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OCCURRENCE OF *CRYPTOSPORIDIUM* OOCYST AND *GIARDIA* CYST IN DRINKING WATER SOURCES OF THE RURAL COMMUNITIES OF DIRE DAWA ADMINISTRATIVE COUNCIL, EASTERN ETHIOPIA

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ABSTRACT

Giardia lamblia and Cryptosporidium parvum are ubiquitous protozoan parasites that affect humans, domestic animals and wildlife throughout the world and have been highlighted as significant waterborne parasitic pathogens. The present study was conducted to assess the prevalence of the two parasitic among communities using protected and unprotected water sources in three rural sites (Legedini, Adada and Legebira) in Dire-Dawa, Eastern Ethiopia from February 2011 to May2011. A total of 90 water samples from five types of water sources were collected and parasitological water quality parameters were analysized based on United State Environmental Protection Agency. Water analysis demonstrated that all water sources were contaminated by pathogenic parasites. The mean concentration of Giardia lamblia cyst and Cryptosporidium oocyst ranges from 0 to 5.6 and 0 to 6.5, respectively. In all samples, parasitic counts were above the recommended limit of WHO for drinking water quality, 0cyst/L or 0oocyst/L for parasitic whereas about 83.34% of the water samples in the three selected PAs had high risk of microbiological water quality parameters. High concentration of microbiological indicators in all water sources of this study area suggested that the presence of pathogenic organisms which constitute a threat to anyone consuming or in contact with these waters. This is due to lack of good water treatment, lack of feasible disinfection, improper water

handling practices and lack of the protection of the water sources. Consequently, protection of water sources accompanied by sanitation and hygiene promotion programs can improve the water quality of rural water sources, where disinfection is not feasible. Proper and basic sanitation, are of prime importance to deliver safe drinking water in the study site.

KEYWORDS: Dire Dawa, Drinking water sources, Microbiological quality, Giardia, Cryptosporidium.

INTRODUCTION

Morbidity and mortality due to diarrhoeal disease in developing countries is a major public health problem. Some of the recommended ways to reduce diarrhoeal disease are providing safe drinking water, safe waste removal especially the use of facilities to dispose faeces in a sanitary way and improved hygienic standard (WHO, 1992). Cryptosporidiosis, giardiasis and amebiasis are the common cause of human diarrhoeal disease worldwide, and lead to significant morbidity and mortality in the world, particularly in developing ones. It occurs both in immunocompetent and in immunocompromised individuals. The causative organism for giardiasis is *Giardia lamblia,* for cryptosporidiosis is *Cryptosporidium parvum* and for amebiasis is *Entamoeba histolytica* (WHO, 1992).

Cryptosporidium and *Giardia* are single celled microscopic protozoan parasites that cause enteric disease in humans and other mammals (Abe *et al.*, 2005). *Cryptosporidium* is a ubiquitous protozoa discovered by Tyzzer in 1907 and *Giardia* was first described by Antoine Van Leeuwenhoek in 1681 (Ford, 2005). The health importance of *Cryptosporidium* was not known till b1976, but currently becoming one of the most prevalent emerging waterborne and food borne disease in humans (Xiao *et al.*, 1998). Environmental pollution (climate change) is becoming a global concern and issues like water contamination and lack of safe and sufficient drinking water are problems that can lead to serious public health and life treat consequences. Recently, there has been a dramatic incidence of waterborne disease outbreaks caused by the protozoan parasites, *Cryptosporidium* and *Giardia* spp. transmission is sustained both by zoonotic and anthroponotic cycles (Appelbee *et al.*, 2005).

