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WATER QUALITY DETERMINATION OF RAINWATER HARVESTING BIRKAS IN HARSHIN DISTRICT OF THE JIJIGA ZONE, SOMALI NATIONAL REGIONAL STATES, ETHIOPIA

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Abstract

Harshin district of the Jijiga Zone Administration in the Somali National Regional State (SNRS) lacks ground water and surface water resources. In an effort to address the problems of recurrent drought, famine and food insecurity, attempts were made to harvest run-off water in cisterns (locally known as Birkas) for domestic and livestock use in the district. A study was carried out on 30 Birkas in three Kebeles in Harshin District to monitor quality of harvested water. The study found that EC, TDS, and nitrate in the study area are within the guideline value. However, 16.67 % of pH and 70 % of the measured turbidity are above the guideline value of 8.5 and 5 NTU respectively. Birkas that falls within the moderately hard water range were 86.7%. Of the total samples, 78.7 % exceed the standard COD value for surface water. Birkas with coliform contamination above the guideline value were 90%. Currently, rain water harvesting is the only solution for the severe water shortage problem in the community. However, considering the high bacteriological load and the higher pH and turbidity in the birkas it is essential to treat drinking water prior to consumption.

Keywords: *Harvesting, Birka, Physical, Chemical, Microbiology*

Around 1.1 billion people in the world do not have access to clean water supply sources and two million people, most of them children less than 5 years of age, die every year due to diarrheal diseases associated with poor water quality (WHO/UNICEF, 2003; WHO/UNICEF/WSSCC, 2000). The majority of people who have to struggle with contaminated drinking water and accompanying illnesses live in Asia and Africa among which majority of the victims are women and children (Smith *et al*., 2000).

Water shortage and food shortage are intrinsically interrelated (Smith *et al*., 2000). Water scarcity results in reduction in livestock and crop production, which are the main source of livelihood in many developing countries and ultimately causes food insecurity. Severe water shortage may cause drought and hunger and this is particularly true in the case of East African countries.

In Ethiopia, safe water coverage for urban areas in 2000 was estimated to be 72% (SoRPARI, 2005). In rural areas where nearly 80% of the population resides, the proportion is much lower covering only 24 % (MoFED, 2002; MoH, 1999). The area covered by the pastoral and agro-pastoral communities in Ethiopia is over 50% of the country's land mass and the area is characterized by lack of access to sufficient quantity of safe water and challenged by recurrent drought (Gebre, 2001; Kassahun, *et al.,* 2008; SoRPARI, 2005).

According to Hofkes (1983), "Rainwater harvesting has the potential of meeting water needs of rural communities". Singh *et al.* (1998) argued that the main objective of rainwater harvesting is to provide adequate quantity and quality of water for domestic use, irrigation and livestock.

In Harshin District the problem of water shortage is aggravated due to unavailability of surface water as well as ground water. In an effort to address the problems of recurrent drought, famine and food insecurity, attempts were made to harvest run-off water in Birkas for domestic and livestock use in Harshin district of the Jijiga zone in Somali National Regional State (SNRS).Usually, harvested rainwater is much cleaner than water from any other ground and surface water sources. However, when rain falls after long dry period,

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water collected from ground catchment may carry debris arising from dust and leaves.

Maseko (2002) highlighted that the quality of the rainwater is in line with health standards. However, it is recognized that collecting and storing the scarce water resource for the dry season will result in sustained productivity. Notwithstanding the importance of these positive impacts on improved community welfare, the water quality of the sources requires constant assessment, monitoring and evaluation. Hence, this study aimed to determine the physical, chemical, and microbiological qualities of water from birkas in Harshin district and to compare with the standard benchmarks.

Methodology

Study Area

The study was carried out in Harshin district of Jijiga Zone, Ethiopia located 125 Km east of Jijiga town (Figure 1). According to the 2007 census report, the district has a total population of 80,215 of which 45% are female and 55% male (FDREPCC, 2008). About 90% of the district communities dwell in the rural area and depend mainly on livestock production for their livelihood and 10% are urban and suburban dwellers.

The livelihood of the people mainly depended on extensive traditional livestock production, natural rangeland vegetation, and water resources (SoRPARI, 2005). Yet, environmental degradation throughout the region has intensified in the past 10 years and manifested in the forms of deterioration of drinking water quality, and increased rate of evapo-transpiration (Kassahun, *et al.,* 2008).

