To demonstrate the efficacy of bio-sand water filters in preventing water-borne disease in households using water from different sources in Musoma Mara, Tanzania.

n.b. Following discussion with Dr James Bunn the objective of this project was revised to demonstrate the production of clean, safe, potable water.

SUMMARY

A study designed to demonstrate the production of potable water following filtration by bio-sand water filters was carried out in Musoma Mara, Tanzania. Water samples from natural water sources, commonly used for drinking water and likely to be contaminated with water-borne disease agents, were tested pre- and post-filtration at monthly intervals over a six month period.

The protocol for the study, which involved microbiological testing for the presence of faecal coliform bacteria, was designed and implemented by EACP's overseas partner, HRCO, in conjunction with scientists from the national government's Water Quality Laboratory (WQL). The presence of coliform bacteria was used as an indicator of faecal contamination and the likely presence of water-borne disease agents. Such agents are endemic in the region and the cause of debilitating diseases causing mortality and morbidity in rural village communities.

The study was carried between March and August 2017 in order to collect water samples for testing during both rainy and dry seasons.

Twenty-four households located throughout the Mara region were involved in the study and after the establishment and maintenance of active bio-layers and the use of good hygiene and water management practises all filters were 100% effective in producing clean, safe, potable water.

METHODS

1. Water sampling (see Table 1)

Water from six different water sources (bore-holes, rivers/streams, stand-pipes, Lake Victoria, dams, rain water tanks) was sampled under aseptic conditions by WQL and HRCO personnel and taken to the laboratory in a cool box with ice bags to be tested the same day. Samples were first taken in late March and subsequently at monthly intervals for a total of six months.

The table which follows lists the filters, the households and their location and the water sources sampled.

Table 1: Filters, Households and Water Sources

FILTER NO	DISTRICT	WARD	VILLAGE	SUB-VILLAGE	HOUSEHOLD NAME	WATER SOURCE
1	Musoma Rural	Nyakatende	Kigera Etuma	Kati	Veredianna	Bore Hole
2	Musoma Urban	Buhare	Mugaranjabo		Veronica	Bore Hole
3	Musoma Urban	Buhare	Buhare	Buhare	HRCO Centre	Bore Hole
4	Musoma Rural	Nyakatende	Kigera Etuma	Kati	C Machele	Bore Hole
5	Musoma Rural	Nyakatende	Nyakatende	Gatundu	CDR	River
6	Musoma Urban	Buhare	B.Kati	Bondeni	A Manyama	River
7	Musoma Rural	Kiriba	Makojo	Mtoni	Nyansaungu	River
8	Butiama	Rwamkoma	Makutano		M. Mafulu	River
9	Musoma Urban	Mwigobero	Mwigobero	Kawawa	Tana Nyabange	Stand-Pipe
10	Musoma Urban	Bweri	Bweri	Nyabisare	Maesa	Stand-Pipe
11	Musoma Urban	Kiara	Kiara A.		J. Masinde	Stand-Pipe
12	Musoma Urban	Kamunyonge	Biafura	FFU	P. Kamunyonge	Stand-Pipe
13	Butiama	Nyabange	Nyabange C.		Mama Keraka	Lake Victoria
14	Musoma Rural	Nyakatende	Kakisheri	Ikondo	Charity Home	Lake Victoria
15	Musoma Urban	Bweri	B. Centre	Bondeni	D.Mkama	Lake Victoria
16	Musoma Urban	Bweri	B. Centre	Bondeni	F. Makoya	Lake Victoria
17	Butiama	Nyankanga	Makutano		E.Nyabange	Dam
18	Butiama	Nyankanga	Makutano (C)	Lyamanigwe	M. Waswi	Dam
19	Butiama	Nyankanga	Makutano	Mkiringo	S. Nyaholi	Dam
20	Butiama	Nyankanga	Makutano	Lyamisanga	J. Mabunya	Dam
21	Musoma Urban	Kiara	Kiara B.		M. Rumwamwa	Rain
22	Musoma Rural	Nyakatende	Kakisheri	Ikondo	Charity Home	Rain (2)
23	Musoma Urban	Kiara	Kiara C.		R.Mwesa	Rain
24	Musoma Rural	Nyakatende	Kakisheri	Ikondo	Charity Home	Rain (1)

2. Water testing

Pre- and post-filtration water samples were processed in the laboratory by sterile membrane filtration and the precipitate grown in EMB agar, Levine(7103) using the pour plate method in order to isolate and differentiate faecal coliform bacteria (E.coli). Following incubation the number of colony-forming units (Cfu/100ml) was recorded to assess the likely level of faecal contamination.

