious problem that threatens the health of people. However, even more serious is the microbiological contamination of drinking water supplies, especially from human faeces and

*Author to whom correspondence should be addressed.

animal waste. Faecal contamination of drinking water is a major cause of diarrheal disease, which claims millions of children every year (MoH, 2011). WHO (2011b) states that, approximately 3.7% of deaths and disability-adjusted-life-years worldwide are attributed to unsafe water, poor sanitation and inadequate hygiene.

As populations, pollution and environmental degradation increase, so does the chemical and microbiological contamination of water supplies (UNICEF, 2008). Despite global efforts to provide safe drinking water, the transmission of water-borne diseases remains a significant concern. Therefore, drinking water quality is now a matter of global concern for human health, primarily due to contamination by pathogens and potentially toxic chemicals. This study was conducted to assess the quality of Kachisi town drinking water using selected physicochemical and bacteriological parameters.

MATERIALS AND METHODS

Description of the Study Area

The study area, Kachisi town (Fig. 1) is located at $09^{0}36'$N, $037^{0}50'$E and an elevation of 2585 meters above sea level. It is situated in West Shoa Zone 185 Km away from Addis Ababa, the capital of Ethiopia and equipped with various facilities including a hospital, high schools, hotels and private commercial centers. Currently, the town serves as an administrative center for Gindeberat district and growing fast with an estimated total population of 18,680 (11,126 males and 7,554 females)(CSA, 2007).

For drinking water supply, residents of Kachisi town rely on two ground water sources (boreholes), two water reservoirs ($100M^3$ and$75M^3$capacity), 17 public water points (public fountains) and some had access to private household taps. According to the information obtained from the Water Supply Service of the town, 1,620 households had private connections (household taps).

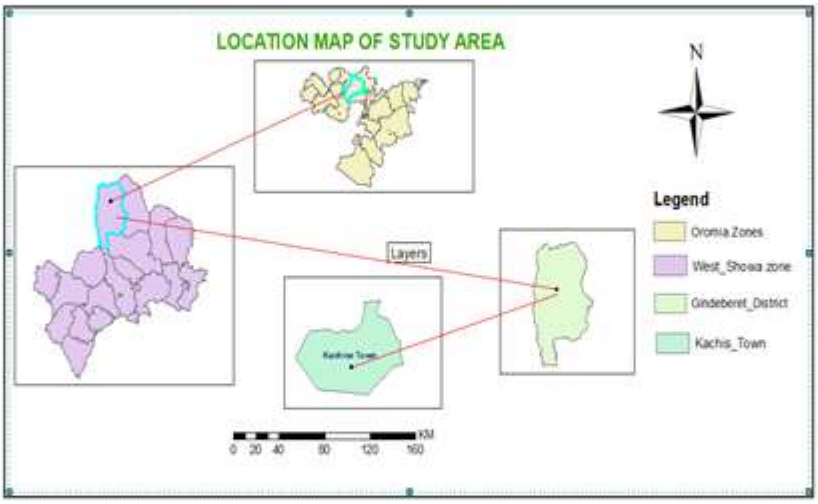

Figure 1. Map of the Study Area.

Research Design

A cross sectional study design was used to assess the physicochemical and bacteriological quality of the drinking water supplied to Kachisi town and the study was conducted from October, 2019 to February, 2020.Water samples (n=20)were collected from the water source (Boreholes, n=2), water reservoirs (n=2), household water taps (n=8) and household storage containers (n=8). The number of water samples collected from household taps/household storage containers was decided based on WHO (2011) and ESA (2013) guideline for drinking water quality and the parameters were measured in triplicate.

Sampling Procedures and Techniques

Sampling containers were cleaned according to the guidelines provided by APHA (1999). Polyethylene bottles were washed thoroughly with tap water and detergent, except for those washed with chromic acidfor phosphate analysis. The bottles were rinsed with distilled water and soaked in 10% (v/v) HNO_3 for approximately 24 hours. They were further rinsed with distilled water, air dried and stored with caps on to prevent contamination. The containers were rinsed with sample water prior to sample collection.

Samples were collected from the sources, reservoirs, household taps and household containers, and systematic random sampling was employed to determine the representative sampling points. The water sampleswere collected following the guidelines provided by WHO (2004c) for drinking water quality assessment as well as the guidelines of the American Public Health Association (APHA, 1998).

For physicochemical analysis, samples were collected in 2000ml polyethylene bottles and immediately analyzed on site at each sampling site using portable electro-analytical and spectrophotometer equipment. For bacteriological analysis, 200ml water samples were collected from eachsampling site in pre-sterilized plastic bags and tested on site using portable bacteriological analysis equipment (ELE Paqualab 25).

Physicochemical Analysis

All glassware used for analysis were cleaned before and after use with detergent, rinsed with distilled water, soaked in 10% (v/v) nitric acid, re-rinsed with distilled water and allowed to fully air dry to ensure decontamination. Onsite measurements were used for temperature, pH, EC, and total dissolved solids (TDS) determination.

