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Assessing the Contamination Level of water and Determination of the Major Sources of Contaminants among Rural Community of Dire Dawa Administrative Council

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Abstract

In Ethiopia, more than 75 % of the health problems the rural communities' is the communicable diseases and the problem is majorly due to lack of safe water sources and poor sanitation. The study was conducted to assess the level of contamination and as well as the determination of the major sources of contaminant in rural communities of Dire Dawa. For the present study three rural kebeles were selected like adada, legabira and legedeni. A total of 90 water samples from five types of water sources (protected and unprotected spring, protected and UN protected well, tap water) were collected and bacteriological water quality were analyzed following American Public Health Association. Water analysis demonstrated that all water sources in the study areas were contaminated with total coliforms, fecal coliform and fecal streptococcus. The average counts of TC were in the range of 1.5-133.05CFU/100ml whereas the average counts of FC were found to be 0.34-54CFU/100ml. In all samples, the TC, FC and FS counts were above the recommended limit of WHO for drinking water quality (1-10CFU/100ml for TC, 0CFU/100ml for FC, 0CFU/100ml FS) whereas about 83.34% of the water samples in the three selected PAs had high risk of microbiological water quality parameters. Fecal coliform - fecal streptococci ratios in all water sources in this study showed that 45.0% indicated enteric contamination from human wastes and 55.0% was from domestic animal wastes. 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: Drinking water sources, Total Coliform, Fecal streptococcus, fecal coliform, contamination level, sources of contaminants

1. Introduction

Access to safe water is a fundamental human need and it is the basic human right. Contaminated water jeopardizes both the physical and social health of all the communities including urban and rural areas of the peasant association. According to WHO, more than 80% of diseases in the world are attributed to unsafe drinking water or to inadequate sanitation practices (WHO, 2003). According the recent WHO, reports, about 1.1 billion people rely on unsafe drinking water sources from lakes, rivers, and open wells (WHO, 2000). In Ethiopia drinking water coverage was less than or equal to 21% for the rural, 84% for the urban and 30% for the country level. Over 60% of the communicable diseases are due to poor environmental health conditions arising from unsafe and inadequate water supply and poor hygienic and sanitation practices and the badly-behaved is more related to polluted water and improper sanitation (FDRE, MOH, 2006).

In rural areas and villages of Ethiopia, water for human consumption, drinking, washing (bathing, laundry), for preparation of food etc, is obtained from rivers, streams, shallow wells, springs, lakes, ponds, and rainfall. The main contaminants of these water sources are from human excreta because of open field defecation practices, animal waste and effluent from sewage system. Thus, the majority of rural communities use water from contaminated or doubtful sources, which expose the people to various water-borne diseases (FDRE, 2004). The use of indicator organisms, in particular the coliform group, as a means of assessing the potential presence of water-borne pathogens has been of paramount importance in protecting public health (Barrell *et al*., 2000). As the previous study conducted on the prevalence of parasitic infections among children in Dire Dawa surrounding areas revealed that, safe water supply was not available or sufficient, so people revert to unhygienic and unsafe sources of water (Dawit, 2006). Many populations of the rural communities use water for different purpose from un-protected sources like; the spring, boreholes, wells for domestic and other purpose. There is also improper household water storage and handling practices in all the villages. Therefore, this study was used to evaluate to assess the microbiological quality of water sources in rural communities of Dire Dawa Administrative council, in reference to the level of contamination and major sources of contaminations.

2. Materials and Methods

2.1 Study area and period

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. A cross-sectional study was conducted to determine the contamination level of water sources and laboratory investigation was carried out by collecting water samples from different sources during January, 2011 and July 2011.

2.2 Sample Collection

The water samples were collected from five types of water sources, viz., protected well, unprotected well, protected spring, unprotected spring and tap water. A total of 90 water samples were collected and analyzed during January, 2011 and July 2011 and the samples were transported to Haramaya University, Biology Department.

2.3 Bacteriological analysis

The membrane filter technique was used for the present study and the samples were analyzed for total coliform (TC), faecal coliforms (FC) and fecal streptococcus using the membrane filter technique as outlined by the APHA (1998). Using sterile forceps, a sterile membrane filter paper (0.45µm pore sizes, 47mm in diameter, sterile) was placed on the membrane filter support assembly. The filtrate water samples were immediately placed on Membrane Lauryl Sulphate broth with a rolling motion to avoid entrapment of air in Petri dishes. Finally, the prepared culture dishes were incubated for 18 to 24hrs at 37^0C. Up on completion of incubation period, typical coliform colonies (yellow colour) were seen on the surface of membrane filter paper. All yellow colonies extending on the membrane were counted with the aid of a magnifying lens and recorded as total coliform (APHA, 1998).

