Ghana 2012 Group Project Report

MIT Civil and Environmental Engineering Department
Master of Engineering Students:

Connie Lu
Matthew Miller
Adam Questad

Supervisor: Susan Murcott
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Introduction

Pure Home Water (PHW) is a non-profit social enterprise that was founded by Susan Murcott and local partners in 2005, and is registered in Tamale in Northern Ghana. The goals of PHW are "to provide safe drinking water to those most in need in Northern Ghana, and to become locally and financially self-sustaining." PHW manufactures and distributes ceramic water filters, locally known as *Kosim* filters. Ceramic filters are a proven HWTS technology for improving water quality at the point of use (Clasen *et al*., 2007). Moreover, ceramic filters can be manufactured at low cost and with local materials in Ghana. PHW has already reached over 100,000 people directly with its *Kosim* water filter, and also provides education, training and emergency relief. In addition, PHW is expanding its services in the region to include some aspects of sanitation and hygiene education.

This group report consists of three projects that contribute to the water, sanitation and hygiene projects by PHW in Northern Ghana. The first paper (1) identifies the best filter composition found to date for the PHW factory in Tamale, (2) develops two simple and low-cost quality control measures, the First Drip Test and the tortuosity representation, to determine ceramic pot filter effectiveness in removing harmful pathogens, and (3) develops a Quality Assurance Program for the PHW factory. The second paper contributes to the monitoring and evaluation of a ceramic water filter and hand-washing intervention in Northern Ghana by (1) developing a three-part evaluation framework and (2) presenting results from baseline surveys conducted in January 2012. The third paper evaluates the current approaches towards providing access to improved sanitation facilities in the rural areas of Northern Ghana by (1) investigating the reasons that the I-WASH program was not successful in its sanitation goal and (2) evaluating alternative sanitation options such as simple pit latrines, ArborLoo, Uniloo, the EcoSan Pod (EcoSan 3), Sanivation and Sanergy.

Ceramic Pot Filters Evaluation as a Point-of-Use Water Treatment in Northern Ghana

By Matthew Miller

Background

According to WHO/UNICEF (2012) 778 million people in the world do not have access to improved sources of drinking water. An improved supply of drinking water is defined as "a household connection, or access to a public stand pipe, a protected well or spring, a borehole, or a sample of rainwater collection." The definition requires that at least twenty liters per person per day are available within one kilometer of a person's home. However, the reality of the situation is much worse, due to how an improved drinking water source is defined. The definition does not take into account whether the supply is regular or intermittent. If there is water available only a part of the year, as occurs in locations with wet and dry seasons, then this cannot count as an improved water supply, as it is not available. Additionally, the definition does not take into account the safety of the water, which is vital to a person's health. It also does not count handpumps that are in disrepair. It is possible that an improved source as defined above could still contain the presence of fecal matter. For example, according to the United Nations Statistics Division (2010), 82% of Ghanaians have access to an improved drinking water supply. However, this number is most likely much lower than stated due to the discrepancies in the definition.

The ceramic pot filter (CPF) is an adequate technology in providing safe drinking water and safe storage. However, it is not the silver bullet in household water treatment and storage (HWTS) products as the context in which a technology is placed is vital to its success. It comes in many shapes, from flowerpot to parabolic to hemispheric, and is made of clay and a combustible material, typically sawdust or rice husk. The combustible incinerates when the CPF is fired in the kiln, leaving small pores which give the CPF its filtering ability. Both materials are acquired locally, and the filters are made locally as well. The local availability and production are two features that enable self-reliance in the filter manufacturing process. The filters go through a process of mixing, molding, drying, firing, and drying once again, after which a coating of colloidal silver is painted on each filter. In some instances the filter is dipped in colloidal silver. The silver acts a disinfectant. Each CPF is placed in a plastic or clay receptacle with lid and spigot included. This is a vital piece of the CPF insofar as it provides a safe storage environment for treated water.

The ceramic water filter was first invented in 1982 by Fernando Mazariegos in Guatemala. He produced a 50 page manual in which the filter is called "the artisan filter for potable water" (as translated from the Spanish). The manual describes how to build a mixer, kiln, and the filter itself. USAID provided funding for the first filter factory which was built in Ecuador in the 1980s. Mazariegos helped in this process. During this time, technical issues with the filter arose, so Ron Rivera was first introduced to the filter when he came to sort out the issues on this project. Ron Rivera was later hired as the Nicaragua in-country supervisor for Potters for Peace (Lantagne, 2001a). When Potters for Peace decided they wanted to further pursue the application of this filter technology, Ron Rivera, along with Manny Hernandez, and others, played key roles in disseminating it to other countries. Today there are 35 filter factories in 18 countries (Rayner, 2009). The 36th factory, built by Pure Home Water (PHW) in 2010-2011, is the site of this author's research. MIT faculty, students, and alumni, including Susan Murcott, Rebecca Huang, and Danielle Lantagne, were among the first to undertake scientific studies of the CPF and these studies helped to spark interest in the filter by other researchers.

PHW is located in Tamale, Ghana and is a registered non-profit in Ghana. PHW was founded in 2005 by Susan Murcott, a Senior Lecturer at MIT's Department of Civil and Environmental Engineering. PHW's intention is to serve the 900,000 people in northern Ghana who currently use an unimproved drinking water source (Ghana Statistical Survey, 2003). The need for a point-of-use water treatment technology is amplified by the fact that, as of 2011, only 13% of Ghanaians have access to improved sanitation (WHO, 2011). This fact heightens the need for point-of-use drinking water treatment as can be shown in the research of Eisenberg et al. (2007). Eisenburg speaks of different pathways that can prevent pathogenic microorganisms from infecting humans. These include safe hygiene, safe excreta disposal, safe water storage and handling, and water quality improvements. Eisenberg et al found that water quality improvement is a critical pathway *when* excreta disposal and water storage and handling are performed inadequately. Despite many challenges, PHW has successfully distributed 17,400 filters serving more than 100,000 people through 2011. In February 2012, PHW began full production at its still growing factory outside Tamale. PHW currently has a contract with Rotary International through a Future Vision Global Grant to sell 1,250 subsidized filters to Ghanaians in local villages and to construct an equal number of tippy tap hand washing stations. PHW seeks to grow to address sanitation issues, proper hygiene education, and the potential sale of other (HWTS) products in its future.

The two primary goals of Pure Home Water (PHW) are:

(1) to provide safe drinking water to those most in need in Northern Ghana and
(2) to become locally and financially self-sustaining.

This study will provide crucial steps toward making these goals a reality. The three primary goals of this study are to:

(1) Find the optimum filter composition specific to the factory in Tamale, Ghana,
(2) Identify one or multiple simple and cheap indicators for determining ceramic pot filter (CPF) effectiveness in removing harmful pathogens, as will be indicated by total coliform removal, and
(3) Devise a quality control plan for the PHW factory in Tamale, Ghana.

Safe drinking water is vital to health; therefore, the CPF can be thought of as a health product. To that end, every CPF must be tested to ensure proper and adequate performance. Achievement of this study's three goals will help to guarantee that CPFs sold to the public are providing water that is safe to drink.

Although total coliform has been shown to be a poor indicator bacteria (Levy et al, 2012), it is used here to determine how well a CPF filters out bacteria. So the assumption is that a CPF will filter out total coliform similarly to how it would filter out other more harmful bacteria.

Methods

All research was performed in Tamale, Ghana from January 4 to January 24th, 2012. This is during the dry season in Ghana, so there was no rain, and during the annual *harmattan* the average daytime temperature was 90 degrees Fahrenheit. In total, 145 filters were tested, all of which had been manufactured at the PHW factory. Of these 145 filters, 35 different compositions were manufactured. However, not every filter underwent every test due to breakage (20 filters), limited time and limited supplies. 31 filters underwent every test. The composition of each filter, along with the raw data, can be found in the author's thesis titled Hemispheric Ceramic Pot Filter Evaluation, and Quality Assurance Program in Northern Ghana. A total of nine different tests were performed during this study. They included two different turbidity measurements, measured with a digital turbidimeter and a turbidity tube respectively, porosity, pressure or "Bubble Test", flow rate, "First Drip Test", tortuosity, bacteria removal, and qualitative strength inspection. The details of each of these test methods can be found in the author's thesis (Miller, 2012).
Minitab 15 was used to perform all statistical analysis in this research. All graphs titled *fitted line plot* and all outlined statistical tables originate from analysis performed in Minitab 15. Four different types of statistical tests were performed. These include simple regression (both linear and non-linear), multiple regression, ordinal logistic regression, and upper-tailed 2-sample Student's t-tests. All tests were performed at a 95% confidence interval.

Filter Composition Optimization
Nine different production variables were tested to see if they played a role in determining how well a CPF removed total coliform bacteria, how they affect the flow rate of the CPF, and how they affect the strength of the CPF. The nine production variables include the following:

- Percent of rice husk used in the composition mix,
- Percent of Gbalahi clay used in the composition mix,
- Percent of Wayamba clay used in the composition mix,
- Percent of grog used in the composition mix,
- Percent of Gbalahi clay used out of the total clay in the composition mix (this is the percentage of Gbalahi clay used when the total clay used includes both Gbalahi and Wayamba clay. It differs from the second variable because rice husk is excluded when calculating the percentage),
- Duration CPFs were fired in the kiln,
- Maximum temperature the kiln reached,
- Duration of the soak time (which represents the amount of time the kiln's temperature was above 700 degrees Celsius), and
- Dry mass of the CPF after it has been fired.

Results & Discussion

Of the nine different production variables tested, none were found to affect how well a CPF removed total coliform bacteria. However, it was found that percent rice husk used in the CPF composition is the primary production variable that affects flow rate. In Table 1, the p-value in the Analysis of Variance (0.000), at an alpha-level of .05, indicates that the relationship between flow rate and percent rice husk is statistically significant. Additionally, the R-squared value shows that dry mass after firing explains 86.1% of the variance in flow rate, signifying that the model fits the data (Figure 1). The flow rate-percent rice husk relationship explains the flow rate mechanism. As the percentage of rice husk used increases, the flow rate increases because the porous volume in the CPF is increasing. A larger porous volume allows more water to flow through the CPF in a given time.

Table 1: Simple Regression and ANOVA for Flow Rate vs. Percent Rice Husk

The regression equation is
flow rate (L/hr) = - 8.794 + 0.8364 % Rice Husk

S = 1.44416   R-Sq = 86.6%   R-Sq(adj) = 86.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	389.420	389.420	186.72	0.000
Error	29	60.482	2.086		
Total	30	449.902			

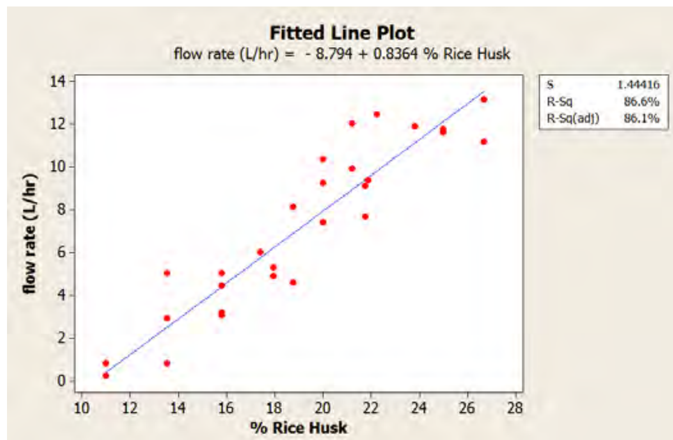

Figure 1: Flow Rate vs. Percent Rice Husk

A 2-sample Student's t-test was performed to see the effect of firing temperature on flow rate. The two samples had nearly identical firing durations (10.5 to 10.75 hours), and identical soak times (120 minutes). In addition, the samples were composed of CPFs with nearly identical compositions (Table 2). Compositions are notated in kilograms as follows: Gbalahi clay-Wayamba clay-grog-rice husk. The first set had compositions of 12-4-0-2.5, 12-4-0-3, 12-4-0-3.5, 12-4-0-4, and 12-4-3-4 (n=15). The second set had compositions of 12-4-0-2.5, 12-4-0-3, 12-4-0-4, and 12-4-0-5 (n=22). The only difference was the maximum firing temperature. The first sample maximum firing temperature was 875 degrees centigrade. The second sample maximum firing temperature was 950 degrees centigrade.

Table 2: Composition Comparison for a 2-sample Student's t-test

Composition	# of CPFs		Composition	# of CPFs
12-4-0-2.5	3		12-4-0-2.5	5
12-4-0-3	4		12-4-0-3	7
12-4-0-3.5	3		12-4-0-4	4
12-4-0-4	3		12-4-0-5	6
12-4-3-4	2			
Total	15		Total	22

Table 3: 2-Sample Student's t-test for 950 Degrees Centigrade vs. 875 Degrees Centigrade

```
                        N  Mean  StDev  SE Mean
950 degrees centigrade  22  4.97   2.20     0.47
875 degrees centigrade  15  2.94   1.66     0.43


Difference = mu (950 degrees centigrade) - mu (875 degrees centigrade)
Estimate for difference:  2.033
95% lower bound for difference:  0.957
T-Test of difference = 0 (vs >): T-Value = 3.20  P-Value = 0.002  DF = 34
```

The null hypothesis assumes the difference between the two population means is 0. That is, the null hypothesis says the difference in flow rate between the 950 degree centigrade sample and the 875 degree centigrade sample is 0. Table 3 above shows that the p-value (0.002) is less than an α-level of 0.01 which means the null hypothesis is rejected. The upper-tailed alternate hypothesis can then be accepted, which says the flow rate for CPFs fired at 950 degrees centigrade is greater than the flow rate for CPFs fired at 875 degrees centigrade. Therefore, we can say that for this set of compositions, the higher firing temperature of 950 degrees centigrade gives a higher flow rate. Thus, firing temperature is a secondary production variable that affects flow rate.

Eight of the nine production variables were analyzed for a third time to see which ones affect the strength of a CPF. As explained previously, the variable dry mass after firing is dependent on percent rice husk. The strength of each CPF was categorized qualitatively. Therefore, in the analysis of the strength, ordinal logistic regression was used. Ordinal logistic regression is based on having predictor variables with three or more values with a natural ordering. In this case those predictor variables are very weak, weak, fair, moderate, strong, and very strong. They suggest a natural ordering of increasing strength. Two ordinal logistic regression tests were performed to split up the two primary aspects of production variables, physical components and firing technique.

Table 4 shows that the predictors percent grog, percent Gbalahi clay, and percent Gbalahi clay of total clay (percent Wayamba clay is implicit due to percentages adding up to 100%) have p-values higher than an α-level of 0.05. There is insufficient evidence to conclude that the predictors mentioned immediately above have an effect on strength. However, the p-value for percent rice husk (0.007) is less than an alpha-level of 0.05 which means there is sufficient evidence to conclude that percent rice husk affects strength. The positive coefficient, and an odds ratio that is greater than one indicates that a higher percentage of rice husk used in a composition tends to be associated with lower CPF strength. The p-value for the Pearson test (0.993) and the p-value for the deviance test (1.00) signify that there is insufficient evidence to claim that the model does not fit the data adequately.

In the second ordinal logistic regression analysis, Table 5 shows the three firing production variables, duration, maximum temperature, or soak time, have p-values higher than an α-level of 0.05. There is insufficient evidence to conclude that the predictors mentioned immediately above have an effect upon strength. The p-value for the Pearson test (1.00) and the p-value for the deviance test (1.00) signify that there is insufficient evidence to claim that the model does not fit the data adequately.

To increase the flow rate one must increase the percentage of rice husk used in the composition and increase the maximum firing temperature. However, as the percentage of rice husk increases, the strength of the CPF decreases. To find the best composition one must balance these two technical requirements.

