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Options for household water treatment, safe storage and on-site sanitation in diarrhoea-prone rural communities of Bindura district, Zimbabwe

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Abstract

A survey was conducted at 252 households (HHs) (from six wards) of a rural district in Zimbabwe in 2012 to assess HH water treatment and sanitation options. Diarrhoeal disease morbidity was recurring despite water and sanitation interventions. Participant observation and in-depth-structured interviews were used during unannounced visits to solicit information. Faecal coliform levels in water samples were estimated using a Potatest field kit. The HH water treatment technologies used were chlorination (19%), biosand filtration (3%) and boiling (1%). Water samples drawn from sources (39.3%, *n=28),* storage vessels (43%, *n=252*) and handwashing facilities (41.7%, *n=24*) had mean faecal coliform levels of 41.1±19.0, 5.9±0.6 and 26.7±7.7cfu/100ml respectively, that were significantly different (p<0.05). Sanitation options used were: pit latrines (44.8%), Blair ventilated pit latrines (42.1%), open defaecation (0.8%) and others (12.3%). Pearson chi-square tests showed no relationship between age and religion on the water treatment and sanitation options (p>0.05). Finance was the major barrier in adopting the standard sanitation option. Hygiene, education and safe water storage could be key in preventing diarrhoeal diseases in the six wards. The traditional pit latrine appeared to be the commonest sanitation option although it is regarded as an unimproved technology on the sanitation ladder.

Keywords: Faecal coliform, Handwashing, Hygiene education, Safe water storage, Sanitation option

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1. Introduction

The millennium development goal target on drinking water became the first one to be achieved globally in 2010 as 89% of the world's population was using an improved water source, leaving about 780 million still relying on unimproved drinking water (UNICEF/WHO, 2012). The sanitation target is however unlikely to be met by 2015 (UNICEF/WHO, 2012). About 70% of Africans without sanitation and 80% without access to improved drinking water sources were living in rural areas (UNICEF/WHO, 2008). This is where the burden of disease associated with unsafe drinking water is borne mostly by the poor, the very young and the immuno-deficient (Trevett et al., 2005; Nath et al., 2006). Water is usually collected from unprotected sources and is consumed without treatment putting people at risk of contracting water-borne diseases.

Household water treatment and safe storage (HWTS) is a two pronged option for improving the quality of drinking water at HH level especially where water handling and storage are necessary and recontamination is a risk (UNICEF/WHO, 2011). Water, sanitation and hygiene (WSH) programmes reduce the risk of contracting gastro-intestinal illnesses by providing barriers to pathogens breaking the cycle of disease transmission (Waddington et al., 2009). Other benefits of WSH programmes have also been reported (Jha, 2003; Poulos et al., 2006; Waddington et al., 2009). After WSH interventions in an area, it may be expected that the incidence of diarrhoeal diseases is reduced.

Household water treatment (HWT) technologies that can be used to eliminate or reduce pathogens from various drinking water sources and rural onsite sanitation technologies are well documented (Nath et al., 2006; WHO, 2006; 2011; UNICEF, 2008; Classen, 2009; Waddington et al., 2009; Morella et al., 2009; NAC, 2010).

The Zimbabwean government recommended the bush pump (borehole) for rural community water supply, chlorination for HWT and the Blair Ventilated Improved Pit (BVIP) latrine and its low-cost models for sanitation. These prescribed technologies have proved not to be sustainable for the rural poor as replication, maintenance, replacement and/or self-funding are poor.

In this study we assessed HWTS and sanitation options that were used by rural communities of Bindura district. A number of non governmental organisations (NGOs) have been working in the district for the past decade in WSH programmes. However, the incidence of diarrhoeal diseases has been recurring with the recent 2008-2009 outbreak being one of the world's largest (WHO/UNICEF, 2011). Such outbreaks can be prevented. There has been no independent assessment of WSH interventions in Bindura district. Identifying populations that do not practice HWTS or acceptable hygiene behaviour may help WSH programme implementers to effectively target their beneficiaries and evaluate their programmes.