2.4 Enterococcus and fecal Streptococcus

For isolation of *Entrococcus* and fecal *Streptococcus*, typical colonies from mEntrococcus agar membrane were streaked on the surface of brain-heart infusion agar plate and incubated at 35°C for 24h. A loopful growth from a well-isolated colony on brain-heart infusion agar was transferred to brain-heart infusion broth tube and to each of two clean glass slides. The

brain-heart infusion broth was incubated at 35°C for 24h. A freshly prepared 3% hydrogen peroxide was dropped to the smear on a slide and detected. A loopful of growth from the brain-heart infusion broth was transferred to bile esculin agar (was prepared according to the direction of APHA, 1998) and incubated at 35°C for 48h, and brain-heart infusion broth with 6.5%NaCl and incubated at 35°C for 48h. Typical colonies from mEntrococcus agar membrane were streaked, prepared for epiflourescence microscope and seen as diploid and small chain coccid shape cells, which is a typical characteristic of the indicator group (e*ntrococcus/streptococcus*).

2.5 Determining the level of contamination and sources of contaminants.

To examine the contamination level of the water sources, sanitary inspection was conducted and the range of the total coliform was ranked as the WHO guide line and based on the ration of fecal coliform to fecal streptococcus the major sources of contamination was determined.

3. Results and Discussion

Bacteriological Quality of Drinking Water Sources

Bacteriological analysis of water samples from the five sources (protected spring, unprotected spring, protected well, unprotected well and tap water) in three sites of Dire Dawa Rural Communities showed that all samples of water sources from each site (Adada, Legedini and Legebira PAs) were positive for total coliforms and faecal coliform in two rounds of triplicate sampling. Indicator bacteria were encountered in all samples from water sources of the study area. Less frequent of indicators organisms were observed from the tap water (Table 4.1a).

The results indicated that all (100%), majority (83.34%) and half (50%) of water samples collected from spring (protected and unprotected), well (protected and unprotected) and tap water sources, were positive for TC, respectively. In addition, enumeration results showed that 66.66% and 33.34% of the unprotected well had TC counts ranging from 11-100 CFU/100ml and above 100 CFU/100ml, respectively (Table 4.1a). The TC count (133.67±21.25 CFU/100ml) was recorded from Legedini unprotected well (Table 4.1a). There was a significant difference among the samples of Adada and the Legedini for TC, but no significant difference was observed between Legedini and Legebira. There was significant difference among the samples of spring, well and tap water sources where as no significant difference between unprotected and protected water sources for TC and TTC/FC (Table 4.1b).

Total Coliforms (TC)

The TC counts were ranging from 1.50±0.71CFU/100ml to 133.67±21.25 CFU/100ml with the lowest and the highest range corresponding to TC counts from samples of Legedini unprotected well and Adada tap water, respectively. The fact that Legedini (133.67±21.25 CFU/100ml), Legebira (110.34±27.43CFU/100ml), and Adada (81.34±8.07 CFU/100ml) from unprotected well contained the highest TC counts reflects that there were high human activities (laundering and bathing activities) and unhygienic practices that leads to the contamination of the water sources (Table 4.1b). The patterns of TC counts showed that, the Legedini water sources were more polluted), followed by Legebira water sources whereas Adada water sources were the least compared to others.

Table 4.1a.Bacteriological analysis of five types of water sources in Dire Dawa communities during February and May 2011**.**

