


Research Paper

Determinants of drinking water quality and sanitary risk levels of water storage in food establishments of Addis Ababa, Ethiopia

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ABSTRACT

The study aimed to assess the determinants of drinking water quality and sanitary risk levels of water storage. An institution-based cross-sectional study was conducted. One hundred and twenty-five drinking water samples were collected directly from food outlets' drinking water storages. An observational checklist was used to assess the sanitary risk levels of the storages. Data analysis was conducted using multivariable logistic regression. Type of primary source of drinking water, having continuous piped water, type of drinking water storage equipment, drinking water storage having a lid/cover, method of drinking water drawn from the water storages, presence of any method of drinking water treatment, and having functional a hand-washing facility with soap near the toilet were identified as major determinant factors. This study revealed that nearly 30% of the food outlets' drinking water was not microbiologically safe. As a result, these establishments could be a source of different health problems for their customers. In the study, many determinant factors that affect the drinking water quality of the food outlets were identified. In addition, 16.3% and 18.7% of the food outlet drinking water storages were grouped into high and very high contamination risk levels, respectively. Therefore, the existing regulatory body should force the food outlets to have effective hand-washing practices, clean, suitable drinking water storage, and to avoid dipping practice.

Key words: Addis Ababa, bacteriological, determinants, drinking water storage, food outlet

HIGHLIGHTS

- Many factors that affect the drinking water quality of the food establishments were identified.
- Significant numbers of food establishment drinking water storages were grouped into high and very high contamination risk levels.
- Significant numbers of food outlet drinking water storages were found to be contaminated.

ABBREVIATIONS

AAFMHACA	Addis Ababa Food, Medicine Health Care Administration and Control Authority
AOR	Adjusted Odd Ratio
CFU	Colony Forming Unit
CI	Confidence Interval
EMB	Eosine Methylene Blue
USA	United States of America
WHO	World Health Organization

INTRODUCTION

Access to safe drinking water is one of the keys to sustaining life and health since it contributes to controlling the spread of waterborne disease (Irianti *et al.* 2016; Gonzalez *et al.* 2020; Rajasingham *et al.* 2020). This is stressed by Sustainable

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Development Goal (SDG) 6, which includes aspirational global targets to achieve universal access to basic services and to progressively improve the standard of water, sanitation and hygiene services by 2030 (McDonald *et al.* 2020). However, due to many determinant factors like poor sanitation and hygiene practices, drinking water can be a vehicle for transmission of many pathogenic organisms (Abera *et al.* 2014; De 2018; Mekonnen *et al.* 2019). Particularly, in developing countries, drinking water is often contaminated at storage and point of use, and consumption of unclean water poses a great public health problem, especially diarrheal disease (Matteson *et al.* 2016; Lilje & Mosler 2017; Dandadzi *et al.* 2019). Diarrheal disease affects rich and poor, old and young, and those in developed and developing countries alike; however, a strong association exists between poverty and an insanitary environment (Hongxing *et al.* 2016; Girmay *et al.* 2020b). According to the World Health Organization (WHO), diarrheal disease accounts for an estimated 4.1% of the total daily global burden of disease and is responsible for the deaths of 1.8 million people and four billion cases of diarrhea every year (World Health Organization 2014). Of the above estimation, 88% of that burden is attributable to utilization of unsafe drinking water, poor sanitation and hygiene practices (Haseena *et al.* 2017). Although the WHO water safety plan is stressed in order to develop better approaches designed to meet the requirements of safe drinking water supply for all mankind, water that looks suitable for drinking may still be contaminated with pathogens that may cause serious health problems in developing countries including Ethiopia. This could be due to many known and unknown determinant factors that affect drinking water quality. In Ethiopia, only 42 and 11% of Ethiopians have access to a clean water supply and adequate sanitation services, respectively (Girmay *et al.* 2020a). Similarly, only 55% of the population of Addis Ababa city receives a basic water supply; half of its population is served for less than 12 hours per day; a quarter of its population has no formal water supply service at all, and the city's average improved sanitation coverage is also below 12.9% (Assefa *et al.* 2019). This scenario of drinking water supply may cause food establishments to have poor sanitation and hygiene practices. Consequently, they are suspected as the main sources of waterborne diseases. Besides, even for those people who have access to potable drinking water, the provision is not sufficient where piped water supply functions intermittently. As a result, residents and public food establishment owners are commonly obligated to use drinking water storage materials to ensure the availability of enough water for long periods of time. In particular, food outlets utilizing different storage materials as a vital instrument to satisfy their customers' needs, even if water is stored in an unhygienic manner and may be easily contaminated, can result in causing different communicable diseases to their clients. Many studies have indicated that water storage materials influence the quality of drinking water if they are not handled in an acceptable environmental, sanitary and hygienic manner (Nnaji *et al.* 2019; Gonzalez *et al.* 2020; Karande *et al.* 2021). Studies done on household drinking water storage reveal that most determinant factors associated with the quality of drinking water and storage materials are the lack of drinking water treatment, poor hygiene practice, low standard of premises, increased storage time, and re-growth of bacteria (Akuffo *et al.* 2013; Kabir *et al.* 2016; Mudau *et al.* 2017; Dandadzi *et al.* 2019). Although Addis Ababa food outlets have a low standard of infrastructure, are suspected of poor water storage conditions that may be permitting entry of particulate matter, poor sanitation and hygienic practices, with persistent scarcity and intermittent drinking water supply that could contribute to drinking water contamination, no study has assessed determinants and sanitary risk levels of the drinking water storage of the food establishments. Therefore, this study aimed to assess the determinants of drinking water quality and sanitary risk levels of water storage in the food establishments of Addis Ababa, Ethiopia.