2. Materials and methods

2.1. Study area

Bindura district (latitude S17°20′52.5′′ and longitude E31°16′47.9′′) consists of 21 wards (Figure 1). It has maximum mean annual temperature of between 26 and 28 ^{0}C and receives between 750 and 1000mm of rainfall annually falling mainly from November to March. Records from the Ministry of Health and Child Welfare (MoHCW) Bindura district (Environmental health) showed that rural water supply and sanitation coverages for the district in 2012 were estimated at 58 and 25% respectively.

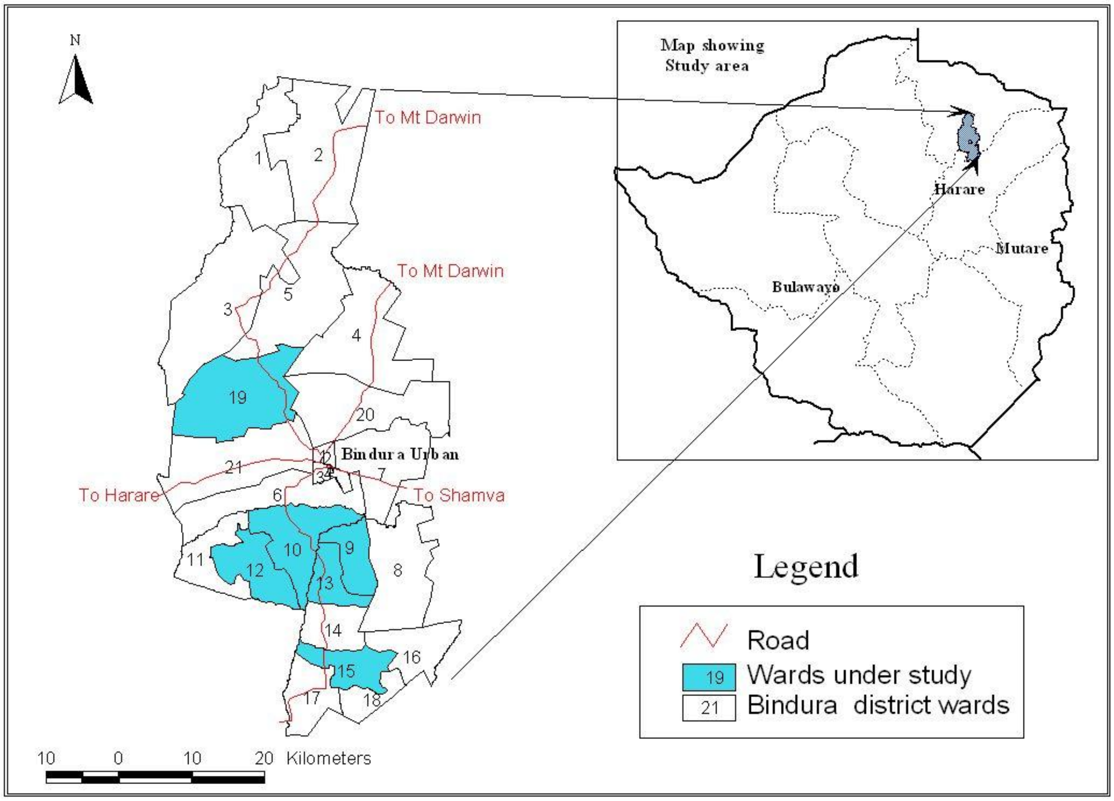

Figure 1. Map showing the position of Bindura District and selected wards for the study

2.2. Sampling and sample analysis

Forty-two HHs were randomly selected from each of the chosen six wards (9, 10, 12, 13, 15 and 19) for the study (Figure 1). A 30-item open-ended questionnaire was pre-tested to 9.9% of the HHs targeting the female head of the HH in the study area. The modified tool was then administered to 252 rural HHs in unannounced visits. Where the female HH head was unavailable, then any adult (>18 years) HH member was considered for the interview. If the interview failed for some reason, the field team would revisit the HH later. Questionnaire items were developed from Dzwairo et al. (2006) and WHO/UNICEF (2012) focusing on HH demography, HWTS, sanitation options and barriers for their adoption by HHs in the six wards. Verbal consent to participate in the survey was sought at HH level through MoHCW Bindura district office, which also participated in the study.

