The Practices and Challenges of Cleaning and Disinfecting Water Storage Tanks in the City of Addis Ababa

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Abstract

Water storage tanks, which are not cleaned and disinfected regularly, undergo a complex interaction with the environment and bring deterioration on the quality of water and thereby health-related problems. This study assessed the practices and challenges of cleaning and disinfecting of household water storage tanks in Yeka and Bole sub-cities of Addis Ababa. Interviews on structured and semi-structured questionnaire and field observation were conducted to collect data on a range of variables such as the number of years the water storage tank is used, the practice of cleaning water tank, the awareness of the society towards cleaning and disinfecting water storage tanks, the frequency of cleaning and disinfection, and how they treat water for consumption, etc. Questionnaire was distributed to a total of 197 respondents, of which 190 of them (96.4% response rate) responded and were included in the analysis. For water quality assessment, 12 water samples were taken direct from household's reservoirs tanks. The collected data were analyzed using descriptive statistics, and laboratory analysis. The results of the study indicated that households give little attention to water storage tanks cleaning and disinfecting. Unavailability of professional water storage tank cleaners, inaccessibility of the location of the water storage tanks, lack of awareness of household's on the sanitary condition of their tanks and lack of modern tank cleaning and disinfecting equipment and products, are some of the challenges that hindered household's water storage tank management. The results of laboratory analysis on water samples taken indicated that a significant level of water-borne pathogens exist in the water storage tanks that deteriorate the quality of water for consumption, which makes it unsafe for use. Thus, using water from water storage tanks for consumption purpose has a severe impact on household's health. Regular monitoring and examination of water storage tanks for the presence of photogenic organisms, chemicals and physical parameters should be made. Furthermore, to maintain the health status of the dwellers of the city, awareness on the safety-level of household's stored water should be created.

Keywords: *Water storage tanks, water-borne pathogens, health risk, water tanks management, Addis Ababa, Ethiopia*

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Background of the Study

Water is an essential resource for life and used by everyone, every day. Not only do all people need drinking water to survive, but water plays an important role in almost every aspect of our lives. When water becomes contaminated by parasites; however, it can cause a variety of illnesses (CDC 24/7). Inadequate sanitation is a major cause of disease world-wide and improving sanitation is known to have a significant beneficial impact on health both in households and across communities.

Worldwide, diarrhea claims the life of 2 million children each year, of which 22% deaths occur in sub-Saharan African countries. The burden of diarrheal morbidity prevails largely in the developing world where water quality and sanitation and the general living conditions remain poor. In Africa, a child below the age of five years experiences five episodes of diarrhea per year, and 800,000 children die of diarrhea and dehydration each year. The World Health Organization (WHO) report in 2004 rated Ethiopia as the 4th among the 15 countries with the highest child deaths due to diarrhea, which was estimated to be 86,000 children. The annual report published in 2008 by the Federal Ministry of Health of Ethiopia showed that diarrhea is the 4th leading cause of morbidity at the national level (Merga and Alemayehu, 2015).

Stored water quality deterioration is a big issue in many countries water supply system, which may be a result of many interconnected physical, chemical, and biological factors. It may or may not be at the source only, rather it may happen in storage tanks. There are several reasons to clean and disinfect water storage tanks regularly including: to kill or prevent the survival of waterborne pathogens that can cause gastrointestinal and other diseases; to prevent the accumulation of scale and slime, which can be sources of contaminants and can also harbor pathogens; and to control the accumulation of sediments and algal growth, which degrade the taste and odor of potable water (Jonick el al 2012).

Statement of the problem

Ethiopia has made remarkable progress in water and sanitation over the last two decades. According to WHO/UNICEF (2014), the country has improved water supply by 57% (97% in urban areas and 42% in rural areas), thus achieving the Millennium Development Goal (MDG). Although the sanitation target has not yet been achieved, there has been tremendous progress during the past decade in improving sanitation. Nevertheless there is always a regular breakdown of electric engine that is used to pump water (Addis Ababa Water and Sewerage Authority 2008 E.C official report). Hence the majority of residents do not have access to safe pipe water and they are obliged to store water. Accordingly, Yeka sub-city Health Office (2003) indicated that among the top ten diseases registered in the area, waterborne disease take the highest rank. On the other hand, the Addis Ababa water and sewerage Authority claims that the quality of the water being distributed to the population is monitored and generally safe for drinking. Thus, un-cleaned water storage tanks and infected stored water are probably the cause of water quality deterioration and use of infected stored water may have a chance to cause waterborne diseases.

Removing the sediment and keeping water tank clean is the best way to maintain health water system. The study done by Schafer and Mihelcic (2012) investigated how the materials used to construct large household water storage tanks and how user maintenance influenced the physical, chemical, and microbial quality of the stored water and also frequent storage tank cleaning can reduce the likelihood of contamination of the stored water.

Several studies were done regarding to household water storage tank in different countries and by different researchers. For example, a study done by Evison and Sunna (2001) found that water temperature inside the tank and tank age were the parameters for bacterial growth. A study undertaken by Tokajian and Hashwa (2003), in rural Bolivia, found that the stored water deteriorated significantly microbiologically after 7 days. In addition Robert et al. (2001), in rural Honduras, chlorinated water in storage containers contamination was only eliminated for the first 4 hours after collection. Moreover, the study overtaken by Schafer (2012) in Tiquipaya, Bolivia found that storage tank material and infrequent or lack of storage tank cleaning can affect drinking water quality. Also storage tank material affects water quality most likely because of different water temperatures inside the tanks.

However, in Ethiopia specifically in Addis Ababa, an integrated study has not been done on the bacteriological quality of stored water in tanks and as well as on the hygiene and sanitation practices of the consumers. Therefore, to fill the gap in information on the quality of stored water in tanks and to assess the hygiene and sanitation practices of the community in the city of Addis Ababa this study is initiated.

