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Assessment of the Effect of Season and Location on Microbiological and Physicochemical Quality of Livestock Drinking Water in Ginchi Watershed, Ethiopia

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Abstract: This study was conducted at Ginchi watershed in Oromia Regional State, Ethiopia to evaluate the physical, chemical and microbiological quality of livestock drinking waters during dry, short rain and wet seasons. Purposive sampling technique was used to obtain samples. Data were collected and analyzed using descriptive statistics. The analysis showed that the overall mean concentrations (mg/l) were 298.33 TDS, 8.0 pH, 15.78 Na, 2.9 K,128.22 $CaCO_3$, 40.89 Ca, 6.32 Mg, 0.26 F, 5.38 Cl, 0.03 NO_2, 5.68 NO_3, 2.67 CO_3, 146 alkalinity, 172.83 HCO_3, 3.42 SO_4 and 0.07 boron. The pH of the water was basic, ranging from 7.8 to 8.2, which is within the normal range for pH in surface water systems (6.5 to 8.5). The waters exhibited a general ionic dominance pattern of Ca > Na > Mg > K. The water was moderately hard to hard (range of hardness 80–170 mg/l CaCO3) with high turbidity due to traditional farming practices, which resulted in large quantities of topsoil runoff ending up in the river after rains. Trace metal levels were low suggesting low metal contamination of the rivers. The dominance of chloride over sulphate could probably be due to domestic activities resulting from fertilizer use, household effluents and other anthropogenic point sources. The TDS varied ($P<0.05$) between dry, short rain and wet seasons. The wet season showed significantly ($P<0.05$) lower value for hardness. Ca varied ($P<0.05$) between short rain and wet seasons, as well as between wet and dry seasons. Alkalinity varied ($P<0.001$) markedly between wet and dry seasons and between short rain and wet seasons ($P<0.05$). A significant ($P<0.05$) variation was also observed for bicarbonate between short rain and wet and wet and dry seasons. Effect of location was significant for K between low and high altitudes. The overall mean total coliform level was 1101.73±114.99 cfu/100 ml. Total coliform count was higher ($P<0.05$) in wet season and no variation ($P>0.05$) was observed between locations. From results of this study, the microbial quality of water was observed to be poor due to direct contamination by animal and human excreta and other activities such as washing of clothes. From both livestock and human health point view, consumption of this coli- form polluted water should be avoided.

Key words: Coliforms · Domestic · Livestock · Microbiological · Physicochemical · Water

INTRODUCTION

Water is a critical nutrient for livestock. As with feed ingredients, livestock water should meet the nutritional needs of the animal. An adequate and safe water supply is essential to the production of healthy livestock [1]. Water that adversely affects the growth, reproduction, or productivity of livestock and poultry cannot be considered suitable. Although water is normally considered as H_2O, all natural waters contain varying amounts of other materials in concentration ranging from a few milligrams per liter in rain to about 35,000 mg/l in seawater [1]. The quality of surface water is governed by its content of living organisms and by the amount of mineral and organic matters, which it may have picked up in the course of its transportation [1]. As rain falls through the atmosphere, it collects dust and absorbs oxygen and carbon dioxide from the air. While flowing over the ground, surface water collects silt and particles of organic matter, some of which will ultimately go into solution. It also picks up more carbon dioxide from the vegetation and microorganisms and bacteria from the

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topsoil and from decaying matter. On inhabited watersheds, pollution may include fecal material and pathogenic organisms, as well as human wastes, which have not been properly disposed off. In most instances, surface water is subjected to pollution and contamination by pathogenic organisms and cannot be considered safe without treatment [2].

Regardless of the availability of water, minimum quality standards apply, depending on the use of the water (human consumption, irrigation, or livestock). Contamination most often caused by salts dissolved in the water. The most common of this are sodium, calcium and magnesium salts. Solid particles suspended in the water decrease its attractiveness and usefulness in certain applications [3]. Water quality is affected by total soluble salt concentration, the presence of some salts specifically toxic to animals even in low concentration and possible contamination with disease producing microorganisms or their spores. It will be usable if its salinity does not lead to functional problems and if it does not contain germs or parasites [4]. Microorganisms are of considerable importance in many aspects of water quality control. They are responsible for diseases. Drinking water can be the vector of viral, bacterial and parasitic diseases [1, 4]. A number of livestock parasites may spend part of their life cycle in or near water, such as protozoa, flukes, flat worms and round worms [5]. The total coliform level per milliliter of water is an indication of the presence of pathogens. In bacteriological analysis, the presence of total coliform bacteria like Escherichia coli and total coliforms are looked for as an indirect evidence of pollution. Although, these total coliforms, which are intestinal flora, are not harmful by themselves but their presence is an indicator of fecal pollution from external sources [6].

