ESJ Natural/Life/Medical Sciences

Detection Of Fecal Coliforms In Water Used In Formal And Informal Food Outlets In Kasungu District, Malawi

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Doi:10.19044/esj.2021.v17n3p300

Submitted: 19 October 2020
Accepted: 15 January 2021
Published: 31 January2021

Cite As:
Chavura E., Kapute F. & Mbakaya B.C. (2021). *Detection of fecal coliforms in water used in formal and informal food outlets in Kasungu District, Malawi.* European Scientific Journal, ESJ, 17(3), 300.
https://doi.org/10.19044/esj.2021.v17n3p300

Abstract

Poor sanitary practices are common amongst many food handlers posing a health risk to consumers. Maintenance of high quality water is one of the most important aspects of ensuring consumer safety. Therefore, regular water testing is critical in public food outlets where bacterial contamination may cause outbreak of disease.

The study aimed at analyzing water samples obtained from the formal and informal food outlets for the presence of fecal coliforms that are indicative of poor sanitation that result in foodborne infections amongst consumers.

Using a cross-sectional design, water samples from participating food outlets (N=40) were analyzed using the membrane filtration method. Samples were filtered, under vacuum, through a cellulose acetate membrane of 0.45 µm pore size.

Fecal coliforms exceeding permissible range were detected in 15 test samples (N=40). The median (IQR) concentrations of fecal coliforms (FC/100ml) in dishwashing water was 1(136) and 145(340) for the formal and informal food outlets respectively. The median (IQR) for drinking water was 0(0) with a minimum and maximum range of 0 and 14 FC/100mls.

The study established a positive correlation between fecal coliforms and electrical conductivity, and total dissolved solids ($p<0.05$) in dish washing water used at both formal and informal food outlets. Contamination was attributed to lack of running water, poor pest control and unwholesome practices in many food outlets.

Based on the study findings, it is concluded that electrical conductivity, total dissolved solids and turbidity values may be used to deduce the presence of fecal coliforms in water. The study recommends that water drawn from unprotected sources must be boiled or treated at the point of use before it can be safely used in food outlets. Periodic water testing and sanitary supervisions for all food outlets must be mandatory to ensure compliance with minimum set standards.

Key Words: Fecal Coliforms, Formal Food Outlets, Informal Food Outlets

Introduction

Drinking non-potable water predisposes people to waterborne disease outbreaks and unprecedented deaths (Prabhu & Shar, 2012) yet in many instances, the opinion of water is subjected to its quantity rather than quality (Neswiswi, 2014). The risks associated with consumption of contaminated water is because of failure in securing optimal hygiene management practices at both formal and informal settings. Water quality encompasses physical, chemical and biological properties that are supposed to be in line with the required specifications (Agensi et al., 2019).

Coliform bacteria are facultatively anaerobic rod-shaped Gram-negative non-spore forming bacteria. They are mostly used as a measure of the sanitary quality of water (Leclerc, 2001). They are capable of fermenting lactose to produce acid and gas when incubated at a temperature range of between 35–37°C (Gruber, 2014). Coliform bacteria are found in large quantities in human excreta. Their presence is suggestive of other infective pathogens of fecal origin such as *E. coli* (Bandekar *et al.*, 2006; Nwachukwu and Otokunefor, 2006). Besides traditional methods of detecting coliform bacteria, water quality factors have also been used as significant predictors of fecal coliform bacteria (Seo *et al.*, 2019; Hayashi, 2004).
In many middle and low-income countries, cases of microbial contamination of water are linked to unwholesome practices, lack of water treatment at the point of use and unhygienic management of water sources (Agensi et al., 2019).

Policy Framework

Drinking water regulations involve the monitoring of bacterial, parasitic and chemical impurities that can endanger lives of consumers (Lee

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

and Kim, 2002). To this end, with good water laws and policies in place, the expectation is provision of safe and potable water to uplift the health of people.

By description, formal food outlets are duly licensed facilities that remit tax to the government. In return, they enjoy access to public services such as piped water connections and waste collection services. Informal food outlets operate from unlicensed premises. They are unregistered, unregulated and unable to access institutional support (Jongh, 2015). The sale of food from unauthorized places is a criminal offence according to the Malawi Local Government sanitation and market By-Laws of 2015 and the Malawi National Environmental policy (2010). The policy framework outlines key policy statements on environmental sanitation, water quality testing and procedures for the certification and auditing of food outlets.

