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Evaluation of Household BioSand Filters in Ethiopia

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Abstract

Point-of-use water treatment is growing in popularity in the developing world especially in rural areas where the costs of providing centralised systems are higher than those of their low cost counterparts. One such technology the household BioSand filter was introduced to Ethiopia by Samaritan's Purse, Canada through the Ethiopian Kale Heywet Church in 1999. Whilst the technology has been shown to be effective in terms of turbidity and pathogen removal in laboratory and field research, the long-term performance of the filter and its sustainability are not well documented. An evaluation was therefore conducted to evaluate filters in rural Ethiopia that were installed more than 5 years previously.

Filters from three villages were examined to assess filter performance, maintenance practices, user perceptions and the supporting environment. The investigation utilised a range of methods including water testing, observation and semi-structured interviews.

The results showed varied levels of usage in each village from 44% to 100%. The working filters showed an average E.coli reduction rate of 87.9% with 75.7 % of filtrate samples achieving E.coli rates of <10cfu/100ml and 81.2% achieving turbidity values of <5TU. The poor performance of some filters and low usage rates in some villages were attributed to the quality of maintenance, the lack of reinforcement of educational messages and the support provided to filter users.

The study also found the subsidised model of adoption used by the implementing NGO resulted in doubt over the continued adoption of the BioSand Filter. Without the clear definition of an exit strategy, most likely including at least some commercialisation, the clear benefits gained by current users seem unlikely to be extended to benefit others in Ethiopia.

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Abbreviations and Acronyms

BSF	BioSand Filter
CAWST	Centre for Affordable Water and Sanitation Technology
CBO	Community Based Organisation
CFU	Colony Forming Units
CIDA	Canadian International Development Agency
EKHC	Ethiopian Kale Heywet Church
FCB	Faecal Coliform Bacteria
HWTS	Household Water Treatment and Safe Storage
NGO	Non-governmental Institution
POU	Point-of-use
SP	Samaritan’s Purse
TU	Turbidity Unit
UN	United Nations
UNDP	United Nations Development Programme
WHO	World Health Organisation
WSP	Water and Sanitation Programme

1 INTRODUCTION

1.1 Context

According to the UN, water is not only a basic need but also a human right (Sobsey, 2004). Despite this recognition it is estimated that approximately one billion people worldwide lack access to adequate amounts of safe water (Duke et al., 2006), while diarrhoea kills 2.2 million people annually, a figure largely attributable to contaminated water (PSI, 2006).

Whilst attempts have traditionally focussed on providing centralised systems for water treatment and distribution, there are millions of people who already have abundant access to water but depend on rivers, streams and other unsafe water sources (Sobsey, 2004). In many such rural areas the implementation of municipal water treatment systems can be impractical and costly due to dispersed populations and poor transport infrastructure. Therefore, low cost household water treatment systems are a reasonable alternative (Duke et al., 2006).

Interest in household water treatment has grown significantly over recent years as studies have concluded that these simple low-cost household interventions may be as effective at preventing diarrhoea as other environmental approaches such as improved sanitation, hygiene (hand washing with soap), and improved water supply (Clasen et al., 2006). The increasing importance of such systems is also highlighted through the creation, by the WHO, of the *International Network to Promote Household Water Treatment and Safe Water Storage*, to support the study and dissemination of both existing and developing technologies.

One such technology, the BioSand Filter (BSF), developed by Dr Eric Mantz at the University of Calgary, Canada has been successfully introduced to many countries worldwide. The technology demands little maintenance, is primarily managed at the household level and has been demonstrated to significantly reduce the potential for diarrhoeal disease. Most studies of the filter have been limited to the laboratory or the first few years after introduction and very little research exists which explores their long-term performance and suitability.

One country identified as having significant potential for the introduction of the BSF, was Ethiopia. Ranked 170 out of 177 countries by its Human Development Index (UNDP, 2005), it is estimated 80% of health problems in Ethiopia are attributable to poor sanitation and inadequate access to safe water (Abitbol, 2000). Given that 85% of Ethiopia's population lives in rural areas (Ministry of Water Resources, 2002) and rural water coverage is estimated at only 11% (UNICEF, 2006) Ethiopia faces a bigger challenge than most in the face of the millennium development goal to "halve, by 2015, the proportion of those without sustainable access to safe drinking water and sanitation" (UN, 2006).

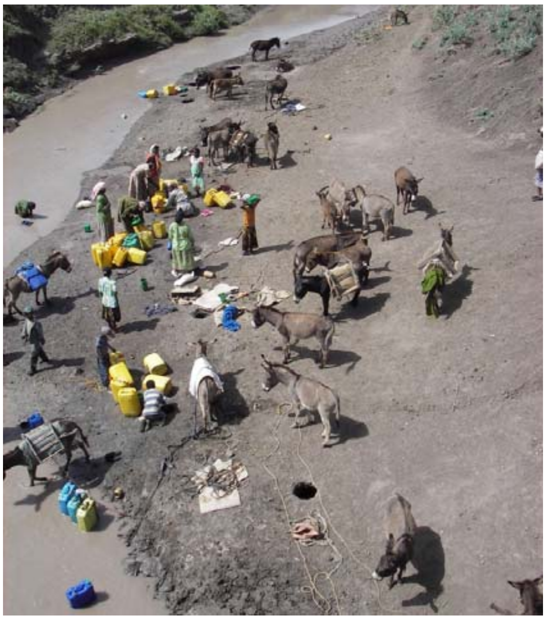


Figure 1.1.1: Water collection from the river Modjo, Oromia region, Ethiopia

The BSF technology was introduced to Ethiopia in 1997 by Samaritan's Purse, Canada through the Ethiopian Kale Heywet Church Water and Sanitation Programme and resulted in the construction of over 1,300 filters in 8 villages between 1999 and 2001. A subsequent evaluation of this pilot project (Dejachew, 2002) revealed vast improvements in water quality and paved the way for a second phase of the project which began in 2003 and is due to end in August 2006. At the conclusion of phase 2 the programme will have distributed over 8,000 filters to recipient communities making it one of the largest BSF programmes in the world. Whilst a mid-term evaluation has recently been completed for the phase 2 programme no one has returned to assess the long term performance of the filters from the original phase.

Now over 5 years since the filter programme began, EKHC, collaborating with Cranfield University, Silsoe, has taken the opportunity to return to and study the villages and households who received the original, first phase filters.

1.2 Aims and objectives

The aim of the study was:

To investigate the long-term sustainability of BioSand Filter use in rural communities of Ethiopia.

The specific objectives of the study were to:

1. Evaluate the long term performance of the BSF
2. Evaluate the adequacy of maintenance procedures used by individual householders
3. Evaluate the support provided to householders to ensure BSFs remain in use
4. Examine the user perception of the contribution of the BSF to their well-being
5. Suggest any additional programme components, which might aid the long-term sustainability of the filter project
6. Determine what practices and other water sources are used during the filter 'down time'*

* During the course of the project it became clear households had been trained to use the filter immediately after cleaning and were continuing to do so. Objective 6 was therefore dropped from the study.

2 Literature review and background

2.1 The growing importance of Household Water Treatment and Safe Storage systems

Despite recognition that safe water supplied by piped infrastructure is a noble goal (Harris, 2005) and despite considerable efforts to provide such facilities, the reality is that water supplies delivering safe water to all will not be available in the near-term (Sobsey, 2002). With an estimated 1.1 billion people reliant on unsafe yet abundant water supplies household water treatment provides a means to make safe water available much more quickly than it will take to design, install and deliver piped community supplies (Sobsey, 2002). This increased speed of delivery is made possible by:

- The simplicity and ease of construction and maintenance
- Low costs and low capital investment
- Instead of relying on community participation, point-of-use (POU) systems can be specifically targeted to individual users making the most of their greater motivation to look after their own interests rather than that of the community (Mol, 2001)

In addition, many observations support the role POU treatment plays in preventing illness by reducing the opportunities for recontamination after the treatment process through storage and handling (Mintz et al., 1995). The process can further be enhanced through the promotion of safe storage and hygiene forming the concept of Household Water Treatment and Safe Storage systems (HTWS). In recent years the growth in the use of low cost interventions for home water treatment and storage has led to dramatic improvements in water quality and reductions in diarrhoeal disease (Sobsey, 2002) in rural populations reliant on unsafe surface water and inadequate water infrastructure.

HTWS has recently come to the forefront of international debate and academic research with the publishing of epidemiological evidence suggesting that simple POU treatment is more effective than previously thought (Fewtrell et al., 2005; Clasen and Cairncross, 2004) and economic evaluations such as one recently commissioned by WHO, which single out HTWS interventions as particularly promising and resulting in health improvements with relatively low costs (Gordon, 2004). There are also several recent papers highlighting the worldwide successes of POU field studies. The importance of HTWS is further highlighted by WHO through their role in the creation of the *International Network to Promote Household Water Treatment and Safe Storage*, which aims to support the study and dissemination of existing and developing technologies (WHO, 2006b).

Currently HTWS technologies are being developed all over the world to provide effective removal of waterborne pathogens at low cost using locally appropriate techniques and materials. Whilst the technical details of individual systems vary considerably, the range of treatment methods used are relatively limited and include: heat and ultra violet radiation, sedimentation, chemical treatment methods using flocculation and coagulation and disinfection (Sobsey, 2002; Skinner and Shaw, 1999a; Skinner and Shaw, 1999b). Although many of these methods are very effective there are several limitations to each. To address some of these deficiencies there has been growing interest in filtration methods, which can reduce turbidity and colour and remove parasites such as Cryptosporidium, Giardia and Entamoeba (Sobsey, 2004).

2.2 BioSand filtration

Slow sand filters have long been known to extensively reduce pathogens in water and are one of the oldest known methods of water purification (Sobsey, 2004; Mol, 2001). Whilst it is recognised that "*no other single process can effect such an improvement in the physical, chemical and bacteriological quality of surface waters*" (Huisman and Wood, 1974), the filter is also easy and cost effective to construct and maintain. One of the reasons for its unrivalled performance is that it combines within itself so many purification functions; within a single unit it incorporates settlement, straining, filtration, organism removal, organism inactivation and chemical change (Huisman and Wood, 1974).

The most important purification processes that exist within a slow sand filter occur within the schmutzdecke, or bio-film, which forms a dense layer in the uppermost surface of the sand (Huisman and Wood, 1974). In order for slow sand filtration to be effective therefore it requires a constant flow of water passing through the filter to provide both oxygen and nutrients to the organisms that make up this important biological layer (Fewster et al., 2004). This requirement of continuous flow operation and the need for regular replacement of sand has traditionally limited slow sand filtration to use in centralised piped water systems.

2.2.1 The household BioSand Filter

Figure 2.2.1: BioSand Filter in Koftu village, Oromia region, Ethiopia

During the 1990’s Dr David Manz at the University of Calgary developed the BioSand Filter, a slow sand filter specifically designed for use at household level. Whilst the processes that occur in the sand column are similar to those in a slow sand filter the BSF is unique in being able to sustain the bio-film between uses (Samaritan's Purse, 2001), allowing the filter to be used intermittently.

This was achieved with two key modifications:

- Raising of underdrain pipe to 5cm above the top surface of the sand column. This ensures a constant aquatic environment conducive to the survival of the bio-film
- Introducing a diffuser plate to prevent the input of water from disturbing the top of the sand and the bio-film

The 5cm resting level is not arbitrary but is based on research which determined the optimum level at which oxygen diffuses through to the bio-film to allow aerobic respiration whilst still providing protection from incoming water (Samaritan's Purse, 2001). In construction of the BSF, certain rules must be followed to ensure an adequate flow rate is achieved, conditions are ideal for growing the bio-film and that the filter yields clean, safe water. The success of the filter is therefore dependent on upholding the principles outlined in Figure 2.2.2.

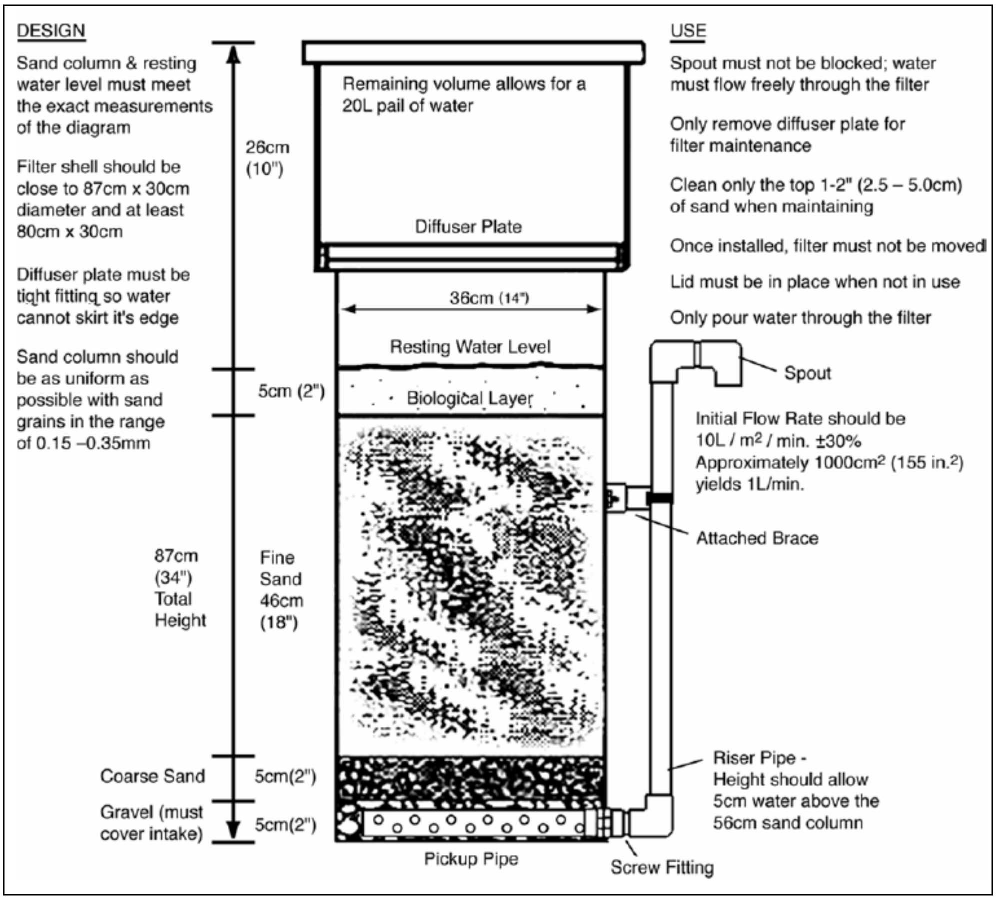


Figure 2.2.2: Diagram of the BSF outlining the rules for design (Samaritan's Purse, 2001)

Unlike its continuous counterpart, the BSF does not require periodic replacement of the top few centimetres of sand or backwashing. The filter is small enough to fit easily into almost any home, is easy to use, requires little maintenance and does not require high cost, sophisticated components nor chemical additives (Samaritan's Purse, 2001). Whilst designs have explored the use of many different materials, it is generally recognised that a concrete filter offers the highest degree of robustness and the greatest ease of construction (CAWST, undated).

