SECRETARIAT OF THE PACIFIC COMMUNITY
SECRÉTARIAT GÉNÉRAL DE LA COMMUNAUTÉ DU PACIFIQUE

University of the South Pacific and Secretariat of the Pacific Community

Microbiological evaluation on the efficacy of Give Clean Water filters (Sawyer Point One™ filters) in an ideal laboratory setting

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BACKGROUND

In April 2011, the Fiji Ministry of Health (MOH) requested the Applied Geoscience and Technology (SOPAC) Division of the Secretariat of the Pacific Community (SPC) and the World Health Organization (WHO) South Pacific office to evaluate the efficacy of the Give Clean Water filters (Sawyer Point One^{TM} Filter) also known as GCW (Sawyer) filters being used in rural households in the country. The SOPAC Division of SPC along with the World Health Organization (WHO) and the Ministry of Health (MOH) counterparts had facilitated a survey on the use and effectiveness of the GCW (Sawyer) filter units in an effort to gauge the extent to which the filters were being utilised in ensuring communities are getting much safer drinking water. Whilst this survey focused more on social aspects around these filters, the question remained whether the GCW (Sawyer) filters were as effective as claimed by the manufacturers in terms of removing pathogens in the water (Kohlitz *et al.,* 2011).

AIM OF THIS STUDY

The aim of this work was to have an objective analysis of the effectiveness of the GCW (Sawyer) filter units through laboratory based analysis of highly contaminated water sample. Three different loads of bacteria (0-10, 10-100 and greater than 100 loads of total coliform and *Escherichia coli* were used in 3 different GCW (Sawyer) filter units and also compared with H_2S strip test in the laboratory setting. H_2S tests are used in communities to test for drinking water safety. Herein, the hypothesis drawn for this research was that the efficacy of the GCW (Sawyer) filters declines once the filters reach the 'back-flushing' stage and hence the filtered water would be unsafe beyond this stage.

METHODOLOGY

Samples of clean tap water, 10 litres in 3 separate buckets were spiked with an effluent known to be highly contaminated with total coliform. Prior to this, a series of trials were done to estimate the volumes required to obtain a desired range of total coliform. Based on this, the following spikes were done; Bucket 1-10 L of tap water spiked with 4 mL effluent to yield total coliform range of 0-10 total coliform colonies, Bucket 2-10 L of tap water with 10 mL effluent for a range of 10-100 total coliform colonies while bucket 3 had 40 mL of effluent in 10 L of tap water to yield >100 total coliform colonies. Each of the three buckets was connected to a GCW (Sawyer) filter unit which emptied into corresponding buckets for collection of filtered water. Prior to the filtration step, 200 mL of sample (10 L of tap water + effluent) was obtained and total coliform and *E. coli* contents were determined via membrane filtration technique (MFT). Further, 10 mL of the spiked samples (10 L of tap water + effluent) were also tested using the H_2S kit. The same procedure was repeated for the water collected after filtration. The amount of coliform in the sample before and after filtration will provide an indication on the effectiveness of the filter. The time taken for the sample waters to get filtered from their respective buckets was also noted to determine any changes in the rate of flow. A reduction in the rate would indicate clogging and perhaps reduced effectiveness of the filters thus indicating the back-flushing point. For each filtration through the GCW (Sawyer) filters, the volumes to be filtered for Buckets 1, 2 and 3 was maintained at 10 L/bucket, twice a day for consecutive 30 (duplicate) treatments. This volume of 10 litre/bucket filtration was increased to 20 litres twice a day, for the last 8 (duplicate) treatments per bucket until the back flushing point was reached.

RESULTS

The results below were drawn from a total of 38 treatments in each of the three Bucket-filter setup. From this, sample analyses were performed for total coliform and E.coli/100 ml, 38 tests each for water samples before and after filtration through the GCW (Sawyer) filters. These 38 tests were in duplicates of 100 ml of laboratory water test methods (MFT) and the average of the count was taken from the 2 counts obtained in 100 ml duplicates (Appendix I), summary for which is presented below in Part 1.

Further, as a second measure of filter efficiency, the total time taken for each filtration is also stated below. Based on this, the time required to filter 1 litre of the 10 litre samples for each filtration is also presented for successive filtrations till the stage of 'back-flushing' was reached.

PART I: Comparison of total coliform and E.coli/100 ml in contaminated water samples before and after filtration through GCW (Sawyer) filters.

Table 1: Presence of total coliform and E.coli/100 ml in water samples 'before filtration' through GCW (Sawyer) filters.

Bucket/Expected range	Total no. of samples analysed (N)	Mean of verified total coliform/100 ml	Actual range of verified total coliform/100 ml	Mean of verified E.coli/100 ml	Actual range of verified E.coli/100/ml
Bucket 1 (0-10 colonies)	38	7	<1 -32	3	<1 - 20
Bucket 2 (10-100 colonies)	38	20	1 - 95	10	<1 - 81
Bucket 3 (> 100 colonies)	38	69	3 - TNTC	45	<1 - 80

Interpretation: *The above table shows the average total coliform (TC) and E.coli per 100/ml that were allowed to be filtered by the GCW (Sawyer) filters per each filtration. Hereby, it shows that for Bucket 1 (with desired range of 0-10 bacterial colonies/100 ml) was able to filter an average of 7 coliform forming units (CFU) of TC and 3 CFU of E.coli/100 ml from the 10 litres of the contaminated water sample (10 L of tap water spiked with 4 ml of effluent) that was filtered in each filtration. Similarly, for Bucket 2, where the spiked bacterial load was approximated to give 10-100 CFU/100 ml, apparently had bacterial concentration higher than that of Bucket 1, however, statistical analysis shows that at 95% confidence interval the bacterial concentration in Bucket 1 was fairly similar ($p > 0.05$) and removed an average of 20 CFU of TC and 10 CFU of E.coli/100 ml from every 10 litre filtrations.*

For Bucket 3, the desired number of bacterial colonies on the plate was greater than 100 colonies and hence in many of its filtrations the bacterial growth was too numerous to count (TNTC). Hence, for TNTC counts the numerical values were adjusted at 80 CFU /100 ml to yield the presumptive TC/100 ml count. From this, the best estimate of average total coliform and E.coli/100 ml were estimated at 69 CFU of TC and 45 CFU of E.coli/100 ml for each of the 38 filtrations of Bucket 3.