Table 4: Ordinal Logistic Regression: Strength vs. Four Materials Production Variables

Response Information

Variable	Value	Count
strength	1	4
	3	6
	4	5
	5	6
	6	10
	Total	31

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower
Const(1)	-66.1312	24.4363	-2.71	0.007		
Const(2)	-61.1258	23.4174	-2.61	0.009		
Const(3)	-50.8755	20.8324	-2.44	0.015		
Const(4)	-34.5455	16.7947	-2.06	0.040		
% Grog	0.745646	0.676501	1.10	0.270	2.11	0.56
% Rice Husk	3.37285	1.25134	2.70	0.007	29.16	2.51
% Gbalahi Clay	-0.847263	0.844251	-1.00	0.316	0.43	0.08
% Gbalahi Clay of Total Clay	0.401637	0.635162	0.63	0.527	1.49	0.43

Predictor	Upper
Const(1)	
Const(2)	
Const(3)	
Const(4)	
% Grog	7.94
% Rice Husk	338.82
% Gbalahi Clay	2.24
% Gbalahi Clay of Total Clay	5.19

Log-Likelihood = -7.177
Test that all slopes are zero: G = 82.314, DF = 4, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	27.3951	48	0.993
Deviance	14.3545	48	1.000

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	371	99.2	Somers' D	0.98
Discordant	3	0.8	Goodman-Kruskal Gamma	0.98
Ties	0	0.0	Kendall's Tau-a	0.79
Total	374	100.0		

Table 5: Ordinal Logistic Regression: Strength vs. Three Firing Production Variables

Response Information

Variable	Value	Count
strength	1	4
	3	6
	4	5
	5	6
	6	10
	Total	31

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower
Const(1)	9805.51	305886	0.03	0.974		
Const(2)	11086.0	321225	0.03	0.972		
Const(3)	11113.3	194949	0.06	0.955		
Const(4)	11114.7	194949	0.06	0.955		
firing duration (hrs)	-959.051	25009.5	-0.04	0.969	0.00	0.00
soak time (min)	16.7071	2424.47	0.01	0.995	18021499.80	0.00
Max Temp (degrees celsius)	-3.21037	83.3650	-0.04	0.969	0.04	0.00

Predictor	Upper
Const(1)	
Const(2)	
Const(3)	
Const(4)	
firing duration (hrs)	*
soak time (min)	*
Max Temp (degrees celsius)	3.69357E+69

Log-Likelihood = -19.879
Test that all slopes are zero: G = 56.912, DF = 3, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	0.0105110	13	1.000
Deviance	0.0105241	13	1.000

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	296	79.1	Somers' D	0.75
Discordant	16	4.3	Goodman-Kruskal Gamma	0.90
Ties	62	16.6	Kendall's Tau-a	0.60
Total	374	100.0		

Identifying Quality Control Measures for Filter Efficacy

The first test that was a successful QC test for total coliform removal was the Bubble Test. A 2-sample Student's t-test was performed to see if CPFs that passed the Bubble Test had a higher total coliform bacteria removal than did CPFs that failed the Bubble Test. The null hypothesis states that the difference in total coliform removal between the two populations (CPFs that pass the Bubble Test and CPFs that fail the Bubble Test) is zero. Table 6 below shows that the p-value (0.003) is less than an alpha-level of 0.01 which means the null hypothesis is rejected.

There is a low probability that the populations are equal. The upper-tailed alternate hypothesis can then be accepted, which says that the total coliform removal for CPFs that passed the Bubble Test have a higher total coliform bacteria removal than did CPFs that failed the Bubble Test. Therefore, the Bubble Test is recommended for use in the Quality Assurance program.

Table 6: 2 Sample Student's t-test: Total Coliform LRV for Passing or Failing the Bubble Test

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Two-sample T for PASS Bubble Test vs FAIL Bubble Test

                   N   Mean  StDev  SE Mean
PASS Bubble Test  50  1.661  0.414    0.058
FAIL Bubble Test  14  1.307  0.372    0.099

Difference = mu (PASS Bubble Test) - mu (FAIL Bubble Test)
Estimate for difference:  0.354
95% lower bound for difference:  0.156
T-Test of difference = 0 (vs >): T-Value = 3.07  P-Value = 0.003  DF = 22
```

The second test that was a successful QC test for total coliform removal is the "First Drip Test". In Figure 2 the R-squared value shows that the First Drip Time explains 70.9% of the variance in total coliform removal, signifying that the model fits the data. The total coliform removal and First Drip Time are both represented logarithmically in Figure 2 for the purpose of representing it linearly. In Table 7, the p-value in the Analysis of Variance (0.000), at an alpha-level of 0.05, indicates that the relationship between total coliform LRV and First Drip Time is statistically significant.

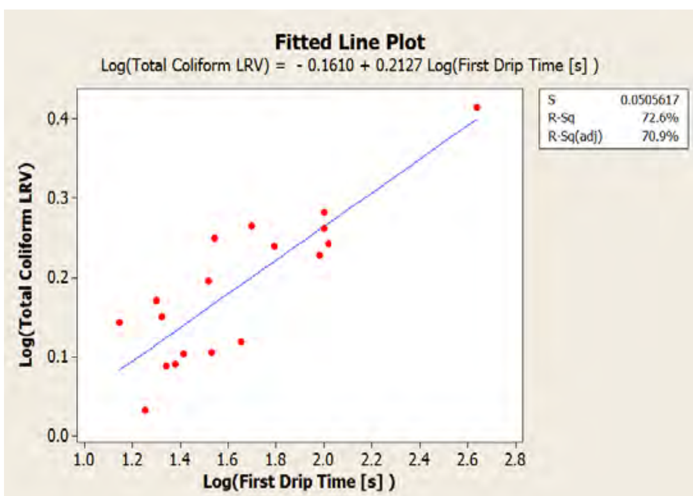

Figure 2: Log(Total Coliform LRV) vs. Log(First Drip Time)

Table 7: Regression Analysis: Log(Total Coliform LRV) versus Log(First Drip Time [s])

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The regression equation is
Log(Total Coliform LRV) = - 0.1610 + 0.2127 Log(First Drip Time [s] )

S = 0.0505617   R-Sq = 72.6%   R-Sq(adj) = 70.9%

Analysis of Variance

Source      DF        SS        MS      F      P
Regression   1  0.108404  0.108404  42.40  0.000
Error       16  0.040904  0.002556
Total       17  0.149308
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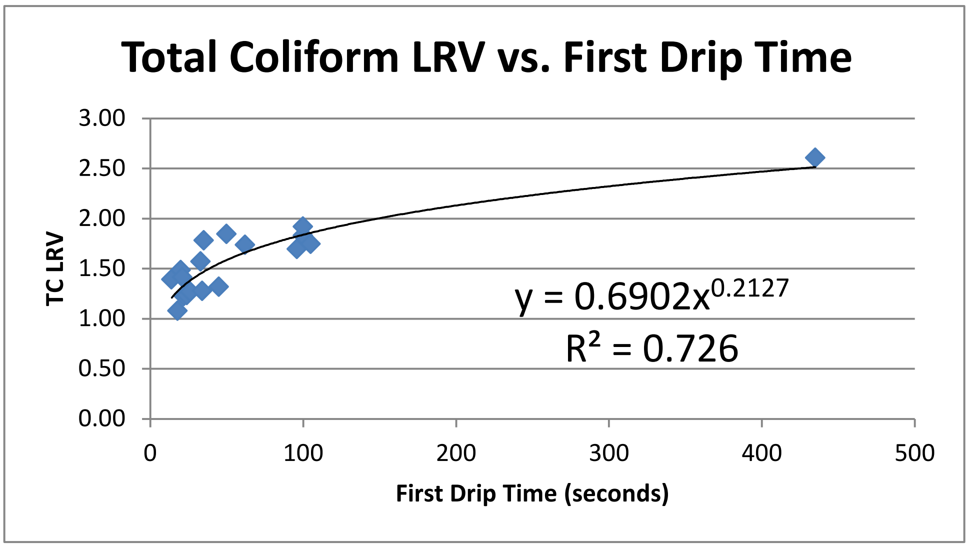

Figure 3: Total Coliform LRV vs. First Drip Time

Figure 3 shows that the actual relationship between total coliform removal and First Drip Time follows a power curve according to the following equation:

Equation 1: $$TC\ LRV = 0.6902 \times First\ Drip\ Time^{0.2127}$$

This equation allows one to accept the CPFs that reach a minimum desired level of total coliform removal. For example, if one desired to accept CPFs that had a minimum total coliform LRV of 2, then 2 would be plugged into the left hand side of equation 1. First Drip Time could then be solved for, giving an answer in seconds. In this example, the minimum First Drip Time would be 149 seconds. This means all filters with a First Drip Time faster than 149 seconds do not pass the test because their total coliform LRV will be lower than 2. Table 8 gives some possible desired total coliform LRVs and their corresponding minimum First Drip Times in seconds.

Table 8: Total Coliform LRV and Corresponding First Drip Time

Desired Total Coliform LRV	Corresponding First Drip Time (s)
1	6
1.25	16
1.5	38
1.75	79
2	149
2.25	259

At first glance, the farthest point on the right in Figure 3 would appear to be an outlier. However, it is not an outlier for two reasons. First, the data point was collected from a filter with 13% rice husk. This was one of the lowest percentages of rice husk tried when testing various compositions. It follows that the lower the percentage of rice husk used the longer the First Drip Time will be. This is because the filter will be less porous, which makes it harder for water to pass through the filter. The second reason this data point is not an outlier is because another filter with the identical composition to the one in question did not have a First Drip at all (within the context of the First Drip test). This means there is an imaginary point even farther to the right on the graph, further securing the reliability of the trend.

The correlation between total coliform removal and first drip time also helps to explain the filtering mechanisms of the CPF. The test shows that a slower drip time gives a higher total coliform removal because a slower drip time implies stronger capillary forces withholding the flow of water. Stronger capillary forces imply smaller pore sizes because as the length of the interface (pore size) decreases the capillary force increases (see equation 3). The smaller pore sizes more readily screen, adsorb, or contain bacteria in their pores. This means it is important to have small pore sizes in CPFs to remove bacteria.

The First Drip Time was also found to be an accurate indicator for flow rate. In Figure 4 the R-squared value shows that the First Drip Time explains 92.4% of the variance in flow rate, signifying that the model fits the data. The flow rate and First Drip Time are both represented logarithmically in Figure 4 for the purpose of representing the correlation linearly. In Table 9, the p-value in the Analysis of Variance (0.000), at an α-level of 0.05, indicates that the relationship between flow rate and First Drip Time is statistically significant.

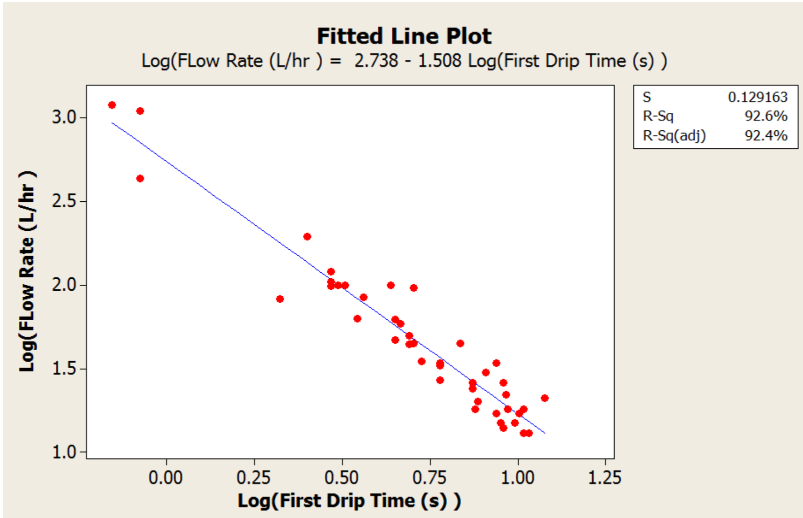

Figure 4: Log(Flow Rate) vs. Log(First Drip Time)

Table 9: Regression Analysis: Log(Flow Rate (L/hr)) versus Log(First Drip Time (s))

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The regression equation is
Log(FLow Rate (L/hr ) = 2.738 - 1.508 Log(First Drip Time (s) )

S = 0.129163   R-Sq = 92.6%   R-Sq(adj) = 92.4%

Analysis of Variance
Source       DF       SS       MS       F      P
Regression    1  8.52626  8.52626  511.08  0.000
Error        41  0.68400  0.01668
Total        42  9.21026
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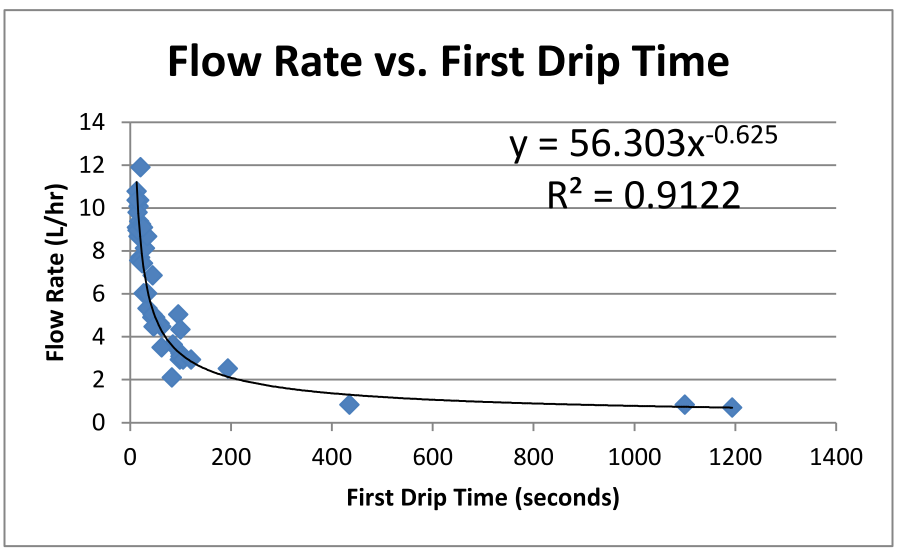

Figure 5: Flow Rate vs. First Drip Time

Figure 5 shows that the actual relationship between flow rate and First Drip Time follows a power curve according to the following equation:

Equation 2: $$Flow\ Rate = 56.303 \times First\ Drip\ Time^{-0.625}$$

Equation 2 allows one to accept the CPFs that reach a minimum desired flow rate. For example, if one desired to accept CPFs that had a minimum flow rate of 6 L/hr, then 6 would be plugged into the left hand side of Equation 2. First Drip Time could then be solved for, giving an answer in seconds. In this example the maximum First Drip Time would be 36 seconds. This means all filters with a first drip time slower than 36 seconds do not pass the test because their flow rate will be less than 6 L/hr. Table 10 gives some possible desired flow rates and their corresponding maximum first drip times in seconds.

Table 10: Flow Rate and Corresponding First Drip Time

Desired Flow Rate (L/hr)	Corresponding First Drip Time (s)
2	209
3	109
4	69
5	48
6	36
7	28
8	23

The correlation between flow rate and First Drip Time also accurately reflects the Young-Laplace equation for capillary pressure (Equation 3). For the CPF, the surface tension and wetting angle are assumed to remain constant. This means the capillary pressure is inversely proportional to the length of the capillary interface, or pore size. When capillary pressure is graphed versus pore size, such a relationship should produce an asymptotic graph, as it does in Figure 5. Flow rate is a reflection of capillary pressure because a higher pressure gradient will create a faster flow rate. It can then be concluded (as it was in the previous section) that First Drip Time varies based on average pore size. Therefore, a smaller pore size implies a slower flow.

Equation 3: $$\Delta p = \frac{2\gamma cos\theta}{a}$$ Young-Laplace Equation for Capillary Pressure

Where,

Δp = capillary pressure

γ = surface tension

θ = wetting angle of the liquid on the surface

a = length of the capillary interface

As the First Drip Test can be performed more quickly than the flow rate test, it can help save time in the quality control process, if substituted in its place.

A third and final indicator for total coliform removal is a representation of tortuosity. Flow rate, porosity, First Drip Time, and thickness can be used to calculate tortuosity. Multiple regression was performed with three of these factors, thickness was excluded as all CPFs tested were of equal thickness, to find the best correlation to total coliform removal.
In Table 11 the R-squared value shows that the regression equation formed explains 85.2% of the variance in total coliform removal, signifying that the model fits the data. Also in Table 11, the p-value in the Analysis of Variance (0.000), at an α-level of 0.05, indicates that the relationship between the regression equation and the total coliform removal is statistically significant. When examining the regression equation, one can deduce that a faster flow rate signifies a lower tortuosity which produces a lower LRV. A greater porosity signifies a higher tortuosity which produces a higher LRV. A longer First Drip Time signifies a higher tortuosity which produces a higher LRV.

This test would provide a more accurate representation of total coliform removal than would the first drip test by itself. However, the tortuosity representation requires one to perform three tests on every CPF. The choice between accuracy and time spent is a decision that affects the factory's level and degree of quality control.

Table 11: Regression Analysis: Total Coliform LRV vs. Flow Rate, Porosity, First Drip Time

```
The regression equation is
Total Coliform LRV = - 0.058 - 0.110 Flow Rate (L/hr) + 5.53 Porosity
                     + 0.00197 First Drip Time (s)

Predictor                 Coef    SE Coef      T      P
Constant               -0.0583     0.5774  -0.10  0.921
Flow Rate (L/hr)      -0.10989    0.02202  -4.99  0.000
Porosity                 5.527      1.668   3.31  0.005
First Drip Time (s)  0.0019687  0.0004649   4.23  0.001

S = 0.138463   R-Sq = 87.6%   R-Sq(adj) = 85.2%

Analysis of Variance
Source          DF       SS       MS      F      P
Regression       3  2.03739  0.67913  35.42  0.000
Residual Error  15  0.28758  0.01917
Total           18  2.32497