Study sites	Water sources	Number of Samples examined	Occurrences of indicators bacteria		
			Total coliform	Fecal colform	Fecal Streptococcus
			Frequency (%)	Frequency (%)	Frequency%
Adada	Unprotected well	6	6(100%)	6(100%)	5(83.34%))
	Unprotected spring	6	6(100%)	6(100%)	5(83.34%))
	Protected well	6	5(83.34%)	5(83.34%)	4(66.67%)
	Protected spring	6	5(83.34%)	4(66.67%)	4(66.67%)
	Tap water	6	3(50%)	2(33.34%)	2(33.34%)
Legebira	Unprotected well	6	6(100%)	6(100%)	6(100%)
	Unprotected spring	6	6(100%)	6(100%)	6(100%)
	Protected well	6	6(100%)	5(83.34%)	5(83.34%)
	Protected spring	6	6(100%)	4(66.67%)	4(66.67%)
	Tap water	6	4(66.67%)	3(50%)	3(50%)
Adada	Unprotected well	6	6(100%)	6(100%)	6(100%)
	Unprotected spring	6	6(100%)	6(100%)	6(100%)
	Protected well	6	6(100%)	6(100%)	6(100%)
	Protected spring	6	6(100%)	5(83.34%)	5(83.34%)
	Tap water	6	44(66.67%)	3(50%)	3(50%)

Table 4.1b.Mean bacteriological count (total Coliform, Thermotolerant/fecal Coliform) of water sources in Dire Dawa rural communities between February 2011 and May 2011 (n =6) (Mean ±SE).

Sites	Sources	Total Coliform	Fecal Coliform	Fecal Streptococci	FC/FC
Adada	Unprotected well	81.34±8.07	33.33±8.80	11.33±8.80	3.10
	Unprotected spring	64.5±8.61	21.16±6.2	6.46±6.2	3.20
	Protected well	67.83±14.00	18±7.68	22.5±7.68	1.80
	Protected spring	59.17±6.66	15.34±6.59	3.34±6.59	5.60
	Tap water	1.5±0.71	0.34±0.2	0.34±0.2	0.00
Legebira	Unprotected well	110.34±27.20	51±11.90	17±11.90	3.12
	Protected well	80±17.07	33.5±6. 73	11.5±6. 73	3.21
	Unprotected spring	100±14. 3	26.5±9.12	25.5±9.12	1.25
	Protected spring	79.34±10.11	29.67±9.15	5.8±9.15	5.00
	Tap water	5.66±0.61[d]	1.5±0.20	1.5±0.20	1.00
Legedini	Unprotected well	133.67±21. 25	45.5±12.00	14.5±12.00	3.0
	Protected well	99.5±13.72	54.83±11.84	18.83±11.84	3.12
	Unprotected spring	120.16±23.73	25.83±7.03	5.4±7.03	1.56
	Protected spring	90.5±13.79	26±9.05	5.3±9.05	5.4
	Tap water	4±0.50	1±0.36	1±0.36	1.00

Table 4.1c.The degree of bacteriological contamination from each study sites and in five types of water sources in DDAC, 2011.

Study sites	Water sources	Total coliform CFU/100ml				Thermotolerant/ Fecal coliform CFU/100ml			
		Sanitary infection score				Sanitary infection score			
		0	1-10	11-100	>100	0	1-10	11-100	>100
Adada	Unprotected well	0(0%)	0(0%)	6(100%)	0(0%)	0(0%)	0(0%)	6(100%)	0(0%)
	Unprotected spring	0(0%)	0(0%)	6(100%)	0(0%)	0(0%)	2(33.34%)	4(66.67%)	0(0%)
	Protected well	1(16.67%)	0(0%)	5(83.34%)	0(0%)	1(16.67%)	1(16.67%)	4(66.67%)	0(0%)
	Protected spring	1(16.67%)	0(0%)	5(83.34%)	0(0%)	2(33.34%)	1(16.67%)	1(16.67%)	0(0%)
	Tap water	3(50%)	3(50%)	0(0%)	0(0%)	4(66.67%)	2(33.34%)	0(0%)	0(0%)
Legebira	Unprotected well	0(0%)	0(0%)	3(50%)	3(50%)	0(0%)	0(0%)	6(100%)	0(0%)
	Unprotected spring	0(0%)	0(0%)	3(50%)	3(50%)	0(0%)	3(50%)	3(50%)	0(0%)
	Protected well	0(0%)	0(0%)	3(50%)	3(50%)	1(16.67%)	0(0%)	5(83.34%)	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	0(0%)	6(1000%)	0(0%)	0(0%)	0(0%)	6(1000%)	0(0%)	0(0%)
Legedini	Unprotected well	0(0%)	0(0%)	2(33.34%)	4(66.67%)	0(0%)	1(16.67%)	5(83.34%)	0(0%)
	Unprotected spring	0(0%)	0(0%)	1(16.67%)	5(83.34%)	0(0%)	1(16.67%)	5(83.34%)	0(0%)
	Protected well	0(0%)	0(0%)	3(50%)	3(50%)	0(0%)	0(0%)	6(1000%)	0(0%)
	Protected spring	0(0%)	0(0%)	3(50%)	3(50%)	0(0%)	0(0%)	6(1000%)	0(0%)
	Tap water	0(0%)	6(1000%)	0(0%)	0(0%)	2(33.34%)	4(66.67%)	0(0%)	0(0%)