Temperature and pH of each water samples were measured at the sampling points by using portable pH meter. The pH meter was calibrated with standard buffer solutions of pH-4 and pH-10 prior to pH measurement according to operational manual of the manufacturer. The meter connects with smart probe that automatically recognize the testing parameter, calibration history, and method settings to minimize errors and setup time.Theprobe of the instrument was immersed in the sample of the water to be tested and the measured parameters were displayed on the LCD screen of the instrument. Portable digital conductivity meterwas used to measure EC and total dissolved solids of the water samples by immersing the electrode of the meter into the samples to be tested. The instrument was calibrated with 1400ppm NaCl and 1000ppm KCl for EC and TDS measurements as per the instruction manual. With regard to turbidity, the measurements of the samples were performed by using portable micro-processor turbidity meter after calibrating with standard solutions as per the procedure stated on the instruction manual. Chemical parameters such as phosphate (PO_4^{3-}), nitrate (NO_3^-), and total iron were tested at the study area using portable digital spectrophotometer (DR/6000) following the instructions provided by HACH (2004). To analyze the parameters, the appropriate reagent chemicals were dissolved in 10 ml of water sample in a cylindrical cell and allowed to react. The color developed with intensity proportional to the amount of the target parameter to be measured. The spectrophotometer was adjusted to the unique maximum absorption wave length of each parameter. Light was allowed to pass through the sample cell where it was absorbed at the required wave-length. The results were displayed on the LCD screen as mg/l of the parameter under analysis, proportional to the amount of light absorbed at that particular wave-length.

Bacteriological Analysis

The samples were analyzed using membrane filtration (MF) method to determine the presence of total coliforms (TC) and fecal Coliforms (FC/*E. Coli*), which indicate the extent of contamination (APHA, 1998; WHO, 2006). Each test involved Filtering 100 milliliters (100ml) of watersample through a sterile cellulose membrane filter (0.45μm) to retain the indicator bacteria as specified in standard methods (APHA, 1998).

The filtration apparatus was sterilized before use and re-sterilized between samples using methanol when analyzing water samples (OXFAM, 2004). The cellulose membrane filter was then aseptically transferred from filtration apparatus to sterilized aluminum petri-dish containing absorbent pad soaked with m-Coli Blue24 Broth.This medium is used to grow total coliforms (TC) and fecal coliforms (FC) and eliminates measuring, mixing, and autoclaving dehydrated media. Hach's m-ColiBlue24 Broth media helps to simultaneously detect and identify both total coliforms and FC/*E. coli.*

Next, the petri-dishes were incubated in an ELE Paqualab 25 field incubator at temperature of 37^0C and 44^0C for the growth of total coliforms and FC/*E. Coli,*respectively for period of 24 hours. After 24 hours, the filters were examined to count the colonies that had grown, which determined the presence of TC and FC in the samples.

RESULTS

Physicochemical quality of the water from boreholes and reservoirs

The water temperature recorded at the sampling points in boreholes and reservoirs (Table 1) exceeded the recommended limit of 15^0C set by World Health Organization (WHO, 1996; WHO, 2011). The pH measurements from all four sampling points (Table 1) indicated that the water is slightly basic and the values fell within the acceptable range of 6.5 – 8.5 set by the WHO and National standard (WHO, 2011; ESA, 2013). Turbidity level in the water samples (Table 1) were found to meet the standards set by WHO (2011) and ESA (2013), which stipulate that it should be less than 5NTU. Therefore, the water is aesthetically acceptable to consumers. The TDS and EC values showed a consistent pattern across the sampling sites (Table 1) and were significantly different ($p<0.05$) among the sampling points. The TDS values ranged from 98-109 mg/l which are lower than those recorded from water sources inBishoftu town (332.4-363.4 mg/l) (DestaKassa, 2009) but higher than records from Ghimbi town surface water sources (42.6-51.6 mg/l) (GurmessaOljira, 2015). The results of thisstudy align with the WHO (2011) limit of<600 mg/l and the National maximum permissible level of 1000mg/l (ESA, 2013). Nitrate concentrations in this study (Table 1) were far much lower than the maximum permissible limits of 50mg/lset by the WHO (2011) and ESA (2013). The average phosphate value recorded was 0.68 mg/l and there was no significant difference among the mean values of the sampling points ($p>0.05$).

Bacteriological Quality

The bacteriological results of the water samples from the boreholes and reservoirs revealed that all samples (100%) tested positive for total coliform counts ranging from 1.00 CFU/100ml (boreholes) to 2 CFU/100ml (reservoirs) with statistically significant difference among the mean values of the sampling points ($p<0.05$). Total coliform counts showed positive correlation with turbidity ($r=0.06$) and nitrate ($r=0.21$). No faecal coliform was detected in anyof the water samples from boreholes and reservoirs (Table1).

Table 1. Physicochemical and bacteriological characteristics of water samples from boreholes and reservoirs

Parameter	BH-1	BH-2	WR-1	WR-2	P-value	WHO Limit	National Standard
Temp (^{0}C)	20.60±0.03	20.93±0.07	19.57±0.03	20.70±0.06	0.000*	<15	
pH	7.36±0.03	7.15±0.01	7.64±0.02	7.71±0.02	0.000*	6.5-8.5	6.5-8.5
Turbidity(NTU)	0.00±0.00	0.00±0.00	1.67±0.88	1.67±0.33	0.047*	<5	<5
TDS(mg/l)	103.00±0.83	109.00±0.13	99.00±0.26	98.00±0.13	0.000*	<600	1000
EC(µS/cm)	206.00±1.5	218.23±0.26	198.37±0.52	195.00±0.26	0.000*	-	-
Total Iron(mg/l)	0.22±0.02	0.17±0.00	0.02±0.01	0.14±0.07	0.002*	0.3	0.3
Nitrate(mg/l)	4.25±0.15	3.55±0.69	6.16±0.51	4.69±0.39	0.025*	50	50
Phosphate(mg/l)	0.61±0.15	0.61±0.31	0.59±0.08	0.93±0.29	0.435 *	-	-
TC(CFU/100ml)	1 ±0.00	1±0.00	2±0.15	2±0.15	0.000*	0	0
FC(CFU/100ml)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.000*	0	0

****The mean difference is significant at the 0.05 level***
BH-1, Borehole-1; BH-2, Borehole-2; WR-1, Water Reservoir-1; WR-2, Water Reservoir-2
TC, Total Coliforms; FC, Faecal Coliforms; CFU, Colony Forming Unit