Duplicate water samples (10%) were randomly selected from sources, storage vessels and hand-washing facilities and analysed in the laboratory (membrane filtration method) to validate the field method**.** The membrane filtration method was used to determine bacteriological water quality (thermotolerant coliforms). The Palintest was used to determine residual chlorine in stored water using a Potatest field kit (Wagtech International, WE10005) based on the field kit manual. Water samples were collected in sterilised polythene bottles (100ml) between March and August 2012. Samples were manually vacuum-filtered. Faecal coliforms were recorded as coliform forming units per 100 mL of a water sample (cfu/100mL).

2.3. Statistical analysis

Descriptive statistics were used to analyse coded questionnaire data and to determine mean faecal coliform levels in water sources. Significant differences (at 95% confidence level) between the measured faecal coliforms and WHO (2006) microbiological drinking water quality guidelines were determined using a chi-square test. A paired sample t-test was run to validate the field procedure against laboratory analysis. Faecal coliform levels in the three water sources were tested for normality using the Q-Q plot and compared using one –way Analysis of Variance (ANOVA) and LSD post hoc to check for significant differences between individual means. A chi-square test was used to determine any relationship between age and religion on the choice of a water treatment and sanitation options.

3. Results and discussion

A 100% response rate was achieved. Amongst the respondents, 61.1% were women and 41-50 year age group dominant (55.2%). The average HH size was 5.6 persons. Household heads that had reached at most primary formal education were 76.6%. Diarrhoeal disease incidences were reported in 19.9% of the HHs 2 months prior to the survey mostly in children under five years. The mean faecal coliform level of the randomly collected duplicate water samples that were tested in the laboratory (4.29 ± 1.73cfu/100ml) was not significantly different ($p>0.05$) from that of samples that were tested by the Potatest field kit (8.57 ± 7.01cfu/100ml). This may indicate that the field method could be used to estimate microbiological water quality in Bindura district.

3.1. Household water treatment technologies used in six wards of Bindura district

Most HHs (68.7%) indicated ignorance on the existence of HWT technologies other than boiling and chlorination. These two HWT technologies have been widely promoted by various stakeholders in the water and sanitation sector during episodes of diarrhoeal diseases. Chlorination was practised in all the six wards with wards 10 and 19 recording the highest and lowest usage of chlorination respectively (Figure 2). Close proximity to a rural health centre where chlorine tablets (aquatabs) were freely distributed could explain the high usage of chlorination. However, the sustainability of chlorination as a HWT technology has been questioned especially after termination of assistance from implementers (Dzwairo et al*.,* 2006). The limited usage of chlorination (<25%) observed in wards near rural health centres could be attributed to aesthetic objections of odour and taste (24.2%) as well as religious beliefs (4.4%). Objections by HHs to consume chlorinated water due to perceived unpleasant change in taste and smell has been reported elsewhere (Nagata et al., 2011).

