Research Paper

Point-of-use water chlorination among urban and rural households with under-five-year children: a comparative study in Kersa Health and Demographic Surveillance Site, Eastern Ethiopia

Abraham Geremew, Bezatu Mengistie, Esayas Alemayehu, Daniele Susan Lantagne, Jonathan Mellor and Geremew Sahilu

ABSTRACT

Point-of-use water chlorination is one of the most effective means to prevent diarrhea in under-five children although challenges remain in its adoption and effective use. In Ethiopia, evidence of point-of-use water chlorination among households with under-five children in rural and urban settings that is verified with water testing is scarce. A comparative cross-sectional study was conducted among urban and rural households with under-five child in Kersa Health and Demographic Surveillance Site, Eastern Ethiopia from June to August, 2016. Data were collected from a caregiver of systematically selected households and analyzed using multivariable logistic regression. A total of 1,912 households were included in the analysis with a 96.5% response rate. In rural areas, 4.6% of caregivers were reportedly chlorinating water at point-of-use and 1.2% were confirmed with free residual chlorine. In urban areas, 17.1% of caregivers were reportedly chlorinating water and 6.6% were confirmed to have free residual chlorine. In two settings, caregivers' point-of-use water chlorination was associated with chlorine taste and water quality perception. Inaccessibility to treatment products in rural areas and use of bottled water in urban areas were among the reasons to discontinue point-of-use water chlorination. Behavior changing interventions with proper distribution and marketing is needed for sustainable point-of-use chlorination.

Key words | caregivers, point-of-use, rural, urban, water chlorination

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INTRODUCTION

Provision of improved water and sanitation are effective methods to minimize diarrheal diseases, which cause 842,000 deaths every year, of which 90% are children under the age of five (Prüss-Ustün *et al.* 2014). However, 663 million people globally are still using water from unimproved sources (WHO/UNICEF 2015). Furthermore, the potential for recontamination during collection, transport, and storage is reported as a challenge (Clasen & Bastable 2003).

Point-of-use water chlorination, using Waterguard®, Aquatabs or chlorine-flocculants treatment combination (PUR™), is among the recommended means to improve drinking water quality and reduce diarrhea incidence (Lantagne *et al.* 2006; Clasen *et al.* 2007; Mengistie *et al.* 2013a). However, demand for and utilization of the treatment options remain a challenge due to contextual, psychosocial, and technology-related factors (Dreibelbis *et al.* 2013).

doi: 10.2166/washdev.2018.173

In Ethiopia, for more than a decade, the Health Extension Program (HEP) has sought to increase household safe water practices for those households with unimproved water sources including point-of-use treatment (Bilal *et al.* 2011). In addition, the Ethiopian government advocates different point-of-use water treatment options including chlorine-based products such as Waterguard (local name Wuha Agar), Bishan Gari, PUR™ and Aquatabs (FMOH 2013; MoWIE 2014). The government is engaged in advocating healthy practices including demand creation regarding safe handling of water and point-of-use treatment via an innovative HEP (FMOH 2007; Workie & Ramana 2013). More importantly, the government is working with organizations like UNICEF, PSI, PATH, South Pole, and World Vision, as well as the private sector, to facilitate partnerships and effective implementation (FMOH 2013). Despite these efforts, national level statistics indicate that only 6.1% of households in urban areas and 2.5% in rural areas chlorinate their water (CSA & ICF 2016).

Household adoption and consistent use of point-of-use water chlorination options in rural and urban areas of Ethiopia can vary significantly (CSA & ICF 2016). However, these data are from self-reported behaviors. Evidence based on water testing at the household level about how the treatment options are adopted and used in the two settings has, to our knowledge, not been explored in Ethiopia. Moreover, study findings show that diarrhea associated with water and sanitation is a common health problem in children under five (Mengistie *et al.* 2013b; Hashi *et al.* 2016; Anteneh *et al.* 2017). However, to our knowledge, no investigation has been conducted on caregivers' point-of-use water chlorination for the prevention of diarrhea in this age group in rural and urban areas of the country. Therefore, this study is intended to investigate point-of-use water chlorination and associated factors in both rural and urban settings to better understand how sustainability can be assured in each location.

METHODS

Study area and period

The study was conducted in Kersa Health and Demographic Surveillance Site (KHDSS) located in Eastern Ethiopia (Figure 1). The surveillance site was selected by Haramaya University in 2007 to serve as one of the six Demographic Surveillance Sites in the country (Assefa *et al.* 2016). The surveillance site contains 36 Kebeles (the smallest administrative unit in the country). Twelve urban Kebeles are found in Harari regional state which is 526 km from the nation's capital, Addis Ababa. Similarly, 24 Kebeles (21 rural and 3 semi-urban) are found in Kersa Woreda, East Hararghe zone in Oromia region which is 482 km from Addis Ababa. Data were collected from 35 Kebeles from June to August, 2016.

Study design

A quantitative comparative cross-sectional study design was used to assess point-of-use water chlorination practices in two population groups (urban and rural households) with an under-five-year-old child.