These characteristics, together with the low dose (oo) cysts required for an infection make them among the most critical pathogens in the production of safe drinking-water from surface water. For instance, the infectivity dose of the *C. parvum* oocyst can be around 132 in health individuals and it can also be as low as 30 (Dupont *et al.*, 1995). While the median dose of

infection for *Giardia lamblia* in humans reaches around 50-100 cysts, but some individuals can be infected 10 or fewer cysts. *Cryptosporidium* and *Giardia* causes diarrhea in a wide range of vertebrate organisms including humans and this is especially significant in immune compromised individuals (Watanabe *et al.*, 2005). *Cryptosporidium* is the main cause of diarrhea around the world. Especially in developing countries diarrhea is the main cause of mortality and morbidity (Kosek *et al.*, 2003). Studies indicate that *Cryptosporidium* seroprevalence in developed nations covers 25-35% where in developing nations the figure is higher ranging from 60-90% (Chen *et al.*, 2002). *Cryptosporidiosis* is one of the main causes of mortality for infants and young children in developing countries. In children the prevalence of *Cryptosporidium* in developing nations is 1.3-22% where as in developed nations it is about 0.3-4.3% (Casemore, 1990). Similar to other developing countries in Ethiopia diarrhea and HIV/AIDS are a major cause of mortality (Kosek *et al.*, 2003). *Cryptosporidiosis* accounts about 12% and 7% of children disease respectively in developing and developed nations (Chen *et al.*, 2002).

Worldwide around 1.1billion peoples have no access for adequate water, 2.2billion for proper sanitation, and 2.2million dies every year because of these problems (WHO, 2002). In Ethiopia, where water supply and sanitation services are inadequate, only 32% of the total population has reasonable access to adequate water supply. In this study area, Rural Communities of Dire Dawa, nearly 80% of the population is dependent on public water points and in-house storage of water (Dawit, 2008). The community possesses health threats including diarrhea, typhoid, cholera, and intestinal worms due to contamination of water and food, poor waste collection, overcrowded housing and insufficient water for hygiene. In AIDS patient's *C. parvum* causes diarrhea 10-16% in developed nations and 30-50% of population in developing countries. Previous studies conducted in Dire Dawa Administrative Council reported high prevalence of *Cryptosporidiosis* and *Giardiasis* among diarrheic children (Dawit, 2008). In Ethiopia studies on *Giardia* cysts and *Crypto* oocyst in humans is well documented (Halileeyesus Adamu *et al.*, 2005 Dawit Ayalew *et al.*, 2008) but on drinking water (Nigus Fikrie *et al.*, 2008) it is not studied in detail. In the recent period *Giardia* and *Crypto* are becoming an emerging pathogen (Karanis, 2006), as a result identification of these parasites in the surface drinking water samples is becoming an essential factor for public health particularly in reservoirs and public supply points. Therefore, it is essential to evaluate the status of *Cryptosporidium* oocysts and *Giardia* cysts

in drinking water systems of Dire Dawa Rural Communities. In order to determine the existing conditions of (oo) cysts in water their viability was tested.

MATERIALS AND METHODS

The present study was conducted between February and May, 2011 in three purposively selected Peasant Associations (PAs) named Legedini, Adada and Legebira, which are found in Dire-Dawa Administrative Council: (Figure 3.1). The Dire-Dawa town is located in Eastern parts of Ethiopia, which is 508 km away from Addis Ababa, capital city of Ethiopia. As previously study conducted by Dawit (2008) on the association of the parasitic infection with drinking water sources revealed that farmers in this study area are engaged in crop-livestock mixed agriculture, they are not food self-sufficient and most of the time they are dependent on donation from government and other donor organizations. The major crops cultivated by the farmers are maize and sorghum. The livestock owned by the people are mainly camels, cows, donkeys, oxen, goats and sheep. The above mentioned author further reported that in each study sites some people uses water from protected sources such as springs, boreholes, deep and shallow protected well, hand-dug wells, and others use from unprotected water sources such as surface water, river, seepage, unprotected well. The common problems of the three study sites are inadequacy of clean drinking water, lack of water for agricultural and household activities and insufficient sanitary facilities. As a result, waterborne and hygiene related diseases occur frequently (Dawit, 2008).