Physicochemical quality of water samples from the tap

The mean temperature of tap water samples ranged between 18.77^{0}C and 20.90^{0}C and found significantly different among the sampling points ($p<0.05$) (Table 2). The measurements of turbidity for the tap water samples showed a minimum record of 1.33NTU at HHT-3, a maximum record of 4.00NTU at HHT-7 and average value of 2.33 NTU. A significant difference was observed between the mean values at HHT-7 and HHT-3 ($p<0.05$). The mean values of the turbidity records in all tap water samples were found to be within the limits of the standards set by WHO (2011) and ESA (2013) which is <5NTU. The TDS values of the samples from tap water fell within the range of 93.07-116.33 mg/l and comparable to the values of the samples from boreholes and reservoirs. Values of EC fell within the range of 186.13-232.67µS/cm and were comparable to average values of the samples from boreholes and reservoirs with significant difference among the mean values of the sampling point ($p<0.05$), respectively. The iron records for the tap water samples of Kachisi town ranged between 0.01 and 0.26 mg/l and the mean values of the sampling points were not significantly different ($p>0.05$) except HHT-5 which was significantly different from all the other samples ($p<0.05$. The nitrate records for the samples from the tap water ranged between 3.08mg/land 5.72 mg/l with average values of 4.22 mg/l and were far less than the WHO and national maximum permissible limits. There was no significant difference between the mean values of the sampling points (p>0.05). The phosphate records for the samples from tap water ranged between 0.23mg/l and 0.66 mg/l and mean values showed significant difference among the sampling points (p<0.05). The average concentrations of phosphate for Kachisi town tap water samples was 0.69 mg/l and comparable to that of source and reservoir water samples.

Bacteriological quality of the tap waters

The bacteriological result of the tap water samples showed that all the water samples (100%) were positive for total coliform counts ranging from 1.00 CFU/100ml (HHT-2) to 12 CFU/100ml (HHT-7) with the average value of 3.75 and statistically significantly different between the mean values of the sampling points (p<0.05). The rest sampling points had mean values of TC that did not show significant difference (p>0.05) and faecal coliforms were not detected in any of the tap water samples.

Table 2.Physicochemical and Bacteriological characteristics of tap water

Parameter	HHT1	HHT2	HHT3	HHT4	HHT5	HHT6	HHT7	HHT8	P-Value
Temp (0C)	20.73±0.03	19.47±0.03	19.93±0.03	19.70±0.10	18.83±0.03	20.27±0.03	20.90±0.06	18.77±0.07	0.002*
PH	7.35±0.03	7.65±0.02	7.62±0.05	7.51±0.06	7.50±0.01	7.20±0.01	7.36±0.01	705±0.02	0.000*
Turbidity (NTU)	1.7±0.33	2.00±0.00	1.33±0.67	1.7±0.33	3.33 ±0.67	1.67 ±0.33	4.00±0.58	3 ±0.58	0.029*
TDS (mg/l)	116.33±0.17	98.25±0.08	94.72±0.08	93.07±0.31	94.98±0.02	93.82±0.11	94.15±0.06	96.87±0.16	0.000*
EC(µS/cm)	232.67±0.33	196.50±0.15	189.43±1.17	186.13±0.62	189.97±0.03	187.63±0.22	188.30±0.12	193.73±0.33	0.000*
Iron (mg/l)	0.01±0.01	0.04±0.01	0.05±0.01	0.05±0.00	0.26±0.112	0.05±0.01	0.05±0.00	0.05±0.02	0.021
Nitrate (mg/l)	4.11±0.15	4.84±0.88	4.84±0.88	4.55±1.31	3.08±0.25	3.81±0.64	5.72±0.67	3.71±0.57	0.685
Phosphate (mg/l)	0.54±0.14	0.38±0.01	0.23±0.03	0.66±0.27	0.27±0.03	0.26±0.03	0.39±0.07	0.32±0.08	0.020
TC(CFU/100ml)	2.00±1.15	1.00±0.00	2.00±1.00	5.00±1.73	3.00±2.00	2.00±0.58	12.00±2.00	4.00±01.15	0.001*
FC(CFU/100ml)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.000*

The mean difference is significant at the 0.05 level; HHT-Household Taps

Physicochemical quality of water from household storage containers

The average temperature records of the household containers water samples was 19.96^{0}C which is comparable to the average temperature of tap water samples 19.83^{o}C. The mean temperature of the water from household storage containers varied significantly among the different sampling points (p<0.05). The pH values for the samples from household containers ranged 7.12 to 7.73 with average value of 7.43. The mean pH values also showed significant variation among the sampling points (<0.05). The turbidity results for the household container water samples ranged from 1.00 and 3.7 NTU with statistically significant difference in the mean values among the sampling points (p<0.05). The results were within the permissible limits set by WHO and Ethiopian compulsory limit of <5NTU (WHO, 2011; ESA, 2013).

The TDS (Total Dissolved Solid) values for the household storage container water samples ranged from 93 to 103mg/l with statistically significant difference in mean values among the sampling points (p<0.05). The EC (Electrical conductivity) values for the water from household storage container ranged between 185 to 210µS/cm which were comparable to the EC values of the tap water samples (186.2 – 232.7). The mean EC values also showed significant variation among the sampling points (p<0.05). The iron concentration in the household storage container water samples ranged from 0.01 to 0.09 mg/l, with an average value of 0.06 mg/l. There was statistically significant difference in mean values of the sampling points (p<0.05). The maximum iron in HHC-3 was significantly different from the mean values of all the other sampling points (p<0.05). The nitrate concentration in the household storage container samples ranged from 2.2 mg/l to 4.4 mg/l with average value of 3.37 mg/l. There was no statistically significant difference in mean values among the sampling points (p>0.05). Phosphate concentrations ranged from 0.12 to 0.38 mg/l, with statistically significant difference in mean values among the sampling points (p<0.05). These concentrations were comparable to those found in tap water, reservoirs and boreholes samples.