The BSF does have some technical limitations. It cannot operate at freezing temperatures and its ability to treat water, like many other filters, is dependent on the turbidity of the source water. The filter will clog with large amounts of fine silts and other fine particles, which are unable to be digested by the biological layer eventually reducing the flow rate.

Unlike many filters, however, the reduction in flow rate will not compromise the quality of the filtered water. When the filter becomes ‘dirty’ the resulting reduced flow rate actually increases contact time with a mature biological layer therefore cleaning of the sand should only be carried out when the outflow of water has become inconveniently slow for the user (Samaritan's Purse, 2001). Even then the maintenance required is limited to in situ cleaning of the sand, known as ‘wet harrowing’ (see Appendix 6 for recommended procedure). This method, compared with removal of the sand, allows for the maintenance of a higher bacterial population and affects performance of the filter far less (Lukacs, 2004).

2.2.2 Filter performance

Laboratory studies have shown that the BSF is capable of removing 100% of protozoa, 99.9% of viruses (Canadian Water Treatment Research Institute, 1996) and 99.5% of bacteria (Lee, 2001) once the bio-film has had time to mature[†]. Since maintenance to the filter disturbs the bio-film, the removal rate of bacterial can be reduced to 60-70% (Lukacs, 2004; Samaritan's Purse, 2001) similar to the rates expected of an unripened filter. Such laboratory studies have also shown the ability of the BSF to produce filtrate quality of <1NTU (Buzunis, 1995).

In addition to the laboratory studies there have also been a significant number of field tests carried out on the BSF. A summary of all tests found by the researcher is included in Appendix 1. Whilst these studies vary significantly in the observed removal rate of faecal coliform, the data has been used to determine the Samaritans Purse target removal rate of 95-97% for a mature BSF (Samaritan's Purse, 2001). The studies have also shown the excellent capability of the filter to remove turbidity with several studies showing filtrate qualities of <5NTU.

It is important to realise that faecal coliform reduction rates only represent a measure of performance and do not necessarily reflect whether the filtrate was of acceptable bacterial quality since this depends on the quality of the original source water. In

[†] The length of time it takes for the bio-film to mature varies due to its variability of growing conditions in the field. Estimates in literature of the time taken to achieve full maturity vary from one week (Skinner and Shaw, 1999b) up to 3weeks (Samaritan’s Purse, 2001).

addition, whilst the BSF may remove microbes from the water, the filter technology itself provides no assurance the water will not become recontaminated during storage and use in the home.

2.3 The Ethiopian Kale Heywet Church Water and Sanitation Programme

The EKHC Water and Sanitation Programme began in 1986 with the overall aim of improving the quality of life in rural communities by improving water supplies and sanitation (Schotanous, 1995). It is funded by a range of national and international donors and works under agreements with the national government in the several regions.

Working out of 7 regional offices and employing a staff of over 75, its work to date has produced:

- Over 7,500 BioSand Filters
- Over 720 productive wells
- 105 spring protection schemes
- 35 gravity supply systems
- 52 hand-dug wells
- Over 3,000 latrines with sanplats

In addition all recipients of these technologies have benefited from health, hygiene and sanitation training as well as the capacity building of caretakers and water committees in order to provide the maintenance and management capabilities required to support for the physical hardware (Mehari, 2006).

2.4 The Ethiopian Kale Heywet Church BioSand Filter Programme

The EKHC BSF programme began as a result of a workshop held by Samaritan's Purse in May 1997. The resulting implementation programme jointly funded by Samaritan's Purse, Canada and CIDA began in 1999 and continued through to 2001, successfully distributing 1,300 filters to 8 villages. In 2003, phase 2 of the project began, again funded by Samaritan's Purse, Canada and CIDA, with the aim of installing 7,000 filters over 2 years. By March 2006 a total of 6,600 filters had been produced taking the total number of filters provided by the programme to nearly 8,000.

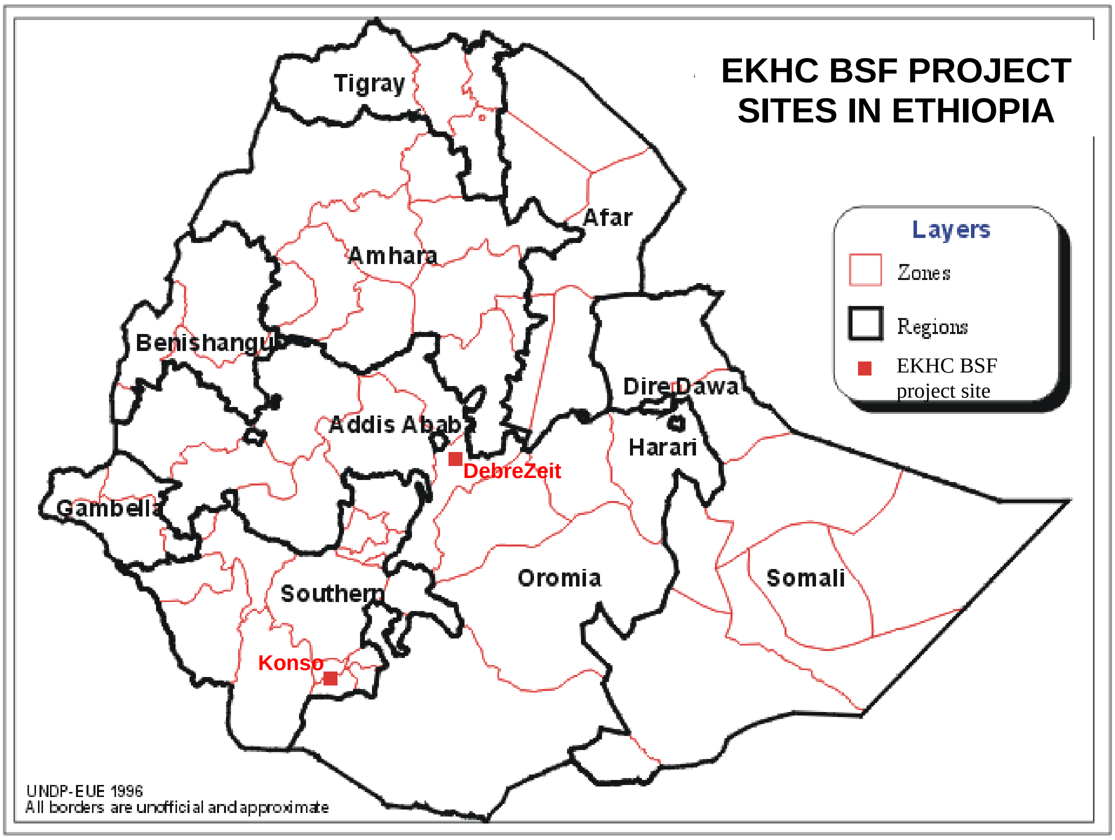


Figure 2.4.1: Map showing EKHC BSF project sites in Ethiopia [source: (UNDP-EUE, 1996)]

The programme runs concurrently in two regions, the Konso region and the DebreZeit region, under agreement from the national government. It is implemented using two separate teams, which are responsible for overseeing the whole process from initial village selection to ongoing monitoring. This process can broadly be considered in three main components:

- Community education
- Construction
- Maintenance training (Webster, 2002)

In addition, phase 2 has added a fourth component of evaluation and monitoring, which was not explicitly included in phase 1.

Community education

After selection, beneficiary communities are sensitised to their full involvement in the project and an intense health, hygiene and sanitation training programme is undertaken.

Construction

Households to receive filters are selected based on their commitment to the construction of the filter. The household is responsible for labour and transportation to their dwelling from the construction site and, if they are prepared to contribute this, they will be able to receive a BSF. The filters themselves are constructed at a central ‘construction site’ and then moved under the supervision of the health workers and technicians into individual dwellings. EKHC provides the moulds, sand, cement, gravel, pipes, lids and diffuser plates. In addition, those who receive filters as part of phase 2 also receive a jerry can for the collection of clean water.

Maintenance training

The households also receive maintenance training, an essential supporting component to ensure full local sustainability of the project. The training is usually accompanied by distribution of posters and stickers (phase 2 only) providing information on the use and maintenance of the filter. (See Appendices 2-4).

2.4.1 The caretakers

Another important programme component is the caretakers who are responsible for dealing with problems experienced by filter users. Normally selected by the water committee with the aid of EKHC, phase 1 caretakers received training whilst working on the construction of the filters with EKHC. Phase 2 caretakers were trained in the EKHC compound over several days. Whilst the caretakers are paid for the time they aid EKHC working in the villages they do not receive payment from EKHC for carrying out their normal duties.

3 METHODOLOGY

The field assessment was carried out between 5th June 2006 and 14th July 2006 and comprised 4 main components:

- Household interviews and observations
- Water quality testing of the BSFs
- Village caretaker interviews
- Project staff interviews

3.1 Village, household and caretaker selection

During phase 1 of the BSF programme around 1,300 BSFs were installed in 8 villages. Due to restrictions of time and transport only the three located in the Oromia region, Koftu, Nenema and Filtino were surveyed. Within these selected villages 10% of phase 1 filter recipients were surveyed. A summary of the selected villages and the number of households surveyed in each is given in Table 3.1.1.

Households were selected at random. From a central point in each village a direction was chosen by spinning a pen. Each household along that route identified by the accompanying caretaker as having received a filter in Phase 1, was selected. Where possible the member of the household responsible for looking after the filter was identified and asked to participate in the survey. If they were not available, another member of the household who actively participated in the use and maintenance of the filter was invited to take part. If they were not available the household was skipped. Where phase 1 filters had been replaced by a phase 2 filter the household was invited to take part in the questionnaire if their maintenance training dated from phase 1 although water testing data was not collected since the filter dated from phase 2. Respondents took part in the survey voluntarily and their details remain confidential.

Table 3.1.1: Summary of the villages and filters surveyed

Region	District	Village	Number of households	Phase 1 BSFs	BSFs surveyed
Oromia	Liben Woreda	Koftu	300	200	20
Oromia	Liben Woreda	Nenema	300+	250	25
Oromia	Liben Woreda	Filtino	200+	100+	12

Where there was more than one caretaker in a village, the interviewee was selected by EKHC project staff. Whilst this may introduce bias, since it is likely this caretaker is the most active, it was considered the most appropriate method of selection to gather the most information.

3.2 The survey instrument

The primary survey instruments used were the semi-structured interview and observation.

Semi-structured interviews were chosen instead of a more rigid questionnaire as they allow for the sympathetic collection of data, enabling respondents to speak in their own words in rich detail (Herod, 1993). They allow the interviewer to build a rapport with respondents as they are allowed to lead the direction of the interview rather than following a pre-planned format, which ignores their concerns. The format also elicits in-depth responses allowing the possibility of bringing in a breadth of information not possible with a closed interview and enabling a further understanding of issues surrounding the data gathered. This was especially important for the project staff and village level caretaker interviews as the topics were difficult to fully determine prior to the interviews and many issues raised required far-ranging exploration.

Observations allowed for the quick collection of data, reduced the extent of the interviews, allowed for data collection without respondent bias and additionally allowed for cross-referencing of data from the semi-structured interviews.

Interviews in the villages were carried out using translators. Interviews with EKHC project staff were carried out in English. Notes of interviews were taken by hand in English in the field and transferred to an electronic database as soon as practicably possible. Final versions of all survey questionnaires and observation checklists are given in Appendices 7-9.

3.3 Water quality testing

Water testing was carried out in the field using the Oxfam DelAgua kit to determine the following parameters:

- Number of thermotolerant coliform colony forming units per 100ml of raw and filtered water
- Turbidity of the raw and filtered water
- Flow rate of the filter

Since it has been repeatedly demonstrated and is generally accepted that the most important and immediate risks to human health from using contaminated dirty water are those from enteric microbes of faecal origin (Sobsey, 2002), the main test for water quality was the quantification of faecal contamination through measuring faecal coliform bacteria (fcb), or more specifically in this case, thermotolerant coliform (E.coli). The number of E.coli present in the sample raw and filtered waters was determined using the membrane filtration method, which, whilst best suited to laboratory conditions, has been specially adapted in the DelAgua kit to ensure the best possible accuracy during field testing. Samples taken were allowed to recuperate for a minimum of 1 hour, cultured on membrane lauryl sulphate broth and enumerated after 16-18 hours of incubation at 44.5°C (+/- 0.5°C). Where 1ml samples were taken and diluted with bottled water, tests were carried out on the bottled water to ensure it was free from bacterial contamination and blank samples were taken every 30 samples as a control to ensure the samples were not being affected by contamination in the field. Constant checking of the incubator temperature, including recalibration where necessary, further ensured the validity of results.

The turbidity of the sample, a measure of physical quality, is also considered an important measure since it impacts upon the acceptance of water by the user. The turbidity was determined using the DelAgua turbidity tube due to the simplicity and fail-safe nature of the equipment. Errors in measurement were minimised by ensuring readings were taken in similar conditions (outside houses, in the shade) and using the same reading technique.

The flow rate was measured due to its importance as an indicator of filter performance, as outlined in section 2.2.2, and was determined through measuring the time it took to fill the 100ml sampling cup.

Raw water samples were taken directly from the vessel in which the water was dispensed into the filter. The vessel was disturbed prior to sampling to ensure a representative sample was taken even if the water had been standing for some time prior to testing.

Filtered water samples were taken after the water had been allowed to flow from the filter for 1 minute. The sample was then taken directly from the filter spout. The spout was not cleaned in order to be representative of the water quality the household receives from the filter under ‘normal’ maintenance conditions.

All data was recorded initially by hand and transferred immediately to an electronic database back at base.

3.4 Limitations

3.4.1 Limiting factors affecting interviews

In one village in particular (Nenema) there was a very low availability of householders for interview meaning the researcher had to skip many houses. This may introduce a small bias as it favours those who are not occupied away from their homes and therefore more likely to have time to look after their filter. The need to carry out the research during normal EKHC working hours to obtain transport made this bias unavoidable.

Language was also a significant barrier with translators employed to aid the interview process. Since two translators were used for the study there is a possibility that the accuracy and completeness of the information may vary depending on the translator used. It should also be noted that whilst some interviews were carried out in Oromifa, the local language, others were carried out in Amharic, the national language depending on the preference of the interviewee. The small bias this may have introduced was minimised by specifically instructing translators to provide as full a translation as possible and resist temptation to summarise or pre-empt people's answers. Where interviews with project staff were carried out in English, some inaccuracies may have crept in due to errors in understanding. This was negated as far as possible by stressing at the beginning of interviews that anything not fully understood should be pointed out so it could be rephrased or explained.

3.4.2 Limiting factors affecting water testing

The measurement of low turbidity water was limited since the minimum reading of the turbidity tube is 5TU. This meant the full reduction in turbidity was often not measurable.

