Bacteriological Quality of Drinking Water and Associated Factors at the Internally Displaced People Sites, Gedeo Zone, Southern Ethiopia: A Cross-sectional Study

Environmental Health Insights
Volume 15: 1–6

DOI: 10.1177/11786302211026469
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ABSTRACT

BACKGROUND: Providing safe and adequate Water, Sanitation and Hygiene (WASH) services in response to emergencies is a major problem. Globally, few studies have investigated the bacteriological quality of drinking water at the IDP sites. Therefore, the objective of this study was to evaluate the bacteriological quality of drinking water and associated factors at the IDP sites of Gedeo zone.

METHODS: A cross-sectional study was conducted on 213 water samples collected from November to December 2018. The membrane filter technique was used to retain bacteria and lauryl sulphate broth media was used to detect faecal coliforms. After incubation of 14 hours at 44°C, faecal coliforms with yellow colonies were counted and expressed in terms of CFU/100 ml of water. The data were entered into Epi data version 3.1 and exported to STATA version 14 for analysis. Binary logistic regression analysis with 95%CI and $P \leqslant .05$ was used to identify factors associated with an outcome variable.

RESULTS: Out of 213 water samples collected, 107 (50.2%) samples were tested positive for faecal coliforms. The presence of latrines in uphill (AOR: 6.7, 95%CI: 1.0-42.9), other sources of pollution (AOR: 5.0, 95%CI: 1.1-22.3), inadequate fencing (AOR: 7.1, 95%CI: 1.3-40.2) and lack of diversion ditch (AOR: 6.3, 95%CI: 1.0-37.6) were factors significantly associated with faecal contamination of springs. Dug wells that had a latrine within 10 m (AOR: 11.4, 95%CI: 1.8-72.1), other pollution sources within 10 m (AOR: 7.9, 95%CI: 1.9-32.4), inadequate fencing (AOR: 2.8, 95%CI: 1.0-7.9), drawing water using a bucket with rope (AOR: 7.3, 95%CI: 1.6-33.4) and unsanitary well cover (AOR: 3.4, 95%CI: 1.1-10.4) were factors significantly associated with faecal contamination of wells.

CONCLUSIONS: The majority of the water sources in internally displaced people sites were tested positive for faecal coliforms. The presence of latrine in uphill, other sources of pollution, inadequate fencing, lack of diversion ditch, drawing water using a bucket with rope and unsanitary well cover were factors associated with the presence of faecal coliforms. Therefore, adequate fencing, proper diversion ditch construction and hygiene promotion should be done to protect water sources from faecal contamination. Furthermore, latrines and other point sources of contamination should be located at least 10 m away or at a lower elevation from water sources.

KEYWORDS: Bacteriological quality, *E. coli*, internally displaced people

RECEIVED: March 12, 2021. **ACCEPTED:** June 1, 2021.

TYPE: Original Research

FUNDING: The author(s) received no financial support for the research, authorship, and/or publication of this article.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Introduction

Internally displaced persons (IDPs) are people or groups of people who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters and who have not crossed an internationally recognized state border.[1]

Water supply, sanitation and hygiene promotion are critical determinants for survival in humanitarian situations. People may live in densely populated settlements and be susceptible to faecal-orally transmitted illness (such as cholera) and vector-borne illness, largely as a result of inadequate Water, Sanitation and Hygiene (WASH) services.[2-4]

Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all.[5] Without safe water, infectious diseases, including hepatitis E, cholera and other diarrhoeal diseases can quickly spread, causing suffering and loss of life. Ensuring access to adequate quantities and quality of water is essential for the control of waterborne diseases in internally displaced people (IDP) sites.[6,7]

Drinking water must always be safe and satisfy minimum recommended standards of physical, biological and chemical quality. Standards for water supply in emergencies typically focus on access, quantity, quality and reliability. While everyone is cannot live without water the most common and widespread problem associated with drinking water is contamination, either directly or indirectly, by human or animal excreta,

