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Assessment of Physico-Chemical and Bacteriological Quality of Drinking Water at the Source, Storage, Point-of-Use, Dry and Wet Season in Damot Sore Woreda, Southern Regional State, Ethiopia

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Abstract: Source to in-house and seasonal contamination of drinking-water quality is a persistent problem in developing countries. This study was conducted in Damot Sore Woreda, Southern Ethiopia to examine physico chemical and bacteriological quality of drinking water. For this study, four Kebele administrations were selected by purposive sampling technique. Location map and water quality sampling point were prepared using Arc GIS 9.2 software. A total of 55 water samples were taken and examined for physico-chemical and bacteriological parameters;11from source,11 from household containers,11 from drinking cup,11 for dry and 11 for wet season. One way ANOVA and correlation was employed to see the statistical difference of the variables at 5% significant level and to observe associations of variables. The result of water quality revealed that average value of all selected physico chemical parameters showed variation from source to storage. But only the value of temperature decrease significantly from supplied source to household storage (p=0.036). However, other parameters showed no significant change from source to storage. Bacteriological parameters showed variation from source to household storage and from storage to point of use. The concentration of total coliform increases significantly from supplied source to point of use (p=0.024). The dry and wet season measurement showed variations in physico-chemical and bacteriological parameters. However, statistically no significant difference observed between dry and wet season in all parameters studied. The result of water quality test revealed that average values for all selected physico-chemical parameters were found within the acceptable limit of ES and WHO standards, except Temperature and Phosphate. But the result of bacteriological water quality for all sampled sites exceeded the ES and WHO standards. So, supplied water in the area is bacteriologically contaminated and therefore not suitable for domestic purposes unless treated.

Keywords: water quality, source, storage, dry season, wet season.

INTRODUCTION

No other single intervention is more likely to have a significant impact on global poverty than the provision of safe water. Water is a central theme, which can be used to achieve millennium development goals (MDGs) (Schuster-Wallace *et al.,* 2008).Water is a natural resource of fundamental importance. It supports all forms of life and creates jobs and wealth in the water sector, tourism, and recreation. As global slogan, “Water is Life” implies that water is one of the critical life needs for a human being. Without water, life as it exists on our planet is impossible (Asthana and Asthana, 2001).

Ethiopia ranks among the lowest countries in the world in levels of safe water and sanitation coverage; 66% of Ethiopia’s 83 million citizens do not have access to an improved water supply and 79% lack access to basic sanitation. The majority of Ethiopia's citizens live in rural areas where rates of coverage are even worse. Among rural Ethiopians, only 34% have access to an improved water supply (Water Access in Ethiopia, 2013).Most behaviors related to water collection, storage and use in Damot Sore are not unique to that community. The following common practices have been observed elsewhere worldwide (Trevett, *et al.,* 2004; WHO, 2010); Water collected in open top buckets or jerry cans, buckets cleaned before use by swirling water and rubbing with a hand, hand-water contact, common in transit between source and household storage, water stored in clay pots with loose lids, water scooped out of clay pots with communal cup, not observing hand washing and storage containers kept in an area that may be shared with animals. While most behaviors related to water are universal, the basis for these behaviors may be derived from different nuances in culture, beliefs and understanding.

Damot Sore Woreda is characterized by potential surface water sources having a number of rivers and springs. There are different rivers originating /crossing the Woreda like Xagacha, kuliya and Mere Rivers. There is a huge ground and surface water potential in the Woreda. Despite the ground water supply potential of the Woreda, it is not possible to construct enough water schemes in all Kebeles. Even in Kebeles where there are improved water schemes, the water supply is not adequate for all and the functioning schemes themselves are not providing reliable and adequate services for different reasons to respective communities (DSWWIO, 2016).

The available sources for a potable water supply are groundwater and surface water. Therefore, it should be protected, used and maintained in an appropriate way. There are several parameters used to determine the suitability of water and the health contaminants such as microbiological, physical, chemical, and microscopic examinations, which may be found both in untreated and treated water. To provide safe water, there is a need to ensure that the quality of drinking water assessed and monitored. Even a personal preference such as taste is a simple evaluation of acceptability. Drinking water qualities are assessed by comparisons of water samples to drinking water quality guidelines or standards. These guidelines and standards provide for the protection of human health by ensuring that clean and safe water is available for human consumption (WHO, 2008).

