

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

Aderajew Mekonnen Girmay (✉ [Aderajewmekonen1@gmail.com](mailto:Aderajewmekonen1@gmail.com))

Ethiopian Public Health Institute <https://orcid.org/0000-0002-7911-4152>

Sirak Robel Gari

Ethiopian Institute of Water Resources

Gebreab Teklebirhan Gessew

Addis Ababa University

Mulumebet Tadesse Reta

Gullele subcity City Health Office

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## Research

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# Abstract

**Introduction:** Clean and suitable drinking-water is a key component to enhance human health. However, obtaining safe and adequate water is limited in many developing countries. Besides, treated drinking-water are often contaminated at storages and point of use with contaminants and consumption of unclean water poses a great public health problem. This study aimed to assess the determinants of drinking-water quality and sanitary risk levels of water storages in food establishments of Addis Ababa, Ethiopia. Institution-based cross-sectional study was conducted. 125 food outlets were selected using a simple random sampling technique. Then, 125 drinking-water samples (250 from each) were collected directly from the food outlets drinking-water storages. Moreover, observational checklist was used to assess determinants of drinking-water quality and sanitary risk levels of the storages. Data analysis was conducted using multivariable logistic regression.

**Results:** This study revealed that, 28.5% of the drinking-water was contaminated with fecal coliforms. Besides, based on WHO criteria, 16.3% and 18.7% of the food outlet drinking-water storages were grouped into high and very high contamination risk levels respectively. Seven (7) explanatory variables were identified as main determinant factors which significantly associated ( $p$ -value < 0.03) with the contaminated drinking-water.

**Conclusion:** Most of the food establishments' drinking-water was free from bacteriological contamination and safe from biological hazards. However, significant number of food establishments' drinking-water storages had fecal contamination. In the study, many determinant factors that affect drinking-water quality of the food outlets were identified. Therefore, good sanitation and hygiene practice should be practiced at the food establishments. Besides, creation of awareness about drinking water contamination and its health risks should be done by concerned bodies.

## Introduction

Based on the WHO Guidelines for Drinking-water, bacteriological water quality is defined in terms of the absence or presence of indicator organisms in any 100 ml sample of drinking-water (World Health Organization 2011). Global water quality standards and analytical methods to detect drinking-water contamination may differ in some aspects, but they are primarily based on percentage compliance with fecal indicator bacteria levels (fecal coliforms, etc.) (World Health Organization 1999). The presence of those indicator bacteria represents the fecal contamination of drinking-water with pathogens and quality deterioration (Fawell and Nieuwenhuijsen 2003, Odonkor and Ampofo 2013, Girmay et al. 2020a). That is the case, bacteriological examination of drinking-water for the presence of indicator microorganisms (fecal coliforms) is a key to determine microbiological quality and ensuring public health safety (Saxena et al. 2015). Although providing adequate and potable water to all citizens is among the top public health concerns and priority of governments in all nations, still it is not attained (Mraz et al. 2021, Varol and Davraz 2016, Chalchisa et al. 2018). Particularly, with the help of the developed countries, this concern is high in the developing countries because of the levels of water, sanitation and

hygiene services coverage as well as health attainment are low (Jiménez et al. 2014, Girmay et al. 2019, Nnaji et al. 2019). However, impact of poor drinking-water quality and sanitation continues as major public health problem in those nations (Li and Wu 2019, Goel et al. 2015, Meride and Ayenew 2016). Drinking-water is prone to fecal contaminants which is the sources of diarrheal diseases for the public (Chauhan et al. 2017, Azizullah et al. 2011, Matteson et al. 2016). Because, drinking-water can be polluted at any point along the way from the source to the point of consumption if the sanitation and hygiene practices are low (Clasen and Bastable 2003). Most of waterborne diseases are characterized by diarrhoea, which involves excessive stooling, often resulting to dehydration and possibly death. According to the WHO and other studies, 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(Girmay et al. 2020a, World Health Organization 2014). Further estimates suggest that 88% of that burden is attributable to unsafe drinking-water supply, poor sanitation and hygiene practice and is mostly concentrated on children in developing countries (Haseena et al. 2017). That is why, the contamination of drinking-water by pathogens causing diarrheal disease is the most important aspect of drinking water quality assessment (Levy 2015).

