International Journal of Science, Technology and Society
2014; 2(1): 1-5
Published online January 10, 2014 (http://www.sciencepublishinggroup.com/j/ijsts)
doi: 10.11648/j.ijsts.20140201.11

Practices and perceptions of biosand filter users in treating drinking water in a rural district of Zimbabwe

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To cite this article:
KANDA Artwell, GOTOSA Jephita, MASAMHA Blessing, NYAMADZAWO George, MISI Shepherd Norman. Practices and Perceptions of Biosand Filter Users in Treating Drinking Water in a Rural District of Zimbabwe. *International Journal of Science, Technology and Society.* Vol. 2, No. 1, 2014, pp. 1-5. doi: 10.11648/j.ijsts.20140201.11

Abstract: A field survey was conducted in Bindura district of Zimbabwe in January 2012 to evaluate the perceptions and practices of rural households on biosand filters after two years of use. A questionnaire was administered to 33 sampled households during an unannounced visit to solicit information on demography, use of biosand filters and safe water storage. A field kit (Oxfam delAgua) was used to estimate faecal coliforms in 83 water samples drawn from the household source (17), filter-spout (33) and storage vessel (33). Results indicate that biosand filters were structurally intact and operational with a mean treatment efficiency of 95.9±1.4% (*n=33*) suggesting a high sustained use. Households (*n=33*) expressed great satisfaction with the use of biosand filters as they got adequate drinking water (90.9%). Households cited improved health (100%), clean water (100%); good taste (100%) and ease of use (90.9%) as perceived benefits of using the biosand filter. The mean faecal coliform level of biosand filter-treated water (3.2±1.4cfu/100ml) was significantly lower than that of source water (37.1±8.9cfu/100ml) ($p<0.05$). Biosand filters (78.8%) provided safe drinking water (0cfu/100ml) but were recontaminated (26.9%, *n=26*) during storage. Poor household hygiene, unrecommended storage methods and withdrawal practices were attributed to recontamination of stored treated water.

Keywords: Biosand Filter, Household Water Treatment, Safe Water Storage, User Perceptions

1. Introduction

A major challenge faced by the world today in the water sector is improving access to safe drinking water to rural people in developing countries. The access to clean water in rural areas is difficult [1]. Household water treatment (HWT) technologies that have been tested and proven in the field are well documented [2] and have non sustained use. The biosand filter (BSF) has been designed for household use [3, 4]. Both field and laboratory studies have reported its ability to reduce certain types of pathogens in source water in varying proportions [3, 5].

The bush pump and protected deep wells (>15m) were recommended as improved water sources for rural water supply by the Zimbabwean government. However, the bush pump has been criticized for its long down times and high maintenance costs while deep wells usually dry up during the long hot and dry season (May - October). The deep wells are also prone to contamination during water withdrawal which is done manually using ropes (bark, polythene) or chains. In this case, the BSF becomes a potential alternative HWT option for supplying clean drinking water at the point of use in order to improve access to clean water and the health of rural communities.

The study sought to investigate the perceptions and practices of households on the use of BSFs two years after their installation. It is these perceptions and daily practices of BSF users that will affect the acceptability, performance and ultimately, the sustainability of this 'new' technology. It is not clearly known how rural households are using BSFs in a post-emergency phase of the disaster cycle in Zimbabwe. Thus the levels of faecal contamination in primary water sources (PWSs), BSF-spout and water storage containers (WSCs) as well as the effectiveness of the BSFs in reducing the faecal coliform (FC) levels in household drinking water were determined.

2. Materials and Methods

2.1. Description of the Study Area

The study was carried out in 3 villages of ward 12 in Bindura district (17^o 30’ 18” S; 31^o 19’ 49” E) in north-eastern Zimbabwe. Bindura is a small (142 231 persons) mining and agricultural town. The district has 21 wards divided into 210 villages. Only three villages of ward 12 received 33 BSFs (Timuri: 17, Tsunda 8 and Murungweni: 8) from an international relief organisation. Bindura district has aunimodal rainfall pattern with rainfall ranging from 750 to 1 000mm/year and mean annual temperature of 15 – 20^{o}C. The water supply coverage was 58%.

2.2. Household Perceptions and Practices on the Use of the Biosand Filter

Perceptions and practices of households with BSFs were solicited through an unannounced visit [6] to all households. A questionnaire was administered at each household in the local vernacular language (*Chishona)* targeting the female head of the household. The questionnaire sought information on family demography, BSF quality of construction, proper installation and use, safe water storage practices and perceived benefits of using BSFs in treating source drinking water. The questionnaire was developed from a BSF monitoring form [7]. It was revised after field pre-testing to ten households (30%) with BSFs that were randomly chosen from the study area. Confidentiality of information was preserved by assigning numerical identities to all households (HH1–HH33) throughout the study. Verbal consent to participate in the study had earlier been sought during BSF installation when BSF beneficiaries were told that the BSFs were going to be monitored. The authors were neither involved in the selection of BSF beneficiaries nor the installation of the BSFs.