The Tanzanian domestic standard for potable water is 0 Cfu/100ml.

3. Water usage

During the course of the study householders were instructed in good water management, including differential use and storage of filtered and unfiltered water and the maintenance of filters. They were also encouraged to keep a water log in order to record availability of filtered water and to ensure that the filters were kept in optimal condition.

RESULTS

1. **Microbiological Test Results and Effectiveness of B-sw Filtration** (see Table 2)
The table that follows lists the pre- and post-filtration results of microbiological testing of water samples taken from the six commonly-used water sources in Musoma Mara. Groups of four households each received water from the same source throughout the six month period of study.

From the table it can be seen that for the first three months (March, April and May) pre-filtered water samples all indicated high levels of contamination by faecal coliform bacteria, as demonstrated by high Cfu/100ml counts.

Following filtration, water samples from 9 households in March, 21 in April and 23 in May had no evidence of faecal contamination. The effectiveness of the filters in these households are therefore expressed as 37%, 87% and 95% respectively.

Pre-filtration samples taken during June, July and August are seen to have generally lower levels of contamination and all post-filtration samples are completely free of faecal coliforms. All filters during the months of June, July and August were considered to be 100% effective in producing clean, safe, potable water.

Table 2: Microbiological Test Results, March to August 2017

		March/Cfu		April/Cfu		May/Cfu		June/Cfu		July/Cfu		Aug/Cfu	
Filter No	**Water Source**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**
1	BH	50	10	40	0	40	0	20	0	0	0	10	0
2	BH	80	0	40	0	40	0	30	0	2	0	0	0
3	BH	20	0	20	0	20	0	15	0	5	0	0	0
4	BH	60	0	50	0	30	0	20	0	0	0	0	0
5	R	90	0	60	0	30	0	10	0	8	0	10	0
6	R	50	0	30	0	20	0	20	0	10	0	0	0
7	R	50	10	40	2	20	0	10	0	10	0	10	0
8	R	35	2	20	2	20	0	15	0	13	0	0	0
9	SP	90	10	60	0	30	0	0	0	0	0	0	0
10	SP	50	20	40	0	15	0	15	0	0	0	10	0
11	SP	20	0	20	0	20	0	0	0	0	0	0	0
12	SP	90	15	0	0	0	0	0	0	0	0	0	0
13	L	90	10	60	0	20	0	0	0	0	0	0	0
14	L	70	2	40	20	10	2	5	0	5	0	5	0
15	L	60	2	40	0	5	0	5	0	5	0	0	0

		March/Cfu		April/Cfu		May/Cfu		June/Cfu		July/Cfu		Aug/Cfu	
Filter No	**Water Source**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**	**Pre Filter**	**Post Filter**
16	L	90	0	90	0	30	0	20	0	4	0	5	0
17	D	90	20	20	0	20	0	0	0	0	0	0	0
18	D	70	5	70	0	20	0	20	0	8	0	0	0
19	D	55	2	50	0	30	0	10	0	10	0	5	0
20	D	90	2	70	0	40	0	20	0	6	0	0	0
21	RA	50	0	50	0	10	0	0	0	0	0	0	0
22	RA	50	1	20	0	20	0	10	0	0	0	5	0
23	RA	40	0	40	0	10	0	0	0	0	0	0	0
24	RA	50	8	10	0	10	0	5	0	2	0	0	0

Effectiveness of Filtration

MARCH	37%
APRIL	87%
MAY	95%
JUNE	100%
JULY	100%
AUG	100%

2. Water Sampling and Household Water Management

During the six month period of study WQL staff and their HRCO colleagues sought to educate and instruct householders in good hygienic practises and improved sanitation both in the home and whilst collecting, storing and using water.