Sample size determination and sampling technique

EPI INFO ™7, a series of microcomputer programs for word processing, data management, and epidemiological analysis (CDC Epi Info™ 7. 2010), was used to calculate the sample size using the double population formula. The sample size was calculated using the national reports of 9.2% of households in urban and 4.9% of households in rural areas chlorinating their water at point-of-use (CSA & ICFI 2011). Consequently, 991 households per study population (urban and rural) were included by considering the ratio of 1:1, non-response rate of 10% and a design effect of 1.5. The sample was first categorized into urban and rural, and proportionally allocated to each of the 35 Kebeles. Households were selected using a systematic random sampling technique using their identification code obtained from the surveillance site. Prior to household selection, all households with an under-five-year-old child in each Kebele were obtained from the surveillance site and listed sequentially. The interval 'K' for each Kebele was then calculated. Finally, the first household was selected randomly and then every 'K' interval household was selected until the last sample was obtained.

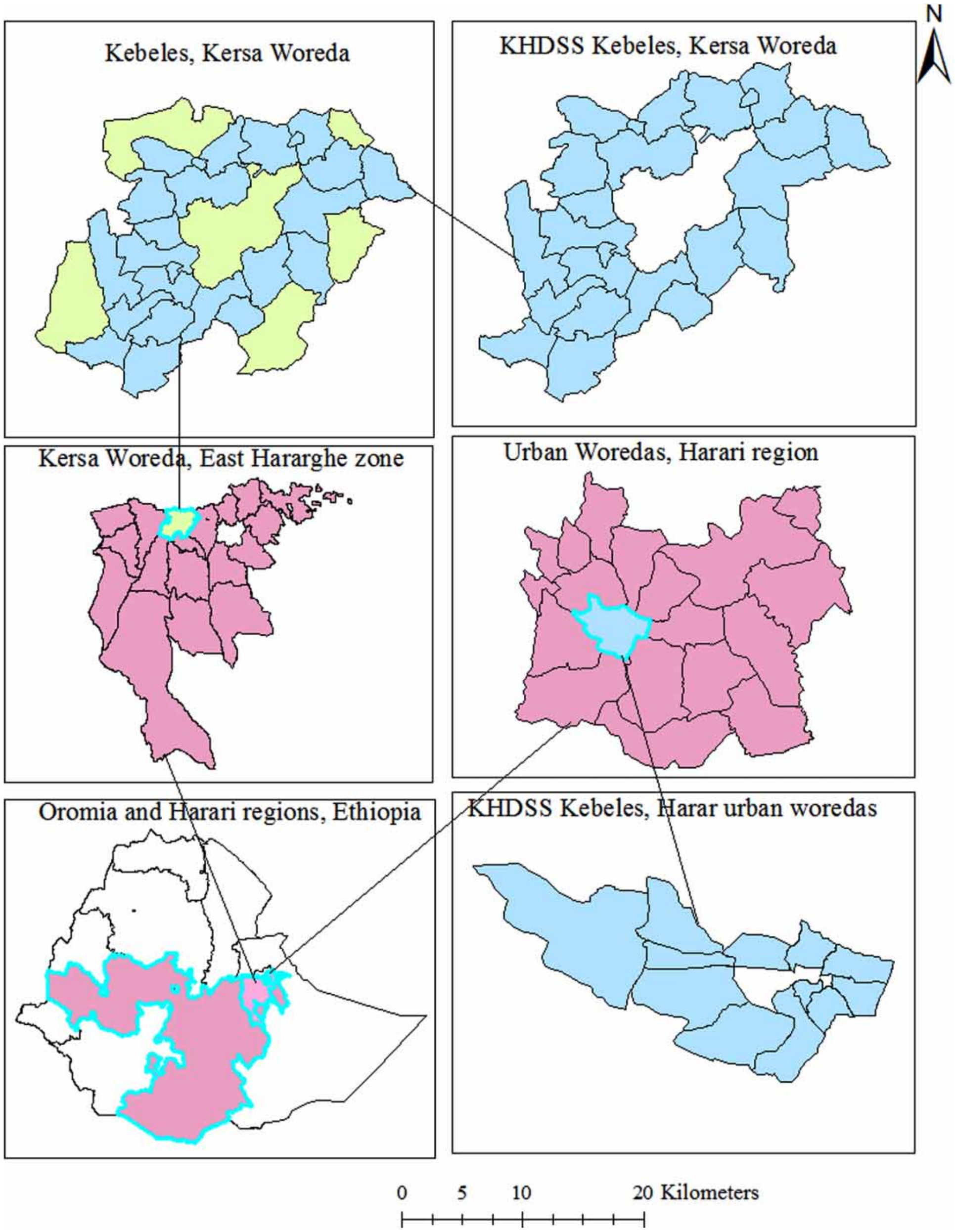

Figure 1 | Map of Kersa Health and Demographic Surveillance Site (KHDSS).

Data collection method and procedure

Data were collected by interviewing the mother or caregiver of the child using a structured questionnaire. The questionnaire contains questions related to socio-economic and demographic information, household water treatment options and use as well as behavioral risk factors. Some parts of the questionnaire, especially the household water treatment use and behavioral assessment part, is adopted from the World Health Organization water quality monitoring tools, PSI Monitoring and Evaluation on Household Water Treatment and United States Agency of International Development (MacDonald & Bank 2011; WHO 2012; PSI 2013). The questionnaire was initially developed in English and then translated to local languages (Amharic and

Oromiffa) for data collection purposes, then back to English for analysis.