In this study we aimed (1) to analyze the microbial quality of water used in formal and informal food outlets; (2) to establish correlation between fecal coliforms and determinants of water quality (Water pH, Turbidity (T), Total Dissolved Solids (TDS) and Electrical Conductivity (E.C.); and (3) to compare the level of risk of faecal contamination between the water used at formal and informal food outlets.

Materials and methods

Design, sample size and sampling technique

The study employed a cross-sectional design, using observational methods. The Municipal Chief executive provided a list of forty (40) licensed food outlets. The investigators identified eighty-six (86) informal food operations within the same locality. Using a simple random sampling technique on each cluster (formal & informal), ten (10) formal and ten (10) informal food outlets were selected. Two (2) sample types, namely dishwashing water and drinking water, were collected from the twenty (20) randomly selected food outlets making a total sample size of **(forty) (40)** from both formal and informal food outlets in the Municipality. The sample size justification was based on the water quality studies by WHO (2008), that recommend testing as a minimum, 30% of households or locations in small projects of less than 500 households. See Table 1 showing recommended sample sizes according to WHO, (2008).

Table 1. Recommended sample sizes for water projects

Project size	Sample size
500	41-85
1,000	43-91
2,000	43-95
3,000	44-97
4,000-6,000	44-98
7,000-15,000	44-99

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

>20,000	44-100

Source: WHO, (2008).

Study site

The study was conducted in the municipality of Kasungu District in Central Malawi between April to July, 2019. The district has a population of 735,836 and is bordered by Zambia to the West, Mchinji district to the Southwest, Dowa and Lilongwe districts to the South, Ntchisi and Nkhotakota districts to the East, and Mzimba District to the North. (See Figure 1) Kasungu Manucipality is on grid reference 33o 30' east and 13o 03' south and about 127 kilometers North of Lilongwe, the capital city of Malawi. It is along the M1 Road running from Lilongwe to Mzuzu (Kasungu Urban socio-economic profile, 1998). The municipality is supplied with piped water by Central Region Water Board (CRWB).

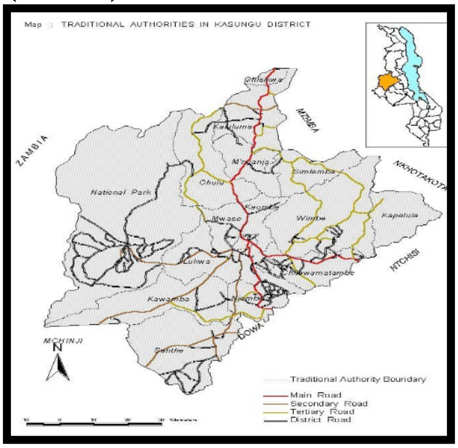

Figure 1. Map of Kasungu district (Source: Urban socio-economic profile, 1998)

Ethics

Ethical approval to conduct the study was obtained from National Council of Science and Technology (NCST), with approval number **NCST/RTT/2/6.** Clearance was obtained from the Chief Executive of Kasungu Municipal Council and food outlets managers. Written informed consent was obtained from food outlet managers in order to get permission to collect water samples and to inspect their premises.

Data collection and study instruments

Samples were collected by a public health graduate with expertise in water and sanitation. Samples for Measurement of pH, Total dissolved solids, and Turbidity were tested on site using a lab Force TS- PH200 portable pH meter, a digital TDS tester meter electrode (HM Digital TDS-4), and a battery-operated digital turbidity meter (model number WGZ- 20) respectively. For

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thermo tolerant (faecal) coliforms, samples were transported on ice in a cooler box at a temperature below 10° C to CRWB lab in Kasungu within 30 minutes from the last sample collection point. Samples were incubated at 44.5° C for 24 hours using a portable Millipore bacterial incubator.
The following checklist and observational methods were used to collect data:

Sanitary inspection and risk score for the food premises

Intrinsic bias was eliminated by the application of two data collection methods (sanitary inspection and sample testing) to facilitate reliability and validity. Sanitary inspection was done in order to identify the possible sources of faecal contamination.