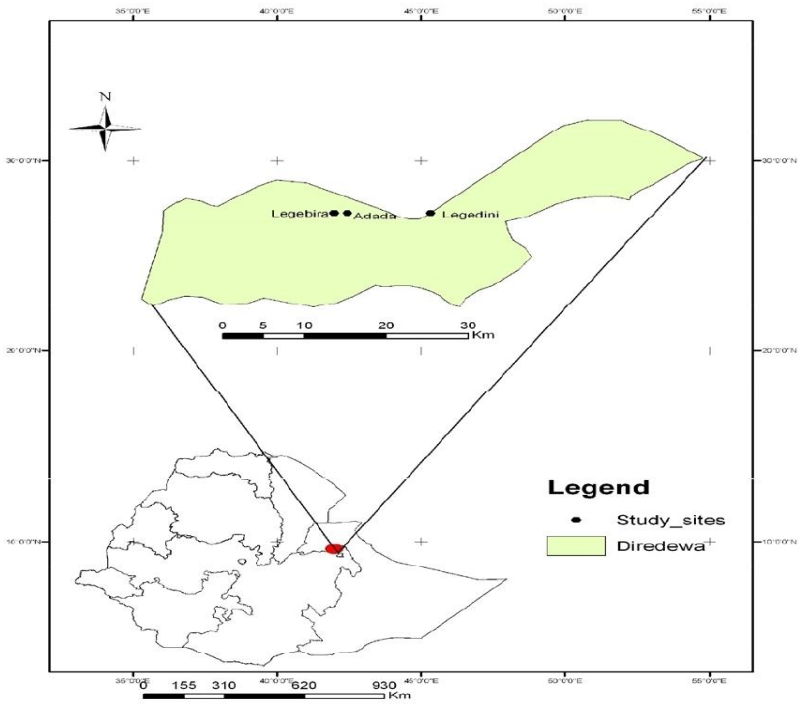

Figure. 3.1. Map of Study Area showing the location of sampling sites

The Study Design

A cross-sectional survey was conducted to determine the occurrences of pathogenic parasites (*Cryptosporidium* and *Giardia*) in rural communities in surrounding area of Dire Dawa Town. The laboratory investigation was carried out by collecting water samples from different sources during February, 2011 and May 2011.

Water Sample Collection

In each study area and sampling site the water samples were collected from five types of water sources, viz., protected well, unprotected well, protected spring, unprotected spring and tap water. That means, a total of three study areas (Legedini, Legebira and Adada), one sampling site was used in each study area; and five types of water sources were used in each study sites. Therefore in two rounds of sampling, triplicate samples of 400-600ml of water were collected from each type of water sources in each study area and sampling site. A total of 90 water samples were collected and analyzed during February and May, 2011. Samples were collected in sterilized glass bottles that were washed and rinsed thoroughly with nitric acid and distilled water. In each round of sampling, one sample was taken at the center and the other two samples from the two edges of each site. These water samples were transported to Dire Dawa water supply and sanitation laboratory for microbiological water quality analysis. The water samples were handled aseptically in sterilized glass bottled, labeled and kept in ice box during transportation.

Parasitological laboratory examination procedures

The collected water samples were first transferred to the 250ml bottle and the cysts and oocyst was concentrated by centrifugation at 5000rpm at 4^{o}c for 15 minutes. The sediment was transfer into 15ml centrifuge tube and centrifuge at 5000rpm for 15minuties, suction the water until the sediment was 1ml. and transfer the sediment to 1ml conical centrifuge tube and centrifuge at 5000rpm for 15minuties. Preserve the sediment at 4^{o}c to investigate the presence of *Girdia lamblia* cysts and *cryptosporidium* oocyst (WHO, 1991). The parasitological water quality parameters (identification and enumeration of the *Girdial lamblia* cyst and *Cryptosporidium* oocyst were conducted based on the USEPA (USEPA, 2005).

Direct wet smear

Using an applicator (wire loop), a small portion of (2-3cm diameter) of the preserved sediment and a drop of iodine solution were place on clean slide. The sediment was mixed

with a drop of iodine solution. The mixed solution was spread over an area of approximately 2cm×1cm and the mixture of sediment and iodine solution was covered with cover slip. Finally, the cyst was examined under the microscope using 10× and 40× objectives (WHO, 1991). The cysts and oocyst were identified following the procedure of WHO parasitological laboratory examination (WHO, 1991).