Table 2: Presence of total coliform and E.coli/100 ml in water samples 'after filtration' through GCW water filter units (Sawyer Filters).

Bucket/Expected range	Total no. of samples analysed	Mean of verified total coliform/100 ml	Actual range of verified total coliform/100 ml	Mean of verified E.coli/100 ml	Actual range of verified E.coli/100 ml
Bucket 1 (0-10 colonies)	38	<1	<1	<1	<1
Bucket 2 (10-100 colonies)	38	<1	<1	<1	<1
Bucket 3 (> 100 colonies)	38	<1	<1	<1	<1

Intepretation: *The above table shows that sample analyses of contaminated water after being filtered through the GCW (Sawyer) filter showed no growth of colonies and thus, it was reported that <1 total coliform and E.coli/100 ml were present in the water that was collected after filtration through the GCW (Sawyer) filters. Hence, all water samples collected after filtration through the GCW (Sawyer) filters were potable (safe for consumption).*

Table 3. Comparison of membrane filtration technique (MFT) andhydrogen sulphide (H_2S) paper strip test for total coliform/100 ml in water samples before filtration with GCW(Sawyer) filters.

Bucket/desired colony range	No. of samples analysed (N)	MFT		H_2S		Comparison of MFT and H_2S results			
		No. positive for total coliform/100 ml at 35 ± 0.5 °C		No. positive at room temp. (16 - 23 °C)		Before filtration (BF) with GCW filter		After filtration (AF) with GCW filter	
		BF	AF	BF	AF	Agree	Not agree	Agree	Not agree
Bucket 1 (0-10 colonies)	38	38	0	3	0	3	35	38	0
Bucket 2 (10 – 100 colonies)	38	38	0	30	0	30	8	38	0
Bucket 3 (>100 colonies)	38	38	0	36	0	33	2	38	0

Summary: Appendix I

Note: *H_2S positive result is seen through blackening of the water submitted to H_2S test over a period of 3 days. If there is no colour change (-) in the water on the 3rd day it indicates that the water is free from bacterial contamination. A slight greyish colour change (+) on the first day indicates bacterial contamination and the water should be further incubated for few more days. Colour change to partial blackness (++) indicates higher bacterial contamination and necessitates decontamination of all drinking water, perhaps by boiling. If the water and the strip are noticeably black (+++) on the 3rd day*

then there is very high risk of bacterial contamination and that the water is not safe for drinking. Also, if the water and the strip turn noticeably black (+++) overnight then there is a high probability of bacterial presence in water and decontamination of water storage vessels should be considered (Community toolkit − Keeping your drinking water safe, 2013).

Interpretation: *The above table shows the summary of results obtained for total coliform count using the standard laboratory water test method of membrane filtration technique (MFT) and H_2S paper strip test. Herein, total coliform counts were observed with MFT, for all the water samples collected from Buckets 1, 2 and 3 'before filtration' by GCW filters. However, this result differed from the H_2S test which detects presence and absence of pathogenic bacteria in water. For Bucket 1 (4 ml effluent + 10 L of tap water) only 3 out of 38 water samples that were tested by H_2S method agreed with the results of MFT while 35 samples disagreed. For, Buckets 2 and 3 which contained 10 and 40 ml of effluent respectively, the positive results with both the techniques were quite comparable.*

A 100% agreement was achieved between the two techniques with water samples that were collected and tested 'after filtration' with the GCW (Sawyer) water filters. This indicates that samples with no contamination will also be negative for the H_2S test. At levels between 0-10 counts/100 mL the H_2S results still tend to show negative, between 10-100 colonies agreement is about 75% whereas above 100 colonies the agreement is nearly 95%. Note that while totally 'safe' water has no indicator bacteria counts, many communities consume water from 1-100 counts with no apparent health effects. This suggests that at practical level the H_2S kit is likely to be a useful indicator of badly contaminated water. For E.coli, however, the level at which the agreement becomes dominant is about 10 counts/100 mL. Also, the H_2S test methods only detect the hydrogen-producing bacteria which are normally pathogenic (disease-causing) while MFT detects pathogenic and non-pathogenic forms of bacteria.

Table 4: Comparison of membrane filtration technique (MFT) and hydrogen sulphide (H_2S) paper strip test method for E.coli/100 ml in water samples after filtration with GCW (Sawyer) filters.

Bucket/desired colony range	*No. of samples analysed*	MFT		H_2S	
		No. positive for E.coli/100 ml at 35 ± 0.5 °C		No. positive at room temp. (16 - 23 °C)	
		Before Filtration	After Filtration	Before Filtration	After Filtration
Bucket 1 (0-10 colonies)	38	34/38	0/38	3/38	0/38
Bucket 2 (10 – 100 colonies)	38	36/38	0/38	30/38	0/38
Bucket 3 (>100 colonies)	38	33/38	0/38	36/38	0/38

Summary: Appendix I

Intepretation: *The above table displays the counts of E.coli/100 ml identified/verified from the total coliform/100 ml. This count is being compared with the H_2S paper strip test which detects the presence or absence of hydrogen-sulphide producing bacteria (pathogenic bacteria) in water. Herein, observation similar to Table 3 is seen whereby Bucket 1, which has a lower volume of*

effluent, has not produced H_2S results as competent to the results of MFT while H_2S results of water samples from Buckets 2 and 3 strongly agree with the E.coli identified from the total coliform/100 ml of the MFT.

