World Journal of Arts, Commerce and Sciences
Vol. 1, No. 2, December 2013, PP: 01 - 08
Available online at http://wjacs.com/

Research article

Drinking Water Quality

DesalegnAmenu

College of Natural and Computational Science, Wollega University, Biology Department, P.Box, 395, Nekemte, Ethiopia
E-mail: wadadesalegn@gmail.com

Abstract

Over 60% of the communicable diseases are arising from unsafe and inadequate water supply, poor hygienic, and sanitation practices. Three- forth of the health problems of children in Ethiopia are communicable diseases due to polluted water and improper water handling practices. High concentration of microbiological indicators in all water sources of this study area may demonstrate the presence of pathogenic organisms which constitute a threat to anyone consuming or in contact with these waters. This is due to lack of good water treatment, improper water handling practices and lack of the protection of the water sources. Consequently, protection of water sources accompanied by sanitation and hygiene promotion programs can improve the water quality of rural water sources, where disinfection is not feasible.

Keywords: Microbiological water quality, fecal colifrom, total coliform

Introduction

Water is one of the most important compounds that constitute the largest part of life. About 70% of the earth's surface is water and 3% of this is fresh water. So far, out of the 3% fresh water, 99% is found beneath the surface (Jarrett, 1995). The major water sources for use are surface water bodies such as rivers and lakes, and underground sources and pore spaces down the water table (Ring, 2003). Water derived from these sources is not necessarily pure since it contains dissolved inorganic and organic substances, living organisms (viruses, bacteria, parasites, etc). For this reason, water intended for domestic uses should be free from toxic substances and microorganisms that are of health significance (WHO, 2005). According to WHO (2003), more than 80% of the human diseases in the world are caused by unsafe water supply and due to inadequate environmental sanitation practices. One billion people lack access to safe water, while 2.4 billion people have inadequate sanitation (Macy and Quick, 2004). The latter has an impact on individuals, households, communities and countries. In a situation where there is no clean water and proper sanitation; millions of people would suffer from devastating diseases and millions of children would die due to water borne diseases (Hoffman, 2003). Protection of water sources from contamination is the first line of defense against water borne disease. Because of the essential role water plays in supporting human life, it has great potential for transmitting a wide variety of disease and illnesses if contaminated. Source protection almost consistently is the best method of ensuring safe drinking water (Richards, 1996).

In rural areas and villages of Ethiopia, water for human consumption, drinking, washing (bathing, laundry), for preparation of food etc, is obtained from rivers, streams, shallow wells, springs, lakes, ponds, and rainfall. Unless water is made safe or treated for human consumption, it may be hazardous to health and transmit diseases. The main contaminants of these water sources are from human excreta because of open field defecation practices, animal waste and effluent from sewage system. Thus, the majority of rural communities use water from contaminated or doubtful sources, which expose the people to various water-borne diseases (MWR, FDRE, 2004). Different types of pathogens can contaminate water, food, air and other environmental media in many different ways. Measuring all of these pathogens routinely for determining presence or absence or acceptable concentration is not possible. This is due to the following reasons: the methods are not available to recover and measure all microbes, the methods are available for only some selected microbes and not applicable for others; they are technically demanding, some methods are slow to produce results and their costs are high and it's impossible to enumerate all pathogenic microorganisms. Therefore, measuring something other than a pathogen that is indicative of contamination predicts the presence of pathogen and estimates human health risks. In addition, these indicators can tell whether the water is safe or not. So by using indicators the water quality can be assessed. The most applicable and recommendable indicator bacteria are fecal coliform and total colirfrom (Mark, 2006).

