Journal of Environmental and Occupational Science
www.jenvos.com
DOI: 10.5455/jeos.20140924105123

Original Research

GESDAV

Assessment of microbiological and physico-chemical quality of drinking water in North Gondar Zone, Northwest Ethiopia

Debasu Damtie[1], Mengistu Endris[2], Yifokir Tefera[3], Yabutani Tomoki[4], Yohei Yamada[4], Afework Kassu[2]

ABSTRACT

Introduction: Assessing the microbiological and physico-chemical quality of drinking water sources is important to protect public health. Little is known about the microbiological and physico-chemical quality of drinking water in North Gondar Zone. Therefore, this study was aimed to assess the microbiological and physico-chemical quality of drinking water sources in North Gondar Zone, Northwest Ethiopia. **Methods:** A cross-sectional study was conducted from April to May 2014 in seven districts (Chilga, Debark, Dabat, Dembia, Gondar Town, Gondar Zuria and Wogera) in North Gondar. The physico-chemical and microbiological quality of 71 drinking water samples were determined following the standard procedure. Turbidity, pH, and temperature were measured using a turbidity meter, pH meter, and thermometer, respectively. Arsenic, chlorine, Cr_6+, NO_2, NO_3 and residual chlorine were determined by the colorimetric methods and rapid kits using disruptive pattern material apparatus (Kyoritsu chemical-check Lab., Corp. Japan). Coliforms and *Vibrio parahemolyticus* were tested by rapid microbiological test strips (Sankori coliform and Sankori *V. parahaemolyticus*) following appropriate standard procedure. Consumer's assessment was also conducted using a questionnaire about the water sources. Data were entered and analyzed using SPSS version 20 software. **Results:** The physico-chemical and microbiological quality of 71 water samples (tap $n = 29$, spring $n = 15$ and well $n = 27$) were assessed. The mean turbidity of water samples was 19.35 ± 5.75 standard deviation nephelometric turbidity unit, temperature 21.34 ± 3.68°C, pH 6.88 ± 0.6, nitrate 10.02 ± 8.72 mg/l, nitrite 0.33 ± 0.64 mg/l, residual chlorine 0.01 ± 0.06 mg/l, arsenic 0.2 ± 0.00 mg/l, and chromium 0.51 ± 0.01 mg/l. Almost all samples were complying with the World Health Organization acceptable range for nitrate arsenic and chromium among the physico-chemical parameters. However, turbidity was found to be unacceptably high in 21 (29.6%) samples, pH was unacceptably low in 26 (36.6%) of the samples and residual chlorine was unacceptably low in 69 (97.2%) of the samples. The majority of samples ($n = 46$; 64.8%) had coliforms, and 12 (16.9%) had *V. parahemolyticus*. **Conclusion:** Most of the physical and chemical parameters measured were within the recommended range except turbidity and residual chlorine. However, the majorities of drinking water samples were found to be contaminated and were potential risk to public health. Therefore, regular quality monitoring and frequent water treatment in the study area is mandatory.

KEY WORDS: Drinking water, microbiological, physicochemical, quality

[1]Department of Immunology and Molecular Biology, University of Gondar, Gondar, Ethiopia, [2]Department of Medical Microbiology, University of Gondar, Gondar, Ethiopia, [3]Department of Environmental and Occupational Health & Safety, University of Gondar, Gondar, Ethiopia, [4]Department of Chemical Science and Technology, Tokushima Universities, Tokushima, Japan,

Address for correspondence:
Debasu Damtie,
Department of Immunology and Molecular Biology,
University of Gondar,
Gondar, Ethiopia.
E-mail: debidam@gmail.com

Received: August 20, 2014
Accepted: September 24, 2014
Published: October 03, 2014

INTRODUCTION

The provision of good quality household drinking water is often regarded as an important means of improving health [1]. The World Health Organization (WHO) in its 2002 report recommended that increased emphasis be placed on home water treatment and storage [2]. Contaminants can be in the form of microorganism or chemicals that are hardly visible in unaided eyes. Most gradual deterioration of water quality results due to increase in human population and urbanization [3].

Globally, 1.1 billion people rely on unsafe drinking water sources from lakes, rivers, and open wells. The majority of these are in Asia (20%) and sub-Saharan Africa (42%). According to WHO 2000 report, there were an estimated 4 billion cases of diarrhea and 2.2 million deaths annually [4]. Diseases caused by contaminated water consumption and poor hygiene practices are the leading causes of death among children worldwide [5]. Inadequate protection of water collection and storage containers and unhygienic conditions contribute to contamination at home [5]. Hence, drinking water quality assessment is an integral part of safe drinking water supply.