The measurement of microbiological improvement from raw to filtered water assumes the water being poured into the filter then comes out of the other end of the filter immediately. In reality there is a delay as the BSF retains water from the previously filtered water and the new water 'pushes' it through. Whilst this is likely to have little effect where water is regularly taken from the same source, it does not take account of fluctuations caused by heavy rainfall or pollution events. In addition, it can be highly problematic where different water sources are used, especially if use of a highly polluted water source i.e. from an irrigation channel was used prior to a cleaner source i.e. rainwater. Since the majority of samples are routinely collected from the same source the bias this introduces is very limited. Cases where obvious differences were noticed, i.e. rainwater used after surface water, were specifically recorded by the researcher.

4 RESULTS AND ANALYSIS

4.1 Background data

All the filters tested during the survey were constructed and distributed 5-6 years prior to the visit of the researcher. Nenema was the first village to receive filters followed by Koftu and Filtino respectively.

All the villages use surface water as their main source. Koftu takes its water primarily from a dam, which serves an irrigation system lower down the valley from which the village of Filtino collects its water. The community of Nenema primarily collect their water from the nearby river Modjo. A few households occasionally purchase water from the piped supply in a nearby village and there was also evidence that houses seasonally collect small amounts of rainwater. The water sources used by the villages are viewed as being very poor with 93% (53/57) of the households surveyed describing the water they collect as being ‘not good’ or ‘bad’ although 24.6% (14/57) pointed out that they have no other options.

Inevitably the job of fetching water falls to the women and the children of the villages with water collected direct from source using jerry cans or clay pots which are then carried back to the village on people’s backs or, if available, using donkeys. The average size of a family in the surveyed households ranges from 3-12 with an average of 6.6 people. The amount of water collected by individual households varies from 1-10 jerry cans a day with an average of just over 3.5 jerry cans or around 77l[‡].

Of the water collected from source, between 1 and 4.5 jerry cans per household per day (average 1.7 or 37.4l) pass through the filter, equating to between 25 and 100% of that collected (average 52%). The water from the filter is used primarily for drinking but is also used for cooking, preparing drinks and, in some cases, for washing as indicated in Figure 4.1.1.

[‡] Assuming an average jerry can volume of 22l.

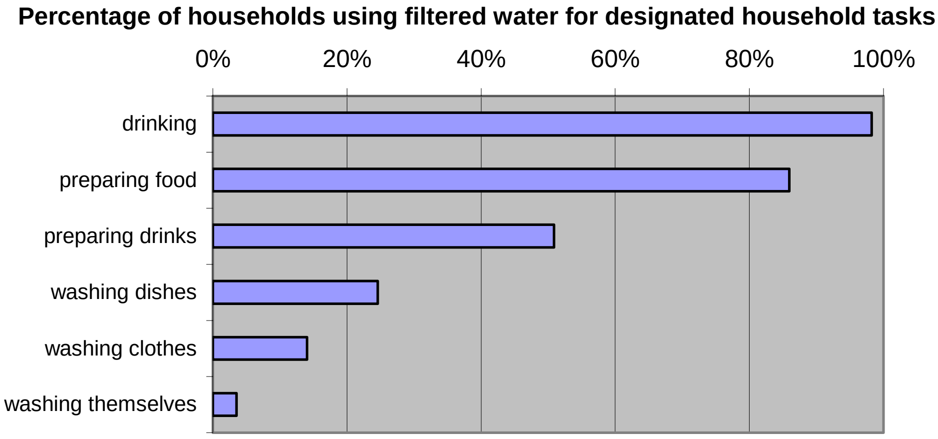


Figure 4.1.1: Household uses of filtered water

4.2 Filter usage

Out of the 57 households surveyed 70.2% (40) regularly used their BSF. 39 of these filters were original phase 1 filters, and 1 was a replacement BSF provided during phase 2. Of the remaining 29.8% (17) of households, 5.3% (3) were temporarily not using their BSF meaning 24.5% (14) of households had permanently stopped using their BSF. The reasons for permanent filter non-use are discussed in section 4.7.1.

Table 4.2.1: Observed usage of filters

Filter in use	Filter situation	Koftu (20)	Nenema (25)	Filtino (12)	Total (57)
Household using filter	in constant use	80% (16)	40% (10)	100% (12)	**66.7% (38)**
	in seasonal use	0%(0)	4% (1)	0%(0)	**1.8% (1)**
	replacement filter in use	5% (1)	0%(0)	0%(0)	**1.8% (1)**
Household not using filter	temporarily not in use	10% (2)	4% (1)	0%(0)	**5.3% (3)**
	not in use	5% (1)	44% (11)	0%(0)	**21% (12)**
	replacement filter not in use	0%(0)	8% (2)	0%(0)	**3.5% (2)**

(Numbers in brackets indicate the number of filters in each category)

It is important to note from Table 4.2.1 that the rate of usage in individual villages varied considerably. Whilst two of the study villages, Koftu and Filtino, achieved the overall project goal of *"85% being regularly maintained, functional and used after five years"* (Webster, 2002), the village of Nenema falls well short, achieving a figure of 44% and bringing down the overall average considerably.

4.2.1 Use of other sources

The majority of households, 56% (32), drank water only from the filter and no other source. Since 5 of the households without working filters collected their drinking water from the filters of their neighbours and one purchased water from a piped supply in a nearby village (at the time of the study), only 19.3% (11) of households had to resort to drinking water directly from source as indicated in Figure 4.2.1. Of the remaining 24.6% (14) households who sometimes drink water from a source other than the filter, 1.8% (1) bought piped water, as mentioned above, and the other 22.8% (13) drank directly from source, 17.5% (10) doing so out of convenience, 3.5% (2) in the belief the raw water was suitable for drinking and in one household lack of supervision meant children sometimes drink raw water before they could be stopped.

It should be noted that the researcher came across many households where water from the household filter was shared with neighbours and workers on an irregular basis. This is important as it indicates that larger numbers of people than those who own a BSF benefit from its use.

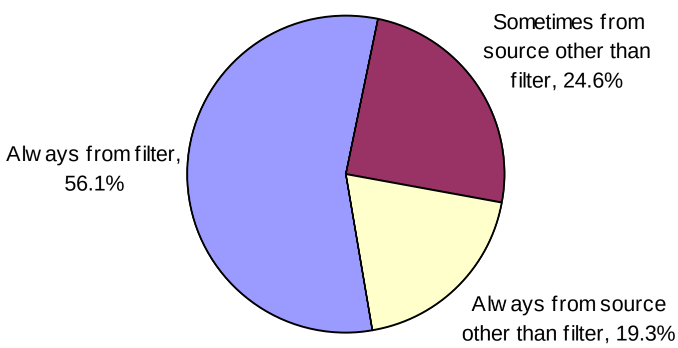


Figure 4.2.1: Sources of household drinking water

4.2.2 Pre and post treatment

Whilst the BSF is the main method of water purification for all households, many people settle their water before pouring it into the filter or use holes at the side of the river to improve the raw water they collect before it is passed through the BSF. One household also uses purification tablets after filtration.

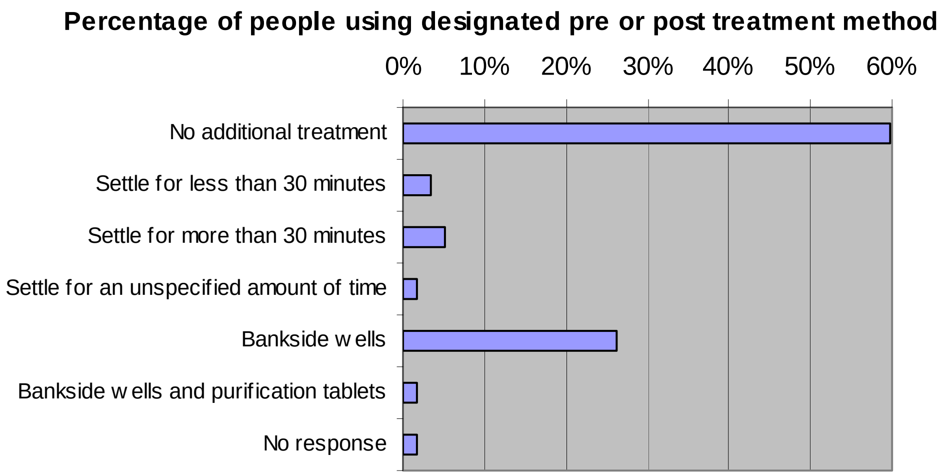


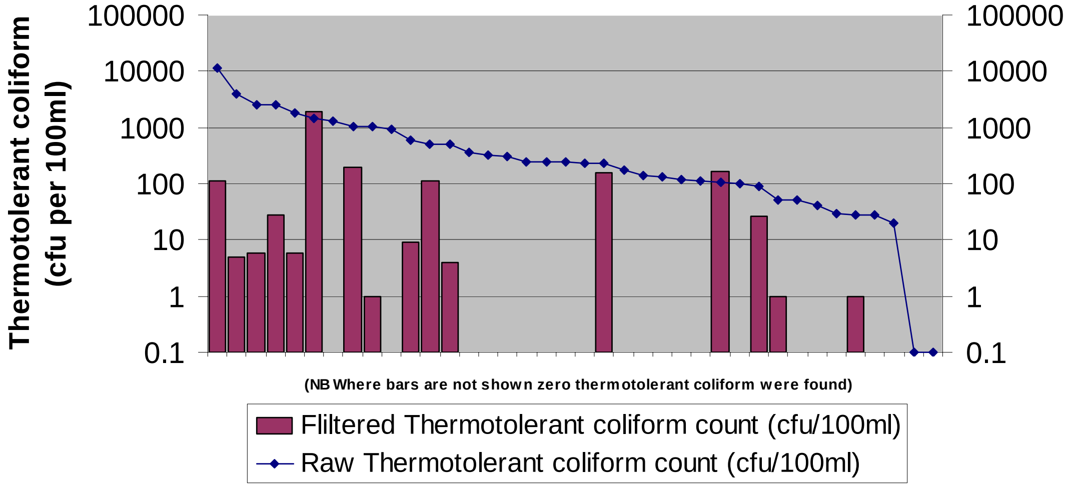
Figure 4.2.2: Use of pre and post treatment methods

4.3 Filter performance

4.3.1 Bacterial quality

The water tested from the 39 phase 1 filters in regular use showed reductions in E.coli counts in all but two cases. It should be noted, however, that in one of the samples where the count increased, the raw water tested was rainwater whereas more highly contaminated river water had been used the previous day. The mean (arithmetic) reduction in E.coli counts was 87.9%. This is greater than the expected rate of an unripened filter of 70% but lower than both the project target of 93% and the general target rate for a matured filter of 95-97% (Webster, 2002, Samaritan's Purse, 2001). This figure ignores one sample where, whilst a reduction was apparent to the researcher, it was not quantifiable since the number of E.coli present on the sample membranes exceeded 200[§] despite dilution to 1ml, and two samples where the raw water contained zero cfu before and after being filtered. It should also be noted that 71.8% (28) of samples achieved >99% reduction in E.coli. Figure 4.3.1 shows the distribution of E.coli counts in the raw and filtered water samples taken during the study.

Figure 4.3.1: Levels of thermotolerant coliform in raw and filtered samples for each household ranked by raw water thermotolerant coliform levels.



The values of bacterial contamination for the filtered water given in Table 4.3.1 indicate 75.7% (28) of samples were acceptable in terms of the project goal and Sphere guidelines for undisinfected supplies (Webster, 2002; Sphere, 2004), achieving <10cfu per 100ml and 54.1% (20) achieved the WHO guideline value of 0cfu per 10ml (WHO, 2006a).

Table 4.3.1: Classification of filtered water samples based on levels of thermotolerant coliform

Quality	Range (cfu per 100ml)	No of samples	% of samples
Good	0	20	54.1
Reasonable	1-10	8	21.6
Polluted	10-100	2	5.4
Dangerous	>100	7	18.9

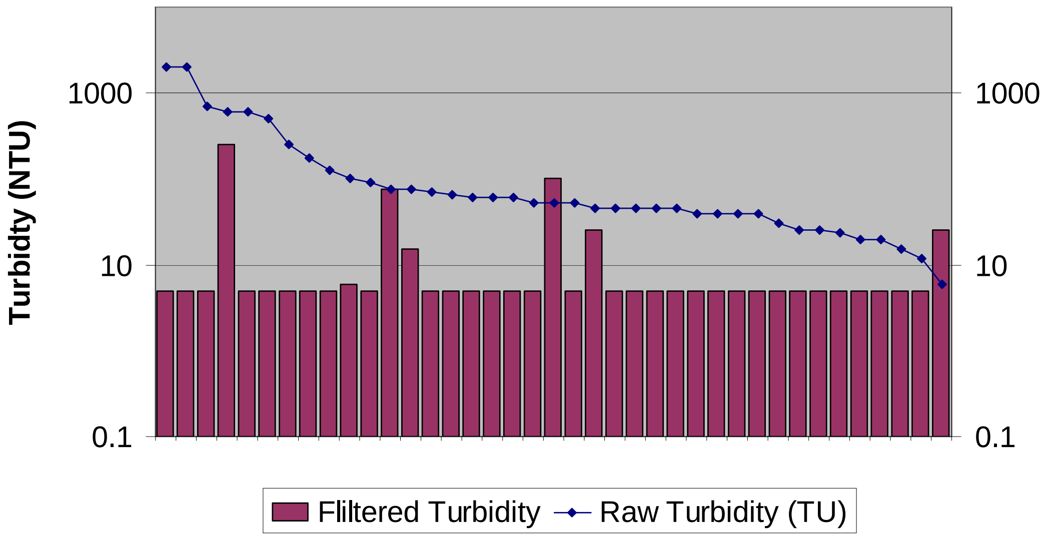
[Designations from (WHO, 2006a)]

§ The maximum number of cfu per membrane to allow for accurate recording is considered to be 100 (Robens Centre, 2004).

4.3.2 Turbidity

The same 39 filters showed reductions in turbidity in all but 3 cases with an average reduction of over 69.0%. Figure 4.3.2 shows the distribution of turbidity measurements in raw and filtered water samples taken. It should be noted that the real reduction rate is likely to be higher since the minimum measurable value of turbidity with the equipment used was 5TU and 82.1% (32) of filtered samples achieved this figure (see Table 4.3.2) with many visibly achieving higher standards.

Figure 4.3.2: Levels of turbidity in raw and filtered samples for each household ranked by raw water turbidity levels



Whilst 5TU is the level at which the WHO suggests water is acceptable to the user (WHO, 2006a), it is suggested that the acceptable level in rural Africa would be nearer to 15TU, a figure which 87.1% (34) of filters achieved.

Table 4.3.2: Classification of filtered water samples based on levels of turbidity

Quality	Range (TU)	No of samples	% of samples
Good	<5	32	82.1
Reasonable	6-15	2	5.1
Polluted	15-100	4	10.3
Highly polluted	>100	1	2.5

4.3.3 Combined quality

Combining the 2 criteria, 46.2 % (18) of filtrate samples were classified as 'good' quality, 28.2% (11) were classified as 'reasonable' quality, 7.7% (3) were classified as 'polluted' and 17.9% (7) were classified as 'dangerous' based on designations generated by the researcher given in Table 4.3.3.

