Kale Heywet Ethiopia
Household Water and Sanitation Project Evaluation
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Nomenclature

BSF – BioSand Water Filter

CIDA – Canadian International Development Agency

cfu / 100 mL – colony forming units per 100 mL sample

KHC – Kale Heywet Church

KPC – Knowledge Practices and Coverage

L - Liter

n – Number of samples included in the calculation

L / c * d – Liters per capita per day

NTU – Nephelometric Turbidity Units

SPIR – Samaritan's Purse International Relief

WHO – World Health Organization

Abstract

The World Health Organization (WHO) has estimated that only 11% of the rural Ethiopian population have access to an improved water source and 4% have access to improved sanitation facilities (WHO; UNICEF, 2004). In 2003, the Kale Heywet Church (KHC), Samaritan's Purse International Relief (SPIR) and the Canadian International Development Agency (CIDA) began Phase II of a Water and Sanitation Project (the Project) to improve rural household water quality through the introduction of BioSand water filters (BSF) and health and hygiene education. In October 2005, SPIR and KHC conducted a mid-term assessment of the current Project to assess the progress on Project objectives and performance indicators.

The evaluation assessed Project and non-Project villages in Southern Ethiopia, with similar populations and water sources, on indicators of hygiene, sanitation, and health. Project households were also evaluated on the performance of the BSF. The BioSand filters evaluated removed on average 1.86 log (98.6%) of Total coliform, 1.57 log (97.3%) of *E.coli* and 85% of turbidity from the source water.

There was a significant difference observed between Project households and improved health indicators as compared to non-Project households. The Project population reported 65% less occurrences of worms, 89% less occurrences of skin infections, 92% less occurrences of vomiting and 82% less occurrences of diarrhea than non-Project households.

Regarding water management, sanitation and hand washing practices, 78% of Project households stored their water in a clean, covered container versus 36% of non-Project households. 24% of Project households had access to improved sanitation through an improved or protected pit latrine and 48% with an unimproved or unprotected pit latrine compared to 0% and 6% of non-Project households, respectively. 22% of Project household caretakers identified washing hands after defecation and one other appropriate time, which contrasts with 0% of non-Project households. It is recommended to increase educational messages regarding hand washing that target specific appropriate times such as after cleaning a child who has defecated in order to increase health and hygiene status.

It was observed that the BSF filters are being challenged with high levels of faecal contamination and turbidity. This lends to suggested pre-treatment improvements of raw water quality to decrease the burden on the BSF by promoting settling and straining of water sources and post treatment chlorination. As well, special detail by the implementers must be taken to ensure the flow rates of installed BSF filters are within the specified operating parameters.

1. INTRODUCTION

The World Health Organization (WHO) has estimated that only 11% of rural Ethiopians have access to an improved water source and only 4% have access to improved sanitation facilities (WHO; UNICEF, 2004). As well, Ethiopia is ranked 170 out of 177 countries in the world according to the UN Human Development Report 2005. The burden of water-borne and water washed disease has a significant impact, especially for children under five years of age; Ethiopia has an under five years of age mortality rate of 169 per 1000 (UNICEF, 2005). These facts are further complicated by minimal investments in rural household water, sanitation and health and hygiene promotion programs.

The Kale Heywet Church (KHC) in Ethiopia has been implementing a Water Supply and Sanitation Program since 1986, incorporating spring protection, gravity water supply, well drilling, community education, maintenance training and, more recently, the household point of use technology BioSand water filter (BSF). The BSF technology was first introduced to Ethiopia in 1998 and has been supported by the Canadian International Development Agency (CIDA) with two multi-year Water and Sanitation projects starting in 1999. The current Water and Sanitation Project is in the final year of a three-year phase funded by CIDA and Samaritan's Purse International Relief (SPIR), hereafter referred to as the Project. The purpose of the Project is to improve water quality at the household level, sanitation and hygiene practices amongst 6,630 rural Ethiopian households, or approximately 53,000 beneficiaries through the installation of 6,630 point-of-use BioSand filters, provision of water storage containers, health, hygiene and sanitation education, encouraging the construction of latrines, BSF user compliance and maintenance education and the training of local technical experts in the BSF technology.