Bacteriological Qualityof water samples from household storage containers

All samples from household storage containers tested positive for Total Coliforms (TC) with a count ranging from 6CFU/100ml to 22 CFU/100ml, and average value of 13.54. There was statistically significant difference mean values among the sampling points ($p<0.05$).

A positive correlation was observed between temperature and TC (r=0.38). Similarly, a positive correlation was also found between temperature and Fecal Coliforms (FC) in the household container water samples (r=0.09).

Table 3: Physicochemical characteristics of the water from household Containers

Parameter	HHC1	HHC2	HHC3	HHC4	HHC5	HHC6	HHC7	HHC8	P-Value
Temp (0C)	19.6±0.03	19.4±0.33	19.8±0.09	19.7±0.33	19±0.23	20.1±0.54	20.3±0.09	21.4±0.0.29	0.000
PH	7.73±0.01	7.64±0.03	7.39±0.01	7.36±0.01	7.42±0.02	7.12±0.14	7.22±0.00	7.03±0.09	0.000
Turbidity (NTU)	1.00±0.00	3.7±0.3	3.7±0.3	3.3±0.3	1.3±0.3	2.00±0.00	2.00±0.00	1.3±0.00	0.000
TDS (mg/l)	1001±0.53	103.±0.03	95±0.00	93±0.08	93±0.01	94±0.03	94±0.00	98±0.02	0.000
EC (μS/cm)	210.0±1.1	206.9±0.1	190.1±0.0	185.2±0.2	185.0±2.0	187.4±0.1	188.4±0.0	196.5±0.0	0.000
Total Iron (mg/l)	0.03±0.01	0.01±0.01	0.12±0.01	0.06±0.01	0.05±0.00	0.04±0.01	0.09±0.01	0.05±0.01	0.000
Nitrate (mg/l)	3.67±0.15	3.52±0.76	3.52±0.67	3.67±0.59	4.40±1.17	2.20±0.44	2.79±0.39	3.23±0.39	0.431
Phosphate (mg/l)	0.32±0.07	0.37±0.03	0.20±0.03	0.38±0.02	0.25±0.04	0.12±0.04	0.32±0.08	0.14±0.03	0.000
TC(CFU/ 100ml)	19.00±1.15	6.00±0.58	10.00±1.00	8.00±1.15	12.00±1.73	14.00±1.76	22.00±1.15	17.00±2.08	0.000*
FC(CFU/ 100ml)	0.00±0.00	0.00±0.00	0.00±0.00	3.00±0.58	0.00±0.00	0.00±0.00	5..00±1.16	0.00±0.00	0.001*

The mean difference is significant at the* ***0.05* *level; HHC-household container*

Table 4. Trends of selected parameters across the water supply

Sampling Point	Parameter					
	Temperature (^{0}C)	Turbidity (NTU)	Iron (mg/L)	Nitrate (mg/L)	TC (CFU/100ml)	FC (CFU/100ml)
BH	20.77	0	0.2	3.9	1	0
WR	20.13	1.67	0.08	5.43	2	0
HHT	19.83	2.33	0.07	4.22	3.75	0
HHC	19.96	2.29	0.06	3.37	13.54	1

DISCUSSION

Physicochemical quality of Boreholes and Reservoirs waters

The high temperature values inKachisi town can be attributed to its elevation, which falls within the range of 2,470m-2,562 ma.s.l. and is approaching the upper elevation limit of the warm semi-arid climatic zone of the country. The pH value (7.4) of the water sources in Kachisi town is comparable to the pH value of Akaki-Kality sub - city (7.6) (MengstayehuBirhanu, 2007) and slightly lower than that of Ziway town (8.3) (KassahunBedane, 2008) and Woliso town (8.22) (BirhanuFurgassa, 2016). The absence of turbidity in the water from boreholes suggests that there are no inert clay or chack particles present and that the wells are well protected from foreign materials and surface runoffs. Ground waters are typically clear due to the filtration by slow movement and infiltration of the rain water through the soil and rock formations (UNESCO, 2004). The slightly higher turbidity in the water from the reservoirs compared to that from the boreholes could be attributed to the presence of suspended, colloidal and silt materials, possibly due to lack of timely and regular cleaning and washing of the water reservoirs. The average turbidity records of this study were lower than the turbidity records of 2.35NTU inBishoftu water sources (DestaKassa, 2009) and 1.62 NTU inWoliso water sources (BirhanuFurgassa, 2016).

Both TDS and EC values showed a similar pattern across the sampling sites (Table 1) which may be due to the type of rock through which the water infiltrates. The EC range in the current study (195-218μS/cm) was lower than that ofBishoftu town water sources (511.3-559.0 μS/cm) and higher than that ofGhimbi town surface water source (85.6-103.3 μS/cm) (GurmessaOljira, 2015). The variations in TDS and EC among different location could be attributed to the degree of weathering and dissociation of underground rocks that are influenced by various climatological and geological factors (TamiruAlemayehu, 2000). According to WHO (2011), the water with a total dissolved solids (TDS) level of less than 600 mg/l is generally considered palatable, and drinking-water becomes significantly unpalatable at TDS levels greater than about 1000 mg/l. Therefore, the TDS and EC values of the samples from the boreholes and reservoirs indicate that the water is suitable for drinking.