The use of indicator organisms, in particular the coliform group, as a means of assessing the potential presence of water-borne pathogens has been of paramount importance in protecting public health. The principle of the detection of selected bacteria that are indicative of either contamination or deterioration of water quality has been the foundation upon which protection of public health from water-borne diseases has been developed (Barrell *et al*., 2000). Ethiopia is one of the developing countries where only 52% and 28% of its population have access to safe water and sanitation coverage, respectively (MoWR, 2007). For this reason, 60- 80% of the population suffers from water-borne and water-related diseases (MOH, 2007). This burdens the country with enormous financial and social costs to take care of such a huge number of people suffering from these debilitating infections. Some report showed that water sources and distribution systems of towns and rural communities alike have serious water quality problems. Assessment of bacteriological and physico-chemical qualities of urban source water and tap water distribution systems in Akaki- Kalit sub-city of Addis Ababa (Mengestayehu,2007), Ziway town (Kassahun, 2008), Bahir Dar town (Getnet,2008), Nazareth (Adama) town (Temesgen, 2009) showed contaminations of water by indicator bacteria such as total coliforms, faecal coliforms and/or faecal streptococci. Similarly, underground water sources (hand dug wells) from rural areas in Menge District, BenishangulGumuz region (Mebratu, 2007), and protected springs and hand pumped wells in Werebabo District, South Wello (Atnafu, 2006) indicated that 60-100% of the water samples were positive for total coliforms and faecal coliforms. This shows that the provision of safe water through extraction of water from deep underground and protected water sources from relatively less contaminated rural areas was not even immune from contamination. All these findings give conclusive evidence that water quality problems are rampant both with small-scale and large-scale water delivery systems in the country. This would pose high health risks to users unless prompt intervention is undertaken. This, therefore, necessitates the evaluation and putting in place of sustainable monitoring system to determine the water quality status of municipal and rural water distribution systems. This study is to evaluate the drinking water quality.

Drinking Water Quality

According to a study conducted by Curtis *et al* (2000), the basis of good water quality isimportant to human health. In fact, it is agreed that the principal risk to human healthassociated with the consumption of polluted water are microbiological. The provision of anadequate supply of safe water was one of the components of primary health care identified bythe International Conference on Primary Health Care (Curtis *et al*., 2000). Water qualitystandards have been developed to minimize the known chemical and microbial risks of humanhealth. Safe drinking water does not imply risk free; it simply denotes risks are veryinsignificant which could not result in serious health problems (Clasen *et al*., 2006). Theimportance of doing away with microbiological contamination is the major benefit of ensuringgood water quality for drinking and reducing of water-borne diseases transmitted by thefaecal-oral route. Generally, improvements in microbiological water quality as well as the prevention of use of unhygienic water sources are best interventions to prevent water-bornediseases (Brown, 2003).

In accordance with the research conducted on the microbiological water quality of groundwater, protected springs and protected wells and protected water connection system, it shouldbe possible to achieve very low levels of contamination (Cheesbrough, 1987). However,different water sources are highly subjected to bacterial contamination, due to various reasons.To assess this problem, WHO prepared a standard for microbiological water quality evaluationchecklist which have five categories (zero=safe, 1-10=reasonable quality, 11-100= pollutedwater, 101-1000=dangerous and >1000 very dangerous) (WHO, 2004).The result of sanitary and quality monitoring in a pilot water quality surveillance study inSrilanka demonstrated that, 65.0% to 85.0% of public water supplies; mostly springs becomefeacally contaminated because of poor site selection, protection and unhygienic managementof facilities (Sutton, 1989).A study conducted in rural Zambia showed that poor community sanitary practices around thesource and in the catchments area together with failure in the protection of water sourcescontributed to the contamination of drinking water (Sutton, 1989). Likewise, study conductedin South Wollo, Ethiopia, clearly revealed that improper sanitary survey and failure in theprotection of water sources together with poor community sanitary practices around the sourceand in the catchments area contributed to the contamination of drinking water with faecalmatter (Seid *et al*., 2003).