The BioSand water filter is an intermittently operated slow sand filter that was designed by Dr. David Manz at the University of Calgary, in Canada. It incorporates a schmuzdeke to biologically treat drinking water as it flows by gravity through the filter media. BSFs are constructed by the household recipients themselves using locally procured materials. These same recipients are then trained how to use and maintain the BSF as well as various aspects of health and hygiene practices through community teaching sessions and household visits.

2. OBJECTIVE

The specific objectives of this Report are to:

a) Measure achievement of specific water, hygiene, sanitation and health indicators.
b) Assess aspects of BSF performance and user compliance with the BSF technology
c) Identify and define key recommendations to improve the Project.

The measurement of these objectives is achieved through examining the following performance indicators that were selected during the planning of the Project:

a) Improvement in water quality in terms of Total coliform, *Escherichia coli*, and turbidity reductions
b) % reduction in symptoms of water and excreta-related diseases such as parasitic worms, diarrhea, skin and eye diseases.
c) % of households storing water in a clean, covered container and the % of households treating their drinking water at the household level
d) % of households that use an improved sanitation facility
e) % of household caretakers washing their hands properly with soap and at appropriate times
f) % of households complying with BSF usage and maintenance specifications

This report is a mid-term evaluation of the progress in the Project indicators which is necessary to allow staff the opportunity to improve the Project to achieve the desired outputs. The results of the midterm evaluation will provide guidance for a final evaluation at the end of the three year Project. Power calculations in the sample size determination for the final evaluation will account for the significance to determine health improvements.

3. METHODS

The methodology section discusses the procedures and references that were used in the design and implementation of the evaluation. The methodology includes the determination of the survey instrument, determination of sample size, description of survey sample size selection, water quality testing parameters and statistical analysis.

3.1. Determination of the Survey Instrument

The methodology for developing the survey instrument was adapted from the *Water and Sanitation Indicators Guide* (USAID, 1999); *Assessing Hygiene Improvement* (USAID, 2004); *Knowledge, Practices and Coverage (KPC) Survey 2000+ Field Guide* (Child Survival Technical Support Project, 2001), *Rapid Knowledge, Practices and Coverage (KPC) Survey: Household Water Supply, Sanitation and Hygiene* (Child Survival Technical Support Project, 2005) and *Methodology and Sampling Issues for KPC Surveys* (Johns Hopkins University, 1999).

The survey instrument was developed in English and translated into Amharic, the national language of Ethiopia, field tested and revised with the assistance of trained surveyors and Project management before being implemented. As a control, the survey was back translated from Amharic into English after the field trial.

The survey instrument was comprised of 61 questions for Project households and 33 questions for non-Project or control households. Survey questions were grouped into general categories including household water management practices, water filter usage and maintenance practices, health, hygiene and sanitation practices (including safe hand washing, and usage of latrines).

3.2. Determination of the Sample Size and Household Selection

The sample size for the evaluation was determined using simple random surveying methods from villages in Oromyia and Southern Nations, Nationalities and Peoples Region where the Project has been implemented. Initially, all Project villages were included in the random village selection process, but due to the limitations of setting up a field laboratory for microbiological testing and the lack of access to some areas because of the rainy season, a village shortlist was created. The villages included in the shortlist were within transportation range of the remote field laboratory to ensure that water quality samples could be analyzed within 24 hours of sample collection. Consequently, of the available Project villages only villages in Oromyia were surveyed.

Household selection in the villages followed simple random sampling procedures. Each of the three surveying teams located the centre of the village and spun a pen or stick to randomly determine the direction that each team would pursue. Every third household was selected for the survey along the direction that had been determined for each of the survey teams. Wherever possible, the female caretaker of the household was interviewed, as females are typically responsible for water and health in Ethiopian culture. If the female caretaker was not available at the household, the next preference was for an adolescent female, followed by the eldest male. If no adults or adolescents were available, the household was skipped. Respondents participated in the survey voluntarily and steps were taken to ensure the confidentiality of the respondent while participating in the survey.

3.3. Control Households

A control group of households was selected to establish baseline data to compare against Project households. This control group consisted of households identical in culture and language group and had similar populations as Project villages. Communities are initially selected to participate in the Project based on their reliance on contaminated surface water sources for their drinking water and are almost entirely saturated with BSFs. As such, the control households had to be carefully chosen from communities that had not been exposed to the Project and also reliant on contaminated surface water sources. Only two villages in the district satisfied these criteria.