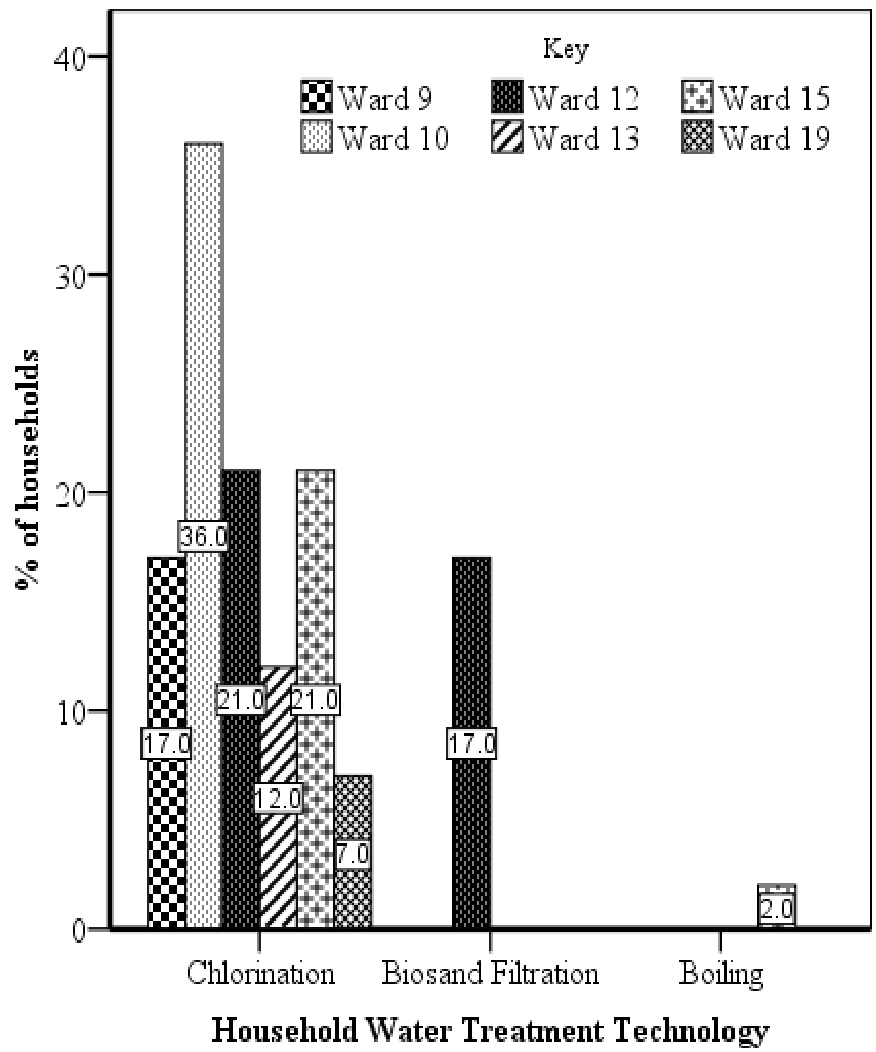

Figure 2. Household water treatment technologies used in six wards of Bindura district

Biosand filtration was only used in ward 12 by 40% (*n=42*) of the HHs (Figure 2) possibly because the filters were donated to a few (17) HHs in village 12. The low usage of boiling (only in ward 15 by 2% of the HHs) could have been a result of shortage of firewood (52.4%) that was then attributed to long distances from the homestead or fear of prosecution for cutting down trees (82.1%) as reasons for not boiling drinking water. However, it was observed that firewood was being used by all HHs for cooking. Dzwairo et al. (2006)

reported shortage of firewood and being time-consuming as reasons for low usage of boiling to treat drinking water by HHs in a similar study in Mutoko, Zimbabwe. Unlike chlorinated drinking water, boiled water is susceptible to recontamination if no proper water storage and withdrawal methods are used (Classen, 2009).

3.2. Onsite sanitation technologies used in the selected wards

Most (87.7%) HHs had a sanitation facility (improved or unimproved). It was assumed that where there was no latrine, open defaecation was practised, as sharing of latrines between HHs was not observed. This assumption may however result in reporting a low proportion of HHs that practised open defaecation which could have been practised even where there were sanitation facilities. There were no significant differences in the proportions of HHs with pit latrines (ave 44.8%) and those with BVIP latrines (ave 42.1%) within wards ($p>0.05$). The BVIP was considered expensive to construct by 62.3% of the HHs. Of the sanitation facilities observed, 86.0% *(n=221)* of them appeared to be functional and 63.3% were single squat hole latrines.

Open defaecation was presumably practised in five of the six wards (12.3%) (except ward 12). Ward 19 recorded the highest proportion of HHs that practised open defaecation (Figure 2). NAC (2010) observed that standardising the BVIP latrine as the only rural sanitation technology was not aimed at eradicating open defaecation. Zimbabwean national figures in 2010 showed that more than 33% of the population still practiced open defaecation while 82% of the poorest did so (NAC, 2010). Morella et al. (2009) also observed that countries in sub Saharan Africa had 41% (rural) and 34% (national) open defaecation figures.