METHODS

Study area

The study was conducted in Addis Ababa city administration. It is the capital city of the Federal Democratic Republic Government of Ethiopia and the seat for the African Union (Kefeni & Yallew 2018; Defar *et al.* 2021). In 2017, according to the Addis Ababa Food, Medicine Health Care Administration and Control Authority (AAFMHACA), the Addis Ababa food establishments were categorized into slum and non-slum areas based on 12 criteria. These are presence of better liquid and solid waste management practice, presence of improved toilet, having a septic tank, good premises conditions (clean, ventilated), acceptable dishwashing system practice, food handlers with medical check-ups, availability of enough space for work, availability of continuous water supply, availability of shower, good food storage conditions, and presence of hand-washing facilities. There are 1,141 licensed food establishments in the city (Girmay *et al.* 2020c). From the total food outlets, 95 (8%) are high quality hotels with one or more star ratings (Girmay *et al.* 2020b). However, the majority, 1,046 (92%), are small food establishments which include non-star rated hotels, bars and restaurants, cafes and restaurants, etc.

(Girmay *et al.* 2020d). The government provides safe water supply to the food outlets. However, this supply is inadequate for the needs of the food establishments and frequently interrupted.

Study design

An institution-based cross-sectional study was conducted in Addis Ababa city.

Source population

All food outlets were located in Addis Ababa city administration.

Study population

All selected food outlets were located in the study area.

Inclusion criteria

All food outlets that provided a service to clients were included.

Exclusion criteria

Food outlets that provide only packed drinking water were excluded from the study.

Sample size determination

For the study, the sample size was calculated using an unmatched cohort and cross-sectional study formula (EPI INFO version 7.2.2.6, STATCALC) by considering 95% confidence interval, 80% power, 1:1 ratio, and 15.9% occurrence of salmonella (outcome in unexposed group), based on the results of a study done in treated, stored, and drinking water in Nakuru North, Kenya in 2014 (Waithaka *et al.* 2014). Then, using EPI INFO version 7.2.2.6, STATCALC, the sample size was equal to 114 samples of food outlets. Adding 10% for the non-response rate, the final sample of food outlets was equal to 125.