3.4. Description of Survey Sample Size Selection

A sample size of 50 Project households and 50 control households was determined using the simple random sampling formula $n = z^2 (pq) / d^2$ with the parameter values listed below as:

n = sample size
z = statistical certainty, or confidence
p = prevalence
q = 1-p
d = error

The sample size of 50 was calculated based on 90% confidence level and 50% prevalence of BSF households in Project villages. The prevalence of BSF households is actually higher than 50% in the Project villages; however, 50% represents the lowest threshold of coverage.

Village names were randomly drawn from the short listed villages, and 10% of the total Project households in the village were cumulated until the sample size of 50 was reached. Table 3.1 is a summary of the Project villages and the number of household surveyed in those villages. The control or non-Project villages are shown in Table 3.2

Table 3.1: Summary of Project Evaluation Villages

Region	District	Village	Total Households	BSF Filters	Households Surveyed
Oromyia	Liben Woreda	Filtino	152	85	6
Oromyia	Liben Woreda	Hidi	186	150	15
Oromyia	Liben Woreda	Katila	234	200	20
Oromyia	Liben Woreda	Gende Gorba	214	95	9

Table 3.2: Summary of Control Villages

Province	District	Village	Total Households	Households Surveyed
Oromyia	Liben Woreda	Yatu	156	22
Oromyia	Liben Woreda	Giche	176	28

3.5. Water Quality Testing Procedures

Standard Methods for the Examination of Water and Wastewater (APHA, 1998) procedures were followed in the analysis of the water quality samples. In order to test water samples, a field laboratory was set up at a KHC field office in Oromyia. Water samples collected during the survey were transported to the laboratory in hand held coolers with ice packs, and refrigerated so that analysis could be completed within 24 hours of water sample collection. Total coliform and *E. coli* were isolated from water samples using the membrane filtration method, cultured on Hach® mColiblue 24 broth at 37ºC and enumerated after 24 hours of incubation. Turbidity of each water sample was measured using a Hach 2100 portable turbidity meter. The raw data was collected and entered directly into an electronic spreadsheet.

For the Project households, one raw water sample and one filter effluent sample were taken from each household. The raw water samples were drawn directly from water storage containers in the household using 100mL Whirlpak® sample bags. For the effluent water samples, the filter spout was first sterilized using a dilute chlorine bleach solution and raw water was then poured into the filter until the filter basin was completely full. When half of the water in the basin had run through the filter to flush out the spout, the effluent water sample was taken from the filter spout with the Whirlpak bag. The sample bags were then immediately stored in a portable cooler.

One water sample was taken from each of the control households directly at the household. If a control household treated their water by settling, straining, filtering, boiling or chlorinating, the sample was taken after the treatment had been implemented to ensure that the water sampled was that of the drinking water consumed by the household. Taking samples from households using the settling method proved difficult, as there was no standard time limit that households consistently followed to settle their water and such times could not always be determined when the sample was taken.

3.6. Statistical Analysis

The survey questionnaire was coded and entered into SPSS version 13 in order to conduct statistical correlation analysis of both categorical and numerical data. 95% confidence parameters were used to determine significance, based on P value < 0.05. As well, hand calculations were used to determine t-test confidence intervals necessary to compare significant data trends between Project and non-Project data sets. However, this trend observation in the data is limited as the sample size was determined to calculate benchmark, or mid-term data rather than allow for complete significance between two sample groups.

4. RESULTS AND DISCUSSION

The following section discusses general household characteristics and water sources, water treatment and storage practices, results of drinking water quality, water and excreta-related diseases, usage of latrines, hand washing practices and BSF usage and maintenance compliance results.

4.1. General Household Characteristics & Water Sources

The average family size of the Project Households is 6.5 people whereas the average family size per non-Project household is 5.4, which relates to a larger total population surveyed from the Project households. The housing conditions vary between Project and non-Project households in roofing material, but the floors and walls are similarly constructed from mud in 100% of the households surveyed. In the Project villages, 20% of the roofs are constructed from thatch and 80% are constructed from corrugated steel, whereas in non-Project villages 54% of the household roofs are constructed from thatch and 46% of the roofs are constructed from corrugated steel.

