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Assessment of physico-chemical and bacteriological quality of drinking water at sources and household in Adama Town, Oromia Regional State, Ethiopia

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Water quality is a critical factor affecting human health and welfare. This study aimed at examining the physico-chemical and bacteriological quality of drinking water in Adama town. A total of 107 triplicate water samples were examined; 1 from inlet point (raw water), 1 from outlet (the water after treatment, 1 from reservoir (treated water stored), 52 from pipe water and 52 from systematically selected household's containers. Six physico-chemical parameters namely temperature, turbidity, pH, free chlorine residual (FCR), nitrate, fluoride and three bacteriological parameters: total coliform (TC), fecal coliform (FC) and fecal streptococci (FS) were analyzed. Temperature was average of 23.30, 21.23 and 22.57°C at the inlet, outlet and reservoir sampling points, respectively, which were above WHO and national standard limits of <15°C. Concerning FCR, at the outlet, FCR was 0.78 mg/l which was in the WHO recommended limit of 0.6-1 mg/L and at reservoir sampling point, the FCR was 0.35 mg/l which was in the WHO and national standard limit of 0.2-0.5 mg/L. The average concentration of TC, FC and FS at the inlet point was 196, 142 and 117 cfu/100 ml, respectively. On the other hand, at the outlet and reservoir sampling points, no indicator bacteria were found. In all pipe water samples, pH values were within the recommended limit (6.5-8). In the pipeline, 82.7 and 92.3% of sampling sites were found acceptable based on WHO and National standard for FC and FS counts, respectively. In household water container, 55.8 and 71.1% were in the acceptable limit of WHO and National standard for FC and FS, respectively. Pearson correlation analysis indicates that a significant positive correlation between TC/temperature (r = 0.809063) and a significant negative correlation exist between TC and FCR (r = -0.689336) in tap water samples. Using Pearson's correlation coefficient, TC was found to be positively and significantly related to FC (r = 0.836887) and FS (r = 0.674766), FC was found to be positively and significantly correlated to FS (r = 0.84345) in household water.

Key words: Physico-chemical parameter, bacteriological quality, pipe water, household water, total coliform (TC), fecal coliform (FC), fecal streptococci (FS).

INTRODUCTION

Water is the vital resource for development and essential for all economic activities. It is a very precious resource of this planet as it is an established source of life. Water is considered as one of the nutrients, although it yields no calories, yet it enters into structural composition of cell and is an essential component of diet.

A correct balance in the sensory, physical, chemical and bacteriological qualities of water makes it drinkable. In order to be used as healthful fluid for human consumption, water must be free from organisms that are capable of causing diseases and from minerals and organic substances that could produce adverse physiological effects. Drinking water should be aesthetically acceptable; it should be free from apparent turbidity, color, odor and from any objectionable taste. Drinking water should also have a reasonable temperature. Water meeting these conditions is termed “potable” meaning that it may be consumed in any desirable amount without concern for adverse effects on health (AWWA, 1990).

The quality of water for drinking has deteriorated because of the inadequacy of treatment plant, direct discharge of untreated sewage into rivers and inefficient management of piped water distribution systems (UNEP, 2004).

Water quality is a critical factor affecting human health and welfare. Studies showed that approximately 3.1% of deaths (1.7 million) and 3.7% of disability-adjusted-life-years (DALYs) (54.2 million) worldwide are attributable to unsafe water, poor sanitation and hygiene (WHO, 2005). Ethiopia is one of the countries in the world with the worst of all water quality problems. It has the lowest water supply and sanitation coverage in sub-Saharan countries is only 42 and 28% for water supply and sanitation, respectively (MoWR, 2007). For this reason, 60-80% of the population suffers from water-borne and water-related diseases (MOH, 2007). The problem is the backward socio-economic develop-ment resulting in one of the lowest standard of living, poor environmental conditions and low level of social services (UNWATER/WWAP, 2004).

Adama, like other cities in Africa, lacks adequate sanitation services. The sanitation coverage of the city was only 51%, from which more than 75% is pit latrine (AWSSS, 2008). The sanitation and hygiene situation, particularly in low income areas is very poor. The poor sanitation systems and practices and the environmental pollution result in direct and indirect threats to the public health. Just a third of the sludge is collected, to be dumped in a pond near Adama. The rest of the sludge is leaked into the drainage system and infiltrates to the ground water; polluting both the surface and groundwater.