The sanitary inspection checklist was designed based on standards and guidelines drawn by city/ municipal councils, The Malawi Bureau of Standards (MBS), Malawi National Environmental Health, and Sanitation policy. This checklist was used to inspect water storage areas, assess employee hygiene, as well as facility design. The sanitary checklist had 10 hazard statements designed to capture the most likely sources of water contamination such as availability of running water, pest control, use of protective wear/ uniforms etc. See Table 2 below:

Table 2. The sanitary inspection tool for the food outlets

	Hazard	**Formal**		**Informal**	
		Yes	No	Yes	No
1	Does facility have running water?	9	1	0	10
2	Is the quantity of water that you receive from your main source of water adequate?	9	1	0	10
3	Is water reserved for drinking safely covered?(tight lid cover)	8	2	6	4
4	Is the water treated at source point?	9	1	3	7
5	Are refuse bins having tight-fitting lids, kept at a distance from the kitchen and emptied regularly?	8	2	0	10
6	Is staff trained in basic food hygiene practices?	3	7	0	10
7	Are food handlers provided with uniforms, caps, aprons and hair nets?	5	5	0	10
8	Is jewelry limited to a plain ring, such as a wedding band, and no bracelets?	6	4	4	6
9	Is there a procedure for referring sick employees for a prompt medical opinion on fitness for work?	2	8	0	10
10	Are kitchen storage areas regularly checked for pest infestations (mice, insects, etc.)?	2	8	0	10
	Total	61	39	13	87

Field testing procedure

Using a membrane filtration method, a volume of 100mls of water sample was filtered, under vacuum, through a cellulose acetate membrane of 0.45 μm pore size. The sampling bottles were labeled with sample reference number, site, date and time and were incubated for 24 hours at a temperature of 44.5 °C.

Data analysis

Data was collected using a checklist and entered into an excel sheet, cleaned and sorted. Thereafter, Statistical Package for Social Sciences (SPSS) version 20 was used to analyze the data. For descriptive statistics, the Median with an associated Interquartile Range (IQR) was used and the Wilcoxon Rank Sum statistical test was employed to determine systematic differences in the risk of faecal coliform contamination between formal and informal food outlets and the level of contamination between drinking water and dishwashing water. The relationship between faecal coliforms and other determinants of water quality were compared using Spearmans Rho because

	Drinking Water						Dish Washing					
	Formal			Informal			Formal			Informal		
Parameter	Median(IQR)	Min	Max	Median(IQR)	Min	Max	Median(IQR)	Min	Max	Median(IQR)	Min	Max
FC/100mls	0(0)	0	14	0(0)	0	96	1(136)	0	450	145(340)	0	680
pH	7.6(0.18)	7.46	7.8	7.7(0.11)	7.58	7.93	7.62(0.22)	6.94	7.93	7.66(0.26)	7.01	7.89
EC	175(2)	167	181	178.5(5)	163	182	178(6)	76	1094	182(7)	177	991
TDS	104.5(2)	100	107	107.5(3)	98	109	107(4)	45	657	109.5(4)	106	598
T	1.6(0.72)	0.68	135	1.88(1.23)	0.59	6.78	1.42(2.22)	0.59	8.58	4.95(12.56)	1.98	460

available data was not normally distributed. We used a checklist for sanitary inspection to ascertain possible sources of water contamination at food outlets.

Results

Water quality refers to the chemical, physical, biological and radiological characteristics of water relative to the requirements of any human need. Water is a critical raw material in many food establishments; and contaminated water can become a public health risk when it is used for activities such as drinking, washing of foods, incorporated as a food ingredient, or for washing utensils and hands. All food outlets (formal and informal) used piped water as their primary source of drinking water. However, when piped water could not be accessed, people drew water from alternative sources within their reach. Water quality testing gave us a snapshot of the quality of water that was found in use at the time of the study.

A summary of the questions in the checklist is tabulated as in Table 6

Objective 1: In this study, we aimed to analyze the quality of water used in formal and informal food outlets. The following is the results table (Table 3).

Table 3: Analysis of water quality parameters

ISSN: 1857-7881 (Print) e - ISSN 1857-7431

To establish strength of association between fecal coliforms and determinants of water quality (Water pH, Turbidity (T), Total Dissolved Solids (TDS) and Electrical Conductivity (E.C.); the results table 4 below shows a positive correlation between FC and other determinants of water quality.