Table 4.3.3: Combined classification of filtered water samples

		Bacterial Quality (cfu per 100ml)			
		0	**1-10**	**11-100**	**>100**
Turbidity	**<5**	Good (18)	Reasonable (7)	Polluted (2)	Dangerous (5)
	6-15	Reasonable (2)	Reasonable (0)	Polluted (0)	Dangerous (0)
	15-100	Reasonable (2)	Polluted (1)	Polluted (0)	Dangerous (1)
	>100	Polluted (0)	Polluted (0)	Dangerous (0)	Dangerous (1)

(Numbers in brackets indicate the number of filters in each category)

4.3.4 Flow rates

The flow rates of filters were generally very low in comparison with the recommended rate of 1l/m (+/- 30%). 43.2% (17) of filters had a flow rate of less than 0.2l/min meaning it would take almost 2 hours to fill a 22 litre jerry can, a service level likely to cause inconvenience if households did not plan their water needs in advance. This is likely to affect the figures given in section 4.2.1 relating to the use of other water sources. It should be noted that several households mentioned flow problems increased with the rainy season (the early part occurring during the period of the study) due to the associated increase in turbidity.

Table 4.3.4: Summary of observed filter flow rates

Range (l/m)	Number of samples achieving this range	% of samples achieving this range
0-0.2	17	43.5
0.2-0.7	15	38.5
0.7-1.3	6	15.4
>1.3	1	2.6

4.3.5 Factors affecting performance

The flow rate of the filter did not only affect user convenience. Using Pearson's' correlation test the flow rate was shown to be inversely correlated to the reduction of E.coli ($p<=.01$) supporting the theory that whilst slow filter rates may prove inconvenient to some users, they increase the efficiency of the filter at removing bacterial contamination. Pearson and Chi-squared tests were also performed to determine if the influent turbidity, the volume of water treated, the time since the filter was last cleaned, the cleaning of the spout and the pause water depth were correlated to E.coli reductions but no significant correlations were found (see appendix 10).

It should be noted however that a complex interaction of factors such as sand grain size, quality of installation, filter condition and maintenance practices affect the performance of the filter as well as the parameter tested above. These tests therefore should not be taken as ruling out an important role for any of these factors.

4.4 Filter condition and usage

For the BSF to function correctly it is necessary that filter components are in good physical condition, clean and free from damage, and users follow the instructions given to them. In general users appeared to be using and caring for their filters well with observed filter condition and usage ranging from 70% to 97.5% compliance for the parameters measured in Table 4.4.1.

Table 4.4.1: Filter condition and usage observations

Observed parameter	Condition	No of filters	% of filters
Exterior condition	fine	33	82.5
	seeping or leaking	7	17.5
Level filter?	level or almost level	36	90
	angled	4	10
Lid	in place	39	97.5
	aside or missing	1	2.5
Diffuser plate	present	39	97.5
	aside or missing	1	2.5
Sand surface	not visible	14	35
	smooth	19	47.5
	pitted or scoured	7	17.5
Separate containers used for raw and filtered water	yes	37	92.5
	no	3	7.5
Clean and protected containers	clean and protected	20	50
	clean	13	32.5
	dirty	7	17.5
Proximity of animals	no access	28	70
	domestic animals	7	17.5
	access	5	12.5

(Observed parameters adapted from (Samaritans Purse, 2003) - see Appendix 5)

4.5 Filter maintenance

4.5.1 Frequency of cleaning

The frequency of cleaning varied between households ranging from once a day to once every three months. Only 26.3% (15) of households indicated filter performance was a significant factor for initiating cleaning of the filter suggesting that the rest of the households do so out of routine rather than necessity. This implies the filters of these users are being cleaned unnecessarily; disturbing the bio-film more often than is necessary and therefore leading to water quality lower than would be possible with timely maintenance.

Table 4.5.1: Frequency of filter cleaning

Frequency of cleaning (days)	No of households	% of households
1-3	16	28.1
4-7	14	24.6
8-14	9	15.8
15-31	7	12.3
>31	3	5.3
(OR when water stops flowing correctly/filter is dirty)	(8)	(14.0)
ONLY when water stops flowing correctly/filter is dirty	7	12.3
Not sure	1	1.7

4.5.2 Sand cleaning

Whilst 57.9% (33) use the sand removal technique to clean the BSF sand as originally taught, 40.4% (23) have picked up that the wet harrowing technique is also effective and requires less work than removing the sand (see Appendix 6 for details of the techniques). Whilst it is not clear how this practice has been adopted, it is likely to be due to the teaching of the technique to phase 2 filter users and caretaking staff. Many households who have adopted this technique use wet harrowing for regular maintenance and remove sand for cleaning when they experience significant problems with water flow.

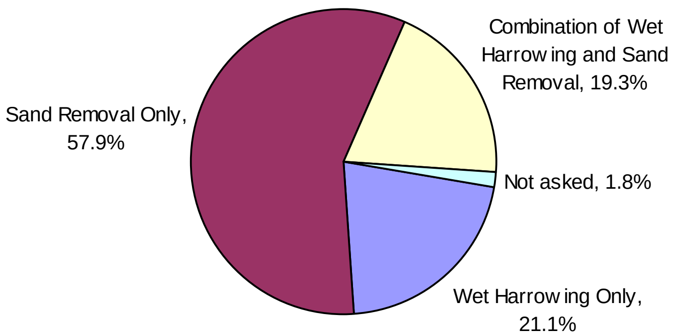


Figure 4.5.1: Methods for cleaning the BSF sand

Wet harrowing

Households using the wet harrowing technique generally harrow to a depth greater than the recommended 2-10cm[**], disturbing the bio-film more than necessary and leading to water of quality lower than is possible.

In addition, over half the filter users wash the sand a prescribed number of times rather than washing until the water runs clear, thus not necessarily ensuring particles reducing performance have been removed. Although not specifically addressed in the survey, the researcher also observed some householders were wet harrowing with dirty water, reducing the effectiveness of the cleaning method and preventing the user determining when the sand had been adequately cleaned. Both practices lead to less effective cleaning, decrease the time required between cleaning and disturb the bio-film more than necessary, leading to water quality lower than is possible.

Table 4.5.2: Wet harrowing maintenance procedures

Observed parameter	Observation	No of filters	% of filters
Depth to which sand is mixed	<10cm	2	8.7
	10-25cm	14	60.9
	>25cm	7	30.4
Number of times sand is mixed and water removed	1	4	17.4
	2-3	8	34.8
	4-5	1	4.3
	Until runs clean	10	43.5

Sand removal

Householders generally removed large volumes of sand for cleaning. It is considered this is generally unnecessary as most particles get trapped in the top few centimetres of the sand (Fewster et al., 2004). This has two major implications. Firstly the bio-film is disturbed far more than necessary and secondly the sand is less likely to be installed correctly. Although not specifically addressed in the questionnaire, the researcher observed in several households that rather than following the procedure of adding sand to water to prevent air pockets, dry sand was 'dumped' into the filter

[**] Literature does not agree on the recommended depth with ranges including 2-3cm (Samaritan's Purse, 2001) ~5cm (Lukacs, 2004) and 5-10cm (Duke et al., 2006)

body after cleaning and then water subsequently added. Removing all of the sand also allows a greater chance of different sand layers becoming mixed.

As with the wet harrowing technique, it was also observed that many users washed the sand with dirty water. The result was that the user was unable to tell whether the sand had been adequately cleaned and that there is likely to be a greater number of particles trapped in the sand as a result, leading to increased filter cleaning, greater disturbance of the bio-film and water quality lower than is possible.

Table 4.5.3: Sand removal maintenance procedure - depth of sand removed

Condition	No of filters	% of filters
<10cm	4	9.1
10-25cm	7	15.9
>25cm	9	20.5
All fine sand	7	15.9
Al fine sand and some/all of the coarse sand/gravel	17	38.6

The technique of sand removal is also problematic in that it increases the likelihood of losing sand from the filter. A number of users pointed out that they had adopted the process of wet harrowing ‘out of fear of losing sand’. This hypothesis is reinforced by the fact 21.2% (12) of households have added sand to their filter due to a loss of sand.

4.5.3 Pause water depth and sand levels

The pause water depth of filters ranged from 0-20cm with only 10% (4) filters observed to have a pause water depth within 20% of the recommended 5cm. This is likely to have a significant effect on the health of the bio-film as it is forced to fight for survival in far from ideal conditions, either starved of oxygen or vulnerable to damage. This will therefore have a knock-on effect of reducing the potential effectiveness of the filter in removing harmful pathogens from the water.

Table 4.5.4: Pause water depth

Depth	No of filters	% of filters
<2 cm	14	35
2.01-4 cm	9	22.5
4.01-6 cm	4	10
6.01-8 cm	4	10
>8cm	9	22.5

The extreme variations in pause water depth also indicate there are problems both with people losing sand and the sand height increasing as people place sand incorrectly after cleaning.

4.5.4 Other cleaning

The observation of the cleanliness of the filter and associated items indicated the filters were generally cleaned well with the exception of the spout. This was confirmed by the reported cleaning of filter parts.

Table 4.5.5: Observed cleanliness of filters

Observed Part	Condition	No of filters	% of filters
Interior	Clean	28	70
	Dirty or very dirty	12	30
Dispersion Plate	Fine	33	82.5
	Rusted or broken	7	17.5
Spout	Clean	20	50
	Dirty or broken	20	50
Clean containers for filtered water	clean	33	82.5
	dirty	7	17.5
Cleanliness of filter area	Clean	35	87.5
	Dirty or very dirty	5	12.5

With 50% of the spouts observed as being visibly dirty or broken, cleaning of this item is clearly not adequate. Acceptable cleaning methods such as the use of a clean cloth/sponge or soap and detergent are practiced by only 36.8% (21) of households and 21% (12) of households do not attempt to clean the spout at all. The remaining 40.4% (23) of households use unacceptable cleaning methods which pose a risk of recontamination of the water as it leaves the filter.

Table 4.5.6: Reported cleaning of filter spouts

Cleaning method	No of filters	% of filters
With finger	13	22.8
With grass/stick	6	10.5
With cloth/sponge/brush	18	31.6
With water only	4	7.0
With detergent/soap	3	5.3
Not cleaned	12	21.0
Not asked	1	1.8

4.6 Training

The initial training of all phase 1 filter users was carried out during the construction of the filters 5-6 years previously. The survey revealed that there were many filter users who did not receive this training and maintain the filter through what they have been taught by other users. In 14% (8) of households this user was the main person responsible for the filter.

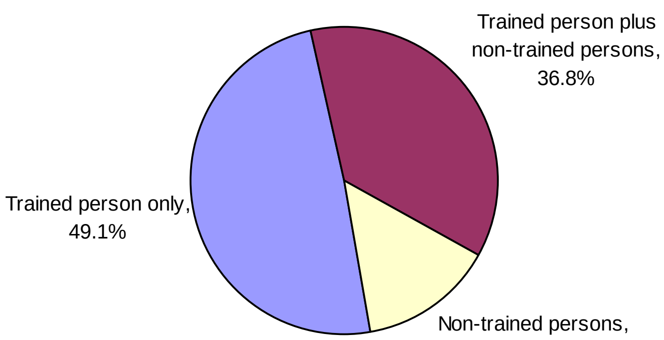


Figure 4.6.1: Training status of filter users

Despite this, and the absence of any follow-up training from the EKHC team, the users are very confident that they are maintaining the filter correctly. In many cases however, this is directly contradicted by the obvious maintenance errors discovered by the researcher and highlighted in previous sections.

Table 4.6.1: Recollection of training and confidence of users

	Confident they are maintaining correctly	Not confident they are maintaining correctly
Remembers all training	57.1% (32)	1.8% (1)
Does not remember all training	16.1% (9)	3.6% (2)
Not trained	10.7 (6)	1.8% (1)

It should also be noted that only 8 out of 57 (14%) households reported they had received instructional posters during phase 1 and at least half of those had been lost. These posters were identified as useful reminders of use and maintenance practices by all 8 users who received them.

Households were also asked whether they had any specific areas where they required additional training. Whilst no household identified any specific areas where training was required, 43.8% (25) said more training would be useful and 3.5% (2) requested the initial training as they had not received it.

4.7 Support

4.7.1 Household problems

Table 4.7.1 shows the many reasons for filter non-use dominated by filters broken beyond repair. It should be noted that it is the researcher's opinion that 7 filters or 50% of those filters permanently not in use could be brought back into use with correct caretaker support. Filters in this category include filters in need of replacement sand, filters that no longer drop the water correctly and filters that leak.

Table 4.7.1: Reasons for permanent filter non-use

Reason for non-use	Number of filters	% of filters
Filter broken beyond repair	5	35.7
In need of replacement sand	2	14.3
No longer drops the water correctly	3	21.4
Filter leaks	2	14.3
Nothing to collect filtered water	1	7.1
Too tired to use properly	1	7.1

In addition, although 54.3% (31) of households reported they had experienced no problems with their filter since they received them 5-6 years ago, the remaining 45.6% (26) reported a variety of problems, which should be solvable by local caretakers, including cracks and leaks, loss of sand and low flow rates.

Table 4.7.2: User observed filter problems

Reason for non use	Koftu	Nenema	Filtino	Total
No problems	10 (50%)	10 (40%)	11 (91.7%)	31 (54.4%)
Crack/breakage/leak	6 (30%)	9 (36%)	1 (8.3%)	16 (28.1%)
Low flow rate	3 (15%)	6 (24%)	1 (8.3%)	10 (17.5%)
Loss of sand	1 (5%)	1 (4%)	0 (0%)	2 (3.5%)
Not installed level	1 (5%)	0 (0%)	0 (0%)	1 (1.8%)

(N.B. Some filter users reported more than one problem with their filter)

It should also be noted that there was a very low rate of reporting these problems, averaging 42.3%, to those responsible as well as a worrying number (73%) of reported problems remained unsolved.

Table 6.7.2: Assistance requested from users

Assistance requested from	Koftu	Nenema	Filtino	Total
Caretaker	3	2	0	5
Project Staff	1	2	0	3
Other	0	2	1	3
Total requests for help	4	6	1	11
As % of problems	(40%)	(40%)	(100%)	(42.3%)
Problems not solved	3	4	1	8

One reason for the lack of reporting was a lack of knowledge of to whom to report the problem with only 36.8% (21) of households identifying the caretaker as the first person to ask and 43.9% (25) of households stating there was no one to turn to if they experienced a problem.

It should also be noted, however, that according to EKHC staff, this is a common problem among all their projects and stems not just from lack of information but also lack of acceptance by some that a locally trained person has adequate skills to help them. Instead they expect visits from ‘more educated’ project staff and, if they do not receive them, bemoan the fact they have no one to ask for help. Whilst the problem has been improved by EKHC training caretakers outside their villages, it remains an issue which causes problems in all of EKHCWSPs programmes.