Drinking water has to be wholesome and clean when it becomes available for the consumers. However, from the time water leaves the water works, an array of processes may affect its quality during transport and storage (WHO, 2010). Water quality degradation between the sources and point-of-use may be due to several reasons such as the hygienic condition of the water storage containers and the environment of storage (Trevettet *et al.,* 2004). A number of processes may alter water quality during transport and in the distribution system to the consumer/point of use. This may be due to inherent properties of the water which may lead to microbial growth or corrosion, or to the choice of materials in contact with drinking water which may allow migration of organic materials that can sustain microbial growth or may release heavy metals such as copper, lead or nickel. Finally, leaks or fractures may permit the entry of pollutants such as organic micro pollutants (for example gasoline compounds) or pathogens from surface or wastewaters (Trevett *et al,* 2004). While it is important to increase access to improved water sources, the assumption that improved sources of water are of microbial quality does not necessarily hold true after the water has been transported and stored in the home. For example, there are chances for the water to become re-contaminated, between the water source and the household, through contact with unwashed hands and further perpetuating the cycle of poor quality drinking water. Household storage containers often allow for recontamination when water is removed using a cup through the opening at the top of the storage container, be it a traditional clay pot or a plastic bucket (Kausar *et al.,* 2012).

Improving the water supply coverage and evaluating from source to point of use and seasonal variation of water quality has a number of advantages for the society of the Woreda as well as for the government socially and economically. It was observed that there are several factors in the community that were likely resulting in water contamination at sources or during collection, storage and point of-use in household level. In addition, seasonal variation also had impact in water quality based on the public complaint. These factors called for question the basic assumption that water will remain safe from the time it leaves the tap to when it is consumed. If this assumption is shown to be faulty, it would have implications for future development strategies focused on water quality.

This research work therefore, specifically investigated the water quality variation at different point of utilities, season and the gap associated with water quality to initiate intervention measures in order to address the aforementioned problems in Damot Sore Woreda.

MATERIALS AND METHODS

Description of the Study Areas

This study was carried out in a rural area in Damot Sore Woreda, Ethiopia. The Woreda lies between 06°50’0’’N-07^{0}4’00’’N latitude and 37°35’00"E - 37°42'30" E longitude. The Woreda is located 347 km away from the country capital South West of Addis Ababa and 178 Km away from the northeast of regional capital, Hawassa. The altitude of the Damot Sore Woreda is ranges from 1350 to 2200 m.a.s.l. (WZANRO, 2016). The total population of Damot Sore Woreda is 116,847 from which are 59,825 males and 57,022 are females with average family size of 6 persons per household. The majority of the populations who are living in the rural and urban areas are 109,682 and 7,165 respectively, with the annual population growth rate of 2.8% (CSA, 2007).

Damot Sore Woreda is the study area and the location experiences an average daily temperature of 17.6℃ to 32℃. The rainfall distribution system of the Woreda is bimodal with average annual rainfall between 1100 and 1700 mm. There are three agro-ecologic conditions comprising of 18% “kola” (lowland), 67% “woyna dega” (midland) and 15 % “dega” (highland) (DSWANRO, 2016).