PART II: Monitor of time taken by each GCW (Sawyer) filter unit to filter the 10 litres of contaminated water

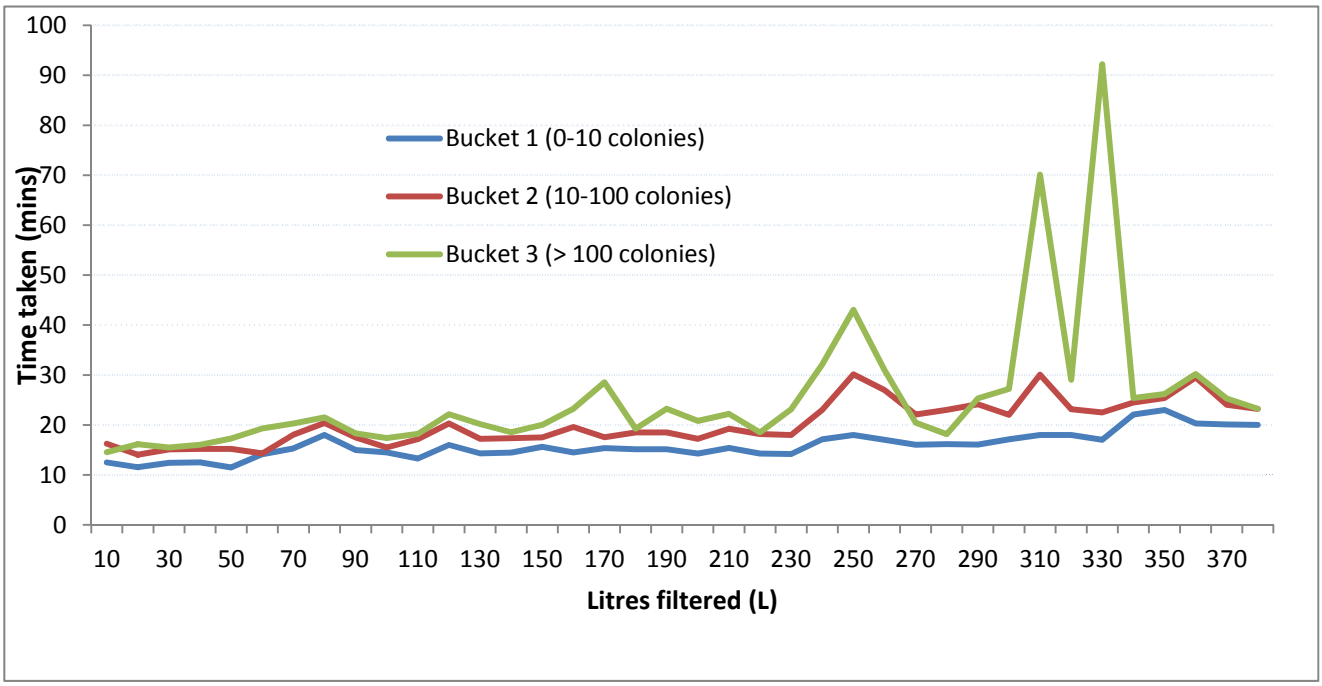

Figure 1: Graph showing the total time taken for every 10 litres of filtration in the bucket-filter setup.

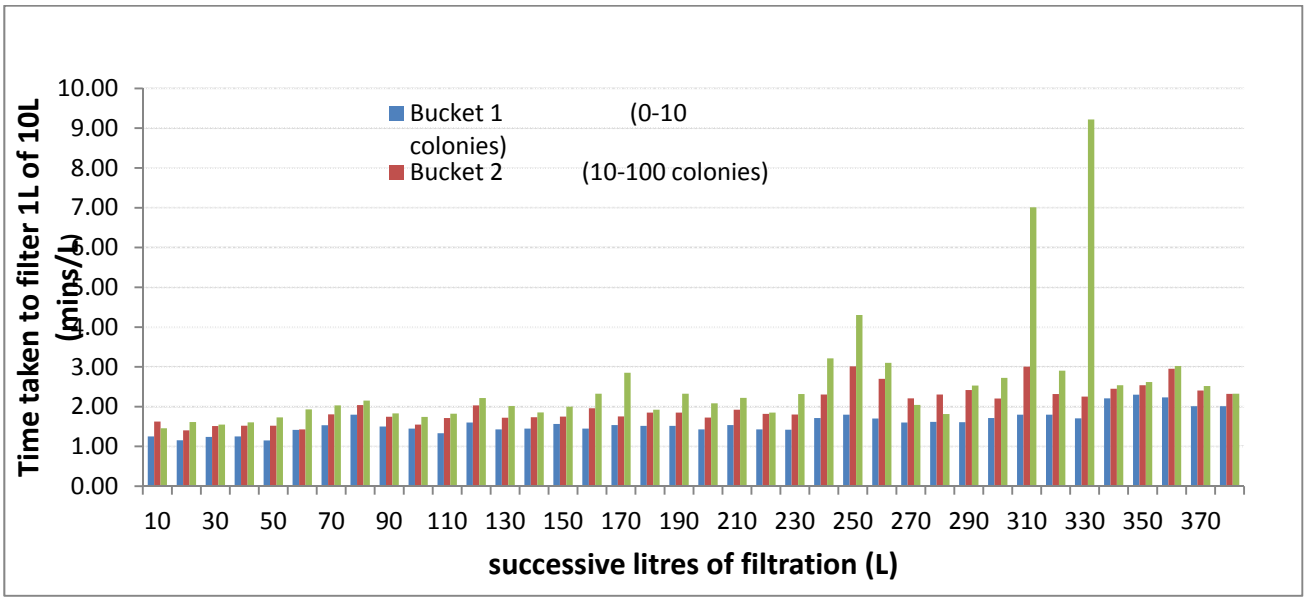

Figure 2: Graph showing the time taken to filter 1 litre from the total of 10 litres of water sample in the bucket-filter setup.