Source               DF   Seq SS
Flow Rate (L/hr)      1  1.48131
Porosity              1  0.21226
First Drip Time (s)   1  0.34382
```

Devising a Quality Assurance Program for Pure Home Water

According to the American Society for Quality (2012), Quality Assurance is defined as "the planned and systematic activities implemented in a quality system so that quality requirements for a product or service will be fulfilled." The American Society for Quality (2012) define Quality Control as "the observation techniques and activities used to fulfill requirements for quality." In this chapter a Quality Assurance Program for the PHW factory in Tamale, Ghana will be proposed based on the experience of Curt and Cathy Bradner (ThristAid) and described in the Masters of Engineering thesis of Kleiman (2010), on results from extensive filter testing and analysis,on the author's observations made at the factory in January 2012, and on relationships developed with the Ghanaian factory workers. This QA plan will only be for the nine quality control tests described here and in the thesis of Miller (2012). A complete QA program will also include best practices involving clay, combustibles, pressing, firing, storage, packaging and transport, which are not covered here.

The Quality Assurance/Quality Control Program is important because it acts as the bridge which transfers the technical benefits to the people who need that benefit. That is, Ghanaians need filters that effectively remove pathogens, will not break, and provide a sufficient amount of water for their family's daily needs.

The following describes the QA process for the PHW hemisphere filters:

1. Remove filters from kiln, dust off ash, and place on factory drying rack.

2. Break and discard any misshapen filters in the designated filter disposal site.

3. Follow the First Drip Test procedure as found in Section 3.9.

4. Record results in Table 6-1 using each filter's ID.

5. Place filters in soak tank,

6. Follow the Bubble Test procedure as found in Section 3.6. Record results in Table 6-1.

7. All filters that have passed the Bubble Test should be examined according to their First Drip test results. As explained in Section 5.3 and Section 5.4, the First Drip Test will provide upper and lower bounds for accepting filters. If a filter exceeds the upper bound that means its flow rate is too slow. If a filter falls below the lower bound that means its total coliform removal is too low. In either case, the filter should be broken and discarded.

8. All filters that fail the Bubble Test should be broken and discarded in the designated disposal site.

9. Place all filters that have passed both the First Drip test and the Bubble test on racks and move racks to the "clean section" (Section 1) which is the laboratory silver application and inventory section (Figure 6-1). (Note: this section of the factory is currently under construction and is planned to be completed by January 2013).

10. Apply silver to filters according to the methods introduced in Section 3.14.

11. Select two filters from each batch for bacteriological tests. (Note: from 2011 to the present IDEXX QuantiTray has been used to determine total coliform/E. *coli* bacterial indicator removal performance. Beginning in June 2012, a new, lower cost hydrogen sulfide bacteria (H_2S) most probable number (MPN) test will be used).

12. Perform bacterial test and record result in Table 12-1.

13. At the end of each month, fill out Table 12-2.

Table 12-1: Pure Home Water – Quality Control Test Results

Filter ID	First Drip Time (seconds)	Bubble Test (P/LB/F)	Bacterial Indicator Test (LRV)	Filter Fate (to sale/destroyed)
e.g. 4-11-1	34	Pass	2.3	To sale

Table 12-2: Pure Home Water – Monthly Filter Production

# of Filters:	Total	Remarks
Manufactured	e.g. 400	
Rejected Before Firing	e.g. 30	
Rejected During Testing	e.g. 100	
To be Painted with Silver and Sold	e.g. 270	

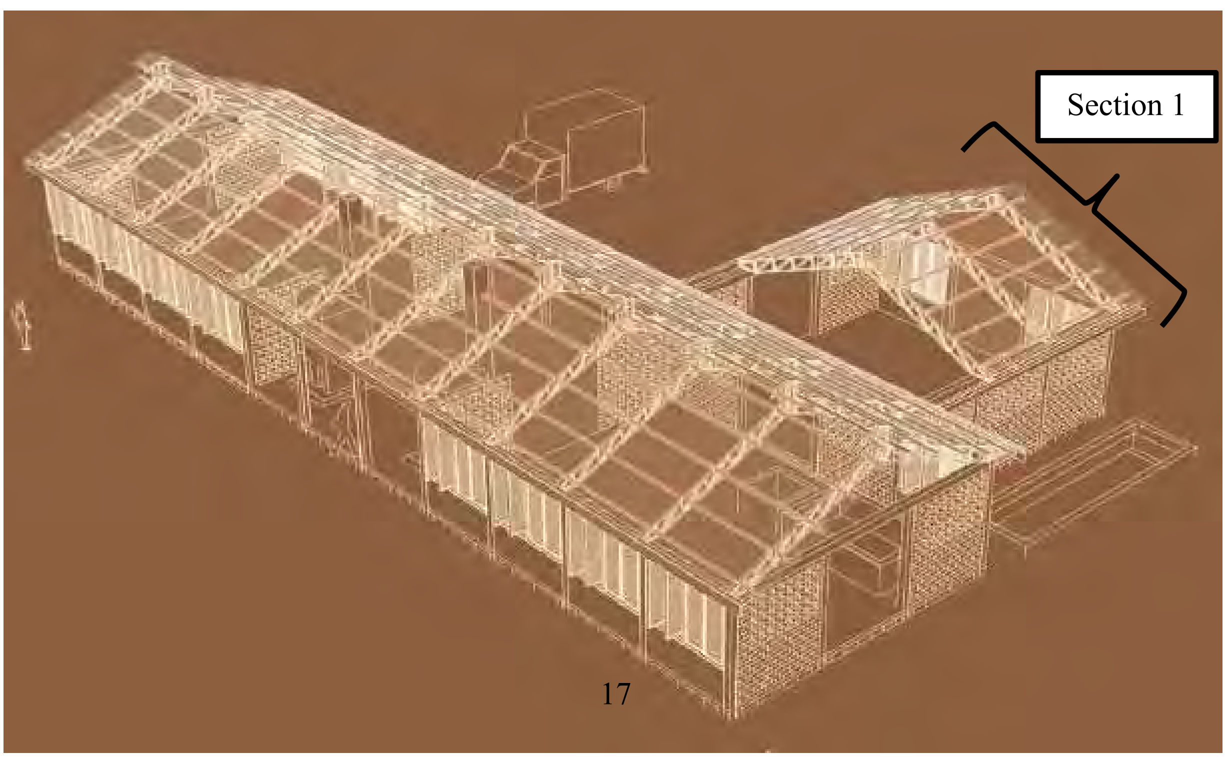

Figure 6-1: Plan Layout of the PHW Factory (credit: Chris de Vries)

The following provides the schedule of the trained QA/QC PHW employee:

<table>
<tr><th colspan="6">Table 12-3: Quality Control Test Schedule</th></tr>
<tr><th>Time/day</th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><td>9AM-12PM</td><td>First Drip Test (Batch 1)</td><td>First Drip Test (Batch 2)</td><td>Microbiological Testing</td><td rowspan="2">Office Work</td><td rowspan="2">Apply Silver</td></tr>
<tr><td>1PM-4PM</td><td>Apply Silver</td><td>Bubble Test (Batch 1)</td><td>Bubble Test (Batch 2)</td></tr>
</table>

Each week at the PHW factory two batches of filters are fired in the kiln. While the kiln firing schedule does not match the schedule in Table 12-3, it is not necessary to immediately perform the First Drip Test the day the filters come out of the kiln. This way, the QC schedule can be repeated uniformly each week regardless of when filters come out of the kiln. So the first batch that was fired the previous week can undergo the First Drip Test on Monday morning. As each batch currently contains 32 filters, that allows approximately six minutes to test each filter, which is feasible. The first batch is then Bubble Tested on Tuesday afternoon, which allows 24 hours for the filters to soak and reach saturation. This schedule is used for the second batch except it is shifted one day so that it is performed on Tuesday and Wednesday instead of Monday and Tuesday. Wednesday morning is set aside for microbiological testing of two filters from each batch. Limited bacteriological testing will ensure the First Drip test is correctly identifying filters that should be discarded. On Thursday several tasks need to be performed at the PHW office. This includes data entry for Table 12-1 and Table 12-2, emailing all data to PHW Manager, and accounting tasks. On all of Friday and Monday afternoon, all filters that have passed both the Bubble Test and First Drip test are painted with colloidal silver. If it is assumed that 50% of all filters can be sold, then 32 filters need to be painted each week. This allows approximately 17 minutes to paint each filter, which again is feasible. In reality, the filters painted on Monday will be filters from the previous week that were not painted on the previous Friday. Alternately, filters that pass all QC tests can be stockpiled for painting on a bi-monthly or monthly basis.

The responsibilities that are required of the QC employee are based on the process and schedule sections directly above. They must perform steps 1-9 in the process section individually as well as perform bacteriological testing, and the necessary data entry and analysis work.

The following provides some additional comments for the QA program:

- Soak Tank: Large amounts of dust gets into the soak tank. Also, mosquito larvae grow in the soak tank if it is not diligently covered while not in use. So it is essential to cover the soak tank whenever possible.
- Treatment of Soak Tank to Prevent Algae: the soak tank should be cleaned periodically to keep algae from growing in it. If algal cells get into the filters, they are not easily removed and filters could have an undesirable algae taste in treated water. This is not a health concern, but rather an aesthetic concern. Moreover, algae in the filter would not be a good selling point. To start, the tank should be scrubbed with a strong chlorine solution and rinsed out. Then the tank can be chlorine shocked once a month or so to kill any

algae. Once chlorine is added, it will dissipate over 24 hours if the tank is left uncovered during that period only. Otherwise, the tank should be kept covered when not in use.

- Data Recording: QA data recording must be standardized. It is recommended that Table 12-1 be used for the field data sheet. Table 12-2 also must be filled out monthly. A large number of these sheets should be bound together and one sheet should be used for each batch of filters from the kiln. Completely filling out and detailing any problems on each sheet must be stressed during training.
- Communication among Staff: The results of the quality control tests must be relayed by the QA/QC staff back to the filter production staff. Creating this line of communication will do two things:
    1. Instill a sense of pride in their work among the filter production staff.
    2. Help the filter production staff see problems with how the filters are turning out (if problems like uneven pressing, firing, or mixing occur) and enable them to look for a solution.

There are two overarching themes that guide the training for the QA program. Both of them arise from the advice of consultants Curt and Cathy Bradner, whose work for PHW is documented in the Master of Engineering thesis of Shanti Kleiman (2011).

Staff Participation and Leadership Training:

1. "Engage the staff from the very beginning, working together in the process of trial and error as part of training. In this way, leadership is being transferred from the start" Kleiman (p. 62, 2011)

2. "Bradner finds that when manufacturers and their employees understand that they are making a public health product, adding another level of responsibility to their consumers, greater attention to quality is cultivated." Kleiman (p. 64, 2011)

Based on the first overarching theme, it is very important that the staff is taught through a hands on approach. Additionally, based on observational experience, the staff will learn best by repetition of tasks. To this end, we recommend letting the staff attempt all the tasks while overseeing their work. If they are incorrectly doing something or forget a step, it is important to correct it. Cultivating this attention to detail can be accomplished through the second overarching theme and through giving simple visual explanations as to why a certain step or task is important.

Once a staff member has fully learned their duties and has a general understanding of the reason for each task and step, they can be trusted to perform their job with excellence. They will gain a greater understanding of why what they do is important and will begin to understand how their job relates to the jobs of other staff members.

We welcome other ceramic pot filter factories around the world in borrowing and applying relevant parts of this program that they feel would benefit their own factory production. Additionally, if other factories are being started, this experience and documentation may be able to help jumpstart their own Quality Assurance/Quality Control Program. At the same time, we recognize that the results found in this research and the methods developed by PHW may not necessarily be transferrable to other factory locations. It is up to the factory managers to adjust the procedures and methods to best fit their own setting.

The most useful part of this program that other factories may want to adopt is the dual use of the Bubble Test and First Drip Test as quality control measures because they are performed quickly, simply, with low-cost, and encompass all the necessary testing required. That is, they can indicate flow rate, total coliform removal, and if any cracks or large holes are present. It is our hope that the ability to test CPFs quickly, simply, with low-cost, and thoroughly will be beneficial to the success of PHW and potentially other factories around the world.

Conclusions

This nine month research project, including three weeks of field research, draws several conclusions beneficial to Pure Home Water's goals of providing safe drinking water to those most in need in Northern Ghana and becoming a locally and financially self-sustaining organization. The three primary goals of this study were accomplished:

(1) The best chosen filter composition to date specific to the factory in Tamale, Ghana was found (see Table 13-1) and the chosen filter performance was specified. These composition/performance specifications are currently being applied in making 1,250 filters under the Rotary International, Future Vision Global Grant, the PHW factory's first large order.

Table 13-1: Chosen Filter Composition

Gbalahi Clay (kg)	Wayamba Clay (kg)	Rice Husk (kg)
14	4	4

Table 13-2: Chosen Filter Performance

Flow Rate (L/hr)	LRV without Silver	Expected LRV with Silver	Turbidity Removal (Percent)	Manufacturability (Percent Pass)
6-10	1.2	2.7	92	75

(2) Two simple and low-cost quality control measures, the First Drip Test and the tortuosity representation were developed to determine ceramic pot filter effectiveness in removing harmful pathogens, as is indicated by total coliform removal.

The equation to screen the acceptance/rejection of CPFs which reach a desired minimum level of total coliform removal is:

$$TC\ LRV = 0.6902 \times First\ Drip\ Time^{0.2127}$$

The equation to screen the acceptance/rejection of CPFs which reach a desired minimum flow rate is:

$$Flow\ Rate = 56.303 \times First\ Drip\ Time^{-0.625}$$

(3) A Quality Assurance Program has been developed for nine quality control tests, covered in this report and in the thesis of Miller (2012). A complete QA program should also include best practices involving clay, combustibles, pressing, firing, storage, packaging and transport, which have not been covered here

One of the two secondary goals was achieved. That is, the flow rate was maximized, but maximizing the total coliform removal was not achieved.

Summary of Results

What follows is a summary of research results followed by recommendations for future research that we think is important to successfully making CPFs.

- The primary production variable that affects flow rate is percentage of rice husk used in making the CPF. As the percentage of rice husk used increases, the flow rate increases because the porous volume in the CPF is increasing.

- A secondary production variable that affects flow rate is maximum firing temperature. As the maximum firing temperature increases, up to 950 degrees Celsius, the flow rate increases.

- The primary production variable that affects strength is percentage of rice husk used in making the CPF. As the percentage of rice husk used increases, the strength decreases because the CPF structure is compromised as less and less clay is used.

- The Bubble Test is an adequate quality control measure. The total coliform removal for CPFs that passed the bubble test has a higher total coliform bacteria removal than did CPFs that failed the bubble test.

- The First Drip Test is an adequate quality control measure. An increase in First Drip Time means an increase in total coliform removal (according to a power curve). The correlation between total coliform removal and First Drip Time also helps to explain the filtering mechanisms of the CPF. The test shows that a slower First Drip Time gives a higher total coliform removal because a slower drip time implies stronger capillary forces withholding the flow of water. Stronger capillary forces imply smaller pore sizes because as the length of the interface (pore size) decreases the capillary force increases (see equation 5-3). The smaller pore sizes more readily screen, adsorb, or contain bacteria in their pores. This means it is important to have small pore sizes in CPFs to remove bacteria.

- The First Drip Test was also found to be a good quality control measure to substitute for the flow rate test. As the first drip time increases, the flow rate decreases (according to a power curve). The correlation between flow rate and first drip time also accurately reflects the Young-Laplace equation for capillary pressure (Equation 3). For the CPF, the surface tension and wetting angle are assumed to remain constant. This means the capillary pressure is inversely proportional to the length of the capillary interface, or pore size. When capillary pressure is graphed versus pore size, such a relationship should produce an asymptotic graph, as it does in Figure 5 showing flow rate versus first drip time. Flow rate is a reflection of capillary pressure because a higher pressure gradient will create a faster flow rate. It can then be concluded (as it was in the previous section) that first drip time varies based on average pore size. Therefore, a smaller pore size implies a slower flow.

- A third and final quality control measure for total coliform removal is a representation of tortuosity. As described above, flow rate, porosity, first drip time, and thickness can be used to calculate tortuosity. Multiple regression was performed with three of these factors, thickness was excluded as all CPFs tested were of equal thickness, to find the best correlation equation to total coliform removal.