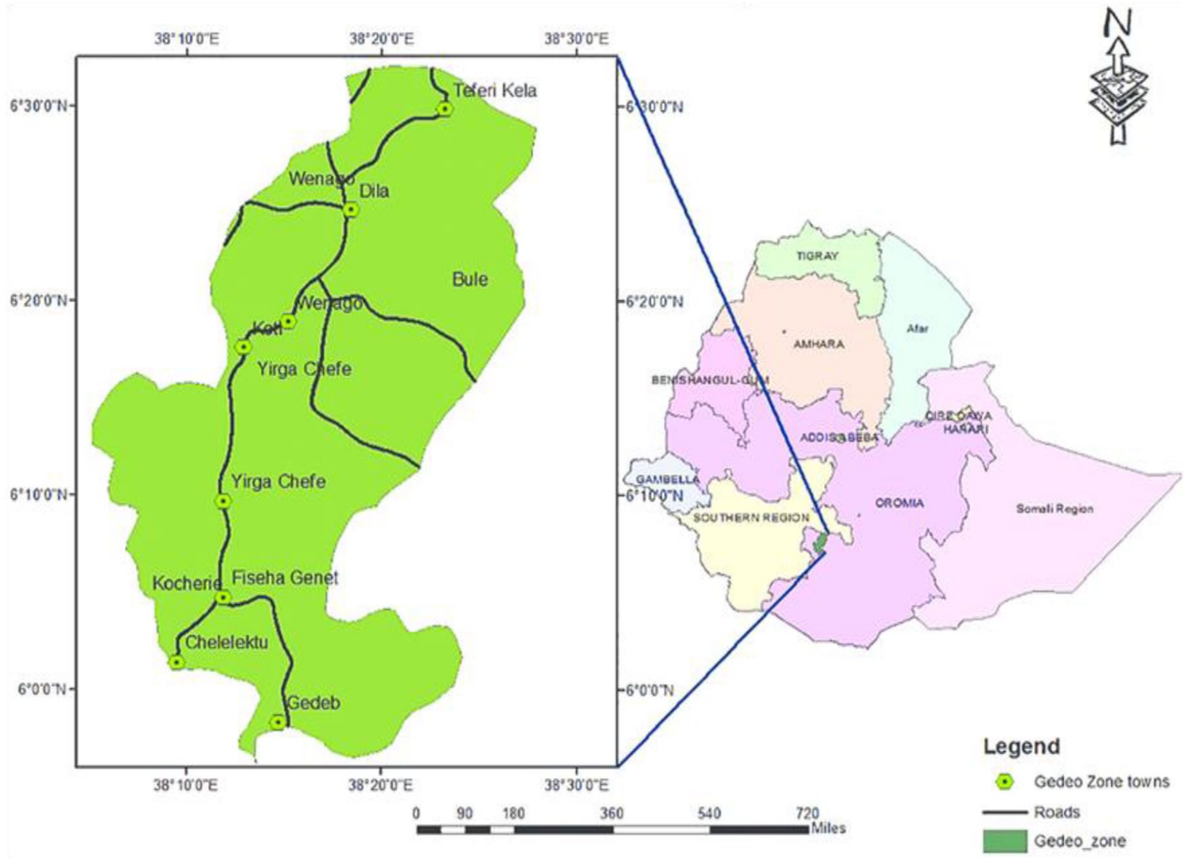

Figure 1. Map of study area.

industrial and other wastes.[2,8] Globally, 1.8 billion people use a source of drinking water which suffers from faecal contamination, of these 1.1 billion drink water that is of at least 'moderate' risk (>10 *E. coli* per 100 ml).[9]

The World Health Organization (WHO)[10] of 2017 guidelines for drinking water and quality drinking water standards for Ethiopia recommend that coliform bacteria must not be detectable in any 100 ml sample of all water directly intended for drinking. Faecal contamination of drinking water is a major problem in both urban and rural communities of Ethiopia, where surface water sources like rivers, wells and lakes are used for drinking.[11,12]

In Ethiopia, a total of 60% to 80% of the population suffer from waterborne and water-related diseases. This situation is at its highest peak at the IDP sites. Since using improved water sources is a major problem in both IDP and host communities as discussed by Mekonnen et al[13,14] that is why it is important to keep water safe from faecal contamination and all other sources of pollutions.[15]

Globally, few studies have investigated the bacteriological quality of drinking water in the IDP sites.[16,17] In recent years, there has been a large movement of IDP in areas of Gedeo zone because of the conflict between Gedeo and Guji ethnic groups. Therefore, the objective of this study was to evaluate the bacteriological quality of drinking water and associated factors at the IDP sites of Gedeo zone, Southern Ethiopia.