Intepretation: *Figure 1 shows the total time taken for filtration of every 10 litres of sample water while Figure 2 shows the time taken for 1 litre to filter from the 10 litres until the back-flushing point was reached. In both the graphs, the general trend observed for Buckets 1, 2 and 3 shows an increase in the time taken for filtration over successive filtrations. This increase in time had almost doubled upon filtration of 360 to 380 litres of filtrations from the initial rate. This is when the back-flushing stage was reached. This is roughly when the time for filtration is 50% greater than that at the outset.*

NB: *The exceptionally longer filtration time shown at 310 litres to 330 litres of filtrations was due to high density of suspended particulate and colloidal matter in the effluent used for spiking in the 10 litres of tap water. The respective effluent was collected after a heavy rainfall.*

DISCUSSION

This research confirms the efficacy of the GCW (Sawyer) filter units in removing pathogenic bacteria from water and that its efficacy is not compromised by the time the filter reaches its back-flushing stage. The back-flushing is the technical term used for the stage that necessitates cleaning of the filter.

As depicted by the results, the GCW (Sawyer) filter unit is highly efficient in removing greater than 100 bacterial colonies per 100 ml of contaminated water. This is evident from the comparison of total coliform and *E.coli*/100 ml for contaminated water samples before and after being filtered by the GCW (Sawyer) filters (Tables 1 and 2). Despite the high count of total coliform observed in the sample water before filtration through the GCW (Sawyer) filter, the laboratory water test method (MFT) shows less than 1 (<1 bacteria) in water collected after filtration through the GCW (Sawyer) filter units (Appendix 1).

The H_2S tests in general agree with this result of MFT, whereby the colour of the strips changed relatively with the increasing concentration of bacteria in the water samples 'before filtration' by the GCW (Sawyer) filter units. There was absolutely no colour change observed for the water collected after being filtered through the GCW (Sawyer) filter units. The H_2S paper strip tests detect the presence of hydrogen sulphide producing bacteria that are indicative of fecal coliform. E.coli is one such indicator of coliform hence the H_2S results are more comparable to the presence of E.coli/100 ml in the tested water samples.

The 'before filtration' results obtained with MFT and H_2S showed a greater correlation between Buckets 2 and 3 where the bacterial load was high compared to Bucket 1. Though the average bacterial load for Bucket 1 reached up to an average of 20 CFU of total coliform/100 ml, for some samples, this was not detected by H_2S. This observation may also be accounted for by the difference in temperature of incubation used in the MFT and H_2S technique. According to Pillai *et al.* (1999), positive results with H_2S are best seen within 18 to 48 hours of incubation at 22 – 45°C. The room temperature at which the H_2S test was performed in this research ranged from 16 – 22°C; hence, with lower load of bacteria, the sensitivity of H_2S test was reduced in the 16 – 22°C temperature range. Also, if the 10 ml water samples submitted to H_2S test missed out on the fecal material because of the very low number of the bacteria in the inoculum then the H_2S test will show negative presence of pathogenic bacteria even if high total coliform counts are observed with MFT (Pillai *et al*., 1999).

Nonetheless, there was 100% correlation between the two techniques when the contaminated water samples were tested after filtration by the GCW (Sawyer) filters, showing that there was <1% bacteria in the filtered water. Thus, this indicates that the GCW (Sawyer) filter units effectively removed pathogenic bacteria from contaminated water. Therefore, water produced through filtration via GCW (Sawyer) filter units is clean and safe for drinking.

Furthermore, as per earlier hypothesis, the efficiency of the GCW (Sawyer) filter in removing the pathogenic bacteria declined once the filter reached its back-flushing stage and hence the filtered water was expected to be non-potable (unsafe for drinking). However, this research showed that the GCW (Sawyer) filter units continued to produce clean and bacteria free water despite reaching the back-flushing stage.

According to the manufacturer's guide, the back-flushing point of the GCW (Sawyer) filters is reached upon a noticeable decrease in the flow rate giving a much slower filtration process by the GCW (Sawyer) filters. In this research, the back-flushing stage was reached upon filtration of 380 litres of highly contaminated water as evident for Buckets 2 and 3 ($p < 0.05$). At this stage the time taken for the filtration process had almost doubled from its initial rates in all the three buckets (Figure 1). Therefore, it can be stated that at household level the stage of back-flushing can be identified when the filtration time increases to about 50% above its initial rate. However, the filters will continue to give clean and potable water even upon reaching the back-flushing stage.

The results of this research agree with the manufacturers claim that with a pore size of 0.1 absolute micron (µm), it is almost impossible for bacteria to pass through the hollow filtration membrane of the GCW (Sawyer) filters (Sawyer®, 2013). This is also supported by scientific theory that bacterial size ranges from 0.5-1.0 µm in diameter and 2.0 – 5.0 µm in length (Shrivastava and Shrivastava, 2003). Thereby, bacteria will not be able to pass through the pore size of 0.1 absolute microns. Hence it can be inferred that the GCW (Sawyer) filters have a high degree of efficacy in producing clean and potable water.

CONCLUSION

It is concluded that the GCW (Sawyer) filters are highly effective in removing pathogenic bacteria from water thus, producing potable water that is safe for drinking. The minimum time for the GCW (Sawyer) filters to reach the back flushing point can be upon 360 litres to 380 litres total filtration of highly contaminated water. Hence, the higher the level of contamination in water, the slower the rate of filtration will be and the filters will reach the back flushing point more rapidly. However, the filters maintain the effectiveness even when the back-flushing stage is reached, thus continuing to produce potable water.

RECOMMENDATIONS

1. Given the ease of use and the high efficiency of the **GCW (Sawyer) filter** filters in removal of bacteria from water, the **GCW (Sawyer) filter** could be a rapid source of clean and potable water for households that lack proper water supply. The use of this filter can aid in prevention of common water borne illness like, stomach pains, diarrhoea and typhoid that are contracted through consumption of contaminated water.

2. Consumers and/users could also be educated on the proper usage and cleaning of the **GCW (Sawyer) filter** in order to ensure that the **GCW (Sawyer) filter** are maintained at maximum level

of efficiency in producing potable water. Proper storage of filtered water is also a vital issue and household members should be advised in this regard.