Keys: 0CFU/100ml=safe, 1-10CFU/100ml=reasonable quality, 11-100CFU/100ml=polluted and >100cfu/100ml=dangerous (WHO, 2004a, FDRE, WRM, 2002).

Table 4.1d.The degree of bacteriological contamination from each study sites and in five types of water sources in DDAC, 2011 Continued

Study sites	Water sources	Fecal Streptococcus			
		Sanitary infection score			
		0	1-10	11-100	>100
Adada	Unprotected well	0(0%)	0(0%)	4(66.67%)	0(0%)
	Unprotected spring	0(0%)	1(16.67%)	3(50%)	0(0%)
	Protected well	0(0%)	1(16.67%)	3(50%)	0(0%)
	Protected spring	0(0%)	1(16.67%)	1(16.67%)	0(0%)
	Tap water	0(0%)	0(0%)	0(0%)	0(0%)
Legebira	Unprotected well	0(0%)	0(0%)	3(50%)	0(0%)
	Unprotected spring	0(0%)	1(16.67%)	2(33.34%)	0(0%)
	Protected well	1(16.67%)	0(0%)	2(33.34%)	0(0%)
	Protected spring	1(16.67%)	0(0%)	3(50%)	0(0%)
	Tap water	0(0%)	0(0%)	0(0%)	0(0%)
Legedini	Unprotected well	0(0%)	0(0%)	2(33.34%)	3(50%)
	Unprotected spring	0(0%)	0(0%)	1(16.67%)	3(50%)
	Protected well	0(0%)	0(0%)	2(33.34%)	2(33.34%)
	Protected spring	0(0%)	0(0%)	2(33.34%)	2(33.34%)
	Tap water	0(0%)	0(0%)	0(0%)	0(0%)

Fecal coliform/fecal *Streptococcus* ratios

Following the concept of this ratio is not reliable if the contamination of fecal streptococci is less than 100 CFU/100 ml (APHA, 1998). Hence, FC/FS ratios were computed only for sites with mean FS counts ≥100cfu/100 ml water samples. To differentiate the sources of contamination the method of (Coyne and Howell, 1994) was used.

FC/FS< 0.1 - the ratio less than 0.1 for wild life wastes.
0.1≤ FC/FS ≤ 4 - the ratio between 0.1 and 4.0 for domestic animal waste.
FC/FS >4 - the ratio greater than 4 for human wastes

With this definition among the considered FC/FS ratios in all spring sites pollution could be derived from livestock wastes. While, results of FC/FS ratios in the remaining sites of the river were not considered due to the mean FS counts were less than 100cfu/100 ml water samples. The degree of bacterial pollution in the water samples was very high. The bacteriological counts in most sites were in the dangerous range of pollution for drinking (101-1000 CFU/100 ml). None of the water sources were found to be safe for drinking. Moreover, most of water samples taken from spring had very high pollution levels categorized under dangerous and very dangerous. While samples from the upper river site had lower pollution levels, none of the other samples could be categorized under the very dangerous degree of pollution.

With regards to thermotolerant (faecal) coliforms, all water samples (100%) were found to contain thermotolerant (faecal) coliforms in the range of 0.34-54 CFU/100ml with significant variation at $p<0.0001$ (Annex III). The highest and lowest levels of thermotolerant (faecal) coliforms, i.e., 54 CFU/100ml and 0.34 CFU/100ml, were recorded from Legedini protected well and Adada tap water, respectively. The high level of coliform count recorded in this study may be attributed to the high degree of contamination of the water sources due to unhygienic practices around and near water sources. From all the study sites, the highest TTC/FC count was recorded from Legedini PAs followed by the lowest counts from Adada PAs. The largest TTC/FC count (54CFU/100ml) was recorded from Legedini protected well followed by 51CFU/100ml and 33CFU/100ml from water samples of Legebira and Adada (unprotected well), respectively. Therefore, all water sources except tap water were polluted by TTC/FC.