Traditionally, the microbiological quality of drinking water is assessed by monitoring non-pathogenic bacteria of fecal origin (faecal indicator bacteria) [6]. *Escherichia coli* and *Enterococcus spp*. members are traditionally used as hygiene indicator bacteria. In the recently adopted European drinking water directive, only *E. coli* and *Enterococcus spp*. are defined as obligatory microbial parameters [7]. In addition to microbiological quality, the untreated or partially treated waste waters from the industry have potentially affecting the chemical quality of drinking water sources. Nitrate is one of the most common groundwater contaminants in rural areas. It is regulated in drinking water primarily because high levels can cause methemoglobinemia or "blue baby" disease [8,9].

Although there was some routine microbiological quality check conducted in tap water sources of major urban towns of Ethiopia, there was no adequate survey on assessment of both microbiological and physicochemical quality of drinking water sources in rural and urban settings. Therefore, the aim of this study was to determine the microbiological and physico-chemical quality of drinking water samples collected from the tap, spring and well sources found in urban and rural settings of North Gondar Zone.

METHODS

Study Design, Period, and Setting

A cross-sectional study was conducted from April 2014 to May 2014 in North Gondar Zone. 71 drinking water samples from seven districts (Chilga, Debark, Dabat, Dembia, Gondar Town, Gondar Zuria and Wogera) of North Gondar Zone were collected by convenient sampling technique. Water samples were collected from well, spring, and tap water sources and their physico-chemical and microbiological quality were analyzed. Data about the condition of water sources were collected using structured questionnaires from sampled water source users.

Water Sample Collection and Analysis

Water samples from different sources were collected using sterile plastic bags following the appropriate procedure. The physico-chemical quality indicators such as pH, turbidity, and temperature were analyzed using pH meter, turbidity meter, and thermometer, respectively. Residual chlorine, nitrate, nitrite, chromium, and arsenic level of the drinking water samples were determined using rapid digital pack test apparatus (Kyoritsu Chemical-Check Lab., Corp. Japan). The total coliforms (TC) and *Vibrio parahemolyticus* was determined using rapid test kits (Sankori coliform and Sankori *V. parahaemolyticus*). Laboratory tests were performed after validating the laboratory equipment's and reagents using control samples to ensure data quality.

Data Entry and Analysis

Data were entered and analyzed using SPSS version 20 software (Armonk, NY: IBM Corp.). Descriptive analysis was made for categorical variables while mean and standard deviation were calculated for continuous variables.

Ethical Consideration

Ethical clearance (Ref. R/C/S/V/P/05/283/2013) was obtained from institutional review board of the University of Gondar prior to the conduct of the study.

RESULTS

A total of 71 water samples was collected from seven districts of the zone where around 1.5 million people were living (census 2007) and analyzed for microbiological and physico-chemical quality parameters. Slightly larger numbers of samples were collected from urban areas (57.7%). The majority of the samples was collected from tap water originated from surface water and wells 29 (40.9%), owned by public (52.1%) and were from treated water sources (63.4%) [Table 1].

The mean turbidity of water samples was 19.35 ± 5.75 standard deviation nephelometric turbidity unit, temperature 21.34 ± 3.68°C, pH 6.88 ± 0.6, nitrate 10.02 ± 8.72 mg/l, nitrite 0.33 ± 0.64 mg/l, residual chlorine 0.01 ± 0.06 mg/l, arsenic 0.2 ± 0.00 mg/l, and chromium 0.51 ± 0.01 mg/l [Table 2]. Even though almost all samples were complying with the WHO acceptable range for nitrate arsenic and chromium

Table 1: Characteristics of protected water sources taken for microbiological and physico-chemical analysis from different sites in North Gondar Zone, 2014

Characteristics	Frequency	Percent
Area		
Urban	41	57.7
Rural	30	42.3
Specific sites		
Chilga	8	11.3
Debark	10	14.1
Dabat	6	8.5
Dembia	13	18.3
Gondar Town	19	26.8
Gondar Zuria	8	11.3
Wogera	7	9.9
Ownership		
Government	8	11.3
Private	26	36.6
Public	37	52.1
Service of water		
Domestic use	67	94.4
Domestic and animal use	4	5.6
Treatment at source		
Yes	45	63.4
No	26	36.6
Frequency of treatment		
Always	18	40.0
Once/week	14	31.1
Once/month	2	4.4
Once/year	11	24.4
Establishment (year)		
<10	46	64.8
>10	25	35.2
Total	71	100.0

among the physico-chemical parameters, turbidity was found to be unacceptably high in 21 (29.6%) samples, pH was unacceptably low in 26 (36.6%) of the samples and residual chlorine was unacceptably low in 69 (97.2%) of the samples [Table 3]. The majority of unacceptably high level of turbidity was observed among samples collected from tap water 12 (41.4%) [Table 4].