3. Cloudy water should be pre-filtered with a clean cloth to delay clogging of the filter and on-set of back-flush threshold. It is advisable for households to back flush their filters using clean water after filtering 360-380 L of water.

REFERENCES

Community toolkit- Keeping your drinking water safe. (2013). *'Tool for Water Quality Monitoring Using the Hydrogen-Sulphide (H_2S) Paper-Strip Test'.* Retrieved on June 10, 2013*.* http://www.pacificwater.org

Kohlitz, J., Hasan, T., Khatri, K., Arieta, S., Iddings, S., Bera, U. and Psutka, R. (2013). 'Assessing reported use and microbiological performance of a point-of-use household water filter in rural Fiji.' Journal of Water, Sanitation and Hygiene for Development **3**: 207-215.8

Pillai, J. K., Gibbs, M.R., Ho, G. (1999). 'H_2S Paper Strip method - A bacteriological test for fecal coliforms in drinking water at various temperatures.' Water, Science and Technology **40**: 85-90.

Sawyer® (2013). Sawyer Point One Filter Instructions SP-180. Retrieved on March 15, 2013. http://www.sawyer.com/sawyersaves/documents/pointONE-instructions.pdf

Sawyer® (2013). Sawyer Water Filter FAQs*.* Retrieved on March 15, 2013. http://www.sawyer.com/sawyersaves/FAQ.html

Shrivastava, S. and Shrivastava, P., S. (2003). 'Delineations, Cell Structure and Organization', *Understanding Bacteria.* Retrieved on April 6, 2013. http://books.google.com.fj/books

APPENDIX I RESULT/DATA FOR LAB ANALYSES OF SAMPLES

Table 5: Average verified total coliform/100 ml & E.coli/100 ml and H_2S test results for Bucket 1 (4 ml of effluent in 10 L of tap water).

Before filtration							After filtration							
							H_2S results			Ave TC/ 100 ml	Ave TC/ 10 L	H_2S results		
Volume filtered	**Ave TC/ 100 ml**	**Ave TC/10 L**	**Verified ave. TC/100 ml**	**Verified ave. TC/10 L**	**Verified ave. E.coli/ 100 ml**	**Verified ave. E.coli/10 L**	**Day 1**	**Day 2**	**Day 3**			**Day 1**	**Day 2**	**Day 3**
10	6	$1.50X10^4$	5	$1.20X10^4$	3	$6.30X10^3$	-	-	-			-	-	-
20	10	$2.50X10^4$	10	$2.50X10^4$	6	$1.40X10^4$	-	+	++	<1	<1	-	-	-
30	8	$1.90X10^4$	8	$1.90X10^4$	3	$7.50X10^3$	-	-	-	<1	<1	-	-	-
40	14	$3.40X10^4$	14	$3.40X10^4$	<1	<1	-	+	++	<1	<1	-	-	-
50	1	$1.30X10^3$	<1	<1	<1	$1.30X10^3$	-	-	-	<1	<1	-	-	-
60	3	$1.30X10^4$	3	$1.30X10^4$	2	$3.80X10^3$	-	-	-	<1	<1	-	-	-
70	2	$3.80X10^3$	1	$1.30X10^3$	1	$1.30X10^3$	-	-	-	<1	<1	-	-	-
80	38	$9.40X10^4$	32	$7.90X10^4$	<1	<1	-	-	-	<1	<1	-	-	-
90	2	$3.80X10^3$	1	$3.80X10^3$	1	$1.30X10^3$	-	-	-	<1	<1	-	-	-
100	4	$1.00X10^4$	3	$6.50X10^3$	2	$3.20X10^3$	-	-	-	<1	<1	-	-	-
110	17	$4.20X10^4$	15	$3.80X10^4$	8	$1.90X10^4$	-	-	-	<1	<1	-	-	-
120	14	$3.50X10^4$	8	$2.00X10^4$	4	$1.00X10^4$	-	-	-	<1	<1	-	-	-
130	15	$3.80X10^4$	13	$3.30X10^4$	<1	<1	-	-	-	<1	<1	-	-	-
140	9	$2.30X10^4$	6	$1.60X10^4$	2	$3.30X10^3$	-	-	-	<1	<1	-	-	-
150	32	$7.90X10^4$	23	$5.80X10^4$	6	$1.50X10^4$	-	-	-	<1	<1	-	-	-
160	33	$1.63X10^5$	22	$5.50X10^4$	16	$4.00X10^4$	-	-	++	<1	<1	-	-	-
170	26	$6.50X10^4$	16	$3.90X10^4$	3	$6.00X10^3$	-	-	-	<1	<1	-	-	-
180	1	$1.30X10^3$	1	$1.30X10^3$	1	$1.30X10^3$	-	-	-	<1	<1	-	-	-
190	16	$3.90X10^4$	15	$3.70X10^4$	15	$3.70X10^4$	-	-	-	<1	<1	-	-	-
200	25	$6.20X10^4$	22	$5.40X10^4$	20	$4.80X10^4$	-	-	-	<1	<1	-	-	-
210	1	2.50X103	1	2.50X103	1	2.50X103	-	-	-	<1	<1	-	-	-
220	<1	<1	<1	<1	<1	<1	-	-	-	<1	<1	-	-	-
230	2	$5.00X10^3$	1	$2.50X10^3$	1	$2.50X10^3$	-	-	-	<1	<1	-	-	-
240	2	$5.00X10^3$	1	$2.50X10^3$	1	$2.50X10^3$	-	-	-	<1	<1	-	-	-
250	2	$5.00X10^3$	1	$2.50X10^3$	1	$2.50X10^3$	-	-	-	<1	<1	-	-	-
260	2	$5.00X10^3$	1	$2.50X10^3$	1	$2.50X10^3$	-	-	-	<1	<1	-	-	-
270	5	$1.20X10^4$	5	$1.20X10^4$	3	$8.20X10^3$	-	-	-	<1	<1	-	-	-
280	5	$1.20X10^4$	5	$1.20X10^4$	3	$8.20X10^3$	-	-	-	<1	<1	-	-	-