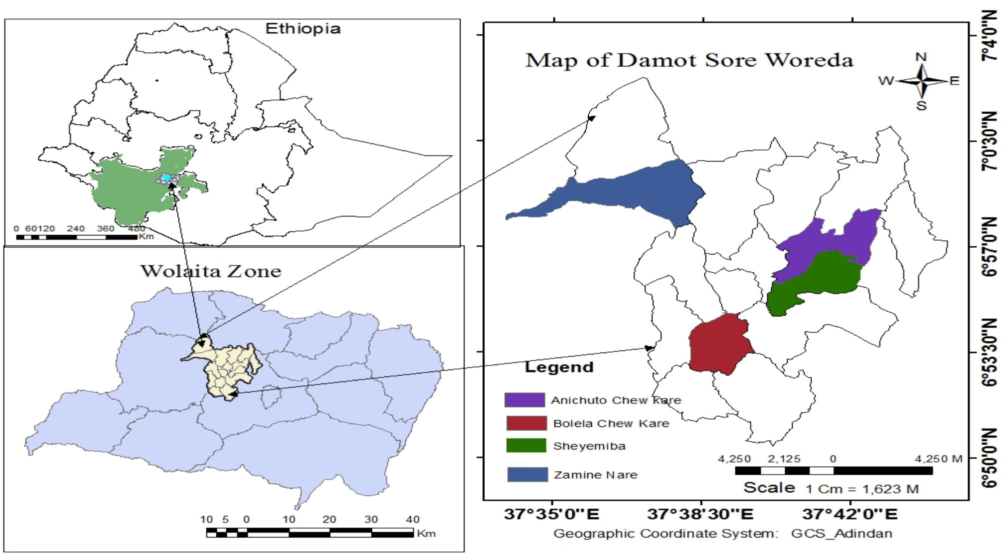


Figure 1: Location map of the study area

Water Samples and Sampling Points

Sampling techniques

For this study, out of the 21 rural Kebele Administrations in Damot Sore Woreda, , about 20% were selected, due to budget and time constraint, by using purposive sampling techniques for household water use pattern.

Damot Sore Woreda has three agro-climatic zones from which 18% was ‘kolla’ (lowland), 67% was “Woindega’’ (midland) and 15 % was “Dega’’ (highland). Proportionately, one Kebele was selected from “kolla” agro-climatic zone, two Kebeles were selected from Woindega whilst the remaining one Kebele was selected from “Dega” agro climatic zone. Accordingly, four Kebeles selected for this purpose are Zaminenare kebele from ‘’Kolla’’, Shamba and Anchituchawk kebeles from “Woinadega” and Bolelachawk kebele from ‘’Dega’’ agro-climatic zonation. Finally, probability proportional sampling technique was used to select the households from each sampled Kebeles.

Water Quality Assessment

Sample size for water quality analysis

Temporal and spatial variation of water quality analysis is very important for the water sampling points to evaluate the water quality changes at one sampling point to the next sampling points and at different seasons respectively. To analyze selected physico-chemical and bacteriological parameters, eleven major functional water supply schemes were selected based on the public complaint on the water quality from four sampled kebeles (Figure 2). Then, the analyzed laboratory results were taken for eleven samples from the source, eleven samples from storage (household containers) and eleven samples from the point of-use(drinking cups). Totally, thirty-three samples were taken to evaluate the average mean values for the selected physicochemical and bacteriological parameters during dry season of January. For seasonal water quality analysis during the dry month of January and the wet month of April, eleven samples were taken for each month from the same water points. All the analyzed laboratory results were compared with the Ethiopian standards and WHO guideline for drinking water quality and interpreted in accordance with the results obtained.

Water sampling procedure

Samples were collected in 1000ml polyethylene plastic bottles for different parameters from sampled water supply schemes. Water sampling and preservation techniques followed the standard methods of water sampling and preservation techniques (APHA, 1998; Hutton, 1996). Before collection, bottles were washed with concentrated nitric acid and distilled water to avoid contamination. The water samples were handled aseptically in sterile glass bottles, labeled and kept in an ice-box during transportation to the laboratory of school of Bio-system and Environmental Engineering, Hawassa University, for physico-chemical quality analysis and Wolaita Zone Water and Irrigation Department for bacteriological quality analysis. Bottles were preserved using icebox and the water samples from sampled sites of the study area were taken and studied for the selected physicochemical and bacteriological parameters.