Objectives

The main objective of the study is to assess the practices and challenges of cleaning and disinfecting drinking water storage tanks in the city of Addis Ababa. The specific objectives of the study are;

- to determine the stored drinking water quality status and explain its associated risks;
- to assess the public practice and opinion of drinking water from storage tanks;

- to assess the practices of cleaning and disinfecting water storage tanks;
- To assess the challenges of cleaning water storage tanks.

Significance of the Study

The information from the study about the condition of water tank quality and contamination can be used by the government to make necessary intervention on pre-cautions to prevent contamination. Government organizations (Ministry of Health and Water and Sewerage Authority) can benefit from the research finding to adopt preventive health measures. Regulatory bodies (Ministry of Water resource and or water resources development bureau) can use the results of this study in regulating and planning activities related to water quality. And also the resident of Addis Ababa can be made aware about the condition of their water storage tanks and can take necessary treatment action to improve health effects.

Scope and Limitation of the Study

The study focuses on the strategy of conventional and properly managed drinking household water treatment and safe water storage practices in Addis Ababa, particularly in the Bole and Yeka sub-cities. The emphasis is to identify the practices and challenges of cleaning and disinfecting drinking water storage tank and assessing its sanitation situation.

There is a growing body of evidence that distribution systems can cause a decrease in the quality of water, which can lead to illness in consumers in developed countries (e.g. Craun and Calderon, 2001), emerging countries (e.g Mermin et al., 1999; Basualdo et al., 2000; Egorov et al., 2002) and developing countries (e.g. Agard et al., 2002; Lee and Schwab, 2005). As stated above, there are several reasons to contaminate drinking water, even though this study confines (limited) itself only to the issues of drinking water storage tanks accessibility and inadequate basic sanitation practice

It is restricted to the study of only two sub-cities water storage tank cleaning and disinfecting practice and challenge of Addis Ababa City, and this finding was extrapolated to other sub-cities. This study is not immune from limitations. Due to high professional cost to laboratory test, this study is limited in bacteriology and physicochemical parameters, scope and sample size. And also unidentified number of product of water storage tank in the city was another constraint to select sample size.

Basic Concepts of Water Storage Tanks and Water Quality

There are several types of water storage tanks common to water distribution systems that come in contact with treated or finished water. Water storage tanks or domestic water systems in use today are typically made of steel, fiberglass, or polyethylene. Today, thicker walled carbon steel tanks are made and sold for in- the-ground water storage, as are ribbed poly tanks, and reinforced fiberglass tanks. Above-ground storage tanks are typically made out one of three materials: 1) thin-wall, welded, galvanized steel; 2) fiberglass blown around molds; and 3) extruded white, black, and green colored polyethylene Earthen pots also function as water storages, shape (cylindrical, spherical, torridly, rectangular), and ownership (utility, private) (Janick et al., 2012).

Factors Affecting Stored Water Quality

If water stagnates or does not cycle or turnover in a storage tank, it will age indefinitely until it happens to mix with active water or get drawn from the tank into the distribution system. Such stagnant water will not be of the highest quality and may result in low chlorine residuals, pathogen contamination, high disinfecting by products (DBPs) and taste and odor complaints.

Temperature of the stored water is an important influence on the growth rate of bacteria that have survived treatment processes. Various field studies have shown that significant bacteria growth can occur in water of 15°C or higher (Fransolet et al., 1985; Smith et al., 1989; Donlan et al., 1994 cited in LeChevallier et al., 1996). For example, another study found that coliform bacteria occurred more frequently and in higher concentrations at water temperatures greater than 15°C (LeChevallier et al., 1996). Results from that study indicate that for a temperature increase from 5°C to greater than 20°C, there was an 18-fold increase of coliform occurrence in free-chlorinated systems (LeChevallier et al., 1996).

Residence time has major impact on water quality. Many studies have shown that water quality degrades as the water travels through the distribution system and in some cases is stored before use (e.g., Evison and Sunna, 2001; Tokajian and Hashwa, 2003). A study of a water distribution system in urban Trinidad found that microbial water quality degraded significantly as the water traveled through the distribution system even though the reservoir repeatedly tested negative for microbial contamination (Agard et al., 2002). The presence of E. coli suggests fecal contamination is occurring within the distribution system.

Parameters to Assess Water Quality

1) Physicochemical Water Quality Parameters

Drinking water, or potable water, is defined as having acceptable quality in terms of its physical, chemical, bacteriological parameters so that it can be safely used for drinking and cooking. WHO defines drinking water to be safe if and only if no any significant health risks during its lifespan of the scheme and when it is consumed (WHO, 2004). Drinking water quality acceptability is governed by limits of microbiological and physicochemical parameters. Some of the physicochemical parameters essential in water quality investigation are discussed hereinafter.

Turbidity: Turbidity is a measure of the amount of suspended particles in the water Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibers, sawdust, wood ashes, chemicals and coal dust. Any substance that makes water cloudy will cause turbidity (EPA, 1999).

Color: Color in drinking water may be due to the presence of colored organic matter, drinking water should be colorless. Changes in color from that normally seen can provide warning of possible quality changes or maintenance issues and reflect degradation of the source water, corrosion problems in distribution and storage systems, and changes in performance of adsorptive treatment (Payment et al., 1997).

Taste and Odor: taste and odor problem to be serious. Conditions at reservoirs, the type of disinfectant used, and decaying vegetation in the influent water were reasons given for these taste and odor problems (Suffet et al., 1996).

Temperature is one of the most important water quality parameters. It affects both biological and chemical functions. Chemical equilibrium constants, solubility's, and the rates of chemical reactions are all temperature dependent. High water temperature enhances the growth of microorganisms and may increase taste, odor, and color problems of drinking water (Atnaf, 2006**).**).

Nitrate: Nitrates can be reduced to toxic nitrites in the human intestine, and many babies have been seriously poisoned by well water containing high levels of nitrate-nitrogen (WHO, 2004).