- This research was unsuccessful in finding which production variable, if any, affects total coliform removal

Recommendations for Future Research

Eleven areas of research on the CPF are recommended:

1. How thoroughly the clay and rice husk are mixed and how that affects total coliform removal.

2. How the distribution of the rice husk particle sizes affects total coliform removal.

3. How tortuosity affects total coliform removal.

4. How kiln variables (maximum temperature, firing duration, and soak time) affect total coliform removal or (other microbial indicator removals).

5. How soak time in the kiln affects flow rate.

6. How firing duration affects flow rate.

7. How the distribution of the rice husk particle sizes affect flow rate.

8. What production variables determine the manufacturability of a given CPF composition? That is, what determines how well a certain composition's CPFs pass the Bubble Test?

9. How does the carbon layer affect filter durability/longevity .

10. How the carbon layer affects the removal of contaminants such as metals, pesticides, filter longevity and/or taste/odor.

11. How the total coliform removal and flow rate are affected over long term consistent use.

Recommendations to Pure Home Water on Implementation

Finally, recommendations are given to PHW on how to best implement the findings of this research. The first recommendation for PHW is to use the Quality Assurance/Quality Control Program outlined in above and to refine this plan in the months ahead. We specifically recommend using only the Bubble Test and First Drip Test as the quality control measures because they are performed quickly, simply, with low cost, and encompass all the necessary testing required. That is, they can indicate flow rate, total coliform removal, and if any cracks or large holes are present. As the production at PHW increases with time, the ability to test CPFs quickly, simply, and thoroughly at low cost will be critical to the factory's success.

The second recommendation for PHW is to continue to improve the current CPF composition. This can be accomplished by increasing the bacteria removal, manufacturability, and strength of the CPF. Increasing bacteria removal will best be accomplished by further researching topics 1-4 in the section above. Increasing manufacturability can be accomplished by further researching topic 8 in the section above. Because flow rate and strength are inversely related by percentage of rice husk used (i.e. as percent of rice husk used increases flow rate increases and strength decreases), a way to increase strength while maintaining a high flow rate needs to be found. To best accomplish this, further research on topics 5-7 in the section above should be carried out. With successful findings in research topics 1-11 and practicing the recommended Quality Assurance/Quality Control program, we hope Pure Home Water will successfully help those most in need in Ghana for years to come.

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Monitoring & Evaluation of a Ceramic Water Filter and Hand-washing Intervention in Northern Ghana

By Connie C. Lu
By Connie C. Lu

Abstract

Through a Rotary Club contract, PHW will sell *Kosim* filters and install Tippy-Tap hand-washing stations in 1250 households in Northern Ghana. This paper presents the following project monitoring and evaluation components: (1) three-part evaluation framework; and (2) baseline results. The evaluation framework consists of a baseline survey, one-month follow-up survey, and six-month follow-up survey, and includes a staggered cross-sectional study that compares health outcome between purchasers and non-purchasers, and between purchasers from intervention households and purchasers from control households. January 2012 baseline surveys collected information on household characteristics, water source, household water management, hand-washing practices, diarrheal disease prevalence, and respiratory disease prevalence. In total 429 households were sampled from 20 villages, and the results from 10 villages are reported in this thesis. Overall, 98.6% of the survey population uses surface water as a primary dry season drinking water source, and 79.9% uses unprotected water sources in the wet season. An estimated 52.6% of households use cloth filters to treat their drinking water at home. Only 5.0% of households practice hand-washing with soap, yet 99.2% of households have soap present in the home. The prevalence rate for diarrhea was 23% (95% CI 17% to 29%) for children under the age of five and 9% (95% CI 5% to 13%) for the general population. For cough and difficulty breathing, prevalence rates were 25% (95% CI 19% to 31%) for children under the age of five and 13% (95% CI 8% to 17%) for the general population.

Introduction

In Ghana, 9 percent of the urban population and 20 percent of the rural population use unimproved drinking water sources (UNICEF/WHO, 2012). Actual proportions of populations using unimproved drinking water sources may be significantly higher than the proportions reported in government sources. The WHO/UNICEF Joint Monitoring Program estimates that worldwide, 783 million people (11%) use unimproved sources. However, Onda et al. (2012) estimate that an additional 1.2 billion (18%) worldwide use water from improved sources with significant sanitary risks. In rural Northern Ghana, most households are not connected to the piped network and other improved sources including protected dug wells, protected springs, boreholes and rainwater are often available only during the 3- to 4-month wet season. People who report using these water sources would therefore need to use alternative sources in the 8- to 9-month dry season. Officially published data generally do not reflect this critical detail. In other cases, improved sources break down frequently, and users must resort to unimproved sources for many weeks at a time (Majuru *et al.*, 2011). From unstructured interviews in Tamale and the observations of the author and collaborators, it seems that many boreholes and hand-dug wells in Northern Ghana do not produce water consistently or in ample quantities. Importantly, many "improved" water sources are in fact contaminated. Patrick *et al.* (2011) sampled both unimproved and improved sources in Capiz Province in the Phillippines, and found that over 40 percent of the "improved" sources had significant levels of fecal contamination (> 10 CFU/100 mL). Similarly, in two countries in Africa, Gundry et al. (2006) found that more than 40 percent of water from improved sources collected from household storage were microbiologically unsafe for consumption (Gundry et al., 2006). Even if water is uncontaminated at the source, it can become microbiologically unsafe by the time it reaches the consumer, due to recontamination during transport and storage (Mintz *et al.*, 1995).

Observed rates of hand washing with soap in Ghana are very low, even though soap is often used for laundry and bathing. A national survey of Ghanaian mothers found that 4 percent of mothers practiced hand-washing with soap after defecation, 2 percent practiced hand-washing with soap after cleaning a child's bottom, and only 1 percent practiced hand-washing with soap before feeding children (Scott *et al.,* 2007).

According to the World Health Organization (WHO), diarrheal diseases and pneumonia respectively cause 12 and 13 percent of child deaths in Ghana (WHO, 2011). Table 1 shows the prevalence rates of diarrhea by region in children under five estimated by the 2008 Ghana Demographic and Health Survey (GDHS, 2008). From the 2008 GDHS values, we can see that under-five diarrhea is more prevalent in the north of Ghana, where PHW operates, than in the south. The Northern Region, where the PHW factory is located, has the highest prevalence of diarrhea in children under five, 32.5 percent. Similarly, the Northern Region also has the highest prevalence of acute respiratory illness in children under five, 9.3 percent.

Table 1: Prevalence rates of diarrhea and acute respiratory illness (ARI) in children under five (Data from GDHS, 2008). For diarrhea, 95% confidence intervals are included in this table. However, the GDHS did not calculate 95% confidence intervals for ARI.

Region	Sample size (number of children)	Diarrhea in the two weeks preceding the survey	Acute respiratory illness in the two weeks preceding the survey
Western	260	15.3% (9.6% to 21.1%)	3.8%
Central	268	19.3% (12.1% to 26.5%)	3.5%
Greater Accra	329	12.4% (8.5% to 16.3%)	6.3%
Volta	237	5.1% (2.3% to 7.9%)	3.4%
Eastern	240	17.3% (11.8% to 22.7%)	4.1%
Ashanti	510	20.2% (15.2% to 25.3%)	5.8%
Brong Ahafo	260	28.4% (20.4% to 36.5%)	5.7%
Northern	413	32.5% (27.6% to 37.4%)	9.3%
Upper East	142	19.5% (11.6% to 27.4%)	3.1%
Upper West	72	23.6% (16.3% to 31.0%)	7.7%
Total	**2731**	**19.8% (17.9% to 21.8%)**	**5.5%**

Unimproved water sources and hands serve as major environmental vectors, transmitting diarrheal pathogens to the mouths of new hosts. Hands are also known to transport respiratory disease pathogens. Microbiological studies have identified respiratory pathogens on hands (Hendley *et al.*, 1973; Reed, 1975; Rabie and Curtis, 2006), confirming that hands carry respiratory microorganisms shed from the nose, mouth or anus to the nasal mucosa, conjunctiva (Hendley *et al.*, 1973), or to the mouths of new hosts (Rabie and Curtis, 2006).

Household water treatment and safe storage (HWTS) and hand-washing interventions can have a considerable positive impact on public health if water treatment devices and hand-washing practices are used correctly, consistently and in a sustained manner (Huttly, 1997; Curtis and Cairncross, 2003; Rabie and Curtis, 2006; Clasen et al., 2007; Waddington et al., 2009; Hunter, 2009). HWTS improves the quality of water used for drinking and cooking, and can minimize recontamination during transport and in the home, which is a known cause of water quality degradation (Clasen *et al*., 2007). Hand-washing with soap (both plain or antibacterial) cleanses hands of viruses and bacteria (Faix 1987; Rabie and Curtis 2006), and when used at critical times, can reduce the incidence of diarrheal and respiratory diseases (Global Public-Private Partnership for Hand-washing with Soap (PPPHW). Critical times for hand-washing include: (1) after defecation or using the toilet, (2) after cleaning up a child or handling diapers, (3) before eating, and (4) before preparing or handling food (Curtis and Cairncross, 2003). Lu (2012)[1] reviews the current literature on the impact of HWTS and hand-washing interventions on rates of diarrheal and respiratory illnesses (Lu, 2012).

While HWTS and hand-washing can have a considerable impact on public health, correct, consistent and sustained use is difficult to achieve, and as a result, HWTS and hand-washing interventions are not as effective as they could potentially be. Sustained use is often particularly low, so public health impacts achieved initially tend to decrease in the long-term (Arnold et al., 2009; Hunter 2009; Brown and Clasen, 2012). Organizations such as Pure Home Water (PHW) innovate and invest resources with the intention of increasing the short- and long-term public health benefit of water, sanitation and hygiene (WASH) projects. Monitoring and evaluation of HWTS and hand-washing interventions is critical to assessing and improving projects as PHW and other WASH organizations develop and learn.

Monitoring is the ongoing process by which stakeholders obtain regular feedback on progress made towards achieving objectives (UNDP, 2009). *Evaluation* is a rigorous and objective assessment of either completed or ongoing activities to determine the extent to which they are achieving stated objectives (UNDP, 2009).

This study contributes to the monitoring and evaluation of a ceramic water filter and hand-washing intervention in Northern Ghana. Through a Rotary Future Vision Global Grant (Rotary FVGG), PHW will sell 1250 *Kosim* ceramic pot water filters at GHC 5 (US$ 3)[2] each in poor

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[1] This thesis can be downloaded at the following website: http://web.mit.edu/watsan/documents.html >> Click "Theses" >> Click "Ghana" >> Under "Ghana 2012", click Monitoring and Evaluation of a Ceramic Water Filter and Hand-Washing Intervention in Northern Ghana. All MIT Master of Engineering supervised by Murcott are accessible on this website.

[2] The monetary conversion rate used throughout this study is GHC 1.67 = US$ 1.00, which was the exchange rate at time that the Rotary Club of Malden and PHW wrote the Rotary FVGG project contract. The GHC 5 (US$ 3) price

rural communities in the Northern Region of Ghana and work with community members to install Tippy Tap hand-washing stations in each household that purchases a filter. PHW will take measures to train users and work with local committees to help maintain the technologies and encourage correct, consistent and sustained use. This report presents a three-part evaluation framework for Rotary FVGG, consisting of a baseline survey, one-month follow-up survey, and six-month follow-up survey. In addition, the report presents results from the surveys conducted in January 2012.

Rotary FVGG Evaluation Framework

The purpose of the Rotary FVGG evaluation is to assess the user adoption, sustained use, and health impact of the Rotary FVGG project. With the overarching goal of measuring the benefits of the ceramic filters and Tippy Taps in mind, the author and her thesis advisor interpreted the Rotary FVGG project evaluation needs as follows:

- Measure user adoption, effective use, and sustained use of ceramic filters and Tippy Taps
- Collect the following use-related information:
    - Water source(s);
    - Person responsible for filtering water, maintaining filter;
    - Understanding of filter use, cleaning procedure;
    - Condition of safe storage container;
    - Person responsible for maintenance of Tippy Tap; and
    - Problems with filter or Tippy Tap.
- Measure the prevalence of diarrheal and respiratory illnesses prior to use of ceramic filters and Tippy Taps
- With reasonable certainty, assess impact of ceramic filters and Tippy Taps on the incidence of diarrheal and respiratory illnesses

The Rotary FVGG evaluation will be conducted as a hybrid of a longitudinal study and a cross-sectional study, which Brown has termed a staggered cross-sectional study (Brown, personal com., 2012)[3]. An annotated schematic of the final evaluation framework is shown in Figure 1. Using this framework, we will have diarrheal and respiratory illness data from two points in time, for all households. Health outcome can therefore be calculated as a ratio of prevalence rate at follow-up (in January 2013) to prevalence rate at baseline (in January and April 2012). Lower ratios represent better health outcomes.

The staggered cross-sectional study will enable three comparisons of health outcomes:

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was set based on the preliminary results of a bidding-based willingness to pay (WTP) study conducted using *Kosim* filters in Northern Ghana. It should be noted that when the Rotary FVGG project contract was written, the final results from the WTP study were not available, and the contract price was determined based on a draft of the study. In the final published results of the WTP study, the results indicated that the price should be closer to GHC 2 (US$ 1.20) to reach approximately 75 percent of the study population (Berry *et al*. 2011).

[3] The author is grateful to Joe Brown of the London School of Hygiene and Tropical Medicine for his advice and guidance in the design of this study.

1. Between purchasers (those who choose to purchase filters) from intervention communities (where filter sales occurred in June 2012) and non-purchasers (those who choose not to purchase filters) from intervention communities;

2. Between purchasers from control communities (where filter sales occurred in January 2013) and non-purchasers from control communities; and

3. Between purchasers from intervention communities and purchasers from control communities.

The first comparison measures how choice to purchase a filter AND six months of filter use affect the health outcome. The second comparison measures how choice to purchase a filter, alone, affects the health outcome. The third comparison measures how six months of filter use, without any use of the filter, affects the health outcome. The second and third comparisons are critical because they account for the systematic differences between households who choose to purchase filters and households who choose not to purchase filters (i.e., households that choose to purchase filters may be wealthier, better educated, or otherwise systematically different from households that choose not to purchase filters).

