

Bacteriological and physico-chemical quality of drinking water sources in a rural community of Ethiopia

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Abstract

Background: Accesses to safe water is a universal need however, many of the world's population lack access to adequate and safe water. Consumption of water contaminated causes health risk to the public and the situation is serious in rural areas.

Objectives: To assess the bacteriological and physico-chemical quality of drinking water sources in a rural community of Ethiopia.

Methods: Water samples were collected from tap, open springs, open dug wells and protected springs for bacteriological analysis of total coliforms and thermotolerant coliforms. The turbidity, pH and temperature were measured immediately after collection.

Results: Most drinking water sources were found to have coliform counts above the recommended national and international guidelines and had high sanitary risk scores. There was a statistically significant difference among water sources with respect to TC and TTC ($p < 0.05$) and there was a statistically significant positive correlation between coliform counts and sanitary risk scores ($p < 0.01$). Most water sources didn't satisfy the turbidity values recommended by WHO.

Conclusion: The water sources were heavily contaminated which suggested poor protection and sanitation practice in the water sources. Source protection strategies as well as monitoring are recommended for this community.

Key words: Coliforms; physico-chemical; rural community; water quality

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Introduction

Accesses to safe water and sanitary means of excreta disposal are universal needs and indeed basic human rights; however, many of the world's population lack access to adequate and safe water¹. Use of improved sanitation facilities is low especially in Sub-Saharan Africa and South Asia. Eight hundred eighty four million people in the world still do not get their drinking-water from improved sources; Sub-Saharan Africa accounts for over a third of that number. Fresh water has become a scarce commodity due to over exploitation and pollution. Increasing

population and its necessities have led to the deterioration of surface and sub surface water².

The greatest risk to public health from microbes in water is associated with consumption of drinking-water that is contaminated with human and animal excreta³. Human faeces can contain a variety of intestinal pathogens which cause diseases ranging from mild gastro-enteritis to the serious dysentery, cholera and typhoid. The most predominant waterborne disease, diarrhea, has an estimated annual incidence of 4.6 billion episodes and causes 2.2 million deaths every year⁴. Children are the main victims of diarrhea and other faecal-oral disease, and also the most likely source of infection⁵.

Total and fecal coliforms have been enumerated from various water sources⁶. The presence of fecal coliforms indicates the contamination of water with fecal material than may contain pathogenic organisms. These indicator bacterial were found to be more common in unprotected water sources than protected water sources⁷.

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Ethiopia is characterized by lower water supply and sanitation coverage. It is estimated that 62.7% of the Ethiopian population relies on unimproved water sources and more than 80% of diseases in Ethiopia are attributed to poor access to clean water and sanitation⁸. The problem is more serious in rural area where the majorities of the people do not have access to potable water and therefore, depend on well, stream and river water for domestic use¹. In the rural area where the study was conducted, there is insufficient amount of water during the dry season and hence, people are forced to fetch water from unimproved sources, travelling 2 km away from their homes. Even though certain households have pit latrines, they are poorly constructed and many people practice open defecation in places including those nearby the water sources.. There is also intensive farming in the area and farmers introduce domestic animals in the field where drinking water are available. There is also no proper damping of animal wastes. Garbage and liquid waste are disposed in the surrounding field as well. These situations may lead to contamination of water sources.

Five hundred ninety one diarrheal cases were reported in the study area from July to December 2011. Among these, 305 were children (Personal Communication with District Health Officer). Despite these health hazards, no study has been done on the bacteriological and physico-chemical quality of waters in this area. Hence, the aim of this study was to analyze the bacteriological and physico-chemical quality of drinking water from seven different water sources found in the rural areas of Northwest Ethiopia.

Methods

Description of the study area

The study was conducted in rural part of Northwest Ethiopia located 810 Km from the capital Addis Ababa. The area is located between 12°27'37½ - 12°38'27½ North latitude and 36°57'30½ - 37°10'06½ East longitude with an elevation range between 1860 – 2240 m above sea level.

Water sampling and analysis

A cross sectional prospective study was conducted in rural areas of Northwest Ethiopia from November 2011 to February 2012 to assess the bacteriological and physico-chemical quality of water. A total of 53 water samples were collected from four sources namely: tap, protected dug well, open dug well and open spring. For bacteriological analysis,

250 ml of water sample was collected between 8:30 and 10:30 am with sterile glass bottle and transported to the laboratory in ice box. The number of total coliforms and thermotolerant coliforms was determined with the membrane filtration methods using Lauryl Sulfate-Broth (Blulux laboratories Ltd, India)⁹. For the determination of total coliforms and thermotolerant coliforms, incubation was carried out at 37°C and 44°C, respectively. Bacteriological analysis was done in triplicate within three hours of collection.