Objective 2: To establish correlation between fecal coliforms and determinants of water quality (Water pH, Turbidity (T), Total Dissolved

	Drinking Water									Dishwashing Water								
	formal			Informal			overall			formal			Informal			overall		
Param	N	Rho	P-val	N	Rho	P-val	N	Rho	P-val	N	Rho	P-val	N	Rho	P-val	N	Rho	P-val
PH	10	0.52	0.120	10	0.53	0.117	20	0.55	0.012	10	-0.23	0.530	10	0.23	0.516	20	0.05	0.811
EC	10	0.53	0.116	10	-0.26	0.474	20	0.06	0.815	10	0.65	0.043	10	0.74	0.014	20	0.70	<0.001
TDS	10	0.47	0.168	10	-0.21	0.558	20	0.02	0.934	10	0.76	0.011	10	0.77	0.001	20	0.76	<0.001
T	10	0.41	0.242	10	-0.14	0.703	20	0.07	0.780	10	0.76	0.011	10	0.37	0.287	20	0.60	0.005

Solids (TDS) and Electrical Conductivity (E.C.) using Spearman's correlation.

Table 4. Correlation between fecal coliforms and determinants of water quality

The study also sought to compare the level of risk of faecal contamination between the water used at formal and informal food outlets; and the extent to which drinking water differed with dishwashing water in terms of FC contamination. Basically, for both drinking water and dishwashing water, the sum of ranks for Informal outlets was higher than that of formal outlets but the difference was not statistically significant. See results Table 5.

Objective 3: To compare the level of risk of faecal contamination between the water used at formal and informal food outlets.

Table 5. A comparison table between formal and informal food outlets

	Drinking Water			Dishwashing Water		
Classification	**N**	**Sum of Ranks**	**P-value**	**N**	**Sum of Ranks**	**P-value**
Formal	10	99	0.466^{NS}	10	90	0.241^{NS}
Informal	10	111		10	120	

- **Method used**: Mann-Whitney U test (Non Parametric test)
- **NS**: Not statistically significant

Discussion

Water is an essential resource in food outlets. Using water of potable quality is the safest option in food outlets; however, access to exclusive potable water requirements may not always be feasible and practical due to intermittent supply outages of the commodity. This prompts food workers to

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

fetch water from unprotected water sources thereby risking consumers to waterborne infections.

Formal food outlets

Using the sanitary inspection tool in figure 3, Formal food outlets enjoyed better sanitary services such as running water, and waste collection services by municipal authorities. However, food handlers working therein were not trained in basic food hygiene. There was no proper mechanism of handling sick food handlers and about when they would return to work after recovery. Their kitchens and storage areas were not regularly checked for pest control. This increased the risk of water contamination at these premises. Only one (1) single food outlet at the formal section served water to consumers that had a higher level of faecal coliforms of up to 14 FC/100mls that exceeded WHO (2008) and the MBS MS: 214 (2013) permissible range of 0 FC/100mls in any water intended for drinking (see Table 6). None compliance to expected standards can put the lives of consumers at risk. The median (IQR) for drinking water at this section was 0(0) with a minimum and maximum range of 0 and 14 FC/100mls.

For dishwashing water, the quality was severely compromised. High levels of faecal coliforms were detected in this type of water and at several outlets. Better sanitary services provided by the municipal council here did not translate into desired outcome as evidenced by the detection of large quantities of faecal coliforms with a median (IQR) of 1(136) and a minimum and maximum range of 0 and 450 FC/100mls respectively. These findings are consistent with Asogwa *et al.* (2015) and Marobhe and Sabai (2016) who detected high bacterial counts from dishwashing water that was used by food handlers as it was not regularly replaced with fresh water - a practice they attributed to lack of food hygiene training.