The water resource in the district is scarce and with erratic nature. Traditionally, the people in Harshin district store the only available source of water, rain water, in cisterns (known as Birkas) for domestic as well as livestock consumption. For the study, three sub-districts (kebeles) were selected in consultation with the heads of district Administration, Health Bureau, Water Bureau, Food Security, Veterinary Service, and Police. Accordingly, the selected Kebeles were Harshin, Medeweyn, and Lanquerta.

Sampling

Ten functional birkas were carefully selected in each three kebeles during the dry season (three months from last rain). Representation and geographical distribution within the kebele were considered during selection. The selected physical parameters for the study were temperature (^oC), electric conductivity (EC), pH, turbidity and total dissolved solids (TDS). The physical parameters were measured on site for all 30 selected birkas in the three kebeles using ELE international Conductivity meter 4071 U.K, ELE international PH/mV meter U.K, HANNA instruments HI 9635 microprocessor conductivity/TDS meter, and HANNA instruments HI 93703 microprocessor turbidity meter using the standard procedures (Tortora *et al*., 2003; APHA, 1998).

Samples were taken carefully to avoid accidental contamination during sampling. The ice box used to carry samples were cleaned and disinfected after each use to avoid contaminating the surfaces of bottles and the sampler's hands. Sterile gloves were used during sampling to avoid external contamination. In addition, sample collection bottles were removed from their container near the birkas and the rest will not be contaminated by immediately closing the container. Samples were clearly labeled with the site, date and other relevant information and transported from Harshin district to Haramaya University laboratory for analysis within 24 hours. Water samples were kept at +4°C so that changes that may occur in the bacterial content of water on storage can be reduced to a minimum by ensuring that samples were not exposed to light and are kept cool. Examinationof samples began within 48 hours after sampling (Tortora *et al*., 2003; WHO, 2003; APHA, 1998).

For chemical analysis, water samples were collected using half liter plastic bottles from the selected birkas. Duplicate samples were collected from each birka for replication (accuracy) purpose. A total of 60 samples (replicates of the 30 birkas in three Kebeles) were analyzed for the selected parameters. Separate analysis for the two samples was conducted and average values were taken. Parameters analysed were nitrate (NO_3^-), hardness, and chemical oxygen demand (COD) following standard laboratory procedures.

Nitrate (NO_3^-) was analysed using UV Spectrophotometric Screening Method (APHA, 1998). Hardness, which reads the concentration of calcium and magnesium ions, was determined as described in APHA, 1998.

For determination of COD, the procedure explained in Bartram and Balance (1996) was followed. The sample was boiled under reflux with potassium dichromate ($K_2Cr_2O_7$) and silver sulphate catalyst in strong sulphuric acid. After digestion, the remaining unreduced $K_2Cr_2O_7$ was titrated with ferrous ammonium sulfate to determine the amount of $K_2Cr_2O_7$ consumed. The oxidizable matter is calculated in terms of oxygen equivalent.

Microbiology samples were analyzed according to a standard procedure by membrane filtration method followed by incubation of the membrane to give direct count of colonies after 24 hours for total coliforms (APHA, 1998; Tortora *et al.*, 2003; WHO, 2003).

Result and Discussion

The results of physical, chemical and microbiological analysis of samples were compared with standard values set by WHO to determine the suitability of water for drinking and other domestic purposes.

Physical Parameters Analysis

In-situ samples were taken for physical parameters. EC values of the sampled water ranges from 180 - 240 μScm^{-1} in Lanqerta Kebele, 160 - 270 μScm^{-1} in Medeweyn Kebele and 180 - 250 μScm^{-1} in Harshin Kebele (Table 2). All the samples have EC value below the standard and since the water in the district is below 300 μScm^{-1}, it implies the absence of organic pollution and low level of suspended clay material in the waters. It also implies suitability for human and livestock consumption and such water is also good for irrigation purposes even for salt sensitive plants. However, microbiological test is recommended to confirm suitability as potable water (Helen and David, 1999).

The pH value of Harshin district ranged from 7.64 to 9.03 where 16.67 % of pH values are above the guideline value of 8.5. pH is an important operational parameter particularly in terms of the efficacy of chlorination (WHO, 2007). Water with high pH value needs longer contact time or a higher free residual chlorine level at the end of the contact time than water with low pH value. In the study area since 90% of the water in Langerta, 80% in Medeweyn, and 60% in Harshin have pH from 8 to 8.5, at this pH range the water is alkaline, so unfavorable reaction will not occur however the chlorine consumption for disinfection increases up to 50% comparing with disinfection of water with lower pH value of less than 8 (WHO, 2008; Zhu *et al.*, 2004).