Temperature and pH were measured using WE30200 microprocessor; whereas, turbidity was measured using WE30140 potable turbidimeter (Singapore). Free residual chlorine, for 16 chlorinated water samples were determined using Wagtech comparator – Disc CD 109 with DPD number 1 chlorine tablets. All physico-chemical parameters were measured on site. Sanitary inspection of the water sources was also carried out using standard sanitary inspection formats and procedures⁴.

Data analysis

Data were entered, cleaned and analyzed using SPSS statistical package version 16.0. One way ANOVA was used to test if there are statistical differences in the tested parameters among the water sources. Spearman's correlation was used to check if there is correlation between bacteriological and physicochemical parameters. The results of bacteriological and physicochemical analyses were compared with national and WHO guidelines for drinking water. P-value < 0.05 was considered to indicate statistically significant association.

Results

All open springs and open dug wells, 63.6% of protected dug wells and 30% of the tap water samples had total coliform counts above the national and WHO recommended limits. Similarly 72.8% of open springs, 63.7% of open dug wells and 36.4% of protected springs had thermotolerant coliform counts above the recommended national and international guidelines (table 1).

All open dug wells and open springs were at high risk category for total coliforms and the majority of open dug wells and 27% of protected dug wells and 20% tap water had high risk categories for total coliforms. Four water samples from each of protected dug wells and open dug wells had medium risk categories for total coliforms. Regarding thermotolerant coliforms, 6 (54.5%) and 4 (36.4%) of open springs and open dug wells respectively had high risk categories (table 2).

Table 1: Comparison of the bacteriological quality of four sources of water in rural Ethiopia

Recommended levels of parameters	Results				P=value
	Tap (n=20)	Protected dug	Open dug	Open spring	
TC counts/100 ml		well (n=11)	well (n=11)	(n=11)	0.001
0	9 (45%)	-	-	-	
0.01-1.01	1 (5%)	1 (9.1%)	-	-	
1.01-9.99	4 (20%)	3 (27.3%)	-	-	
10-100	6 (30%)	5 (45.5%)	8 (72.7%)	6 (54.5%)	
> 100	-	2 (18.2%)	3 (27.3%)	5 (45.5%)	
TTC counts/100 ml					0.004
0	20 (100%)	7 (63.6%)	4 (36.4%)	3 (27.3%)	
0.01-1.01	-	3 (27.3%)	3 (27.3%)	-	
1.01-9.99	-	1 (9.1%)	1 (9.1%)	4 (36.4%)	
10-100	-	-	3 (27.3%)	4 (36.4%)	
> 100	-	-	-	-	

Table 2: Overall risk-to-health Classification of drinking water sources in rural Ethiopia

Risk category	Tap (n=20)		Protected dug well n= 11		Open dug well n=11		Open spring n= 11	
	TTC	TC	TTC	TC	TTC	TC	TTC	TC
Very low	6 (30)	13 (65)	6 (54.5)	-	-	-	-	-
Low	8 (40)	7 (35)	3 (27.3)	4 (36.4)	3 (27.3)	-	4 (36.4)	-
Medium	2 (10)		1 (9.1)	4 (36.4)	4 (36.4)	-	1 (9.1)	-
High	4 (20)		1 (9.1)	3 (27.3)	4 (36.4)	11 (100)	6 (54.5)	11 (100)

TC, Total coliforms; TTC, Thermotolerant coliforms

The mean pH of tap water, protected dug well, protected spring, open dug well and open spring were 7.5 ± 0.4 , 7.3 ± 0.4 , 7.3 ± 0.4 , 6.8 ± 0.3 and 6.7 ± 0.4 , respectively. All tap and protected dug wells met national and WHO guidelines. However, 3 (27.3%) and 5 (45.5%) of open dug wells and open springs had pH values below the recommended national and WHO limits (table 3). All water samples had temperatures above 20°C. The average temperature recorded was 22.71 ± 1.01 and ranged between 19.97-25.67°C (table 4). The minimum temperature was recorded in protected spring, whereas the maximum temperature was observed in open and protected wells. The mean turbidity values for tap water, protected dug well, protected spring, open dug well and open spring were 24.31 ± 10.26 , 0.89 ± 0.38 , 5.78 ± 5.39 , 5.5 ± 4.2 and 1.9 ± 9.9 , respectively. The Majority (90%) of tap water and 72% of open hand dug well samples had turbidity values above the

recommended WHO limits, whereas most of protected and open hand dug wells had turbidity values below the recommended values (table 3).