Factors Affecting Water Quality

The quality of protected water sources can be deteriorated due to poor site selection, inadequate protection and unhygienic management of facilities (Richards, 1996). The result ofsanitary and quality monitoring in a pilot water surveillance study in Yogyarkarata, Jauademonstrated that 65.0-85.0% of public water supplies; mostly springs became faecallycontaminated because of poor site selection, protection and unhygienic management offacilities (RichSeid *et al*., 2003). Water may become unsafe at any pointbetween collection and use (WHO, 1994). Unrestricted and unhygienic water collectionactivities, soiled hands and unclean water collection vessels were potential contributors for thecontamination of drinking water sources (Kravitz, 1999). The highest level of household watercontamination is found in stored water, since stored water became contaminated when it istouched by unclean fingers during over dipping (Kravitz, 1999).

Microbiological Water Contamination

Water from contaminated sources may cause numerous diseases and premature deaths. Thefact that, man needs water and cannot live without it, forces him to use it even for drinkingpurposes, whether clean or contaminated. As a result, people suffer from water-borne diseasesespecially in Ethiopia. In rural villages and urban areas of Ethiopia, the main contaminants forwater are human excreta, animal waste, liquid waste from factories, garages, pesticides fromdifferent sources. Water sources contaminated with these wastes is not fit for human use,unless it is made safe or treated (FDRE, MoH, 2007).A large variety of bacteria are capable of initiating water borne infections. The entericbacterial pathogens include early-recognized agents, such as *Salmonella* and *Shigella* speciesand newly recognized pathogens from fecal sources, such as *Campylobacter jejuni* and*Escherichia coli*. Several bacterial pathogens, such as *Legionella* species, *Aeromonas* species,*Pseudomonas aeruginosa* and *Mycobacterium avium*, have a natural reservoir in the aquaticenvironment and soil (Leclerc, 2001). More than 15 different groups of viruses, encompassingmore than 140 distinct types, can be found in the human gut. These enteric viruses areexcreted by patients as well as asymptomatic carriers and find their way into sewage (Leclerc*et al.*, 2003).The most common manifestation of water-borne illness is gastrointestinal upset (nausea,vomiting, and diarrhea), and this is usually of short duration. However, in susceptibleindividuals such as infants, the elderly, and immuno-compromised individuals, the effects maybe more severe, chronic (e.g., kidney damage) or even fatal. Other pathogens may infect thelungs, skin, eyes, central nervous system, or liver (Health Canada, 2006).

World Journal of Arts, Commerce and Sciences
Vol. 1, No. 2, December 2013, PP: 01 - 08
Available online at http://wjacs.com/

Water Borne Pathogens and Diseases

Water-borne diseases are typically caused by enteric pathogens, which are mainly excreted infaeces by infected individuals and ingested by others in the form of faecally contaminatedwater or food. These pathogenic organisms include many types of bacteria, viruses, protozoaand helminthes, which differ widely in size, classification, structure and composition.Pathogenic organisms are highly infectious and disease causing which are responsible formany thousands of diseases and deaths each year especially in tropical regions with poorsanitation (WHO, 2005).All potential water-borne human pathogens present a serious risk of disease whenever they areconsumed in drinking water and are given high priority for health significance. Animalsincluding humans are typically the main carriers of large populations of these bacteria,protozoa, and viruses. Pathogens originating from human sources, often from human faeces,are called enteric (of intestinal origin) pathogens. The most common ones include strains of *Escherichia coli, Salmonella, Shigella, Vibrio cholerae, Yersinia enterocolitica,* and*Campylobacter jejuni*. Some organisms may cause disease opportunistically and causeinfection mainly among people with impaired natural defence mechanisms. These peopleinclude the very old, the very young, immuno-compromised people and patients in hospitals.Examples of such opportunistic organisms include *Pseudomonas, Klebsiella,* and *Legionella*(WHO, 1995). Drinking water is the main route of transmission for pathogens of faecal origin.Unhygienic practices during the handling of food, utensils and clothing also play an important role (WHO, 2006).