Sampling procedure

The food outlets were selected using a stratified, simple random sampling technique. Sampling frame or a listing of the 1,141 licensed food establishments was obtained from the AAFMHACA. These food outlets were stratified into slum and non-slum areas based on their location. Moreover, they were also divided into large and small food outlets. Then, sample allocation was carried out on the slum and non-slum areas, in addition to the large and small food outlets. The main purpose of stratification and sample allocation was to obtain representative samples of food establishments, which are located in different areas, of various status with different characteristics and environmental hygiene and sanitation practices. Based on the allocation, from the non-slum area (51), 7 samples from the large and 44 samples from the small food outlets were taken. From the slum area (74), 3 samples from the large and 71 samples from the small food outlets were included. In total, 10 samples from the large and 115 samples from the small food outlets were included in the study. Finally, using a simple random sampling technique (a lottery method), 125 drinking water samples (250 mL from each) were collected directly from the food outlets' drinking water storages (Girmay *et al.* 2020a). Simultaneously, an observational checklist was completed to assess determinant factors and sanitary risk levels of food outlet drinking water storages. The sampling procedure of the study is depicted in [Figure 1](#).

Data collection procedures

To assess determinant factors and sanitary risk levels of food outlets' drinking water storages, an observational checklist was prepared. Then, data were collected using a standardized observational checklist, and heat-sterilized bottles of 250 mL capacity from June to September, 2019. To prevent lysis of microorganisms, the bottles were delivered to the laboratory within 6 hours and kept in a refrigerator at 4 °C until the time of analysis.

Data quality control

To assess the determinant factors of drinking water storages, a questionnaire was prepared in English and translated to Amharic and back to English to keep the consistency of questions. Moreover, to determine sanitary risk levels of drinking water storages, ten standardized questions adopted from the WHO were used. The principal investigator checked and reviewed the entire completed questionnaire to ensure the completeness and consistency of the information. The validity of laboratory results was ensured by all the necessary procedures being followed by experienced laboratory professionals. The instruments and reagents used to do the test were calibrated and the expiry date ensured.