Although the World Health Organization (WHO) water safety plan is stressed in order to develop better approaches designed to meet the requirements of safe drinking-water supply for all manhood, still water that looks suitable for drinking may be contaminated with pathogens that may cause serious health problems in the third world countries(Schriks et al. 2010). This could be due to many known and unknown determinant factors that affect drinking-water quality. Clean and suitable drinking-water is a key element to enhance human health. However, obtaining safe and adequate water is limited in many developing countries. Besides, treated drinking-water are often contaminated at storages and point of use with contaminants and consumption of unclean water poses a great public health problem. Like many developing countries, Ethiopia has lack of safe and quality drinking-water, poor sanitation and hygienic practices. Even if access to quality drinking-water and good sanitation and hygiene are crucial factors of preventable diseases in developing countries like Ethiopia, a study conducted by Water.org stated that, only 42 and 11% of Ethiopians have access to a clean water supply and adequate sanitation services, respectively (Girmay et al. 2020a). The food outlets of Addis Ababa have not safe drinking-water, sanitation and hygiene practices. Consequently, they are supposed to be main sources of waterborne diseases. Therefore, this study aimed to assess the determinants of drinking-water quality and sanitary risk levels of water storages in food establishments of Addis Ababa, Ethiopia.

## Methods

### Study Area

The study was conducted in Addis Ababa city Administration, the capital city of the Federal Democratic Republic Government of Ethiopia and the seat for the African Union(Girmay et al. 2020b). 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 rating with one or more star. However, the majority 1,046 (92%) are small food

establishments which includes like non-star rating hotels, bar and restaurants, cafe and restaurants, restaurants etc. The Government provides safe water supply to the food outlets. However, this supply is inadequate and frequently interrupted as compared to the needs of the food establishments. The location map of Addis Ababa city is shown below in Fig. 1.

### Study Design

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

### Source Population

All food outlets located in Addis Ababa city administration.

### Study Population

All selected food outlets located in the study area.

### Inclusion Criteria

All food outlets that have provided service to the clients of the city were the inclusion criteria.

### 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 unmatched cohort and cross sectional study formula (EPI INFO version 7.2.2.6, STATCALC); through considering, 95% confidence interval, 80% power, 1:1 ratio and 15.9% occurrence of salmonella (outcome in unexposed group), based on a study result done in treated, stored and drinking water in Nauru 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 none response rate, the final sample of food outlets were equal to 125.

### Sampling Procedure

The food outlets were selected using a stratified, simple random sampling technique. Sampling frame or a listing of the 1141 licensed food establishments was obtained from Addis Ababa Food, Medicine Health Care Administration and Control Authority (AAFMHACA). These food outlets were stratified in to slum and non-slum areas based on their location. Moreover, they were also divided into large and small food outlets. Then, sample allocation was done to the slum and non-slum areas in addition to the large and small food outlets. 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. Besides, from the slum area (74), 3 samples from the large and 71 samples from the small food outlets were included. Entirely, 10 samples from the large and 115 samples from the small food outlets were included to the study. Finally, using a simple

random sampling technique, 125 drinking-water samples (250 ml from each) were collected directly from the food outlets drinking-water storages. The sampling procedure of the study is depicted in Fig. 2 as follows:

### Data Collection Procedures

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

### Data Analysis

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

### Bacteriological analysis

Membrane filtration method was used for bacteriological analysis of the drinking-water. 100ml of water samples were filtered using membrane filters using 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 EMB agars (Himedia) and incubated at 44.5 °C for 24 hours for isolation of fecal coliforms. To approve positive samples whether they were fecal coliform or not, they were re-inoculated into peptone broth test tubes for 24 hr at 44.5 °C. After this, drops of Kovac's reagent were added to the re-incubated peptone broth test tubes. Lastly, test tubes which indicated 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 is 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 standardized observational checklist. Depend on this, drinking–water storages who scored 0–2 low risk, 3–5 medium risk,6–8 high risk and 9–10 were considered as very high risk.