The persistence of a pathogen in water affects their transmission to humans. A more persistentpathogen that can survive longer outside the host body is more likely to be transmitted to otherpeople. The infective dose (ID) of the pathogen determines the number of organisms needed toproduce an infection in humans. The ID50 is the dose required to produce a clinicallydetectable infection in 50% of the subjects (Meylan, 2004).Therefore, improvements in the quality and availability of water, sanitation facilities andgeneral hygiene education will all contribute to the reduction of morbidity and mortality ratesdue to water-borne diseases (Meylan, 2004).

Microbial Indicators of Water Quality

A bacterial indicator of faecal pollution is any bacteria whose presence can indicatecontamination of water with faecal matter. Faeces of warm-blooded animals including humanbeings regularly discharge a diverse micro-flora of bacterial taxa like *Enterococcus faecalis,Clostridium perfringens, Lactobacillus bifidum (Bifidobacterium), Escherichia coli,Enterobactoraerogenes, Staphylococcus aureus, Pseudomonas aeroginosa, Proteus* andcertain spore forming bacteria. In addition, pathogens like *Salmonella, Shigella, Brucella,Micobacterium, Vibrio and Leptospora*together with certain viral and protozoan pathogensmay also present (Moe, 1997).The probability that a person will be infected by a pathogen cannot be inferred from thepathogen concentration alone. This is because different humans respond differently to thepathogens. As a result, there is no real lower limit for acceptable levels of pathogens in water.Instead, it follows that safe drinking water intended for human consumption should containnone of these pathogens. To determine if a given water supply is safe, the source needs to beprotected and monitored regularly (WHO, 1996).

There are two broad approaches to water quality monitoring for pathogen detection .The firstapproach is direct detection of the pathogen itself, for example, the protozoan*Cryptosporidium parvum*. While it will be more accurate and precise if specific diseasecausingpathogens are detected directly for the determination of water quality, there areseveral problems with this approach. First, it would be practically impossible to test for eachof the wide variety of pathogens that may be present in polluted water. Second, even thoughmost of these pathogens can now be directly detected, the methods are often difficult,relatively expensive and time-consuming. Instead, water monitoring for microbiologicalquality is primarily based on the second approach, which is to test for indicator organisms(APHA, 1998).

According to the report of Slaats *et al*. (2002), water quality indicator organisms should fulfillthe following criteria; an indicator organism should always be present when pathogens arepresent, indicators and pathogens should have similar persistence and growth characteristics,indicators and pathogens should occur in a constant ratio so that counts of the indicators give agood estimate of the numbers of pathogens present, indicator concentrations should far exceedpathogen concentration at the source of pollution, the indicator should not be pathogenic andshould be easy to quantify, tests for the indicator should be applicable to all types of water andthe test should detect only the indicator organisms thus not giving false-positive reactions.Another reason for using simple indicator tests is that pollution is often intermittent and/orundetectable. It is often better to monitor drinking water frequently by means of a simple testthan to monitoring infrequently using a longer and more complicated direct pathogen detectiontest. While these indicator bacteria or viruses are not necessarily pathogenic themselves, someof them have the same faecal source as the pathogenic bacteria and can therefore indicatefaecal contamination of water. One example that fulfils many of the above criteria is theindicator organism Thermotolerant/fecal coliforms .Therefore, it may be sufficient to get anindication of the presence of pathogens of faecal origin with the detection and enumeration ofcoliform. Such a substitution is especially valuable when resources for microbiologicalexamination are limited as in developing countries (WHO, 1993).