Modified Ziehl – Nelson method

The drop of sediment was emulsify on clean slide and spread over an area of 2cm ×1cm and allows the smear to dry before fixing in absolute methanol for 10 minutes. The slide was flooded with carbol fuchsine for 20 minutes. Again, the slide was rinsed in tap water for 2 minutes and decolorized in 5% H_2SO_4 for 30 minutes and also rinsed the slide with tap water for additional 20 minutes and flood the slide with 0.3%methylene blue. Lastly, the presence of oocyst was confirmed under oil immersion objectives lenses (WHO, 1991).

RESULTS AND DISCUSSION

Parasitological Quality of Drinking Water Sources

From the recapitulate results, above (83.34%) of unprotected wells water sources, (50%-100%) from unprotected springs and protected wells, (33.34%-66.67%) from protected springs and (50%) from tap water were positive both for the presences of *Cryptosporidium* oocysts and *Girdia lamblia* cyst. In addition, as the enumeration results showed, unprotected well and protected well, unprotected spring and protected spring had the parasitic counts ranging from 0cyst/L to10 cyst/L and 0 oocyst/L to 10 oocyst/L, respectively.

Mean value of *Girdia lamblia* cyst was highest in unprotected well of Adada 5.5±0.670cyst/L, where as the lowest mean observed at the tap water of 0±00cyst/L. The mean counts of the *Cryptosporidium* oocyst was highest at Adada unprotected spring and lowest at Legebira tap water but there was no significantly different from Legebira and Adada water sources (Table 4.1). There was variation on cyst and oocyts count among the different sample with the highest count where recorded from unprotected spring (Table 4.1).

There was significant difference among the samples of Adada and the Legedini for *Cryptosporidium* oocyst, but no significant difference between Adada and Legebira. There was variation between wells, springs and tap water but there was no much difference between unprotected and protected water sources.

Table: 4.1. Parasitological analysis of five types of water sources in rural communities Dire Dawa Administrative Council during February and May 2011.

Study Site	Water sources	Number of sample examined	Occurrences of parasites	
			Girdia lamblia	*Cryptosporidium*
			Frequency (%)	Frequency (%)
Legedini	Unprotected well	6	6(100%)	5(83.34%)
	Unprotected spring	6	4(66.67%)	3(50%
	Protected well	6	3(50%)	3(50%
	Protected spring	6	3(50%)	2(33.34%)
	Tap water	6	0(0%)	0(0%)
Legebira	Unprotected well	6	6(100%)	6(100%)
	Unprotected spring	6	6(100%)	5(83.34%)
	Protected well	6	4(66.67%)	4(66.67%)
	Protected spring	6	3(50%)	3(50%
	Tap water	6	0(0%)	0(0%)
Adada	Unprotected well	6	6(100%)	6(100%)
	Unprotected spring	6	5(83.34%)	5(83.34%)
	Protected well	6	6(100%)	5(83.34%)
	Protected spring	6	4(66.67%)	3(50%
	Tap water	6	3(50%)	3(50%

Table: 4.2. Mean parasitological count (*Cryptosporidium* and *Girdia lamblia*) of water sources in Dire Dawa rural communities between February 2011 and May 2011 (n =6) (Mean ±SE).

Sites	Sources	*Cryptosporidium*	*Girdia lamblia*
Adada	Unprotected well	3 ± 0.41^{ab}	4.5 ± 0.70^{a}
	Unprotected spring	6.5 ± 0.64^{a}	1.5 ± 0.83^{b}
	Protected well	6.16 ± 0.60^{a}	1.34 ± 0.50^{b}
	Protected spring	5 ± 0.89^{ab}	0.67 ± 0.21^{c}
	Tap water	0.67 ± 0.21^{c}	0 ± 0^{c}
Legebira	Unprotected well	5.5 ± 0.67^{ab}	3.84 ± 1.72^{ab}
	Protected well	4.16 ± 2.63^{ab}	3.67 ± 1.96^{ab}
	Unprotected spring	2 ± 1.11^{b}	2 ± 1.78^{b}
	Protected spring	2.34 ± 1.12^{b}	2.33 ± 2.33^{b}
	Tap water	0 ± 0^{c}	0 ± 0^{c}
Legedini	Unprotected well	6.5 ± 1.64^{a}	3.83 ± 3.43^{ab}
	Protected well	4.8 ± 28^{ab}	3.67 ± 2.50^{ab}
	Unprotected spring	5.16 ± 2.40^{a}	5.67 ± 2.58^{a}
	Protected spring	3.33 ± 1.75^{ab}	3.5 ± 1.37^{ab}
	Tap water	0.5 ± 0.54^{c}	0 ± 0^{c}