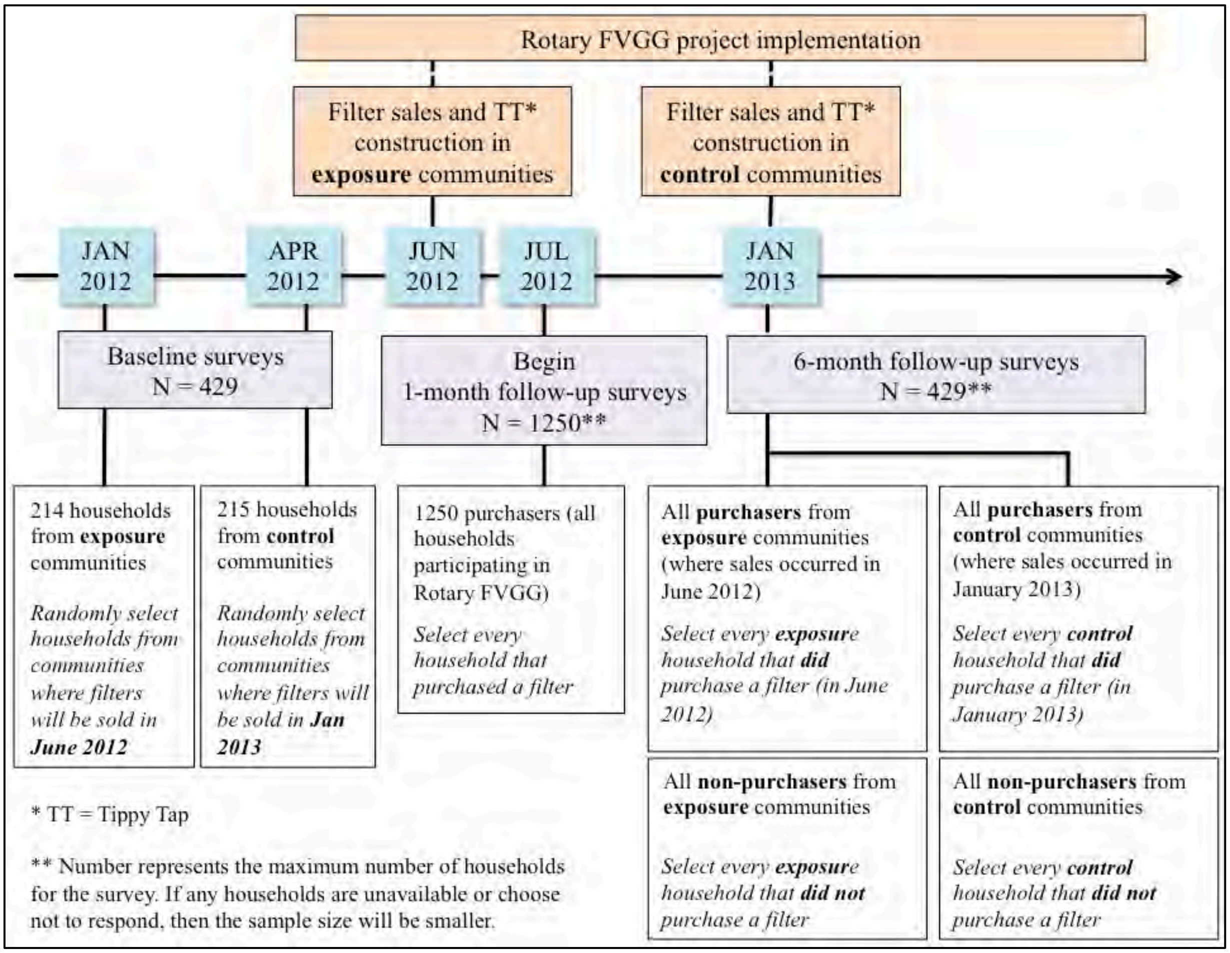

Figure 1: Schematic of the final evaluation framework for the Rotary FVGG project. ***Text in italics indicates method for selecting survey households.***

Baseline

The purpose of the baseline study is to obtain information on household water management, hand-washing practices, and the incidence of diarrheal and respiratory illnesses prior to the use of the ceramic water filters and Tippy Taps. In the baseline study, a household survey, attached as Appendix A, was administered in communities where the Rotary FVGG sales and Tippy Tap construction will occur before the follow-up—intervention communities—and in similar communities where the Rotary FVGG sales and Tippy Tap construction will be concurrent with the follow-up—control communities. The latter are considered control communities because all health data collection is *retrospective*, so all health data collected from households in the control communities is representative of the conditions *without* filter use and Tippy Tap implementation. In total, the baseline survey includes 214 intervention households and 215 control households. This report presents only the results from the 214 intervention households.

One-month follow-up

The first follow-up survey should be conducted approximately one month after the sales of ceramic water filters and installations of Tippy Taps in a given community. The original purpose of the one-month follow-up is to (1) assess user adoption and (2) to identify any need for re-training and maintenance in all households that purchased ceramic water filters. However, since approximately 1250 households will purchase filters, implementing a full-length survey (Appendix B) would require extensive fieldwork. While it is critical to identify any need for re-training and maintenance in all households that purchased filters, the sample size of 1250 is much larger than needed to assess the rate of user adoption (Brown, personal com., 2012).

PHW and Rotary can greatly reduce the fieldwork requirements of the one-month follow-up by creating a "re-train-and-maintain" survey, which is a shorter version of the full-length one-month follow-up (Appendix B). The author recommends that PHW administer the full-length one-month follow-up in a smaller subset of the 1250 purchaser households. The shorter re-train-and-maintain survey should be administered in all 1250 purchaser households. The author recommends that PHW consult an expert on HWTS monitoring and evaluation to determine the sample size and sampling strategy for the subset of households where the full-length survey will be administered.

In the full-length one-month follow-up survey, the following user adoption-related information should be collected to measure the success of the project:

- Person responsible for filtering water and maintaining filter,
- Understanding of filter use and cleaning procedure,
- Condition of safe storage container,
- Person responsible for maintenance of Tippy Tap,
- Problems with filter or Tippy Tap.

In order to facilitate a systematic survey process, a first draft of the full-length one-month follow-up survey is included in this study, as Appendix B. To write the "re-train-and-maintain" survey, PHW should shorten the full-length survey (Appendix B) to include only questions that are essential for identifying which households need re-training and maintenance. The author recommends that PHW staff pre-test the full-length and shortened versions of the one-month follow-up survey, and revise them as necessary, before administering the survey.

Since household surveys are time-consuming, it would be infeasible for the enumerator team to administer the "re-train-and-maintain" survey in all 1250 purchaser households. The responsibility for gathering this information should be assigned to the WATSAN committee in each village. The PHW employee managing the Rotary project would be responsible for providing guidance to the WATSAN committees on the monitoring, along with printed forms and writing implements for recording responses from each household. The additional advantage of assigning the WATSAN committees the responsibility of gathering the user adoption-related information is that the committees will be able to identify households that require filter replacement or maintenance, Tippy Tap maintenance, or better instructions on the use and cleaning of filters and Tippy Taps. In other words, conducting the one-month follow-up survey will assist the committees in fulfilling their responsibilities. Pure Home Water will request access to the collected information for the purposes of measuring project success and monitoring the activity of the WATSAN committees.

The full-length one-month survey, on the other hand, can be administered by either the baseline survey enumerators or the community WATSAN committees. PHW should determine which of these options is more practical given budgetary and logistical constraints, after determining the sample size for the full-length one-month survey.

Six-month follow-up

The second follow-up should be conducted in January 2013, approximately six months after the June 2012 filter sales and Tippy Tap construction in the intervention communities. Data on filter usage, quality of filtered and unfiltered water, Tippy Tap usage, diarrheal illness, and respiratory illness should be collected.

In addition, data on potentially confounding factors should be collected in the six-month follow-up. Potentially confounding factors are those that (1) may affect the intervention uptake in the study population (e.g. household income may be correlated with sustained use of ceramic water filter) or (2) may be risk factors for one of the outcomes (e.g. use of improved sanitation may reduce risk of diarrhea). In this study, potentially confounding factors would include, at minimum, socioeconomic factors and sanitation practices. Statistical analyses should be conducted to determine whether these factors are confounders.

A draft of the six-month follow-up survey tool is included as Appendix C. Currently it does not include a method to collect data on potentially confounding factors. The author recommends that PHW identify potentially confounding factors, and add questions to gather these data to the survey tool in Appendix C. Peletz (2006) and Johnson (2007) collected data on potentially confounding factors in their survey work, and may be a useful resource.

The six-month follow-up survey tool may be shortened to include only questions on diarrheal and respiratory illness and potentially confounding factors. The shortened version can be used in the following types of households: non-purchasers in intervention communities and purchasers and non-purchasers in control communities.

Both the full-length six-month survey tool (draft in Appendix C), and the shortened version must be pre-tested by the enumerators and revised as necessary before use for data collection.

Enumerators who meet the criteria described in Survey Team (Section 3.4.1 of Lu (2012) should conduct the six-month follow-up surveys[4]. This round of follow-up surveys should take place concurrently, or in as small a time frame as is logistically feasible, in both intervention and control communities.

[4] The author recommends that Ataya and Salifu, the enumerators who conducted the baseline surveys, also conduct the six-month follow-up, if they are available and willing.

Procedures for conducting the six-month surveys differ for the intervention and control communities and are described below:

Intervention Communities

PHW should survey all households that were surveyed at the baseline, regardless of whether they chose to purchase filters in June 2012, as long as they are available and give informed consent to be interviewed. In addition to the information on diarrheal and respiratory illness and potentially confounding factors, the enumerators should take note of which households chose to purchase filters and which households did not choose to purchase filters.

In the households that did purchase filters, PHW should collect information on filter and Tippy Tap usage (as outlined in survey tool in Appendix C), and collect samples of the treated and untreated water. The water quality data should be used in combination with survey responses to determine effective use of ceramic water filter. Relative risk analyses should then be conducted using the water quality data and survey data to understand the connections between interventions (filter and Tippy Tap usage) and outcomes (diarrheal and respiratory illnesses.) Peletz (2006) and Johnson (2007) provide methodologies for collecting and testing household water samples, along with methodologies for the associated relative risk analyses.

In the households that did not purchase filters, PHW need only to collect information on diarrheal and respiratory illness and potentially confounding factors. The shortened version of the survey tool can be used.

Control communities

PHW should implement filter sales and Tippy Tap construction in control communities around January 2013. Concurrent with the filter sales, or in as small a time frame as logistically possible, PHW should survey all households that were surveyed at the baseline, as long as they are available and give informed consent to be interviewed. In the six-month follow-up in control communities, PHW need only to collect information on diarrheal and respiratory illness and potentially confounding factors.

At the time of sale to every purchaser in the control communities, PHW should ask each purchaser whether the PHW enumerator team interviewed their household during the baseline survey April 2012. If they were part of the baseline survey, PHW should request to interview them again, using the shortened version of the six-month survey tool that collects only information on diarrheal and respiratory illness and potentially confounding factors.

Immediately after sales are completed in a given control community, PHW will conduct the same shortened six-month follow-up in all households that were surveyed at the baseline and did not choose to purchase filters. For these non-purchaser households, PHW should again use the shortened version of the six-month survey tool that collects only information on diarrheal and respiratory illness and potentially confounding factors.

Data analysis

The author recommends that PHW get input from various experts on monitoring and evaluation of HWTS to improve the six-month follow-up and to develop a data analysis plan. Methodology for measuring socioeconomic status via household surveys can be found in Peletz (2006) and Johnson (2007)[5]. Methodology for statistical analyses to identify confounders can be found in Brown and Sobsey (2006). An excellent resource for analysis of cross-sectional data is "Ecological and Cross-Sectional Studies" (Chapter 9) in Epidemiology: Concepts and Methods by William A. Oleckno.

Challenge of measuring the effects of a two-part intervention

The evaluation recommended in this study treats ceramic filter usage and Tippy Tap usage as a single entity. In reality, households may choose to use one or the other, and not necessary both. For this reason, it will be challenging to assess the effect of a two-part intervention, especially if the evaluator wants to distinguish between the effects of each of the two parts. Should PHW decide to explore possible methods for evaluating ceramic filter usage and Tippy Tap usage as two separate entities, the author recommends obtaining input from experts on monitoring and evaluation of HWTS. However, addressing this challenge may be outside the scope of the Rotary FVGG monitoring and evaluation study.

Baseline Survey Methodology

The primary purpose of this portion of the study is to obtain baseline data on drinking water sources and management, hand washing practices, and prevalence of diarrheal and respiratory illnesses in households in rural villages of Tamale, Northern Region, Ghana. Many existing surveys were studied to inform the development of this survey (UNCEF, 2005; Peletz, 2006; Fowler, 2009; UNICEF-PHW, 2009), which itself evolved through many iterations both before and during pre-testing in Tamale.

The baseline survey was modified several times before travel to Ghana, with the help of thesis advisor Susan Murcott, Joanne Cohn of the Rotary Club of Malden, and Jim Niquette of the PHW board. In the interest of shortening the survey, a number of questions in the initial questionnaire were omitted, including those on cultural beliefs (such as understanding of diarrheal and respiratory illness causes), although they would have likely obtained interesting information.

The survey was conducted by two survey teams, including one MIT graduate student and two Ghanaian enumerators, and supervised by the principal investigator Susan Murcott. Emelia

[5] All MIT M.Eng theses that were supervised by Murcott are available at web.mit.edu/watsan >> click "Thesis" >> click "Ghana".

Ataya and Zainab Salifu were hired to form the enumerator team. Essential qualities for the Ghanaian enumerators included: ability to speak English and Dagbani fluently and translate between the two languages, familiarity with Pure Home Water's mission and/or other water-related projects, excellent communication abilities, and familiarity with local customs.

One day of fieldwork was devoted to pre-testing the survey in Jerigu, a community that will not participate in the Rotary FVGG project. Pre-testing the survey greatly increased the clarity of the survey, alignment of survey enumerator's goals, and overall quality of the data collected.

All household surveys were conducted in or translated on-site into the local language, Dagbani. Because Dagbani is predominantly an oral, not a written language, the survey tool was written in English and each enumerator translated the questions and interpreted the responses in the field.

Since this study aims specifically to evaluate the Future Vision Global Grant project, PHW Board members and the Rotary Club completed community selection during the process of planning for the project. Niquette and Ataya selected the baseline communities using the following criteria: (1) they were in rural areas near Tamale, (2) there was high use of unimproved water, and (3) they were formerly endemic guinea worm communities (Niquette, personal com., 2012).

Prior to undertaking the surveys of households in each community, the enumerator team completed a formal introduction process that is the cultural norm in traditional rural communities. The enumerators aimed to randomly sample households within the chosen communities. Since written or electronic records of the households and compounds did not exist, it was not possible to draw a simple random sample. The enumerators used systematic sampling, where they targeted every house, every other house, or every third house to generate a random sample that was spatially representative of the entire community. For efficiency, the enumerators worked in only one community each day, and surveyed as many households as possible in each community within time limitations. In the smaller villages, such as Futa, all households were targeted, so every household with a person present in the home was surveyed. In the largest village, Tugu, the enumerators targeted one of every three households. In the villages of intermediate size, every other household was targeted.

Enumerators recorded responses on hard-copy survey tools during the household surveys. The responses were then entered into an Excel spreadsheet manually. Each item in the data was double-checked at initial time of entry. Digitized data were then randomly spot-checked with the responses recorded on the printed survey tools throughout the process of data analysis in order to catch inadvertent data corruption or deletion.

Baseline Results

This report presents results from the baseline surveys conducted in January 2012. Table 2 is a summary of the baseline survey results, including key variables pooled across all communities.

Basic household information