Total Coliforms Bacteria (TC)

Total coliforms are the ones that are commonly measured as indicator bacteria for drinkingwater quality (Hurst *et al.,* 2002). They are defined as aerobic and facultatively anaerobic nonsporeforming bacteria that ferment lactose at 35 to 370C with the production of acid and gaswithin 24-48 hours (Hurst *et al.*, 2002). Coliform bacteria belong to the family*Enterobacteriace* and include *Escherichia coli* (*E.coli*) as well as various members of thegenera *Nitrobacteria*, *Klebsiella* and *Citrobacter* (Hurst *et al.,* 2002). These bacteria originatein the intestinal tract of warm-blooded animals and can be found in their wastes. They can alsobe found in soil and on vegetation (Nold, 2008).Although coliform bacteria are not pathogens, their presence indicates the possibility of finding pathogens in drinking water (Nold, 2008). Consequently, they are used to assess possible faecal contamination or water pollution from sewage. According to Hurst *et al* (2002), the persistence of total coliform bacteria in aquatic systems is comparable to that ofsome of the waterborne bacterial pathogens. Furthermore, coliform bacteria are relativelysimple to identify and are present in much larger numbers than more dangerous pathogens(Hurst *et al.,* 2002). For this reason the degree of faecal pollution and the presumed existenceof pathogens can be estimated by monitoring coliform bacteria (Volk *et al*., 2002).

Thermotolerant (Fecal) Coliforms (TTC/FC)

Thermotolerant/Fecal coliforms bacteria are a subset of the TC group, with the same definitionas total coliforms bacteria except that they grow at 44.5 0C. Many countries have been adopteduse of TTC /FC as indicator in their water quality standards and they have been recommendedas the indicator of choice for evaluating the microbiological quality of recreational water(Toranzos et al., 2002). The reason for testing for fecal coliforms is that they are morerestricted in their source to the gastro intestinal tract of warm-blooded animals. Likewise, theyhave an excellent positive correlation with fecal contamination from warm-blooded animals(Toranzos et al., 2002). TTC /FC are present in virtually all warm-blooded animals, includinghumans, in numbers far exceeding the numbers of pathogens (MSSC, 1992).

In a study conducted in Gondar, Ethiopia, 75% of the samples taken from unprotected wellsand springs were contaminated by fecal coliforms (Mengesha*et al*., 2004). The authors furtherreported that fifty percent of the samples in both cases had a coliform count of 180/100 ml andabove. No sample in either case had a coliform count of less than 10/100 ml. The leastcoliform count seen was 13 coliform /100 ml and based on these; they concluded that themajority of the drinking water sources were either of unacceptable quality or grossly polluted(Mengesha*et al*., 2004).

The Sanitary quality of water sources

Availability of safe water alone does not reduce diarrheal diseases significantly. Even if thesource is safe water become faecally contaminated during collection, transportation, storageand drawing in the home (Thomas and Cairncross, 2004). Inadequate hygiene practices must be targeted as well when implementing water and sanitation projects, to decrease morbidity and mortality especially in rural area. Along with building or improving water points thereforewe should provides hygiene education for all user groups. Hygiene Promoters informcommunity members about the correct use and storage of water, the need for safe sanitationfacilities, personal and environmental hygiene and diarrhea transmission and management,aiming at sustainable behavior change (WHO, 2006).Key factors in the provision of safe household water include the conditions and practices ofwater collection, storage and the choice of water collection and storage containers or vessels.Numerous studies have documented inadequate storage conditions and vulnerable waterstorage containers as factors contributing to increased microbial contamination and decreasedeither microbial quality compared to source waters or water stored in improved vessels(WHO.2002). Some studies documented increased risks of waterborne infectious diseasesfrom inadequately stored water compared to water stored in an improved vessel (safe storage).In India morbidity and mortality due to waterborne diseases have not declined proportionatewith increase in availability of potable water supply, largely owing to the fact that quality ofwater is not maintained at consumer point and that safe water may become contaminatedduring storage due to poor handling practices and poor personal hygiene (Thomas and Cairncross, 2004).