Prior to data collection, data collectors were recruited and trained (4 days of training and 3 days of pilot testing) for enumeration, supervision, and water sample testing. The data collectors used direct observation to assess water storage containers, housing conditions, the opening/mouth of the water storage containers, type of water treatment used, sanitation and water storage facilities. Furthermore, the data collectors conducted a free residual chlorine test of stored water in the households that claimed to be using products on the day of the interview. This was done by taking a 5 mL sample of water and conducting a free chlorine residual test using Hach Co. (Loveland, CO) and DPD-1 free chlorine reagent powder. The test result was recorded as positive if a pink color was observed (indicating presence of a free chlorine residual of at least 0.2 mg/L, the Centers for Disease Control and Prevention and World Health Organization recommended concentration for adequate residual chlorine) (CDC 2008; WHO 2008).

Self-efficacy on chlorination, belief water chlorination reduces diarrhea, outcome expectation from chlorinating water, motivation to chlorinate water, perceived severity of diarrhea associated with water, perceived susceptibility to diarrhea, and water quality perception were measured using Likert-scale questions (1 – strongly disagree, 2 – disagree, 3 – no opinion, 4 – agree, and 5 – strongly agree). Self-efficacy, perceived severity, perceived susceptibility, and water quality perception was assessed using six, seven, eight, and thirty questions, respectively. Similarly, belief, outcome expectation, and motivation were each measured with five questions. To minimize the effect of subjectivity for Likert-scale measurement, important steps were taken. First, respondents were asked if they agreed or disagreed to each question. Second, they were asked to indicate their level of agreement, or disagreement. The question that is typically asked was, 'Do you agree a little or a lot?' or 'Do you disagree a little or a lot?' (Hernandez & Tobias 2010). The mean scores for each Likert-scale constructs were computed and dichotomized by taking the mean scores. Respondent scores above the mean were labeled as having positive belief, positive outcome expectation, high motivation to chlorinate, high self-efficacy, high perceived severity of diarrhea, high perceived susceptibility to diarrhea, and high perception to water quality. Respondent scores below the mean were labeled as having negative belief to products, negative outcome expectation from water chlorination, low motivation to chlorinate, low self-efficacy, low perceived severity of diarrhea, low perceived susceptibility to diarrhea, and low perception to water quality.

Water quality perception was assessed based on the household responses on the perceived health risk of water from different sources and the changes in taste, odor, and smell during the rainy season.

Data analysis

After data entry in Epidata 3.1 software, it was exported to Stata version 13 and summarized descriptively using frequency distribution and proportion for the measured variables prior to further analysis. The wealth index was constructed using household asset data via a principal component analysis (PCA). Using the factor score generated from PCA, the population was categorized into wealth quintiles following Central Statistical Agency's category (lowest, second, medium, fourth, and highest). Cronbach's alpha reliability coefficient was checked for each Likert-scale construct before dichotomization. To determine the association of independent variables with household water chlorination, two step analyses were conducted. First, bivariate analysis was conducted for each variable to observe its unadjusted effect. Second, variables with p-value cut-off point ≤ 0.1 from bivariate analysis were invited to multivariable logistic regression to estimate their independent effects at $p \leq 0.05$. During multivariable analysis, the effect of multicollinearity among independent variables was controlled using a variance inflation factor of less than 10.

Data quality control

To maintain the quality of data, different measures were used. The data collectors were trained and closely supervised during data collection. The questions were pilot tested and modified as appropriate using a 2% sample. In every test of free residual chlorine, the sample vials were rinsed three times with the water sample from the next household to be tested. In addition, about 25% of water samples (20 households) were tested twice for free residual chlorine.

Ethical approval

The study was conducted after obtaining an ethical clearance from the Addis Ababa University Ethiopian Institute of Water Resources institutional review committee. During actual data collection, mothers or caregivers were briefed about the study purposes and then only those who were willing to give responses were interviewed. Furthermore, all collected data were kept confidential.

RESULTS

Socio-demographic characteristics of study households

A total of 1,912 households (930 in rural and 982 in urban areas) with under-five children were interviewed, with a response rate of 96.5%. Most of the respondents to the study were mothers (97.0%). The socio-demographic characteristics of the study households indicate that nearly four-fifths of rural caregivers had no formal education and four-fifths of urban caregivers had attended formal education. Similarly, most caregivers were housewives (96.1% rural and 62.3% urban). Among household heads, 97.7% in rural areas were farmers in their occupation and nearly one-third in urban areas were government employees. Furthermore, 8.4% of rural respondents and 94.3% of urban respondents were exposed to television. Similarly, nearly one-fifth of rural and about half of urban caregivers were exposed to radio during the last week of data collection (Table 1).

For drinking water sources, storage, and point-of-use chlorination, of the 1,912 households, 86.6% of households were using water from improved sources for drinking purposes. In rural areas, about a quarter of respondents were using unimproved water sources and 84.8% did not store drinking water separately. In urban areas, approximately one-third of respondents stored drinking water in a jerrycan and plastic barrel, 35.8% of households dipped a cup to draw water from a storage vessel, and 69.5% stored water for 1 week or more (Table 2).

