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Research Paper

Assessment of Bacteriological and Physico-Chemical Quality of Drinking Water in Munesa Woreda, Arsi Zone, Oromia, Ethiopia

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Abstract

Potable and accessible household drinking water is essential means of improving communities' health both in urban and rural areas. The potability of drinking water is affected by bacteriological and physico-chemical parameters. Thus, cross-sectional study was conducted during September 2015 to June 2016 to assess the bacteriological and physico-chemical quality of drinking water sources in Munesa Woreda, Arsi zone, Oromia, Ethiopia**.** In total sixty four samples from four different water sources were sampled. Water samples of tap water, protected boreholes, protected springs and household from different sites were collected. The total coliform, fecal coliform, temperature, pH and total dissolved solids were analyzed based on the standard methods prescribed by APHA (2017). The mean counts of total coliform were in the range of 3±2.36 to 30±5.01 (CFU/100 ml) whereas, the mean counts of fecal coliform were found to be 2±1.93 to 22±2.74 (CFU/100 ml). The total and fecal coliforms counts in all water samples were above the recommended limit set by WHO and Ethiopian standard for drinking water quality. However, the results of physico-chemical parameters tested in relation to temperature, pH and TDS were observed within the permissible ranges of national and international standards. The presence of fecal coliforms in the water samples demonstrates the presence of pathogenic organisms that would be a threat to anyone consuming the water. Thus, it can be suggested that regular monitoring of drinking water sources and hygiene promotion programs can improve quality of drinking water in the study area.

1. Introduction

The availability of adequate and quality household drinking water is essential means of improving communities' health both in urban and rural areas (WHO, 2011). The rationale for promoting safe drinking water in rural and urban communities in developing countries is the persistently high level of morbidity and mortality (WHO/UNECEF, 2017). Worldwide, in (2016), 1.9 million deaths and 123 million disability-adjusted life-years (DALYs) have been registered related to water, sanitation, hygiene and health (WHO, 2019). The lack of access to water also limits sanitation and hygiene practices in many households because of the priority given for drinking and cooking purposes. Only one out of three people using safely managed drinking water services (1.9 billion) lived in rural areas (WHO/UNECEF, 2017).

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It is evident that people who are most vulnerable to water-borne diseases are those who use polluted drinking water sources from rivers, streams and hand dug wells. Since these sources are open, they are susceptible to animals, birds and human contamination. An estimated 2 billion people drink water that is faecally contaminated, 4.5 billion people use a sanitation system that does not adequately protect their family (WHO, 2019).

Ethiopia is one of the countries in the world with water quality problems. It has one of the lowest coverage in Sub-Saharan countries with 57 % and 28 % for improved drinking water supply and improved sanitation, respectively (UNICEF and WHO, 2015). Since the traditional water source users are highly vulnerable to water borne diseases, there is a need to check the drinking water regularly 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 (Doria, 2010).

The quality of drinking water is assessed by monitoring non-pathogenic bacteria of fecal origin (fecal indictor bacteria). Fecal coliform and total coliform comprise several genera, including *Escherichia, Klebsiella*, *Enterobacter*, *Citrobacter*, *Serratia* and *Hafnia* belong to the family *Enterobacteriaceae.* These are functionally-related group of bacteria which have been used to indicate the general quality of drinking water although different types of pathogens can contaminate water, food, air and other environmental media in many ways (Stevens et al., 2003; Ashbolt, 2004). Besides to bacteriological quality, the chemical quality of the drinking water have received particular attention because of their strong toxicity effect at high level of concentration.

The major problems of the study area is population growth, expansion of settlements, shortage of potable drinking water access and supply coverage, environmental management, uncontrolled liquid and solid waste disposal (Doria, 2010). There was no previous study conducted in this study area regarding to the bacteriological and physico-chemical quality of drinking water from different sources. However, studies have been conducted in several rural and urban areas of the country. Several studies carried out in Ethiopia on the bacteriological and physico-chemical quality assessment of drinking water (Atnafu Melaku, 2006; Tsega et al., 2013; Debasu Damtie et al., 2014; Mohammed Yasin et al., 2015; Gonfa Duressa et al., 2019). These reports revealed that the bacteriological and physico-chemical parameters of the different water sources had values beyond the maximum limit of WHO and Ethiopian recommendation. They suggested the need for the appropriate intervention including awareness creation and improving of existing infrastructure.