Previously, no study has been done on physico-chemical and bacteriological quality of drinking water from the source, disinfection point, main distribution system (Reservoir), tap water and households. The aim of this study was therefore to determine the physico-chemical and bacteriological parameters that deteriorate the quality of drinking water at their sources to household level in Adama town.

MATERIALS AND METHODS

Description of the study area

The study area is Adama town located in eastern Showa in the Oromiya Region (Figure 1). It is one of the largest and most populated towns in Oromiya National Regional State, the third largest urban center in Ethiopia and is located about 100 km south east of Addis Ababa. Geographically, the town is located on longitude 39° 27’ E and latitude of 8° 54’ N at an altitude of 1720 M.A.S.L. The town is in the Great Rift Valley of East Africa on the flat low land between two mountain ridges (Ketchama and Kafagutu). Adama has a total area of about 13,000 hectares, which has been subdivided into 16 urban kebele (least administrative structure) administrations. The mean annual ambient temperature in Adama town is between 19 and 22°C. Adama drinking water treatment plant provides treated water to the residents of Adama town. The treatment plant is found 17 km in the southern part of the town near the Awash River (raw water source) and was established in July 2003. The treatment plant has a capacity of pumping 17,000 m^3 water per day (Technical Staff in Adama Town Water Supply and Sewerage Service, AWSSS). The coverage level of the treated water is about 323 km and the treatment plant supply about 95% treated water to the town population (AWSSS). The plant used calcium hypochlorite for disinfection and aluminium sulphate and polyelectrolyte (organic compound) for coagulation and clarification purpose.

Water samples and sampling points

Triplicate water samples were collected from one sample from each of inlet (raw water), outlet (the treated water) and reservoir sampling points; 52 water samples from water taps, likewise, 52 water samples were collected from selected household containers from May to July, 2008. The selected households were the ones that use the protected water sources for their drinking and domestic purposes.

The method of sample collection from each water tap was according to the WHO (2004c) guidelines for drinking water quality assessment. Convenience (non-probability) sampling was applied to select samples from water taps based on convenience and logistic ground of the thirteen main distributions network systems that are found in the four directions of the town (AWSSA). Each of these thirteen main distribution networks are stratified into four distributions sub-networked area of the four directions of the town. Therefore, a stratified random sampling was used for the selection of fifty two water samples for tap water (WHO, 2004c). Systematic random sampling method was used to select representative sample households from each of sixteen kebeles (least administrative structure) (Daniel, 1995).

Water samples from each site were collected by using a sterile glass bottles with capacity of 500 ml containing sodium thio sulphate for complete neutralization of residual chlorine (1 ml of 10% $Na_2S_2O_3$), labeled and kept in icebox (4°C) during transportation to Oromiya Water Laboratory, Addis Ababa, Ethiopia. The bacteriological tests were undertaken within 6 h of collection to avoid the growth or death of organisms in the sample (Monica, 2002). With regard to physico-chemical analysis, all physical parameters were evaluated immediately atthe site during the period of sample collection, while the rest of the analyses were carried out at Oromiya Water Laboratory.

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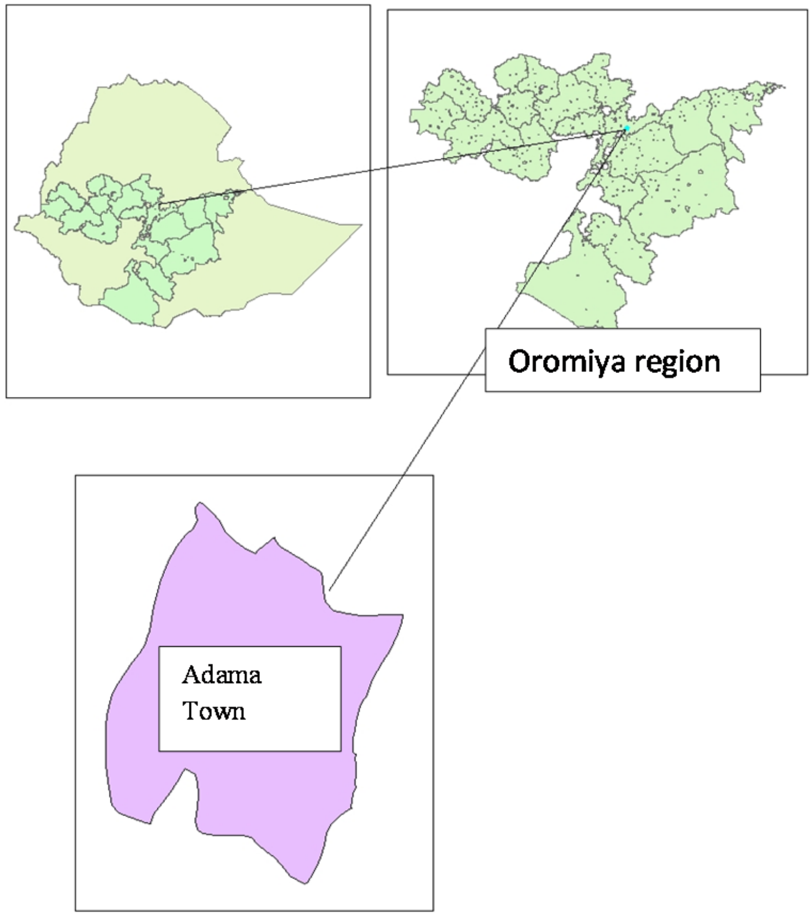