Concerning the microbiological quality of the samples, the mean coliform and V. *parahemolyticus* count was 40.08 ± 50.88 and 0.86 ± 2.93 per 100 ml of water sample, respectively. Even though all water samples were collected from protected sources, all samples 15 (100%) from spring sources were found to contain coliforms and 4 (26.7%) were found to contain V. *parahemolyticus* [Table 5]. Samples collected from rural areas, owned by public and being established recently (<10 years) have shown the highest probability of contamination ($P < 0.05$).

DISCUSSION

Turbidity was found to be unacceptably high in 21 (29.6%) samples. This finding is higher than a nationwide survey result in Ethiopia [10] which reported 13.1% of the total samples did not comply with the WHO "suggested" value and the national standard. This might be due to the difference in the sample collection seasons. In our case there were light showers during sample collection which may intern contribute for high turbidity level.

Almost all samples were complying with the WHO acceptable range for nitrate arsenic and chromium among the chemical parameters measured. Our finding is supported by a nationwide survey result in Ethiopia, which revealed 99.0% and 100% compliance of nitrate and arsenic respectively [10]. This might be due to the fact that there is very poor industrialization and mining in the study area. Moreover, since all samples were collected from protected water sources the possibility of entrance of nitrogen-containing compounds from the surrounding is minimal. Study from Turkey reported 11 (27.5%) of samples analyzed exceeded the EU water directive value of 50 mg/l for nitrate in drinking water [11]. This might be

Table 2: Mean±SD of microbiological and physico-chemical quality parameters of drinking water in North Gondar Zone, 2014

Parameter	Mean±SD (minimum, maximum)
Physical	
Temperature (°C)	21.34±3.68 (14.8, 30.2)
Turbidity (NTU)	19.35±5.75 (0, 328.00)
pH	6.88±0.36 (6.08, 7.75)
Chemical	
Nitrate (mg/l)	10.02±8.72 (1.00, 25.00)
Nitrite (mg/l)	0.33±0.64 (0.02, 0.53)
Residual chlorine (mg/l)	0.01±0.06 (0.00, 0.50)
Arsenic (mg/l)	0.20±0.00 (0.20, 0.20)
Chromium (mg/l)	0.51±0.01 (0.05, 0.12)
Microbiological	
Coli form (count)	40.08±50.88 (0.00, 150)
V. parahemolyticus (count)	0.86±2.93 (0.00, 20.88)

SD: Standard deviation, NTU: Nephlometric turbidity unit, *V. parahemolyticus: Vibrio parahemolyticus*

Table 3: Proportion of water samples compliance to WHO phisico-chemical quality standards of water, North Gondar Zone, 2014

Parameter	Result	
	Compliance	Non compliance
Physical		
Turbidity (NTU)	50 (70.4)	21 (29.6)
pH	45 (63.4)	26 (36.6)
Chemical		
Nitrate (mg/l)	71 (100)	0 (0)
Residual chlorine (mg/l)	2 (2.8)	69 (97.2)
Arsenic (mg/l)	71 (100)	0 (0)
Chromium (mg/l)	70 (98.6)	1 (1.4)

NTU: Nephlometric turbidity unit, WHO: World Health Organization

Table 4: Proportion of water samples with unacceptable physicochemical parameters by source type, North Gondar Zone, 2014

Parameter	Total unacceptable range	Source		
		Tap (n=29)	Spring (n=15)	Well (n=27)
Physical				
Turbidity (NTU)	21 (29.6)	12 (41.4)	2 (13.3)	7 (25.9)
pH	26 (36.6)	6 (20.7)	8 (53.3)	12 (46.2)
Chemical				
Residual Cl (mg/l)	69 (97.2)	28 (96.6)	15 (100)	26 (96.3)
Chromium (mg/l)	1 (1.4)	1 (3.4)	0 (0)	0 (0)

NTU: Nephlometric turbidity unit, WHO: World Health Organization

Table 5: Detection of coliforms and *V. parahemolyticus* in drinking water, North Gondar Zone, 2014