The iron concentrations in the water samples collected from boreholes and reservoirs were significantly below the limits set by the WHO (2011), the National maximum permissible limit (ESA, 2013), and records from Ghimbi town surface water sources (0.6-2.5 mg/l) (GurmessaOljira, 2015). The drinking water sources for Kachisi town, which are the water wells, have a designated ground water protection area that is safeguarded by the Town Water Supply Office.This prevents any human and animal interference and restricts agricultural activity in the area of ground water wells. The nitrate records were also much lower than the maximum values of 10.8mg/l and 12.9mg/l from source waters of Ziway town (KassahunBedane, 2008), and Bahr Dar town (GetnetKassahun, 2008), respectively. The potential pollution of the water wells by nitrate from agricultural activity, waste water disposal, human and animal excreta (including septic tank) was greatly reduced by the buffer zone that was well protected. The range records of this study slightly exceeded the phosphate records (0.2-0.4 mg/l) from water sources inBishoftu town (DestaKassa, 2009), but were lower than the records from surface water sources inGhimbi town (GurmessaOljira, 2015).

Bacteriological Quality

The presence of total coliform (TC) in the water samples (Table 1) may be attributed to lack of chlorination in both the wells and reservoirs. The water supply system did not use any type of disinfectant. Additionally, TCs could have resulted from re-growth and possible bio-film formation or contamination from foreign material such as soil or plants (WHO, 2006). This contamination often occurs during maintenance activities when immediate well disinfection is not carried out The relatively higher numbers of TCs in the reservoirs water samples compared to boreholes water samples could be due to the lack of regular cleaning and disinfection of the reservoirs. It is important to note that the absence of fecal coliforms (FCs) in the water samples indicates that the detected TCs were environmental species. Unlike TC, FC results comply with the WHO and national standards of 0CFU/100ml (WHO, 2011; ESA, 2013). The range of TCs in the tested water samples (1-2 CFU/100ml) was lower than the records from Bishoftu town water sources (1-4 CFU/100ml) (DestaKassa, 2009). The absence of FC in the water samples confirmed that both the wells and reservoirs arefree from coliforms that originating from faecal matter, makings the water microbiologically acceptable according to WHO and ESA guidelines. According to WHO (1997), if water sample does not contain any FCs/*E. Coli* count, it is in conformity with WHO guideline. According to ESA (2013), FCs/*E. Coli* should not be detectable per 100ml of water sample tested. WHO (1997) also states that community water supplies are not chlorinated like that of Kachisi town, will inevitably contain large numbers of total coliform bacteria, which may have limited sanitary significance. Microorganisms such as bacteria and protozoa are typically attached to particulates (WHO, 2011), which could explain the positive correlation between TC and turbidity. The positive correlation between TC and pH (r=0.38) may be due to the fact that coliforms survive better in alkaline environment than in acidic one (ICTCRED, 2014). The correlation matrix showed strong positive correlation between EC and TDS (r=1.00).

Physicochemical qualityof tap water samples

The significant difference in the mean temperature of tap water may be due to the variation in elevation and the level of protection from sunlight that the water pipes have. It is worth nothing that the temperature records of the tap water in this study exceeded the WHO (2011) permissible limit of $<15^0$C which negatively affects the taste of the water. High water temperature enhances the growth of microorganisms leading to issues with taste, odour, color and corrosion (WHO, 2011). The average temperature of tap water samples in this research was lower than that of tap water samples of Bishoftu town (22.7^0C) (DestaKassa, 2009) and Woliso town (21.75^0C) (BirhanuFurgassa, 2016). Additionally, the average temperature of tap water was slightly lower than that of water samples from boreholes and reservoirs (Table 1). The pH measurements of the tap water fell within the range of 7.05-7.65 and mean values varied significantly among the sampling points ($p<0.05$) (Table 2). The average pH of the tap water samples was similar to that of boreholes and reservoir water samples. The pH range observed in this research is slightly higher than that for tap water samples from Bishoftu town (6.9-7.4) (DestaKassa, 2009), but lower than that of Woliso town (8.24) (BirhanuFurgassa, 2016). The results fall within the acceptable range set by the WHO and National standard limit of (6.5-8.5). The low turbidity level in the water usually enhances its aesthetic value. However, the turbidity records for the tap water samples were higher than those of the boreholes (0NTU for both boreholes) and most of the tap water samples had slightly higher turbidity records than the samples from reservoirs (1.67 NTU for both reservoirs). According to WHO (2011), disturbance in sediments and biofilms as well as the ingress of dirty materials from outside the system, can cause turbidity distribution systems. Therefore, the slight increase in turbidity from reservoirs to tap water suggests a potential ingress of foreign materials such as soil particles into the distribution networks as pipes aget and fittings become looser. Particularly, the relatively high turbidity records of 2.00 NTU from HHT-2, 3.33 NTU from HHT-5,4.00NTU from HHT-7 and 3.00 NTU from HHT-8 were associated with the older pipelines as these samples were collected from the older pipelines which confirmed that as water pipe gets older the probability for the ingress of foreign matters increases. The average turbidity of the tap water samples in this study was similar to that of tap water samples from Woliso town (BirhanuFurgassa, 2016). Turbidity in this study was lower than the ranges reported for taps water samples from Bishoftu town (0.3NTU-7.6NTU) (DestaKassa, 2009) and Ziway town (0.3 -7.0NTU) (KassahunBedane, 2008),

These findings show that there was no entrance of foreign materials that could affect TDS and EC values in the distribution system. TDS in drinking-water comes from natural sources, sewage, urban runoff and industrial wastewater (WHO, 2011). The TDS and EC values in the present research were below the TDS and EC values of 339-367.7 mg/l and 520-565.7 µS/cm for tap water samples from Bishoftu town (DestaKassa, 2009). The results also align with the WHO (2011) limit of <600 mg/l and the National maximum permissible level of 1000mg/l (ESA, 2013).