Although 98% of both Project households and non-Project households use surface water as their main water source, 56% of Project households use river water compared to 96% of non-Project households that use pond water. In the case of the Project villages, only 2% of the water sources are protected compared to 80% of water sources protected in non-Project villages. For Project households, the average time to travel to the water collection point and return to the home is 44 minutes, similar to the average collection time of 46 minutes for non-Project households.

Project households use on average 13.7 L of water per person per day, whereas non-Project households use on average 16.8 L of water per person per day. 32% of Project households consume greater than the Sphere Standard of 15 L of water per person per day per household and 80% consume more than 10L per person per day. Water Source and Quantity data is included in Table 4.1.

Table 4.1: Water Source and Quantity Characteristics

		Project Households (n=50)	Non-Project Households (n=50)
Primary Water Source	Surface water – River	56%, (28)	2%, (1)
	Surface water – Pond	28%, (14)	96%, (48)
	Surface water – Irrigation canal	14%, (7)	0%
	Dug shallow well	2%, (1)	2%, (1)
	Borehole	0%	0%
	Rain Water	0%	0%
	Don't know	0%	0%
% of water sources protected		2%, (1)	80%, (40)
Average time to collect water and return to household		44 minutes	46 minutes
Volume of household water use per person per day (L/c*d)		13.7	16.8

4.2. Water Quality

In both non-Project and Project households, initial water quality is fairly similar, with high levels of Total coliform, *E.coli* and turbidity. The average total coliform concentration in the water samples taken from non-Project households is 230 000 cfu/100mL across all methods of treatment, Table 4.2. In Project households using BSF technology to treat drinking water, the average reduction of total coliform between source and effluent water is 1.86 log (98.6%) reduction across 50 BSF samples and 1.6 log (97.3%) reduction of *E.coli* with an average source water total coliform concentration of 132,303 cfu/100mL and an average source water *E.coli* concentration of 28,000, Table 4.3. The average reduction of turbidity between source and effluent water for Project households is 85%. The overall average turbidity of drinking water samples from non-Project households is 230 NTU compared to an average turbidity of treated drinking water samples from Project households of 48 NTU.

Table 4.2: Non-Project Household Water Quality

Treatment Method	Average Total coliform (cfu/100mL)	Average *E.coli* (cfu/100mL)	Average Turbidity (NTU)
No water treatment	347 000	8 800	280
Settling in one container	9 700	9 500	241
Straining through cloth	197 000	9 300	198
Boiling	NA	NA	NA
Chlorination	NA	NA	NA

Table 4.3: Project Household Water Quality Results

	Raw Water Sample	BSF Treated Water Sample
Average Total coliform (cfu/100ml)	132 000	2 800
Average *E.coli* (cfu/100mL)	28 000	400
Average Turbidity (NTU)	240	48

4.3. Health Indicators

The health indicators investigated during the evaluation are presented in Table 4.4. These health indicators and their prevalence in the community is one of the measurements of the long-term health impact of the Project. There was no medical professional present during the survey and thus households were asked recall questions on specific health conditions. Each household reported the number of individuals in their homes that had suffered from intestinal worms, skin or eye infections, abdominal pain, vomiting and diarrhea in the previous two weeks. These indicators are reported as a percentage of the total population included in the survey. There is an observed lower reported point prevalence of intestinal worms, skin and eye infections, abdominal pain, vomiting and diarrhea between Project households and non-Project households. Project households report experiencing 65% less occurrences of worms (95% confidence interval (CI), 1.1% - 8.1%), 90% less occurrences of skin infections (95% CI, 0.5% - 4.8%), 69% less occurrences of abdominal pain (95% CI, 2.9% - 11%), 92% less occurrences of vomiting (95% CI, 1.1% - 5.7%) and 82% less occurrences of diarrhea (95% CI, 0.4% - 5%). Project households were observed to have 43% less occurrences of eye infections than non-Project households, but this difference was not statistically significant (95% CI, -0.4% - 7.7%).