There is scanty information on physicochemical and microbial quality of water sources for domestic and livestock use in the study area. Therefore, the aim of the present study was to evaluate the physicochemical and microbial quality of livestock drinking water at the Ginchi watershed, Ethiopia.

MATERIALS AND METHODS

Site Selection and Sample Collection: The study area was surveyed and sites where samples are to be taken were identified. A non-statistical approach for locating sites was used, wherein sites were purposely selected at major livestock watering points and domestic uses. A total of three composite water samples from 60 sampling sites (20 from each land type and for each season) during each season were collected in 2000ml polyethylene bottles thoroughly cleaned and rinsed with deionised water in duplicates for assessment of physicochemical quality tests following water sampling procedures [7]. All samples were submitted to the Ethiopian Water Works Design and Supervision Enterprise, Water Quality Laboratory for chemical analysis. For the bacteriological analysis 22 water samples [two from land type A (low altitude), four from land type B (medium altitude) and sixteen from land type C (high altitude)] were collected in 2000ml sterilized glass bottles, following water sampling procedures [7] and were submitted to the Ethiopian Health and Nutrition Research Institute for bacteriological analysis.

Sampling Frequency: Fixed stations were sampled three times; once in April representing the small rainy season, July representing the main rainy season and November representing the dry season. For bacteriological analysis stations were sampled during November and December representing dry season, March and April representing small rain season and July and August representing the main rainy season.

Laboratory Analyses: The physicochemical parameters were determined according to procedures outlined in the Standard Methods for the Examination of Water and Waste water [8]. The pH was read on calibrated Beckman's 050 pH meter. The total dissolved solid (TDS) were measured by evaporating the sample by a steam bath and dried at 105°C and was measured using an analytical balance. The Sodium and potassium were determined by flame emission photometry, Ca and Mg were determined using EDTA titrimetry, trace metals by atomic absorption spectrophotometer. Fluoride by SPADNS, 580 nm method, total dissolved solids was measured gravimetrically after drying in an oven to a constant weight at 105°C. Fluoride was determined using SPADNS 580 nm. Chloride was run using Argentometric method. Nitrite was determined by Diazotization, 507 nm, Nitrate using Cadmium reduction, 500nm, alkalinity by acid titration to pH 4.5 and sulphate was determined using the Nephelometry method. Total coliforms were determined using 100 ml of water aseptically filtered through a nitrocellulose filter. The filters were then layered on endoagar. Twenty four hours later the number of visible bacteria colonies were counted. Further test were conducted on those membranes that had visible bacteria colonies. To do this, 10 ml of Laury tryptose broth (35.6 mg/l) were inoculated by about 10 viable colonies and the mixture was incubated at 37°C for 24 hours and counts were made using a colony counter.

Statistical Analysis: The data were analyzed using Statistical Package for Social Sciences (SPSS, version 10.0) computer software. It involved descriptive statistics such as mean, percentile and standard deviation for the different variables. A paired sample T-test was performed for seasons and locations. Statistical significance was accepted at $p<0.05$ and 0.01. All data were expressed as mean ± SE.

RESULTS AND DISCUSSION

Physicochemical Quality: The overall mean concentrations of the physical and chemical concentrations of livestock drinking water sources in the Ginchi watershed are shown in Table 1. The mean concentrations of TDS was 298.33±20.63 mg/l. The TDS of water in the Ginchi watershed may be considered satisfactory for all classes of livestock of 3,000 mg TDS per liter [9]. The World Health Organization [10] recommended guideline for normal value of TDS for drinking water 1000 mg/l. The overall average value of pH was 8.05 ranging from 7.8 to 8.2 and is more or less within the range of 6-8 as recommended by WHO [10]. NRC [9] indicated that natural waters are known to have a pH value generally in the range of 6 – 9 and as a factor in itself does not directly affect animal nutrition, but it does serve to screen water that may create problems, particularly when the value lies out side the 6-9 range.

In the present study, the mean hardness value as $CaCO_3$ was 128.22±10.24 mg/liter. Most surface waters have hardness values of less than 1,000 mg per liter and hardness per se is not a problem in livestock drinking water but generally the concentrations of individual ions that may be nutrient or toxicant are important [12]. Hardness is classified as soft (0-60mg/l), moderately hard (61-121mg/l), hard (121-180mg/l) and very hard (>180mg/l) [9]. Blosser and Soni [11] in an experiment with lactating cows, found no difference in performance when the cows were offered hard or soft water.