Note: a= the highest, b= moderate, ab= between the two (a&b), c= the list i.e, the presence of absence of significance variation between the sources.

The parasitological counts in most sites were with the range of less polluted (1-10 oocyts/L or cyst/L). Moreover, most of water samples taken from spring (unprotected and protected) and well (unprotected and protected) had moderate pollution levels categorized under low risk or low pollution. While samples from the tap water had lower pollution levels, none of the other samples could be categorized under the very dangerous degree of pollution (Table 4.3).

Table: 4.3. The degree of parasitological contamination from each study sites and in five types of water sources in DDCA, 2011.

Study sites	Water sources	*Cryptosporidium* (oocyts/L)				*Girdia lamblia* (cyst/L)			
		Sanitary infection score				Sanitary infection score			
		0	1-10	11-100	>100	0	1-10	11-100	>100
Adada	Unprotected well	0(0%)	6(100%)	0(0%)	0(0%)	0(0%)	6(100%)	0(0%)	0(0%)
	Unprotected spring	1(16.67%)	5(83.34%)	0(0%)	0(0%)	2(33.34%)	4(66.67%)	0(0%)	0(0%)
	Protected well	2(33.34%)	4(66.67%)	0(0%)	0(0%)	3(50%)	3(50%)	0(0%)	0(0%)
	Protected spring	2(33.34%)	4(66.67%)	0(0%)	0(0%)	2(33.34%)	4(66.67%)	0(0%)	0(0%)
	Tap water	6(100%)	0(0%)	0(0%)	0(0%)	6(100%)	0(0%)	0(0%)	0(0%)
Legebira	Unprotected well	1(16.67%)	5(83.34%)	0(0%)	0(0%)	0(0%)	6(100%)	0(0%)	0(0%)
	Unprotected spring	0(0%)	3(50%)	3(50%)	0(0%)	0(0%)	6(100%)	0(0%)	0(0%)
	Protected well	2(33.34%)	4(66.67%)	0(0%)	0(0%)	2(33.34%)	4(66.67%)	0(0%)	0(0%)
	Protected spring	0(0%)	0(0%)	4(66.67%)	2(33.34%)	2(33.34%)	0(0%)	4(66.67%)	0(0%)
	Tap water	3(50%)	3(50%)	0(0%)	0(0%)	0(0%)	6(1000%)	0(0%)	0(0%)
Legedini	Unprotected well	0(0%)	6(100%)	0(0%)	0(0%)	0(0%)	1(16.67%)	0(83.34%)	0(0%)
	Unprotected spring	0(0%)	6(100%)	0(0%)	0(0%)	0(0%)	1(16.67%)	0(83.34%)	0(0%)
	Protected well	1(16.67%)	5(83.34%)	0(0%)	0(0%)	0(0%)	0(0%)	6(100%)	0(0%)
	Protected spring	0(0%)	0(0%)	6(100%)	0(0%)	0(0%)	1(16.67%)	0(83.34%)	0(0%)
	Tap water	3(50%)	3(50%)	0(0%)	0(0%)	3(50%)	3(50%)	0(0%)	0(0%)

Parasitological water quality analysis demonstrated that, 100% of water samples were positive with *Cryptosporidium* oocysts and *Girdia lamblia* cyst both from unprotected and protected wells and springs and the least percent was detected at tap water. In addition, the statistical analysis result demonstrated that, there was significant difference between the untreated water sources (unprotected well and unprotected spring) and treated water sources (tap water) ($p<0.001$). Similarly, as the researched conducted in Addis Ababa drinking water sources demonstrated that there is was a significant difference in concentration of *Giardia* and *Cryptosporidium* between treated and untreated water (Nigus *et al.*, 2008).