Table 4.4: Point Prevalence of Reported Health Conditions

Health Indicator	Project Households (Population n = 327)	Non-Project Households (Population n = 270)
Worms	2.45%, (8)	7.04%, (19)
Skin Infection	0.31%, (1)	2.96%, (8)
Eye Infection	4.89%, (16)	8.52%, (23)
Abdominal Pain	3.06%, (10)	10.00%, (27)
Vomiting	0.31%, (1)	3.70%, (10)
Diarrhea	0.61%, (2)	3.33%, (9)

4.4. Water Treatment and Storage

In non-Project Households, 26% of households drink water that has not undergone any form of primary treatment including filtration, settling, straining, chlorinating or boiling. 6% of non-Project households settle their water, 66% strain their water using a piece of rough cloth and 2% boil their water prior to drinking, Table 4.5. It is important to note that there was no consistent length of time that was observed for how long households settled their water, and no household was observed using a three-pot settling system. In contrast, 100% of Project households indicated using the BSF to treat their water with no other form of treatment after filtration. When considering how frequently households drink water that has not been treated, 2% of Project households report drinking raw water compared to 30% of non-Project households that drink untreated water everyday.

Water storage containers are distributed with each filter to help ensure that the filtered water is not post-contaminated after filtration. 78% of Project households store their filtered water in these designated containers and clean them once per week with soap or bleach. 36% of non-Project households store their water in a clean, covered container that is cleaned at least once per week with soap or bleach. The household water containers were spot checked during the survey based on visual cleanliness and 64% of all or some of the water containers in Project households were clean compared to 14% of containers in non-Project households.

Table 4.5: Household Water Treatment and Storage

	Project Households (n=50)	Non-Project Households (n=50)
Reported household treatment method		
Filtration	100%, (50)	0%
Settling	0%	6%, (3)
Straining through cloth	0%	66%, (33)
Boiling	0%	2%, (1)
No treatment	0%	26%, (13)
Frequency of drinking untreated water		
Every day	2%, (1)	30%, (15)
Few times per week	2%, (1)	2%, (1)
Less frequent	6%, (3)	24%, (12)
Never	86%, (43)	44%, (22)
Don't know	4%, (2)	0%
% of households storing water in a covered container cleaned once per week with soap or bleach	78%, (39)	36%, (18)
% of households with clean containers upon observation		
All containers clean	34%, (17)	6% (3)
Some containers clean	30% (15)	8% (4)
None clean	36% (18)	82% (41)
Could not observe/don't have container	0%	4% (2)

4.5. Sanitation

Access to improved sanitation refers to facilities that hygienically separate human excreta from human, animal and insect contact and include sewers or septic tanks, poor-flush latrines and simple pit or ventilated improved pit latrines. Based on previous baseline surveys, basic pit latrines and open defecation are the only sanitation facilities available in this area of rural Ethiopia, thus none of the other options were included in the survey instrument. Pit latrines are categorized as improved if covered with a protective slab, and unimproved if not having a protective cover. 24% of Project households have access to an improved pit latrine compared to 0% of non-Project households, Table 4.6. 48% of Project households use an uncovered latrine compared with 6% of non-Project households. 28% of Project households do not have access to any sanitation facility - improved or unimproved - and defecate openly, compared with 94% of non-Project Households who defecate openly.

4% of households in Project villages permit animals into their homes whereas 18% of non-Project households allow animals into their homes. The lack of access to improved sanitation and a higher degree of animal access to households increases the risk of fecal contamination in non-Project villages.

Table 4.6: Access to Sanitation

	Project Households (n=50)	Non-Project Households (n=50)
Type of Sanitation Facility		
Improved pit latrine	24%, (12)	0%
Unimproved pit latrine	48%, (24)	6%, (3)
No facility	28%, (14)	94%, (47)
% of households with animal access inside main dwelling	4%, (2)	18%, (9)

4.6. Hand Washing

Based on current literature on hygiene practices, it is understood that recipients poorly recollect times for appropriate hand washing and that it is very difficult to observe hand washing practices during surveying. In order to obtain a reasonable picture of hand washing practices, the survey instrument included questions about the presence of soap in the household and the percentage of caretakers and children washing hands properly with soap or ash during at least two critical times in the past 24 hours - after defecation and one of the following: before preparing food, before eating, after cleaning a child who has defecated and before feeding a child. Hand washing practices are presented in Table 4.7.