The mean values for fluoride, chloride, nitrite, nitrate, alkalinity, carbonate, bicarbonate, sulfate and boron were 0.26, 5.38, 0.03, 5.68, 146.11, 2.67, 172.83, 3.42 and 0.07 mg/liter, respectively. King [12] reported that the safe upper limit of concentration of fluoride in drinking water for livestock is 2mg/ liter. NRC [9] indicated that 11.8, 5-10, 10 and 20 mg per liter of fluoride causes mottled teeth in cattle & sheep, decreased wool production in sheep and decreased health, respectively. The mean concentration of nitrate obtained in this study was lower than the safe limit in livestock drinking water that is 90 to 200 mg/l [12]. The mean value for sulfate obtained in this study was lower than the safe limit in stock drinking water that is 1000 mg per liter [12]. According to WHO [10] the maximum allowable concentrations of nitrate, nitrite, chloride, fluoride, sulfate and boron for drinking water for livestock are 50, 3, 250, 250, 1.5 and 0.3 mg/l, respectively.

Table 1: Over all mean of chemical concentrations (mg/l) of livestock drinking water in the Ginchi watershed, 2001.

Parameter	N	Minimum	Maximum	Mean±SE
TDS	9	215	395	298.33±20.63
pH	9	7.80	8.20	8.05±0.05
Na	9	11	25	15.78±1.36
K	9	2.2	3.7	2.91±0.17
Total hardness	9	80	170	128.22±10.24
Ca	9	28	58	40.89±3.44
Mg	9	2.43	11.19	6.32±0.93
F	9	0.08	0.54	0.26±.05
Cl	9	2.61	9.93	5.38±0.79
NO_2	9	0.01	0.08	0.03±0.09
NO_3	9	1.32	11.44	5.68±1.15
Alkalinity	9	106	180	146.11±9.72
CO3	9	0	12.00	2.67±1.47
HCO_3^-	9	129.32	219.60	172.83±10.69
SO_4^{2-}	9	0.65	9.42	3.42±1.04
B	4	0.04	0.11	0.07±0.02

N= number of composite samples collected in three seasons from 60 sampling stations

The mean concentration of sodium was 15.78±1.36 mg/liter. The maximum allowable concentration of sodium for human drinking water is 200 mg/l [10] and the safe limit of Na salts in livestock drinking water is < 1,000 mg/l [9]. In this study, the overall average concentration of potassium was 2.91±0.17 mg/liter, while the mean level of calcium was 40.89±3.44 mg/l. King [14] reported that the safe level of calcium in livestock drinking water is 1000 mg/l. The overall mean magnesium values observed in the present study was 6.32±0.93 mg/l, which was lower than the recommended concentration limit of 250 to 500 mg/l in livestock drinking water [13]. SECV [14] reported that magnesium content of less than 200 mg per liter is suitable for all stock except for poultry.

The overall mean concentration of alkalinity was 146.11 mg/l. Water with alkalinities of less than 1000 mg/l is considered satisfactory for all classes of livestock and poultry [15]. In general, the values of chemical qualities obtained from water sources for livestock in the Ginchi watershed were far below the maximum allowable and toxic levels.

Effects of Season on Water Quality Parameters: The effect of season showed significant ($P<0.05$) difference between the short rain, wet and dry seasons for

Table 2: Mean concentration (mg/l) of chemical parameters of water during three seasons in the Ginchi watershed, 2001

	Short rain		Wet season		Dry season	
Parameter	N	Mean	N	Mean		Mean
TDS	3	339.67[a]	3	223.67[b]	3	331.67[c]
pH	3	8.03[a]	3	7.95[a]	3	8.16[a]
Na	3	14.67[a]	3	16.00[a]	3	16.67[a]
K	3	3.20[a]	3	2.80[a]	3	2.73[a]
Hardness	3	146.00[a]	3	90.67[b]	3	148.00a
Ca	3	49.87[a]	3	29.07[b]	3	43.73[ac]
Mg	3	5.18[a]	3	4.38[a]	3	9.41[b]
F	3	0.29[a]	3	0.26[a]	3	0.22[a]
Cl	3	7.45[a]	3	2.90b	3	5.80[a]
No_2	3	0.03[a]	3	0.05[a]	3	0.01[a]
No_3	3	5.72[a]	3	8.07[a]	3	3.25[a]
Alkalinity	3	162.00[cb]	3	110[a]	3	166.33[b]
Carbonate	3	0.00[a]	3	0.00[a]	3	8.00[b]
Bicarbonate	3	197.64[a]	3	134.20[b]	3	186.67[ac]
Sulfate	3	3.21[a]	3	5.67[a]	3	1.39[a]
Boron	-	-	3	0.07[a]	3	0.09[a]

N=number of composite samples, means within the same row with different letters are significantly different at p<0.05, 0.001

Table 3: Mean concentration (mg/l) of physical and chemical quality of water for livestock in the Ginchi watershed, 2001.