Table 1 | Socio-demographic characteristics of respondents in KHDSS, Eastern Ethiopia, 2017

			Rural, n (%)	Urban, n (%)
Education of mother/caregiver	No formal education		741 (79.7)	193 (19.7)
	Grade 1–4		70 (7.5)	83 (8.5)
	Grade 5–8		80 (8.6)	270 (27.5)
	Grade 9–10		25 (2.7)	187 (19.0)
	Grade 11–12		4 (0.4)	78 (7.9)
	College/ University		10 (1.07)	171 (17.4)
Education of household head	No formal education		610 (68.4)	73 (8.0)
	Grade 1–4		77 (8.6)	48 (5.3)
	Grade 5–8		121 (13.6)	201 (22.1)
	Grade 9–10		52 (5.8)	207 (22.8)
	Grade 11–12		6 (0.7)	125 (13.7)
	College/ University		26 (2.9)	256 (28.1)
Occupation of mother/caregiver	Housewife		894 (96.1)	612 (62.3)
	Farmer		15 (1.6)	–
	Government employee		9 (1.0)	156 (15.9)
	Merchant		12 (1.3)	121 (12.3)
	Private organization		–	68 (6.9)
	Daily labor		–	25 (2.6)
Occupation of household head	Farmer		871 (97.7)	38 (4.2)
	Government employee		21 (2.4)	290 (31.9)
	Merchant		–	209 (23.0)
	Private organization		–	226 (24.8)
	Daily labor		–	49 (5.4)
	Other		–	98 (10.8)
Caregivers exposure to mass-media in the last week	Radio	No	750 (80.7)	464 (47.3)
		Yes	180 (19.4)	518 (52.8)
	Television	No	852 (91.6)	56 (5.7)
		Yes	78 (8.4)	926 (94.3)

Percentages in the column may not be equal to 100% because of rounding of decimals.

Regarding household awareness and practices of point-of-use water treatment options, 1,353 (70.8%) of respondents have ever heard of at least one point-of-use water treatment option (64.5% chlorine based and 55.6% boiling) (Figure 2). Of the respondents who had ever heard of a water treatment option, 94.0% were using improved water sources. In rural areas, more caregivers were aware of boiling compared to other treatment options. Regarding chlorine-based treatment options, about 40% of rural respondents and most urban respondents (87.5%) had ever

Table 2 | Household drinking water sources and handling practices in KHDSS, Eastern Ethiopia, 2017

			Rural, n (%)	Urban, n (%)
Drinking water sources	Piped water connected house		–	27 (2.8)
	Piped into yard	Private	–	533 (54.3)
		From neighbor	–	133 (13.5)
	Public tap		400 (43.0)	83 (8.5)
	Protected well		246 (26.5)	2 (0.2)
	Unprotected well		46 (5.0)	–
	Protected spring		30 (3.2)	33 (3.4)
	Unprotected spring		198 (21.3)	2 (0.2)
	Surface water/river		10 (1.1)	–
	Storage tanker		–	2 (0.2)
	Bottled water		–	197 (20.1)
Storage container	Jerrycan		930 (100.0)	485 (61.8)
	Plastic bucket		–	17 (2.2)
	Barrel/Roto		–	25 (3.2)
	Jerrycan and barrel		–	258 (32.9)
Drinking water storage practice separately	No		789 (84.8)	167 (21.3)
	Yes		141 (15.2)	618 (78.7)
Storage duration	One day		857 (92.2)	45 (5.7)
	Two days		57 (6.1)	34 (4.3)
	Three days		16 (1.7)	23 (2.9)
	One week		–	375 (47.8)
	Two weeks		–	290 (36.9)
	Other		–	18 (2.3)
How water retrieved from storage vessel	Pouring into cup		930 (100.0)	485 (61.8)
	Dipping cup into storage		–	19 (2.4)
	Both		–	281 (35.8)

Percentages in the column may not be equal to 100% because of rounding of decimals; 197 households drinking bottled water were not considered for handling practices.

heard about that treatment option. Among chlorine-based treatment products, Wuha Agar (waterguard) was the most widely known (78.7% in rural areas and 89.2% in urban areas). The main sources of information were mass media (62.8%), Health Extension Worker (HEW) house visits and promotion (41.8%), and health institutions (22.4%). However, about three-fifths of rural and 8.6% of urban caregivers did not know where to purchase the treatment options.

Of caregivers who had ever heard of any point-of-use water treatment technologies, 13.8% of rural caregivers and 21.4% of urban caregivers claimed to be treating water during data collection. The two most common treatment options used were chlorine-based (85.7% in urban and 71.7% in rural) and boiling. In rural areas, 11.5% of caregivers who had ever heard of chlorine-based point-of-use water treatment technologies were chlorinating their water, of which a quarter were confirmed to have residual chlorine in their water samples. Similarly, in urban areas, of caregivers who had ever heard of chlorine-based point-of-use water treatment products, 19.6% were chlorinating their water and 7.6% were confirmed to have residual chlorine in the water samples. Out of 930 respondents in rural areas, 3.4% were reportedly chlorinating water while only 1.2% of caregivers were confirmed to have residual chlorine in the water samples. In urban areas, out of 982 respondents, 17.1% were reportedly chlorinating their water while only 6.6% of caregivers were confirmed to have residual chlorine in the water samples (Figure 2).