According to the study conducted in Northeast Thailand suggested that there was a far greaterrisk of ingestion faecal coliform bacteria resulting from the cross contaminations occurringwithin the house hold than from the faecal pollution of drinking water sources (John, 1991).Mean coliform counts were substantially higher in household water containers than in watersources. In their study on water borne transmission of cholera in Trujillo, Peru, Swerdlow *etal*, tested the water quality variation at the source and later in the household (i.e. stored water).The result showed that, the mean coliform counts were 1 and 20 fecal coliform /100 ml for thewell water and stored water respectively (Swerdlow*et al.*, 1992).A study conducted in rural Bangladesh showed water stored for longer period increase vibrocholera rate by 10 folds (Spira, 1980). Similarly study conducted in Calcutta, India waterstorage vessels, which have wide mouth increase cholera infection by 4 folds (Deb *et a.*,1982). Likewise, as the study conducted by Verweij (1991) in Venda, South Africa indicatedthat water stored in plastic vessels have higher levels of coliform over time. Another study inthe same area of rural Bangladesh showed water stored in traditional pots increase faecalcoliform levels and multiply antibiotic resistance flora than other storage containers (Shears,1995). Because unrestricted and unhygienic water collection activities, soiled hands and unclean water collection vessels were potential contributor for the contamination of drinkingwater. The highest level of household water contamination found in stored water, since storedwater becomes contaminated when unclean objects touch it over dipping (Kravitz, 1999).A study conducted in Jimma Town showed among the total of 192 study households141(73.4%) rinsed their collection containers. In addition, 178(92.7%) had cover for theirstorage vessels and 138(72%) drew water from storage container by dipping (Teklu andKebede, 1998). In Garamuleta district Eastern Ethiopia, only 60.0% of the studied familiesstored their water in covered containers. In another study conducted in KidameGebeya, it wasfound out that 58.0% of the households kept their water in clean and covered containers.Similarly, study conducted in Jimma town showed 70.4% of the studied population takingwater from the storage container by dipping rather than pouring, out of these, 52 .2% use cupwithout handle (Teklu and Kebede, 1998).

References

[1] American Public Health Associations (APHA), 1998. Standard Methods for the Examinationof Water and Waste Water. American People Health Association, 20th edn, Washington DC.

[2] Atnafu, M., 2006. Assessment of Bacteriological Quality of Drinking Water Supply at thesources and Point of Use at Home in Worebabu District, South Wollo.M.Sc Thesis.Addis Ababa University, Addis Ababa.34-57.

[3] Barrell, R., P. R Hunter and G. Nichols, 2000. Microbiological standards for water and their relationship to health risk. *Commun. Dis. Public Health,* 3: 8-13.

[4] Birhanu, M., 2008. Assessment of the contamination level of water and determines the major sources of contamination at water collection point in Yubdo –Legebatu River, East Show, and Ethiopia. Addis Ababa.34-65.

[5] Brown, J., 2003. Evaluation of Point-of-Use Microfiltration for Drinking Water Treatment in Bolivi*a*. Cambridge University Press, London. 234p.

[6] Curtis, V., S. Cairncross and R. Yonli, 2000. Domestic Hygiene and Diarrhea: Pinpointing the Problem. *Journal of Tropical Medicine and International Health, 5(1): 22-32.*

[7] Dawit,Ayalew., 2006. Association of *Cryptosporidium Parvum, Giardia Lamblia*and *EntamoebaHistolytica/Dispar*Infection with Drinking Water Sources among Children in Rural Part of Dire-Dawa. Addis Ababa, Ethiopia, p.20-30.

[8] DestaKassa, 2009. Bacteriological and Physicochemical Quality assessment of Drinking Water Supply from source to taps in Debrezeit town, Ethiopia. Addis Ababa University, Addis Ababa.M.Sc.Thesis Addis Ababa University, Ethiopia 50-60.

[9] Federal Democratic Republic of Ethiopia, Ministry of Health (FDRE, MoH), 1997. Rapid assessment of drinking water quality in the Federal Republic of Ethiopia, country report.