Materials and Methods

Study design, area and period

A cross-sectional study was conducted in 6 districts and 2 town administrations of the Gedeo zone, from November 2018 to December 2018. The zone is located in Southern Ethiopia at a distance of 359 km from the capital city, Addis Ababa and an elevation of 1268 m above sea level and latitude of at 6°09′60.00″N, longitude 38°19′60.00″E (Figure 1). According to the 2007 Ethiopian national census data, Gedeo zone has a population of 847,434 members. As of the 2019 report, Zonal water and mining department average safe drinking water coverage was 25.73% only.

Sample size determination and sites selection

The samples were taken from all water sources used by IDPs. Two hundred thirteen water samples were collected according to WHO Guidelines for Drinking Water Quality[5] from different water sources, including 138 dug well with the hand pump, 43 protected springs, 10 dug well with rope and 22 unprotected springs from the IDPs sites of 6 districts and 2 town administrations located in Gedeo Zone, Southern Ethiopia.

Sterilization of the filtration apparatus

The vacuum cup and the filtration apparatus were sterilized by using methanol before use and re-sterilized between samples

Table 1. Faecal coliform count per 100ml of all water samples at the IDP sites of Gedeo zone, South Ethiopia, 2018.

DISTRICTS/TOWN	TOTAL SAMPLE TAKEN	FAECAL COLIFORM COUNT			
		MEMBRANE FILTER (MF) TECHNIQUE			
		⩽0 CFU/100ML		>0 CFC/100ML	
		FREQUENCY	%	FREQUENCY	%
Bule	18	6	33.3	12	66.7
Dila town	9	7	77.8	2	22.2
Dila zuria	27	11	40.7	16	59.3
Wonego	64	35	54.7	29	45.3
Yirga chefe town	4	3	75.0	1	25.0
Yirga chefe	36	13	36.1	23	63.9
Gedeb	31	15	48.4	16	51.6
Kochere	24	16	66.7	8	33.3
Total	213	106	49.8	107	50.2

Abbreviation: CFC, colony forming units.

when analysing water from 2 different sources. Petri-dishes were sterilized in an autoclave at 121°C, 15psi for 15minutes. Forceps were sterilized by using Ethanol.

Water sample collection procedure

Water samples were collected by using DelAgua Portable Water Testing Kit (DelAgua Water Testing Ltd, The Old Dairy, Lower Fyfield, Marlborough, Wiltshire, SN8 1PY, United Kingdom) and DelAgua Water Testing Kit Manual Version 5.1. The sample cup was rinsed twice before taking the sample.

Bacteriological analysis of water

Analysing water samples for thermotolerant (faecal) coliforms. Water was passed through a sterile filter and the filter was placed in a petri (culture) dish on a pad with lauryl sulphate broth media which feeds coliform bacteria and inhibits the growth of other bacteria. After 4hours at 30°C of resuscitation of bacteria incubated for 14hours at 44°C, the samples were inspected and faecal coliforms with yellow colonies were counted within 10minutes after the petri dishes removed from the incubator. Results are expressed as colony-forming units per 100ml of water (CFU/100ml).

Sanitary survey

We conducted a sanitary survey for 213 water sources in the IDP sites of Gedeo Zone. We used the sanitary survey Observational checklist adapted from WHO Guidelines for Drinking Water Quality for water sources (springs and dug wells).[5]

Data processing and analysis

Data entry was done by using Epi data version 3.1 (EpiData Association, Odense Denmark) and exported to STATA version 14 (StataCorp LP, College Station, TX, USA) for analysis. Descriptive statistics were used to summarize categorical data. Multivariate logistic regression analysis was used to identify factors significantly associated with faecal coliform contamination of water sources by controlling confounding factors. The *P*-value of $<.05$ was considered as statistically significant. The results were presented by using tables and bar graph.