Only about a quarter of rural residents who had ever heard of point-of-use water treatment technologies and 35.0% of urban residents knew the correct contact time (waiting time) of chlorine to be effective. Fifty-four percent of rural caregivers and 64.7% of urban caregivers knew the amount of water needed to treat with one cup of water with waterguard (which is 20 liters), and 22.6% of rural caregivers and 59.8%

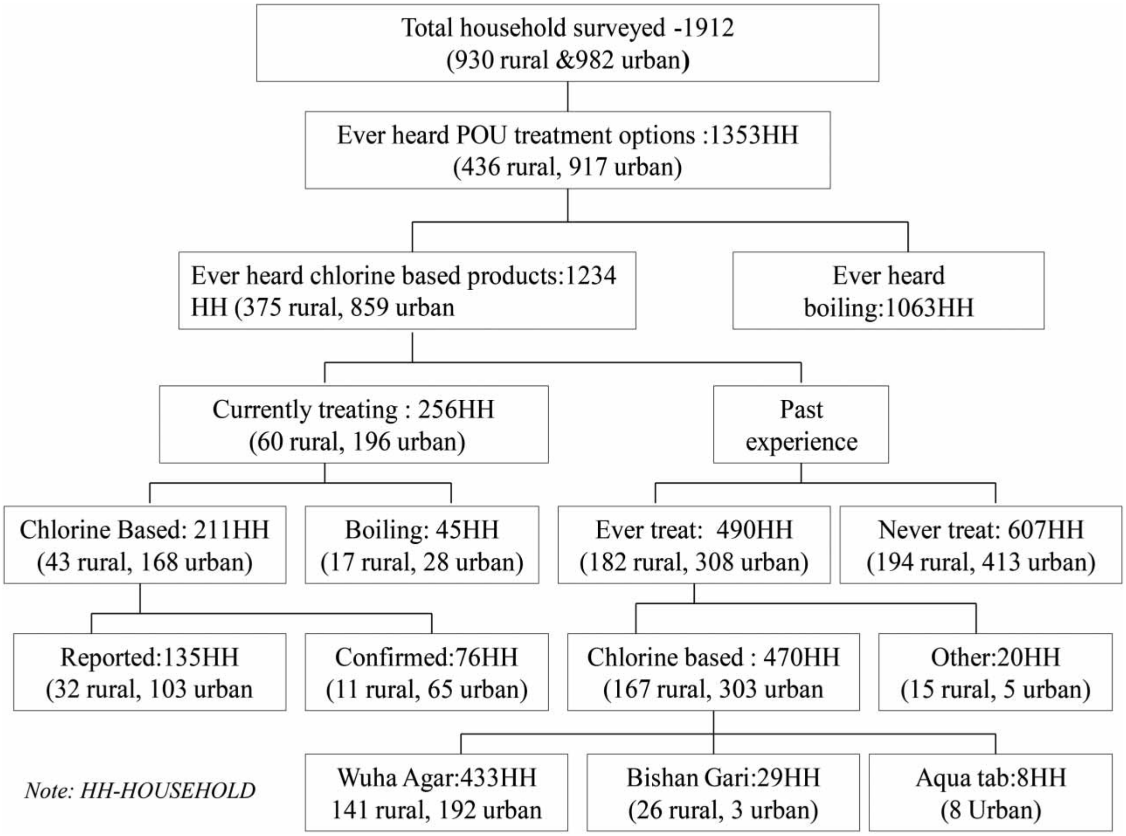

Figure 2 | Caregivers' awareness of POU water treatment options and practices in KHDSS, Eastern Ethiopia, 2017.

of urban caregivers knew the amount of water that can be treated with one sachet of Bishan Gari. Only 3.7% of respondents knew that Bishan Gari is more effective than the other treatment options when the water is turbid.

The current finding indicates that below one-third of households with unimproved water sources had ever heard of at least one of the household water treatment options, of which 16.1% were reportedly treating their water. However, there was no residual chlorine detected at any households during the survey.

A total of 44.5% of caregivers who had ever heard of point-of-use water treatment technologies in rural areas reported that they discontinued water chlorination for the following reasons: unavailability of products (70.1%) and inaccessibility of treatment options (27.3%). Thirty-five percent of caregivers in urban areas reported that they discontinued water chlorination because they thought that their water is chlorinated at the source (38.9%) and preferred bottled water (29.4%).

Factors associated with point-of-use water chlorination

The result indicates that the odds of chlorinating water at household level were 1.9 times higher for urban caregivers than rural caregivers ($p = 0.001$).

Bivariate analysis shows that water chlorination at point-of-use in rural areas was associated with perceived belief in chlorine effectiveness, water quality perception, and the chlorine taste. From the multivariable analysis, household water chlorination was independently associated with chlorine taste and water quality perception in rural areas (Table 3). More specifically, the odds of water chlorination was two times higher among caregivers with high perception to water quality compared to low water quality perception counterparts (AOR = 2.01, 95% CI = 0.95, 4.28). Rural caregivers complaining about the taste of chlorine had ten times lower odds of chlorinating water than those who did not complain about the taste (AOR = 10.26, 95% CI = 4.92, 21.42).