- Cleaning the site when collecting water and removing standing water from immediate surroundings.
- Using the same water source each time when filtering water.
- Use clean water storage containers
- Always keep filtered and unfiltered water in different containers.
- Keep b-swfs clean and maintain the bio-layer in good condition.
- Allow turbid water to sediment in order to prevent muddying the filter sand.
- Prioritise the use of precious, filtered water for certain tasks (drinking, cleaning food, toilet ablutions etc).
- Use unfiltered water for other tasks e.g cleaning and cooking which involves prolonged boiling.

3. Anecdotal Evidence of Disease Control

Whilst water-borne diseases (diarrhoea, typhoid, amoebiasis, cholera, UTI and parasites) are endemic in the area, all households in the study reported reduced ill-health amongst family members. The following testimonies are a representative sample.

"My name is Tana Nyabange. I am a widow and a nurse in Nyakatende dispensary. I very much appreciate the work done by this Group. After the training of BioSand Filters, there has been a real improvement in eliminating waterborne diseases and especially cholera in Nyakatende as compared last reported cause in the dispensary. As a result, I am now a great advocate of the BioSand Fitlers, and I am advising all the community to get and use Filters for the better health of their families."

"My name is S. Nyaholi. I am single mother living with HIV with children, a daughter and a boys. My husband died due to HIV and my health is not promising at all but BioSand project has helped me become psychologically stable, especially as I get to work with other women in a similar condition. In difficult living situations, I believed that the high frequency of recurrent cholera in my family was a curse. But since I have a BioSand Filter in my home, cholera, typhoid fever, and diarrhea has reduced in my family."

"My name is R. Mwesi. I am 68 years old and a widow. Since I started using treated water filters, I feel energetic and stronger. Before, I had no energy or strength to do my daily shores my strength has returned and I now work normally. I think if you drink clean water you will not age quickly."

"My name is Jannet Maungo. I live in Musoma Rural, I am HIV positive currently I am using filtered water with my family. Since I started using filtered water in bathing my skin have started changing to smooth and healthier. I wish all the HIV positive people to start using BSWF so that to extend their life and reduce waterborne diseases."

"My name is Mama Keraka. I am a HIV positive mother of three children, all at school age. I have no income, and my children are always absent in school. All my children have at some point suffered from waterborne diseases, in particular cholera and typhoid. After I was trained in the making of BioSand Filters, I have reduced to attend hospital in very week with my family, my family's health has improved dramatically within a very short time."

"I Tabu Marwa, I would like to give my sincerely testimonial on the use of BSWF in my family is of great help especially by obtaining clean and safe water for my family. I would like to say to you that before I start using filter at my home,
I and my family were suffering from water borne disease like UTI, Amoebic and Typhiod and Cholera. Almost all my salary ended in treating the family which was very expensive. But now I am thanking FWFW and HRCO for introducing to us such a wonderful service which is helping us improve our health and also save our income since we do not buy fire wood nor charcal for boiling water".

"I Juliana as a matron at Charity home would like to declare from the bottom of my heart that the introduction of the use of BSWF at our charity is an enormous help since the charity has a lot of people and we use a lot money to buy firewood for boiling water and also a lot of environment destruction is done but now by using BSWF has cut down the use of fire wood and the people health at the charity is viva forever BSWF".

DISCUSSION

Results of the first set of microbiological tests (in March 2017) were surprising for two reasons. Firstly, because every water source sampled appeared highly contaminated and secondly, only nine filters out of 24 households appeared to remove coliform bacteria from the contaminated water (37% effective). Before these early results it was considered likely that water from deep underground sources (bore-holes and standpipes) might be less susceptible to faecal contamination than ground-water sources (rivers, Lake Victoria, and dams). As the study progressed, at least until the end of May, this trend of high contamination of all water sources continued, however an apparent drop-off in water source contamination began in June and accelerated through July and August.

Whilst improved cleanliness and better hygiene, particularly at sampling sites, may have been partially responsible for these observations, it is difficult not to also imagine a correlation between high contamination in the rainy season (March, April, May) falling off in the dry season (June, July, August) as heavy rain causing flooding of running groundwater had ebbed, the water table lowered and faecal contamination of water sources reduced accordingly.