2.2.1. Quality of Construction and Installation

The quality of construction of the BSF was determined regarding the presence of leaks or cracks, lid and the diffuser plate. Proper installation considered the presence of an installation inspection certificate at each household. The concrete BSFs were constructed by a locally contracted company. They were installed and inspected by trained field technicians.

2.2.2. Use and Safe Water Storage Practices

The proper use of BSFs were operational and maintenance issues which included cleaning of the filter spout, intermittent use, consistent use of the same PWS and turbidity <50NTU, flow rate, recommended filter cleaning technique (swirl and dump) and frequency of cleaning, observing recommended pause times, filter feed or the charge volume and microbial reduction efficiency. Safe water storage practices were investigated considering the water withdrawal techniques, type and cleanliness of the storage container, microbial recontamination, household hygiene practices and the existence of different water collection and storage containers. A standardized check list was used household hygiene practices.

2.2.3. Perceived Benefits of Using Biosand Filters

This was investigated by considering the incidence of diarrhoeal diseases in the household, characteristics of the treated water to the consumer (aesthetic) and other household-specific benefits.

2.3. Microbiological Quality of Drinking Water

The microbiological quality of water samples drawn from 17 PWSs, 33 BSF-spouts and 33 WSCs was determined by estimating FC levels using the membrane filtration method. Water samples were collected in sterile 100ml polythene sample bottles (field kit), labelled and analysed within 8 hours [4]. The water samples were manually vacuum-filtered (direct or after dilution) through a 0.45µm membrane. These were then placed on a growth pad saturated with about 2ml membrane lauryl sulphate broth in petri dishes and incubated in a temperature-calibrated portable incubator at 44.5^{o}C for 16-18 hours (Field kit Manual). Filter apparatus and flasks were methanol sterilized between water samples. FCs were identified by their characteristic yellow colony on this medium. All materials and consumables that were used were mainly from the field kit except for distilled water that was prepared at Bindura University of Science Education, Chemistry laboratory.

The field method was validated by analysing 33% of duplicate water samples (across water sources) [1, 6] using the membrane filtration method in a microbiology laboratory at Bindura University of Science Education, Astra Campus. All samples were tested for FCs running 10% duplicate [7] and blank tests in between daily determinations [6, 7].

2.4. Statistical Analyses

Data were analysed with SPSS for Windows (version 16.0) (SPSS Inc, Chicago, IL, USA). Descriptive statistics were used to analyse questionnaire responses and to estimate mean FC levels in water samples from PWS, BSF-spout and SWCs. The mean BSF FC reduction efficiency (performance) was determined as the difference between FC content in PWSs and BSFs, and then expressed as a fraction of the FC content in PWS. The result was finally expressed as a percentage.

A paired samples t-test was run to determine any significant differences between mean FC levels determined using the field and laboratory procedures. Statistical differences in microbial content between water samples from PWSs and BSFs, and between BSFs and SWCs were investigated using an independent samples t-test. A $p<0.05$ was considered statistically significant.

3. Results and Discussion

The average rural household size was 5.5 persons. BSFs in the study area supplied reasonably safe drinking water (1-10cfu/100ml) [8] to about 182 persons including 25 children under the age of five.

3.1. Perceptions and Practices of BSF Users

All BSFs were still in use after two years of their installation suggesting a high (100%) sustained use. This value appeared to be relatively higher than values of up to 88% that were reported elsewhere (4, 7], and for up to 8 years of BSF use [5]. The high sustained use observed in the study could be due to the relatively short time of BSF evaluation post intervention, or the relatively small sample size that had BSFs. The possible effect of the cholera outbreak in the same area (2009- 2010) on the use of the BSF was beyond the scope of this study.

3.1.1. Quality of Construction and Installation

All households had their installation inspection certificates which were availed upon request. The presence of inspection certificates was considered as evidence for proper BSF installation. All BSFs were structurally intact without leaks and with the original diffuser plates. Structurally intact and properly installed BSFs were assumed to function well and any observed changes in the treated water were assumed not to be due to structural defects or installation problems.

3.1.2. Operation and Maintenance of BSFs

BSFs are well operated when they are used intermittently observing recommended pause times, using the same source of water of turbidity <50NTU, presence of a 5cm standing head and proper cleaning among other factors [9]. It was observed that most households (75.8%) did not pre-treat their source water although 29.4% had turbidity values >50NTU prompting filter cleaning (27.3%). During the field visit, 54.5% of the BSFs were found running. This resulted in the flat top sand layer and the 5cm water head not being observed in them. These two characteristics are normally observed during the pause period. The recommended intermittent use of one or two days was reported in 90.9% of the households. These observations may suggest that BSFs were well operated and maintained in most households. This was also seen by the low level of coliforms in BSF-treated water and the mean high performance of the BSFs. It could also be suggested that BSFs are easy to use, operate and maintain as regarded in literature [9] leading to users accepting the technology.