Result

A total of 213 water samples were examined from different water sources from IDPs sites, 107 (50.2%) samples showed above the WHO guidelines (0 faecal coliform count per 100ml) for drinking water. The majority of the samples from Yirga chefe district, 23 (63.9%) and Bule district, 12 (66.7%) were above WHO standard (0 faecal coliform count per 100ml) for drinking water (Table 1).

Bacteriological water quality by the type of water source

Microbiological tests showed that the highest faecal coliform bacteria counts were observed in water sources of dug well with rope, 9 (90%) and unprotected spring, 14 (60.9%). Whereas the lowest faecal coliform count was observed in dug well with a hand pump, 62 (44.9%) (Figure 2).

Contamination risk score for water sources used for IDP sites in Gedeo zone

A sanitary survey was conducted for 213 water sources which were used as an emergency water source for the IDP's in Gedeo Zone. The sanitary survey results of the study showed that, 31%, 49.8% and 18.2% of water sources were under high, medium and low-risk level respectively (Table 2).

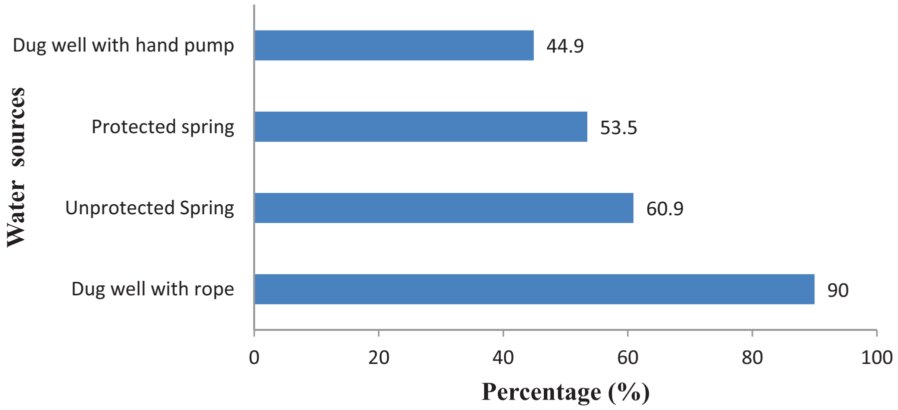

Figure 2. Percentages of faecal coliform positive water sources at the IDP sites in Gedeo zone, South Ethiopia, 2018.

Table 2. Risk level at different water sources at the IDPs sites in Gedeo zone, South Ethiopia, 2018.

WATER SOURCES	RISK LEVEL			
	LOW	HIGH	MEDIUM	VERY HIGH
Spring	12	24	28	1
Dug well	27	42	78	1
Total	39	66	106	2

Contamination risk score: 9-10 = Very high; 6-8 = high; 3-5 = Medium; 0-2 = Low.

Factors associated with the presence of faecal coliform in the assessed water sources of IDP sites

Multivariate logistic regression analysis summarized in (Table 3) showed that the presence of latrine in uphill (AOR: 6.7, 95%CI: 1.0-42.9), other source of pollution (AOR: 5.0, 95%CI: 1.1-22.3), inadequate fencing (AOR: 7.1, 95%CI: 1.3-40.2) and lack of diversion (AOR: 6.3, 95%CI: 1.0-37.6) around springs were significantly associated with faecal coliforms contamination.

Multivariate logistic regression analysis summarized in Table 4 showed that the dug well that had a latrine within 10 m radius (AOR: 11.4, 95%CI: (1.8-72.1), other pollution sources within 10 m (AOR: 7.9, 95%CI: (1.9-32.4), inadequate fencing (AOR: 2.8, 95%CI: (1.0-7.9), drawing water using a bucket with rope (AOR: 7.3, 95%CI: (1.6-33.4) and unsanitary well cover (AOR: 3.4, 95%CI: 1.1-10.4) around water sources were significantly associated with the presence of faecal coliforms in water samples.