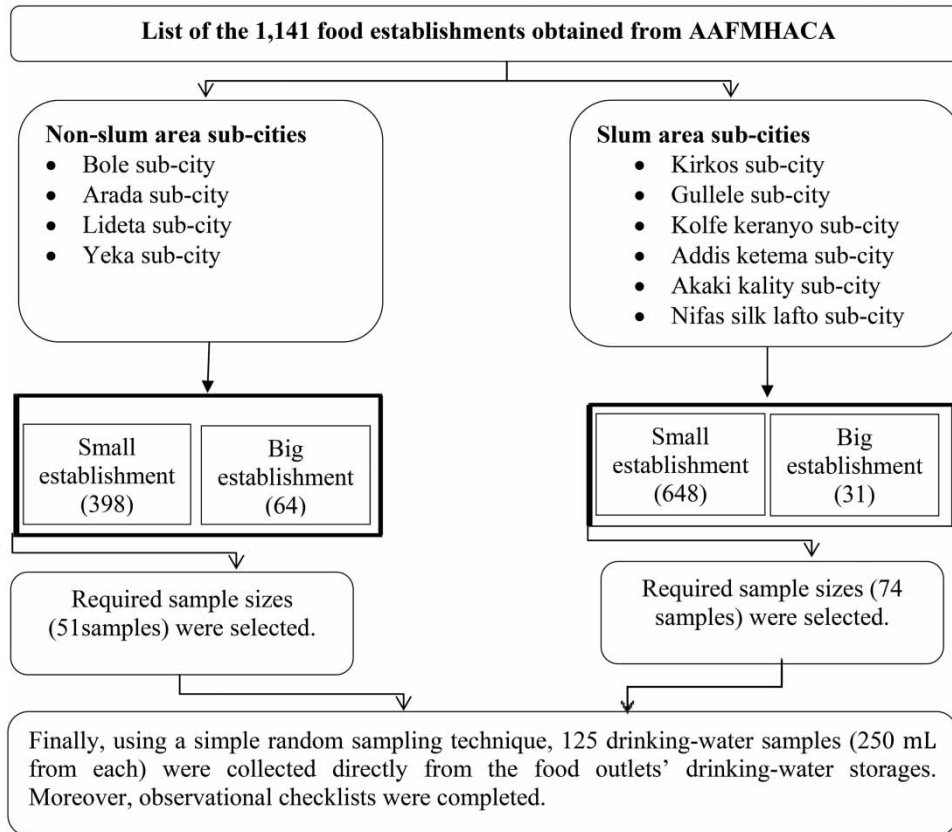


Figure 1 | Systematic sampling procedure of the study (Girmay *et al.* 2020a).

Data analysis

Data were cleaned, recorded, and coded appropriately. Then, data were entered into SPSS (Statistical Package for the Social Sciences) software version 20. Data analysis was conducted using binary logistic regression and multivariable logistic regression. In all analyses, a *P*-value less than 0.05 was considered statistically significant.

Bacteriological analysis

The membrane filtration method was used for bacteriological analysis of the drinking water. Water samples of 100 mL were filtered using membrane filters with 0.45 µm cellulose nitrate membrane (Millipore, USA) to retain the indicator bacteria. Then, the filters were aseptically removed from the membrane holder, placed on Eosine Methylene Blue (EMB) agars (Himedia) and incubated at 44.5 °C for 24 hours for isolation of fecal coliforms. To accept whether positive samples had fecal coliform or not, they were re-inoculated into peptone broth test tubes for 24 hours at 44.5 °C. After this, drops of Kovac's reagent were added to the re-incubated peptone broth test tubes. Lastly, test tubes that showed a reddish color at the top were identified as positive for fecal coliforms. Then, the results of the study were compared with the WHO recommended drinking water standards.

Operational definitions

The quality of the drinking water was defined based on the WHO drinking water standard (World Health Organization 2011), that water samples with <1 CFU/100 mL were considered to be safe and samples with ≥1 CFU/100 mL to be contaminated. Moreover, the sanitary risk assessment of the drinking water was done based on the WHO guidelines for drinking water quality (World Health Organization 1997) using a standardized observational checklist. Depending on this, drinking water storages that scored 0–2 were considered as low risk, 3–5 medium risk, 6–8 high risk, and 9–10 very high risk.

Other operational criteria are defined as:

- Food outlets/establishments: Institutions that provide food and drinks for selling to customers.
- Large/big food establishment: Hotels ranked with one or more stars.
- Small food establishment: Small vendors, non-star ranked hotels, bars, restaurants, cafes.
- Slum area: Area with poorer sanitation infrastructure.
- Non-slum area: Area with better sanitation infrastructure.
- Continuous water: The presence of water in the food establishments for 24 hours per day.

Study variables

Predictor variables of the study

The independent variables of this study are types of food outlets, having a license, primary source of drinking water (improved or unimproved), having continuous piped water, type of drinking water storage equipment used, drinking water storage having a lid/cover in place at the time of visit, method of drinking water taken/drawn from the drinking water storages/containers, presence of any drinking water treatment, and availability of functional hand washing.

Outcome variable of the study

The response variable of this study is the bacteriological quality of drinking water (fecal coliforms).

Ethical approval

Ethical approval was obtained from the Ethiopian Public Health Institute, Scientific and Ethical Review Board with reference number EPHI 613/138 in June, 2019. The confidentiality and privacy of food outlets were ensured throughout the research process. The study design did not include any identifying information such as name and address of food establishments.