All samples of the water sources in this study were contaminated with total coliforms. Except the water samples from the tap water that had 50% contamination , all the others had 100% contamination with total coliforms. Out of these, 100% of the samples from unprotected well and protected well, 83.34% the sample from unprotected spring and protected spring had unacceptable levels of total coliforms according to the suggested criteria for drinking water sourses (WHO, 2004a; FDRE, MoH, 2002). Likewise, all water sources were 100% contaminated with thermotolerant (faecal) coliforms, except the sample from tap water, which had only 50% of contamination level. Similarly, 100% of the samples from unprotected well and protected well, 83.34% from unprotected and protected spring were contaminated by thermotolerant (faecal) coliforms. A similar study conducted by Getnet (2008) from Bahir Dar town showed that 100% of the analyzed water samples from the source had a mean total coliform count of 35.5CFU/100ml which is above the acceptable level recommended by WHO (2005). This is much lower than the present study. This difference may be due to the site selection, inadequate protectation of water sources and unhygienic practices near the water sources (Richards, 1996).

According to the study conducted by Mengesha in North Gonder ,out of the seventy analyzed protected spring and protected well water samples, 71.43% and 28.6% had levels of total coliform (TC) and faecal coliform /thermotolerant(TTC/FC) count, respectively and the author also further demonstrated that, 50% of the samples had a coliform count of 180 and above /100 ml and the lowest coliform count was 13 coliform /100 ml (Mengesha *et al*., 2004), which was higher than the present study that was 133.65 coliform /100 ml and the lowest total coliform 1.50 coliforms/100ml. In another study in South Wello, Ethiopia, Atnafu demonstrated that 75% of the samples from protected springs were contaminated with total coliforms (Atnafu, 2006). This was less than the present study, where all water sources were contaminated with total coliform. As the research conducted in Yubdo-Legebatu by Birhanu (2008) indicated that, all the water samples were contaminated by the total coliform in which the highest total colifrom was 1447.47 coliform/100ml and the lowest coliform was 193.8 coliform/100ml and this was also much higher than the present study. This difference may be due to the lack of water sources protection in the case of Yubdo-Legebatu and not in case of Dire Dawa Rural Comunities. In contrast, results of monitoring six sampling stations in the Geum River in Korea showed average concentrations of total coliforms ranging from 1670 to 8510 CFU/100 ml (Geonha *et al*., 2005). This was higher than the present study and the possible reasons for this variation might be differences in dilution and sources of contaminants.

Alternatively, as the research conducted in Debrezeit town (Desta, 2009) from all water source samples (100%) were contaminated by TC to the range of 1-4 coliform/100ml, but within the acceptable limit of 1-10coliform/100ml set by WHO (1997). In a similar study conducted on rural hand-dug pump well water from South Wello, Atnafu (2006) reported that 50% of the underground wells contain TC counts of 3.3CFU/100ml. This had lower range of total colifrom than present study, but the (100%) of water samples contain total coliform. This indicates that the degree of risk factors for the contamination of water sources in Rural Communities of DDAC is tremendously increasing due to uncontrolled waste disposal and inadequate water treatment around the water sources (Tamiru, 2001).

ANOVA of total coliform concentration among all sources demonstrated that there was a significant difference ($p< 0.001$) in the average counts of TC between the water sampling sources and sites .Total coliforms in unprotected spring and unprotected well of the Legedini were significantly higher than in all other sources of all sites. Moreover, there is poor sanitation and unhygienic practices near the water sources. In addition drawing water is done using unclean cups and cans, while there is also open access for livestock and wildlife. All these factors might be possible reasons for the high concentrations in total coliforms in this site. This result was supported by questionnaires survey on households' water handling practices.

Unprotected wells and springs demonstrated that 100% of the samples taken from both sources were contaminated by total coliform and fecal coliforms. In addition, analysis of the water samples from the protected spring and wells demonstrated that 100% of the water sources were contaminated by coliform. These results were supported by the research conducted by Mengasha and his co-worker in Goder (Mengasha *et al*., 2004). Analysis of protected springs confirmed that 71.43%, of the samples had indicator bacteria that are lower than the present study (Mengesha *et al*., 2004).