Ward 12 had the highest proportion of HHs with pit latrines (Figure 2). It had no open defaecation recorded indicating that all HHs had a sanitation facility. Most of the traditional pit latrines observed had superstructures that were made of local materials such as plastics, grass, mud and poles. Similar observations were also reported by Tumwine et al. (2003) in a related study. The proliferation of pit latrines, in some cases with wooden floors and not the standardised BVIP latrines may indicate that HHs wanted their own latrines but often could not afford what was being offered. Traditional pit latrines were reported as most common and fast growing (52%) in Sub Saharan Africa (Morella et al., 2009) despite being considered an unimproved sanitation technology on the sanitation ladder. Tumwine et al. (2003) observed that the pit latrine was the commonest sanitation facility in unpiped sites in a study of 1 015 HHs in Uganda, Kenya and Tanzania. Under such situations the health benefit of access to improved sanitation is compromised by the cost and the choice of a sanitation technology, potentially increasing the health risk. In our study the traditional pit latrine was considered an unimproved sanitation facility.

The highest proportion of HHs that had BVIP latrines was observed in ward 15 although pit latrines were still used and open defaecation was still practised (Figure 2). All of the BVIP latrines built in wards 13 and 15 were donor-assisted projects although relatively high proportions of HHs (29.8%; *n=84)* used pit latrines which they funded.