RESULTS

Determinant factors of drinking water quality

Of the assessed food establishments, 76 (61.8%) of them had a legal license from the authorized body AAFMHACA. The majority (78%) of the food outlets' primary source of drinking water was improved water sources. However, the rest (22%) of the food establishments' drinking water sources were unimproved, such as unprotected spring, unprotected dugwells, and others. Of all food establishments, only 46 (37.4%) received continuous piped water, but above half (62.6%) had received intermittent water supply. Regarding type of drinking water storage used, 39 (31.7%) of the food outlets used rough and untidy drinking water storage/containers. In this study, 42 (34.1%) of the food outlets' drinking water storage had no lid/cover in place at the time of the visit. In addition, 42 (34.1%) of the food establishments used dipping practice to draw the drinking water from the storage or containers. From the assessed food outlets, 72 (58.5%) of them had a method of drinking water treatment at the food establishment level like filtration, chlorination, and others. However, 45 (36.6%) of the food establishments had no standardized and functional hand-washing facility with soap near the toilet (Table 1).

Contamination risk levels of the assessed drinking water storage of the food establishments

Of the evaluated food establishment drinking water storages, 68 (55.3%) and 12 (9.8%) had low and medium contamination risk level, respectively. However, 20 (16.3%) and 23 (18.7%) had high and very high contamination risk levels, respectively. The study also indicated that drinking water storage categorized as having medium, high and very high sanitary risk levels had a positive relationship with the presence of fecal coliforms in the drinking water storages (Table 2).

Laboratory results of bacteriological drinking water quality

In the presumptive laboratory test, 45 (36.6%) of the samples had fecal coliforms, although the majority, 78 (63.4%), of the samples were found to be safe. Also, in the confirmatory test, nearly three-quarters, 88 (71.5%), of the samples were safe. However, in this test, 35 (28.5%) of the drinking water storages were contaminated with fecal coliforms. In this study, the mean score of fecal coliforms count per 100 mL was found to be 8.20 (Table 3).

Table 1 | Determinant factors of drinking water quality in food establishments of Addis Ababa, Ethiopia ($n = 123$)

Study variables	Category/Item	Frequency	Per cent (%)
Type of food outlets	Small	114	92.7
	Large	9	7.3
Having legal license by FMHACA	Yes	76	61.8
	No	47	38.2
Primary source of drinking water for the food establishments	Improved	96	78
	Unprotected spring, dug-wells and others water sources	27	22
Having continuous piped water in the food establishments for 24 hours per day	Yes	46	37.4
	No	77	62.6
Type of drinking water storage equipment used by the food establishments at the time of visit	Rough and untidy	39	31.7
	Easily cleanable	84	68.3
Drinking water storage having a lid/cover in place at the time of visit	Yes	81	65.9
	No	42	34.1
Method of drinking water taken/drawn from the drinking water storages/containers	By dipping	42	34.1
	By pouring	81	65.9
Presence of any method of drinking water treatment at the food establishments like filtration, chlorination and others	Yes	72	58.5
	No	51	41.5
Food establishments having functional hand-washing facility with soap near the toilet	No	45	36.6
	Yes	78	63.4

Table 2 | Contamination risk levels of the drinking water storage of the food establishments in Addis Ababa, Ethiopia ($n = 123$)

Sanitation risk scores	Frequency	Per cent	Risk category	Exp(B)	COR 95% CI	
					Lower	Upper
0–2	68	55.3	Low	Reference		
3–5	12	9.8	Medium	3.293	0.669	16.211
6–8	20	16.3	High	5.927	1.271	27.633
9–10	23	18.7	Very high	3.128	0.959	10.206

Table 3 | Laboratory test results of bacteriological drinking water quality in food establishments of Addis Ababa, Ethiopia ($n = 123$)

Fecal coliforms (CFU/100 mL) at 44.5 °C		Frequency	Per cent	WHO standard in number of fecal coliforms (n)
Growth of any microorganisms in the presumptive test	Yes	45	36.6	0
	No	78	63.4	
Mean of fecal coliforms/colony count per 100 m	Mean	8.20		
Having confirmed fecal coliforms	Yes	35	28.5	0
	No	88	71.5	

Multivariate logistic regression analysis of fecal coliforms with selected explanatory variables