Table 4.7.3: Household identification of support personnel

Support personnel	Koftu	Nenema	Filtino	Total
Caretaker	9 (45%)	9 (36%)	1 (83.3%)	21 (36.8%)
Project Staff	3 (15%)	4 (16%)	0 (0%)	7 (12.3%)
Caretaker and project staff	0 (0%)	1 (4%)	2 (16.7%)	3 (5.3%)
Other	0 (0%)	0 (0%)	3 (25%)	3 (5.3%)
No one to ask	8 (40%)	11 (25%)	6 (50%)	25 (43.9%)

(Numbers in brackets indicate the percentage of responses for each category)

4.7.2 The caretakers

Out of the 3 caretakers interviewed those in Koftu and Filtino proactively visited households in their community to ensure everything was running smoothly whereas in Nenema where the greatest number of non-functioning filters was found, this was not the case.

The Nenema caretakers obviously had little time to carry out their role as they were engaged in both farming and paid labour in order to support their families. The Koftu caretaker whilst appearing to have more time, still could not afford to leave work for substantial periods of time. The Filtino caretaker, however, charges for the time he spends on a filter thus compensating for money he might have earned elsewhere and allowing greater availability when required.

Despite the presence of tools for maintenance being specified as an indicator of achieving the overall programme objective of fully equipping caretakers (Webster, 2002), a lack of materials was clearly preventing them from carrying out repairs. Only in the case of Filtino where these supplies are not always expected to come from the EKHC, is replacement sand instead occasionally acquired from a local river and householders instructed to buy cement for the repairs they require. It should be noted however that in none of the villages did the caretakers have the tools they required to carry out their full duties.

4.7.3 EKHC support

Whilst the aim of the project was to provide villages with autonomous caretakers the EKHC team still provides a degree of support to the village caretakers and has visited villages to deal with problems beyond the scope of the caretaker. There is however no formal way of receiving and documenting requests for help and help is therefore given on an ad hoc basis depending on when and to whom the request was made. Since the funding for phase 1 ended many years ago assistance for phase 1 filter users is generally restricted to advice given to caretakers as part of phase 2 and the provision of replacement sand where requested.

Whilst some people received replacement filters after theirs broke during installation and some have managed to get replacement filters as part of phase 2 there are currently no mechanisms to allow for the replacement of filters broken beyond repair. This means families with such filters are left without a means to purify water and the benefits it provided.

Table 4.7.4: Summary of caretaker interviews

Area	Koftu	Nenema	Filtino
No of village Caretakers	1 – but sometimes others help	2	1 – but the EKHC technician also lives in the village and helps
Perception of role	He checks every house and where he finds problems he gives instructions or helps make repairs. If the problem is beyond his scope He reports it to the EKHC team.	He tries to maintain filters that have become damaged.	He checks all the filters and if they have problems he tries to solve them.
Time spent in role	Not able to specify	Visits houses once every month	He visits 4 houses a week (15 if monitoring phase 2 filters)
Means of dealing with problems: a) Low flow rates/blocked filters	Carries out and demonstrates cleaning of the filter using the wet harrowing technique. This solves the problem every time.	Carries out and demonstrates cleaning of the filter removing and replacing all the sand.	Carries out and demonstrates cleaning of the filter using the wet harrowing technique. If it does not work he removes all the sand, cleans and replaces it and checks pipe is not blocked.
b) Cracked leaking filters	Previously carried out repairs and reported problems he could not deal with. He now no longer has any cement and tools therefore reports rather than repairing.	Previously repaired the filter but now no action taken as there is no cement to carry out repairs.	If he is able to fix the filter he instructs the household to buy cement and he fixes it. If not he reports the problem.
c) Loss of sand	Used to replace with sand provided by the EKHC team but now no longer has any sand to do so.	Previously added sand but no longer does anything as he has run out of sand and additional sand has not been brought by EKHC staff.	He reports to the EKHC team to allow them to get replacement sand or collects from river Modjo and advises on sieving, cleaning and replacing.
View of biggest problem(s)	The lack of time people have to maintain the filter adequately and a lack of material resources (for him to work)	Users wash the sands more often and more deeply than is needed in order to make it flow freely. They often do not wash perfectly.	They clean too often, don't settle the raw water and lose sand. Many people do not report their problems and there is a lack of education.
Training	Trained 'on the job' during phase 1, 5-6 years ago, and trained for 4 days at the EKHC compound for phase 2, 2 years ago.	Trained at the EKHC compound during phase 1, 5-6years ago.	Trained 'on the job' during phase 1, 5-6 years ago, and trained for 4 days at the EKHC compound for phase 2, 2 years ago.
Available resources	He has no tools, no cement and no replacements sand. He uses the checklist given for phase 2 filters to check phase 1 filters as well.	He has no cement, no replacement sand. He has a one page document to help him teach people how to use the filter.	He has no tools but needs a torch and tape measure to inspect the filter. He also does not have tools for repairs.
Reporting to EKHC	He has difficulties reporting to EKHC as he has to wait for transport to go there. He therefore waits for them to visit. He keeps no records of what is reported to him or what he reports.	Because he has no alternative than to travel to the EKHC office he often does not report problems. He used to keep records of problems, which he shared with the church but has lost them.	He reports problems as he passes the EKHC compound on the way to market. He keeps no records of what is reported to him or what he reports to EKHC
Do you receive help from EKHC when you require it?	When he reports problems they normally come to visit but often priority is given to different Woreda with phase 2 filters.	He has not asked the church for help.	They try to help as much as possible. The problem is they have to collect materials from the compound but he does not have time to do so.
Are you paid?	He is not paid for work carried out in the village unless he works with the EKHC team or on phase 2 monitoring. Although not discussed, he had expected to be paid as he cannot do work whilst he is dealing with peoples filters	No, his work is voluntary. However, when he needs to spend time on filters he feels he needs payment as he has to leave his fields	When he fixes filter problems he is paid 2-3 birr by the household for the time he spends. He is also paid when he accompanies EKHC staff.

4.8 User perception

Of the 57 households interviewed all had a positive view of the filter and were pleased they had chosen to receive one as part of the project. However, whilst 40.4% (23) of households responded that the filter always provided them with the water they required, when they required it, 35.1% (20) complained the filter yielded less water than was put into it and 12.3% (7) complained it took too much time for the water to run through.

When quizzed about what changes the filter had brought to their lives only 3.5% (2) of users reported no change and no one reported any negative effects resulting from its introduction. By far the most recognised benefits were those of improved health and the ability to use pure/clean water, which were reported by 91.2% (52) and 75.4% (43) of respondents respectively (see Figure 4.8.1).

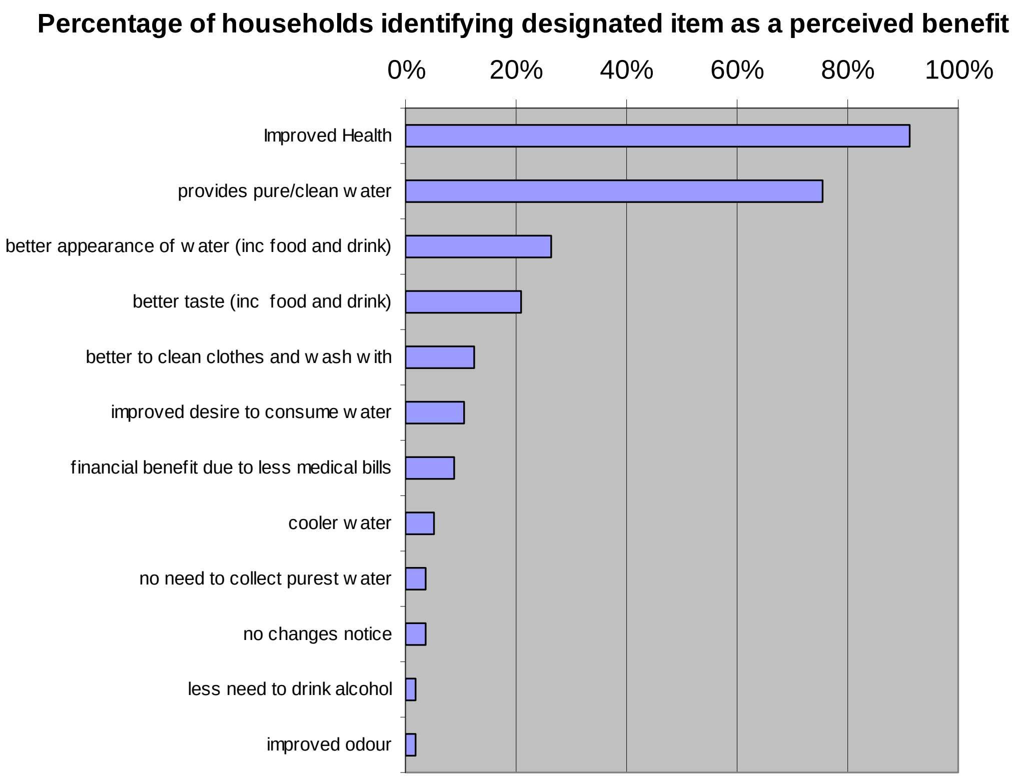


Figure 4.8.1: Observed changes attributed to BSF introduction

5 DISCUSSION

The objectives from chapter 1 were:

1. Evaluate the long-term performance of the BSFs
2. Evaluate the adequacy of the maintenance procedures used by individual householders.
3. Evaluate the support provided to householders to ensure BSFs remain in use
4. Examine the user perception of the contribution of the BSF to their well-being
5. Suggest any additional programme components, which might aid the long-term sustainability of the filter project

All these objectives are addressed chronologically in this chapter and the resulting recommendations given in chapter 6.

5.1 Filter performance

Phase 1 of the BSF programme in the DebreZeit region has undoubtedly been a success. Hundreds of people reliant on the use of contaminated surface water are still benefiting from the opportunity to improve their water quality using the filters they received more than 5 years ago. It should also be noted that the study also found the number of people benefiting from the filter project was not simply limited to those living in households. Friends, neighbours and workers of those with filters were also beneficiaries.

In terms of the technology itself there seems to be little to fault. Even after many years of use and, in some cases, highly dubious maintenance procedures, 71.8% of filters are still managing to remove >99% of faecal contamination. Whilst the average removal rate is lower, indicating there are factors preventing optimal filter performance, this upper figure demonstrates that if well-maintained the technology can prove to be sustainable in the long-term. Even where filters are functioning at lower removal rates they are still benefiting householders, improving their water quality whilst reducing possible exposure to a 'significant infectious dose' (Fewster et al., 2004) and therefore reducing their overall risk of waterborne disease.

In two of the study villages the rates of usage exceed those of the project goal. In the third village, however, a far lower rate of usage was observed, indicating there are factors preventing optimal filter usage. Overall usage rates are nonetheless impressive when it is remembered that these were the pilot villages in Ethiopia for the introduction of the filter and the lessons learnt from mistakes made in their introduction led to improvements in subsequent villages.

This assessment of filter performance raises three major questions:

1. What factors influence the significant differences between the three study villages?
2. What needs to be addressed to raise performance towards the potential levels demonstrated through other studies in Ethiopia and around the world?
3. What needs to be addressed to raise usage levels?

The research suggests the answers to these questions can be found in evaluating the adequacy of maintenance procedures, the support provided to householders and looking at the reinforcement of educational messages.

5.2 Maintenance

The research shows significant numbers of people are cleaning their filter too often, too deep and with dirty water. This conclusion is important as all of these errors result in the disturbance of the bio-film more often than necessary, reducing its effectiveness and leading to water of lower quality than is possible. Furthermore, incorrect maintenance procedures result in lower depths of sand and incorrect pause water depth further compromising the health of the bio-film and reducing the effectiveness of the BSF. Poor sand cleaning also contributes to the very low flow rates that have been observed which, in extreme cases, have led to people ceasing to use the BSF.

These problems are particularly acute when the sand removal method is used as opposed to the wet harrowing method, which reduces the disturbance of the bio-film and allows for greater health and better efficiency in removing contamination from the water.

If all households were to clean the filter only when flow rates became a significant problem for use and adopted the correct wet harrowing procedure, harrowing to a depth of a few cm, using clean water and cleaning until the water ran clear there would be several beneficial effects. It would reduce the time taken to carry out the cleaning procedure (compared to sand removal), increase the effectiveness of the sand cleaning and therefore lead to a reduction in the required intervals between cleaning. The increased interval and reduced depth of cleaning would ensure minimum disturbance to the bio-film allowing it to develop fully and provide the best potential for the removal of pathogenic organisms.

Another area where the cleaning procedure could be significantly improved is the cleaning of the spout. At present a large number of people use unsanitary cleaning practised utilising their fingers, grass and sticks. The possibility of recontamination of the filtered water as it leaves the unit is significantly enhanced by choosing these implements rather than cleaning the spout regularly using a clean cloth, sponge or brush and some detergent, soap or dilute chlorine solution

Better teaching of correct maintenance practices could therefore be an effective and simple method to improve the quality of water produced by a significant number of the filters.

5.3 Support

5.3.1 Caretaker presence and availability

Whilst only 36.8% of filter users stated they would turn to the local caretaker for help if they had a problem, it is unclear whether this figure represents the true awareness of who they can turn to for help or whether it represents a lack of acceptance by some within the community that a locally trained person has adequate skills to help them. In either case it is clear there is a lack of ‘presence’ of the caretakers’ role in the minds of the villagers. If people are aware not only that the caretaker is available but aware of what help he can provide and how to obtain his services the potential for support would be greatly improved. In addition when EKHC staff deal directly with individual villagers, albeit on an ad hoc basis, rather than channelling all communications through the caretaker or village water committees the status of the caretaker is further reduced.

There is also a significant problem with the poor availability of some caretakers. Faced with the same challenge of carrying out their caretaking role whilst still providing a substantial income for their family, the three village caretakers achieved varying degrees of success. The caretaker in Filtino has balanced the situation with the greatest skill and with the support of the water committee, is charging for the time he spends repairing people’s filters. Whilst this charge is small enough to allow people to access his help, it is significant enough to be equivalent to the money that he would have earned out farming his land or working for wages. This charge may also be a partial incentive for him to proactively visit households to seek out problems. Conversely the caretakers in Nenema have faired the worst. They have prioritised their income earnings at the expense of their caretaking role making them almost completely unavailable to help BSF users. The availability of caretakers in Nenema and Koftu to work for EKHC when there is payment involved, indicates that their time is available for the right price. The adoption of a payment scheme in all villages might therefore significantly increase caretaker availability, allowing more of householders’ filter problems to be addressed.

A lack of tools, sand and cement is also hampering caretakers from sufficiently carrying out their roles and is directly or indirectly responsible for some users no longer using their filters and forcing others to use filters which perform below expected standards. The encouragement of payments could also address the current lack of tools, sand and cement for repairs. The increased activity generated would also have a knock on effect on the caretakers' image within the community and further increase their presence.

Although payments for individual filter repairs will allow for greater functioning of the caretakers within the communities and payments for the village caretaker have been successfully raised from individual householders in Filtino there is no guarantee this approach will succeed in other villages. Since water committees have been trained in revenue collection other alternatives include the raising of funds locally in the form of fees or 'taxes'. Such an approach, however, remains untested and would require householders to put a significant amount of trust in water committees without necessarily seeing any benefits from the money they pay.