All tap water samples had iron concentrations below maximum permissible limit of 0.3 mg/l set by WHO (2011) and ESA (2013). The exceptionally highiron concentration in HHT-5 could be attributed to pipelines corrosion, as pipe line for HHT-5 was older, potentially increasing corrosion and exposing the iron parts of the pipe. This dissolved iron then enters the water, leading to increased concentration. However, the iron records for tap water samples in this study were lower than those for tap water samples fromWoliso (0.16 mg/l) (BirhanuFurgassa, 2016) and Gimbi (0.6-2.5mg/l) (GurmessaOljira, 2015) towns.

The Household taps (HHT-2 and HHT-7) were connected to the old pipelines of the town's water supply system which might be the major cause of relative water contamination with nitrate. When pipeline gets older, the fittings become loose allowing the entrance of foreign materials that contribute to increase in nitrate concentration. The average nitrate level in the tap water samples for Kachisi town was lower than that of Bishoftu town (7.05 mg/l) (DestaKassa, 2009) and Bahir Dar town (19.5 mg/l) (GetnetKassahun, 2008) tap water samples. All the samples met WHO and national standards, similar to the tap water samples from Adama town (TemesgenElikuand Hameed, 2015).

The average phosphate level in the tap water samples for Kachisi town exceeded the European community (1980) proposed guideline value of 0.4mg/l. The present result slightly exceeded the 0.22-0.48 mg/l levels for tap water samples of Bishoftu town (DestaKassa, 2009) but lower than values for Bahir Dar town (0.1-5.5 mg/l) (GetnetKassahun, 2008).

Bacteriological Quality of tap water samples

Although the results for total coliforms did not comply with WHO and National standard limit, the absence of fecal coliforms in the tap water samples indicates no fecal contamination. The level of total coliforms did not conform to the WHO and National standard which require the absence of coliforms in 100ml of water sample (WHO, 2011; ESA, 2013). The increasing level of contamination from source to distribution system may be attributed to the age of pipelines as older pipes have less tight fittings allowing the ingress of foreign materials. This is supported by the total coliform count record of 12 CFU/100ml from HHT-7 as this tap water line was one of the lines connected to older distribution mains.

According to WHO (1997), bacteriological water quality evaluation should be based on thermotolerant (faecal) coliform bacteria or *E. coli* rather than on total coliform count. Thus, the tap water sample from this study satisfied the requirements of WHO (2011) and compulsory Ethiopian standard (ESA, 2013) as 100% of the samples were free from fecal coliform/*E-coli*. The results of total coliform count in the tap water samples for Kachisi town were found to be lower than the count for Bishoftu town (1CFU/100ml-108 CFU/100ml) (DestaKassa, 2009), and the average value was also slightly lower than that for Woliso town (3.85) (BirhanuFurgassa, 2016). The results of the current study showed zero fecal coliform count for all tap water samples indicating that the water supply inKachisi town is of high microbiological quality compared to tap water samples of Bishoftu town, where 86% of the samples tested positive for fecal coliforms (DestaKassa, 2009), Woliso town tap water samples, where the average fecal coliform count was 3.52 (BirhanuFurgassa, 2016) and Adama town tap water samples, where only 82.7% of the samples were negative for fecal coliforms (TemesgenElikuand Hameed, 2015).

However, it is crucial to address the presence of TC in the water samples by taking urgent corrective measures. This is because the presence of total coliforms in distribution systems and stored water supplies can indicate the possibility of re-growth and potential formation of biofilm or contamination due to the entry of foreign substances such as soil or plants along the line that extends from the reservoirs to individual household taps (WHO, 2006).

Physicochemical Quality of the water from household containers

The temperature records of the samples from household containers exceeded the WHO (2011) permissible limit of <15°C which might enhance bacterial growth and associated problems. The difference in pH values among different household containers could be attributed to the storage styles and water handling practices of the households. The pH range was comparable to that of samples from household taps (7.05 to 7.65) and pH records of the samples from household containers were within the WHO and national standard limits of 6.5-8.5 (WHO, 2011; ESA, 2013).

The difference in turbidity records among household containers could be attributed to differences in degree of exposure of the pipe water to ingress of foreign materials, and water storage and handling practices. The turbidity results of the household containers were lower than those of the tap water samples which might be due to the settling and precipitation of colloidal and suspended materials in the household containers over time. The lower turbidity value recorded at boreholes compared to tap water and household container water sources could be associated with the fact that ground waters are usually clear because the turbidity has been filtered out by slow movement and infiltration of rain water through the soil and rock formations (UNESCO, 2004). Moreover, water wells were delineated and well protected by the Town's Water Supply Service Office. The slight increase in turbidity from reservoirs to house hold containers indicated the possibility of ingress of foreign materials such as soil particles into the distribution network. The status of the pipe lines might have also contributed to the higher turbidity value of tap water samples. As the pipe lines gets older, the fittings become looser and allow the ingress of foreign materials such as soil particles.

TDS values were comparable to those of the samples from tap water (93-116mg/l) and boreholes (103-109 mg/l). According to WHO (2011), water with a total dissolved solids (TDS) level of less than about 600mg/l is generally considered to be good in terms of palatability; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l. Therefore, the TDS and EC values of the samples from the HHCs indicate that the water is generally considered to be good for drinking.