Even though ground water has lower possibilities for contamination by cysts or oocysts but it can be contaminated from surface activities through infiltration. For instance ground water (well) is usually free of *Giardia* and *Cryptosporidium* but it can be contaminated occasionally (LeChevallier *et al.*, 1995). Likewise, Karanis *et al.* (2006) demonstrated that, 11.1% of Giardia *lamblia* and 16.7% of *Cryptosporidium* were detected from the well water sources, respectively. Similarly, as the research conducted by Bakir and Watanabe, the samples from well water and underground well water were positive for the presences of *Giardia* cysts and *Cryptosporidium* (Watanabe *et al.*, 2005).

From the total collected samples, 100 % of *Girdia* from both unprotected well and unprotected spring , was detected in unprotected and protected well of the Adada and the *Cryptosporidium* was detected in springs and wells with low percent from the tap water . In contrast to this, *Girdia* was detected in 100% in Legebira springs, 83.34% in wells while the tap water of these sites has no any *Girdia* detected and the *Cryptosporidium* was detected in 100% from both springs and well except the tap water in which there was no detected *cryptosporidium*.

According to the study conducted by LeChevallier *et al.* (1995), the average concentration of *Girdia lamblia* (range 0.4-6.3) and *Cryptosporidium (*range 0.3 - 9.8) were detected. The present findings were much lower than the finding of Sigudu *et al.* (2008) that reported the concentration of more than 1,400 oocysts/10 liters and 2,700 cysts/10 liters were detected. In contrast, the mean concentration of 0.15 oocysts/l and 0.2 cysts/l recorded by Nishi *et al.* (2008). This was lower than the present study. An investigation made by Stoyanovai *et al.*

(2006) on drinking water supply contamination with *Giardia* and *Cryptosporidium* in Varna found positive with an average number of 5 cysts/liter. These differences may be resulted due to the sources of contaminations, lack of adquated water treatment and unhygienic practices near and around the water sources in this study area. Protection of water sources and treatment of water supplies have greatly reduced the microbial load in water sources (WHO, 2003).

Contrary to these, there are studies that in which either or both *Giardia* cysts and *Cryptosporidium* were not detected in treated and untreated water sources (Karanis *et al.*, 2002). These differences may be due to lack of proper water treatment, poor site selection, unhygienic practices around water sources. According to the study conducted in Addis Ababa drinking water sources by Nigus and his co-workers, untreated water source and treated water (protected and unprotected) had different concentration of *Giardia* and *Cryptosporidium* (Nigus Fikrie *et al.*, 2008).

In agreement with the research conducted in South Africa revealed that, *Giardia lamblia* and *Cryptosporidium* were detected in all (100%) raw water samples collected from selected catchments (Sigudu *et al.*, in 2008). In contrast, *Giardia* cysts was found in (50%) of samples from river water while no *Giardia* and *Cryptosporidium* were reported both in untreated water sources and municipal drinking water (Bakir *et al.*, 2003). As study conducted in Norway water sources demonstrated the presence of *Cryptosporidium* in 13.5%, *Giardia* in 9% and both parasites in 2.5% samples were detected (Robertson *et al.*, 2001). According to Nishi *et al.* (2007), 6.66%, 26.66% and 13.33% of *Giardia* and *Cryptosporidium* were found in samples from untreated water sources, respectively. In the same manner as the research reported by Karanis, 81.81% of *Giardia* and *Cryptosporidium* were detected in samples from river water (Karanis *et al.*, 2005). Research conducted by Wallis *et al.* (1996) reported that, 21% of *Giardia* was detected in raw water samples. Once more, this is lower than the present study conducted at Dire Dawa rural communities, in that above 33.34% of water samples were contaminated with *Girdia lamblia* and *Cryptosporidium.*

This variation may be due to lack of regularly treatment and protection of water sources in the study area and it had wide possibilities for contamination than that of reservoirs and tap water

which they are treated and confined in pipelines. Source water can be easily contaminated by grazing animals, animal farming and run off specially the springs. This analysis can be supported by the study conducted on microbial pollution of major rivers in Greece that indicated human interference and lack of proper pollution monitoring activities are the main factors for the contamination of rivers by *Giardia* and *Cryptosporidium* (Karanis *et al.*, 2005).