In the binary logistic regression analysis, eight predictor variables were significantly correlated (p -value < 0.022) with the presence of fecal coliforms in the drinking water storages. However, in the multivariable logistic regression analysis, seven explanatory variables were significantly associated (p -value < 0.03) with drinking water contamination (Table 4). These included type of primary source of drinking water for the food outlets, having continuous piped water for 24 hours per

Table 4 | Multivariate logistic regression analysis of confirmed fecal coliforms with selected explanatory variables ($n = 123$)

Study variables		Confirmed fecal coliforms		B	Wald	P-value	AOR with 95%CI
		Yes	No				
Having legal license by FMHACA	Yes	16	60	0.015	0.00	0.99	1.02 (0.17–6.27) Reference
	No	19	28				
Primary source of drinking water for the food outlets	Improved	20	76	−4.10	8.63	0.003	0.017 (0.001–0.26) Reference
	Unimproved/unprotected spring, dug-wells and others	15	12				
Having continuous piped water in the food establishments	Yes	3	43	−3.29	5.54	0.019	0.04 (0.002–0.58) Reference
	No	32	45				
Type of drinking water storage equipment used by the food outlets at the time of visit	Rough and untidy	19	20	2.72	5.85	0.016	15.16 (1.68–137.14) Reference
	Easily cleanable	16	68				
Drinking water storage having a lid/cover in place at the time of visit	Yes	8	73	−4.15	10.77	0.001	0.016 (0.001–0.19) Reference
	No	27	15				
Method of drawing drinking water from the water storages	Dipping	26	16	1.93	4.69	0.030	6.9 (1.20–39.63) Reference
	Pouring	9	72				
Any method of drinking water treatment at the food establishment level	Yes	12	60	−2.39	5.64	0.018	0.092 (0.013–0.66) Reference
	No	23	28				
Food establishments having functional hand-washing facility with soap near the toilet	No	23	22	2.66	6.54	0.011	14.35 (1.86–110.44) Reference
	Yes	12	66				

day in the food establishments, type of drinking water storage equipment used by the food outlets, drinking water storage having a lid/cover in place at the time of visit, method of drawing drinking water from the water storage, presence of any method of drinking water treatment at the food establishment level, and food establishments having a functional hand-washing facility with soap near the toilet.

DISCUSSION

In this study, 71.5% of the food establishments' drinking water storages were free from bacteriological contamination and safe from biological hazards. This could be due to the presence of effective water treatment technologies as most of the food establishments' drinking water sources were improved. Moreover, most of them could fit the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) concept regarding sources of improved water which states improved drinking water sources are those that have the potential to deliver safe water by nature of their design and construction. They include piped water, boreholes or tube wells, protected dug-wells, protected springs, rainwater, and packaged or delivered water (World Health Organization 2017). However, 28.5% of the food establishments' drinking water storage had confirmed fecal coliforms. This might be as a result of anthropogenic actions in the food establishments. Moreover, the type of source of the drinking water may be a core factor for the presence of the contamination. 28.5% of the drinking water storages had fecal coliforms, and this finding is consistent with a study done in Gondar, Ethiopia although the setting is different (Mengesha *et al.* 2004). However, the result of this study was lower than a study done in Bermuda (Lévesque *et al.* 2008). Based on WHO criteria for sanitary risk assessment levels of drinking water storages (World Health Organization 2011), 55.3% and 9.8% of the food outlets had low and medium contamination risk levels, respectively. This indicated that the drinking water of the food establishments needs attention and action to prevent the risk of contamination. Moreover, 16.3% and 18.7% of food establishments' drinking water had high and very high contamination risk levels, respectively. This indicated that these food establishments' drinking water requires higher action priority and urgent action, respectively. In addition, this finding revealed that a significant number of the food establishments' drinking water storage lacks good sanitation and safety practices. The findings of the sanitary scores of this study were higher than a study done in Ethiopia (Gebrewahd *et al.* 2020).