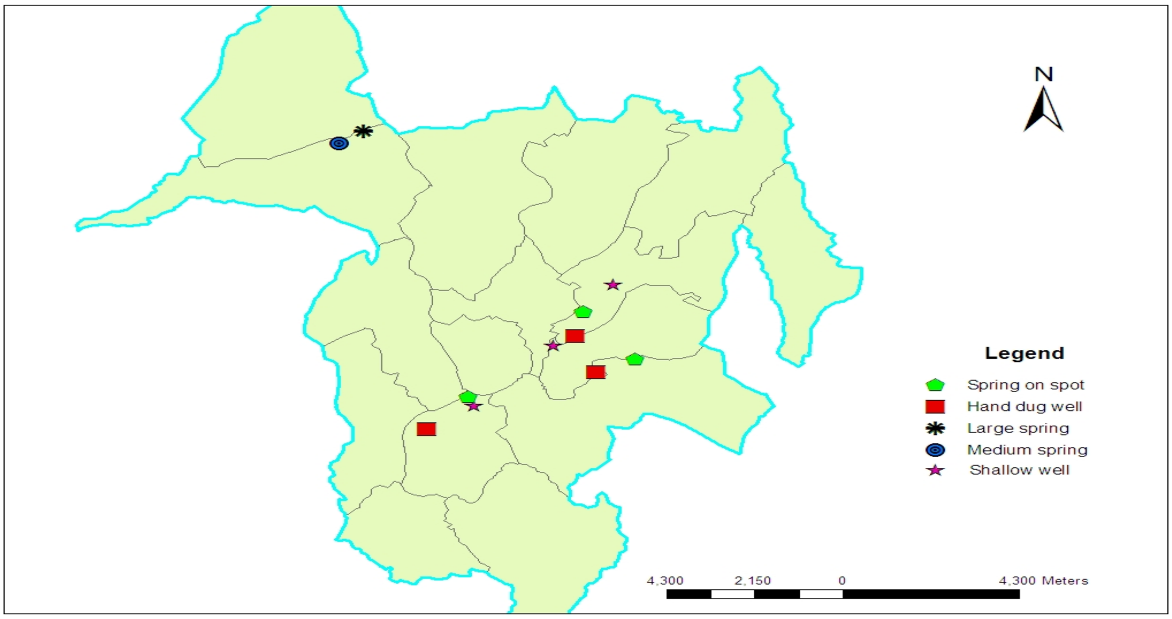


Figure 2: Water source mapping point of the study area

Method of Water Quality Analysis and Instruments

Analysis of physico-chemical parameters

In-situ measurements were used to determine sensitive water quality parameters, which include; temperature, pH, turbidity, EC and TDS. Temperature and pH was analyzed by using thermometer and portable digital pH meter (pH meter ELE international), respectively. The pH meter were calibrated just before analysis using pH 4.0 and pH 7.0 and it was rinsed with distilled water from one sample to the other following the pH meter operation manual. With regard to turbidity, it was analyzed using portable Wagtech International turbidity meter (Weg-WT 3020 Wagtech International), whereas electrical conductivity and Total Dissolved Solids (TDS) were analyzed using portable digital conductivity meter. Their measurements were taken immediately after the samples were collected on each site. Magnesium, total hardness, chloride and Fluoride was determined by photometric measurements using Paqualab photometer by adjusting the wavelength (580 μm) and keeping their reaction periods and analytical reagents were analyzed by using their respective standards. Iron was determined by using Paqualab photometer with 520μm wavelength. The nutrients like nitrate and phosphate were measured by photometric measurements using Paqualab photometer by adjusting the wavelength to 560 μm, keeping their reaction periods and the analytical reagents analyzed by following standard methods (APHA, 1998) and using a standard laboratory setup. All chemicals and reagents used for this analysis were analytical grade. Equipment were cleaned and sterilized thoroughly before each use to avoid secondary contamination and ensure accurate results.

Analysis of bacteriological parameters

With regard to bacteriological parameters, samples were analyzed using membrane filtration method for water quality to determine the degree of contamination (WHO, 2008; APHA, 1998). All samples were analyzed for the presence of total coliforms (TC).The procedures include membrane filtration followed by incubation of the membranes on selective media. Composite samples were used to improve the precision of the estimated average contaminant concentrations. In the laboratory, three samples from each site were mixed into one and a composite sample was subjected to membrane filter analysis of total coliform. The composite samples were mixed thoroughly by shaking and filtered under laboratory hood, using WagTech membrane filtration apparatus and membranes, pore size 0.45µm, 47mm diameter, sterile and gridded. It was shaking properly to get red color. The membranes then transferred aseptically to m-FC agar with rosolic acid in glass Petri dishes. Prepared culture dishes were inverted and the incubator was calibrated at 37^oC. Upon completion of the incubation period (24 hour) typical Yellow Colonies were seen, which were characteristic of total coliform on the surface of membrane filter then counted using a low power binocular wide field-dissecting microscope, with a cool white fluorescent light source for optimal viewing sheen.