Table 3. Faecal coliforms contamination and associated factors in springs of IDP sites, Gedeo zone, Southern Ethiopia, 2018.

VARIABLES		95%CI	
		COR	AOR
Latrine uphill			
Yes	19 (29.2%)	9.1 (2.3-35.8)	6.7 (1.0-42.9)*
No	46 (70.8%)	1.00	1.00
Other source of pollution			
Yes	23 (35.4%)	9.5 (2.7-33.3)	5.0 (1.1-22.3)*
No	42 (64.6%)	1.00	1.00
Unfenced			
Yes	25 (38.5%)	2.4 (0.8-6.7)	7.1 (1.3-40.2)*
No	40 (61.5%)	1.00	1.00
Animal access			
Yes	38 (58.5%)	6.2 (2.1-18.6)	2.9 (.7-13.2)
No	27 (41.5%)	1.00	1.00
Lack of diversion ditch			
Yes	23 (35.4%)	6.5 (2.0-20.1)	6.3 (1.0-37.6)*
No	42 (64.6%)	1.00	1.00
Unprotected			
Yes	15 (23.1%)	5.5 (1.4-22.0)	3.7 (0.6-20.5)
No	50 (76.9%)	1.00	1.00

Abbreviations: AOR, adjusted odds ratio; COR, crude odds ratio.
*Statistically significant at p-value < 0.05.

Discussions

Access to safe drinking water is one of the basic human rights and is extremely important for health.[14] However, our finding shows that majority of water sources in IDP sites were contaminated. The highest contamination was observed in water from roped well (90%) followed by water from unprotected springs (60.9%), protected springs (53.5%) and dug well with hand pump (44.9%) sources. This finding is in agreement with the studies conducted in South Darfur, Sudan.[17,18]

In this study, faecal coliform were observed above the WHO guidelines (0 faecal coliform count per 100 ml) for drinking water in 107 (50.2%) of the water samples. This finding is in line with the study conducted on a similar setting (IDP site) in South Darfur, Sudan.[17] This might be due to poor hygiene and sanitation practices around water sources causes' faecal contamination.

Table 4. Faecal coliforms contamination and associated factors in dug well of IDP sites, Gedeo zone, south Ethiopia, 2018.

VARIABLES		95%CI	
		COR	AOR
Latrine within 10 m radius			
Yes	30 (20.3%)	12.6 (3.6-44.2)	11.4 (1.8-72.1)*
No	118 (79.7%)	1.00	1.00
Other pollution source within 10 m			
Yes	58 (39.2%)	3.8 (1.9-7.7)	7.9 (1.9-32.4)*
No	90 (60.8%)	1.00	1.00
Drainage faulty allowing ponding			
Yes	90 (60.8%)	7.3 (3.4-15.5)	4.9 (1.6-14.4)
No	58 (39.2%)	1.00	1.00
Inadequate fencing			
Yes	76 (51.6%)	4.1 (2.1-8.2)	2.8 (1.0-7.9)*
No	72 (48.4%)	1.00	1.00
Cracks in the cement floor			
Yes	54 (36.5%)	5.03 (2.4-10.5)	2.7 (0.9-8.0)
No	94 (63.5%)	1.00	1.00
Drawing water using a bucket with rope			
Yes	41 (27.7%)	6.7 (2.8-15.9)	7.3 (1.6-33.4)*
No	107 (72.3%)	1.00	1.00
Unsanitary well cover			
Yes	84 (56.8%)	3.8 (1.9-7.7)	3.4 (1.1-10.4)*
No	64 (43.2%)	1.00	1.00
Drainage channel cracked			
Yes	60 (40.5%)	5.4 (2.6-11.1)	0.9 (0.3-2.6)
No	88 (59.5%)	1.00	1.00
Spilt water collect in the apron			
Yes	42 (28.4%)	4.6 (2.1-10.3)	1.4 (0.4-4.5)
No	106 (71.6%)	1.00	1.00
Cement less than 1m in radius			
Yes	35 (23.7%)	4.4 (1.9-10.2)	1.4 (0.4-5.4)
No	113 (76.3%)	1.00	1.00

Abbreviations: AOR, adjusted odds ratio; COR, crude odds ratio.
*Statistically siginficant at *p*-value $<$ 0.05.