This seasonal effect may also be partially responsible for the improved performance of the filters as the study progressed throughout the dry season when bacterial counts in filtered water had reduced to zero. However, during this period, coliform bacteria were still present in pre-filtered water samples and the effectiveness of b-sw filters was seen to increase from 87% in April, to 95% in May, and to 100% during each of the last three months, in the dry season.

At the start of the study in March a heterogeneous collection of b-swfs was installed in the 24 households. Some were new installations, others had been in use for months, and of these some were in good, clean condition whilst others were dirty with dysfunctional bio-layers. This motley mix of filters received appropriate remedial attention as the study progressed and good hygienic practises and improvement in sanitation and other household practises also made a difference to their performance. New installations had to develop fully active bio-layers, taking up to 30 days to do so and others required resetting of the bio-layer through cleaning and scraping of the diffuser plate and addition of clean water.

Therefore it is considered that the improved performance of the filters over the period of study was due to the improved conditions in which they were kept and how they were used and this resulted from the training by WQL and HRCO staff to facilitate better hygienic procedures, sanitation and management of water resources. Subsequent improvements in

the health of family members and the economic benefits of fewer absences from school, more time at work and lower bills for medicines and firewood were documented in the Testimonies included in this report.
The results of this study have shown that b-sw filtration can reliably produce clean, safe potable water from various contaminated water sources providing that filters are used and maintained in clean, hygienic conditions with active bio-layers as part of an established water management system.

Bio-sand water filters represent an excellent opportunity to provide clean, safe potable water to households in rural village communities where piped, treated water is not available. In Musoma Mara region to date, 123 men, women and young people from 9 community groups have been trained in the manufacture, installation and maintenance of filters and 181 b-swfs are now in use. Regional government has recently provided land to build a Youth Training Centre for training unemployed young people in filter manufacture, and construction materials for the building's foundations has already been provided. A resulting explosion in filter production would undoubtedly bring economic benefit to the region. However the main lesson learnt from this study suggests that a public educational programme including the correct use of filters, good hygiene, sanitation and water management will be required before filter users can be fully protected from an unnecessary loss of life and the debilitating morbidity of water-borne diseases.

FINANCIAL SUMMARY

Budget for revised project was £4750
Award granted by Sir Halley Stewart Trust was £4750
The project was fully funded by Sir Halley Stewart Trust
Two disbursements of grant monies were made to HRCO by EACP

7 March 2017 £2948 @ 2510 = Tsh 7,400,000
6 June 2017 £1799.49 @ 2638 = Tsh 4,750,000
small transaction fees were applied
Total monies received by HRCO = Tsh 12,150,000

Individual receipts covering project expenditure amounting to Tsh 12,192,000 were received. These receipts are kept on file and are available on request.

Three categories of costs are described, Transport & Logistics, Water Sampling and Water Testing and these are detailed in the following table (3)

Table 3: Receipts for study expenses (03/17 to 08/17)

	Tsh	Tsh	Tsh
Date	Transport and Logistics +	Water sampling +	Water testing
05/03-19/05		494,000 *	
25/03	1,000,000^	390,000 3	
28/03			1,056,000
01/05		390,000 3	
04/05	1,000,000^		1,056,000
26/05	1,000,000^		1,056,000
26/06		192,500 2	1,056,000
21/07		192,500 2	
25/07			1,056,000
21/08		192,000 2	
25/08	1,005,000#		1,056,000
Totals	4,005,000	1,851,000	6,336,000

Total study expenditure Tsh 12,192,000

+Water sampling for all 24 households often carried out over two or three days
* Pre-sampling visits to train householders and prepare for water sampling over first 3 months
3 Three people water sampling
2 Two people water sampling
^ Hire of motor vehicle for water sampling visits
# Motorbike hire for last 3 months water sampling visits

ACKNOWLEDGEMENTS

This study was fully funded by a One-Off Small Grant of £4,750 from the Sir Halley Stewart Trust, for which East Africa Children's Project and Hope Revival Children's Organisation were enormously grateful.

Should the results of the study be placed in the public domain the role of the Sir Halley Stewart Trust will be further acknowledged together with an appropriate disclaimer that views expressed were those of the authors and not necessarily those of the Trust. Copies of any publication will be provided to the Trust as requested.

REPORT SIGNATORIES

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Stephen Marwa	David Lewis
Executive Director	Trustee
HRCO	EACP
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Date	Date

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