Figure 1. Map of the study area.

Physicochemical analysis

Temperature and pH were measured by portable 370 pH meter on site. Turbidity was measured colorometrically using a spectrophotometer (DR/2010 HACH, Loveland, USA) at the laboratory following HACH instructions. FCR test was performed on site during sample collection by using N,N-diethyl-1,4-phenylenediamine (DPD1) HACH chlorine test kit. Nitrate was measured colorometically using spectrophotometer (DR/2010 HACH, Loveland, USA) by following HACH instructions (1998). Fluoride concentrations in water samples were determined by spectrophotometer by using SPADNS reagent (DR/2010 HACH, Loveland, USA) by following HACH instructions (1998).

Bacteriological analysis of water samples

Samples for microbial indicators (TC, FC and FS) were analyzed by 100 ml membrane filtration technique, using 0.47 mm diameter, 0.45 µm pore size filters (Gelman Sciences sterilized membrane) as specified in standard methods (APHA, 1998). For TC and FC membrane, lauryl sulfate (mLS) medium (PARK) was used and incubated at 35 and 44.5°C for 24 h, respectively; and all yellow colonies were counted as TC and FC. FS was detected using M Entrococcus agar which was prepared according to APHA (1998); plates were incubated at 44°C for 24 to 48 h. All black colonies were counted as FS.

Statistical analysis

Data was analyzed by Statistical Package for the Social Sciences (SPSS) version 16.0 and Pearson's correlation (r) values were determined by Microsoft Excel version 2010.

RESULTS AND DISCUSSION

Physico-chemical analysis of inlet, outlet and reservoir sampling points

A total of fifty five water samples were analyzed from the sample points of inlet (the raw water sources, Awash River), outlet (site of disinfection and treated water leaves the treatment plant), reservoir (site of treated water stored) and water taps. A water sample from inlet point was taken before water entering into the water treatment plant. There was a high turbidity of 197.67 NTU at the inlet point than the outlet (4.50 NTU) and in the reservoir (4.57 NTU) (Table 1).

At the outlet, the treatment plant effectively reduces the turbidity level and the treated water met WHO and national standard limit. This is because the water passes

Table 1. Mean value of physico-chemical and bacteriological analysis of sampling points of inlet, outlet and reservoir.

Parameter	Mean values of sample sites			WHO standard	National standard
	Inlet	Outlet	Reservoir		
Turbidity (NTU)	197.67±6.03	4.50±0.36	4.57±0.25	<5	<5
Temperature (°C)	23.30±1.45	21.23±1.36	22.57±0.31	<15	
pH	8.10±0.20	7.43±0.25	6.80±0.23	6.5-8	6.5-8.5
FCR (mg/l)		0.78±0.15	0.35±0.08	0.2-0.5	0.2-0.5
Nitrate (mg/l)	17.38±2.04	2.71±0.38	3.05±0.25	45	50
Fluoride (mg/l)	2.71±0.18	1.23±0.08	1.27±0.13	<1.5	3
TC (cfu/100 ml)	196.00±15.87	0	0	0	10
FC (cfu/100 ml)	142.00±24.25	0	0	0	0
FS (cfu/100 ml)	117.00±20.66	0	0	0	0

FCR, free chlorine residual; TC, total coliform; FC, fecal coliform; FS, fecal streptococci; cfu, colony forming unit

through a number of treatment processes. Clarification followed by coagulation helps to reduce suspended solids and can remove significant numbers of harmful organisms from polluted water (WHO, 2004c).