	Land type A		Land type B		Land type C		
Parameters	N	Mean		Mean	N	Mean	P-value
TDS	3	301.00	3	281.00	3	313.00	
pH	3	8.14	3	8.06	3	7.93	
Na	3	19.67	3	13.67	3	14.00	
K	3	3.47[a]	3	2.67	3	2.60[b]	*
Hardness	3	123.3	3	121.33	3	140.00	
Ca	3	40.00	3	38.40	3	44.26	
Mg	3	5.67	3	6.16	3	7.13	
F	3	0.24	3	0.33	3	0.2033	
Cl	3	5.01	3	5.21	3	5.92	
NO_2	3	0.03	3	0.04	3	0.02	
NO_3	3	3.23	3	6.48	3	7.33	
Alkalinity	3	149.67	3	136.00	3	152.67	
Carbonate	3	2.40	3	1.60	3	4.00	
Bicarbonate	3	177.71	3	162.67	3	178.12	
Sulfate	3	1.76	3	4.81	3	3.70	
Boron	1	0.04	1	0.06	2	0.10	

N= number of composite samples, * = significant at P<0.05

Table 4: Total coliform bacteria (CFU/100ml) in different locations and seasons in livestock drinking water sources in the Ginchi watershed

Parameter	Mean±SE
Location	
Land type A	1016±471[a]
Land type B	1346±312[a]
Land type C	1051±126[a]
Overall	1137±181
Seasons	
Short rain	866±144[a]
Main rainy/wet	1935±187[b]
Dry	503±117[a]
Overall	1101±744

Means under the same column with different superscripts are significantly different (P<0.001)

TDS (Table 2). The seasonal effect was observed to be significant for Ca (P<0.05) between the short rain and wet seasons and between the wet and dry seasons.

The seasonal effect was observed to be highly significant (P<0.001) for alkalinity during the wet and dry seasons and significant (P<0.05) for short rain and wet seasons. A significant variation was observed for bicarbonate during short and wet seasons (P<0.05) and highly significant difference (P<0.001) was observed between wet and dry seasons.

Effects of Location on Chemical Quality of Water: For all chemical parameters of water determined in the study area, the effect of location was not significant (P>0.05) except for K, which showed significant difference (P<0.05) between low altitude and high altitude (Table 3).

Microbial Water Quality: The mean total coliforms ranged between 1016 and 1346 CFU/100ml (Table 4). This indicates the sanitary quality of the water sources was unacceptable. This might be due to contamination caused by human excreta, livestock and wild animals' defecation and urine, bathing and clothes washing and agricultural wastes. The U.S. Environmental Protection Agency recommends that livestock water contain less than 5,000 coliform organisms per 100 ml. For water to be considered as not harmful to human health, the fecal coliforms per 100ml should be zero [10]. The mean total coliform bacteria in low, medium and high altitudes were 1016±471.27, 1346.25±312.27 and 1051±126 CFU/100ml, respectively with an overall mean of 1101.73±114.99 (CFU/100ml (Show in table 4??). There was no significant (P>0.05) variation in total coliform bacteria between the different locations.

The mean total coliform count/ml during the short rain, wet and dry seasons were 866±144, 1935±187 and 503±117 CFU/100ml, respectively. There was a highly significant (P<0.001) variation in total coliform between the short rain and the wet seasons and between the wet and dry season. The high number of total coliform during the main rainy season might be due to the entrance of animal and human wastes into the water bodies by surface run off. Generally speaking, water samples for bacteriological quality from all livestock drinking sources in the Ginchi watershed showed major contamination from biological effects, with a high number of total coliform bacteria that exceeds [10] recommended limits for human consumption that is zero total coliform number per 100 ml and less than 200 per 100 ml for livestock. This high total coliform count in the area may be due to lack of a waste disposal system; excreta are eliminated directly onto the land outdoors, in particular near rivers where some remnants of forest are seen.

Edwards *et al*. [16] indicated that bacteriological standards for animals are difficult to assess because of the varying degree of immunity to certain infectious or parasitic diseases which indigenous livestock may possess. It must be emphasized, however, the fecal pollution of water is potentially pathogenic to humans, where human and livestock population using the same water source can produce harmful effect. Australian Water Resources Council [17] recommended that the coliform count should be used as an indicator of pathogenic organisms. The maximum monthly mean should be less than 1000 organisms per 100 ml or five times that in any one sample [13].

The physicochemical water quality of the examined samples was found to be within the safe upper limit for livestock drinking water. The microbiological quality of all the water sources in the study area was poor, which could be due to animal, human and agricultural activities. Generally, the presence of coliform bacteria could be an indicator of the existence of other pathogenic organisms. Thus, there is a need to identify the types of bacteria species in the area to isolate the potential pathogenic organisms.

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