Therefore, this study was aimed to determine bacteriological and physico-chemical contamination of drinking water from different water sources (protected springs, protected boreholes, household water and tap water) in the residents of the Munesa Woreda, Arsi zone, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Munesa woreda, Arsi zone, Oromia Regional State, Ethiopia, located at 232 km south of the capital city Addis Ababa and 57 km south of Asella. It is bounded on the south and west by the west Arsi zone and lake Langano, on the northwest by Ziway Dugda, on the north by Tiyo, on the northeast by Digeluna Tijo, and on the east by Bekoji. The administrative center of the Woreda is Kersa (Figure 1).

According to the CSA (2007) report, the total population of Munesa is estimated to 207,944 having an increment of 28.8% from the 1994 Census. The population density is estimated 142.6 people per square kilo meter which is greater than the zone average of 132.2. About 90.95% of the total populations are rural residents. According to the district water supply documentation, the district has 32 rural and 6 urban kebeles having about 23,111 housing units of which 2,092 urban and 21,019 rural households showing 1:8.9 ratio of housing unit to population. About 69% of the urban population receives water from improved sources. 62% of rural population is covered by improved water supply system. In the district, there are 185 water points of which 92 springs on spot (SOS), 5 hands dug wells (HDW), 22 springs with distribution system (SWDS) and 66 water extensions constructed by government and respective projects (District Water Office Documentation).