Method of Data Analysis

Results of water quality analysis from the source, storage containers, point of-use (consumption) and dry and wet season variation were compared against standards set by Ethiopian standards(ES) (2002) and WHO (2008). Moreover, ANOVA was used to determine the significant differences in the mean values of the water quality parameters at the various sampled sites at $p< 0.05$ significant level and also correlation was employed to see statistical significance relation between physico-chemical and bacteriological parameters.

RESULTS AND DISCUSSION

Physico-Chemical Analysis of the Source, Storage and Point of-Use Samples

A total of thirty three water samples were analyzed from the sample points of source (from water developed schemes), storage (household containers) and point of use (water used for actual drinking from cup).

There was a variation in the mean values of water temperature in most of sampled sites from the source to storage as they have different atmospheric temperature. As a result, the differences in the mean temperature for the source to storage sampled sites were significant at $p< 0.05$ significant level with $p=0.036$ (Table 1). A slightly higher temperature of 25.5^0C reported from water source samples than the storage from Nigeria (Agbogu *et al.,* 2006).

The pH result showed that a decrease of the pH value in stored water samples. Normally, the variation in pH is due to nitrates, carbon dioxide or dissolved minerals that normally affect the pH and may be related to the bacterial development and activity. This finding agreed with previous research by Achadu *et al.* (2013). However, the differences in the mean pH of the source, storage and point of use sampled sites were not significant at $p <0.05$ significant level.

At the source, high turbidity value was observed as the particulate matter floats on the surface of the source. But, in the household water storage container, the particulate matter settles

Table 1: Mean value of physico-chemical parameters for the source, storage and point of-use samples.

Parameters	**Units**	**Source**		**Storage**		**Point of-use**		**Standards**	
		Mean	**Std**	**Mean**	**Std**	**Mean**	**Std**	**ES**	**WHO**
Temp.	^{o}C	23.27	1.737	21.63	1.566	21.63	1.567	--	<15
EC	µs/cm	100.8	25.54	81.7	20.93	81.7	20.93	1500	1000
pH	Ph	7.22	0.93	7.04	0.835	7.04	0.835	6.5-8.5	6.5-8.5
Turbidity	NTU	12.18	17.75	10.74	15.85	10.74	15.75	7	5
TDS	Mg/l	67.39	17.19	54.69	14.15	54.69	14.15	1000	1000
TH as $CaCO_3$	Mg/l	49.63	28.786	39.36	25.6	39.36	25.6	300	300
Nitrate	Mg/l	1.91	0.875	1.53	.58	1.53	0.58	50	50
Chloride	Mg/l	7.64	1.14	7.29	1.02	7.29	1.02	250	250
Fluoride	Mg/l	0.63	0.28	0.59	0.28	0.58	0.28	3	1.5
Iron	Mg/l	0.07	0.06	0.06	0.06	0.06	0.06	0.4	0.3
Magnesium	Mg/l	10.89	1.61	8.9	1.27	8.9	1.27	50	50
Phosphate	Mg/l	0.44	0.18	0.4	0.18	0.4	0.18	0.02	0.005

down resulting in low turbidity value. However, the differences in the mean turbidity of the source, storage and point of use sampled sites were not significant at $p<0.05$ significant level. Some forms of primary treatment like coagulation and flocculation, therefore needed to be carried out on this water sources before any disinfection treatment can be done, otherwise, high turbidity values will shield the pathogenic organisms from chemicals and render the treatment ineffective (Hunter *et al.,* 2009).

The laboratory results showed a decrease of the electrical conductivity level in stored water samples. This is due to conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) and magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge).However, the differences in the mean EC of the source, storage and point of use sampled sites were not significant at $p <0.05$ significant level. The correlation result for the association between temperature and electrical conductivity revealed that there was a positive relationship between them with the correlation value of 0.372.