Since there is also a significant problem with the availability of replacement filters, a further and possibly more attractive alternative might be attempting to expand the operations of one or several local iddirs[††], or funeral associations, for raising funds. These 'informal' risk-sharing arrangements involve collecting fees from members on a regular basis in order to provide a one-time financial assistance (insurance) to members in case of death or illness. Such associations have legal status under Ethiopian law and, whilst many concentrate on the provision of funeral insurance, there is a long history of engaging in development activities such as water (Soloman, 1999). Since a number of NGO projects in Ethiopia are showing success in working with the iddir structure to provide community related development (Soloman, 1999) and since providing insurance against the breakage of a filter might not be a significant departure from current activities, the strategy shows significant promise. An initial trial of the scheme to cover only the replacement of filters might later be adapted to cover caretaker wages should it prove successful. It should also be noted that the concept also fits well with EKHCWSPs strategy to further utilise existing CBOs in the enhancement of their programmes.

[††] 'Iddir' (e'dir) is the generic name although in some areas local names are used (Dercon, 2004).

5.3.2 Support structures

It is essential if caretakers are supposed to act as an autonomous entity that they have a clear definition of what their responsibilities are. Currently it appears unclear to the caretakers exactly what they are expected to provide in terms of support to the community, what they are supposed to organise themselves and what authority they have to charge fees. The village water committee seems to play very little role in supporting the caretaker. It should be helping enhance the presence of the caretaker within the village and provide authoritative support for him to charge fees and raise funds for tools and spares.

One further problem is that the support the caretaker receives from the church is highly variable with differing responses generated from seemingly similar requests. In some cases sand, cement and replacement filters are provided when asked for and in other cases no action is taken.

There appear to be three significant reasons for this:

A lack of clear communication lines - reporting occurs informally when EKHC staff are passing through villages and/or when a caretaker is passing by the EKHC compound meaning the person told of the problem varies and the resulting actions vary

A lack of recording of reported problems – not recording reports means that it is easy for problems to be forgotten especially when staff other than those responsible receive the reports

A lack of a clear definition as to what the EKHC team will provide – this is especially important as the response varies depending on whether it is a phase 1 or phase 2 filter due to funding restrictions

All of these areas could be addressed through the simple definition of the role of EKHC and the implementation of a standardised reporting system thus enabling the caretaker to fully understand what aid he can obtain, and rely on its receipt.

Since there is such a huge variation in the success of the three geographically close villages there is also scope in encouraging caretakers to meet to discuss successes and problems in their individual villages. Peer to peer interaction through regular meetings would allow caretakers to support each other rather than relying on the church, whilst also promoting best practice.

5.3.3 Supply chains

There is a clear problem not only with the supply chains for both sand and cement but also for replacement filters. The current supply chain for sand and cement comes directly through the church for the construction phase but later dries up or is at best unreliable as EKHC responds to demands from other construction projects. A secure supply chain would ensure caretakers could get supplies as necessary and enable them to carry out their role more effectively. Whilst costs should be met by communities, as described in section 5.3.1, this supply chain might be provided by the church with materials available for purchase at cost from the EKHC compound. Alternatively, materials could be sold to local entrepreneurs for sale at local markets ensuring availability at a local level but possibly at a higher cost. Whichever method is chosen it is important that the local caretakers are made aware of exactly where and at what cost such materials are available.

More importantly, however, there appears to be no supply chain for replacement filters. When a filter breaks beyond repair there is no way the filter user can obtain a replacement. Therefore, those with broken filters are forced to revert to using polluted water sources. This is especially important as a current increase in flower production facilities is increasing the wealth of many in the studied communities and the resulting mobility has led to an increased number of filters breaking whilst moving house.

Whilst the church has in the past provided replacement filters, local caretakers have been trained in the construction of the filters to meet local demand once project funding ceases. The caretakers do not, however, have access to the moulds and tools to construct replacement filters and therefore there is no village level control over filter replacement. Again whilst funds should be provided from the communities themselves, as described in section 5.3.1, the church should make moulds available to local caretakers so they can construct new filters when funds are available.

If coupled with suitable pricing the provision of a sustainable supply chains will enable caretakers to access all the materials they require to carry out their role.

5.4 Reinforcement of educational messages

The successes of the phase 1 project have come despite the fact the education programme was carried out during the period of construction only. Despite the initial success of the education, since there have been no return visits by project staff to reinforce the messages either in relation to basic health and hygiene or in relation to the technical requirements of the BSF, people are relying on education received over 5 years ago. This is problematic for several reasons. Firstly it is widely recognised that to bring about behaviour change people require reinforcement of the messages and secondly the period that has passed allowed educational messages to become diluted. In addition, there are large numbers of people involved in the use and maintenance of the filters who did not benefit from the initial training but rely on the successful relay of information from others who attended a single training course and received no reminders.

The research and subsequent experience of the BSF programme has also revealed that informational posters and stickers are a vital tool in reminding people how to correctly use and maintain the filter. This information not only reinforces the message given in education sessions but provides the user a reference by which they can check procedures are correct.

Reinforcement of educational messages and distribution of promotional material could therefore be an effective and simple method to improve filter maintenance procedures and general hygiene behaviour.

5.5 Sustainability

Whilst the items discussed above will have an impact on the future sustainability of the project as it exists, with current funding due to run out in a few months time and no plans for future phases there is no clear exit strategy to allow continued and active long-term adoption. Whilst EKHC has spent time engaged in sharing the technology with other NGOs and government departments within Ethiopia in a bid to continue the subsidised model of distribution, their success in selling many filters and several filter moulds has not generated sufficient interest for the continuation of the work started by EKHC. Without a clearly defined alternative strategy it is difficult to envisage how the BSF programme will continue to proliferate and benefit the people of Ethiopia.

Whilst commercialisation of POU projects in many other countries have had mixed success in the recovery of full costs, the adoption of the commercial approach has been proven to be highly successful in recovering the production costs of the products themselves (Harris, 2005). Since many production facilities set up in commercialised BSF projects elsewhere have continued to function long after the support NGO has finished, the approach therefore shows promise. Whilst little effort has been made to promote commercial businesses that would continue to function after EKHC finish their work, there are a number of elements which suggest commercialisation presents a promising strategy. There is a demand for filters which cannot be satisfied (although the extent is not fully known), there is a team of well-trained technical staff who have the skills to construct install and teach people how to use filters and there are several moulds available which can be used to construct filters.

Ultimately the successful commercialisation of the project relies on whether a price could be set to enable the commercial venture to be self-sufficient whilst also making it affordable for the local population. On this front there is hope from the fact that some users are at least aware that the filters give them the financial benefit of reduced medical bills which could be utilised as part of a marketing strategy for the units. It may also be worth investigating the possibility of reducing construction costs by switching to an improved round filter which utilises less concrete in the construction (biosandfilter.org, 2004). There is also the question of whether there are people willing to take on the risk of attempting such a venture. Since EKHC has not made any attempts to commercialise the project, all these areas are currently unknown and investigations would need to be made to determine the feasibility of such an approach.

Perhaps a compromise between the status quo and full commercialisation would be the provision of stepped subsidies to support embryonic commercial businesses with marketing as part of a larger environmental health programme promoted by the EKHC. These businesses could set up workshops in villages, as has proved successful in other programmes (Mol, 2001), with the start-up costs and early production costs provided through subsidies that reduce as businesses become recognised and demand grows. Such an approach would also allow for setting up a small low-cost pilot project to test the concept and iron out any significant problems before a larger programme was implemented. It would also lay the foundations for a full commercial approach were conditions found to be favourable.

Investigations into commercialising the BSF project could therefore lead to the development of an alternative to full subsidies and possibly aid the long-tern sustainability of BSF adoption.

5.6 User perceptions

It is clear people are generally very satisfied with the filters they have received and the benefits they receive from them. Whilst many perceived benefits including better taste, odour and look, were recorded, the research shows that by far the largest perceived benefits are improved health and access to pure water. Whilst this study confirms the perception that the filter provides purer water it does not confirm that the health of people has improved, merely that they perceive it to be better. The researcher was particularly struck by the fact many respondents' answers seemed to list the micro-biological agents they perceived were no longer in their water, raising the possibility that some perceive better health based on benefits suggested during their training. That said, many noted they had less medical bills and evidence from the recent evaluation by Samaritans Purse covering phase 2 filters in the same area showed significant health benefits. Therefore, it is likely that people's health had actually improved.

It should also be noted however, that many people perceived problems with the BSF retaining some of the water placed in it. Whilst it is likely user estimates were exaggerated it is a significant issue affecting the habits of users and increasing the risk of filter non-use.

5.7 Limitations of the study

Research suggests that whilst the potential for recontamination after using POU treatment systems is greatly reduced, there is still potential for recontamination of water through poor household water management and poor hygiene as documented by Trevett (2003).

Whilst these issues are important and have been addressed by the overall EKHC BSF programme, this study specifically addresses the issues relating to the quality of water that emanates from the BSF. In doing so it neither specifically examines the path of the water from leaving the spout to being consumed by the user nor the risks of recontamination. Conclusions drawn from this study are therefore not related to the quality of the water actually consumed by the users but only the potential benefits provided by the filter technology.

6 RECOMMENDATIONS

6.1 General recommendations

The research has highlighted several significant areas where improvements can be made and the following recommendations aim to suggest how to raise usage levels and filter performance towards potential levels demonstrated through other studies in Ethiopia and around the world, and increase the sustainability of the project.

6.1.1 Reinforcing educational messages

There is clearly a need to reinforce the educational messages presented to villages during the construction of filters at least five years ago. Educational visits should be planned to cater for both those who wish to refresh their memories and those not able to benefit from the original training. Visits should cover aspects of general hygiene as well as filter use and maintenance and should include:

- Teaching of the wet harrowing technique as the sole means for cleaning the filter. It should stress the need to only harrow to 2-3cm, using clean water and continuing the process until the water being dumped runs clear.
- Teaching of the importance of correct cleaning of the spout using a clean cloth, sponge or brush with a soap or detergent.
- Distribution of printed materials such as posters and stickers to remind the attendee of the teaching they have been given and the process of using and maintaining the filter.
- Information regarding the ways in which the caretaker can help them if they have problems with the filter.
- Where possible the caretakers should be included in some of the teaching of filter use and maintenance.

6.1.2 Increasing capacity of caretakers

There is also a need to increase the capacity of caretakers so that they are able to carry out their role with minimal restrictions. Activities which will facilitate this include:

- Involvement of the caretaker in village training, specifically demonstrations of filter use and cleaning so villagers are aware he has the knowledge to help with any problems.
- Encouragement of payments to caretakers from individual householders to cover time spent repairing filters and consumables such as sand and cement as well as tools.
- Setting up a supply chain where caretakers can get materials delivered from EKHC at cost price or from local markets.
- Providing caretakers with access to moulds so they can construct replacement filters when funds are available.
- Encouraging caretakers to keep records of problems reported to ensure all problems receive the required attention.
- Encouraging caretakers to meet to discuss the successes and problems they in their villages.

6.1.3 Increasing village autonomy

There are many factors which currently prevent caretakers and village water committees operating as autonomously from EKHC as possible. In order to give caretakers this greater autonomy and to transfer work from EKHC to the village level the researcher recommends:

- Clearly defining the role of caretaker, what responsibilities he has and what control he has over the way he operates.
- Clearly defining the role of EKHC and what support they will provide to caretakers and water committees.

- Channelling all EKHC communication with individual householders through the village caretaker or members of the water committee.
- Defining a clear communication procedure where caretakers can report problems to a single responsible person within the EKHC team.
- Encouraging and building the capacity of the village water committees to support the caretaker in non-technical aspects of his role such as revenue collection and acquiring materials.

6.2 The future of the BSF in Ethiopia

Whilst the recommendations in section 6.1 address many issues to improve the sustainability of the phase 1 filters they do not specifically target continued and active long-term adoption of the BSF. In order to address this complicated issue and determine the most applicable strategy the researcher recommends a number of further investigations. These are:

- A study to determine the ability of communities to provide the funds for replacement filters (including investigation of using the traditional iddir structure).
- Investigations into the commercialisation of filter production including:
  - Determination of the willingness and ability of households in the region to purchase new and replacement filters to assess the necessity of subsidies.
  - Determination of the level of demand for new and replacement filters in the region and demand generated in villages adjacent to implementation areas.
  - Determination of the start-up costs and overheads for small local workshops to produce the current BSF filters.
  - Determination of the costs of switching from the current design to the ‘improved’ round BSF design.
  - Determination of the associated costs of health education and marketing to enable a commercial business to function successfully.

Determination of a suitable starting subsidy followed by a small pilot study would enable the full feasibility of such an approach to be assessed and any significant problems associated with it identified.

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8 APPENDICES

Appendix 1 – Summary of field tests on the BSF

Worldwide BSF field tests

Tested by, Place, Year	Time since installation	Average faecal coliform removal rate (%)
Dr Manz, Nicaragua, 1993	21 days	97 (86.67-100)
	2 months	96.4
Agua de Saude, Brazil, 1998	2 weeks	98.64
Samaritan's Purse, Vietnam, 1998	unknown	95.8
Samaritan's Purse, East Africa, 1998	8 weeks	93.32
MedAir, Kenya 2000	3-4 weeks	93
Nicaragua	unknown	79.9 (64.4-95)
GOSA, Guatemala 2001	14 days	99.61
FBS Guatemala/El Salvador 2002	unknown	83.1
Samaritan's Purse, 6 countries, 2002	unknown	Honduras 100% Nicaragua 99% Mozambique 98% Kenya 94% Cambodia 83% Vietnam 81% (Average 93%)
MedAir, Kenya 2003	2.5-4	80.7 % producing <10 CFU
Duke, Haití, 2005	2.5 (average)	98.5

Ethiopian BSF field tests

Dejachew, Etiopía 2002	2.5	90
Samaritan's Purse, Ethiopía, 2005	2.5	97.3

Sources:(biosandfilter.org, 2004; CAWST, undated; Fewster et al., 2004; Maertens and Buller, 2006; Dejachew, 2002)

Appendix 2 – EKHC BioSand Filter promotional leaflet

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1 *ውኃን በአሸዋ የማጣራት ሥራ አጀማመር*

በምድራችን በተለይም የታዳጊው ዓለም ሕዝብ የንጹህ መጠጥ ውኃ አቅርቦት እጥረት በከፋ ደረጃ ላይ ይገኛል:: ይህን ችግር ለማስገወድ በመስኩ የተሠማሩ ተመራማሪዎች ለረዥም ጊዜ ጥረት ካደረጉ በኋላ ውኃን በአሸዋ በሳይንሳዊ መንገድ በማጣራት ንጹህና ለጤና ተስማሚ የሆነ ውኃ ማግኘት እንደሚቻል በማብሰር መፍትሔውን ጠቁመዋል::