Chlorine residual: Disinfection is a process designed for the deliberate reduction of the number of pathogenic microorganisms. In areas where there is little risk of a waterborne outbreak, residual free chlorine of 0.2 to 0.5 mg/l at all points in the supply is recommended (CDC 2014).

PH: The pH of water affects treatment processes, especially coagulation and disinfection with chlorine-based chemicals. Changes in the pH of source water should be investigated as it is a relatively stable parameter over the short term and any unusual change may reflect a major event. PH is a measure of how acidic or basic (alkaline) the water is (Suffet et al., 1996).

Ammonia: Pure ammonia is a strong smelling, colorless gas. It is manufactured from nitrogen and hydrogen or is produced from coal gas. In nature, ammonia is formed by the action of bacteria on proteins and urea. Ammonia concentration is measured at Point of entry, Reservoir inlets/outlets the end result is important to develop baseline data for prediction of the onset of nitrification. Degradation of nitrogenous organic matter, industrial and municipal waste discharges are typical sources of ammonia (EPA, 1999).

Nitrogen (NO3-N) Nitrogen is a nutrient that occurs naturally in both fresh and salt water. Too much nitrogen, as nitrate, in drinking water can be harmful to young infants or young livestock. Excessive nitrate can result in restriction of oxygen transport in the bloodstream. Infants under the age of 4 months lack the enzyme necessary to correct this condition ("blue baby syndrome"), (USGS, 2017).

2) Bacteriological Water Quality Parameters

There are three different groups of coliform bacteria; Total coliform, fecal coliform, and E. coli, each have a different level of risk. Total coliform, fecal coliform, and *E. coli* are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. *E. coli* is a sub-group of fecal coliform.

Total coliform bacteria are commonly found in the environment. If environmental contamination can enter the system, there may also be a way for pathogens to enter the system. Therefore, it is important to find the source and resolve the problem.

Fecal coliform bacteria are a sub-group of total coliform bacteria. They appear in great quantities in the intestines and feces of people and animals. The presence of fecal coliform in a drinking water sample often indicates recent fecal contamination, meaning that there is a greater risk that pathogens are present than if only total coliform bacteria is detected.

Table 1: USPHS (IS: 10500) WHO and ES for Quality of Drinking Water

Parameters	Permissible value	Standard	WHO (1993)	Ethiopian (2001)
Color	Unobjectionable	IS:10500		15 TCU
Taste	Agreeable	IS:10500		Unobjectionable
PH	6.5-7.5	IS:10500	6.5-8	6.5-8.5 Unit
Turbidity (Max NTU)	5	IS:10500	<5	<5
TDS (Max)	500 mg/l	IS:10500		1000
Chloride (Max)	250	IS:10500		250
Alkalinity 120	120	USPHS		
Residual chlorine	0.2 mg/l	IS:10500	0.2-0.5 mg/l	0.1- 0.5 mg/l
Fecal coliform	-	-	0 mg/l	0 mg/l
Total coliform	-	-	-	0
Nitrate	-	-	0.5 mg/l	0.5 mg/l
Ammonia (Max)	-	-	-	1.5 mg/l

Source: USPHS, ES 261 (2001) and WHO (1993)

Water Borne Diseases

The World Health Organization (WHO) estimates that over one billion people lack access to improved water sources. Contaminated drinking water contributes substantially to the 3-5 billion episodes of diarrhea that occur annually, 80% of which occur among children aged <5 years, and kill over two million people. In 1992, the Centers for Disease Control and Prevention (CDC) and Pan American Health Organization (PAHO)/WHO developed the Safe Water System (SWS) to prevent diarrhea through the promotion of household water treatment, safe water storage and behavior change communications. Point-of-use water treatment and safe water storage, has been shown to reduce diarrhea risk by 25-85 %, depending on the population, setting, and other factors (WHO 2011).

According to WHO the major diseases in developing countries have been reported to be related to water and sanitation. In Ethiopia the World Health Organization reported that some 4.2 million people suffered from acute lack of water (WHO, 2004). The lack of access to safe drinking water and sanitation places a heavy burden on children who are especially vulnerable to diarrheal disease. Moreover, to the Ethiopian Ministry of Health, diseases related to water, sanitation and hygiene problems are among the leading causes of morbidity and mortality, accounting for a large portion of the deaths of 500,000 children each year (MOH, 2001).

Household Drinking Water Storage Treatment Practices

To examining access to improved water, sanitation and therefore increase hygiene practices, Often, household storage of water has been associated with evidence of increased fecal contamination, with levels of contamination depending on a number of factors including the site of storage, type of container and handling practices (Brick et al., 2004). Households will employ some sort of treatment method prior to consumption. In underdeveloped regions boiling may be one of the simplest ways to achieve a better quality of drinking water, and if done properly, should eliminate all fecal coliforms. A study by VanDerslice and Briscoe (1993) actually concluded that boiling water had a more significant impact on its levels of contamination than does the type of container it is stored. Though, water is boiled for too short of a duration or either at too low of a temperature, and is not as effective at completely eliminating any contaminants (Brick et.al. 2004). Another technique of water treatment in developing and developed countries alike is the process of chlorinating the water. This can be done with the use chlorine in the form of liquid, tablets or powders. But in some instances, chlorine additives are not accepted by all because of the effect they have on the color, taste and smell of the water (Brick et.al, 2004).

Filtration is also a relatively easy procedure that can be done to remove a great deal (but not all) of the contaminants from drinking water. Several different methods of filtering are used worldwide, and some of these may employ apparatuses like ceramic candle filters, cloth sieves, and bio-sand filters. Previous research has found that when participants of studies report having either boiled or filtered their water, microbiological testing indicated that contaminants were still present (Brick et al., 2004). Solar disinfection (SODIS) is by far the cheapest method of decontaminating water, and also one of the safest (EPA, 1996). Solar radiation can remove a wide variety of organic chemicals and pathogenic organisms from water with the use of ultraviolet rays from the sun and clear plastic bottles.