72% of Project households had soap in their homes at the time of questioning, compared to 82% for non-Project households. 22% of Project household caretakers were able to identify washing hands after defecation and one other appropriate time, which contrasts with 0% of non-Project Households. 66% of Project caretakers reported washing their hands with soap or ash in the previous 24 hours compared to 54% of non-Project caretakers.

In Project households there is a significant relationship between having soap in the household and reported hand washing with the 24 hours to the household visit (P = 0.038). As well, in non-Project households there was a significant relationship between households having soap and reporting hand washing within the 24 hours prior to household visit (P = 0.015).

Table 4.7: Hand Washing Practices

	Project Households (n=50)	Non-Project Households (n=50)
% of households with soap in home at time of survey	72%, (36)	82%, (41)
% of caretakers using soap in previous 24 hours	66%, (33)	54%, (27)
% of caretakers identifying at least 2 appropriate times for hand washing (including after defecation)	22%, (11)	0%

4.7. BSF Project Specific User Compliance Characteristics

The performance of the filters can be divided into four categories: 65-75% reduction, 75-90% reduction, 90-99% reduction and >99% reduction of Total coliform. 80% of BSF filters are removing > 90% of coliform, 10% are within 75-90% reduction and 10% are within 65-75% reduction.

Table 4.8 shows the trends of flow rate and turbidity that are observed of the BSF with increased reduction of indicator organisms. The maximum flow rate specification recommended for the BSF is 1000mL per minute. 84% of filters are operating within these criteria, whereas 10% are in the 1000-1500mL/min range, and 6% are above this range. The flow rate is controlled through the preparation of the filter media and the installation process.

Regarding influent turbidity of the source water going into the filter, 48% of samples are between 100-1000 NTU while 42% had turbidity ranging between 10-100 NTU. Effluent turbidity is less than or equal to 1 NTU in 26% of samples, and within 1-10 NTU in 44% of samples. The average reduction of turbidity across all filters is 85%. It is important to note that 48% of raw water samples were greater than 100 NTU and the average influent turbidity was 241 NTU.

After applying bivariate statistical analysis, it was observed that there are significant relationships between certain criteria and water quality, as measured by Total coliform and *E. coli* reductions. Specifically, there is a significant trend with lower reduction of Total coliform and increased BSF flow rate (P = 0.000), and an increased reduction of total coliform observed with increased volumes of water filtered (P = 0.036). Thus, ensuring the specified flow rate is critical in obtaining the best water quality possible. With the indicator *E. coli* there is a significant correlation between decreased *E. coli* reductions and increased effluent turbidity (P = 0.026). This indicates that it is essential to reduce levels of turbidity challenging the filter so to reduce the instances of *E. coli* passing through the filter.

Table 4.8: Filter Flow Rates and Turbidity

Outcomes		65-75% reduction of *Total Coliform* *(n=5)*	75-90% reduction of *Total Coliform* *(n=5)*	90-99% reduction of *Total Coliform* *(n=20)*	>99% reduction of *Total Coliform* *(n=20)*	Total (n=50)
Filter flow rate (mL/min)	<500	2%, (1)	2%, (1)	22%, (11)	34%, (17)	60%, (30)
	501-1000	2%, (1)	4%, (2)	14%, (7)	4%, (2)	24%, (12)
	1000-1500	4%, (2)	2%, (1)	2%, (1)	2%, (1)	10%, (5)
	1500-2000	0%	0%	2%, (1)	0%	2%, (1)
	>2000	2%, (1)	2%, (1)	0%	0%	4%, (2)
Influent Turbidity (NTU)	<1	0%	0%	0%	0%	0%
	1-10	0%	2%, (1)	4%, (2)	4%, (2)	10%, (5)
	10-100	6%, (3)	6%, (3)	18%, (9)	12%, (6)	42%, (21)
	100-1000	4%, (2)	2%, (1)	18%, (9)	24%, (12)	48%, (24)
Effluent Turbidity (NTU)	<1	0%	2%, (1)	10%, (5)	14%, (7)	26%, (13)
	1-10	6%, (3)	6%, (3)	18%, (9)	22%, (11)	52%, (26)
	10-100	2%, (1)	0%	4%, (2)	4%, (2)	10%,(5)
	100-1000	2%, (1)	2%, (1)	8%, (4)	0%	12%,(6)

4.7.1. Specific Usage Compliance

One aspect of the successful implementation of the BSF is the need to achieve a high degree of recipient compliance with issues relating to the usage and maintenance of the BSF as outlined in Table 4.9. Generally, households are complying to a high degree with the usage instructions for the filter. User operating criteria such as the level of the filter and the presence of the protective lid and diffuser plate all have a high level of compliance, ranging from 88% to 100% compliance. 100% of filters were observed to be functional and 92% of filters had been used in the previous 24 hours to questioning.