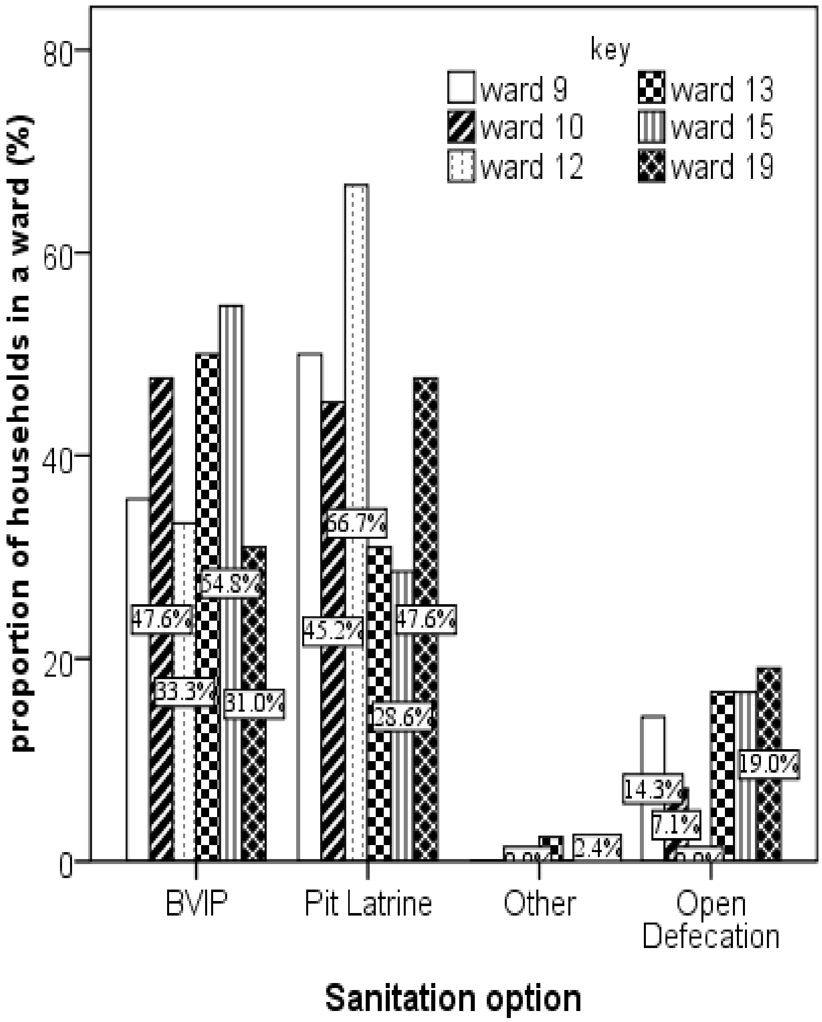

Figure 3. The proportion of households using a sanitation option

The proportion of HHs in a ward did not show strong positive correlation with open defaecation in the six wards. This may suggest that the presence of a sanitation facility (improved/not improved) may not necessarily eliminate the practice of open defaecation. Access, according to Poulos et al. (2006) does not reflect actual use, efficiency or sustainability. This may suggest that HHs either preferred the pit latrine or they could not afford constructing the BVIP latrine without subsidy. Although 63.1% of the HHs indicated willingness to pay for sanitation services, the majority of them (82.3%; n=159) reported that they could only afford to pay <$50.00 for the construction of a latrine unit. This may indicate inability to finance the construction of the standard BVIP latrine which costs about two times greater than this value.

Wards 9 and 19 had HHs with relatively more pit than BVIP latrines (Figure 2). This may suggest that although BVIPs were built, HHs seemed to prefer pit latrines. It was also observed that ward 19 had the highest proportion of HHs that practised open defaecation and had the lowest proportion of HHs that had

BVI (Figure 2). The same ward had the lowest proportion of HHs that practised chlorination (<10%) (Figure 1). Reasons to explain this were not solicited, although socio-economic status and the level of education of the HH head have been reported to influence the sanitation option and hygiene behaviour (Tumwine et al., 2003; Jha, 2003). HHs in ward 19 could be at a high risk of contracting diarrhoeal diseases when compared to other wards.

3.3. Microbiological water quality

3.3.1. Primary source water quality

Results indicated that 65.1% of the HHs abstracted water from protected sources (Table 1) yet only 32.5% treated their water before use by either chlorination, boiling or biosand filtration (Figure 2).

Table 1. Proportion of households in a ward using water from a given source (%)

Water source	% households using a water source in a given ward *(n=42)*						% overall *(n=252)*
	Ward 9	Ward 10	Ward 12	Ward 13	Ward 15	Ward 19	
A	0	11.9	19.0	21.4	7.1	23.8	13.9
B	0	4.8	0	0	21.4	0	4.4
C	0	0	2.4	0	19.0	31.0	8.7
D	66.7	59.5	57.1	31.0	21.4	2.4	39.7
E	0	0	2.4	9.5	4.8	0	2.8
F	33.3	16.7	19.0	14.3	9.5	14.3	17.9
G	0	0	0	21.4	0	0	3.6
H	0	7.1	0	2.4	2.4	0	2.0
I	0	0	0	0	14.3	28.6	7.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

A= Borehole B= River sand abstraction C= tap water D= protected shallow well
E= Protected deep well F= Unprotected shallow well G = unprotected deep well
H= Dam and river I= other sources

Primary water sources that provided microbiologically safe drinking water (0cfu/100ml) and polluted water (>10cfu/100ml) were each 39.3% (*n=28*) (Table 2). Microbiologically polluted water could have been from unprotected water sources (27.9%) (Table1). On average, all wards (except ward 13) had water sources that were microbiologically polluted (>10cfu/100ml) with faecal coliforms. Open water sources are subject to faecal contamination during abstraction or by animals that may have access to them.

Table 2. Microbiological quality of drinking water sources in selected six wards of Bindura district (*n=28*)

Microbiological drinking water quality category (WHO, 2006) (cfu/100ml)	WARD 9	10	12	13	15	19	Total	% of Samples
0	3	0	1	3	2	2	11	39.3
1 – 10	0	4	2	0	0	0	6	21.4
11 – 100	2	2	2	0	2	0	8	28.6
>100	0	0	0	0	2	1	3	10.7
Total	5	6	5	3	6	3	28	100.0

WHO (2006) Microbiological drinking water quality categories: 0 (safe); 1-10 (reasonably safe); 11-100 (polluted); >100 (dangerously polluted)

Communities in the study area were drinking microbiologically unsafe water, therefore were at risk of contracting diarrhoeal diseases.