Table 3 | Factors associated with rural caregivers' water chlorination in KHDSS, Eastern Ethiopia, 2017

	Point-of-use-water chlorination			
Variables	**Yes**	**No**	**COR (95% CI)**	**AOR (95% CI)**
Exposure to radio in the last week				
No	37	237	1	1
Yes	6	95	0.40 (0.17, 0.99)*	0.41 (0.15, 1.10)
Self-efficacy				
Low	27	221	1	
High	16	111	1.18 (0.61, 2.28)	
Motivation to chlorination				
Low	35	270	1	
High	8	62	0.99 (0.44, 2.28)	
Outcome expectation				
Negative	27	223	1	
Positive	16	109	1.21 (0.63, 2.34)	
Belief on chlorine				
Negative	10	137	1	1
Positive	33	195	2.32 (1.11, 4.86)*	2.13 (0.93, 4.88)
Perceived severity to diarrhea				
Low	32	163	1	1
High	11	169	0.33 (0.16, 0.68)*	0.35 (0.15, 0.78)
Perceived susceptibility				
Low	29	205		
High	14	127	0.78 (0.40, 1.53)	
Water quality perception				
Low	16	201	1	1
High	27	131	2.59 (1.34, 4.99)*	2.01 (0.95, 4.28)*
Taste of chlorine				
No	4	70	1	1
Yes	39	262	11.65 (5.80, 23.41)*	10.26 (4.92, 21.42)*
Wealth status/quintile				
Lowest	11	68	1	
Second	13	55	1.46 (0.61, 3.52)	
Medium	8	65	0.76 (0.28, 2.01)	
Fourth	4	52	0.48 (0.14, 1.56)	
Highest	7	92	0.47 (0.17, 1.28)	
HEW promotion				
No	17	208	1	
Yes	16	124	2.23 (0.72, 14.55)	

1, base category; *significantly associated.
COR, crude odds ratio; AOR, adjusted odds ratio.

In urban areas, the bivariate analysis shows that point-of-use water chlorination was associated with exposure to radio, self-efficacy, perceived motivation, perceived susceptibility, perceived water quality, perceived outcome expectation from chlorination, chlorine taste, and HEWs' promotion. Multivariable analysis found that five explanatory variables were independently associated with point-of-use water chlorination (Table 4). The odds of water chlorination were 6.8 times higher among caregivers with high perception of water quality when compared with low water quality perception (AOR = 6.81, 95% CI = 2.76, 16.78). The odds of water chlorination were 2.8 times higher among caregivers with high self-efficacy compared to caregivers with low self-efficacy (AOR = 2.78, 95% CI = 1.43, 5.41). Caregivers who complained about chlorine taste were 1.8 times less likely to chlorinate compared to caregivers who did not complain about the taste (AOR = 1.82, 95% CI = 1.08, 3.07). Urban caregivers with high perceived susceptibility to diarrhea were 2.7 times more likely to chlorinate water than those with low perceived susceptibility (AOR = 2.66, 95% CI = 1.43, 4.97). Caregivers who claimed HEWs' promotion were 2.2 times more likely to chlorinate water compared to caregivers who did not claim HEWs' promotion (AOR = 2.24, 95% CI = 1.28, 3.93).

DISCUSSION

Prior research indicates that households take different actions whenever there is poor perception of their drinking water quality in order to prevent themselves from contracting different health problems (Hu *et al.* 2011; Jain *et al.* 2014). Household water chlorination is one of the recommended options to be practiced to prevent diarrhea disease, especially in households with under-five-year-old children. In this regard, the current survey is focused on whether households in urban and rural settings with under-five-year-old children chlorinate their drinking water prior to drinking and the factors that influence that decision.

More than three-fifths of households (64.5%) had ever heard about chlorine-based water treatment methods, of which 15.6% claimed to use the products. The free residual chlorine test in treated water however shows that only 6.2% of households which had heard about chlorine-based water

Table 4 | Factors associated with urban caregivers' water chlorination in KHDSS, Eastern Ethiopia, 2017

	Point-of-use-water chlorination			
Variables	**Yes**	**No**	**COR (95% CI)**	**AOR (95% CI)**
Exposure to radio in the last week				
No	57	342	1	1
Yes	111	349	1.91 (1.34, 2.71)*	0.69 (.38, 1.25)
Exposure to television in the last week				
No	10	33		
Yes	158	658	0.79 (0.38, 1.64)	
Motivation to chlorination				
Low	45	339		
High	123	352	2.63 (1.81, 3.82)*	0.93 (0.51, 1.69)
Self-efficacy				
Low	20	290	1	1
High	148	401	5.35 (3.27, 8.74)*	2.78 (1.43, 5.41)*
Outcome expectation				
Negative	72	510		
Positive	96	181	2.11 (1.49, 3.00)*	1.48 (0.87, 2.51)
Belief on chlorine				
Negative	27	250	1	1
Positive	141	441	2.96 (1.91, 4.60)*	1.85 (0.93, 3.63)
Perceived diarrhea severity				
Low	82	348	1	
High	86	343	0.97 (0.69, 1.36)	
Perceived susceptibility				
Low	31	307	1	1
High	137	384	3.53 (2.33, 5.37)*	2.66 (1.43, 4.97)*
Water quality perception				
Low	12	218	1	1
High	156	473	5.99 (3.26, 11.01)*	6.81 (2.76, 16.78)*
Taste of chlorine				
No	56	351	1	1
Yes	112	340	2.06 (1.45, 2.94)*	1.82 (1.08, 3.07)*
Wealth status/quintile				
Lowest	29	145	1	1
Second	27	151	0.89 (0.50, 1.58)	0.92 (0.42, 2.02)
Medium	29	145	1.00 (0.57, 1.76)	1.21 (0.55, 2.67)
Fourth	45	128	1.76 (1.04, 2.97)*	1.80 (0.83, 3.89)
Highest	38	122	1.56 (0.91, 2.67)	1.25 (0.53, 2.94)
HEW promotion				
No	23	153	1	1
Yes	88	178	3.29 (1.98, 5.46)*	2.24 (1.28, 3.93)*