One area where households demonstrated less compliance is keeping food out of the filter. 16% of BSFs were observed to have food inside the filter, which increases the risk of a faecal contamination spike in the effluent water.

Crosstabulations using Chi squared parameters were used to observe significant relationships in categorical data. There was a significant relationship in the user compliance issues of the BSF having a lid and being level with the observance of food inside the BSF ($P = 0.021$, $P = 0.015$) and specifically in the data relationship of the BSF having a lid and also being level ($P = 0.006$) with total coliform reductions. Looking specifically at correlations with these factors and *E. coli* reductions, a significant relationship exists between the presence of food inside the BSF ($P = 0.029$) and decreased *E. coli* reduction.

Table 4.9: BSF Compliance Characteristics

Outcomes		Total (n=50)
The BSF lid is present	Yes	98% (49)
	No	2%, (1)
The BSF is level	Yes	88%, (44)
	No	12%, (6)
The BSF diffuser plate is present	Yes	100%
	No	0%
Observed food in BSF reservoir	Yes	16%, (8)
	No	84%, (42)
The BSF is functioning	Yes	100%
	No	0%
Last time household used BSF	Within 1 day	92%, (46)
	< 1 week ago	8%, (4)

4.7.2. Maintenance Compliance

Maintenance compliance criteria are outlined in Table 4.10. 66% of respondents know all the steps required to maintain their filter according to specifications, while 32% have some knowledge. 94% of households know when the correct time is to maintain the filter. One major specification of the BSF that can be affected during maintenance is the pause water depth, or the height of the sand column inside the filter. The design specification is to allow 5cm for pause water depth in the BSF. If sand is improperly removed from the BSF during maintenance, this depth increases. 68% of filters were functioning within the observed pause depth of 5cm plus or minus 1cm. 12% had 3cm or less while 14% had the range of 7-9cm.

66% of BSF filters had clean spouts upon observation, while 34% were dirty. Dirty spouts can re-contaminate filtered water as it leaves the filter. While 40% of households cleaned the filter spout at least once per week, 48% had never cleaned the spout at all.

Table 4.10: BSF Maintenance Compliance Outcomes

Outcomes		Total (n=50)
Household has knowledge of BSF maintenance procedures	Yes	66%, (33)
	No	2%, (1)
	Some	32%, (16)
How often is BSF maintained	1 - 3 days	32%, (16)
	Once / week	28%, (14)
	Once / 2 weeks	26%, (13)
	Once / month	14%, (7)
	Never	0%
Household has knowledge of when to maintain BSF	When flow rate slows	94%, (47)
	Unsure	6%, (3)
The BSF has visibly clean spout	Yes	66%, (33)
	No	34%, (17)
Household-reported frequency of spout cleaning	1 -3 days	18%, (9)
	Once/week	22%, (11)
	Once/2 weeks	10%, (5)
	Not remember	2%, (1)
	Never cleaned	48%, (24)
BSF pause water depth (cm)	< = 3	12%, (6)
	4 - 6	68%, (34)
	7 - 9	14%, (7)
	> = 10	6%, (3)

5. Conclusions

The indicators for evaluating the objectives and impact of the Project are summarized below. The mid-term evaluation findings will allow for a determination of how the indicators are being reached and what recommendations are needed to achieve the Project objectives for the end of Year 3, Phase II.

The first indicator was the improvement in water quality in terms of Total coliform, *Escherichia coli*, and turbidity reductions. In using BSF technology to treat drinking water, the average reduction of Total coliform between source and effluent water, is 1.86 log (98.6%) reduction across 50 BSF samples and 1.57 log (97.3%) reduction of *E.coli.* The average reduction of turbidity between source and effluent water for Project households is 85%.