3.3.2. Household stored drinking water quality

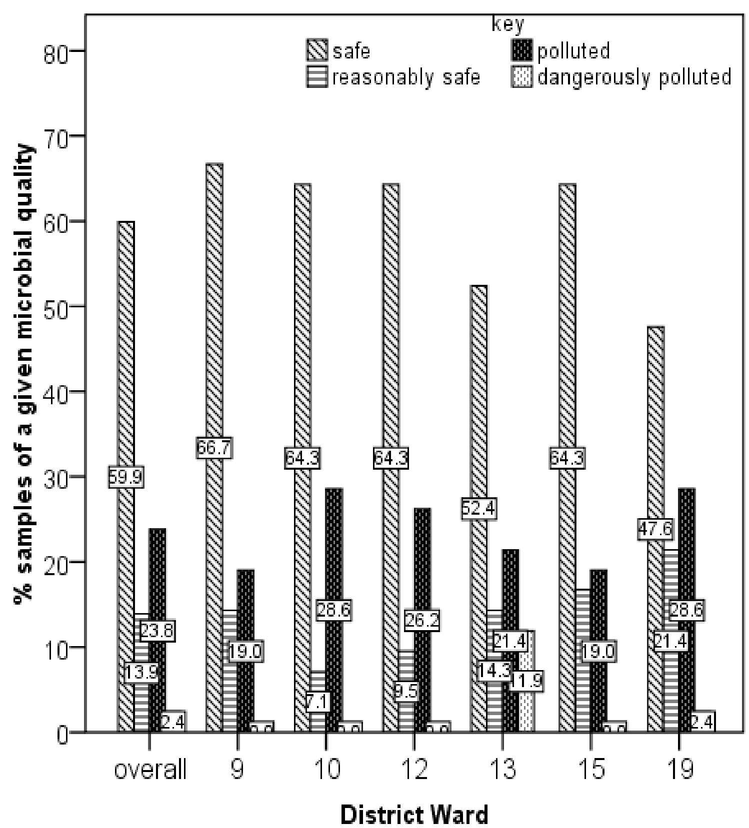

Figure 4. Proportion of household stored water of given microbiological water quality category

All the wards (except ward 19) had more than 50% of the HHs having safe stored drinking water (Figure 3). The proportion of stored water that was safe for drinking (59.9%) was significantly higher ($p<0.05$) than that of the water sources (39.3%). This could suggest that HWT technologies were effective in treating source water or HHs were using recommended water storage practices (21.8%). The recontamination of safe source water at the point of use (19.0% *n=252*) was not surprising. This has been reported as common (Nath et al., 2006; UNICEF, 2008; UNICEF/WHO, 2011) especially in most developing countries where the collection and storage of drinking water was practised (Trevett et al., 2005).

Ward 10 had no water sources that provided microbiologically safe drinking water (Table 2). It recorded the highest usage of chlorination (36%) and ultimately 60% of the stored water was microbiologically safe for drinking. This could be a demonstration that despite its aesthetic objections, chlorination is effective in disinfecting drinking water. Residual chlorine in stored chlorinated water was detected in 64.6% (*n=48*) of the HHs that chlorinated their drinking water. This could be because some HHs did not regularly treat their stored drinking water (25.8%) thus the detection of faecal coliforms where HHs reported to use chlorination. Overally, 26.2% (*n=252*) of the HHs under study were consuming microbiologically polluted stored water with an average faecal coliform load of 19.88±3.6cfu/100ml. This value is significantly higher than WHO (2006) safe drinking water guideline ($p<0.05$) suggesting the need for post disinfection.

3.3.3. Hand-washing facilities at latrines

Of the sanitation facilities recorded in the study 10.9% of them (*n=221*) had hand washing facilities which were somehow built/attached onto or detached from the latrine, generally on the BVIP latrines (except for one on a pit latrine in ward10). Of all hand-washing facilities, 45.8% *(n=24)* had water that was microbiologically safe for drinking while 54.2% had >1cfu/100ml. Only one BVIP latrine (in ward 13) had a hand-washing facility that had a piece of soap. Neither ash nor soap was used for hand washing after using the latrine. Hand washing with soap or ash after using the latrine has been reported to reduce diarrhoea morbidity (Timwine et al., 2003; Waddington et al*.,* 2009; Bloomfield and Nath, 2009).