1, base category; *significantly associated.
COR, crude odds ratio; AOR, adjusted odds ratio.

treatment methods were confirmed in using the products. Based on this, the actual number of households that chlorinated their water in each of the previous studies (Belay *et al.* 2016; CSA & ICF 2016) is highly likely fewer than the number indicated in each report. The result suggests point-of-use water chlorination evaluation to be accompanied by testing of water claimed to be chlorinated to assess the existing caregivers' practices for the prevention of childhood diarrhea at household level.

Specific to each study setting, 4.6% of rural caregivers and 17.1% of urban caregivers self-reported that they were chlorinating water at point-of-use. However, only 1.2% and 6.6% in rural and urban areas, respectively, had confirmed free residual chlorine in the water samples. In rural areas, the number of caregivers using products based on confirmed free residual chlorine was lower than the national report (2.5%) and a finding from north-western Ethiopia (8.78%) (Belay *et al.* 2016; CSA & ICF 2016). This could be because previous reports did not confirm self-reported users of chlorine with free residual chlorine test. In urban areas, the number of reported users and those confirmed to have residual chlorine were higher than the national report (6.1%) (CSA & ICF 2016). From caregivers in two settings, more urban dwelling caregivers chlorinated their water compared to rural dwelling counterparts. The results comply with a review result that indicates higher numbers of urban dwellers chlorinate their water than rural dwellers in low- and medium-income countries (Rosa & Clasen 2010).

From households confirmed to have free chlorine residual in the water samples, 26 (34.2%) households had a free residual chlorine level of less than 0.2 mg/L, which deviates from the recommended dose of a free chlorine residual range of <2.0 mg/L after 1 hour and >0.2 mg/L after 24 hours of dosing (Lantagne 2008). The problem of residual chlorine inadequacy in treated water during acute emergency response in four countries is reported in prior research findings. The findings showed that less than one-fifth of households had adequate free residual chlorine (≥0.2 mg/L) (Lantagne & Clasen 2012b). The possible reason for inadequate free residual chlorine in our study areas could be because households never treated or used the chlorine in any way to begin with and the length of time water was stored.

Household water chlorination was associated with high self-efficacy to chlorination in urban areas. This means those households that did not have the capability to perform chlorination at household level were less likely to use the products than those that had capability. This result is similar to study findings in Zimbabwe that show households with high self-efficacy about water treatment are more likely to chlorinate drinking water (Imanishi *et al.* 2014).

The finding that indicates the association of caregivers' water chlorination with unpleasant taste of chlorine is corroborated by a study in Zambia (Olembo *et al.* 2004). Furthermore, the concern of the esthetics of water (taste, color, odor) after chlorination were common complaints by participants of other studies (Lantagne & Clasen 2012a).

The chlorine-based treatment options were more readily accessible to urban dwellers than rural dwellers. However, within urban areas, accessibility to treatment options did not have significant association with water chlorination, which is inconsistent with a study finding in rural Kenya that indicates that the ease of accessing products leads to higher rate of water treatment option adoption and use (Makutsa *et al.* 2001). In rural areas, the sale points were not available and the drug shops were not accessible to residents. In addition, unavailability of treatment options was a reason for 70.1% of caregivers to discontinue water chlorination in rural areas. Therefore, low self-efficacy and poor knowledge of treatment options in rural areas compared to urban areas could be because of inaccessibility to treatment products. Study findings in Zambia show that there is an improved sense of self-efficacy and knowledge to treatment options derived from easy access to treatment options and behavior changing communication (Quick *et al.* 2002). In Haiti, less access to treatment options by households in a mountainous region was stated as a possible reason for the decline of total chlorine residual during assessment of sustained use in a relief-to-recovery household water chlorination program (Wilner *et al.* 2017).

Households were asked about health extension workers' promotion of different point-of-use water treatment options. The result indicates that HEWs' promotion of chlorine-based treatment options was an effective means of increasing uptake of chlorination, mainly in urban areas. This result is consistent with a study result in Zimbabwe that indicates household visits by promoters together with persuasive messaging resulted in high adoption of SODIS products (Mosler *et al.* 2013). Other study results indicate that providing information about household water chlorination has a strong association with adoption of protective behaviors and technologies (Parker *et al.* 2006; Madajewicz *et al.* 2007; Chankova *et al.* 2012). However, rural household water chlorination at point-of-use was not associated with HEW promotion which could be derived from the extent of promotion services and household acceptance.