Regular cleaning and disinfecting water storage tank also makes water looks and taste better. It is the owner's responsibility to make sure that the water tank is cleaned and disinfected on a regular basis. According to a code of practice in the Emirates of Abu Dhabi (2014) the minimum frequency of cleaning and inspecting water storage tanker for residential and commercial buildings depends on the tank material and location of the tank available as shown table below.

Table 2: Minimum Frequency of Water Storage Tank Inspection

Tank Material	Tank Location	Frequency of Inspection
Concrete	Underground	Quarterly
	Ground	Bi-annually
	Roof	Bi-annually
Plastic	Ground	Bi-annually
	Roof	Annually
FRG	Ground	Bi-annually
	Roof	Annually
FRP	Ground	Bi-annually
	Roof	Bi-annually
GL/STEEL	Ground	Bi-annually
	Roof	Annually

Source: The Emirates of Abu Dhabi (2014, Page 20)

Health Effects of Disinfecting Byproducts

Chlorine revolutionized water purification, reduced the incidence of waterborne diseases across the western world, and "chlorination and/or filtration of drinking water has been hailed as the major public health achievement of the 20th century"(Calderon, 2000). Chlorine remains the most widely used chemical for water disinfection in the United States (Gordon et al., 1990) However, close to 1 billion people in the world still lack access to safe drinking water, and new questions about health effects from chlorine byproducts formed during disinfection have led to questions about the advisability of using chlorine to provide safe water for this population (CDC, 2016).

According to the American water work association, byproducts used for disinfection have been linked to bladder and rectum cancer, and may also have reproductive and developmental effects. Chloroform affects liver and kidney function in humans in both acute and long-term exposures. In lab studies on mice and rats, three THMs (bromoform, bromodichloromethane, and dibro-mochloromethane) caused changes in kidney, liver, and serum enzyme levels and decreased body weight. Dichloroacetic acid (DCA) and trichloroacetic acids (TCA) are found more often among the HAA5s. EPA has classified DCA as a human carcinogen. Studies conducted on humans showed that a DCA exposure for six to seven days at 43 to 57mg/kg/day resulted in mild sedation, reduced blood glucose, reduced plasma lactate, reduced plasma cholesterol, and reduced triglyceride levels. Studies in mice and rats showed that it causes liver tumors. Studies have shown that TCA can produce developmental malformations in rats, particularly in cardiovascular systems (AWWA, 1999).

Studies on Drinking Water Storage Tank Management

Microbial re-growth in potable water supplies is often a problem that is intensified by household water storage practices. A laboratory study found that factors such as long retention times of 4 to 7 days, low or no chlorine residual and temperatures above 15°C have all been shown to increase microbial re-growth in commonly used 1000 L fiberglass, polyethylene and cast iron household storage tanks (Evison and Sunna, 2001). This study also found that water temperature inside the tank and tank age were the parameters most important for bacterial growth and were responsible for 77.7% of the heterotrophic plate count values measured for water stored for 4 days (Evison and Sunna, 2001). Additionally, the HPC counts between the water stored for 4 days and the water stored for 7 days were not significantly different which, this author believes indicates that the bacteria in the tank had been shocked initially by the chlorination but had survived in the distribution system and were able to grow in the conditions provided by the storage tank and that an increase in bacterial growth may be observed for shorter residence times. Furthermore, this study did not find significant variations in HPC counts or in physical and chemical parameters between the different tank types tested (polyethylene, fiberglass and cast iron). However, it did find that the bacteria taxa within the different tanks did differ, most likely due to differences in water temperature and light penetration (Evison and Sunna, 2001).

A separate laboratory study looking at the effects of cast iron and black polyethylene household storage tanks (1000 L capacity) found that the stored water deteriorated significantly microbiologically after 7 days of storage in both types of storage tanks, but did not find a significant difference in HPC counts between the two types of storage tanks (Tokajian and Hashwa, 2003). HPC counts varied seasonally, with the highest levels being measured during the summer months (Tokajian and Hashwa, 2003). Increased microbial growth in household storage tanks compared to source water may also be due to the design of household storage tanks. It is not possible to completely empty most tanks, and that allows for sediment buildup which can act as a growth medium for microbes in the incoming water (Tokajian and Hashwa, 2004). This leads to persistence of coliforms in the stored water. Increased storage time, water temperature and microbial quality of the incoming water are also significant factors that contribute to poor water quality (Tokajian and Hashwa, 2004).

A study looking at post-supply drinking water quality in rural Honduras found that source water quality appeared to be a significant factor in determining household water quality and that storage factors such as covering the household storage tank, tank material and residence time did not make a significant difference on the stored water quality. There was also no correlation between storage container type and water quality. The source water in this study came from hand-dug and bore-hole community wells of varying water quality, but every source saw a deterioration of water quality between collection and consumption. Contamination was measured by the presence of thermotolerant coliforms found in the household storage containers. These containers were either made of plastic or clay and had either wide openings in which water was ladled or dipped out or narrow openings in which water was poured (Trevett et al., 2004).

Residence time was determined simply by asking the female head of household the last time water was collected; no specific times were reported. Due to the small size of the water storage containers (~25 L) this study's author believes the residence times to have been relatively short (< 1 day). This indicates that contamination was occurring between the point of supply and consumption and that the bacteria were able to grow within the household storage container. Clasen et al. (2003) noted that intervention studies that employ a 3 part intervention program involving 1) narrow mouth storage containers with spigots that prevent hands from entering container; 2) point-of-use disinfection; and 3) community hygiene education have led to reductions in waterborne disease incidence, as can be seen by a m50% reduction in diarrhea incidence in Bangladesh (Sobsey et al., 2003), 44%

(Quick, 2002), 50% Bolivia (Sobsey et al., 2003), and 62% in Uzbekistan (Semenza et al., 1998). Another intervention study using a narrow-neck clay container found that cholera carrier rates were 17.3% in the control group and 4.4% in the intervention group (Deb et al., 1986). These results agree with the results from Trevett et al. (2004), which found that the type of storage container and whether the container allowed contact of hands with the stored water were associated with increased diarrheal disease incidence.