General information on the number of individuals in each household was recorded. In each household, there were a mean of 8.0 individuals and a median of 7.0 individuals. There were a mean of 1.6 children under five and a median of 1.0 child under five. In each household, the relationship of the respondent to the youngest member of the household was recorded. Often, more than one member of the household participated in the interview, and in these cases, the primary respondent was identified as the person who initially and formally agreed to participate. Approximately 75.5 percent of respondents were mothers, 8.7 percent were grandmothers, and 15.9 percent were other primary caretakers.

Household water management

The most common water sources used by the households surveyed were surface water, unprotected hand-dug wells, boreholes, community water treatment and rainwater.

The baseline survey was conducted in January and April, months which both fall within the 8- to 9-month dry season in Ghana. Overall, 98.6 percent of households surveyed (n=214) used surface water as a dry season drinking water source, and 77.5 percent of households surveyed used surface water as the only source of drinking water during the dry season. Only 1.4 percent of households surveyed did not use surface water for drinking water during the dry season, and for that fraction, 0.9 percent use unprotected hand-dug wells[6] and 0.5 percent use boreholes. In

Table 2: Summary of key variables (pooled across communities).

[6] One hand-dug well in the communities surveyed was directly observed to be unprotected, and photographs taken by Jenny VanCalcar, a past M.Eng student, in 2009 showed that other hand-dug wells observed in Northern Ghana were also unprotected. During the baseline study, we were unable to confirm whether all of wells in the communities we surveyed were protected or unprotected. However, all hand-dug wells were assumed to be unprotected based on unprotected status of the wells we were able to observe.

Pooled estimates (95% CI, if applicable)		
Average number of individuals per household (n = 214)		8.0
Average number of children <5 per household (n = 214)		1.6
Respondent (n = 208)	Mother	75.5%
	Grandmother	8.7%
	Other primary caretaker	15.9%
Primary dry season water source (n = 214)	Surface water	98.6%
	HDW unprotected	0.9%
	HDW protected	0.0%
	Borehole	0.5%
	Piped	0.0%
	Community	0.0%
Secondary dry season water source (n = 47)	Surface water	0.0%
	HDW unprotected	20.7%
	HDW protected	0.0%
	Borehole	24.1%
	Piped	25.9%
	Community	29.3%
Primary wet season water source (n = 214)	Surface water	55.6%
	HDW unprotected	24.3%
	HDW protected	0.0%
	Borehole	15.0%
	Piped	0.0%
	Community	1.4%
	Rainwater	0.5%
	Spring	3.3%
Secondary wet season water source (n = 110)	Surface water	0.0%
	HDW unprotected	15.4%
	HDW protected	0.0%
	Borehole	4.2%
	Piped	9.8%
	Community	11.9%
	Rainwater	57.3%
	Spring	1.4%
Household water treatment method (n = 213)	None	43.7%
	Cloth filter	52.6%
	Ceramic filter	1.9%
	Boil	0.0%
	Alum	1.9%
	Chlorine	0.0%
Method for dispensing drinking water (n = 213)	Cup or scoop w/o handle	83.6%
	Cup or scoop w/ handle	14.6%
	Spigot	1.9%
	Other	0.0%
Hand-washing with soap (n = 160)	No	95.0%
	Yes	5.0%
Soap present in household (n = 126)	No	0.8%
	Yes	99.2%
Interest in purchasing water filter (n = 209)	No	0.5%
	Yes	99.5%
Under-five prevalence of illness in 48 hours preceeding survey (n = 200)	Diarrhea	23% (17% to 29%)
	Severe diarrhea	11% (7% to 16%)
	HCGI	18% (13% to 23%)
	Cough or difficulty breathing	25% (19% to 31%)
	Severe cough or difficulty breathing	18% (13% to 24%)
General population prevalence of illness in 48 hours preceeding survey (n = 200)	Diarrhea	9% (5% to 13%)
	Severe diarrhea	5% (2% to 8%)
	HCGI	8% (4% to 12%)
	Cough or difficulty breathing	13% (8% to 17%)
	Severe cough or difficulty breathing	10% (5% to 14%)

other words, 99.5 percent of households use unimproved drinking water sources during the dry season.

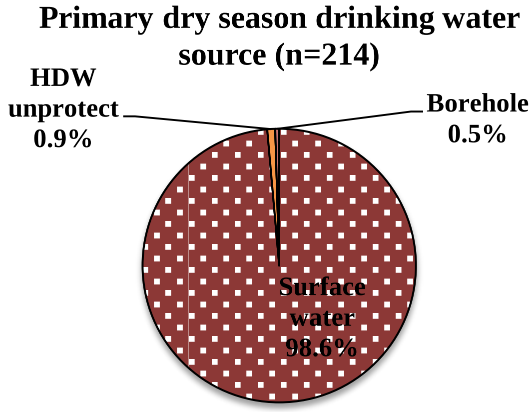

Figure 2: Primary dry season drinking water sources (all communities combined).

The author chose to use a conservative approach in synthesizing the household water management data. The household drinking water sources are presented as a "primary source" and a "secondary source" for each season. If households used more than one source, and one of these sources was unimproved and the other(s) was improved, the unimproved source was counted as the primary source. The other source(s) was counted as secondary. This was done for two reasons. First, since all household water is typically stored in traditional ceramic urns, it seemed that water from improved sources would be mixed in the storage container with any pre-existing supply. Once households have contaminated the water in the storage container, it would remain contaminated until it is properly emptied and cleaned. It appears that the large urns would be difficult to fully empty and clean. Therefore, if the household uses an unimproved source in addition to an improved source, the storage container would likely be contaminated. Second, improved sources, such as boreholes, piped supply, and rainwater, may not provide water consistently and in ample quantity. Unstructured interviews and personal observation by PHW employees Josh Hester and John Adams and the survey enumerators suggested that most of the improved sources in the villages included in this survey did not produce water consistently and in ample quantity.

Of the 214 households surveyed, 47 households had more than one dry season drinking water source. Secondary sources during the dry season (n = 47) were: community treatment (29.3 percent), piped water (25.9 percent), borehole (24.1 percent), and unprotected hand-dug well (20.7%). Thus, 79.3 percent secondary dry season drinking water sources are improved, while 20.7 percent are unimproved.

Considering that only 47 of 214 households had secondary dry season water sources, one can conclude that 82.1 percent of households do not have any access, even intermittent, to an improved water source during the dry season.

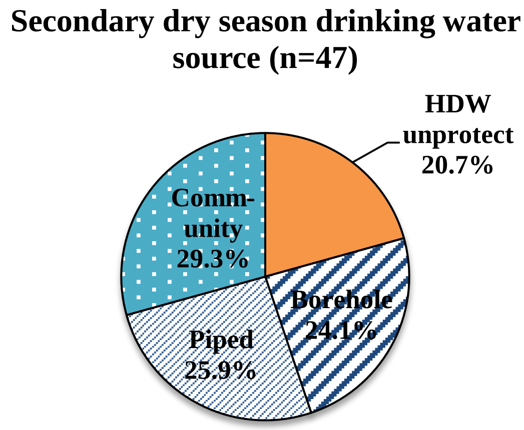

Figure 3: Secondary dry season drinking water sources (all communities combined).

During the 3- to 4-month long wet season, household drinking water sources were more varied than during the dry season. Primary wet season drinking water sources (n = 214) were: surface water (55.6 percent), unprotected hand-dug well (24.3 percent), borehole (15.0 percent), spring (3.3 percent), community treatment (1.4 percent), and rainwater (0.5 percent). In other words, 83.2 percent of the survey population was using unimproved water sources, even in the wet season.[7]

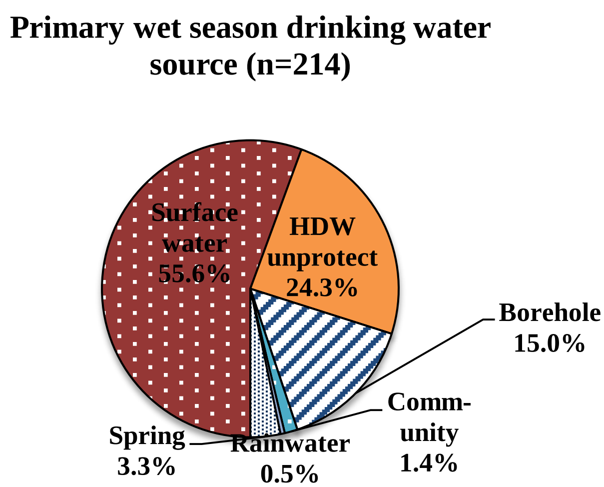

Figure 4: Primary wet season drinking water sources (all communities combined).

Of the 214 households surveyed, 110 households had a secondary wet season drinking water source. Secondary sources during the wet season (n = 110) were: rainwater (57.3 percent), unprotected hand-dug well (15.4 percent), community treatment (11.9 percent), borehole (4.2 percent), and spring (1.4 percent).

Therefore, 35.8 percent of all households surveyed do not have any access to improved water sources, even intermittent, during the wet season.

[7] Springs were assumed to be unprotected, and were therefore considered to be unimproved sources.

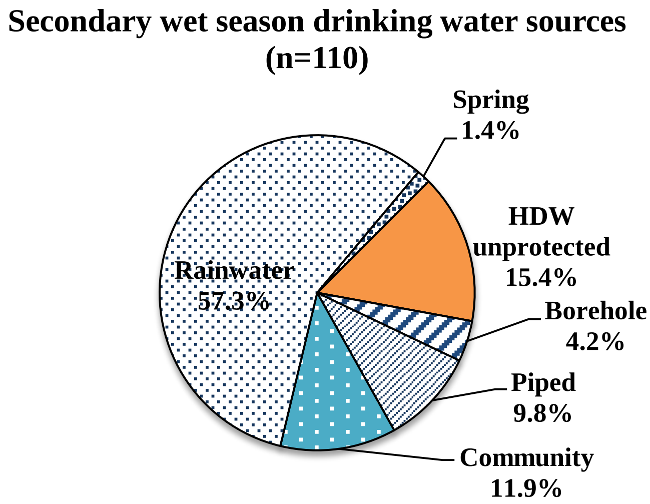

Figure 5: Secondary wet season drinking water sources (all communities combined).

Household Water Treatment

Just over half of the 213 households surveyed (52.6 percent) reported using cloth filters for water treatment. The cloth filters used by households in the Tamale region were either headscarves or specialized filters retained after the end of the Guinea Worm Eradication Program in August 2011. A small number of households surveyed (1.9 percent) were using ceramic water filters from Pure Home Water via a study by Innovations for Poverty Action. These ceramic filters were sold via a bidding game or take-it-or-leave-it offer by a group of researchers (Berry *et al.* 2011). A few households mentioned that they were using ceramic filters in the past, but had not been able to replace them after they were broken.

Another 1.9 percent of households surveyed reported using alum for household water treatment. The remaining 43.7 percent of households did not use any form of household water treatment.

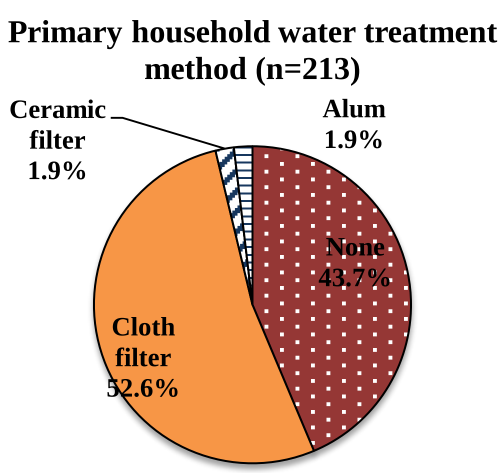

Figure 6: Primary household water treatment method (all communities combined).

Hand-washing practices

In total, 54 households were surveyed using the direct question, "Do you wash your hands (1) after toilet use, (2) after wiping a child's behind or disposing of stools, (3) before eating, and (4) before handling food or water." Of these 54 households, 94.4 percent reported practicing hand-washing with soap at all critical times.

However, 160 households were surveyed using the paired indirect questions, "What kind of soap do you use?" and "What do you use the soap for?" Of these 160 households only 5.0 percent reported hand-washing as one of the uses for soap, even when the enumerators asked "What else do you use the soap for?" repeatedly. While the indirect question does not assess hand-washing at critical times, it does give information on whether soap is used for hand-washing.

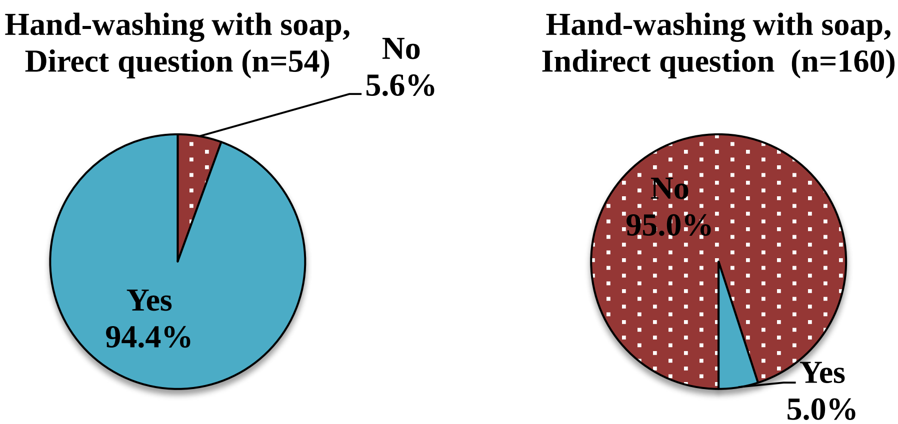

Figure 7: Left, hand-washing with soap (for all communities surveyed using direct question combined); Right, hand-washing with soap (for all communities surveyed using indirect question combined).

The enumerators requested approximately half of the households (n = 126) to show confirmed presence of soap. Overall, 99.2 percent of households surveyed were able to show the soap that they used. Only one household that was asked to present the soap was unable to do so.

Interest in purchasing filter

Households were asked whether they would be interested in purchasing a ceramic water filter for GHC 5 (US$ 3) in the future. Of 209 households asked this question, 208 responded "yes" and one responded "no." While many of the "yes" answers were enthusiastic responses, some households noted that they were interested in purchasing the filter, but would only do so if they had the funds to do so when the opportunity arose. Once the actual sales of these filters begin in June 2012, PHW will know whether these were courtesy responses or not.

Household health

In this study, the prevalence of a disease is defined as the percentage of people that were suffering from that disease within 48 hours of the time of survey. This report presents prevalence rates of diarrhea and cough/difficulty breathing for children under five and for the general population.

The prevalence of diarrhea is defined in this study as the percentage of people that were suffering from diarrhea within 48 hours of the time of the survey. For this survey, the functional definition of diarrhea was the presence of either of the following symptoms: "diarrhea", or "blood or mucus in the stool", with the terms in quotations translated directly into Dagbani.

$$\text{Overall prevalence of diarrhea in children under 5} = \frac{\text{Total number of children under 5 with diarrhea within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households}}$$

$$\text{Community-specific prevalence of diarrhea in children under 5} = \frac{\text{Number of children under 5 in community with diarrhea within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households in a specific community}}$$

$$\text{Overall prevalence of diarrhea in general population} = \frac{\text{Total number of people with diarrhea within 48 hours of time of survey}}{\text{Total number of people in all surveyed households}}$$

$$\text{Community-specific prevalence of diarrhea in general population} = \frac{\text{Number of people in community with diarrhea within 48 hours of time of survey}}{\text{Total number of people in all surveyed households in a specific community}}$$

The overall prevalence of diarrhea in children under the age of five was **23 percent, with a 95% CI of 17 to 29 percent** (n = 200). The community-specific prevalence rates of under-five diarrhea are **not statistically different** from each other. Figure 8 shows community-specific prevalence rates of diarrhea in children under five, with error bars depicting the 95% CI for each community.

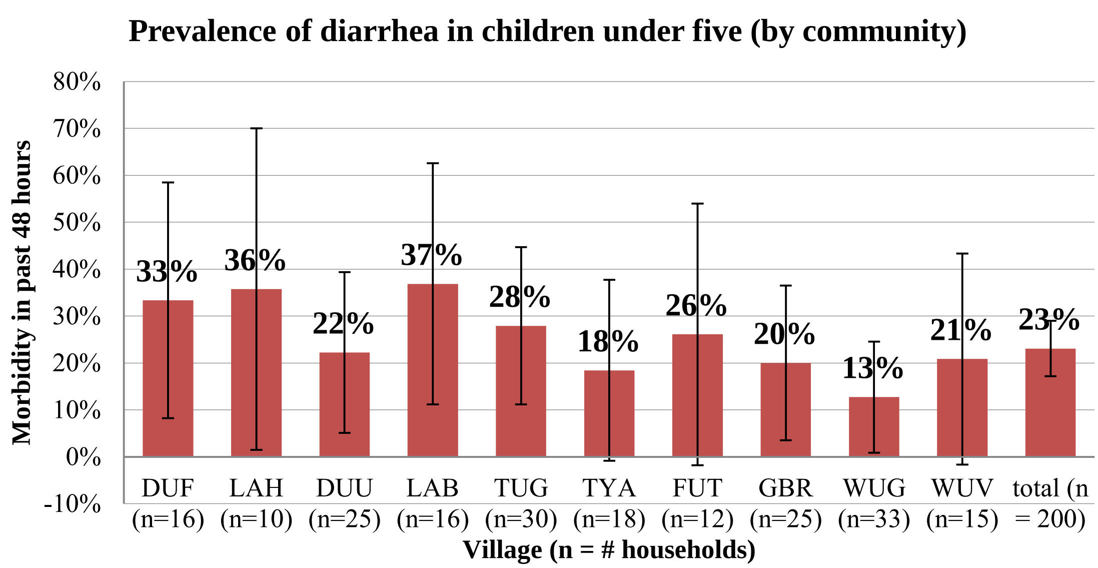

Figure 8: Prevalence of diarrhea in children under five (by community).

The overall prevalence of diarrhea in the general population was **9 percent, with a 95% CI of 5 to 13 percent** (n = 200). Figure 9 shows community-specific prevalence rates of diarrhea in the general population. The community-specific prevalence rates of diarrhea in the general population are **not statistically different** from each other.

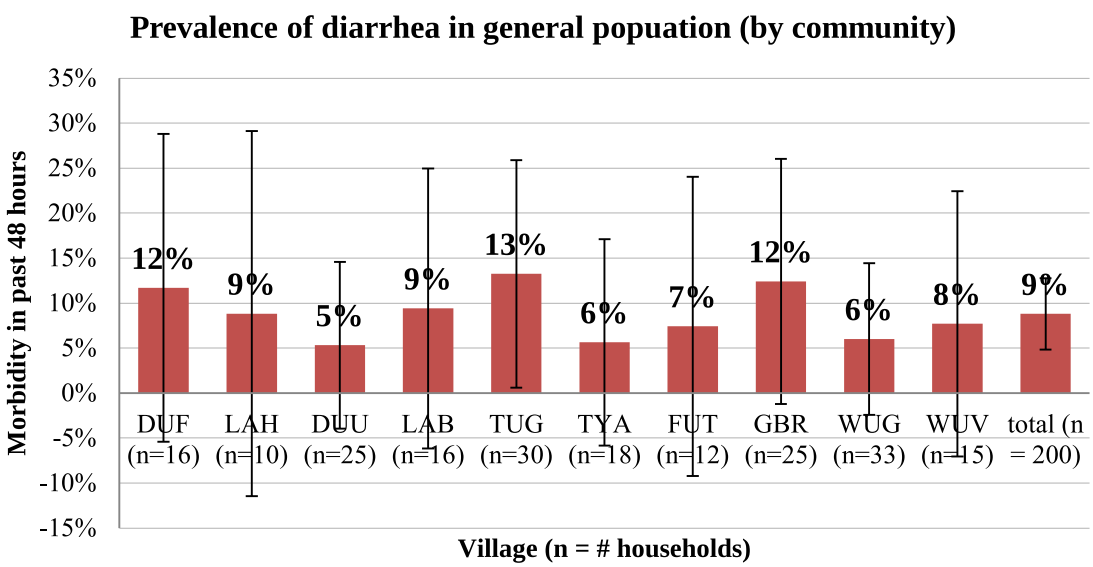

Figure 9: Prevalence of diarrhea in general population (by community).

The prevalence of cough and difficulty breathing is defined in this study as the percentage of people that were suffering from cough or difficulty breathing within 48 hours of the time of the survey.

$$\text{Overall prevalence of cough and difficulty breathing in children under 5} = \frac{\text{Total number of children under 5 with cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households}}$$

$$\text{Community-specific prevalence of cough and difficulty breathing in children under 5} = \frac{\text{Number of children under 5 in community with cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households in a specific community}}$$

$$\text{Overall prevalence of cough and difficulty breathing in general population} = \frac{\text{Total number of people with cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of people in all surveyed households}}$$

$$\text{Community-specific prevalence of cough and difficulty breathing in general population} = \frac{\text{Number of people in community with cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of people in all surveyed households in a specific community}}$$

The overall prevalence of cough and difficulty breathing in children under the age of five was **25 percent, with a 95% CI of 19 to 31 percent** (n = 200). The community-specific under-five prevalence rates of cough and difficulty breathing are **not statistically different** from each other, with one exception. Tugu-Yapala (TYA) and Lahagu (LAH) appear to have significantly lower rates of under-five cough and difficulty breathing, and of under-five severe cough and difficulty breathing, than Gbruma (GBR) and Wuvugu (WUV). However, given the small sample size from each community, survey-derived estimates of small proportions (such as prevalence rates of under-five cough and difficulty breathing Tugu-Yapala and Lahagu) may have confidence intervals that are larger than those calculated using our chosen method. Calculation of a more realistic confidence interval would require statistical methods that are beyond the scope of this study.

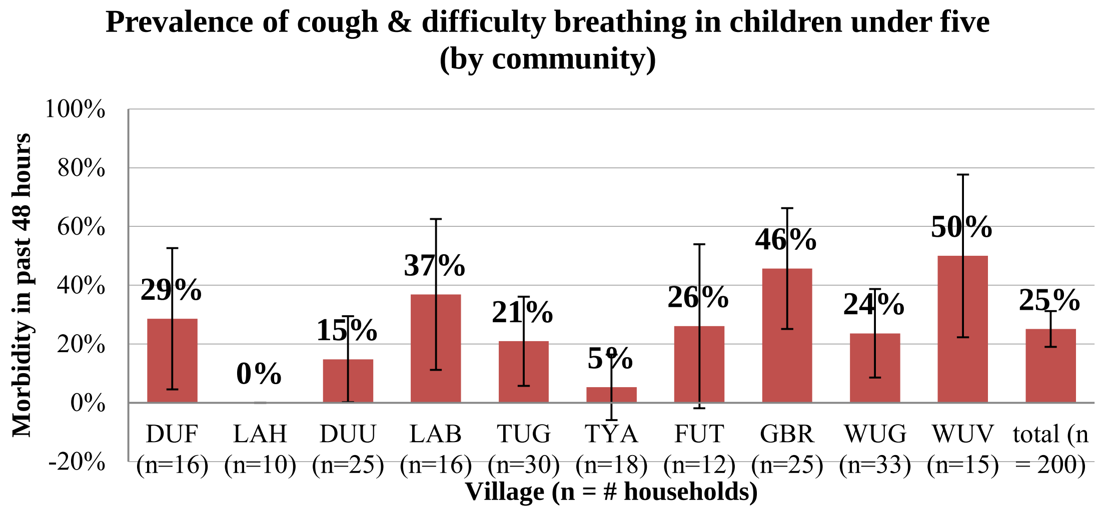

Figure 10: Prevalence of cough and difficulty breathing in children under five (by community).

The overall prevalence of cough and difficulty breathing in the general population was **13 percent, with a 95% CI of 8 to 17 percent** (n = 200). The community-specific prevalence rates of cough and difficulty breathing for the general population are **not statistically different** from each other.

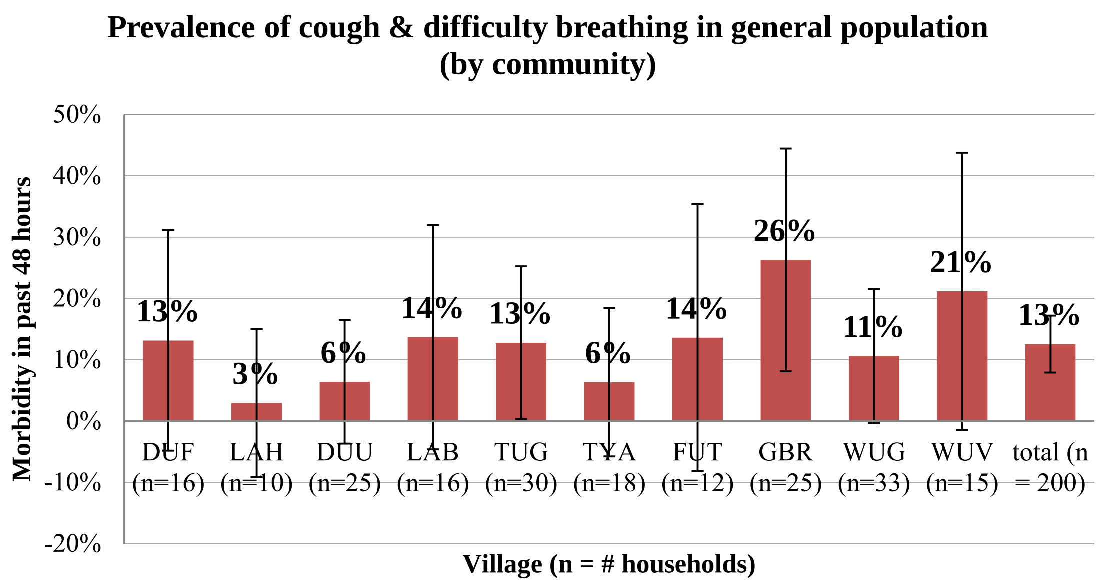

Figure 11: Prevalence of cough and difficulty breathing in general population (by community).

Limitations of Baseline Study

While household surveys are relatively efficient tools for gathering information from data-poor regions, survey responses can be inaccurate for a number of reasons. In this survey, respondents may have given inaccurate answers if they misinterpreted survey questions or could not clearly recall certain events. From informal observations, there seems to be considerable underreporting of cough and difficulty breathing due to cultural interpretation of the survey question. Prevalence rates may have been underestimated because respondents did not know of or recall all cases of illness in the households. Underreporting was particularly apparent in households (fourteen total) with more than fifteen members, and the data from these fourteen households were removed from the prevalence rate estimates. However, it is probable that some underreporting also occurred in mid-sized and even smaller households, particularly for illness in adults and children over the age of five.