The WHO report of 2014, shown that waterborne diseases account for estimated cases 4.1% of the global burden of diseases, and cause about 1.8 million human deaths annually and 88% are attributed to unsafe water supply, sanitation and poor personal hygiene globally.[19] Sanitary inspection scores of this study range from low to very high risk level. The majority of water sources, 49.7% were under medium risk level and 31% of water sources were under high-risk levels. This study finding is in agreement with studies conducted in North Gondar and Eastern Tigrai zone, Ethiopia by Getachew et al[20] and Gebrewahd et al[16] respectively.

This study finding showed that the presence of a latrine in uphill of the water sources was associated with faecal coliform contamination of the springs. This study finding is an agreement with a studies conducted in Uganda and Mozambique by Howard et al[21] and Chaúque et al[22] respectively. The possible reason for contamination with faecal coliform may be faecal matter entered into the water sources by infiltration process from a pit latrine or open field defection (unsafe disposal of human faeces) by surface runoff during the rainy season.

In this study lack of diversion ditch to divert flood or run-off from uphill and inadequate fencing around the water sources were significantly associated with faecal contamination of water sources. This study finding in line with studies conducted in Ethiopia and Uganda by Gebrewahd et al[16] and Howard et al[21] respectively. This might be a flood or run-off from uphill of the water source during rainfall brought faecal matter and animal excreta into the water sources and possible source for faecal contamination of the water sources.

Similarly, in the present study, the majority of samples from water sources (springs and dug well) were positive for faecal coliforms. This study finding in agreement with studies conducted in South Darfur, Sudan and Vina Division, Adamawa, Cameroon by Mohammed Eltahir et al[17] and Viban et al[23] respectively. The reason for contamination with faecal coliforms may be resulted from a lack of fence around the spring and dug well and animals could easily access.

In this study unsanitary well cover and rope used to fetch water were associated with faecal contamination of dug well. This is in agreement with other studies conducted in Gambella Region, Ethiopia and rural Cambodia by Mekonnen et al[14] and Bennett et al[24] respectively. A possible explanation for the faecal coliform counts in water from dug well with rope may be due to the rope was frequently touched with bare hands and it was thrown to the surface while drawing the water from the well. It might be contaminated with bacteria in the soil and then cause water contamination. Using a pulling system of drawing water from the well may reduce the likely chance of water contamination with faecal.

In the study area, improper disposal of sewage and solid wastes were the major sources responsible for contamination of water sources.[25,26] Raising community awareness towards the proper management of human wastes, proper disposal of sewage and solid waste is key solutions to minimize the chances of water source contamination.

Latrines and other point sources of potential faecal contamination should be located sufficiently far from groundwater sources used for drinking purposes to ensure that the risk of pathogen survival is very low.[5,22] So all the sources of water should be properly monitored to provide contamination-free water for the public; and this type of study should be conducted from time to time to ensure quality of drinking water.[27,28]

Conclusions

The health implication of polluted water to a community requires serious attention since people use untreated water for a wide range of domestic activities and most importantly for drinking. The results from this study indicated that the samples had faecal coliform bacteria indicative of faecal pollution. The presence of latrine in uphill, the other source of pollution, inadequate fencing, lack of diversion, drawing water using a bucket with rope and the unsanitary well cover was significantly associated with faecal contamination of water sources. Therefore, adequate fencing, proper diversion ditch construction and, hygiene promotion should be done to protect water sources from faecal contamination. In addition, adequate and enough treatments should be done to reduce the coliform count to WHO guidelines (0 faecal coliform count per 100 ml) before consumption. Furthermore, latrines and other point sources of potential faecal contamination should be located at least 10 m away from water sources and better to be lower elevation than the water sources.

Author Contributions

ZA, MBA, GGK, BN, AA, ST, FB and EA contributed to study design; ZA and BN carried out analysis and interpretation of data; ZA, MBA, BN, ST and GGK made major contributions to writing the manuscript. All authors read and approved the final draft.

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