### **Food outlets/establishments**

Institutions that provide food and drinks for selling to customers.

## **Large 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.

Study Variables

## **A/ Predictor variable of the study**

The independent variables of this study were type of food outlets, presence of license, source of drinking-water, presence of continuous piped water, type of storage, availability of functional hand washing, presence of any drinking-water treatment etc.

## **B/ Outcome variable of the study:**

The response variable of this study is bacteriological quality of drinking-water (Fecal coliforms).

## **Results**

Laboratory results of bacteriological drinking-water quality

In the presumptive laboratory test, 45 (36.6%) of the samples had fecal coliforms though the majority 78 (63.4%) of the samples were found to be safe. Besides, in the confirmatory test, nearly three-fourth, 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 were found to be 8.20. (Table 1).

Table 1

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

<b>Fecal coliforms Cfu/100 ml) at 44.5 °C</b>		<b>Frequency</b>	<b>Percent</b>	<b>WHO standard in number of fecal coliforms (n)</b>
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	

#### Determinant factors of bacteriological water quality

Of the assessed food establishments, 76(61.8%) of them had legal license by the authorized body of Food, Medicine, Health Care administration and Control Authority. The majority, (78%) of the food outlets' primary source of drinking-water was municipal. However, the rest (22%) of the food establishments drinking-water sources were spring, ground and others. Of all food establishments, only 46 (37.4%) of them had received continuous piped water. But, above half (62.6%) of the food establishments had received intermittent water supply. Regarding type of drinking-water storage used, 39 (31.7%) of the food outlets were used rough and untidy drinking-water storage/containers. In this study, 42 (34.1%) of the food outlets' drinking-water storage had not a lid/cover in place at the time of visit. Besides, 42 (34.1%) of the food establishments had dipping practice to draw the drinking-water from their storage or containers. From the assessed food outlets, 72(58.5%) of them had any method of drinking-water treatment at the food establishments level like filtration, chlorination and others. However, 45(36.6%) of the food establishments had not standardized and functional hand washing facility with soap near the toilet (Table 2).

Table 2

Determinant factors of bacteriological water quality in food establishments of Addis Ababa, Ethiopia (n = 123)

Study variables	Category /Item	Frequency	Percent (%)
Having legal license by FMHACA	Yes	76	61.8
	No	47	38.2
Primary source of drinking-water for the food establishments	Municipality	96	78
	Spring, ground and others water sources	27	22
Having continuous piped water in the food establishments	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

#### 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%) of them had low and medium contamination risk level respectively. However, 20 (16.3%) and 23(18.7%) of them had high and very high contamination risk level respectively (Table 3).

Table 3  
Contamination risk levels of the drinking-water storage of the food establishments, in Addis Ababa, Ethiopia(n = 123)

Sanitation risk scores	Frequency	Percent	Risk category
0-2	68	55.3	Low
3-5	12	9.8	Medium
6-8	20	16.3	High
9-10	23	18.7	Very high

Multivariate logistic regression analysis of fecal coliforms with selected explanatory variables

In the binary logistic regression analysis, eight (8) 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 (7) explanatory variables like type of primary source of drinking-water for the food outlets, having continuous piped water 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 drinking-water drawn from the water storages, presence of any method of drinking-water treatment at the food establishments level, food establishments having functional hand washing facility with soap near the toilet were significantly associated (p-value < 0.03) with drinking-water contamination (Table 4).