Turbidity values in the study area varied from 2.02 NTU in Medeweyin to 96 NTU in Lanqerta (Table 2). Most of the water samples in Langerta, Medeweyn, and Harshin (60%, 60%, and 70% respectively) do not meet the WHO turbidity maximum guideline value of 5 NTU (WHO, 2004). About 70 % of the measured turbidity values were above 5 NTU which exceeds WHO guideline. Compared with drinking water standard of 1 NTU, none of the water samples satisfy the guideline value.

As the last rain in the Kebeles was 3 months before, the high turbidity value could neither be associated to soil runoff nor precipitation. Hence, potentially the high turbidity levels are due to the presence of high levels of microorganisms in the cisterns. However, for proper disinfection WHO recommends turbidity of 5NTU (ideally 1NTU) and 0.5 mg/L residual chlorine by the end of 30 minute and pH less than 8. For the samples taken 70% of the turbidity and 90% of the pH is more than these values. The turbidity results in shielding effect during chlorination, whereby the chlorine and organisms do not come in contact and the high pH leads to more chlorine consumption. However, this has its own negative effect. Excess chlorination in the presence of organic matter forms Disinfection Byproducts (DBPs) like TriHaloMethanes which are carcinogenic, mutagenic and with the potential to cause central nervous system damage will be formed hence precaution shall be considered regarding its removal (Tebeje, 2010; 2011).

Total dissolved solids (TDS) are the amount of inorganic salts and some small amounts of organic matter that are dissolved in water and the maximum guideline for TDS is 500 mgl^{-1}. The concentration of TDS for the study areas ranges from 95.45 to 146.50 mgl^{-1} with a mean value of 118.16 mgl^{-1} in Lanqerta, 90.15 to 163 mgl^{-1} with a mean value of 120.06 mgl^{-1} in Medeweyn and from 107.5 to 176.5 mgl^{-1} with a mean value of 137.51mgl^{-1} in Harshin. As per the result, the classification of potability of water in terms of TDS is rated as excellent (Table 1). In addition, the small TDS value indicate that the area has only local flow systems and the water reaches the discharge areas without undergoing substantial flow paths.

Chemical Parameters Analysis

The chemical parameters tested were nitrate (NO_3^-), hardness (calcium and magnesium ions) and chemical oxygen demand (COD). The concentration of nitrate in water from all samples was measured as nitrogen in the form of nitrate. The guideline value of 10 mgl^{-1} is established to protect bottle-fed infants less than 5 years (Audrey, 2002). However, nitrate concentration of up to 20 mgl^{-1} is permissible and can be safely consumed by adults. Nitrate values for all samples are far below the guideline value from 0.08-0.55mgl^{-1}, 0.04-0.09$mgl^{-1}$and 0.08-0.29mgl^{-1} for Lanqayrta, Madaweyn and Harshin kebeles respectively. Concentration below 3mgl^{-1} nitrate as nitrogen is usually considered indicative of absence of anthropogenic pollution and this is an indication that the birkas were not polluted by anthropogenic action (Kross *et al.,* 1993).

Water hardness is a measure of the quantity of divalent ions (salts with two positive charges) such as calcium, magnesium and/or iron in water (WHO, 2009). Table 3 shows degree of water classification in terms of hardness. Hardness for all samples are far below the guideline value from 95.9-152ppm with a mean value of 115.36; from 84.66-168.3 ppm with a mean value of 111.90 and from 51.51-117.10 ppm with a mean value of 83.12 for Lanqayrta, Madaweyn and Harshin kebeles respectively. In general, it was found out that 86.7% of the total water sampled in the study area is moderately hard water and 6.7% are hard water. The rest 6.6 % of the water in the study area are soft water. Since, the hardness of the harvested water is far below 200 mgl^{-1} as Calcium Carbonate, build up of scale on kitchen utensils and adverse health effects are not expected (WHO, 2009).

The chemical oxygen demand (COD) is the amount of oxygen consumed by organic matter from boiling acid potassium dichromate solution. It provides a measure of the oxygen equivalent of that portion of organic matter in water sample that is susceptible to oxidation under the conditions of the test. According to VLAREM II Basic Environmental Quality Standards for Surface Water, the range of COD should be < 30 mgl^{-1}. Water samples analyzed for COD indicate that 56% of the samples in Langerta, 90% in Medeweyn, and 90 % in Harshin are above this value. In general, 78.7 % of the total samples are above 30 mgl^{-1} showing the requirement of excess oxygen to degrade organic compounds found in the harvested water comparing to surface water. Besides, the presence of this extra organic matter in treated waters can also provide a substrate for the re-growth of micro organisms.