From the water quality perception result, caregivers in urban areas had high perception of water quality compared to caregivers in rural areas. In both settings, the perception of poor water quality was associated with point-of-use water chlorination. The perception of poor water quality was associated with point-of-use water chlorination in both settings. Our study result complies with the study finding in Kenyan towns that indicates domestic water treatment is driven by households' risk perceptions (Onjala *et al.* 2014). It also complies with study findings that indicate households with higher perceived risk of water quality were more likely to boil or filter water before drinking (Nauges & Van Den Berg 2009; Jain *et al.* 2014).

Furthermore, household perceived susceptibility to diarrhea is statistically associated with household water chlorination in adjusted analysis, mainly in urban settings. The association of perceived susceptibility to diarrhea with point-of-use water chlorination is consistent with a study finding in Malawi that indicates the perception about vulnerability to diarrhea was associated with Waterguard® use (Kumwenda 2009). Another study in Zimbabwe indicates that high perceived susceptibility to typhoid fever was associated with household water treatment (Imanishi *et al.* 2014).

The association of point-of-use water chlorination with taste of chlorine imparted in the water, caregivers' self-efficacy, susceptibility, and water quality perception, in general, comply with the prior systematic review on Integrated Behavioral Model for Water, Sanitation, and Hygiene (IBM-WASH) that categorized factors into three key dimensions: contextual, psychosocial, and technological (Dreibelbis *et al.* 2013). However, why households differ in water treatment behavior and what contributes to this difference when health extension workers in the country have been deployed and executing promotion services for the last one and a half decades should be further investigated.

In addition, in-depth assessment regarding caregivers' perception about the health benefits of point-of-use water chlorination is needed, as a prior study finding revealed that households that recognized health benefits of water quality intervention were facilitated to use it (Francis *et al.* 2015).

From the survey, household wealth status was not associated with household use of chlorine-based products in both rural and urban areas, which is inconsistent with findings in rural Guatemala (Luby *et al.* 2008). Furthermore, a study finding indicates that households having high socio-economic status were found to quickly adopt point-of-use water treatment products and technologies (Johnson 2007; Katuwal *et al.* 2015). The inconsistency of household water chlorination with wealth status could be because there was a free provision of treatment options to some households during data collection, and some households claimed unavailability and inaccessibility as the reasons for discontinuing product use. However, a study that focuses on the effect of the supply chain and accessibility of the product use in rural areas needs to be conducted. In addition, many wealthy households in urban areas preferred to use bottled water instead of chlorinating water, which leads to the question, 'is bottled water an alternative to point-of-use water treatment for the urban community?' – to be answered by further study. On the other hand, our study finding of no consequence of socio-economic status on point-of-use water chlorination complies with a study finding that indicated there was no significant difference in WaterGuard usage by socio-economic status in rural Kenyan households following a clinic-based intervention (Parker *et al.* 2006).

Strengths and limitations of the study

The study has two main strengths: (1) self-reported products' use was confirmed by testing of free residual chlorine and (2) the study was conducted in one of the six surveillance sites that represent the eastern part of the country. On the other hand, it has the following limitation: except for the free residual chlorine results, other results were measured based on self-reported responses. Therefore, self-reported measures are known to be biased due to social desirability and conception issues. The result shows that a small number of households are chlorinating their water, especially in rural areas, which could lessen the power of predictor variables in the analysis. Currently, only cross-sectional data were used to assess psychosocial factors associated with household water chlorination. A longitudinal, follow-up study is necessary to verify the current findings. In addition, our findings are possibly limited to the eastern part of the country; therefore, the question of comprehensiveness and generalizability for the country could be inadequate and should always be accompanied by further surveys (study that includes the six surveillance sites).

CONCLUSION AND RECOMMENDATION

The result indicates that a small number of households in both settings were using chlorine-based point-of-use water treatment options in Kersa Health Demographic Surveillance Site. From the two settings, caregivers in urban areas were more aware and were treating their water at a higher rate than their rural counterparts. A caregiver's propensity to use water chlorination was associated with some behavioral factors and the taste of products. In rural areas, treatment unavailability and inaccessibility were mentioned as a reason to discontinue water chlorination. We strongly recommend behavior change interventions together with proper distribution, marketing, and promotion of products for the realization of sustainable use in the study area.

ACKNOWLEDGEMENTS

This study was conducted with the financial support of Addis Ababa University and Federal Ministry of Water, Irrigation and Electricity. The findings in this paper are those of the authors and do not necessarily represent the official position of specified offices. We would like to thank employees in the surveillance site, regional and zonal health bureaus and data collectors for their cooperation. Abraham Geremew contributed to design, pre-testing of the questionnaire, data collection, data entry, cleaning, analysis, and manuscript preparation. Bezatu Mengistie contributed to design, data collection, analysis, and manuscript preparation. Esayas Alemayehu contributed to design, analysis, and manuscript preparation. Geremew Sahilu

contributed to analysis and manuscript preparation. Jonathan Mellor contributed to design, analysis, and manuscript preparation. Daniele Susan Lantagn contributed to design, analysis, and manuscript preparation. All authors have read and approved the final manuscript.

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First received 3 October 2017; accepted in revised form 20 April 2018. Available online 11 May 2018