Total Hardness (TH) level showed that there is variation from source to storage. The source has high value of total hardness due to high quantity of magnesium or calcium ions on the source than storage and point of-use value. However, the differences in the mean TH of the source, storage and point of use sampled sites were not significant at $p<0.05$ significant level. This finding agreed with previous research by Douhri *et al* (2015), i.e. the total hardness at source and storage showed variation. Statistical analysis showed that, the differences in the mean from the source, storage and point of use value of nitrate, phosphate, chloride, fluoride, iron and magnesium from sampled sites were not significant at $p<0.05$ significant levels.

Bacteriological Analysis for the Source, Storage and Point of-Use Samples

Table 2: Mean value of bacteriological parameter for the source, storage and point of use samples

Parameters	Units	Source		Storage		Point of-use		Standards	
		Mean	Std	Mean	Std	Mean	Std	ES	WHO
Total coliform	CFU	9.36	5.12	14.27	6.85	17.72	8.02	0	0

For water to be potable, it must be free of any bacterial 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, longer and are easier to detect than other pathogens (Kegley and Andrews, 1998).

In Damot Sore Woreda, the contamination of water source with excreta from people or animals introduces a great variety of bacteria, viruses, protozoan worms. Insufficient protection of water sources or inadequate treatment, handling and storage, thus puts the community at risk of contracting infectious diseases. An important problem is that the communities not perceive the risk of bacteriological contamination as the pollution is often not visible. Local people may value the taste and appearance of the water but not its bacteriological quality unless they understand the risk.

For all of sites inspected, there were changes in the total coliforms counts from source to household storage containers and from household storage containers to point of-use.The mean value of TC for the source, storage and point of-use were 9.36±5.12CFU, 14.27±6.85CFU and 17.72±8.02CFU, respectively (Table 2). As a result, the differences in the mean from the source, storage and point of-use TC of the sampled sites were significant at $p<0.05$ significant level with $p= 0.024$.

In addition, previous researches have reported a significant deterioration of water quality after collection. Deterioration of the water quality has been detected during its storage and drinking cup at home in rural and urban areas throughout Africa, Asia and Latin America (Trevett *et al*., 2004; Hoque *et al*., 2006; Mc Garvey *et al.,* 2008 and Kausar *et al.,* 2012) among others.

Research has shown that these bacteria cannot withstand high temperature (Schmidt and Cairncross, 2008). Of the thirty-three samples analyzed in this study, 100% complied with the Ethiopia standard and WHO guideline value for total coliforms. Compliance was significantly higher for source and household containers than for the point of use (100%).

All bacteriological water quality analysis showed significant deterioration of water quality from source to household storage and from household storage to point of use. Although the Woreda's water supplies service office did not apply any kind of water treatment method on regular basis. It is therefore necessary to encourage the water user to regularly add chlorine and boil their water before using it for domestic purposes and basic water supply; safe water storage and clean washing of storage containers and drinking cups are needed.

Water Quality in Dry and Wet Season

Physico-chemical analysis in dry and wet season

Totally, twenty two water samples were analyzed for selected physico-chemical parameters during the dry month of January and wet month of April to study drinking water quality variation with the seasonal difference as presented in Table 3 and Figure 3.

Table 3: The seasonal mean of physico-chemical parameters

Parameters	Units	Dry season		Wet season		Standards	
		Mean	Std	Mean	Std	ES	WHO
Temp.	^{o}C	23.27	1.73	22	2.09	--	<15
EC	µs/cm	101	25.54	92.7	24.54	1500	1000
PH	PH	7.22	0.93	6.8	0.82	6.5-8.5	6.5-8.5
Turbidity	NTU	12.19	17.75	17.6	23.8	7	5
TDS	Mg/l	67.6	17	62	16.4	1000	1000
TH ($CaCO_3$)	Mg/l	49.63	28.65	44.36	27.27	300	300
Nitrate	Mg/l	1.91	0.92	2.15	0.92	50	50
Chloride	Mg/l	7.64	1.14	7.74	1.2	250	250
Fluoride	Mg/l	0.64	0.28	0.62	0.29	3	1.5
Iron	Mg/l	0.07	0.068	0.04	0.06	0.4	0.3
Magnesium	Mg/l	11.24	1.5	10.8	1.3	50	50
Phosphate	Mg/l	0.44	0.18	0.53	0.17	0.02	0.005