Schafer investigated water quality of household water storage tanks in Tiquipaya, Bolivia. The study summarized how the materials used to construct large household water storage tanks and how user maintenance influenced the physical, chemical, and microbial quality of the stored water. The study site for the research was a rapidly urbanizing city in Bolivia. The study also documented changes in microbial water quality as the water traveled from the treatment plant to the user. The study found that storage tank material and infrequent or lack of storage tank cleaning can affect drinking water quality (Schafer, 2012). Furthermore, storage tank material affects water quality most likely because of different water temperatures inside the tanks. Storage tanks that are not cleaned regularly likely contain sediments that can contaminate incoming water. Use of storage tank materials that reduce water temperature (e.g., fiberglass and fiber cement), locating the storage tank in an accessible and shady location, and thorough and frequent storage tank cleaning (three or more times per year) can reduce the likelihood of contamination of the stored water. Furthermore, redesign of household storage tanks so that they can be completely emptied would aid in cleaning and removal of sediments (Schafer and Mihelcic, 2012).

Additionally, according to Schafer (2010) tanks which are cleaned 3 or more time per year have less *E. coli* than tanks that are cleaned less frequently.

Similarly, turbidity is lower in tanks that are reported to be cleaned 3 or more time per year compared to tanks that are reported to be cleaned 1 – 2 times per year, although the difference is less for tanks that are cleaned less than once per year. Tank age appears to have very little effect on water quality for all parameters. Since chlorine levels are near the detection limits (0.02 mg/L) of the equipment. Based on results of one-way ANOVA performed by Schafer, differences between *E. coli* and total coliform counts for various cleaning schedules are observed. The results show that there is a significant difference between *E. coli* and total coliform counts in storage tanks that are cleaned three or more times per year compared to storage tanks that are cleaned less than once per year. The results also indicate at difference exists between storage tanks that are cleaned three or more times per year and storage tanks that are cleaned once or twice per year (Ibid, 2010).

While there are studies done to evaluate and understand on the mechanisms of drinking water contamination occurring at the public water sources, but only few have looked at the relationship actual storage practices have with the quality of drinking water within the household (Jensen et al., 2002), and very few studies have concentrated on the difference between drinking water contaminated at the source and water contaminated in the home (Feachem et al 1978). In turn, those that have looked at the public and domestic levels as two separate points of possible contamination found their studies to be inconclusive (Jensen et al., 2002).

Research Approach and Design

This study adopted both quantitative and qualitative approaches in making inference; the researcher used a combination of both descriptive design and laboratory analysis. This design helped to examine the sanitary condition of the study area, and to assess attitude and practice of water storage tanks management of residents of Addis Ababa. The sanitary conditions of the study area were assessed using questionnaire. The experimental method using laboratory analysis is the only method of research that can help to check and objectively test evidence collected through observation and questionnaire. This study used laboratory/experimental approach to assess the physicochemical and bacteriological quality of drinking water stored in water storage tanks.

Population and Sampling

According to the CSA (2007), Addis Ababa has a total population of 3,384,569, with an annual growth rate of 3.8%. This number has increased from the originally published 2,738,248 figure and appears to be still largely underestimated. The city is administratively organized in ten sub-cities in which Bole and Yeka sub-city are among them consisting of 14 and 13 woredas and are inhabited by 173,000 and 42,000 people respectively. In analyzing the study at Bole sub city woreda 10 by considering new area and Yeka sub city woreda 8 considering old resident area, focus has been given to households which are using water storage tanks at their residence. To conduct the study the researcher first select Sub-Cities, And then select two woredas purposively as there is no full data about number of water tanks users in Addis Ababa.

The total household population of the two woreda is 215,000. If, on average, one household has 5 family members, the expected permanent residents in two woredas are 43,000 households. Among them at Bole sub-city of woreda 10 more than 18,000 and at Yeka sub-city of woreda 8 around 3,400 households are living in Condominium houses with no water storage tanks. Among the rest of 21,600 households, 6,600 households are living in common private buildings at Bole sub-city of woreda 10. Yet, again among the rest of 15,000 households 40% of them are fairly expected to use a water storage tank, which means 6,000 households (Source: Personal communication with Woreda 8 and 10 Vital statistics office, 2016). The research applied a simplified formula provided by Yamane (1967) to determine the minimum required sample size at 95% confidence level, degree of variability= 0.5 and level of precision (e) = ±7% to calculate sample sizes.

$$n = \frac{N}{1 + N(e)^2}$$

Where n is sample size, N is the total number of study population which is 6,000 households; where e is the level of precision 7%. Using the total population of 6,000 and level of precision of 7%, the sample size is 197. Since people's attitude and practice are different, the total numbers of sample household were used to fill the questionnaires. By using proportion, a total of 110 household units from Bole Woreda 10 and total of 80 household sampling points from Yeka Woreda 8 were used. The selection criterion includes knowledge and using long time water tanker, in addition water sample to test physicochemical and bacteriological quality of drinking water at storage tank to Addis Ababa City Administration Health Research and Laboratory Service is selected by all type of tanks.

Data Sources and Data Collection Instrument

Primary data were collected to attain the research objectives by using questionnaire survey and interview checklists. In addition, field observations were made. Secondary data were collected from different government offices and respective sub-cities. Primary data were collected through survey/questionnaires, interviews, observation and laboratory test.

Water sample: 12 tank water samples were collected and analyzed for different parameters at Addis Ababa City Administration Health Research and Laboratory Service laboratory.