The second indicator was the reduction in symptoms of water and excreta-related diseases such as parasitic worms, diarrhea, skin and eye diseases. The Project population reported 65% less occurrences of worms, 89% less occurrences of skin infections, 42% less occurrences of eye infections, 70% less occurrences of abdominal pain, 92% less occurrences of vomiting and 82% less occurrences of diarrhea than non-Project households.

The third indicator involved observing drinking water management amongst households. This is demonstrated by two indicators, the percentage of households who are storing their drinking water in clean covered containers and the percentage of households treating their drinking water. 78% of Project households store their water in a clean, covered container versus 36% of non-Project households. 100% of Project households are treating their drinking water using the BSF, while for non-Project households, 6% settle their water, 66% strain through a cloth, 2% boil and 26% do nothing to their drinking water.

The fourth indicator was to evaluate the percentage of households using a sanitation facility. It was observed that 24% of Project households have access to improved sanitation through an improved or protected pit latrine and 48% with an unimproved or unprotected pit latrine compared to 0% and 6% of non-Project households, respectively. 28% of Project households did not have access to any sanitation facility, compared with 94% of non-Project households that defecate openly.

The fifth indicator involved investigating hand washing practices and assessing caretakers for appropriate hand washing times. 72% of Project Households had soap in their homes at the time of questioning, compared to 82% for non-Project Households. 66% of Project households washed their hands in the past 24 hours and 22% of Project household caretakers were able to identify washing hands after defecation and one other appropriate time, which contrasts with 0% of non-Project households. While Project households are washing their hands at a higher frequency and at more appropriate times than non-Project households, more education is needed to teach both adults about appropriate times, and more general encouragement of the practice

Regarding compliance with BSF usage and maintenance criteria, 100% of surveyed BSF households had maintained their filters at least once in the past month, 100% of BSF filters surveyed were still functional and 92% had been used in the previous 24 hours to questioning. This demonstrates a high rate of acceptance and use by Project households. However, 32% of respondents did not know the complete steps of maintain the filter, 48% reported never having cleaned the filter spout and 16% of filters were observed to have food inside.

It was observed that the BSF filters are being challenged with extreme levels of faecal contamination and turbidity. This lends to suggested pre-treatment improvements of raw water quality to decrease the burden on the BSF by promoting settling and straining of water sources and possible post treatment. As well, special detail by the implementers must be taken to ensure the flow rates of installed BSF filters are within the specified operating parameters. This will allow for decreased maintenance by the households and allow for ripening of the biological layer in the BSF which affects improved removal efficiencies of indicator organisms.

There are programmatic modifications that can be made to improve BSF efficacy. This includes improving maintenance skills to reduce loss of filter media and encouraging households to obtain soap in order to wash hands. It is also important to know that the educational messages regarding hand washing need to target specific appropriate times such as after cleaning a child who has defecated. Educational messages must continue to encourage proper usage and maintenance improve user compliance with BSF lid usage and not storing food inside the filters. It is also important to vigilantly control the processing of the filter media to ensure that the design flow rate is adhered to.

Improved latrines are more prevalent in villages that have undergone the Project, so it is encouraged to continue in practices that preclude to latrine building in Project households. Regarding drinking water practices, Project households are drinking water that has been filtered and non-Project households are drinking water that has not undergone any form, or very rudimentary forms of primary treatment, which can affect health indicators. This indicates a difference in drinking water behavior between Project and non-Project households, with a greater scope of awareness in Project Households.

5.1. Recommendations

A number of recommendations have been made in response to the findings of the evaluation that should be integrated into the Kale Heywet Water and Sanitation Project.

- Educate implementers to decrease BSF filter flow rates through installation and filter media processing control.
- Educate households on the importance of owning/providing soap – with design to provide soap to households during the course of the project.
- Encourage greater hand washing awareness and practices through improved education promotion strategies targeting caretakers and school-aged children. This includes the recommendations to incorporate hand washing demonstrations, hand washing at appropriate times and further monitoring by Project staff.
- In order to improve water quality, pre-treatments such as settling of water sources and improved maintenance scheduling to reduce turbidity of water as well as post-treatment chlorination.

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