The variance analysis of fecal coliform concentrations among all sources showed that there was a highly significant difference ($p < 0.001$) in the average counts of TTC /FC among all water sites and sources. Mean thermotolerant (fecal) coliform levels in unprotected well of Legebira were significantly higher than in all other sources and sites. Fecal coliforms are indicators of fecal contamination. Hence, categorizing the site in terms of risk to human health, the majority, above (66.67% of sampled water sources in the study area were at high risk.

Bacteriological contamination of water from various sources is commonly due to the lacks of water treatment, good sanitation, good management of water sources, environmental sanitation etc. In South Australia, Esterman *et al*. (1984) surveyed 100 water samples finding 18% of the water sources with at least one unacceptable bacteriological result, but no significant difference between wells and springs was observed. In all cases there was no significance difference between unprotected sources and protected sources in the wells and in spring because, the wells and springs were not properly protected. The spring was not properly covered by stone masonry with one or two boxes and the well was not properly covered by stone masonry (WHO, 1983).

Based on the concept of using ratios between fecal coliform and fecal *Streptococcus* counts to determine the main sources of pollution (Coyne and Howell, 1994), ratios of FC/FS were computed for the study area as summarized in Table 2. Only for those cases where streptococci were equal and above 100cfu/100ml (APHA, 1998). Fecal coliform - fecal streptococci ratios in water sources that had streptococci counts equal and above 100cfu/100ml showed that in 100% of indicated enteric contamination originated from domestic animal wastes. The origin of the bacteria was observed to be livestock wastes, from the numerous settlements situated throughout the watershed characterized by existence of the livestock that have free access to the water sources, graze nearby water points and improper sanitary facility. A similar study in Lebanon and Syria to quantify the fecal coliform to fecal streptococcus ratios sampled for three periods were 1.4 in spring and 1.1, 6.7 and 16.7 in river (Monzer *et al*., 2005), the interpretation of which concurs with this study.

Conclusion and Recommendation

Based on the research findings, the following conclusions have been drawn:

- ☞ Bacteriological quality of the sampled water sources in study area did not meet national or international guidelines for drinking water.
- ☞ The overall bacterial count and sanitary risk factor assessment indicated that the majority of water sources in Dire Dawa Rural Community could be classified as high risk, while some were at intermediate risk and very few water points had reasonable quality.
- ☞ High counts of indicator organisms in all sampled water sources of the study area suggested the presence of pathogenic organisms that constitute a threat to anyone consuming these water sources.
- ☞ The contamination of these water sources with enteric organisms can be explained in part by absence of fencing of watering points that could prevent the entrance of animals, livestock grazing nearby water sources, people's open area defecation, drawing of water with unclean cups and agricultural activities nearby water sources.
- ☞ Fecal coliform - fecal streptococci ratios in this study showed that while human contribution was in place the main sources of contaminants of the water sources could be livestock wastes.
- ☞ Finally, the baseline information generated from this study may contribute to develop similar programs for further studies.

Recommendations

Based on the results and conclusions of this study, the following recommendations are formulated:

- ✓ As indicator bacterial counts in all sampled water sites have exceeded the guidelines set for human use there is, clearly, an urgent need to develop safe water supplies and basic sanitation in the area.
- ✓ Wastes from both livestock and human were found to be causes of the problem, so minimizing fecal contamination of water with livestock and human wastes will have a dramatic impact on reducing water sources pollution in the study area.
- ✓ Priority should be given to create awareness in the community of measures to improve hygiene, such as to develop a habit of using latrines, which is indispensable for improved water quality. Defecation of people around water points should be corrected.
- ✓ Measures have to be taken to divide the water sources for human and livestock uses.

- ✓ Entrance of animals into water sources for human use should be protected by fencing the surroundings.
- ✓ Springs should be cleaned by emptying them and removing any sediment and vegetation. Constructing covers over springs will protect them from free inflow of contaminants.
- ✓ Enabling the community to develop and use this method or other home water treatment techniques is crucial.
- ✓ Protection of water sources accompanied by sanitation and hygiene promotion programs can improve the hygiene quality of rural water sources, where disinfection is not feasible.
- ✓ Hygiene education is an essential part of water supply and sanitation projects.
- ✓ Future studies are needed to determine the seasonal variations in the contamination level of the water sources, to quantify pathogen loads in both the water sources and livestock feces and to develop risk-reducing livestock management systems.

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