Data Analysis Technique

The methods that the researcher used to analyze all gathered data concerning each study parameters and environmental conditions from checklist and observation results were frequencies, means, percent, maximum and minimum values. The results are presented in tables and figures to describe some important variables and laboratory test results. Stored (tanks water) analyses have been compared against standards set by WHO (2004) and Federal Democratic Republic of Ethiopia, Ministry of Water Resource (MoWR, 2002). The analysis was done using IBM SPSS Version 20 Statistics software.

Results and Discussion

Characteristics of the Study Households

The average household size for the respondent is found between a minimum of 4 and a maximum of 9 with mean of 5.88. This result is a major suggestion that the frequency of water consumption is an important factor in shortening or lengthening water storage period at the household level. About 42% of the heads of the households have diploma, 34% of them have collage degree and 24% of them have master's degree. Level of education has important implications as it shapes the attitude towards sanitation and to develop better opinion about water quality deterioration and its associated risks as well as storage handling practice

Practices and Challenges of Water Storage Tank Management

The study areas mainly receive their water directly from AAWSA (Addis Ababa Water and Sewerage Authority) tap network system use three types of water storage tanks, namely metal (steel) tanks, fiberglass and plastic (plotline) tanks for their household water reservoir. This discussion pays attention only to those three types of water storage tanks even though detailed survey was undertaken on the household reservoirs for the end uses. In this study, rough observation of the external part of tanks was also done. Potential sources of pollutants such as corrosion, unsecure cap, poor inspection, weeds and vegetation around the exterior of the base of tanks, grow of algae, sediment etc exist in and outside the drinking water storage tanks. As such, the under-listed activities were planned to be covered by this study.

Main Source of Drinking Water

For the study area, the main source of drinking water for the community, the following results were gained; that 72% is from tap water, 8% from tanks and 20% from bottled water. 72% of those who are using direct tap water are not using it for drinking but for other purposes like washing dish, brushing teeth, bathing etc., and it is highly probable that this may cause water borne diseases.

In Bole Sub-City, Woreda 10, almost all the new buildings water system for household use is directly connected to the storage tank. As a result, people are forced to use stored water in their day-to-day consumption. Also due to the size of their water storage tanks and the size of family members, most of the residents are storing water for more than 8 days depending on the frequency of their consumption.

On the other hand, in the Yeka Sub-City, Woreda 08, sometimes society does not have access to water supply for weeks and they would be obliged to make minimum use of their household water for a week. In addition, in this area, residents are experience yearlong use of metal water storage tanks, which are much likely to rust and possibly could contamination of the household water.

The AWWA (2012) report recommends that water in storage tanks be turned over about every 2.5 days to minimize water age and maximize water quality. Laboratory study discovered factors such as long retention times of 4 to 7 days, increase microbial re-growth in commonly used 1000 L fiberglass, polyethylene and cast iron household storage tanks (Evison and Sunna, 2001).

Assessment of Society Awareness

Due to their inadequate knowledge about their stored water quality deterioration, 52% of the communities do not expect that their tank water would be contaminated, and they use their tank water for drinking, cooking, washing hands, bathing, brushing teeth, etc. Even if they are not drinking it, it is possible that in many other ways the intake of untreated tank water could expose them to water borne diseases. Even though all of them have good understanding of waterborne diseases, the habit of cleaning and disinfecting water storage tanks was very low. This result further in quality deterioration of water as proved by the study undertaken by Getnet (2008), in Bahir Dar to the effect that water stored inside the household often had a worse bacteriological quality than water from source. Moreover, (Brick et al., 2004; Molbak et al., 1989; Sandiford et al., 1989) study detected that stored water contains more contaminated water than tap or pipe water.

Among the remaining 48,% who believe that their tank water is not clean and healthy more than 76,% never use any disinfectant to make their water safe to drink, even the rests do not know the side effects of disinfectants. This indicates the need for the establishment of stricter standards for disinfecting bi-products and precautionary principles, which advocates the avoidance of chemicals. According to the American Water Work Association, (1999), DBPs have been linked to bladder and rectum cancer, and may also have reproductive and developmental effects. Chloroform affects liver and kidney function in humans, and an acute and long-term exposure.

Water Borne Diseases

In the study areas about 12, % had suffered from typhoid, diarrhea, or cholera a year ago and 8, % faced water born disease in recent years, according to O'Reilly et al., (2006). Point-of-use of water treatment and safe water storage proved to have had to reduce diarrhea risks by 25-85 %, depending on the population setting and other factors. This indicates that improved water storage handling practice in the study areas must have made a difference in the health of society.

Household Water Treatment Practice

Tap water physical properties like color and taste of the study areas sometimes was not pure and attractive. These kinds of problems were not actively addressed by the health and water sectors and the people are forced to store and use this water which is highly likely to have growing bacteria. As stated by Payment et al, (1997), changes in color from that normally seen can provide warning of possible quality changes or maintenance issues and should be investigated. That may reflect degradation of the source water and corrosion problems in distribution and storage systems. The household water treatment practice in the society is very poor. According to the results, 44 % of the society water tanks water for day-to-day use remained not treated. But 38 % and18 % use some household water treatment measures like filtering and boiling for drinking purpose only. Even if these options are good, they have limited treatment by their nature Brick et al, (2004). Research found that according participants in studies report, having either boiled or filtered water, microbiological testing has indicated that contaminants were still present. Solar disinfection (SODIS) is by far the cheapest method of decontaminating water, and also one of the safest (EPA, 1996).

Challenges of Water Storage Tank Cleaning and Disinfecting

About 92 % of the household water storage tanks are lifted up on the roof and long tower about 8% are lifted on flat roof tops, which makes them 100% exposed to direct sunlight and difficult either to clean or maintain. According to the study by LeChevallier et al, (1996), coliform bacteria occurred more frequently and in higher concentrations at water temperatures greater than 15°C. Results from that study indicate that for a temperature increase from 5°C to greater than 20°C, there was an 18-fold increase of coliform occurrence in free-chlorinated systems (LeChevallier et al., 1996). These results also indicated that uncovered tank from direct sun light, environmental pollution and dusts can result in bad smell, dirt and rusts in the tank's inlet and outlet fixtures.