This study revealed that food outlets with improved sources of water were 1.7% less likely to have fecal coliforms in the drinking water storages (AOR = 0.017 with 95% CI: 0.001–0.26) than those that had received drinking water from unprotected spring and unprotected dug-wells. As expected, this could be due to effective treatment of the water supply by the government. On the other hand, this indicated that unprotected spring water, unprotected dug-wells, and other sources of drinking water had higher bacteriological contamination levels than the improved sources. Similarly, the odds of food establishments with continuous and uninterrupted piped water were 4% less likely to have fecal coliforms in their drinking water storages (AOR = 0.04 with 95% CI: 0.002–0.58) than those who had not. This revealed that non-continuous and interrupted drinking water sources can be enhancing the proliferation of drinking water contaminants in the drinking water storages. Moreover, this idea was supported by a study done by Brocklehurst & Slaymaker (2015), which reports that there was a significant relationship between interruptions in piped water supply and presence of fecal coliforms, as well as with cases of different diarrheal diseases (Brocklehurst & Slaymaker 2015).

The finding of this study showed that the odds of food outlets with rough and untidy drinking water storage equipment were 15.16 times more likely to have fecal coliforms (AOR = 15.16 with 95% CI: 1.68–137.14) than those that had easily washable and clean drinking water storage equipment. This indicated that, even if treated water was supplied to the food establishments, due to the type of drinking water storage and unhygienic practices, the occurrence of fecal coliforms was high and can indicate and impose health risks on customers as a result of the contaminated drinking water. Moreover, the odds of food establishments that drew drinking water through dipping were 6.9 times more likely to have fecal coliforms (AOR = 6.9 with 95% CI: 1.20–39.63) than those that used pouring to take out drinking water from the storage. This might be due to the presence of cross-contamination between unhygienic hand contact with the water-holding equipment used to draw water. This needs further research as most Ethiopians practice dipping to draw out drinking water from storage equipment. However, the odds of food outlets that had drinking water storage with a lid or cover in place at the time of the visit were 1.6% less likely to have fecal coliforms (AOR = 0.016 with 95% CI: 0.001–0.19) than those without. As expected, the presence of a cover or a lid on water storages can prevent different risk factors and water contamination. Likewise, food outlets with any method of drinking water treatment practice at the food establishment level were 9.2% less likely to have fecal coliforms (AOR = 0.092 with 95% CI: 0.013–0.66) than those without. This indicated that different water treatment technologies had a great effect on the safeguarding and improvement of the water quality and reducing water contamination. Conversely, the odds of food establishments that had no functional hand-washing facility with soap near the toilet were 14.35 times more likely to have fecal contamination in their drinking water (AOR = 14.35 with 95% CI: 1.86–110.44) than those who had. This revealed that the presence of a hand-washing facility with soap near the toilet had a direct effect on human health and indirect effect with water contamination in drinking water storages, but further research is needed to enhance the finding.

CONCLUSION

Most of the food establishments' drinking water storages were free from bacteriological contamination and safe from biological hazards. However, this study also shows that drinking water quality is a major public health concern as a significant number of food establishments' drinking water storages had fecal contamination. The findings of the study revealed that nearly 30% of the food outlets' drinking water was not microbiologically safe. As a result, these establishments could be a source of different health problems for their customers. In the study, many determinant factors that affect drinking water quality of food outlets were identified. A large number of food establishments' drinking water storages had high and very high contamination risk levels. Therefore, good sanitation and hygiene practice should be carried out and promoted at the food establishments. Also, the creation of awareness about drinking water contamination and its health risks should be carried out by the concerned bodies. Moreover, continuous drinking water monitoring and evaluation should be done by the government. On a regular basis, at least within three months, owners of the food outlets should wash their water storages and disinfect them. Besides, to minimize drinking water contamination, the existing regulatory body should force the food outlets to adopt effective hand-washing practice, clean, suitable drinking water storages, and avoid dipping practice. Moreover, improved latrines with standardized hand-washing facilities should be built by the food outlet owners.

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CONFLICT OF INTEREST

We the authors declare that we have no competing interest.

LIMITATION

Not studying chemical and physical properties of drinking water is the main limitation of this study.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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