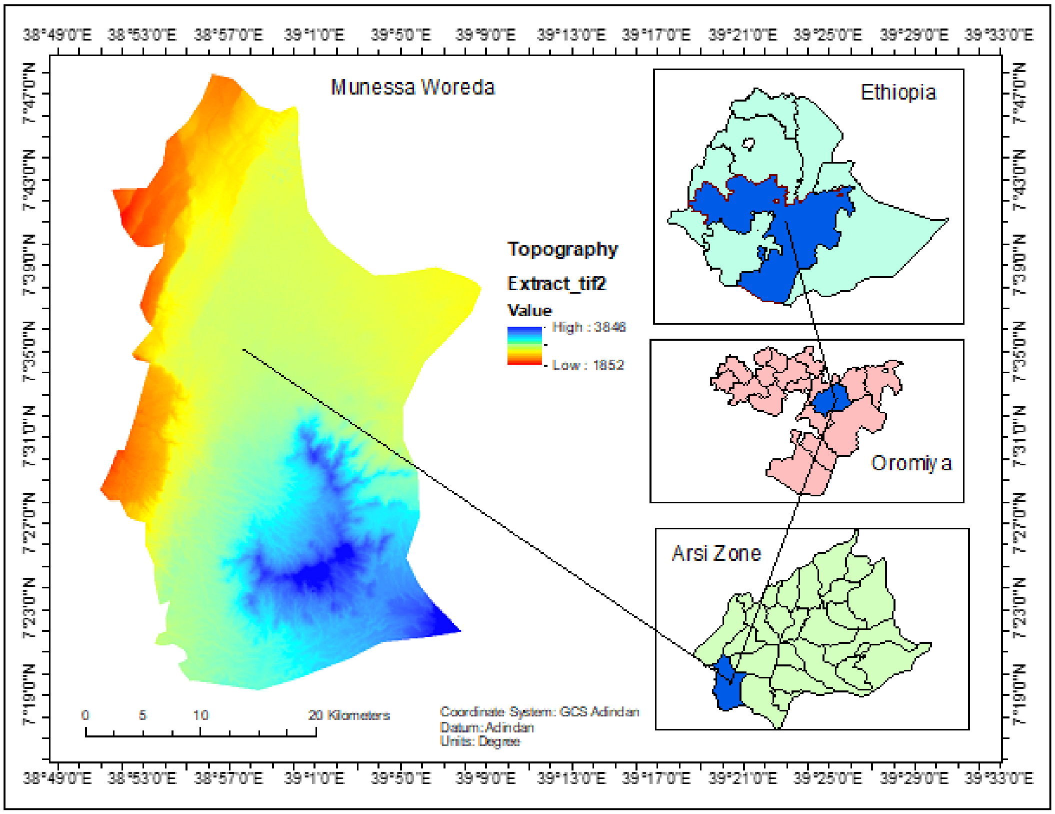

Figure 1: Study area map

2.2. Study Design and Water Sample Collection

A cross sectional prospective study was conducted in Monesa woreda during September 2015 to June 2016. A total of 64 water samples from five sites; Heban Lakicha, Chefa, Ego town, Heban Dubo and Kersa were collected. Purposive sampling techniques were used to include house hold water and all types of water sources used by the community. The set of water samples taken were as follows: 23 samples from household water; 18 from tap water; 18 from protected spring water and 5 from protected borehole water. Triplicate samples in 100 ml polyethylene bottles were collected, labeled and then transported in ice-box to Asella Water Supply and Sewerage Enterprise (AWSSE) for bacteriological and physico-chemical quality analysis. Sampling and preservation techniques were based on the standard method of water sampling and preservation techniques (APHA, 2017).

2.3. Microbial Analysis

The samples were analyzed for total coliform (TC) and fecal coliforms (FC) using the membrane filter technique as outlined by the APHA (2017). Hundred milliliter of water samples were placed on surface of sterile filter membrane with pore size 0.45µm after vigorous shaking and placed on funnel unit of the membrane filter support assembly. The filtration was facilitated by applying a vacuum pump and the assembly was rinsed by sterile dilute water (APHA, 2017).

Up on completion of the filtration process, the bacteria remained on the filter papers were placed on petri dishes containing Eosin Methylene Blue (EMB) agar. EMB agar contains lactose, sucrose and dyes; eosin and methylene blue as indicators. Finally, the cultures were incubated at 37°C for 18 to 24 hrs and at 44.5°C for 24 to 48 hrs for total coliforms and fecal coliforms, respectively. Upon completion of incubation period, colonies were observed and the number of colonies formed on the media was reported as colony forming units (CFU) per 100 ml of sample.

2.4. Physico-chemical Analysis

Physico-chemical parameters such as pH, total dissolved solids (TDS) and temperature were analyzed based on the standard methods prescribed by APHA (2017). Accordingly, well-mixed 100 ml of samples were filtered through a filter paper in a weighed dry glass beaker. The beaker was placed in a drying oven (evaporating dish) maintained at 103°C for 24 hrs. After 24 hrs, the beaker was transferred from drying oven to a desiccator to cool sample for three hours and the beaker was reweighted. The weight of the dried residue was found by subtracting the initial weight from the weight of beaker with the dried residue. Finally, the total dissolved solids were calculated. Temperature of water samples was determined in the field due to their unstable nature. A thermometer calibrated to 0°C to 100°C was used for temperature measurements. Thermometer was immersed in the water sample until the liquid column in the thermometer stops moving for 3 min and the reading was recorded. The pH of the water samples was recorded at the time of sampling by using pocket Digital pH meter (APHA, 2017).

2.5. Data analysis

Data were entered and analyzed using SPSS statistical software (version 16). Descriptive analysis was made for categorical variables while mean and standard deviation were calculated for continuous variables. Results of mean microbial counts and physico-chemical analysis of the water samples were compared with the set standards (WHO, 2011) and interpreted as acceptable or unacceptable. Analysis of variance (ANOVA) at 95% level of significance was used to compare the quality of drinking water among all sites.

3. Results

In total 64 water samples were analyzed for total coliform (TC) and fecal coliforms (FC) count. The result of microbial analysis indicated that water sources from all sites including Heban Dubo, Heban Lakicha, Chefa, Ego and Kersa were found to be positive for total coliforms and fecal coliform (Table 1). The mean total coliform counts were ranging from 3±2.36 to 30±5.01 (CFU/100 ml) with the lowest and the highest range corresponding to the total coliform counts from samples of Ego (TW) and Lakicha (PBHW), respectively. The mean fecal coliform counts were ranging from 2±1.93 to 22± 2.74 (CFU/100 ml) with the lowest and the highest range corresponding to samples from Kersa and Ego (TW) each and Dubo (HHW), respectively (Table 1). The total and fecal coliform counts from Ego HHW samples were the least and Lakicha and Dubo HHW samples were the highest for total and fecal coliform in CFU/100 ml, respectively.