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	.015	0.00	0.99	1.02(0.17–6.27)
	No	19	28				Reference
Primary source of drinking-water for the food outlets	Municipal	20	76	-4.10	8.63	0.003	0.017(.001-.26)
	Spring and others	15	12				Reference
Having continuous piped water in the food establishments	Yes	3	43	-3.29	5.54	0.019	0.04(.002-.58)
	No	32	45				Reference
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)
	Easily cleanable	16	68				Reference
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(.001-.19)
	No	27	15				Reference
Method of drinking-water drawn from the water storages	Dipping	26	16	1.93	4.69	0.030	6.9(1.20-39.63)
	Pouring	9	72				Reference
Any method of drinking-water treatment at the food establishments level	Yes	12	60	-2.39	5.64	0.018	0.092(.013-.66)
	No	23	28				Reference
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)
	Yes	12	66				Reference

## 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 municipal. 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 as a core factor for the presence of the contamination. Though 28.5% of the drinking-water storages had fecal coliforms, this finding is consistent with a study done in Gondar, Ethiopia (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 the 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 call attention and action to prevent risk of drinking-water contamination. Moreover, 16.3% and 18.7% of food establishments drinking-water had high and very high contamination risk levels respectively. This indicated that, the food establishments' drinking-water calls higher action priority and urgent action required respectively. Besides, this finding revealed that, a significant number of the food establishments' drinking-water storage lacks good sanitation and safety practices. The finding 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 who had municipal sources of water were 1.7% less likely to have fecal coliforms in the drinking-water storage (AOR = 0.017 with 95%CI: 0.001–0.26) than those who had spring water, ground water and other sources. As expected, this could be due to effective treatment of the water supply by the Government. On the other hand, this indicated that, spring water, ground water and other sources of drinking-water had high bacteriological contamination level than the municipal. Similarly, the odds of food establishments who had continuous and uninterrupted piped water were 4% less likely to have fecal coliforms in their drinking-water storage (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 proliferation of drinking-water contaminates in the drinking-water storages. Moreover, this idea was supported by a study done by Brocklehurst et al: which states that there was a significant relationship between interruptions in the piped water supply and presence of fecal coliforms, as well as with cases of different diarrheal diseases (Brocklehurst and Slaymaker 2015).

The finding of this study showed that, the odds of food outlets who had rough and untidy drinking-water storage equipment were 15.16 times higher to have fecal coliforms (AOR = 15.16 with 95%CI: 1.68-137.14) than those who 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 indicated and imposed health risks to customers as a result of the contaminated drinking-water. Moreover, the odds of food establishments who had drawn out drinking-water through dipping were 6.9 times higher to have fecal coliforms (AOR = 6.9 with 95%CI:1.20-39.63) than those who used pouring to taken out drinking-water from the storages. This might be due to the presence of cross-contamination between unhygienic hand contact with the water holding equipment that used to drawn water. But, this needs further researches as most of Ethiopian have a practice of dipping to drawn out drinking-water from the storages. However, the odds of food outlets who had drinking-water storage with a lid or cover in place at the time of visit were 1.6% less likely to have fecal coliforms (AOR = 0.016 with 95%CI: 0.001–0.19) than those who had not. As expected, the presence of a cover or a lid to water storage can prevent different

risk factors and water contamination. Likewise, food outlets who had 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 who had not. This indicated that, different water treatment technologies had great effect to safeguard and to improve the water quality and to reduce water contamination. Conversely, the odds of food establishments who had not functional handwashing facility with soap near the toilet were 14.35 times higher 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, presence of handwashing facility with soap near toilet had a direct effect on human health and indirect effect with water contamination in drinking-water storages. But, this needs further research 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. In the study, many determinant factors that affect drinking-water quality of food outlets were identified. Large number of food establishments' drinking-water storages had high and very high contamination risk levels. Therefore, good sanitation and hygiene practice should be done and promoted at the food establishments. Besides creation of awareness about drinking-water contamination and its health risks should be done by concerned bodies. Moreover, continuous drinking-water monitoring and evaluation should be done by the Government.