In some places, water storage tanks are placed near different trees which are getting in touch with solid and liquid birds and small animals wastes in the nearby place and gate. Some tank caps are also open or not secure, which has a probability of birds and small animals like rats drinking and dying in those thanks. Generally, due to the problem of availability of professional cleaners, accessibility to the tank location, lack of cleaning materials, on the other hand, awareness of the society about the sanitation conditions of their tanks, are the most common challenges in the study areas regarding to cleaning and disinfecting their water storage tanks.

Physico-Chemical Water Quality Analysis Result of Stored Water in Tanks

To reach at acceptable and finalized conclusion about stored water quality, it is important to start from storage tanks and then pull out up to the point of use. The results of this study on water quality at Water Reservoir and Consumers end use tap for all selected parameters are presented:

Table 3: Levels of Physico-Chemicals in Stored Water Tanks, Addis Ababa

Type of storage tank	Test Parameters	Results		Acceptable Standards	
		Bole Sub-city	Yeka Sub-city	WHO (Max)	Ethiopia (Max)
Steel	PH	7.89	6.99	6.5-8	6.5-8.5
	TDS	112 mg/l	112mg/l		1000 Max
	Turbidity	0 NTU	0 NTU	<5	<5
	Ammonia	0 mg/l	0 mg/l		1.5 mg/
	Nitrite(NO_3)	5.28 mg/l	4.4mg/l	0.5 mg/l	0.5 mg/l
	Residual chlorine (CL_2)	0 mg/l	0.6 mg/l	0.2-0.5 mg/l	0.1-0.5 mg/l
Fiber glass	PH	7.76	7.46	6.5-8	6.5-8.5
	TDS	220 mg/l	246 mg/l		1000 Max
	Turbidity	0 NTU	19 NTU	<5	<5
	Ammonia	0 mg/l	0 mg/l		1.5 mg/
	Nitrite(NO_3)	3.96 mg/l	5.28 mg/l	0.5 mg/l	0.5 mg/l
	Residual chlorine (CL_2)	0.5 mg/l	0 mg/l	0.2-0.5 mg/l	0.1-0.5 mg/l
Plastic	PH	8.33	7.33	6.5-8	6.5-8.5
	TDS	96 mg/l	154 mg/l		1000 Max
	Turbidity	0 NTU	0 NTU	<5	<5
	Ammonia	0 mg/l	0 mg/l		1.5 mg/
	Nitrite(NO_3)	3.52 mg/l	6.16 mg/l	0.5 mg/l	0.5 mg/l
	Residual chlorine (CL_2)	0 mg/l	0 mg/l	0.2-0.5 mg/l	0.1-0.5 mg/l

Source: Own analysis result

PH: The PH of water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems (WHO, 2008). Household stored water samples tested in Yeka and Bole

Wereda 18 and 10 had a PH value in a range of 6.99-8.33. This shows that only a small portion of households used water in compliance with the standards of drinking water with regard to PH. For drinking purposes, PH value within this range is preferable and recommended.

Having less PH value may be due to mix up of hydrogenous waste with water along the storage tank or distribution system in the presence of leaky pipes. Increase in PH value may result in formation of scale which reduces the carrying capacity of pipes and provides shelter for biofilm growth.

Turbidity: Turbidity of water is one of the important physical parameters that affect not only the quality of water, but also other chemical and bacteriological parameters and efficiency of treatment (WHO, 2006). Household samples tested in Yeka Wereda 08 had a turbidity value of 19 NTU. These were critically above WHO and Ethiopian Standards (≥5NTU) (WHO & ES, 1993, 1998 and 2001). Since turbidity is the measure of cloudiness of water, it mainly indicates growth of pathogen along the storage tank, which may contaminate the water and entrance of any objectionable matter towards the storage system (Olson, 2004).

Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote regrowth of pathogens in the tank, leading to waterborne disease outbreaks. As a result of this, water used by the community was not aesthetically pure.

Free residual chlorine: WHO and ES allow a free chlorine residual of 0.5-1mg/L. On account of this, 80% of water stored in different tanks in study areas were 0 mg/l, which is far from being the accepted limit and only 20 % were 0.5 and 0.6 free chlorine residual starting from 0.7 up to 1mg/L that obey the standard and this amount of free chlorine was assumed to be not sufficient for the whole disinfection process along the water storage tanks and require an excessive disinfectant. This may be the result of the age of the water in the storage tank, microbial re-growth within the storage tank and distribution system reaction with tank corrosion, by-products and cross-connection of other contamination that consumes disinfectant; From the study it can be concluded that only a small amount of household storage tanks get the appropriate proportion of disinfectants.

Ammonia: As a result, concentration of Ammonia in storage tanks was nil, which complies with WHO and ES recommended value.

Nitrate: The detection of nitrate is an important water quality indicator that shows organic matter pollution due to microbial activity and accumulation of Ammonia (Desta, 2009). Even though Ammonia concentration was nil during the analysis, nitrate concentration in different storage tanks was 3.52 mg/l, 3.96 mg/l, 4.4 mg/l, 5.28 mg/l, 5.28 mg/l, and 6.16 mg/l. The total samples have Nitrate concentration of greater than 0.5Mg/l, which is greater than the standard.

Bacteriological water quality of household water tanks.

Quality of drinking water at source is within WHO, 1993 and ES, 1998, 2001, which is 0 CFU/100 ml. This shows that there was no coliform and the water was safe and palatable. Apart from water source and reservoirs, it is most important to analyze water quality that reaches to household storage tanks. This determines the health status of the population. Accordingly, for this study to assess bacteriological quality of drinking water at the household tank level, the following water quality parameters were determined.