In this investigation, the mean average of the *Cryptosporidium* and *Girdia lamblia* were higher at the unprotected well and unprotected spring of the Adada sites and the lowest mean average of the *Cryptosporidium* and *Girdia lamblia* oocysts/cysts were observed at Legedini which was not significantly different from Legebira . The occurrences of *Cryptosporidium* and *Girdia lamblia* oocysts/cysts were in sighted that as there were a significance difference between the sources and the study sites. Therefore, the Adada unprotected well and unprotected spring were more polluted than the tap water while the tap water is less polluted and acceptable as the standard set by WHO water quality guidiles. In related to the sites and the water sources, Adada was more contaminated by *Cryptosporidium* and *Girdia lamblia* oocysts/cysts than the Legedini sites, but not significantly different from the Legebira sites. The Legedini water sources were less polluted by *Cryptosporidium* and *Girdia lamblia* oocysts/cysts in compare to the Adada and Legebira sites.

CONCLUSION

Giardia cyst and *Cryptosporidium* oocyst were detected in Rural Communities of Dire Dawa drinking water. The occurrence of *Cryptosporidium* was more frequent than that of *Giardia* cysts in the drinking water. The possible source of contamination of the treated drinking and source untreated water can be zoonotic and human activities such as agricultural and waste dumping around the water catchment area. This demonstrates the need for continuous monitoring of *Giardia* and *Cryptosporidium* in Rural Communities of Dire Dawa municipal drinking water. The concentrations of *Giardia* cysts and *Crypto* oocysts were highest at source (5 cysts/l and 6 oocysts/l) as compared to than reservoirs (0.15 cysts/l and 0.32 oocysts/l). Accordingly, the concentrations were higher in tap water than reservoir. The statistical test showed significant differences between the concentrations of *Giardia* and *Crypto* in treated and untreated water ($P<0.05$). The treatment plant removal efficiency for *Giardia* and *Crypto* was from 96.60% to 98.31% and 94.54% to 95.91% respectively. Hence,

this treatment plant alone was not sufficient to completely remove *Giardia* cysts and *Cryptosporidium* oocysts.

Like the concentration of the occurrence of *Giardia* and *Crypto* were higher at source (33.3%; 55.6%) than both reservoirs (5.88%; 8.82%) and public tap (12.28%; 15.65%). Viability test at the reservoirs and public tap for the *Giardia* cysts and *Cryptosporidium* oocyst revealed nonviable results. While *Giardia* cysts and *Crypto* oocysts found in raw surface water was viable, nonviable and potentially viable. In this study the water handling parameters were significantly correlated to the occurrence of *Giardia* cysts and *Cryptosporidium* oocyst.

RECOMMENDATION

As described above *Giardia* cysts and *Crypto* oocysts were detected with considerable concentrations. The removal efficiency of treatment plants was not to the required capacity to eliminate the parasites. The following recommendations are drawn in light of these facts.

- ☞ Improving the removal efficiency of the treatment plant through better filtration methods such as slow sand and membrane filtrations.
- ☞ Periodical checking the status of the *Giardia* cyst and *Cryptosporidium* oocyst in the treated and untreated raw water particularly at household level. Because conducting studies at different times help to coup with seasonal variation.
- ☞ Minimize the risk of infection through point use of: filtration, treatment (aqua-tab) or boiling drinking water.
- ☞ Detailed studies on possible sources of *Giardia* cysts and *Crypto* oocysts contamination in recreational water and food items (milk, raw and vegetables and so on) for public health concern.
- ☞ Develop simultaneous method for identifying and conducting viability test for *Giardia* cysts and *Cryptosporidium* oocysts to reduce lengthy process and ease the monitoring of drinking water qualities.

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