### Limitation

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

## Abbreviations

AAFMHACA-Addis Ababa Food, Medicine Health Care Administration and Control Authority

AOR-Adjusted Odd Ratio

CFU-Colony Forming Unit

CI-Confidence Interval

EBM-Eosine Methylene Blue

USA-United State America

WHO-World Health Organization

## Declarations

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

Consent for participation: Written consent was obtained from the food establishment owners.

Consent for publication: None

Competing interests: We the authors declare that we have no competing interest

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Availability of data and materials: All relevant data including dataset are included as supplementary information.

Authors Contributions: AMG contributed to funding acquisition and writing the original draft. All the authors contributed in conceptualization, methodology, investigation, data collection and analysis, reviewed, edited and approved.

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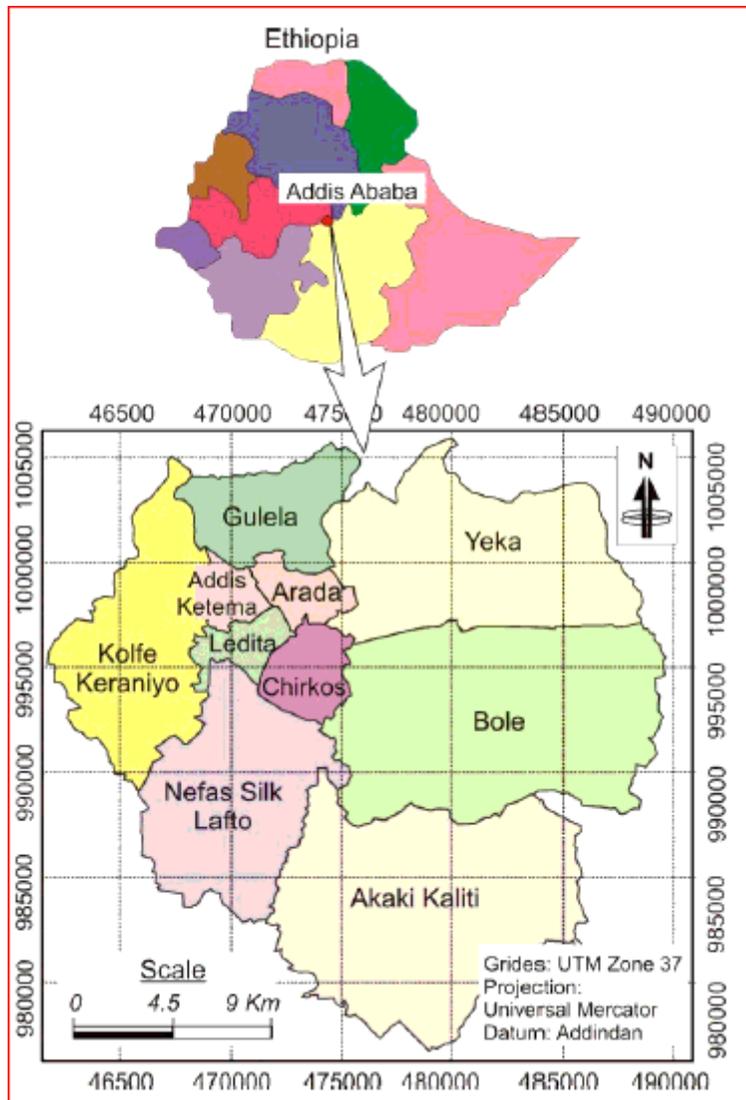
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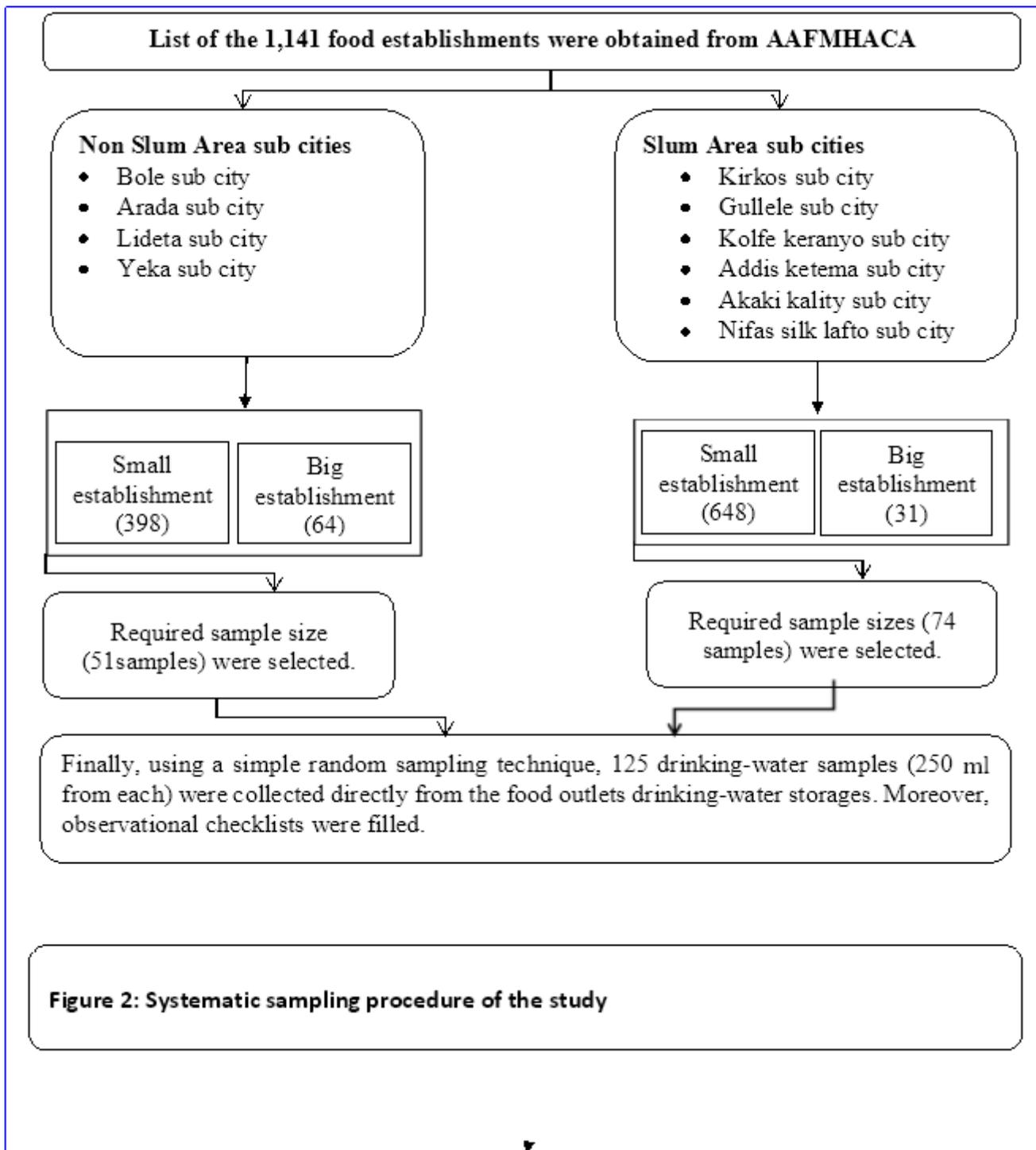
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# Figures



**Figure 1**

Map of Addis Ababa city administration. Source:(Girmay et al. 2020d).



**Figure 2: Systematic sampling procedure of the study**

**Figure 2**

Systematic sampling procedure of the study

## Supplementary Files

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