ከነዚህ ተመራማሪዎች መካከል በግንባር ቀደምትነት የሚጠቀሱትና Biological Sand Filtration (BSF) የተባለውን ማጣሪያ የፈለሰፉት ዶ/ር ዴቪድ ሜንዝ ሲሆኑ ምርምሩንም ያካሄዱት በካልጋሪ አልበርት ዩኒቨርስቲ ውስጥ ነው::

የዶ/ር ዴቪድ ሜንዝ ምርምር በአብዛኛው ትኩረት ያደረገው የታዳጊውን ዓለም ሕዝብ የዕለታዊ ንጹህ የመጠጥ ውኃ ፍጆታን አስፈላጊነት ግምት ውስጥ በማስገባት ነው:: ለዚህም ላገኙት የምርመር ውጤት የፈጠራ ባለቤትነት መብት ሲኖራቸው በማጣሪያው ላይ በየጊዜያቱ የሚደረግ መሻሻልም ካለ በእሳቸው ስምምነት ይሆናል::

ማጣሪያው ንጹህ የመጠጥ ውኃ ከመስጠቱም ባሻገር በቀላሉ በቤተሰብ ደረጃ በአነስተኛ ወጪ መሠራቱ ነው::

ይህም በከፍተኛ ምርምር የተገኘ ቴክኖሎጂ ነው:: ደግሞም ብቸኛውና ውጤታማ የሆነ ውኃን የማጣራት ዘዴ መሆኑ ተመስክሮለታል::

ይኸ የአሸዋ ማጣሪያ ውኃን የሚበክሉ ተኀዋስያን ከመቶ ሰማንያ አምስት እጅ ያህል ሲያጣራ እንዲሁም ባዕድ የሆኑ ነገሮችን ደግሞ ሙሉ በሙሉ ያጣራቸዋል::

2 *ውኃን በአሸዋ የማጣራት አስፈላጊነት*

በአገራችን ንጹህ የመጠጥ ውኃ አቅርቦት በተለይ በገጠር ላለው ኅብረተሰብ ብዙም ያልተዳረሰ ሲሆን ከነዚህም ውስጥ በግንባር ቀደም ተጐጂ የሚሆኑት በኩሬና በወንዝ እንዲሁም በሌሎች ንጹህ ውኃ መገኛ ባልሆኑ አካባቢዎች የሚኖሩት ናቸው:: በእርግጥ ከፍተኛ የሆነ የውኃ አቅርቦት ቢኖራቸውም ከንጽህና ጉድለት የተነሣ በውኃ ወለድና ተዛማጅነት ባላቸው ተላላፊ በሽታዎች የሚጠቁትና ከዕለታዊ እንቅስቃሴአቸው የሚስተጓጐሉት ቁጥር በቀላሉ የሚገመት አይደለም:: በዚያውም አንጻር ወደ ሐኪም ቤት ሄዶ ለመታከም የሚወስደው ጊዜና የሚጠይቀው ወጪ ከፍተኛ ነው:: ከዚህ ሁሉ ቀውስ ለመዳን ውኃን በአሸዋ የማጣራት ዘዴ በቤተሰብ ደረጃ እንደ ዓይነተኛ መፍትሔና የተሻለ አማራጭ ሆኖ ተገኝቷል::

3 *የማጣሪያው አጠቃቀም ዘዴ*

- በማጣሪያው ውስጥ ያለውን አሸዋ እንዳይደርቅ ሁልጊዜ ውኃ እንዲኖር ማድረግ
- በቱቦው በኩል ውኃ ካልመጣ የላይኛውን አሸዋ በእጅ በመበጥበጥ ውኃ መምጣቱን ማረጋገጥ ይህ ካልሆነ እንደ እንጀራ የተጋገረውን የላይኛው አሸዋ አውጥቶ በሣህን አድርጐ በንጹህ ውኃ አጥቦ እንደገና ወደ ማጣሪያው መመለስ
- ከላይ የተጠቀሰውን ድርጊት ተፈጽሞ ውኃ ካልመጣ በአካባቢው ለሚገኙ የሠለጠኑ ባለሙያዎች ማማከር
- በማጣሪያው ውስጥ ካለው አሸዋ በስተቀር ሌላ መጠቀም ክልክል ነው

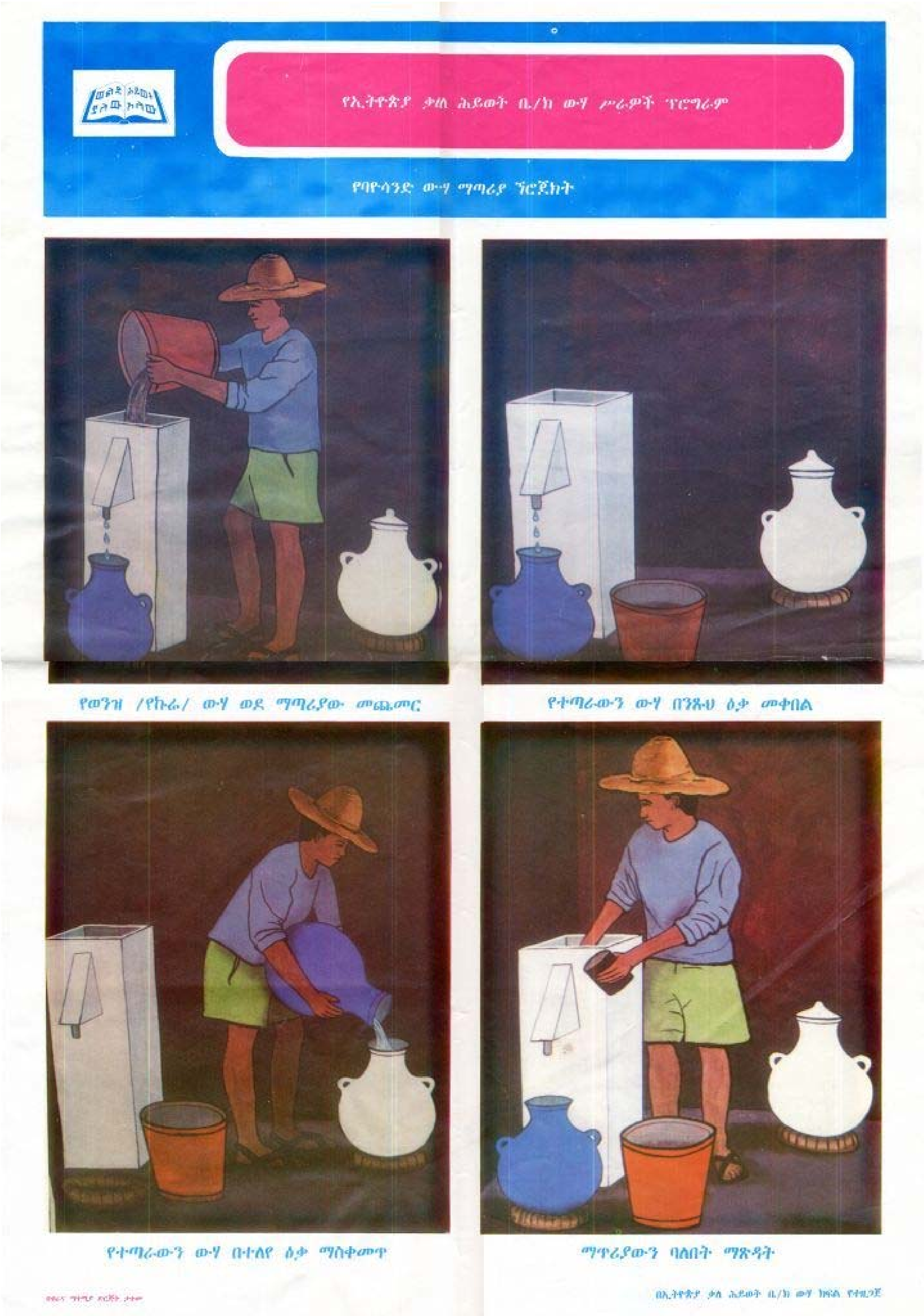
4 *ለማጣሪያው የምናደርገው ጥንቃቄ*

- ለደህንነቱ አስተማማኝ በሆነ ልጆችና የቤት እንስሳት እንዲሁም ፀሐይ በማይደርሱበት በተከለለ ቦታ ማስቀመጥ
- በማሠራጫው ወንፊት ላይ ንጹህ ድንጋይ ወይም ቁራጭ እንጨት መቀመጥ አለበት:: ምክንያቱም በማሠራጫ ሣህኑ ላይ ውኃ በሚጨመርበት ጊዜ እንዳይንቀሳቀስና እንዳይዛባ ያደርጋል :: ይህ ካልተደረገ ግን ውኃው በማሠራጫው ሣህኑ ላይ አለአግባብ እየፈሰሰ የአሸዋውንና የሥነ-ሕይወታዊ ንብብሩን እንዳያፋልስ ማድረግ አስፈላጊ ነው
- ከማጣሪያው ጫፍ (አናት) ጋር ሊገጥም የሚችል ክዳን መሠራት አለበት:: ክዳኑ በጣም ጠቃሚ ነው:: ይኸውም ከአቧራ፣ ከበራሪ ነፍሳትና ውኃን ለብክለት ከሚዳርጉት ነገሮች ስለሚከላከል ነው
- ማጣሪያው አንድ ጊዜ በአሸዋ ከተሞላ በኋላ ከቦታ ወደ ቦታ መንቀሳቀስ የለበትም
- በማጣሪያው ላይ ምንም ዓይነት ዕቃ መቀመጥ የለበትም
- በማጣሪያው ቱቦ ላይ ቧንቧም ይሁን ሌላ ነገር መግጠም ክልክል ነው::
- በየቀኑ ክትትል ማድረግ፣ ድንገት የመስንጠቅ አዝማሚያ ቢያሳይ በአስቸኳይ እንዲጠገን ማድረግ

5 *ውኃ በምናጣራበት ጊዜ የምንከተለው ጥንቃቄ*

- ውኃን ከኩሬ፣ ከወንዝ ወይም ከሌላ መገኛ ስንቀዳ ከልብስ እጣቢና ከሳሙና አረፋ፣ ከእንስሳት እንዲሁም ከሌሎች በካይ ነገሮች የጸዳ መሆን አለበት::
- የተቀዳውን ውኃ ለተወሰነ ሰዓታት በመያዣው ዕቃ በማቆየት ከዚያም የማጣራት ሥራ መጀመር
- በቀዳንበት ዕቃ መልሰን የተጣራውን ውኃ ማከማቸት የለብንም:: ምክንያቱም ዕቃው ንጹህ ካልሆነ ውኃው በድጋሚ ለጤና ጐጂ በሆኑ ተኀዋስያን ሊበከል ስለሚችል ነው::
- የተጣራውን ውኃ ማከማቻ ሁል ጊዜ በንጽህና መያዝ ሲኖርበት አልፎ አልፎ በሙቅ ውኃ ማጠብ አስፈላጊ ነው::
- የተጣራውን ውኃ ጣዕምና ቃና እንዳይበላሽ የመቅጃው ዕቃ በተለይም በገጠር አካባቢ እንሥራውም ሆነ ማጣሪያው ከእርሾ ከሊጥና ከአተላ ወዘተ ንክኪ የፀዳ መሆን አለበት::
- የተጣራውን ውኃ የምናከማችበት ዕቃ የተለየና በንጹህ ቦታ እንዲቀመጥ ማድረግ
- የተጣራውን ውኃ የምንጠልቅበት አንድ ለዚሁ ሥራ የሚያገለግል መጥለቂያ ማዘጋጀትና ሁልጊዜ በንጽህና መያዝና መጠቀም

Appendix 3 – EKHC BioSand Filter posters



Appendix 4 – BioSand Filter instruction sticker

የማጣሪያ አጠቃቀም መመሪያ

1. ከወንዝ ወይም ከኩሬ የቀዱትን ውሃ በጥንቃቄ በወንፊቱ ላይ ይጨምሩ
2. የተጣራውን ውሃና የወንዝ ወይም የኩሬ ውሃ መያዣ ዕቃዎችን ለይተው ይጠቀሙ
3. በውሃ መውረጃ ቀዳዳ ላይ መዝጊያ ወይም ቅጥያ ቱቦ አይጠቀሙ
4. ጤናዎ የበለጠ እንዲሻሻል የተጣራውን ውሃ አስፈላጊ ለሆኑ አገልግሎቶች ይጠቀሙ
5. በማጣሪያው ውስጥ ክሎሪን አይጨምሩ
6. ወደ ማጣሪያው በዝግታ ውሃውን ይጨምሩ
7. ማጣሪያው በተደላደለ ቦታ ከተቀመጠ በኋላ አያንቀሳቅሱ
8. ማጣሪያውን መክደንዎን አይዘንጉ
9. የውሃ መውረጃ ቀዳዳውን ከቤት እንስሳትና ከሕጻናት ንክኪ ይከላከሉ
10. የጥገና መመሪያውን ተግባራዊ ያድርጉ

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English Translation: (courtesy of Ato Tsegaye Gebre)

1. ONLY pour water in the filter with the diffuser basin in place - failing to do this will damage the filter.
2. ALWAYS use two buckets: one to pour in dirty water and one to collect filtered water. If only one bucket is used, the dirty bucket will contaminate the filtered water.
3. NEVER attach anything to the tap, such as a longer pipe, a hose or a valve.
4. ALWAYS use filtered water for as many tasks as possible: drinking, cooking, cleaning food, cleaning clothes, washing children, and feeding animals. Using the filter for all your water needs will contribute to better health.
5. NEVER put bleach in the water before pouring it into the filter and NEVER pour bleach directly into the filter - this will damage the filter.
6. ALWAYS pour the water into your filter SLOWLY.
7. NEVER move the filter once it has been installed - unless it is an emergency. Moving the filter will cause water to come out more slowly. If moved, the filter must be placed in a level position before using.
8. ALWAYS keep the lid on the filter when not in use.
9. DO NOT touch the tap of the filter unless cleaning it - keep animals and children away.