Characteristics	Coliforms		*V. parahemoluticus*	
	Present	Absent	Present	Absent
Source				
Tap	13 (44.8)	16 (55.2)	2 (6.9)	27 (93.1)
Spring	15 (100)	0 (0)	4 (26.7)	11 (73.3)
Well	18 (66.7)	9 (33.3)	6 (22.2)	21 (77.8)
Area				
Urban	22 (53.7)	19 (46.3)	3 (7.3)	38 (92.7)
Rural	24 (80.0)	6 (20.0)	9 (30.0)	21 (70.0)
Ownership				
Government	12 (46.2)	14 (53.8)	2 (7.7)	24 (92.3)
Private	5 (62.5)	3 (37.5)	1 (12.5)	7 (87.5)
Public	29 (78.4)	8 (21.6)	9 (24.3)	28 (75.7)
Service of water				
Domestic use	42 (62.7)	25 (37.3)	11 (16.4)	56 (83.6)
Domestic and animal use	4 (100)	0 (0)	1 (25.0)	3 (75.0)
Treatment at source				
Yes	26 (57.8)	19 (42.2)	5 (11.1)	40 (88.9)
No	20 (76.9)	6 (23.1)	7 (26.9)	19 (73.1)
Frequency of treatment				
Always	10 (55.6)	8 (44.4)	1 (5.6)	17 (94.4)
Once/week	6 (42.9)	8 (57.1)	1 (7.1)	13 (92.9)
Once/month	2 (100)	0 (0)	0 (0)	2 (100)
Once/year	8 (72.7)	3 (27.3)	3 (27.3)	8 (72.7)
Establishment (year)				
<10	35 (76.1)	11 (23.9)	9 (19.6)	37 (80.4)
>10	11 (44.0)	14 (56.0)	3 (12.0)	22 (88.0)
Total	46 (64.8)	25 (35.2)	12 (16.9)	59 (83.1)

V. parahemolyticus: Vibrio parahemolyticus explained by the fact that the studies were conducted at different settings.

In this study, significant number of samples, 36.6% showed pH value of <6.5. Even though there is no health-related guideline value set by the WHO yet, it is recommended to be between 6.5 and 9.5, otherwise extreme pH values may subject the consumers for different health risks such as irritation to the eyes, skin, and mucous membranes [12].

The majority of the samples (n = 69; 97.2%) did not comply with WHO residual chlorine recommended limit of 0.2-0.5 mg/l [13] which indicates the inefficiency of disinfection in the distribution system. As a result, this study revealed a higher count of TCs and V. *parahemolyticus*, which is an important cause of diarrhea.

The majority (64.8%) of the samples were found to have high TC counts. This finding was lower than a study in Bahir Dar city which reported 77.1% of samples with high TCs count [14] and a study in Nigeria which reported 100% of the water samples harbor coliforms in numbers greater than the required WHO standards for drinking water [15]. This difference might be explained by the difference in water source types involved and point of water sampling in the study.

The average count of TCs in the present study was 40.08 which was above the WHO and Ethiopian standards recommended value of 0/100 ml [16,17]. Similarly, a Nigerian study depicted the presence of significant TC count in most of the wells [18]. Significant number of water samples (16.9%) had V. *parahemolyticus*. Samples collected from rural areas, owned by public and being established recently (<10 years) have shown the highest probability of contamination ($P < 0.05$). This could be explained by lack of water treatment facilities in rural settings. On the other hand, public-owned water facilities might not have frequent maintenance and follow-up treatment, unlike government and privately owned once.

CONCLUSIONS

In conclusion, most of the physical and chemical parameters measured were within the recommended range except turbidity, pH, and residual chlorine which were found to be unacceptably high in case of turbidity and unacceptably low in the case of pH and residual chlorine in this study. Unlike the physico-chemical parameters, the majority of the drinking water samples were found to be contaminated as it was indicated by high coliform and V. *parahemolyticus* counts. The water authority of the zone shall regularly monitor the quality of water and frequently treat the water being supplied to the community.

AUTHORS' CONTRIBUTIONS

DD, ME, and YT carried out the proposal writing, participated in the data collection, water sample collection, laboratory analysis, and data analysis. DD, ME, YT, YT, YY, and AK were participated in data analysis, interpretation of the findings and final write up of the paper. DD was responsible for drafting the manuscript. All authors were involved in reviewing the manuscript and approved for publication.

ACKNOWLEDGMENTS

The authors are grateful to the University of Gondar for the financial support of the research project. We are also thankful to Tokushima University for laboratory equipments and reagents support for water quality analysis.