[10] Federal Democratic Republic of Ethiopia, Ministry of Health Addis Ababe , Ethiopia. Federal Democratic Republic of Ethiopia, Ministry of Health (FDRE, MoH), 2007.Rapid assessment of drinking water quality in the Federal Republic of Ethiopia, country report.

[11] Federal Democratic Republic of Ethiopia, Ministry of Health, Addis Ababa, Ethiopia. Federal Democratic Republic of Ethiopia, Ministry of Water Resources (FDRE, MWR) 2002.Ethiopian guidelines specification for drinking water quality.Federal Democratic Republic of Ethiopia, Ministry of Water Resorces, Addis Ababa, Ethiopia.

[12] Federal Democratic Republic of Ethiopia, Ministry of Water Resources (FDRE, MWR), 2004. Rapid assessment of drinking water quality in the Federal Republic of Ethiopia, country report.Federal Democratic Republic of Ethiopia, Ministry of Water Resource. Addis Ababe, Ethiopia.

[13] GetnetKassahun, 2008. Physico-chemical and Bacteriological Drinking Water Quality Assessment of Bahir Dar town water supply from source to yard connection (North- Western Ethiopia).M.Sc Thesis, Addis Ababa University, Addis Ababa.

[14] Health Canada, 2006. Guidelines for Canadian drinking water quality: Guideline Technical.

[15] Hoffman, A.R., 2003. Energy and Water, U.S. and Winrock International, June 2003.1-33.

[16] Hurst, C. J. Kundsen, M. J. Mclnerney, L.D.Stezenbach, and M.V. Walter, 2002. Manual of Environmental Micribilogy.2nd ed. PP: 265-284. American Society for Microbiology.American Society of Microbiology Press, Washington, DC.

[17] Jarrett, A., 1995 .Water Management. Kendall/Hunt Publishing Company, USA.

[18] John, P., 1991.Water use and pattern of contamination in rural northeast Thailand, Southampton row, London; Vol. 9 (27).

[19] Kravitz, J., 1999. Quantitative bacterial examination of domestic water supplies in Leseto high lands: water handling and village health. Bulletin of World Health Organization, 77 (10): 829- 833.

[20] KassahunBedane, 2008. Assessment of Physicochemical and Bacteriological Quality of Drinking water in Central Rift Valley System, Ziway town, Oromia Regional state.M.Sc Thesis.Addis Ababa University, Addis Ababa.

[21] Leclerc, H., 2003. Relationships between common water bacteria and pathogens in drinkingwater.Published by IWA Publishing, London, UK.

[22] Macy, J., and R .Quick, 2004. The Safe Water System: A household Based Water Quality Intervention Program for the Developing World, Centre for Disease Control. p. 1-3.

[23] MebratuJano, 2007. Assessment of Physicochemical and microbiological Quality of rural Drinking water supply at the source in MengeWoreda, BenshangulGumuz Regional state, Ethiopia. M.Sc Thesis. Addis Ababa University, Addis Ababa

[24] Mark, D., 2006. Drinking water and health research: a look to the future in the United States and globally, accessed on October 12, 2006.

[25] MengeshaAdmassu, MamoWubshet and BayeGelaw, 2004. A survey of bacteriological quality of drinking water in North Gondar Ethiop *.J. Health Dev. 2004.18(2)*: *113-135.*