Informal food outlets

The informal food outlets operated without fulfilling minimum set standards. They lacked basic infrastructure and sanitary services thereby increasing the perception that water they served to consumers was potentially harmful to human health. The Malawi National Environmental Health Policy, (2010) advocates for improved water quality, sanitation, and hygiene at public and business institutions. Clause 5.4.1.3.2 of the Malawi Bureau of Standards (MBS) states non-potable water may be used with the acceptance of the MBS for steam production, firefighting, and other similar purposes not connected with food. See table 6 for drinking water standards

Table 6. Drinking Water Standards

Parameter	**Normal value**

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Fecal coliforms	0 FC/100mls
pH	6.5- 8.5
TDS	≤500 mg/l
EC	≤400 µS/cm
T	<1 NTU

Source: WHO, 2008

Drinking water sampled at the informal section was contaminated because of unwholesome food handling practices. Workers performed their duties entirely in their street clothes and lacked basic food hygiene education. Lack of running water ranked so high amongst all informal food outlets basing on the checklist on sanitary inspection. Besides this, the water they used was in insufficient quantities, which compromised hygiene standards. The median (IQR) for drinking water at this section was 0(0) with a minimum and maximum range of 0 and 96 FC/100mls respectively. Despite many challenges consistent with the informal food outlets, water for drinking was safely stored in containers with a lid cover.

As for dishwashing water, the informal section registered unprecedented FC count. The median (IQR) was as high as 145(340) with a minimum and maximum range of 0 and 680 FC/100mls respectively. The usage of such quality of water is unacceptable and demonstrates the highest level of deception and complete lack of integrity in food business which has been going on unchecked. A similar study (Musa and Akande, 2003) recommended strict measures in checking compliance to good hygiene practices amongst informal food handlers because their findings revealed unwholesome practices such as recycling of dirty water, lack of soap, and use of limited utensils. Multiple lines of evidence indicate that water is contaminated by pathogenic bacteria due to poor hygiene practices (Muzaffar *et al.*, 2009; Hanashiro *et al.*, 2005; Kruy *et al.*, 2001) which expose many consumers to risk of waterborne diseases.

Correlation of FC with other determinants of water quality

A positive correlation was noted between FC and EC, TDS and T. ($p<0.05$) in dish washing water used at both formal and informal food outlets. The findings are consistent with an earlier study (Busse and Hefeker, 2007) that confirmed a positive correlation between turbidity and faecal coliforms. Armah (2014) and Nura and Hamzaraj (2016) concluded that pH, electrical conductivity, total dissolved solids, and turbidity were significant predictors of total coliform bacteria in water. Although all other determinants of water quality are in agreement with the studies mentioned above, this study however, failed to prove the relationship between pH and FC. This could be attributed to a smaller sample size that was used. Considering the findings of this study,

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

on the correlation between faecal coliforms and other determinants of water quality, it is concluded that EC, TDS and T values may be used to deduce the presence of faecal coliforms in water.

Comparative analysis of the level of risk of fecal contamination

The study also sought to compare the level of risk of faecal contamination between the water used at formal and informal food outlets; and the extent to which drinking water differed with dishwashing water in terms of FC contamination.

Formal and informal food outlets

Formal food outlets in this study failed to live up to consumer expectation. They demonstrated laxity in quality assurance for use of polluted water for cleaning dishes just as other counterparts in the informal section. This is despite having running water at their premises. Wilcoxon-Mann-Whitney U test *p*- values of 0.466 and 0.241 between formal and informal food outlets respectively were statistically insignificant. We aimed to determine whether there is a difference in the risk of contamination between formal and informal outlets based on the median scores of drinking water as well as dishwashing water quality used at these types of food outlets. A 2010 U.S. Environmental Protection Agency (EPA) study found fecal contamination in nearly half of surveyed water dispensers in Virginia restaurants. In the city of Dhaka, a study (Faruk and Akhter, 2012) detected faecal coliforms in 84% of water samples meant for consumers in restaurants and fast food shops.

Limitations of the study

The study focused on food outlets within the municipal central business market. Peripheral food outlets were not included in the study due to resource limitations as such, the sample size was smaller than previously desired which could trigger type 2 errors, thereby decreasing inference and the statistical power of the study. Secondly, potable water quality defined by levels of fecal coliforms alone is not enough for ascertainment of safe water use in food outlets as it is not considered an appropriate surrogate for the diversity of bacteria, viruses and parasites that may be present in water.