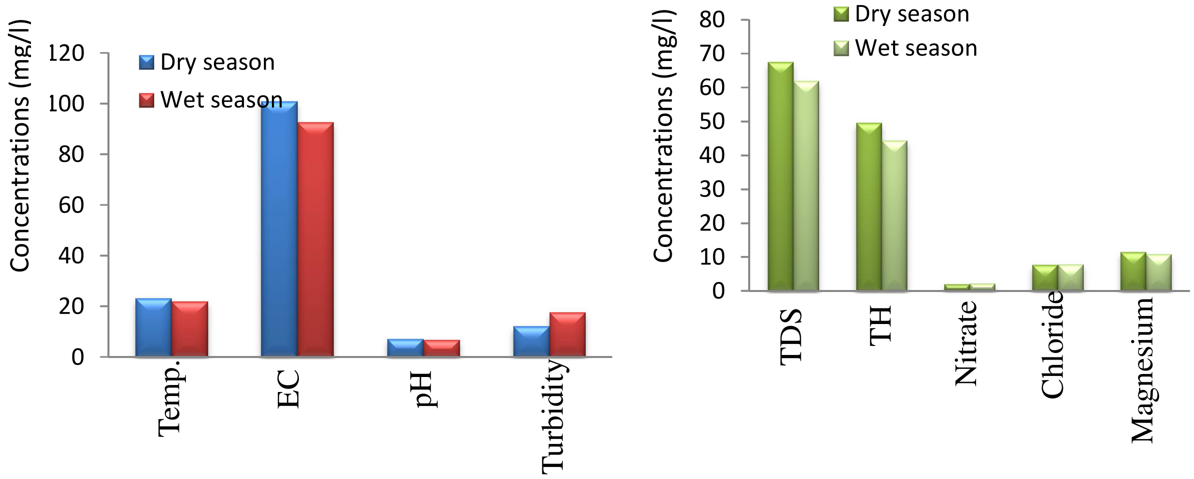
Mean concentrations of temperature were 23.27^{o}C in dry season and 22^{o}C in wet season. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons. A similar study conducted in Ziway town, which is located near the study area showed a mean temperature of 23.2^{0}C from different water source samples (Kassahun, 2008). All the above-mentioned studies were from the tropics, where the climate is characterized by high temperature and rainfall.

Mean concentrations of pH were 7.22pH in dry season and 6.8pH in wet season. The lower concentration of pH during wet season was probably due to rainwater dilution. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons. All the pH values collected during the two seasons showed that within the permissible limit of ES and WHO drinking water guideline. `

Turbidity is one of the important physical parameter that affect not only the quality of water, but also other chemical and bacteriological parameters and efficiency of the treatment of water (WHO, 2008). High turbidity indicates the presence of organic suspended material, which promotes the growth of microorganism. It is used as a crude indicator of contamination with organisms such as *Cryptosporidium* (Momba *et al.,* 2006). Mean concentrations were 12.9NTU in dry season and 17.6 NTU in wet season (Table 3). Similarly, the study conducted by Joseph (2013) mean turbidity values recorded for wet season wells were 14.50±21.51 NTU and that of the dry season showed 4.01±4.96 NTU. Lower turbidity values during the dry season are probably due to lack of runoff and erosion. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons.

Mean concentrations of EC were 101µs/cm in dry season and 92.7µs/cm in wet season. Mean concentrations of TDS were 67.6mg/l in dry season and 62mg/l in wet season. This result was not agreed with previous study conducted in Ghana by Joseph (2013). The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons. The TDS values were lower in the wet season compared to the dry season probably due to the dilution effect of rainwater (Mkandawire, 2008).

Mean concentrations of TH were 49.63mg/l in dry season and 44.3mg/l in wet season. Lower value during wet season may be due to dilution effect of calcium and magnesium ions. The statistical analysis showed that there was no significant difference at $P<0.05$ between the dry and wet seasons. Mean concentration of Nitrate, Chloride, Fluoride, Iron, Magnesium and Phosphate showed variation during the dry and wet seasons but no significant difference observed at $P<0.05$.



(a) (b)

Figure 3: The value of physical and chemical parameters in dry and wet season

Bacteriological analysis in dry and wet season

The water samples were analyzed for selected bacteriological parameter during the dry month of January and wet month of April to study drinking water quality variations with the seasonal difference.