Bacteriological Parameter Analysis

According to WHO guideline, the guideline value of coliform organisms in drinking water is 0 CFU/ml. In the present study, majority (90%) of the water samples collected from Langerta were contaminated with the highest amount (>350CFU/ml) of aerobic bacterial species and the remaining 10% of the samples were contaminated with a bacterial load of 151-350CFU/ml. None of the water samples from this district had an acceptable aerobic bacterial species load. Similarly, the coliform count from this district also showed that, 90% of the samples collected from this district had the highest contamination (>350CFU/ml) with coliforms, in which the

WHO standard was 0CFU/ml. This shows that this area is much neglected and the people are in high risk of waterborne diseases.

Only 30% of Birkas in Harshin had the acceptable coliform count, which is 0CFU/100ml. On the other hand, Medeweyne (60%) and Harshin (40%) had surface water contamination (coliform bacterial count) levels with >350CFU/ml of water. However, none of the water samples from the three districts satisfy the standard drinking water requirement, which should not exceed 10CFU/ml of water.

According to WHO guideline, the value of CFU/ml in drinking water is 0 CFU/100ml. but in the present study, only three wells in Harshin district were found to be not contaminated with coliform bacteria. As indicated in Addo *et al.* (2009), the surface water sources, in general, are not acceptable for drinking purpose as these are often loaded by various organic, inorganic and biological constituents. Similarly, in the present study, the bacteriological quality of majority of the surface waters was contaminated with different bacterial pathogens. The percentages of water samples contamination (90%) of this study are higher than results obtained by Abo-Shehada *et al.* (2004) of cisterns in Bani-Kenanah District – Northern Jordan, as 49% of the tested samples were contaminated with total Coliforms. The high bacteria load coupled with the higer pH and turbidity leads to the requirement further treatment beyond chlorination (Table 5).

In general, bacteriological analysis of water samples in the three selected Kebeles indicated the presence of Salmonella, E. coli, Shigella, and Vibrio species as well as various fungus and parasites. Besides, it was observed during the study period that the community used the water from the Birkas for washing clothes, bathing, drinking animals, etc, in which majority of these activities were done near the Birkas. In addition, children used these water sources for swimming. According to Shamsuddeen *et al.* (2010), the environment, water handlers and unclean containers may be the sources of water contamination. In the study area rainwater harvesting is the most appropriate technology and governments should provide funding for the success of such initiatives. There is also a need for more awareness creation on the potentials of rainwater harvesting and the integration of the technology within the integrated water resource management program to help the community in its endeavor to deal with water issues in a cost effective and sustainable way.

Conclusion

Rainwater harvesting is being the only option to get water in Harshin district. The chemical quality of harvested and stored rainwater in the district is quite satisfactory. On the contrary, microbial indices (Coliform count) were detected in 90 percent of samples. In general, examination of the physicochemical and microbiological composition of the rainwater is a prerequisite before its utilization for drinking purposes. The possible pollution sources discussed in this paper must be considered as the prevention options while Coliform count, as a simple and inexpensive indicator of rainwater quality, are to be examined frequently. The people using the water sources are at high risk for waterborne diseases. Considering the high bacteriological load, higher pH and turbidity in the birkas only chlorination is not effective to make the water potable. Hence, application of appropriate pre-treatment and treatment methods are highly recommended before use. The scheme is environmentally friendly in the sense that it does not cause any harm to the environment. However, the indigenous way of constructing Birkas require improvement in the design. It is recommended that sizing of birkas should depend on the rainfall and catchment area and filtering system should be adapted in the right order. Once the Birkas are functional, there is a need to empty and remove the silt accumulated at the bottom of the Birkas at the end of dry season. The interior of the tank should also be cleaned with a brush. If possible it would be exceptional to provide roof to keep out algae, windblown materials, lizards, birds and insects. When the rainy season starts, the flushed water should be diverted away from Birkas during few minutes of the first rain to reduce contamination. The pastoralists were already using every mechanism at their disposal to survive the droughts. At last to ensure the sustainability and safety of the Birkas strong extension system and responsible institution for training and operation are required.