Table 3: Comparison of the physico-chemical quality of four sources of water with the WHO recommended values in rural Ethiopia

Recommended level of parameters	Results				P =value
	Tap water samples n=20	Protected hand dug well n=11	Open dug well n=11	Open spring n=11	
pH					0.54
>8	0	-	-	-	
6.5-8.0	20 (100%)	11 (100%)	8 (72.7%)	6 (54.4%)	
< 6.5	-	-	3 (27.3%)	5 (45.5%)	
Temperature (°C)					0.01
>20	20 (100%)	11 (100%)	11 (100%)	11 (100%)	
15.01-20	-	-	-	-	
Turbidity (NTU)					0.06
>5	18 (90%)	1 (9.1%)	4 (36.4)	8 (72.7%)	
2-5	2 (10%)	-	1 (9.1%)	2 (18.2%)	
0.1-1.99	-	3 (27.3%)	1 (9.1%)	1 (9.1%)	
0	-	7 (63.6%)	5 (45.5%)	-	
Residual FC (mg/l)*					>0.5
0.2-0.5	8(50%)				
0-0.199	8(100%)				
0	-				

*= Only for chlorinated tap water samples

Of the 16 treated water samples analyzed, 8 (50%) and 8 (50%) had residual free chlorine of 2-0.5 mg/l and of 0-0.199 mg/l respectively (table 3). The concentration of residual free chlorine in most water samples were below the recommended limit of WHO (0.2-0.5 mg/l), which indicates the inefficiency of disinfection in the distribution system. Correlation analysis among bacteriological, physico-chemical and level of risk parameters is shown in table 4.

Table 4: Correlation among bacteriological, physico-chemical and level of risk parameters

Physicochemical parameters	Bacteriological parameters	
	TC	TTC
pH	-0.52**	-0.41**
Temperature	0.09	0.08
Conductivity	-0.06	0.04
Turbidity	-0.15	0.04
Residual free chlorine	-0.37	-
Level of risk	0.60*	0.74*

* = Correlation is significant at the 0.01 level

Discussion

The results of the bacteriological quality of water sources in this study concord with the results of other studies conducted in Africa¹⁰⁻¹². The presence of significant counts of coliform bacteria in the water sources is indicative of inadequacy of the depth of the wells or a breach of sanitary integrity of the wells¹³. The presence of coliforms in groundwater indicates that microorganisms from surface water have been able to reach the aquifer as supported by studies of Payment and Locas¹⁴. The presence of total coliforms in tap water after disinfection indicates inadequate treatment³. There was statistically significant difference among water sources with respect to TC and TTC ($p < 0.05$) where the average total coliform and thermotolerant counts were relatively higher in unprotected water sources compared to protected ones. Gwimbi¹⁵ has reported a similar finding from a study done in Lesotho.

Sanitary inspection is used to identify causes of contamination and the risks of future contamination and overall assessment maintenance and operation of water sources^{4,16}. A study conducted in Uganda, showed that total sanitary risk score showed a significant relationship with level of contamination¹⁷. In this study, there was statistically significant positive correlation between coliform

counts and sanitary scores ($r = 0.817, p < 0.01$) which is an indication for sanitary inspection's being a reliable tool for risk assessment of drinking water sources. A similar degree of correlation was reported from studies done in developing countries¹⁷⁻¹⁹.

Low pH values recorded in some open springs and dug wells may be due to saturation with carbon dioxide as indicated in other studies²⁰. High temperature can favor the growth of organisms in water resources²¹. A similar study in Italy showed that the survival curves of *Aeromonas* spp. decline rapidly at low temperature (5°C), whereas survival at temperatures greater than 20°C increases²². There was statistically significant difference in temperature among the water sources ($p < 0.05$). Turbidity of water is an important parameter as it contributes to the aesthetics of water and leads to its acceptance or rejection for human consumption^{3,23}.

In areas where there is little risk of a waterborne outbreak, residual free chlorine of 0.2 to 0.5 mg/l at all points in the supply is recommended²³. Therefore, when water leaves the treatment plant, residual free chlorine of about 1 mg/l is needed for health reasons and it is recommended that such level should be maintained at points of consumption²⁴. The residual free chlorine recorded in this study is supported by a case study conducted in rural areas of South Africa²⁵. General system failures, inefficiency in disinfection and poor maintenance are some of the factors that affect the quality of water in Ethiopia²³.

The high density of indicator bacteria is therefore attributed to constructional defects, poor sanitation and existence of human activities and grazing near the water sources. The risk to health matrix of the water sources showed from high to very high risks to cause disease. The study indicates that the rural people are under severe threat to water related diseases and health risks. The continuous consumption of such polluted water could pose serious health risks especially in children, elderly and immunocompromised individuals.

Conclusion

Water sources investigated were heavily contaminated. High total coliform and thermotolerant counts and high risk scores found in the water sources suggest poor source water protection and poor sanitation conditions and practices. These findings demonstrate the need to come up with source water protection strategies for rural communities where water

treatment is not available. To this end, keeping the water sources safe by properly constructed fences, regular maintenances and supervisions of water sources and proper disposal of human and animal wastes are recommended.

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