REFERENCES

1. Moyo S, Wright J, Ndamba J, Gundry S. Realizing the maximum health benefits from water quality improvements in the home: A case from Zaka District, Zimbabwe. Phys Chem Earth 2004;29:1295-9.
2. WHO. Reducing Risk, Promoting Healthy Life 2002 Report. Geneva, Switzerland: World Health Organization. 2002. Available from: http://www.who.int/whr/2002/en/whr02_en.pdf. [Last accessed on 2014 Jun 13].
3. Ho KC, Hui KC. Chemical contamination of the East River (Dongjiang) and its implication on sustainable development in the Pearl River Delta. Environ Int 2001;26:303-8.
4. World Health Organization and United Nations Children's Fund (WHO and UNICEF). Global Water Supply and Sanitation Assessment 2000 Report. WHO; 2000. Available from: http://www.who.int/water_sanitation_health/monitoring/jmp2000.pdf. [Last accessed on 2014 Jun 13].
5. WHO. Guidelines for Drinking-Water Quality: Health Criteria and Other Supporting Information. 2nd ed. Geneva, Switzerland: WHO; 1996. Available from: http://www.who.int/water_sanitation_health/dwq/gdwq2v1/en/index1.html. [Last accessed on 2014 Jul 25].
6. Rompré A, Servais P, Baudart J, de-Roubin MR, Laurent P. Detection and enumeration of coliforms in drinking water: Current methods and emerging approaches. J Microbiol Methods 2002;49:31-54.
7. European Drinking Water Directive. Europe council directive 98/83/EC on the quality of water intended for human consumption. Official Journal L 1998;330:0032-54.
8. Mccasland M, Trautmann N, Porter KS, Wagenet RJ. Nitrate: Health effects in drinking water. US, Cornell University: Natural Resources Cornell Cooperative Extension; 2012. Available from: http://www.psep.cce.cornell.edu/facts-slides-self/facts/nit-heef-grw85.aspx. [Last accessed on 2014 May 15].
9. United States Environmental Protection Agency (USEPA). Nitrates and Nitrites TEACH Chemical Summary. US, EPA: USEPA; 2006. Available from: http://www.epa.gov/teach/chem_summ/Nitrates_summary.pdf. [Last accessed on 2014 May 15].
10. WHO. Rapid Assessment of Drinking Water Quality in the Federal Democratic Republic of Ethiopia: Country Report of the Pilot Project Implementation in 2004-2005. Geneva: WHO; 2010. p. 19-28.
11. Aydin A. The microbiological and physico-chemical quality of groundwater in west Thrace, Turkey. Pol J Environ Stud 2007;16:377-83.
12. WHO. pH in Drinking-water: Background Document for Development of WHO Guidelines for Drinking-water Quality. Geneva, Switzerland: WHO; 2003. Available from: http://www.who.int/water_sanitation_health/dwq/chemicals/en/ph.pdf. [Last accessed on 2014 Jun 29].
13. WHO. Technical notes on drinking-water, sanitation and hygiene in emergencies. Geneva, Switzerland: WHO; 2011. Available from: http://www.wedc.lboro.ac.uk/resources/who_notes/WHO_TNE_ALL.pdf. [Last accessed on 2014 Jul 17].
14. Tabor M, Kibret M, Abera B. Bacteriological and physicochemical quality of drinking water and hygiene-sanitation practices of the consumers in bahir dar city, ethiopia. Ethiop J Health Sci 2011;21:19-26.
15. Okonko IO, Adejoye OD, Ogunnusi TA, Fajobi EA, Shittu OB. Microbiological and physicochemical analysis of different water samples used for domestic purposes in Abeokuta and Ojota, Lagos State, Nigeria. Afr J Biotechnol 2008;7:617-21.

16. WHO. Drinking Water Quality Guideline. 2nd ed., Vol. 3. Geneva, Switzerland: WHO; 1997. Available from: http://www.who.int/water_sanitation_health/dwq/2edaddvol2a.pdf. [Last accessed on 2014 Aug 06].
17. The Federal Democratic Republic of Ethiopia Ministry of Water Resources. Specification for Drinking Water Quality. Addis Ababa, Ethiopia: National Meteorological Services Agency; 2002.
18. Akaahan TJ, Oluma HO, Sha AR. Physico-chemical and bacteriological quality of water from shallow wells in two rural communities in Benue State, Nigeria. Pak J Anal Environ Chem 2010;11:73-8.

Source of Support: The authors are grateful to the University of Gondar for the financial support of the research project**, Conflict of Interest:** None declared.