290	5	$1.20X10^4$	5	$1.20X10^4$	3	$8.20X10^3$	-	-	-	<1	<1	-	-	-
300	5	$1.20X10^4$	5	$1.20X10^4$	3	$8.20X10^3$	-	-	-	<1	<1	-	-	-
310	3	$7.80X10^3$	2	$1.60X10^4$	2	$3.20X10^3$	-	-	-	<1	<1	-	-	-
320	3	$7.80X10^3$	2	$1.60X10^4$	2	$3.20X10^3$	-	-	-	<1	<1	-	-	-
330	3	$7.80X10^3$	2	$1.60X10^4$	2	$3.20X10^3$	-	-	-	<1	<1	-	-	-
340	3	$7.80X10^3$	2	$1.60X10^4$	2	$3.20X10^3$	-	-	-	<1	<1	-	-	-
350	10	$2.50X10^4$	5	$1.30X10^4$	2	$3.80X10^3$	-	-	-	<1	<1	-	-	-
360	10	$2.50X10^4$	5	$1.30X10^4$	2	$3.80X10^3$	-	-	-	<1	<1	-	-	-
370	10	$2.50X10^4$	5	$1.30X10^4$	2	$3.80X10^3$	-	-	-	<1	<1	-	-	-
380	10	$2.50X10^4$	5	$1.30X10^4$	2	$3.80X10^3$	-	-	-	<1	<1	-	-	-

Table 6: Average verified total coliform/100 ml & E.coli/100 ml and H_2S test results for Bucket 2 (10 ml effluent in 10 L of tap water).

Before filtration							After filtration							
							H_2S results					H_2S results		
Volume filtered	**Ave TC/ 100 ml**	**Ave TC/10 L**	**Verified ave. TC/100 ml**	**Verified ave. TC/10 L**	**Verified ave. E.coli/ 100 ml**	**Verified ave. E.coli/10 L**	**Day 1**	**Day 2**	**Day 3**	**Ave TC/ 100 ml**	**Ave TC/ 10 L**	**Day 1**	**Day 2**	**Day 3**
10	23	$2.3x10^4$	17	$1.7x10^4$	7	$7.1x10^3$	-	-	-	<1	<1	-	-	-
20	26	$2.6x10^4$	19	$1.9x10^4$	6	$7.0x10^3$	-	-	+	<1	<1	-	-	-
30	58	$5.8x10^4$	58	$5.8x10^4$	15	$1.5x10^4$	-	++	+++	<1	<1	-	-	-
40	50	$5.0x10^4$	46	$4.6x10^4$	7	$6.5x10^3$	-	_	++	<1	<1	-	-	-
50	2	$1.5x10^3$	<1	<1	<1	<1	-	-	-	<1	<1	-	-	-
60	3	$3.0x10^3$	2	$1.8x10^3$	2	$3.5x10^3$	-	-	-	<1	<1	-	-	-
70	3	$3.0x10^3$	3	$3.0x10^3$	2	$1.5x10^3$	-	+	++	<1	<1	-	-	-
80	85	$8.5x10^4$	67	$6.7x10^4$	10	$9.5x10^2$	-	+	++	<1	<1	-	-	-
90	1	$5.0x10^2$	1	$5.0x10^2$	<1	<1	-	++	+++	<1	<1	-	-	-
100	9	$9.0x10^3$	8	$7.5x10^3$	5	$4.5x10^3$	-	++	+++	<1	<1	-	-	-
110	52	$5.2x10^4$	36	$3.6x10^4$	8	$2.1x10^4$	-	+	++	<1	<1	-	-	-
120	43	$4.3x10^4$	25	$4.0x10^4$	10	$1.0x10^4$	-	+	++	<1	<1	-	-	-
130	30	$3.0x10^4$	19	$1.9x10^4$	6	$5.5x10^3$	-	-	+	<1	<1	-	-	-
140	20	$2.0x10^4$	16	$1.6x10^4$	2	$2.2x10^3$	-	+	++	<1	<1	-	-	-
150	109	$1.1x10^5$	95	$9.5x10^4$	81	$8.1x10^4$	-	+	++	<1	<1	-	-	-
160	94	$9.6x10^4$	75	$7.5x10^4$	47	$4.7x10^4$	-	+	++	<1	<1	-	-	-
170	58	$5.8x10^4$	54	$5.4x10^3$	35	$3.5x10^4$	-	-	-	<1	<1	-	-	-
180	1	$1.0x10^3$	1	$1.0x10^3$	1	$1.0x10^3$	-	-	-	<1	<1	-	-	-
190	96	$9.5x10^4$	71	$7.1x10^4$	62	$6.2x10^4$	-	+	++	<1	<1	-	-	-