Table 1: Bacteriological analysis of water samples in each site

Site	Water sample	N	TC (CFU/100 ml)	FC (CFU/100 ml)
Chefa	HHW	6	10±2.82	5±1.97
	TW	6	8±2.82	5±1.93
Dubo	HHW	3	25±4.09	22± 2.74
	PBHW	3	21±4.09	10±2.74
	PSW	9	15±2.36	8±1.58
Ego	HHW	6	4±2.60	3±1.93
	TW	6	3±2.36	2±1.93
Kersa	HHW	6	6 ±2.89	4±1.93
	TW	6	5±2.89	2±1.93
Lakicha	HHW	2	28±5.01	20 ±3.35
	PBHW	2	30 ±5.01	13±3.35
	PSW	9	13±2.36	7±1.58
WHO (2011)			0	0
Ethiopian CSE-58			0	0

CSE=compulsory Ethiopian standard, HHW= household water, TW= tap water, PBH= protected borehole, PSW= protected spring water, WHO= world health organization, TC= total coliform and FC= fecal coliforms.

With regard to total coliform count of TW the maximum (8±2.82 CFU/100 ml) and the minimum (3±2.36 CFU/100 ml) was recorded from chefa and ego site, respectively. With respect to fecal coliform count from TW samples chefa was the highest (5±1.93 CFU/100 ml) and ego and kersa were the lowest (2±1.93 CFU/100 ml) (Table1). In this study, significant differences within and among water samples was detected for the TC and FC ($P< 0.05$; Table 3).

Selected physico-chemical parameters of water samples from all sites were analyzed. The mean temperature, pH and TDS tests were done for house hold water, tap water, protected borehole and protected spring water sample (Table 2). The mean temperature of the water samples were ranging from 13.50±1.00°C to 16.00±0.81°C with low and high range corresponding to temperature of samples from Lakicha and Dubo HHW, respectively. It is shown that temperature values of all water samples met national and WHO guidelines for drinking water.

The mean pH value of water samples were ranging from 6.61±0.37 to 7.54±0.37. The low (6.61±0.37) and high (7.54±0.37) mean pH value was found from the water samples of Lakicha protected borehole and household, respectively. All pH values of water samples met national and WHO criteria for drinking water. The mean concentrations of total dissolved solids were ranging between 525.00±27.63 to 583.00±15.95 (mg/L) for Lakicha protected boreholes and Ego tap water, respectively (Table 2). The minimum mean concentrations of total dissolved solids were recorded in protected borehole water; whereas maximum was observed in tap water sample. In this study, no significant differences within and among water samples was detected for the temperature, pH and TDS values (*P*> 0.05; Table 3).

Table 2: Phyico-chemical parameters of treated water samples in each site

Site	Water sample	N	Temp. (°C)	pH	TDS (mg/L)
Chefa	HHW	6	15.58±0.57	7.13± 0.21	574.00 ± 15.95
	TW	6	14.83± 0.57	7.51± 0.21	568.00± 15.95
Dubo	HHW	3	16.00± 0.81	7.13± 0.30	531.00± 22.56
	PBH	3	14.50± 0.81	7.18± 0.30	559.66± 22.56
	PSW	9	14.00± 0.47	7.25± 0.17	532.66± 13.02
Ego	HHW	6	15.10± 0.57	7.37± 0.21	551.66± 15.95
	TW	6	14.33± 0.57	7.41± 0.21	583.00±15.95
Kersa	HHW	6	14.60± 0.57	7.40± 0.21	546.50± 15.95
	TW	6	13.96± 0.57	7.53± 0.21	571.66± 15.95
Lakicha	HHW	2	13.50± 1.00	7.54± 0.37	556.00± 27.63
	PBH	2	14.50± 1.00	6.61± 0.37	525.00± 27.63
	PSW	9	14.72± 0.47	7.23± 0.17	555.77± 13.02
WHO (2011)			Not exceed 15	6.5 - 8.5	500 – 1000
Ethiopian CSE-58			Not exceed 15	6.5 - 8.5	500 – 1000