MAINTENANCE should be carried out as you have been instructed

Appendix 5 – EKHC phase 2 monitoring check-list

BioSand Water Filter **FOLLOW UP CHECK-LIST**

Filter Code: ______ Village: ______ Installer: ______
Name: ______ District: ______ Educator: ______
Organization: ______ Province: ______

☐ Hospital/Clinic ☐ Home
☐ School ☐ Business

Additional Follow Up Needed?
YES / NO

Rate: 1, 2, 3

Filter Body 1 2 3
Outside body (very dirty, dirty, clean) ☐
Integrity (leaking, seeping, fine) ☐
Level (angled, almost, level) ☐
Position (moved, turned, original) ☐
Spout (missing, dirty, clean) ☐
Lid (missing, aside, always in place) ☐
Inside - dirt/insects/food (very dirty, dirty , clean) ☐
Location (outside, sheltered, inside) ☐

Actions Completed:

Bio Film
Diffuser plate (missing, altered, fine) ☐
Sand surface (scoured, pitted, smooth) ☐
Standing head level: (cm) ______

Further Actions Required:

User Compliance
Effluent Container (none, dirty, clean/covered) ☐
Source water type(s): ______
Source water appearance (very cloudy, cloudy, clear) ☐
Pre treatment (none, attempted, cleaned) ☐
Cleaning Biofilm: ______ per ______
Information Sheet (none, lost, present) ☐
Filter Understanding (none, some, full) ☐

Flow Rate (mL/min): ______

Date of Installation: ______

Clean Water Use
Filter Use (never, sometimes, always) ☐
# of people using filter: ______
Water filtered (L/day): ______
Cooking? Yes / No
Bathing? Yes / No
Drinking BSF water? Yes / No

Health
Anyone with diarrhea in the past month? Yes / No
Explain: ______

What were the illnesses suffered by the family before receiving a BSF:
______

What are the illnesses suffered by the family since receiving a BSF:
______

Rate health of family before BSF (poor, okay, good) ☐
Rate health of family after BSF (worse, same, better) ☐
Access to health care (none, clinic, hospital) ☐
Access to latrine? (none, pit, covered) ☐

Date of Follow Up Visit: ______

______
Signature of Respondent

______
Signature of Interviewer
certifies respondent understands all followup issues

______
Signature of Supervisor

Appendix 6 – Samaritan's Purse recommended maintenance procedures

Phase 1

Remove the filter cover and diffuser plate
Lower the water level in the filter by scooping out water from the top of the filter with a small cup.
Remove approximately 2.5-5cm of sand which should be discarded or washed and reused.
Add water to the filter until it begins to drain. Sand should always be added to water.
Add fresh or washed sand such that the sand surface is 5cm below the water level.
Level the surface of the sand.
Replace the diffuser plate and lid.
The diffuser plate should not touch the surface of the standing water.

(Dejachew, 2002)

Phase 2

Remove the diffuser plate and lid.
Put your hand or a spoon in the filter and down into top 2-3cm of sand. Stir in a circle until the water becomes dark and then scoop this water out with a cup. Continue to stir and scoop water out until all the water is gone above the sand. Be careful not to scoop out the sand. Add water to the filter and repeat this process until the water is clear. Level the sand, replace the diffuser basin and pour water back into the filter. Do not takes and out of the filter. Finally, always check the level of water above the sand once you are finished. It should be 5cm or the second finger joint.
Pour water into the filter until it begins to drain.
The diffuser plate should not touch the surface of the water.

(Samaritan's Purse, 2001)

Appendix 7 – Project staff interview questions

B1 - BSF Coordinator Questions

General Programme

What is the history of the BioSand Filter Project?

How is it funded and how has it been implemented?

Are local authorities overseeing the programme?

How many filters have been produced?

Are they produced centrally and transported or produced locally?

What are the criteria for selection of communities and households?

Are they typically shared by families or wider groups?

Have impacts of the technology been measured? (health and wider impact)

What subsidies are given to households?

Are credit facilities available?

Are there ongoing funds for maintenance of the programme?

Are spares available locally?

Is the project supposed to stand on its own in the market place?

If so, is there evidence that it can and if not, why not?

Is a wider element of household environmental education included in the programme?

What other programmes are run in the village?

Is there any crossover between these programmes?

Is there baseline data for the communities selected?

Was monitoring and evaluation built into the project?

Has the planned monitoring been completed and if so when?

What other information exists regarding the projects?

Household Training

What support is given to the households that receive filters?

What training do individual households receive?

Is follow up training provided as part of the programme?

What promotional material is used?

Has it been updated since the beginning of the project?

Have old villages been distributed new material?

Caretaker Training and Support

Are caretakers paid or voluntary?

How much time do the caretakers spend carrying out their BSF tasks?

How are caretakers selected?

What tasks are the caretakers required to carry out?

What training do they receive?

What support do the caretakers receive?

Is follow up training provided for caretakers?

Are caretakers easily retained?

Have caretakers contacted EKHC reporting problems?

What are common reported problems from caretakers?

How should filters be maintained?

B2 - DebreZeit area BSF team leader questions

1. What are the common problems that are reported to with regards to the filters?
2. What support do you provide to the scheme caretakers?
3. Is it different for phase 1 and phase 2?
4. Do you think that all problems are reported to you or are there many that go unnoticed?
5. Are records kept of problems that are reported to ensure they are followed up?

6 Are materials and tools available to caretakers to allow them to carry out their job?

7 What problems do you have providing the required support to Phase 1 filters?

8. Do you think they need additional support, if so what support?

9 What problems do you see with the way phase 1 has been followed up?

10. What do you think would happen if the filter programme were to finish?
11. What suggestions would you make to improve the situation to make the project more sustainable?
12. Have you tried to make the project commercially independent?
13. Do you think it is viable and would be a good idea?

Appendix 8 – Caretaker interview questions

General Information

How many filters are installed? (Ph 1 and Ph2)

When were the filters installed? (Ph 1 and Ph 2)

Are they typically shared by families or larger groups?

How many households are there in the village?

How many caretakers are there? How do they share responsibility?

Is there a local healthcare worker in the village?

Caretakers' role and common problems

What is your role in the BSF programme?

What are the common problems you deal with and what do you do to solve them?

What common mistakes do you find with people using and maintaining their filters?

Do you ever add sand to filters or completely replace the sand?

How much time do you spend carrying out your role?

Are you paid or voluntary?

Training

What training have you received from EKHC?

Was it adequate or do you feel you need more training to cope with the tasks you are required to carry out?

Do you have any printed material to help you check people are using and maintaining the filters correctly?

Reporting, Support and Materials

Do you have any printed material to help you carry out your role as caretaker?

What support have you previously received from EKHC?

Is it easy to communicate with EKHC?

Do you feel you get enough help from EKHC?

Are there adequate supplies available to deal with all reported problems?

Have you ever asked EKHC for further help? Did you receive it?

Do you keep records of the problems reported to you?

Filters not in use

Are you aware of any filters that have been abandoned and no longer function?

What are the reasons for this?

Are you aware of any filters that have been sold to other people and no longer exist in the village?

Changes attributable to filters

What changes have you noticed in your village as a result of the BSF project?

What help would you like to help the filter programme be more of a success in your village?

Can you make any suggestions as to how the filter programme as a whole can be improved?

Appendix 9 – Household questionnaire

This is my first time in Africa and in Ethiopia. Can you describe to me a little of what life is like here in this village?			
Household Data			
1a	Interviewee		
1b	Male/Female		
1c	Persons living in household		
How do you get water for use in the home?			
2a	Water source used?		
2b	Is this the same all year round or is another source sometimes used?		
2c	How is water collected from source?		
2d	How much water is used each day?		
2e	What is your opinion of this water?		
Raw water testing			
How do you use the water in the home once you have collected it?			
3a	How long have you had the filter?		
3b	Is the filter still in use?		
3c	If not why not?		
3d	How many people use water from the filter?		
3e	How much of the water passes through the filter each day?		
3f	Do you use any other treatment processes?		
3g	How do you use the filtered water?		
3h	Does the filter provide enough water at the required time? (K6 changed from Does the filter provide enough water?)		
3i	Do you ever drink water that has not passed through the filter?		
	If so where from, and why?		
	If filter not in use - Where do you get your drinking water from now the filter no longer works?		
3j	What is your opinion of the filter?		
3k	Have you had any problems with the filter?		
3l	Who did/would you ask to help when you have problems?		
3m	Was the problem solved?		
Filter Inspection Checklist			
4a	Exterior **(leaking, seeping, fine)**	4h	Spout **(missing, dirty, clean)**
4b	Level **(angled, almost level, level)**	4i	Separate containers used for raw and treated water **(1, 2, 3)**
4c	Lid **(missing, aside, in place)**	4j	Clean containers covered and protected **(dirty, clean, clean and covered)**
4d	Interior **(very dirty, dirty, clean)**		
4e	Dispersion plate **(missing, broken/altered, fine)**	4k	General cleanliness of filter area **(very dirty, dirty, clean)**
4f	Water height from sand **(cm)**	4l	Proximity of animals **(animals present, minimal access, no access)**
4g	Sand surface **(scoured, pitted, smooth)**	4m	What level is the water poured up to? **(Below plate, above plate)**
4n	Have you ever replaced sand in the filter?		
	If so, why?		
4o	Have you ever moved the filter?		
	Details		

How do you look after and clean the filter?	
5a	When do you clean the filter?
5b	When did you last maintain the filter?
	Cleaning Checklist
5c	- Lid and diffuser plate
5d	- Interior
5e	- Sand Cleaning (Wet Harrow or sand removal)
5f	- If wet harrow, how deep?
5g	- If wet harrow, how many times?
5h	- If removal, how much sand is removed?
5i	- Spout Cleaned
5j	- How often are storage containers cleaned, with what?
5k	How much time is allowed before the filter is used after cleaning?
5l	Do you run to waste?
5m	What alternative water sources are used in the meantime?
Filtered water testing	
How do you know how to use and maintain the BSF?	
6a	Who was trained to use and maintain the BSF?
6b	Are they the only person/people to maintain it?
6c	What did you learn from your training? (sand replacement and repair?)
6d	Do you have any printed information to refer to, to help use and maintain the filter?
6e	What do you think of it? (Is it easy to understand? Have you used it? Was it helpful?)
6f	Has anyone been to visit to give further advice and training?
6g	Do you remember all of your training and feel confident that you use and maintain the filter correctly?
6h	Are there specific areas where you feel you need further advice or training?
Benefits and Suggestions	
7a	What changes has the water filter brought to the lives of those who use it?
7b	If filter no longer in use, do you fear that these benefits will disappear now you no longer use the filter?
7c	Is there anything that could be provided to help you use and maintain the filter better?
7d	Can you make any suggestions of how the water filter programme might be improved?

Appendix 10 –Correlation tests

	Filtino 1	Filtino 2	Filtino 3	Filtino 4	Filtino 5	Filtino 6	Filtino 7	Filtino 8	Filtino 9	Filtino 10	Filtino 11	Filtino 12
	Koftu 1	Koftu 2	Koftu 3	Koftu 4	Koftu 5	Koftu 7	Koftu 8	Koftu 9	Koftu 10	Koftu 14	Koftu 17	Koftu 18
	Koftu 19	Koftu 20	Nenema 1	Nenema 5	Nenema 8	Nenema 10	Nenema 15	Nenema 16	Nenema 19	Nenema 20	Nenema 22	Nenema 25

Test 1 - E-coli reduction vs Flow rate

E-coli reduction (%)	29.6	100	100	99	100	100	98.4	99.9	100	100	100	100
Flow rate (l/min)	2	0.13	0.026	0.857	0.0286	0.0352	0.105	0.4	0.857	0.08	0.545	0.095
E-coli reduction (%)	98	100	100	100	100	70	100	96	100	99.8	100	99.7
Flow rate (l/min)	0.053	0.46	0.055	0.045	0.12	0.24	0.26	0.4	1.2	0.46	0.207	0.429
E-coli reduction (%)	81.2	78.2	100	-50.5	99.88	98.88	-33.8	100	100	99.2	100	100
Flow rate (l/min)	0.33	0.66	0.038	1.2	0.33	0.031	1.2	0.75	0.043	0.286	0.162	0.461

Pearsons correlation coefficient, r = -0.62548503 Degrees of Freedom = 34 Critical value of r for p = 0.01 is 0.449 **Therefore correlation is significant**

Test 2 - E-coli reduction vs Influent Turbidity

E-coli reduction (%)	29.6	100	100	99	100	100	98.4	99.9	100	100	100	100
Turbidity (TU)	12	15	25	175	30	60	20	25	70	20	2000	2000
E-coli reduction (%)	98	100	100	100	100	70	100	96	100	99.8	100	99.7
Turbidity (TU)	52	52	53	24	40	40	40	40	75	45	45	45
E-coli reduction (%)	81.2	78.2	100	-50.5	99.88	98.88	-33.8	100	100	99.2	100	100
Turbidity (TU)	65	60	700	6	600	500	600	125	90	75	60	100

Pearsons correlation coefficient, r = 0.0172 Degrees of Freedom = 34 Critical value of r for p = 0. is 0.296 **Therefore correlation is not significant**

Test 3 - E-coli reduction vs Volume Treated

E-coli reduction (%)	29.6	100	100	99	100	100	98.4	99.9	100	100	100	100
Volume Treated (Jerry Cans)	2	4	2	3	2	2	1	1	3.5	4.5	1.5	1
E-coli reduction (%)	98	100	100	100	100	70	100	96	100	99.8	100	99.7
Volume Treated (Jerry Cans)	2	2	1	1	1	2.5	2	2	1	1	1	1
E-coli reduction (%)	81.2	78.2	100	-50.5	99.88	98.88	-33.8	100	100	99.2	100	100
Volume Treated (Jerry Cans)	2	1	1	1	1	2	2	1	1	1	2	2

Pearsons correlation coefficient, r = 0.0351 Degrees of Freedom = 34 Critical value of r for p = 0. is 0.296 **Therefore correlation is not significant**

Test 4 - E-coli reduction vs Time since last treated

E-coli reduction (%)	-	100	100	99	100	100	98.4	99.9	100	100	100	100
Time since last cleaning	-	7	7	9	31	3	0	8	11	1	1	5
E-coli reduction (%)	98	100	100	100	100	70	-	96	100	99.8	100	99.7
Time since last cleaning	7	5	5	2	1	2	-	14	5	5	15	31
E-coli reduction (%)	81.2	78.2	100	-50.5	99.88	98.88	-33.8	100	-	99.2	-	100
Time since last cleaning	31	0	31	1	14	2	0	4	-	3	-	6

Pearsons correlation coefficient, r = 0.2075 Degrees of Freedom = 32 Critical value of r for p = 0. is 0.296 **Therefore correlation is not significant**

Test 5 - E-coli reduction vs pause water depth

% decrease in faecal coliform count	29.6	100	100	99	100	100	98.4	99.9	100	100	100	100
Variation from 5cm (cm)	2	0	7.5	1	3	5	2.5	5	2	7	2	4.5
% decrease in faecal coliform count	98	100	100	100	100	70	-33.8	100	100	99.2	100	100
Variation from 5cm (cm)	4	3.5	2	5	1	4.5	1	1	1	3	4	5
% decrease in faecal coliform count	100	96	100	99.8	100	99.7	81.2	78.2	100	-50.5	99.88	98.88
Variation from 5cm (cm)	1.5	4	0	1	5	5	5	2	15	5	1	5

Pearsons correlation coefficient, r = 0.0563 Degrees of Freedom = 34 Critical value of r for p = 0. is 0.296 **Therefore correlation is not significant**

Test 6 - E-coli reduction vs spout cleaning methods

	E-coli reduction			
	<75%	75-90%	90-99%	>99%
acceptable	2	1	1	12
not acceptable	2	1	4	16

Chi square coefficient = 1.15 Degrees of freedom = 3

Critical value for p=.05 is 7.82 **Therefore correlation is not significant**

Test 7 - E-coli reduction vs spout cleanliness

	E-coli reduction			
	<75%	75-90%	90-99%	>99%
clean	1	1	3	14
dirty	3	1	2	14

Chi square coefficient = 1.175 Degrees of freedom =

Critical value for p=.05 i 7.82 **Therefore correlation is not significant**