In some cases, BSFs were shared among households (15.2%). This practice could have resulted in increased frequency of use of BSFs. The effect of sharing a BSF by more than one household did not show any significant difference (p>0.05) in resultant FCs levels with those that were not shared. Instead, BSFs showed that they were performing well and households were getting enough drinking water. Multiple 20L-charges were reported to be possible [10]. The practice of sharing (BSFs) by households is common in African culture where there is high social interaction. Potential effects that could be associated with sharing of BSFs could be on the treatment efficiency of the BSF. This may be more pronounced in cases where different households use different PWSs or even the same PWS that has turbid water >50NTU.

Results indicated that 75.8% of the households consistently used the same PWSs as filter feed water although 29.4% of them had turbidity values >50NTU. This was evident in 12.1% of the BSFs that had flow rates <0.4L/minute. A flow rate of 0.4L/minute required at least 50 minutes to treat 20L of feed water. This value seemed acceptable as households indicated that they were getting enough drinking water (90.9%). Very low flow rates may make users impatient and not always filter their water [9]. The observed flow rates were higher than 0.16L/minute considered convenient in an African household [3]. Similar reports of decreasing flow rates (13%) with increasing turbidity were also observed [6].

The microbial reduction efficiency of the BSF that was determined in this study (95.96%, *n=33*) is consistent with a large body of literature. A 98.5% bacterial removal efficiency (*n=92*) after 2.5 years of BSF use [6], a 96% reduction efficiency for *E.coli* [1] and 80% treatment efficiency after 1 year [7] were reported. The relatively high value observed in this study could have been a result of well operated and maintained filters that were structurally intact. BSFs are most effective and efficient when operated intermittently and consistently [9]. A few BSFs still provided unsafe drinking water. Environmental factors, poor operation and faulty maintenance practices were cited for poor BSF performance [3, 11].

3.1.3. Sustained Use and Perceived Benefits

Results seem to indicate that households used BSFs for the reasons: ease of use (75.8%), provision of enough household drinking water (90.9%), perceived health benefits (100%), better aesthetic water quality such as clear water (93.9%) and better taste/odour (75.7%). In the past 2 months only one confirmed case of a diarrhoeal incidence was reported. These observations may suggest a high level of user satisfaction with the technology. Perceived BSF user benefits, ease of use and the provision of enough clean drinking water seemed to encourage the use of BSFs. This is consistent with other findings where user satisfaction was reported [3, 6].

There were few cases where households with BSFs used other HWT technologies (12.1%) to treat water while other households (15.2%) at times used unfiltered water for drinking. It was observed that in such cases households had moved out of their homes to temporarily stay on their fields that were far away from their homesteads. Their BSFs were left locked up and out of use. Recommended pause times of one or two days were not observed. This revealed the limitation of the BSF that it could not be easily transported wherever users go.

In the event that improved water sources were made available, most households (81.8%) expressed unwillingness to surrender their BSFs while 18.2% reported that they were not sure as to how they would react under such circumstances. None of the households indicated willingness to surrender their BSFs. However, they indicated that in times of failure of the improved water supplies, they would use them.

3.1.4. Safe Water Storage Practices

In 87.9% of the households two or more water containers were present although 20.7% of them were not recommended for water storage. Recontamination of treated water often occurs by using one container for fetching and storage of water, using unclean storage containers and during water withdrawal. Not recommended withdrawal methods of stored water were practised in 24.2% of the households.

3.2. Microbiological Quality of Drinking Water

Mean FCs in 33.3% (*n=33*) of duplicate water samples showed no significant differences between the field (45.6±15.2cfu/100ml) and laboratory (40.4±16.4cfu/100ml) analyses ($p>0.05$). This may suggest that the field method could be an appropriate procedure for use in estimating FCs in the field. The use of field kits for estimating microbes has been reported [7].

3.2.1. Primary Water Sources

There were significant differences ($p<0.05$) between mean FC levels of PWSs and BSFs and between BSFs and SWCs (Fig. 1). Household FC levels in PWSs varied widely depending on a number of factors that included the type of the water source and its vulnerability to contamination from external sources.

Mean FCs in water samples from PWSs increased in the order: Tsunda < Murungweni < Timuri. In water samples from SWCs they increased in the order: Tsunda < Timuri < Murungweni. The study showed that PWS were microbiologically polluted when using international standards [8] with more than 75% of water samples having FCs >10cfu/100ml. This could have been because all PWSs were shallow wells of depth ranging between 1 and 10m with more than 50% of them not protected while some were accessed by livestock.