CSE=compulsory Ethiopian standard, PBH = protected borehole water, PSW = protected spring water, HH = household water, TW = tap water

Table 3: Comparison results of one way analysis of variance (ANOVA) test among and within different drinking water samples at 95% confidence level

Parameters	Comparison	Sum of Squares	df	Mean Square	F_{cal}	*p*-value
TC	Between Groups	1685.309	3	561.770	7.539	0.000
	Within Groups	4470.800	60	74.513		
	Total	6156.109	63			
FC	Between Groups	356.809	3	118.936	2.917	0.041
	Within Groups	2446.550	60	40.776		
	Total	2803.359	63			
Temp	Between Groups	8.067	3	2.689	1.388	0.255
	Within Groups	116.213	60	1.937		
	Total	124.280	63			
pH	Between Groups	1.258	3	0.419	1.636	0.190
	Within Groups	15.374	60	0.256		
	Total	16.632	63			
TDS	Between Groups	9207.444	3	3069.148	2.085	0.112
	Within Groups	88327.493	60	1472.125		
	Total	97534.938	63			

Df= degree of freedom, significant at $p<0.05$

4. Discussion

The result of bacteriological quality of water sources in this study indicated that all samples were heavily contaminated with both total and fecal coliform and exceeded the standard requirements set by WHO and Ethiopian standard guidelines for drinking water quality (ESDWQ, 2002; WHO, 2011). The patterns of total and fecal coliform counts reflected in the water samples shows fecal pollution due to the presence of high human activities and unhygienic practices in the area. In this study, the total coliform and fecal coliform counts were higher in household water samples compared to the tap water ($p = 0.000$). Similarly, other study conducted in Bahir Dar city, Ethiopia indicated that more number of coliform counts in household water than tap water (Milkiyas Tabor et al., 2011). Besides, a country report on the rapid assessment of drinking-water quality in Ethiopia by WHO & UNICEF (2010) showed higher counts of total coliform in household water compared to tap water. The results show that household water are affected by post-source contamination during transportation and after storage at home and serious attention must be given to quality of household water especially for water stored in household containers.

The high level of total and fecal coliform counts recorded in protected borehole water and protected spring water in Lakicha and Dubo water samples may be attributed to the high degree of contamination of the water sources by fecal matters due to herds of cattle and sheep grazing around the water sources and the pollutants being washed to the protected borehole and protected spring water. Likewise, a study in Jimma zone, southwest Ethiopia by Mohammed Yasin et al. (2015) showed that total coliform counts of 33 and 30.6 CFU/100 ml, but fecal coliform counts of 6 and 3.4 CFU/100 ml, in protected wells and protected springs, respectively. Other study by Mengesha Admassu et al. (2004) in north Gondar also revealed total and fecal coliform counts were above the permissible limits for drinking water. They demonstrated that out of seventy analyzed protected springs and protected well water samples, 71.43% and 28.6% had all kind of indicator bacteria and fecal coliform, respectively. The authors also confirmed that 50% of the samples had a coliform count of 180 per 100ml and the lowest coliform counts was 13 per 100 ml. Similar study in southern Wollo, Ethiopia by Atnafu Melaku (2006) demonstrated that, 75% of the samples from protected springs were contaminated with total coliforms. This could be explained by luck of water treatment facilities in rural area of the country. In addition to this, public owned water facilities might not have maintenance and follow-up treatment unlike urban once. Contrary to this, a study done in Bishoftu by Desta Kassa (2009) indicated that the water samples contaminated by total coliforms number was very small compared with this study ranging between 1-4 coliforms/100 ml which is within the acceptable limit (1-10 coliform/100 ml) set by WHO (2011).