Conclusion

Findings of this study concluded there was evidence of fecal contamination of water used in the food outlets in the study area. Contaminated water was used for many activities such as dish washing, washing of food stuffs and served to consumers for drinking. Findings also showed that some determinants of water quality such as turbidity and total dissolved solids were so predictive of faecal contamination. Although formal food outlets had better sanitary conditions than the informal ones, the study

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

did not establish any significant differences in terms of microbial quality. The study observed that poor microbial quality of water was in use in some food outlets in the informal section. The study recommends a robust sensitization campaign on the various methods of in-house water treatment to all food handlers. Under the same observation, the municipal town authority must conduct periodic ascertainment of water quality in food outlets as a strategy to improve the microbial quality. Based on the correlation findings between fecal coliforms and other determinants of water quality, it is concluded that EC, TDS and T values may be used to deduce the presence of faecal coliforms in water. The risk of contamination was the same regardless of type of food outlet. We therefore recommend that issuance and renewal of food business licensing must be effected subject to fulfilling minimum acceptable hygiene and food safety standards.

We propose that future studies (1) should consider bench-marking water at the very source point before the distribution terminal; (2) and a larger sample size to reduce the margin of error.

Appendix

Table 6. Water quality data for drinking and dish washing (N=40)

Sample code	Source	Coordinates		Sample type	Classification	FC/100mls	pH	EC	TDS	Turbidity
1	s2	552820	8557230	Drinking Water	Formal	0	7.46	167	100	1.38
2				Dishwashing water		220	7.93	177	107	3.24
3	s3	551914	8557614	Drinking Water	Formal	0	7.63	175	104	1.6
4				Dishwashing Water		2	7.64	181	108	1.02
5	s4	551892	8557672	Drinking water	Formal	0	7.63	175	104	1.6
6				Dishwashing Water		0	7.63	175	104	1.6
7	s5	552042	8557740	Drinking Water	Formal	0	7.68	178	107	1.58
8				Dishwashing Water		0	7.76	174	104	1.36
9	s6	552047	8557750	Drinking Water	Formal	0	7.48	176	106	135
10				Dishwashing Water		120	7.5	178	107	1.47
11	s7	552018	8558158	Drinking Water	Formal	0	7.56	173	104	1.2
12				Dishwashing Water		0	7.47	178	107	1.26
13	s8	551999	8558198	Drinking Water	Formal	14	7.8	181	107	2.37

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

14				Dishwashing Water		450	6.94	1094	657	8.58
15	s9	552011	8558164	Drinking Water	Informal	0	7.93	182	108	1.59
16				Dishwashing Water		620	7.1	991	598	15.8
17	s10	552020	8558446	Drinking Water	Informal	0	7.58	176	105	1.69
18				Dishwashing Water		340	7.62	184	110	3.24
19	s11	552026	8558448	Drinking Water	Informal	0	7.61	182	109	6.78
20				Dishwashing Water		0	7.55	178	106	3.97
21	s12	552029	8558438	Drinking Water	Informal	0	7.71	179	108	3.83
22				Dishwashing Water		0	7.7	180	109	5.93
23	s13	552034	8558430	Drinking Water	Informal	40	7.75	163	98	2.47
24				Dishwashing Water		680	7.78	706	423	460
25	s14	551923	8558384	Drinking Water	Informal	0	7.64	178	107	2.06
26				Dishwashing Water		0	7.56	177	106	1.98
27	s15	551934	8558396	Drinking Water	Informal	96	7.85	179	108	0.71
28				Dishwashing Water		220	7.89	178	107	3.36
29	s16	551931	8558400	Drinking Water	Informal	0	7.66	175	105	1.24
30				Dishwashing Water		180	7.81	184	111	2.09
31	s17	551945	8558416	Drinking Water	Informal	0	7.69	177	106	2.37
32				Dishwashing Water		110	7.81	185	111	21.3
33	s18	551950	8558472	Drinking Water	Informal	0	7.73	181	109	0.59
34				Dishwashing Water		88	7.01	178	107	14.4
35	s19	552202	8558582	Drinking Water	Formal	0	7.67	177	106	2.1
36				Dishwashing Water		136	7.55	184	110	4.35
37	s21	551756	8558194	Drinking Water	Formal	0	7.49	175	105	0.68
38				Dishwashing Water		0	7.72	76	45	0.59

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

39	s22	551903	8558050	Drinking Water	Formal	0	7.53	172	103	1.81
40				Dishwashing Water		0	7.61	178	107	1.01

Figure 2. Garbage bin without a lid cover in kitchen at an informal food outlet (Photo: E. Chavura)

Figure 3. Visibly dirty water used for dish washing at a food outlet (Photo: E. Chavura

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