The temperature of the three sampling points were found to be 23.30, 21.23 and 22.57°C for inlet, outlet and reservoir, respectively which are above the permissible limit of 15°C recommended by WHO (1996). Since Adama town is found in the central rift valley area, the climatic condition of the area is responsible for high temperature. The average pH values of the inlet, outlet and reservoir were 8.10, 7.43 and 6.80, respectively. The addition of chlorine as a disinfecting agent in the treatment process lowers the pH at the outlet point. The pH values of the inlet, outlet and reservoir sample point were within the acceptable limit of WHO and National standards which is from 6.5 to 8.5 (WHO, 2004b). The concentration of nitrate at the inlet, outlet and reservoir water samples were 17.38, 2.71 and 3.05 mg/l, respect-tively, which comply with both the WHO and National standard. The fluoride values of the outlet and reservoir were within acceptable limit of WHO (1996) and National standard but the inlet average fluoride was beyond the recommended limit of WHO. As shown in Table 1, the mean free chlorine residual (FCR) at the outlet sample point was 0.78 mg/l. At the outlet sample point, free residual chlorine (FCR) was within the recommended limit of 1 or 0.6-1 mg/l for disinfection practice (WHO 2004b, c). This was due to adequate disinfection practice for the treatment plant. An increase of 1 mg/l in free chlorine residual resulted in a decrease of about 0.36 and 0.18 in the mean total coliform and fecal coliform counts, respectively. This indicates that a chlorine residual of about 1 mg/l when water leaves the treatment plant is needed for health reason (Mombal and Kaleni, 2002). The fluoride concentration of analyzed samples of inlet is 2.71 mg/l, outlet 1.23 mg/l and reservoir 1.27 mg/l. The fluoride values of the outlet and reservoir were within acceptable limit of WHO (1996) and National standard but the inlet average fluoride was beyond the recom-mended limit of WHO. At the outlet and reservoir sampling points, no indicator bacteria were found which comply both WHO and National standard.

Physico-chemical and bacteriological analysis of tap water samples

As shown in Table 2, out of 52 pipe water sample investigated, the turbidity of 12 (23.1%) water samples were above the standard and 40 (76.9%) within the WHO and National standard limits of <5. All pipe water samples had pH levels within WHO and National standard limits of 6.5-8.0 and 6.5-8.5, respectively. Regarding the tempera-ture, all pipe water samples were beyond recommended limit of WHO <15°C (WHO, 2004c); this is due to the climatic condition of the rift valley area making the temperature of the water to be high. Nitrate concentration of all the 52 (100%) samples of tap water met the WHO 45 mg/l (WHO, 2004C) and National standard limits of 50 mg/l (ES, 2001). All pipe water samples had fluoride concentration within WHO and National standard limits of <1.5 and 3 mg/l, respectively. The amount of FCR in the pipe water recommended value of WHO and National standard (0.2-0.5 mg/l). In the study area, 40 (76.9%) of water samples met the acceptable level, and 12 (23.1%) of water samples were below the standard.

Of the 52 water samples collected from tap water, 8 had FC concentrations ranging from 1-10 cfu/100 ml, one sample had FC concentration ranging from 11-20 cfu/100 ml, and 43 samples were found to have zero FC per 100 ml which is in the acceptable limit of WHO and National standard. Regarding FS, 4 samples were in the range of 1-10 cfu/100 ml, and 48 samples had no FS cfu/100 ml which meets the acceptable limit of WHO and National standard. The bacteriological test for the samples from water taps contains some fecal coliform and fecal streptococci. This is due to fact that the water

Table 2. Classification of drinking water according to magnitude of contamination of physic0-chemical and bacteriological quality parameters in tap water (N = 52).

Levels on Contamination	Turbidity (NTU)		pH		FCR (mg/l)		Temp (^{0}C)		Nitrate (mg/l)		Fluoride (mg/l)		TC (cfu)		FC (cfu)		FS (cfu)	
	N=52	%	N=52	%	N=52	%	N=52	%	N=52	%	N=52	%	N=52	%	N=52	%	N=52	%
>5	12	23.1																
0-5	40	76.9																
6.5-8			52	100														
0.2-0.5					40	76.9												
<0.2					12	23.1												
20-23							52	100										
<45									52	100								
<1.5											52	100						
11-20													3	5.8	1	1.9	0	0
1-10													11	21.1	8	15.4	4	7.7
0													38	73.1	43	82.7	48	92.3

NTU, Nephelometric turbidity unit; FCR, free chlorine residual; TC, total coliform; FC, fecal coliform; FS, fecal streptococci; cfu, colony forming unit.