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Table 1 Classification of potable water in terms of TDS (WHO, 1984)

Condition	Concentration (mg/L(ppm))
Excellent	< 300
Good	300 - 600
Fair	600 - 900
Poor	900 – 1200
Unacceptable	> 1200

Table 2: Physicochemical Analysis of Harvested Rain Water in Harshin District, Ethiopia

Description	Lanqerta			Medeweyin			Harshin			WHO (2004) Guideline
	Range	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range	Mean	Standard Deviation	
Physical										
pH	7.84-8.65	8.30	0.28	7.82-9.03	8.25	0.37	7.64-8.45	8.03	0.30	6.5-8.5
EC (µS/cm)	180-240	210.0	2.00	160-270	210	4.00	180-250	210	3.00	Up to 2000
Turbidity (NTU)	3.21-96.00	18.22	27.90	2.57-50.00	12.01	14.01	2.02-20.16	11.98	7.08	5
Chemical										
Hardness (ppm)	95.9-152	115.36	17.72	84.66-168.3	111.90	24.60	51.51-117.10	83.12	18.31	NA
NO3- (ppm)	0.08-0.55	0.41	0.13	0.04-0.09	0.06	0.02	0.08-0.29	0.13	0.06	10 as NO_3-N
TDS (ppm)	95.45-146.50	118.16	19.78	90.15-163	120.06	25.12	107.50-176.50	137.51	20.21	500
COD (mg/l)	6.60-317.90	63.73	97.13	21.41-	89.70	49.30	28.57-177.6	79.39	56.73	NA

NA= Not Available

Table 3 Degree of Water Classification (WHO, 1984)

Hardness, mg/L (ppm) as $CaCO_3$	Water Class
0-75	Soft water
75-150	Moderately hard water
150-300	Hard water
Over 300	Very hard water

Table 4 Coliform count per milliliter of water samples from the three selected districts

	Coliform Count (CFU/ml)						
Kebele	0	1-50	51-100	101-150	151-350	>350	Total
Langerta	0 (0%)	0 (0%)	0 (0%)	1 (10%)	0 (0%)	9 (90%)	10 (100%)
Medeweyne	0 (0%)	1 (10%)	1 (10%)	1 (10%)	1 (10%)	6 (60%)	10 (100%)
Harshin	3 (30%)	2 (20%)	1 (10%)	0 (0%)	0 (0%)	4 (40%)	10 (100%)
Total	3 (10%)	3 (10%)	2 (6.7%)	2 (6.7%)	1 (3.3%)	19(63.3%)	30 (100%)

Table 5 Distribution of rainwater tested samples for TC (CFU/100 ml) according to their level of contamination and treatment procedure required.

Range of TC	Degree of Contamination [a]	Number of tested sample and (%)	Treatment procedure
0-3	0	3 (10%)	No treatment required
4-50	1	3 (10%)	Chlorination only
51-50,0000	2	24 (80%)	Flocculation, sedimentation then chlorination
>50,000	3	0	Very high contamination, need specific treatment

[a](Al-Khatib and Orabi, 2004).

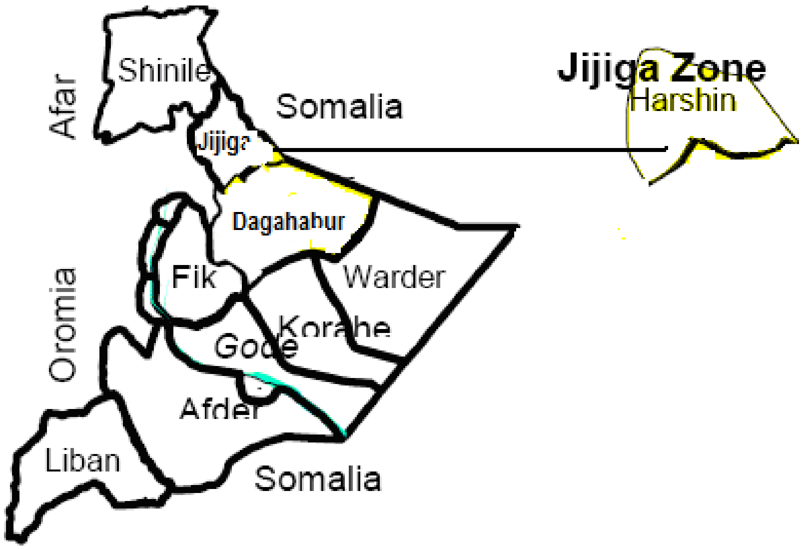

Figure 1: Harshin District, Somali National Regional, Ethiopia