Bacteriological quality is a critical issue in the quality of water in the study area and any areas of Ethiopia. Bacteriological analysis of water samples showed that all samples of water sources were positive for total coliforms in two rounds of triplicate sampling. Mean concentrations were 9.5 per 100ml in dry season and 14 per 100ml in wet season. This indicates the presence of contamination in two seasons and the concentration of TC increase from dry to wet season. The high amount of these coliform during the wet season could be because water availability favors the movement and reproduction of the organisms especially from surface run off, sewage and waste material (Otieno *et al,* 2015) and may be due to the site selection, inadequate protection of water sources and unhygienic practices near the water sources (Richards, 1996).

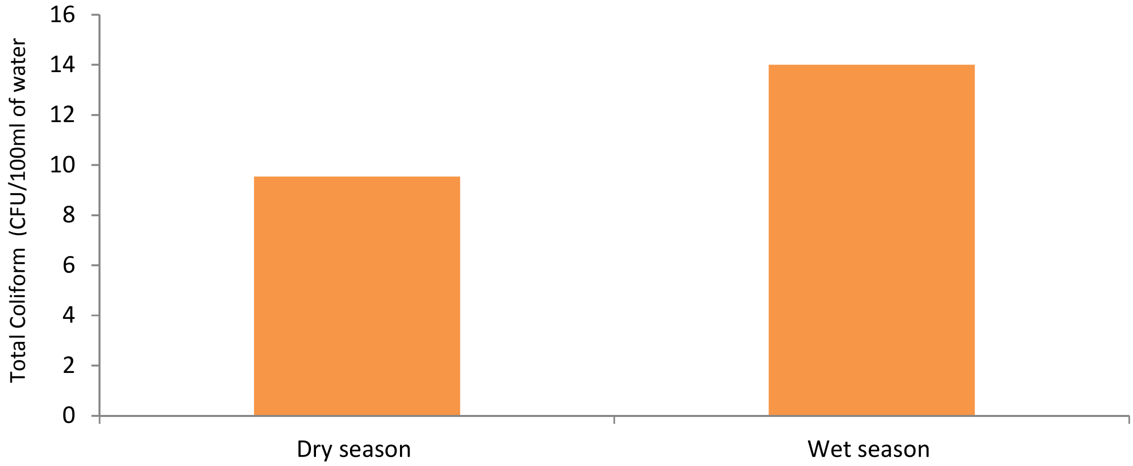


Figure 4.The value of total coliform in dry and wet season

However, the statistical analysis showed that there was no significant difference $P<0.05$ between the dry and wet seasons (Fig 3). In two different seasons the value was beyond the recommended maximum permissible limits of ES and WHO (ES, 2002 and WHO, 2008), zero/100 mL for the drinking (Fig 4).

CONCLUSIONS

Water safety in a community depends on different factors i.e. from the quality of water at the source to transport, storage and handling practices at household level. The physico-chemical parameters showed that drinking water from the source to household storage decrease and it is the same from household containers to point of use. The variability analysis (ANOVA) test indicated that there were no significant differences for mean values of all physico-chemical parameters among various sampled points for the source, storage and point of use at $p<0.05$ significant levels with the exception of temperature($p=0.036$). However, total coliform increased in all sampled points from the source to storage and from storage to point of use. The variability analysis (ANOVA) test also indicated that there were significant differences for mean values of all bacteriological parameter among various sampled points of the source, storage and point of use at $p<0.05$ significant level($p=0.024$).

In addition, the results of seasonal analysis showed that most of the parameters have higher mean values during the dry season, except for turbidity, nitrate, chloride, phosphate and TC, which had higher mean values during the wet season. The variability analysis (ANOVA) test indicated that there were no significant differences for mean values of all physico-chemical and bacteriological parameters for dry and wet season among various sampled sites at $p<0.05$ significant levels.

This study demonstrated that supply of water alone could not guarantee that the water at the source, storage and in the household for drinking purpose is safe as well. An irregular and inadequate water supply compels people to store water for long periods and microbial contamination was found to be higher in stored and point of use water than in source water.

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