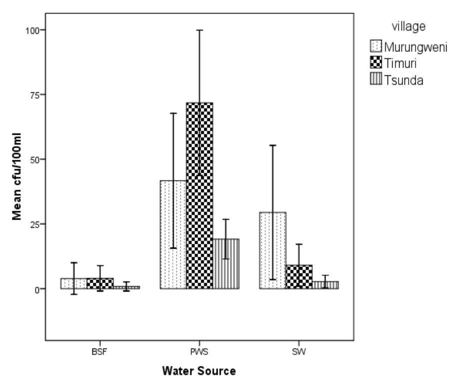

Fig 1. *Mean FCs in different water samples*

Water abstraction was by means of a rope (bark, polythene or iron chains) attached to a collecting can. This was a possible source of water contamination by handling.

Most PWSs were shared by households e.g. in Timuri village a PWS was shared by more than 20 households, six of which had BSFs. The measured mean PWS faecal level was however smaller than the average of 462cfu/100ml reported [11]. Drinking polluted water puts households at health risk of contracting diarrhoeal diseases. Sharing of one polluted PWS by different households has the potential of spreading diarrhoeal diseases quickly, while treating such a source could have the effect of reducing the spread.

3.2.2. BSF-Treated Water

The proportions of BSFs that provided safe, reasonably safe, polluted and dangerously polluted drinking water when using international standards [8] are shown (Fig. 2). Of the 78.8% (*n=33*) of BSFs that provided safe drinking water, 27% (*n=26*) of them were recontaminated during storage. BSF-treated water had significantly lower FC levels (3.2±1.4) than treated stored water samples (13.1.±4.3cfu/100ml) ($p<0.05$) suggesting point of use recontamination. However, the BSFs did not remove all pathogens in source water and it had no residual disinfecting effect [11] making the treated water susceptible to recontamination during storage.

3.2.3. Stored BSF--Treated Water

The proportions of stored water samples that provided safe, reasonably safe, polluted and dangerously polluted drinking water [8] are shown in Fig. 2. BSFs and SWCs provided drinking water (3.2±1.4 and 13.1±4.3cfu/100ml) with lower FCs when compared to PWSs (37.1±8.9cfu/100ml) ($p<0.05$) despite a few cases in which BSFs provided unsafe drinking water (21%) and were recontaminated (33%). This observation is consistent with results reported in literature [12]. Cases where treated stored water contained >0cfu/100ml are common.

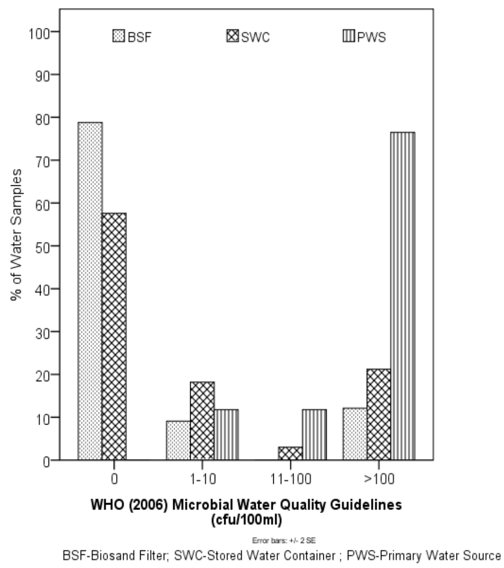

Fig 2. *Proportion of water samples of a given microbial quality [8]*

About 23% of such cases, including 6% of BSFs which had >100cfu/100ml were reported [6]. Deterioration of the quality of stored drinking water has been reported [4] and can be attributed to poor hygiene.

4. Conclusion

The study sought to investigate the use, perceptions and practices of rural households that were using BSFs to treat drinking water in a developmental era (post emergency). During the dry and hot season, households use different water sources that are usually of poor quality for drinking as local sources may run dry.

Results showed that there was high sustained use of BSFs two years after their installation. The communities seemed to have accepted the BSF well mainly because of their perceived health benefits, aesthetic drinking water characteristics and ease of use. These appeared to encourage households to use BSFs. BSFs were capable of reducing FC levels in polluted water sources and provide reasonably safe microbiological drinking water quality. Observations indicated that poor household hygiene and water storage practices caused recontamination of treated water. Future work will have to consider the long term sustainability of the technology as well as its scalability. General household hygiene education including safe water storage practices and post disinfection may improve the provision of clean drinking water and prevent diarrhoeal diseases in households using BSFs in rural Bindura district.

Acknowledgements

The authors would like to acknowledge the support that they got from International Medical Corps Zimbabwe, Ministry of Health and Child Welfare (Bindura District) and the households of Timuri, Tsunda and Murungweni villages for their participation in making this study possible.

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