In ward 19 all latrines (*n=33)* had no hand washing facilities. The mean faecal coliform level of water from the hand washing facilities (26.7±7.7cfu/100ml, *n=24*) was significantly higher than that of water from the HH storage devices (5.9±0.6cfu/100ml; *n=252*) ($p<0.05$) although both waters were from the same source. This difference could be a result of not treating water that is added into the hand-washing facility that was reported by all of the HHs. However, the proportion of hand-washing facilities that had safe water (0cfu/100ml) was relatively higher (45.8%) than in primary water sources (39.3%).

The microbiological quality of water in the hand-washing device should be that of drinking water (0cfu/100ml) in order to break the faecal-oral route of the transmission of pathogens of diarrhoeal diseases. Most hand-washing devices were observed to be placed near the latrine entrance. This may help HH members not to forget to wash their hands after using the latrine. It was also noted that in all latrines that had hand washing facilities only 4.2% (*n=24*) had a piece of soap for use but none had ash as a substitute. The absence of soap at hand washing facility could be linked to its affordability or reserved for other HH uses.

However, the absence of other zero cost hand-washing materials (mud, soil, or ash) could be a result of hygiene behaviour that was not practiced. Soil, mud and ash were reported to be frequently used for hand washing after using the latrine in Southern Africa as zero cost alternatives to soap (Bloomfield and Nath, 2009). This may suggest that HHs that had latrines with hand-washing facilities but were not using soap or ash in hand-washing and were using polluted water, were vulnerable to contracting diarrhoeal diseases.

3.4. Household safe water storage

All HHs stored different volumes of drinking water in various vessels (plastic, earthenware, metal) as perennial drinking water sources become distant (ave >500m) especially in the dry season. It was observed that 99.2 % of the HHs were not using recommended stored water retrieval methods. Cleaning of water storage vessels with fine sand/mud and water was reported by 74.5% of the respondents although only 11.7% of them used soap (not ash). The use of wide-mouthed water storage vessels that was reported by 77% of the respondents may render stored water susceptible to recontamination especially by dipping a cup which was observed to be the main water withdrawal method in 87.8% of HHs. Drinking water, even from improved sources may get contaminated during storage and handling (Nath et al*.,* 2006; UNICEF, 2008; WHO, 2011).

The use of narrow-mouthed water storage vessels together with good hygiene practices have been observed to reduce the chance of recontamination of drinking water by hands especially after boiling (WHO, 2011). These observations may suggest that even if HHs obtained safe drinking water from protected water sources it could get contaminated during storage. Of all the respondents who reported chlorinating their drinking water (19%, *n=252*), residual chlorine was detected only in 25% (*n=48*) of the stored drinking water. This is in contrast to the reported users. Possible explanations could be that the chlorine dosage was not effective, the water was stored for a long time or chlorination was not practised by some of the HHs. Safe water storage becomes key in a water supply intervention as all water, however safe, may be subject to recontamination, except in cases where there is residual treatment effect such as chlorination. Safe water storage practices together with hygiene behaviour may prevent the recontamination of water especially after treatment (Classen, 2009). Hygiene interventions that target the female HH head may help develop HH hygiene practices and forming habits of children (Jha, 2003) who are usually involved in the collection and handling of drinking water. A high proportion of children have been observed to collect and serve water but it is presumed that they are less careful in avoiding hand contact (Trevett et al., 2005).

4. Conclusions and recommendations

Options for rural HWT, safe storage and on-site sanitation were investigated in this study. Chlorination was the most common and effective HWT technology in the study area although it was influenced by the proximity of HHs to a rural health centre and aesthetic objections. There was very limited knowledge and use of other HWT technologies in the study area. The traditional pit latrine seemed to be the most favoured sanitation option although it is regarded as an unimproved technology on the sanitation ladder. The Blair ventilated improved pit latrine appeared to be less popular due to financial reasons, the major barrier in adopting a rural sanitation option.

Change in hygiene behaviour and safe water storage could be key in preventing diarrhoeal diseases in the six wards where source water was polluted, HWT was poorly done and open defaecation was practised.

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