[26] MengistayehuBirhanu, 2007. Assessment of Physicochemical and Microbiological Quality of Rural Drinking Water Supply at the Sources and selected Communities of Akaki- Kality Sub- City, Addis Ababa City Administration. M.Sc Thesis. Addis Ababa University, Addis Ababa
[27] Meylan, W.M., 2004. Finding and estimating chemical property data for environmental assessment. *Journal of Environmental Toxicology and Chemistry*. 23: 22–23.
[28] Ministry of Health (MOH), 2007. Need Assessment to achieve Universal Access to Improved Sanitation and Hygiene, Unpublished Document, Addis Ababa, Ethiopia.
[29] Nold, 2008. Rapid Microbial Monitoring Methods.The Status Quo International Water Associations Blue Pages.
[30] Richards, J. B., 1996. Drinking Water monitoring and surveillance.*African Health*;4, Pp. 10.
[31] Ring, S. 2003. Introduction to Microbial Safety of Drinking Water: Drinking Water Drinking Water Academy USEPA.
[32] SeidTiku, LegesseWorku and kebedeFaris, 2003.Factor affecting water quality from source to home in Tehuledereworeda, Northeast Ethiopia.Ethiop. J. Health Sci. 13 (2): 94-106.
[33] Shears, P., M.A., A.H. Hussein, 1995. Water sources and environmental transmission of multiply resistant enteric bacteria in rural Bangladesh. Annals of Tropical Medicine & Parasitological, 89(3):297-303.
[34] Slaats, P.G., G.Rosenthal. L.P.M.Seiger., W.G.Boomen., M.Beuken and R.H.S.Vreeburg, 2002. Process involved in generation of dissolved water. Report no.KOA02.058.American water works association research foundation/Kiwa, the Netherlands.
[35] Spira, W.M., M.U., Y.A. Khan, 1980. Microbiologic Surveillance of Intra-neighborhood Cholera Transmission in Rural Bangladesh. Bulletin of the World Health Organization, 58:731-740.
[36] Swerdlow, D., 1992. Water borne transmission of epidemic cholera in Trujillo, Peru: lesson for a continent at risk, Lancet vol. 340(22): 28-30
[37] TamiruAlemayehu, 2001. The impact of uncontrolled waste disposal on surface water quality in Addis Ababa. SINET: *Ethiopian Journal of Science* 24 (1):93-104.
[38] TemesgenEliku, 2009. Assessment of Physicochemical and Bacteriological Quality of Drinking Water supply at sources and house hold in Adama town, Oromia Regional state, Ethiopia.M.Sc Thesis. Addis Ababa University, Addis Abab
[39] TekluMulugeta and KebedeFaris, 1998.Survey on practice of water handling and level of contamination in Jimma town. Eth. J. H. Science, Vol. 8(1): 29-34.
[40] Thomas ,C .and S.Cairncross, 2004. Household water management: refining the dominant paradigm. Tropical Med. and International Health; 9 (2):187-191.
[41] Toranzos, G. A., G. GA. McFeters, and J. J. Borrego, 2002. *Detection of Microorganisms inEnvironmental Fresh and Drinking Waters, manuals of Environmental Microbiology, 2nd edn.PP205-219.*Washington DC: ASM press.
[42] United Nations Children’s Fund and World Health Organization (WHO), 2008 Joint Monitoring Programmed for Water Supply and Sanitation. Meeting the MDG Drinking Water and Sanitation Target, A Mid-Term Assessment of Progress. New York, NY.
[43] United States Environmental Protection Agency (USEPA), 2005. Method 1623: *Cryptosporidium* and *Giardia* in water by Filtration/IMS/FA. United States Environmental Protection Agency, Office of water.
[44] Volk, C.J., R.Hofmann, C.Chauret, G.A.Gagnon, G.Ranger, and R.C. Andrews, 2002. Implementation of chlorine dioxide disinfection: Effects of the treatment change on drinking water quality in a full-scale distribution system *J. Environ. Eng. Sci*.1:323–330. http://jees.nrc.ca/.
[45] World Health Organization (WHO), 1993. Water and sanitation: WHO fact sheet no. 112, World Health Organization, Geneva. World Health Organization, 1994 .Drinking water quality control in small community supplies VOL.II, WHO, Geneva
[46] World Health Organization (WHO), 1996. Guidelines for Drinking Water Quality (Health Criteria and Other Supporting Information, Vol. II, 2nd ed., World Health Organization, Geneva World Health Organization (WHO), 1997. Guidelines for drinking water quality: Surveillance and control of community supply, second ed.vol.2. Geneva.