The difference in iron concentrations among HHCs may be related to the corrosion status of the steel pipes that transport the water All the samples records complied withthe maximum permissible limit of 0.3 mg/l set by WHO (2011) and national standard (ESA, 2013). However, the iron levels in the samples from HHCs were relatively lower compared to tap water, boreholes and reservoirs samples. This confirms that when water containing soluble Fe^{2+} is exposed to oxygen, the oxidation process convert it to insoluble Fe^{3+} which precipitates as $Fe(OH)_3$, reducing the detectable iron in the water sample (Mansoor, 2012). The iron concentrations in the samples from BHs exceeded thosein samples from WRs, HHTs and HHCs. This could be because the dominant form of dissolved iron in ground water is soluble Fe^{+2} which iscommonly found within a pH range of 5 to 8. When groundwater is pumped to the surface and exposed to air (O_2), the oxidation process occurs and converts soluble Fe^{2+} to insoluble Fe^{3+} which precipitate as a rusty sediment or $Fe (OH)_3$ thereby reducing the detectable iron in the water sample throughout the water supply system (Mansoor, 2012).

The variation in nitrate levels among different sampling points may be attributed to differences in the pipes exposure to foreign materials, water storage and household handling practices. The nitrate results were comparable to the records of 3.55 to 6.16 mg/l for boreholes and water reservoirs samples, as well as 3.08 to 5.72 mg/l for tap water samples. These results were lower than the WHO and national standard limit. The highest concentration of phosphate was observed in reservoir samples followed by tap water samples across the water distribution system. This may be due to lack of regular reservoirs maintenance.

Bacteriological Quality of the water from household containers

The difference in mean values of TCs from HHC samples may be due to variations in water storage and handling practices at the household level leading to different levels of contamination. The TC counts of samples from household containers (Table 3) exceeded the WHO and National standard limit of 0CFU/100ml. About 25% of the samples from HHCs tested positive for FC, with a count of 3CFU/100ml for HHC-4 and 5CFU/100ml for HHC-7 which did not meet the WHO and national standard of 0CFU/100ml. On the other hand, 75% of the samples from household containers were free from FC and comply with WHO and national standard, despite testing positive for TC (Table 3). There was a statistically significant difference in the mean values ($p<0.05$) among the sampling points indicating variations in water storage and handling practices. The bacteriological analysis of samples from HHCs revealed that the water used for domestic purposes including drinking in the study area was of poor microbiological quality. This contamination could be attributed to inadequate management practices, poor sanitation facilities and lack of disinfection of the water supplied to the town. The water quality deterioration was most severe at the HHCs (point of use) a indicating for poor water management and storage practices at the household level in the study area. The study conducted in Adama town reported that 42.3% of the samples from household containers had TC concentrations and 44.2% had FC concentrations (Temesgen Elikuand Hameed, 2015). Another study conducted in Kolladiba town of Ethiopia found that all water samples from household containers tested positive for total coliforms, while 32.5% were contaminated with fecal coliforms (Sharma *et al*., 2013). These finding indicate that water handling and storage practices are very poor in various towns and rural areas of Ethiopia ,resulting in contamination of drinking water at the point of use in HHCs. Additionally, the study conducted in South Africa and Zimbabwe by Gundry *et al*. (2006)indicated that over 40% of the households using improved water sources had unsafe water samples at the point of use, implying that water contamination at the point of use is a serious issue in other African countries as well. The positive correlation between temperature and coliforms suggests that high water temperature enhances the growth of indicator organisms (WHO, 2011). Microorganisms are typically attached to particulates (WHO, 2011) which may explain the positive correlations between FC/TC and turbidity. The overall bacteriological analysis revealed a progressive deterioration in water quality from source to reservoirs and then to tap water and household containers.

CONCLUSIONS AND RECOMMENDATION

The physicochemical parameters including pH, turbidity, TDS, EC, iron and nitrate were determined in samples collected from boreholes, water reservoirs, household taps and household storage containers along Kachisi town drinking water distribution system. These parameters were found to be in compliance with the WHO and National drinking water standards. However, the temperature recorded in all of the water samples exceeded the WHO limit of <15 ˚C. This may be due to the climatic condition in the area and could potentially promote the growth of microorganisms and associated problems. Total coliform count increased from source to the household containers indicating increased degree of contamination. All the samples were negative for fecal coliform test, except for 25% of the samples from household containers. The presence of total coliforms in all water samples and fecal coliforms in some of the household storage containers may be attributed to factors such as lack of water disinfection, inadequate supervision of the system, poor management practices, and unsafe water storage and handling practices.

To ensure that the drinking water in the town is safe, it is recommended to regularly assess the quality of the water based on basic physicochemical and bacteriological parameters. Measures such as periodic borehole rehabilitation, cleaning of the reservoirs, regular disinfection of the water distribution networks, and frequent supervision of the water supply system, especially the pipelines, should be implemented to address the problem of contamination. It is also recommended to raise awareness among the public regarding safe storage and handling practices of drinking water at household level, as well as promoting environmental sanitation and hygiene practices to prevent related issues.

REFERENCES

1. American Public Health Association (APHA) (1998).Standard Methods for the Examination of Water and Wastewater, 20th ed. American Public Health Association. Washington DC: American Public Health Association,

American water Works association, Water Environment Federation.

2. American Water Works Association (AWWA) (2000).National Water Quality Assessment Progrmme. U.S. Geological Survey of Ground Water and Drinking Water

3. Atnafu, M. (2006).Assessment of bacteriological quality of drinking water supply at the sources and point-of–use at home in Worebabo District, South Wollo.M.Sc Thesis, Addis Ababa University, Addis Ababa.

4. Birhanu Furgassa (2016).Physicochemical and microbial quality of drinking water in WolisoTown, South West Shoa Zone, Oromia, Ethiopia.MSc Thesis, Haramaya University.

5. Brian, O. (2002). Water Testing Bacteria, Coliforms Nuisance Bacteria, Viruses, and Pathogens in Drinking Water.Center for Environmental Quality, Environmental Engineering and Earth Sciences.Wilkes University.