Total coliform: total coliforms were used as the indicator bacteria to assess the level of bacteriological contamination of water supplies. Laboratory analysis of household reservoir water samples in Yeka Sub city Woreda 8 indicates the presence of total coliform. Even if the presence of total coliform is not an index of fecal pollution or of health risk, it provides basic information on treatment efficiency and water quality.

Fecal coliform: household samples tested at the same tank in Yeka Sub-City Woreda 8 study area show the existence of thermo-tolerant (fecal) coliform. There is the presence of Fecal or thermo-tolerant coliform that grows at 44 - 44.5^{0}c. This result shows the presence of fecal coliform. Since they are indicators of the possible presence of waterborne pathogens, one can expect waterborne diseases in the study area. This was proved by the results of the questionnaire and the report from the Sub-city Health Center, which shows their people are rapidly exposed to waterborne diseases. Among the ten top diseases in the study areas, diarrhea was used as an example for being caused by ingestion of contaminated water or food or poor sanitation.

In this study, the average count of total coliforms and thermotolerant coliforms were above the recommended value of WHO and Ethiopian Standards, especially the total coliform and thermotolerant coliform counts were higher in household water samples. Results of this study are in agreement with studies conducted in South Africa and Zimbabwe which reported that compliance is significantly higher for water reservoir than tap water (Gundry, Wright, Conroy, Dupreez, Genthe, 2006).

E-Coli; household water tank samples tested at the same tanks in Yeka Sub-city Woreda 8 show the existence of E-Coli. E-coli is a bacterial species found in the fecal matter of warm blooded animals (humans, other mammals, and birds). Total coliform bacteria are an entire group of bacteria species that are generally similar with, and include the species E-Coli. There are certain forms of coliform bacteria that do not live in fecal matter but instead live in water or soil in temperate climates that have not been subjected to faecal pollution, although there is the possibility of regrowth in hot environments (Fujioka et al., 1999)

Table 4: Summarized Microbiological Result in Yeka Sub-city

Parameters (Tests)	**Method reference**	**Results**	**Acceptable Limit**
APC at 35^{o}c/48 hrs	APHA (1995)	TNTC efu/ml	-
Coliform	WHO (1971/2004)	>161 MPN/100 ML	<1 MPN/100ML
Fecal Coliform	WHO (1971/2004)	>161 MPN/100 ML	<1 MPN/100ML
E. Coli	ICMSF (1988)	Present	Absent

Source: Own Analysis Result

Generally, from bacteriological water quality tests, household water tanker water samples do not meet the TC standard set by WHO and Ethiopia. Due to this, the samples indicate failed to meet safe water quality with regard to TC and FC criteria of 0 CFU/100ml, respectively (WHO, 1971/2004).

Conclusion

All the result from this are study put together in the following conclusion. In the study area most of the people do not expect deterioration in quality status of the drinking water in their storage tanks. This indicates that the level of knowledge on cleaning and disinfecting water storage tank management has been significantly low. Due to this the people have no habit in using home water treatment methods; even though a small portion of the community uses home water treatment mechanisms like boiling, filtering and water tabs. Due to lack of information on selection of treatment alternatives based on status of drinking water quality on basic parameters an antagonist and synergist effect were noticed. Moreover, poor sanitation and lack of attention to clean and disinfect household's water storage tanks were the main factors for the contamination of water during storage at home.

Those drinking water storage tanks not cleaned and disinfected have potential hazard to contaminate the stored water by solid and liquid waste due to poor management of household water storage tanks by the community. The physicochemical and bacteriological test results of samples from different storage tanks were not within the permissible standard limits of WHO and Ethiopia (1971, 2004). Thus from this study, water in different types of storage tanks was grossly contaminated with Nitrate turbidity and lack of residual Chlorine. This result in an increase in Turbidity which reduces performance of disinfection process then leads to continued existence of water associated diseases causing organisms. And also there was an increase in bacterial indicator in the steel type water storage tanks. The level of contamination was higher in Yeka Woreda 8 Area than the new area of Bole Woreda 10 due to tank age and water retention time.

Consequently, the result from health impact assessment of drinking water based on the study area shows that use of water stored in tanks for consumption purpose has a severe impact on the community’s health. Poor attention, low water treatment practice, and poor tank cleaning and disinfecting practice and the way of placing storage tanks, exposure of drinking water tanks and pipes to direct sunlight and presence of leakage due to damaged pipes resulted in cross contamination of stored water with dirty stuff, had contributed greatly to the high level of bacterial contamination of water in the storage tanks.

On the other hand, the regulatory body of Ethiopian Standards Authority doesn't have any standard regarding the inspection and control of water storage tanks quality and water stored in them. Added to this, the Ethiopian Ministry of Health and the National Public Health Institute laboratory Center has not given attention to household water storage tanks and their impact on water quality. Furthermore, AAWSA and the Sub-City Water Supply Sector were not actively participating in drinking water storage management and in tank water quality supervision and monitoring.

Recommendations

- The idea of this project is to create safe and clean water storage tank system as well as healthy and productive society by showing the requirements related to water storage tank management at the household level;
- The stakeholders involved in water sectors should take the responsibility of creating awareness at the level of society and provide the necessary support;
- It is also important to adopt appropriate code of practice for the inspection and cleaning of customer water storage tanks by stakeholders and assign a responsible body as it is the practice in other countries;
- Regular inspection of water storage tank sanitary and hygienic aspects, solid and liquid waste around and inside the tanks, strict control and appropriate management of the storage tanks, should be done;
- Unreachable tanks hinder awareness. Therefore construction professionals should improve ordinary ways of constructing water storage tank placing towers. It should be accessible and shaded from direct sun light. Since the temperature between 15 ^{o}C - 60 ^{o}C is

suitable for bacteria growth steel, black or blue color tanks must be avoided and the use white color should be done;

- The present work is limited to a few bacteriology and physicochemical parameters and sampling frequency. Therefore, wide and year round sampling and analysis of additional parameter of household water storage tank quality is recommended to be undertaken.

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