200	50	$5.0x10^4$	50	$5.0x10^4$	22	$2.2x10^4$	-	-	-	<1	<1	-	-	-
210	8	$8.0x10^3$	7	$6.5x10^3$	4	$4.0x10^3$	-	-	-	<1	<1	-	-	-
220	4	$4.0x10^3$	4	$3.5x10^3$	2	$1.5x10^3$	-	-	-	<1	<1	-	-	-
230	11	$1.1x10^4$	11	$1.1x10^4$	4	$9.5x10^3$	-	-	+	<1	<1	-	-	-
240	11	$1.1x10^4$	11	$1.1x10^4$	4	$9.5x10^3$	-	-	+	<1	<1	-	-	-
250	11	$1.1x10^4$	11	$1.1x10^4$	4	$9.5x10^3$	-	-	+	<1	<1	-	-	-
260	11	$1.1x10^4$	11	$1.1x10^4$	4	$9.5x10^3$	-	-	+	<1	<1	-	-	-
270	7	$7.0x10^3$	5	$7.0x10^3$	4	$4.2x10^3$	-	-	+	<1	<1	-	-	-
280	7	$7.0x10^3$	5	$7.0x10^3$	4	$4.2x10^3$	-	-	+	<1	<1	-	-	-
290	7	$7.0x10^3$	5	$7.0x10^3$	4	$4.2x10^3$	-	-	+	<1	<1	-	-	-
300	7	$7.0x10^3$	5	$7.0x10^3$	4	$4.2x10^3$	-	-	+	<1	<1	-	-	-
310	3	$2.5x10^3$	2	$1.5x10^3$	1	$2.5x10^3$	-	-	++	<1	<1	-	-	-
320	3	$2.5x10^3$	2	$1.5x10^3$	1	$2.5x10^3$	-	-	++	<1	<1	-	-	-
330	3	$2.5x10^3$	2	$1.5x10^3$	1	$2.5x10^3$	-	-	++	<1	<1	-	-	-
340	3	$2.5x10^3$	2	$1.5x10^3$	1	$2.5x10^3$	-	-	++	<1	<1	-	-	-
350	7	$6.5x10^3$	3	$2.5x10^3$	2	$1.5x10^3$	-	-	+	<1	<1	-	-	-
360	7	$6.5x10^3$	3	$2.5x10^3$	2	$1.5x10^3$	-	-	+	<1	<1	-	-	-
370	7	$6.5x10^3$	3	$2.5x10^3$	2	$1.5x10^3$	-	-	+	<1	<1	-	-	-
380	7	$6.5x10^3$	3	$2.5x10^3$	2	$1.5x10^3$	-	-	+	<1	<1	-	-	-

Table 7: Average total coliform & E.coli and H_2S results for Bucket 3 (40 ml of effluent in 10 L of tap water).

Before filtration							After filtration							
							H_2S results					H_2S results		
Volume filtered	**Ave TC/ 100 ml**	**Ave TC/10 L**	**Verified ave. TC/100 ml**	**Verified ave. TC/10 L**	**Verified ave. E.coli/ 100 ml**	**Verified ave. E.coli/10 L**	**Day 1**	**Day 2**	**Day 3**	**Ave TC/ 100 ml**	**Ave TC/ 10 L**	**Day 1**	**Day 2**	**Day 3**
10	114	$2.9x10^4$	109	$2.7x10^4$	16	$4.1x10^3$	-	++	+++	<1	<1	-	-	-
20	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	++	+++	<1	<1	-	-	-
30	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+++	+++	<1	<1	-	-	-
40	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+++	+++	<1	<1	-	-	-
50	79	$2.0x10^4$	55	$2.8x10^4$	5	$1.2x10^3$	-	+++	+++	<1	<1	-	-	-
60	119	$6.0x10^4$	119	$2.3x10^4$	16	$3.9x10^3$	-	+++	+++	<1	<1	-	-	-
70	19	$4.8x10^3$	19	$4.8x10^3$	<1	<1	-	++	+++	<1	<1	-	-	-
80	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	++	+++	<1	<1	-	-	-
90	9	$2.2x10^3$	3	$3.6x10^3$	<1	<1	-	+++	+++	<1	<1	-	-	-
100	55	$1.4x10^4$	45	$5.2x10^3$	26	$6.5x10^3$	-	+++	+++	<1	<1	-	-	-

110	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+++	+++	<1	<1	-	-	-
120	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+++	+++	<1	<1	-	-	-
130	131	$3.3x10^4$	131	$3.3x10^4$	78	$1.9x10^4$	-	++	+++	<1	<1	-	-	-
140	114	$2.9x10^4$	104	$2.5x10^4$	38	$1.6x10^4$	-	+++	+++	<1	<1	-	-	-
150	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+++	+++	<1	<1	-	-	-
160	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+++	+++	<1	<1	-	-	-
170	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	-	++	<1	<1	-	-	-
180	14	$1.8x10^3$	14	$1.8x10^3$	3	$7.2x10^2$	-	-	-	<1	<1	-	-	-
190	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	++	+++	<1	<1	-	-	-
200	126	$3.2x10^4$	126	$3.2x10^4$	40	$2.0x10^4$	-	+++	+++	<1	<1	-	-	-
210	25	$6.3x10^3$	25	$6.3x10^3$	20	$5.0x10^3$	-	-	++	<1	<1	-	-	-
220	7	$1.4x10^3$	7	$1.4x10^3$	3	$7.2x10^2$	-	-	-	<1	<1	-	-	-
230	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+	++	<1	<1	-	-	-
240	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+	++	<1	<1	-	-	-
250	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+	++	<1	<1	-	-	-
260	> 80	$8.0x10^5$	> 80	$8.0x10^5$	> 80	$8.0x10^5$	-	+	++	<1	<1	-	-	-
270	125	$3.1x10^4$	105	$2.6x10^4$	35	$8.6x10^3$	-	+	++	<1	<1	-	-	-
280	125	$3.1x10^4$	105	$2.6x10^4$	35	$8.6x10^3$	-	+	++	<1	<1	-	-	-
290	125	$3.1x10^4$	105	$2.6x10^4$	35	$8.6x10^3$	-	+	++	<1	<1	-	-	-
300	125	$3.1x10^4$	105	$2.6x10^4$	35	$8.6x10^3$	-	+	++	<1	<1	-	-	-
310	13	$3.3x10^3$	11	$2.7x10^3$	8	$2.4x10^3$	-	++	+++	<1	<1	-	-	-
320	13	$3.3x10^3$	11	$2.7x10^3$	8	$2.4x10^3$	-	++	+++	<1	<1	-	-	-
330	13	$3.3x10^3$	11	$2.7x10^3$	8	$2.4x10^3$	-	++	+++	<1	<1	-	-	-
340	13	$3.3x10^3$	11	2.0x100	8	$2.4x10^3$	-	++	+++	<1	<1	-	-	-
350	91	$2.3x10^4$	74	$1.4x10^4$	42	$1.1x10^4$	-	-	++	<1	<1	-	-	-
360	91	$2.3x10^4$	74	$1.4x10^4$	42	$1.1x10^4$	-	-	++	<1	<1	-	-	-
370	91	$2.3x10^4$	74	$1.4x10^4$	42	$1.1x10^4$	-	-	++	<1	<1	-	-	-
380	91	$2.3x10^4$	74	$1.4x10^4$	42	$1.1x10^4$	-	-	++	<1	<1	-	-	-

APPENDIX II: STATISTICAL ANALYSIS OF RAW DATA

Statistical Analysis of Bacterial Concentration in Buckets 1, 2 and 3.