6. DestaKassa (2009).Physico- chemical and bacteriological quality assessment of drinking water from source to household distribution point in Debrezeit town, Ethiopia.M.Sc Thesis, Addis Ababa University, Addis Ababa.

7. Ethiopian Standards Agency (ESA) (2013). Compulsory Ethiopian Standard.Drinking Water Specifications. First Edition, ICS: 13.060.20

8. Genet Gedamu and DestaHaftu (2017).Bacteriological quality of drinking water from source to point of use among rural communities of FartaWoreda in North West, Ethiopia. African Journal of Microbiology Research, 11(26): 1069-1074

9. Getnet Kassahun (2008).Physicochemical and bacteriological drinking water quality assessment of Bahir Dar town water supply from source to yard connection (North-Western Ethiopia).M.Sc Thesis, Addis Ababa University, Addis Ababa.

10. Gundry SW, Wright JA, Conroy R, Du Preez M, Genthe B, Moyo S, Mutisi C, Potgieter N. (2006). Contamination of drinking water between source and point of use in rural households of South Africa and Zimbabwe: Implications for monitoring the Millennium Development Goal for water. *J.Water Pract.Technol*,1(2): 1-9.

11. Gurmessa Oljira(2015). Investigation of drinking water quality from source to point of distribution: the case of Gimbi town in Oromia regional state of Ethiopia.M.Sc Thesis, Addis Ababa University, Addis Ababa.

12. HACH Company (2004). Hach Model DR/2400 Portable Spectrophotometer, USA.

13. HACH Company (2017). HQ440d User Manual. 4th Edition, Hach Lange GmbH.

14. ICTCRED (2014).The influence of PH characteristics on the occurrence of coliform bacteris in Madura Strait.International Conference on Tropical and Coastal Region Eco-Development.Elsevier B.V.

15. Jitendra, S., Agrawal, D.K. and Shradha, P. (2008). Seasonal Variations in Different Physico-Chemical Characteristics of Yamuna River Water Quality in Proposed Lakhwar hydropower project influence Area. Research India Publications, *International Journal of Applied Environmental Sciences*, ISSN 0973-6077 3 (1):107–117.

16. Kassahun Bedane. (2008). Assessment of Physicochemical and bacteriological quality of drinking water in the central Rift valley System, Ziway Town, Oromia Region, Ethiopia. M.Sc Thesis, Addis Ababa University, Addis Ababa.

17. Mebratu Jano (2007).Assessment of Physicochemical and microbiological quality of rural drinking water supply at the source in MengeWoreda, BenshangulGumuz Regional State, Ethiopia. MSc Thesis. Addis Ababa University, Addis Ababa, Ethiopia.

18. Mengstayehu Birhanu (2007).Assessment of Physicochemical and microbiological quality of rural drinking water supply at the sources and selected communities of Akaki-Kality Sub-City, Addis Ababa City Administration.M.Sc Thesis, Addis Ababa University, Addis Ababa.

19. Ministry of water Resources/Federal Democratic Republic of Ethiopia (MoWR/FDRE) (2007).*Ethiopian Water Resources Management Policy*.Ministry of Water Resources, Addis Ababa, Ethiopia.

20. National Planning Commission/Federal Democratic Republic of Ethiopia (NPC/FDRE) (2016).*Growth and Transformation Plan (GTP) II of FDRE, Volume I*: Main Text. National Planning Commission, Addis Ababa, Ethiopia.

21. Olson, E. (2003). Grading drinking water in U.S cities what's on Tap? Pp. 38-42 .Natural Resource Defense Counsel, New York City, and Washington, D.C., Los Angeles, and San Francisco.

22. OXFAM (2004). Oxfam-Delagua Portable Water Test Kit.User Manualp-24. Robens.

23. Oyem, H.H., Oyem, I.M., and Ezeweali, D. (2014).Temperature, PH, Electrical Conductivity, TDS and COD of Groundwater in Boji-BojiAgbor/Owa Area and Immediate Suburbs.*Research Journal of Environmental Sciences*, 8:444-450

24. Sharma HR, Walelegn W, Mohammed H,Yimam T, Mulawshum Z, Destaw K, Adane K. (2013). Water Handling Practices and Level of Contamination between Source and Point-of-Use in Kolladiba Town, Ethiopia.*Environ. We Int. J. Sci. Technol*. 8:25-35.

25. Tamiru A. (2000). Water Pollution by Natural Inorganic Chemicals in the Central Part of the Main Ethiopian Rift.Department of Geology and Geophysics AAU. Addis Ababa, Ethiopia.

26. Temsgen E. and Hameed S. (2015). Assessment of Physicochemical and bacteriological quality of drinking water at sources and household in Adamatown,Oromiya Regional State,Ethiopia. *African Journal of Environmental Science and Technology*, 9(5):413-419.

27. United States Environmental Protection Agency (USEPA) (1986). Safe Drinking Water Act: 1986 Amendments: Washington DC: EPA 570/9-86-002.

28. World Health Organization (WHO) (1996). Guidelines for Drinking-Water Quality, 2nd ed, Vol.2. Health Criteria and Other Supporting Information. International Program on chemical Safety. World Health Organizations, Switzerland, Geneva.

29. World Health Organization (WHO) (2003).Guidelines for drinking water quality, Vol.3. World Health Organizations, Switzerland, Geneva

30. World Health Organization (WHO) (2004b).Guidelines for drinking water quality. Third Edition, Vol.1: Recommendation. World Health Organization, Geneva.

31. World Health Organization (WHO) (2011b). Cause specific mortality, regional estimates for 2008. Geneva, World Health Organization.