Table 3. Classification of drinking water according to magnitude of contamination of bacteriological quality parameters in household containers (N = 52).

Levels on contamination	TC (cfu/100 ml)		FC (cfu/100 ml)		FS (cfu/100 ml)	
	N	%	N	%	N	%
>10	22	42.3	6	11.5	3	5.8
1-10	17	32.7	17	32.7	12	23.1
0	13	25	29	55.8	37	71.1

TC, total coliform; FC, fecal coliform; FS, fecal streptococci; cfu, colony forming unit.

treatment plant is far away from the town, mainly some kebele which are about 21 km away from treatment plant, so that the interconnections between the site of production and the tap, up to the home of the consumers may accumulate pathogenic organisms by formation of biofilms (Skraber et al., 2005). A study conducted by Mengestayhu (2007) showed that out of 35 tap water sample, 6 (17.1%) and 11(31.4%) were in the acceptable limit of WHO and national standard for TTC and FS counts, respectively.

Bacteriological analysis of household container water samples

From 52 household water containers, 22 (42.3%) samples had TC concentrations above WHO and National standard limit whereas 30 (57.7%) were within the standard limit of 10 cfu/100 (Table 3). 29 (55.8%) samples had FC concentrations within the recommended level of WHO and National standard limit of zero FC per 100 ml and 23 (44.2%) above the standard limits. In the case of FS, 37 (71.1%) water sample satisfy the WHO and National standard limits of zero FS per 100 ml and 15 (28.9%) samples above the recommended limits (Table 3). Water used for domestic purposes in household container is of poor quality (microbiologically) and the contamination is

Table 4. Pearson's correlation matrix between physico-chemical and bacteriological parameters of tap water.

Parameter	Turbidity	pH	FCR	Temp	Nitrate	Fluoride	TC	FC	FS
Turbidity	1								
pH	-0.360**	1							
FCR	-0.542**	0.417**	1						
Temp	0.518**	-0.314	-0.584**	1					
Nitrate	0.153	-0.298	-0.177	0.225	1				
Fluoride	0.152	-0.549	-0.235	0.396**	0.149	1			
TC	0.536**	-0.220	-0.689**	0.809**	0.257	0.281	1		
FC	0.313	0.075	-0.558**	0.458**	-0.007	0.034	0.763**	1	
FS	0.257	0.142	-0.518**	0.383**	-0.075	-0.010	0.658**	0.979**	1

**Correlation is significant at the 0.01 level (2-tailed).

Table 5. Pearson's correlation matrix between bacteriological parameters of household water.

Parameter	TC (cfu)	FC (cfu)	FS (cfu)
TC(cfu)	1		
FC(cfu)	0.837**	1	
FS(cfu)	0.675**	0.843**	1

**Correlation is significant at the 0.01 level (2-tailed).

possibly due to poor management of water and existence of poor sanitation The study conducted in South Africa and Zimbabwe indicated that, more than 40% of the survey households using improved sources had water samples that were unsafe at the point of use (Gundry et al., 2006).

Results on Pearson correlation analysis are presented in Table 4. A significant positive correlation was between TC/temperature (r = 0.809), FS/FC (r = 0.979), FC/TC (r = 0.763), FS/TC (r = 0.658), TC/turbidity (r = 0.536), temperature/turbidity (r = 0.518). Increasing temperature enhance the metabolic activity of indicator bacteria. A significant negative correlation exist between TC and FCR (r = -0.689), FC and FCR (r = -0.558), FS and FCR (r = -0.518), Turbidity and FCR (r = -0.542). Free residual chlorine has dominant effect for the decrease of indicator bacteria. Thus, increasing the chlorine concentration has an important implication to reduce or eliminate pathogens in the water.

Statistically, using Pearson's correlation coefficient, TC was found to be positively and significantly related to FC (r = 0.837) and FS (r = 0.675), FC was found to be positively and significantly correlated to FS (r = 0.843) (Table 5). Similar study conducted by Khalil et al. (2013) revealed that total coliform bacteria are significantly correlated with fecal streptococci (r = 0.983).

Conclusion

A combination of safe drinking water, adequate sanitation and hygienic practices are a pre-requisite for reduction of water quality related diseases. To reduce the incidence and prevalence of water-borne diseases, improvements in the availability, quantity and quality of water is required.