Table 8: Descriptive

BUCKET	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	38	7.1316	7.69405	1.24814	4.6026	9.6606	.00	32.00
2.00	38	19.9474	25.42817	4.12499	11.5893	28.3054	.00	95.00
3.00	38	69.3947	36.49475	5.92023	57.3992	81.3903	3.00	131.00
Total	114	32.1579	37.33953	3.49717	25.2294	39.0864	.00	131.00

Table 9: Results of One-Way- ANOVA.

Counts

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	82155.842	2	41077.921	60.478	.000
Within Groups	75393.316	111	679.219		
Total	157549.158	113			

Table 10 : Multiple comparison between bacterial concentration in Buckets 1, 2 and 3 (Tukey's Test).

(I)BUCKET	(J) BUCKET	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2.00	-12.81579	5.97899	.086	-27.0193	1.3877
	3.00	-62.26316*	5.97899	.000	-76.4666	-48.0597
2	1.00	12.81579	5.97899	.086	-1.3877	27.0193
	3.00	-49.44737*	5.97899	.000	-63.6508	-35.2439
3	1.00	62.26316*	5.97899	.000	48.0597	76.4666
	2.00	49.44737*	5.97899	.000	35.2439	63.6508

*. The mean difference is significant at the 0.05 level.

APPENDIX II: STATISTICAL ANALYSIS OF RAW DATA

Statistical Analysis of Time Taken For Back- Flushing Point to be reached in Buckets 1,2 and 3

Table 11: Descriptive

Bucket	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	38	1.599211	.2805145	.0455055	1.507008	1.691413	1.1490	2.3000
2	38	2.031053	.4395381	.0713025	1.886580	2.175525	1.4050	3.0140
3	38	2.445995	1.5549605	.2522479	1.934892	2.957098	.1538	9.2200
Total	114	2.025419	1.0006532	.0937198	1.839744	2.211095	.1538	9.2200

Table 12: Results of Two-Way- ANOVA

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	*13.626*	*2*	*6.813*	*7.599*	*.001*
Within Groups	*99.522*	*111*	*.897*		
Total	*113.148*	*113*			

Table 13: Multiple comparison between time taken to filter 1 litre in Buckets 1, 2 and 3 (Tukey's Test)

Bucket	*Bucket*	*Mean Differe (*	*Std. Error*	*Sig.*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
1	*2*	*-.4318421*	*.2172308*	*.120*	*-.947887*	*.084203*
	3	*-.8467842**	*.2172308*	*.000*	*-1.362830*	*-.330739*
2	*1*	*.4318421*	*.2172308*	*.120*	*-.084203*	*.947887*
	3	*-.4149421*	*.2172308*	*.141*	*-.930987*	*.101103*
3	*1*	*.8467842**	*.2172308*	*.000*	*.330739*	*1.362830*
	2	*.4149421*	*.2172308*	*.141*	*-.101103*	*.930987*

**. The mean difference is significant at the 0.05 level.*

APPENDIX III: ILLUSTRATION OF EXPERIMENTAL SETUP

Figure3: shows the setup of the buckets and the Sawyer Point One™ Filters during filtration.

Filter

The **GCW (Sawyer) filter** (Sawyer Point One^{TM} Filter Bucket Adapter Kit) is a multiple component kit that includes a 0.1 micron hollow fibre membrane filter, a 91 cm long hose, a hole cutter tool, a hanger and syringe and fittings (Sawyer®, 2013). As shown in the picture, one end of the filter unit is inserted in the first bucket (red). This bucket holds the water that needs to be filtered. The other end of the filter is connected with the hollow membrane filter which empties into a second bucket (green) which collects the filtered/clean water. The entire filtration process is carried out using force of gravity only and hence no external force is needed. To 'turn off' the filter, a hanger that connects to the top of the first bucket is used to hang the filter above the water level in the first bucket in order to stop the flow of water from the first bucket to the second (collection) bucket (Kohlitz *et al*., 2013).

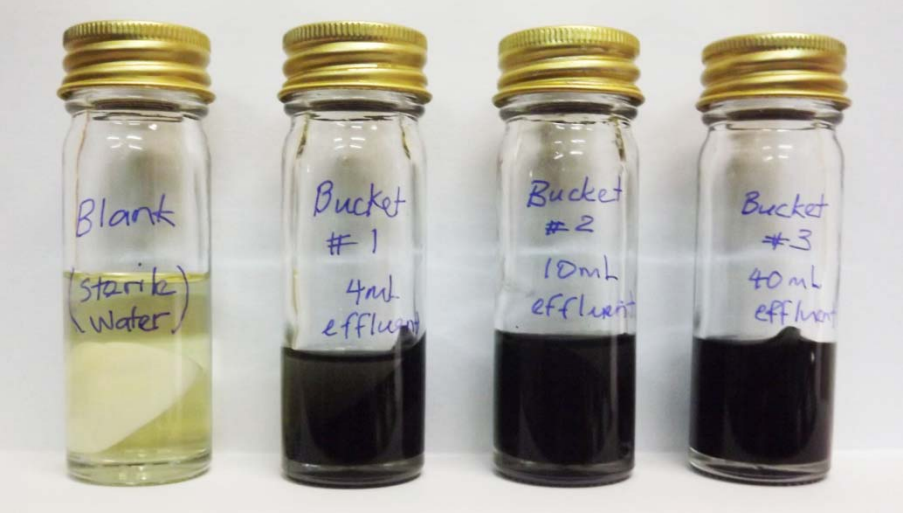

Figure 4: shows the varying degrees of bacterial concentration observed with the H_2S test.