The possible source of variation for the bacteriological contamination of drinking water in different areas is commonly due to differences in water treatment facilities, household sanitation, management of water sources and environmental sanitation. According to Onemano and Otun (2008), the source of water contamination by microbes may be due to the long term usage of boreholes, springs and tap water. These may lead to deterioration of the water quality because of the pipeline may become corroded with random cracks and in most cases clogged with sediment that will allow the passage of inorganic substances and bacteria. Crop cultivation around the water sources, linkage of latrine with drainage systems, the defecation on open areas which could seep slowly into underground water and flows towards gullies and streams as it was highly exposed to waste material. All these factors might be possible reasons for the high total and fecal coliform in the study area.

In this study, no significant variation of temperature observed among the tested water samples. The mean temperature of the water samples were ranging from 13.50±1.00°C to 16.00±0.81°C. Nearly all water samples collected from household sources were found to be higher in temperature than other sources. A temperature recorded in water sample from Dubo household was observed to be 16°C which is above the limit of Ethiopian standards for drinking water quality guidelines (ESDWQ, 2002) and World Health Organization (WHO, 2011).

Contrary to this study, the average temperature of water samples recorded in rural community of Ethiopia was 22.71°C (Tsega et al., 2013) and in Jimma zone, southwest Ethiopia was maximum temperature (25.8°C) and minimum (20.1°C) (Mohammed Yasin et al., 2015). The variation in the temperature of the samples might be attributed to difference in sampling locations and environments. Some of the water sources are collected from underground while others were from surface and house hold.

Temperature is the main factor which affects almost all chemical and biological reactions (Delpa et al., 2009). It can influences the pH, dissolved oxygen, redox potential and microbial activity (Park et al., 2010). Higher temperature can favor the growth of microorganisms and encourage the biofilm formation in the distribution and storages containers which could lead to environmental reservoir for pathogenic microorganism (Wingender and Flemming, 2011).

The pH values of all water samples lies between 6.61± 0.37 and 7.54±0.37 which is slightly alkaline and is in agreement with pH range of Ethiopian drinking water quality standards (ESDWQ, 2002) and WHO (2011) standards. Similarly, the pH value of water samples collected and analyzed from Jimma zone, southwest Ethiopia were found to be between 5.72 and 8.14 (Mohammed Yasin et al., 2015). The main contributing factor for different in the pH of the samples could be the physico-chemical nature of the soil of sampling sites.

The lowest total dissolved solid (TDS) (525.00 mg/l) recorded from Lakicha protected boreholes and the highest value (583.00 mg/l) recorded from Ego tap water were below the maximum permissible limit (1000 mg/l) recommended by WHO (2011). Mohammed Yasin et al. (2015) also reported the lowest total dissolved solid (TDS) (116 mg/l) and the highest value (623 mg/l) in Jimma zone, southern Ethiopia. In contrast, low TDS values (50–70 mg/l) were recorded from source to household tap connection in Nekemte, Oromia, Ethiopia (Gonfa Duressa et al., 2019).

It has been reported that drinking water with extremely low concentration of TDS may be unacceptable because of its insipid taste whereas, the water with high TDS value indicates that water is highly mineralized (WHO, 2008). Water containing high total dissolved solids may cause laxative or constipation effects (Sasikaran et al., 2012). High concentration of total dissolved solids may affect persons who are suffering from kidney and heart diseases and the potable water should not contain more than 1000 mg/L of total dissolved solids (Sasikaran et al., 2012).

5. Conclusions

The bacteriological quality of all water samples analyzed in the current study were not comply with/satisfy national or international guidelines set for drinking water. However, the results of physico-chemical parameters tested in relation to temperature, pH and TDS were observed within the permissible ranges of national and international standards. Based on the water quality parameters analyzed, tap water was found to be of less polluted than the other water sources (protected boreholes, protected spring and household waters). In general, the presence of fecal coliforms in the water samples demonstrates the potential presence of pathogenic organisms that would be a threat to anyone consuming the water in the study area. Thus, it can be suggested that regular monitoring of drinking water sources and hygiene promotion programs can improve quality of drinking water in the study area.

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