In this study, it was shown that in tap water, 3 (5.8%), 9 (17.3%), 4 (7.7%) had TC, FC and FS concentration, respectively, which are above WHO and National standard. The temperature of water sample was above the permissible level of WHO and National standard. The majority of tap water (76.9%) has turbidity within the recommended limit of WHO and National standard and some (23.1%) are above the WHO and National standard. From household water container, 29 (55.8%) samples had FC concentrations within the recommended level of WHO and National standard and 23 (44.2%) above the standard limits. In the case of FS, 37 (71.1%) water sample satisfy the WHO and National standard limits and 15 (28.9%) samples above the recommended limits. Based on the research findings, the following recommendations can be drawn:

1. Periodic estimation of at least some important parameters like bacterial load especially indicating fecal pollution (coliforms, fecal coliforms), free residual chlorine, turbidity and pH both at the source and consumer's ends should be carried out.
2. Treatment procedures are required to be better and well managed, that is, filters should be checked and replaced if required and chlorination should be according to WHO norms, that is, application of chlorine to achieve a free residual chlorine at least 0.5 mg/l in terms of bacterial inactivation.
3. Further study is needed to determine the seasonal variations in the contamination level of the water sources.

Conflict of interests

The authors did not declare any conflict of interest.

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REFERENCES

American Public Health Association (APHA) (1998). Standard Methods for the Examination of Water and WasteWater 20th edition. Washington, DC: American Public Health Association (APHA), American Water works Association (AWWA), Water Environment Federation (WEF).

American Water Works Association (AWWA). (1990). Water Quality and Treatment: A Handbook of Community Water supplies.

AWSSS (2008). Adama Town Water Supply and Sewerage Service Annual Report, Adama

Daniel WW (1995). Biostatistics: A foundation for analysis in health sciences, John Willey and sons; USA.

Gundry SW, Wright JA, Conroy R, Du preez M, Genthe B, Moyo S, Mutisi C, Potgieter N (2006). Contamination of drinking water between source and point of use in rural households of South Africa and Zimbabwe: implications for monitoring the Millennium Development Goal for water. J. Water Pract. Technol. 1(2): 1-9.

Khalil MA, Salem ZE, Gheda SF, El-Sheekh MM (2013). Quality Assessment of Drinking Water in Tanta City, Egypt. J. Environ. Sci. Eng. 2: 257-275.

Mengestayhu B (2007). Assessment of physic-chemical and microbiological quality of drinking water at sources and households in selected communities of Akaki/kaliti Subcity, Addis Ababa City Administration. MSc thesis Addis Ababa University.

Ministry of Health (MOH) (2007). Need Assessment to Achieve Universal Access to Improved Sanitation and Hygiene by 2012, ADDIS Ababa, Ethiopia.

Ministry of Water and Resource (MOWR) (2007). Ethiopian Water Resources Management Policy, Addis Ababa, Ethiopia.

Mombal MNB, Kaleni P (2002). Regrowth and survival of indicator microorganisms on the surfaces of household containers used for storage of drinking water in rural communities of South Africa. South Afr. J. Water Res. 36:3023-3028.

Monica C (2002). District Laboratory Practice in Tropical Country, part-2:208-211.

Skraber S, Schijvenl J, Gantzer C, Roda Husman AM (2005). Pathogenic viruses in drinking water biofilms: a public health risk. Cambridge University Press 2(2):105-117.

UNEP state of the environment Nepal (2004). United Nation Environment Program (UNEP), in collaboration with MoPE/HMGN; SACEP, ICIMOD, and NOROD.

UNWATER/WWAP. (2004). United Nations Educational, Scientific, and Cultural Organization World Water Assessment Program. National Water Development Report for Ethiopia. Addis Ababa. December 2004.

World Health Organization (WHO) (1996). Guidelines for Drinking Water Quality Second Edition Volume 2-Health Criteria and other supporting information. International program on chemical safety. Geneva.

World Health Organization (WHO) (2004b). Guidelines for drinking - Water Quality. Third Edition, Vol.1: Recommendation. World Health Organization, Geneva.

World Health Organization (WHO) (2004c). Guidelines for drinking water quality. Third Edition, Vol. 1: Recommendation. Geneva.

World Health Organization (WHO) (2005). Water, Sanitation and Hygiene Programming Guidance Water Supply and Sanitation Collaborative Council and World Health Organization, 2005 Printed in Geneva 1219 Chatelaine, Geneva, Switzerland. www.who.int.