Respondents may also have deliberately changed certain responses to be polite, withhold sensitive information or demonstrate need for assistance. In this study, it is probable that politeness resulted in overestimation of the proportion of households that use cloth filters for household water treatment and the proportion of households that were interested in purchasing ceramic water filters for GHC 5.

In addition, for this study, while one of the two enumerators had six years of field experience with the Guinea Worm Eradication Program, none of the enumerators had formal academic training in epidemiology or survey methods, so enumerator behavior may be a source of error and inconsistency. In addition, due to limited time in the field, it was not feasible to go through a several-day training process for enumerators, although a pre-test was conducted and learning from that was brought forward into the actual survey itself.

There was inconsistency in how the household was defined in the baseline survey. By and large, the household was defined as the respondent (usually a mother) and her husband, children, and extended family members. However, many of the respondents were members of polygamous compounds, and approximately fourteen of these respondents counted all members of the compound as members of their household.

Community-specific illness prevalence rates should be interpreted and used critically, as the 95% confidence intervals for these values are very large. Where possible, overall prevalence rates should be used instead of community-specific rates.

Baseline Study Conclusions

There is a great need and potential for safe and improved water in the peri-urban villages of Tamale. Overall, 98.6 percent of the survey population is using surface water as a primary drinking water source in the dry season, and 79.9 percent of the survey population is using unprotected water sources in the wet season. The potential for ceramic water filter dissemination is demonstrated by the fact that 99.5 percent of households surveyed expressed interest in purchasing the filter for the sale price of GHC 5 (US$ 3). The success of the Guinea Worm

Eradication Program in establishing the habit of water treatment with cloth filters demonstrates that it is possible to change household water management practices given adequate motivation, training and follow-up. Even two years after the last Guinea Worm Eradication Program follow-up, 52.6 percent of households surveyed were still using cloth filters to treat their drinking water, even though the purpose for which they were intended, the removal of the guinea worm cyclops, is no longer a concern. While the Guinea Worm program was extremely intensive and well funded, it may be possible to borrow some of the key strategies and even hire unemployed personnel for PHW water, sanitation and hygiene dissemination activities.

In addition, safe storage and dispensing is a considerable need, as almost all households use open clay pots for drinking water storage, and 83.6 percent of households dispense drinking water by dipping cups or scoops without handles directly into the pots. Storage containers and dispensing mechanisms that prevent recontamination of drinking water would be significant improvements in rural communities in Tamale.

There is also a great potential for improved hand-washing practices. Only 5.0 percent of the households surveyed currently practice hand-washing with soap, yet 99.2 percent of households have soap present in the home. The great majority of households used bar soaps, which are appropriate for attaching to the Tippy Tap hand-washing stations. The 5.0 percent rate of hand-washing rate with soap, measured using the indirect question method in this study, is comparable to the rate measured by structured observation in a national survey of Ghanaian mothers by Scott *et al.* (2007a). Scott *et al.* found that 4 percent of mothers practiced hand-washing with soap after defecation, 2 percent practiced hand-washing with soap after cleaning a child’s bottom, and only 1 percent practiced hand-washing with soap before feeding children (Scott *et al.,* 2007).

The other piece of evidence for the need for improved water treatment is the high prevalence rates for diarrhea and respiratory illnesses. The prevalence rates for diarrhea were 23 percent (95% CI 17 to 29 percent) for children under the age of five and 9 percent (95% CI 5 to 13 percent) for the general population.

The under-five diarrheal prevalence rate measured by the baseline survey seems to be reasonable, compared to the Northern Region under-five diarrheal prevalence rate measured by the 2008 Ghana Demographic and Health Survey. The 2008 GDHS found that 32.5 percent of children under 5 had diarrhea in the *2 weeks* prior to the survey, with a 95% CI of 27.6 percent to 37.3 percent (n = 413 children). These prevalence rate estimates are not statistically different, although the overlap of the 95% confidence intervals between the two prevalence rate estimates is small. However, since the comparison is between a 48-hour prevalence rate and a 2-week prevalence rate, if we consider this difference in recall period, the estimate of diarrhea prevalence in this study may be higher than the estimate by the GDHS. Lu (2012) discusses the comparison of this study to the GDHS.

By the same reasoning, the estimate of under-five diarrhea prevalence in this study may be higher than the Demographic and Health Survey prevalence estimates in Haiti (2005-2006), where 23.7 percent of children under five (95% CI 21.7 percent to 25.8 percent) were reported to have diarrhea in the two weeks prior to the survey, as well as the prevalence estimates in India (2005-2006) and South Africa, where 9.0 percent and 7.9 percent of children under five were reported to have diarrhea in the two weeks prior to the survey (Enquête Mortalité, Morbidité et Utilisation des Services, Haïti, 2005-2006; India National Family and Health Survey, 2005-2006; South Africa Department and Health Survey, 2003).

For cough and difficulty breathing, prevalence rates were 25 percent (95% CI 19 to 31 percent) for children under the age of five and 13 percent (95% CI 8 to 17 percent) for the general population. The prevalence of cough and difficulty breathing estimated by this study is significantly higher than the 2008 GDHS prevalence of acute respiratory illness (ARI), 9.3 percent of children under five, even though the recall period in this study was shorter than the recall period used by the GDHS.

Similarly, the estimate of under-five prevalence of cough and difficulty breathing in this study is higher than the Demographic and Health Survey under-five prevalence estimates of ARI in Haiti (5.8 percent of children under five), Haiti (8.8 percent of children under five) and South Africa (11.6 percent of children under five) (Enquête Mortalité, Morbidité et Utilisation des Services, Haïti, 2005-2006; India National Family and Health Survey, 2005-2006; South Africa Department and Health Survey, 2003).

Hands ("fingers") and drinking water ("fluids") are two of the five exposure pathways for diarrheal illnesses, and hands are also exposure pathways for respiratory illnesses. Therefore, while other exposure pathways exist, clean drinking water and improved hand-washing practices are two important elements of improving public health in rural Tamale communities.

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Appendices

Appendix A: Baseline survey tool

Rotary Foundation Global Grant (FVGG25252)–Ceramic Filter & Tippy Tap Distribution
Impact Evaluation: Baseline Survey (before or at installation)

Hello, my name is _______ and I am a researcher working with a team from Pure Home Water in Tamale, Ghana and Massachusetts Institute of Technology, in the United States. This study is funded by the Rotary Foundation, an international voluntary organization. We are talking with people in your community to learn what you currently do to manage your household water and wash your hands. This survey is not a test in any way. All information we collect will be kept confidential, which means that we will not share the information you give to us with others. The data will be kept only as a collection of the responses given by all survey participants.

We would like to talk with the mother, grandmother or other primary caretaker of household children for about one hour. We are planning to ask questions about your household profile, health status, water management practices and hand washing practices. You may find some of the questions sensitive. In this case, you may choose to not answer any or all of the questions, and if you wish, you may end the interview at any point.

Participation is completely voluntary. Do you understand? Are you willing to participate?
Yes No

IF NO, thank you for your time and we will end here.
IF YES, do you have any questions about the survey or may we begin?

Household Information

1. We would like to return to you in about 6 months to ask similar questions. You may choose to not participate then, but would you please tell us your name and the name of your compound so that we may ask for you?

Household: ____ Compound: _____________________________________

2. Are you the mother, grandmother, or other caretaker?

Mother Grandmother Other primary caretaker

3. How many people live in your household? Total: _______ Under age 5: ________

Water Use Practices

4. When you are at home, where do you get your drinking water in the dry season? What about the in the wet season?

Dry season:

Surface water HDW unprotected Borehole Other

Piped supply HDW protected Community water treatment

Wet season:

Surface water HDW unprotected Borehole Rainwater

Piped supply HDW protected Community water treatment Other

5. Do you ever treat your water to make it safer to drink? How do you treat it? CIRCLE ALL THAT APPLY

Boil Alum Chlorine tablets/liquid Ceramic filter Cloth filter None Other: ____________

6. Could you show me how you take water from the containers?

Pour directly Draw with cup/scoop w/ handle Draw with cup/scoop w/o handle Spigot Other

Hygiene Practices

7. Could you please show us what kind of soap you have in your home?

   Present   Not present

8. What do you use the soap for? CIRCLE ALL THAT APPLY, DO NOT PROMPT ANSWERS.

   Handwashing   Dishes   Laundry   Other

Diarrhea and Respiratory Disease

We will now ask you some questions about the health status of your family. We will be asking about diarrhea and respiratory illness. If you do not feel comfortable with sharing this information please tell us.

SKIP 11 IF THERE ARE NO CHILDREN UNDER 5 IN HOUSEHOLD.

9. Let's start with your youngest child. USE **FORM A** FOR EACH CHILD UNDER AGE 5.

10. Has anyone (else) in the household had diarrhea or abdominal pain in the last two days?

    Yes   No

11. Has anyone (else) in the household had blood or mucus in the stool in the last two days?

    Yes   No

12. Has anyone (else) in the household had nausea or vomited in the last two days?

    Yes   No

    USE **FORM B** FOR EACH PERSON WHO HAS HAD ANY OF ABOVE SYMPTOMS IN THE LAST WEEK.

13. Has anyone (else) in the household had a cough or difficulty breathing in the last two days?

    Yes   No

    USE **FORM C** FOR EACH PERSON WHO HAS HAD A COUGH OR DIFFICULTY BREATHING IN THE LAST WEEK.

14. Are you interested in purchasing a sale price ceramic water filter for GHC 5?

    Yes   No

THANK SUBJECT FOR HER/HIS TIME.

RECORD THIS INFORMATION UPON LEAVING HOUSEHOLD:

Interview Background:

Community: ________________________ Survey number: _______

Date: ________________________

GPS number: __________________   GPS coordinates: ____

FORM A

Questions	Youngest under age 5	Next youngest	Next youngest	Next youngest	Eldest under age 5
A1. Has he/she had diarrhea in the last 2 days?	Yes No	Yes No	Yes No	Yes No	Yes No
IF HE/SHE HAD DIARRHEA: A2. Was the diarrhea severe or watery?	Yes No	Yes No	Yes No	Yes No	Yes No
A3. Has he/she had blood or mucus present in his/her stool?	Yes No	Yes No	Yes No	Yes No	Yes No
A4. Has he/she vomited in the last 2 days?	Yes No	Yes No	Yes No	Yes No	Yes No
A5. Has he/she had a cough or difficulty breathing in the last 2 days?	Yes No	Yes No	Yes No	Yes No	Yes No
IF HE/SHE HAD A COUGH OR DIFFICULTY BREATHING: A6. Was the cough or difficulty breathing severe?	Yes No	Yes No	Yes No	Yes No	Yes No

FORM B

Questions	Person 1	Person 2	Person 3	Person 4	Person 5
B1. Which symptoms did the individual have? LIST AS NECESSARY (HCGI = PRESENCE OF ANY: WATER DIARRHEA, VOMITING, SOFT DIARRHEA W/ ABDOM PAIN, OR NAUSEA W/ ABDOM PAIN; DIARRHEA = THREE OR MORE LOOSE OR WATERY STOOLS IN 24 HOURS OR A SINGLE STOOL W/ BLOOD OR MUCUS)	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool
IF HE/SHE HAD DIARRHEA: B2. Was the diarrhea severe or watery?	Yes No	Yes No	Yes No	Yes No	Yes No

Questions	Person 6	Person 7	Person 8	Person 9	Person 10
B1. Which symptoms did the individual have? LIST AS NECESSARY (HCGI = PRESENCE OF ANY: WATER DIARRHEA, VOMITING, SOFT DIARRHEA W/ ABDOM PAIN, OR NAUSEA W/ ABDOM PAIN; DIARRHEA = THREE OR MORE LOOSE OR WATERY STOOLS IN 24 HOURS OR A SINGLE STOOL W/ BLOOD OR MUCUS)	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool
IF HE/SHE HAD DIARRHEA: B2. Was the diarrhea severe or watery?	Yes No	Yes No	Yes No	Yes No	Yes No

FORM C

Questions	Person 1	Person 2	Person 3	Person 4	Person 5
C1. Was the individual's cough or difficulty breathing severe?	Yes No	Yes No	Yes No	Yes No	Yes No

Questions	Person 6	Person 7	Person 8	Person 9	Person 10
C1. Was the individual's cough or difficulty breathing severe?	Yes No	Yes No	Yes No	Yes No	Yes No

Appendix B: Draft of one-month follow-up survey tool

DRAFT – 1 Month Followup
Rotary Foundation Global Grant (FVGG25252) –Ceramic Filter & Tippy Tap Distribution
Impact Evaluation: 1-Month Follow-Up

Hello, my name is _______ and I am a researcher working with a team from Pure Home Water in Tamale, Ghana and Massachusetts Institute of Technology, in the United States. This study is funded by the Rotary Foundation, an international voluntary organization. We are talking with people in your community to see if the ceramic filters and hand-washing stations we installed last month are helpful. We want to hear about your current water use and hand washing practices. We would like to talk with one of the primary caretakers in the household for about ten to fifteen minutes. Participation is voluntary; you may decline to answer any or all of the questions, and you end the questionnaire early if you wish. All identifying information will be kept confidential.

Do you understand? Will you be willing to participate?
(1) Yes (2) No (If no, thank and close)

Interview Background:

Household: ______________________________ Date: ______________________

Filter Use:

1. Were you the person who purchased the filter? Yes No
2. Were you present the day the filter was installed? Yes No
3. Did you receive training on how to use the filter? Yes No (Who was? ___________)
4. Are you using the filter? Yes No
5. How often do children <5 in your household drink untreated water?
   Daily Weekly Monthly Never
6. How often do others in your household drink untreated water?
   Daily Weekly Monthly Never
7. If you are not using the filter, why? (Don't read the options, circle all that they say)
   (1) Filter/Storage container/Spigot broke
   (2) Did not like using it
   (3) Felt it was not necessary
   (4) Felt it was not improving the quality of your water
   (5) Too time consuming
   (6) No longer here in this household
   (7) Found a better or more trusted source of water

8. Filter Problems (multiple answers possible)

breakage! since:! ! where:! pot!lip! pot!side! container! other:!
reason:! !

leakage! since:! ! where:! filter!tap! container! other:! !
reason:! !

other! since:! ! where:! !
reason:! !

9. Replacement Parts Required (multiple answers possible)

filter!pot! container! lid! ring!lid! tap! washer(s)! brush! other:!

10. Can you tell me how you would describe to a neighbor how to use this technology?
Correct use Incorrect use

11. Can you please pour me a cup of your drinking water?
Safely removing water Incorrect method of removing water

12. Do you clean the filter? Yes No

13. How often?
Daily Weekly Monthly Never

14. Will you please demonstrate how you clean the filter?
Correct cleaning Incorrect cleaning

Observation:

15. Is the ceramic filter moist or wet? Yes No

16. Is safe storage container securely covered? Yes No
…out of reach of small children or animals? Yes No
…clean (free of dirt, debris, garbage, fecal matter)? Yes No

OTHER! OBSERVATIONS! !

Tippy Tap Use:

17. Were you present the day the Tippy Tap was installed? Yes No

18. Were you one of the people who received training on how to use the Tippy Tap? Yes No (Who was? ______________)

19. Are you still using the Tippy Tap? Yes No

20. If not, why? (Don't read the options, circle all that they say)

    (1) Problem with Tippy Tap
    (2) Did not like using it
    (3) Felt it was not necessary
    (4) Felt it was not improving hand cleanliness
    (5) Too time consuming
    (6) No longer here in this household
    (7) Found a better way to wash hands

21. Have you noticed any problems with the Tippy Tap?
    (1) Yes (2) No

22. If yes, what was the problem?
    (1) Structure broke
    (2) String tore
    (3) Container broke
    (4) Ran out of soap
    (5) Messy
    (6) Other: ______________

23. Can you please ask one of your children demonstrate how to use the Tippy Tap? (If no children present, indicate this and ask respondent to demonstrate)

    Correct use Incorrect use

!
!
Name!Surveyor:!! ! ! ! ! Date!Survey:!

!

Appendix C: Draft of six-month follow-up survey tool

DRAFT – 6 Month Followup
Rotary Foundation Global Grant (FVGG25252)–Ceramic Filter & Tippy Tap Distribution
Impact Evaluation: 6-Month Follow-up Survey

Hello, my name is _______ and I am a researcher working with a team from Pure Home Water in Tamale, Ghana and Massachusetts Institute of Technology, in the United States. This study is funded by the Rotary Foundation, an international voluntary organization. We are talking with people in your community to learn what you currently do to manage your household water and wash your hands. We would like to talk with the mother, grandmother or other primary caretaker of household children for about one hour. We are planning to ask questions about your household profile, health status, water management practices and hand washing practices. Participation is voluntary; you may decline to answer any or all of the questions, and you end the questionnaire early if you wish. All identifying information will be kept confidential.

Do you understand? Will you be willing to participate?
(1) Yes (2) No (If no, thank and close)

Household Information

1. Would you please tell us your name and the name of your household and compound? This information will be kept confidential.

Household: ______________________________ Compound: ______________________________

2. Are you the mother, grandmother, or other caretaker?

Mother Grandmother Other primary caretaker

3. How many people live in your household? Total: _______ Under age 5: ________

Filter Use:

1. Were you the person who purchased the filter? Yes No
2. Were you present the day the filter was installed? Yes No
3. Did you receive training on how to use the filter? Yes No (Who was? ___________)
4. Are you using the filter? Yes No
5. How often do children <5 in your household drink untreated water?
Daily Weekly Monthly Never
6. How often do others in your household drink untreated water?
Daily Weekly Monthly Never
7. If you are not using the filter, why? (Don't read the options, circle all that they say)

(1) Filter/Storage container/Spigot broke
(2) Did not like using it
(3) Felt it was not necessary
(4) Felt it was not improving the quality of your water
(5) Too time consuming
(6) No longer here in this household
(7) Found a better or more trusted source of water

8. Filter Problems (multiple answers possible)

breakage! since:! ! where:! pot!lip! pot!side! container! other:!

reason:! !

!

leakage! since:! ! where:! filter!tap! container! other:! !

reason:! !

!

other! since:! ! where:! !

reason:! !

!

!

!

!

9. Replacement Parts Required (multiple answers possible)

!

filter!pot! container! lid! ring!lid! tap! washer(s)! brush! other:!

!

10. Can you tell me how you would describe to a neighbor how to use this technology?

Correct use Incorrect use

11. Can you please pour me a cup of your drinking water?

Safely removing water Incorrect method of removing water

12. Do you clean the filter? Yes No

13. How often?

Daily Weekly Monthly Never

14. Will you please demonstrate how you clean the filter?

Correct cleaning Incorrect cleaning

Observation:

15. Is the ceramic filter moist or wet? Yes No

!

!

16. Is safe storage container securely covered? Yes No

…out of reach of small children or animals? Yes No

…clean (free of dirt, debris, garbage, fecal matter)? Yes No

!

!

!

!

OTHER! OBSERVATIONS! !

!

!

!

H2S!Test! **Take!sample!and!test!water!for!H2S!**

!

!

!

!

SUGGESTIONS! !

!

!

!

OBSERVATIONS! !

!

!

!

Hygiene Practices

4. Could you please show us what kind of soap you have in your home?

Present Not present

5. What do you use the soap for? CIRCLE ALL THAT APPLY, DO NOT PROMPT ANSWERS.

Handwashing Dishes Laundry Other

Tippy Tap Use:

17. Were you present the day the Tippy Tap was installed? Yes No

18. Were you one of the people who received training on how to use the Tippy Tap?

Yes No (Who was? _______________)

19. Are you still using the Tippy Tap? Yes No

20. If not, why? (Don't read the options, circle all that they say)

    (1) Problem with Tippy Tap
    (2) Did not like using it
    (3) Felt it was not necessary
    (4) Felt it was not improving hand cleanliness
    (5) Too time consuming
    (6) No longer here in this household
    (7) Found a better way to wash hands

21. Have you noticed any problems with the Tippy Tap?

    (1) Yes (2) No

22. If yes, what was the problem?

    (1) Structure broke
    (2) String tore
    (3) Container broke
    (4) Ran out of soap
    (5) Messy
    (6) Other: _______________

23. Can you please ask one of your children demonstrate how to use the Tippy Tap? (If no children present, indicate this and ask respondent to demonstrate)

    Correct use Incorrect use

Diarrhea and Respiratory Disease

We will now ask you some questions about the health status of your family. We will be asking about diarrhea and respiratory illness. If you do not feel comfortable with sharing this information please tell us.

SKIP 11 IF THERE ARE NO CHILDREN UNDER 5 IN HOUSEHOLD.

6. Let's start with your youngest child. USE **FORM A** FOR EACH CHILD UNDER AGE 5.

7. Has anyone (else) in the household had diarrhea or abdominal pain in the last two days?
Yes No

8. Has anyone (else) in the household had blood or mucus in the stool in the last two days?
Yes No

9. Has anyone (else) in the household had nausea or vomited in the last two days?
Yes No

USE **FORM B** FOR EACH PERSON WHO HAS HAD ANY OF ABOVE SYMPTOMS IN THE LAST WEEK.

10. Has anyone (else) in the household had a cough or difficulty breathing in the last two days?
Yes No

USE **FORM C** FOR EACH PERSON WHO HAS HAD A COUGH OR DIFFICULTY BREATHING IN THE LAST WEEK.

11. Are you interested in purchasing a sale price ceramic water filter for GHC 5?
Yes No

THANK SUBJECT FOR HER/HIS TIME.

RECORD THIS INFORMATION UPON LEAVING HOUSEHOLD:

Interview Background:

Community: _________________________ Survey number: _______

Date: _________________________

GPS number: ___________________ GPS coordinates: ____

Name!Surveyor:!! ! ! ! ! Date!Survey:!

FORM A

Questions	Youngest under age 5	Next youngest	Next youngest	Next youngest	Eldest under age 5
A1. Has he/she had diarrhea in the last 2 days?	Yes No	Yes No	Yes No	Yes No	Yes No
IF HE/SHE HAD DIARRHEA: A2. Was the diarrhea severe or watery?	Yes No	Yes No	Yes No	Yes No	Yes No
A3. Has he/she had blood or mucus present in his/her stool?	Yes No	Yes No	Yes No	Yes No	Yes No
A4. Has he/she vomited in the last 2 days?	Yes No	Yes No	Yes No	Yes No	Yes No
A5. Has he/she had a cough or difficulty breathing in the last 2 days?	Yes No	Yes No	Yes No	Yes No	Yes No
IF HE/SHE HAD A COUGH OR DIFFICULTY BREATHING: A6. Was the cough or difficulty breathing severe?	Yes No	Yes No	Yes No	Yes No	Yes No

FORM B

Questions	Person 1	Person 2	Person 3	Person 4	Person 5
B1. Which symptoms did the individual have? LIST AS NECESSARY (HCGI = PRESENCE OF ANY: WATER DIARRHEA, VOMITING, SOFT DIARRHEA W/ ABDOM PAIN, OR NAUSEA W/ ABDOM PAIN; DIARRHEA = THREE OR MORE LOOSE OR WATERY STOOLS IN 24 HOURS OR A SINGLE STOOL W/ BLOOD OR MUCUS)	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool
IF HE/SHE HAD DIARRHEA: B2. Was the diarrhea severe or watery?	Yes No	Yes No	Yes No	Yes No	Yes No

Questions	Person 6	Person 7	Person 8	Person 9	Person 10
B1. Which symptoms did the individual have? LIST AS NECESSARY (HCGI = PRESENCE OF ANY: WATER DIARRHEA, VOMITING, SOFT DIARRHEA W/ ABDOM PAIN, OR NAUSEA W/ ABDOM PAIN; DIARRHEA = THREE OR MORE LOOSE OR WATERY STOOLS IN 24 HOURS OR A SINGLE STOOL W/ BLOOD OR MUCUS)	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool	Diarrhea Abdom. Pain Vomiting Nausea Blood/mucus in stool
IF HE/SHE HAD DIARRHEA: B2. Was the diarrhea severe or watery?	Yes No	Yes No	Yes No	Yes No	Yes No

FORM C

Questions	Person 1	Person 2	Person 3	Person 4	Person 5
C1. Was the individual's cough or difficulty breathing severe?	Yes No	Yes No	Yes No	Yes No	Yes No

Questions	Person 6	Person 7	Person 8	Person 9	Person 10
C1. Was the individual's cough or difficulty breathing severe?	Yes No	Yes No	Yes No	Yes No	Yes No

Investigation of I-WASH's Community-led Total Sanitation and Alternative Decentralized Sanitation Models in Rural Ghana

By Adam Questad

Abstract

All people everywhere need basic sanitation in order to lead healthy and dignified lives. As of 2010, Ghana has achieved 14% national improved sanitation coverage and is not projected to meet the MDG sanitation target by 2015 (WHO, UNICEF, 2012). UNICEF, in partnership with the European Union, developed the I-WASH program that intended the construction of 48,000 latrines over the four-year project duration. However, only 3,100 latrines were constructed after the project completion. UNICEF has since been attempting to validate their projects by switching the goal from latrine construction to Open Defecation Free (ODF) communities created by the use of Community-led Total Sanitation (CLTS). The author observed that only 9% of the villages throughout the I-WASH project area had achieved ODF status as of January 2012; again validating the failure of the I-WASH project to improve sanitation coverage throughout Ghana. By conducting an extensive literature review and interviewing international development experts, local government officials, and members of the community in Ghana, the author investigated the reasons that the I-WASH program was not successful in its sanitation goal and what alternatives may be available for future initiatives.

Introduction

This paper is a synopsis of the MIT Master of Engineering Thesis of the lead author Adam Questad (Questad, 2012)[8]. The intent of this paper is to evaluate the current approaches towards

[8] The full thesis is available at http://web.mit.edu/watsan/docs_theses_ghana.html, under Ghana 2012, Investigation of I-WASH's Community-led Total Sanitation and Alternative Decentralized Sanitation Models in Rural Ghana "Questad."

providing access to improved sanitation facilities in the rural areas of Northern Ghana. The author was privileged to spend the month of January 2012 in Ghana with Susan Murcott and the non-profit, Pure Home Water, she helped to found, conducting the necessary fieldwork required to evaluate the aforementioned topic. Through the guidance of Susan Murcott and Jim Niquette, a PHW Board member who played a key role in the procurement of the I-WASH[9] funding for water/sanitation in Northern Ghana through his role as director of the Carter Center's Guinea Worm Eradication Program (GWEP), the author was able to conduct interviews with international development/design experts, local government officials, a UNICEF official, NGO representatives, and village members. The data obtained during these interviews is synthesized and explained throughout the following sections, leading to conclusions and recommendations for improving rural sanitation in the future.

Motivation, Goals, and Strategy

The motivation for this research is in part a result of the Millennium Development Goal (MDG) target 7.C. set in 2002, which includes reducing by half the proportion of population without sustainable access to basic sanitation by 2015 (United Nations, 2010). Reaching the sanitation goal by 2015 does not seem achievable at the current rate as estimates show that the world is on track only to meet this goal by 2026 (WHO, UNICEF, 2012). The additional motivation for this paper stems from a desire to conduct an independent review of sanitation initiatives currently in place in Ghana in order to better understand how to move forward.

In order to define a tangible framework for this research, it was necessary to limit the scope to evaluating one approach: community-led total sanitation (CLTS), a community-based behavior-change sanitation model. The reason for this focus on CLTS is because this approach is government policy in Ghana, as articulated in the National Environmental Sanitation Strategy and Action Plan (NESSAP) (March 2010) of the Ministry of Local Government and Rural Development of Ghana. In Ghana, CLTS was most significantly promoted through the implementation of UNICEF's I-WASH program, the main (and successful) goal of which was to eradicate guinea worm.

To thoroughly investigate and understand the current sanitation situation in Ghana, the two-fold strategy involved **interviews** and **site visits**. To understand how training was implemented and CLTS knowledge disseminated, interviews were arranged with local District Assembly (DA) WASH officials who were directly involved with the I-WASH or other CLTS initiatives. To then determine the efficacy of the CLTS program, site visits and household interviews were carried out in certain villages throughout the Northern Region. Finally, in order to assess additional opportunities or alternatives to CLTS, interviews with international development/design experts were conducted and various sanitation projects/technologies were evaluated to determine whether they could replace or enhance CLTS to more successfully provide access to improved sanitation facilities in Ghana. Through these interviews and site

[9] I-WASH is the Integrated Approach to Guinea Worm Eradication through Water Supply, Sanitation and Hygiene project that budgeted €19,550,528 ($25 Million) towards eradicating Guinea Worm through various water, sanitation and hygiene initiatives throughout the Northern Region of Ghana from 2007 to 2011 (UNICEF, 2006).

visits, the author gained significant understanding of the implementation of CLTS in Ghana, the reaction from the people, and potential opportunities for improvement in the future.

Sanitation in Ghana

Only 19 percent of the urban population and 8 percent of the rural population have access to improved sanitation facilities throughout Ghana for an overall average of 14 percent4 coverage. According to the UNICEF-WHO Progress on Sanitation and Drinking water, 2012 update report, approximately 33 percent of the rural population in Ghana practice open defecation and the poorest quintile is more likely to practice open defecation than the richest quintile (WHO, UNICEF, 2012). It is estimated that in 2007, $52 million per year was being spent on sanitation in Ghana, $1.8 million coming from the Government of Ghana. Foreign donors such as the World Bank, UNICEF, the EU, and the Danish International Development Agency provided the remaining $50.2 million amount. (Thrift, 2007) In his thesis, Jonathan Lau (MIT CEE MEng 2011) examined several recent annual budgets of the Government of Ghana's (GoG) spending on rural sanitation and found it to be a meager 0.1% (the GoG spending on rural sanitation varied between 2000 and 2008 from $0.5 million to $20 million (2008 dollars)) of their entire budget (Lau, 2011).

Environmental Sanitation Policy (ESP)

The Ministry of Local Government and Rural Development revised the Environmental Sanitation Policy (ESP) in 2009 (it was previously published in 1999). The updated policy specifically references the MDG target year of 2015 and claims to include updated policy that will redirect Ghana towards achieving these goals. Additionally, a National Environmental Sanitation Strategy and Action Plan (NESSAP) (March 2010) and a Strategic Environmental Sanitation Investment Plan (SESIP) were developed to meet the objectives of the ESP.

The ESP consists of general guidelines such as "the polluter-pays principle" and "the principle of subsidiarity in order to ensure participatory decision making at the lowest appropriate level in society" as well as more specific recommendations (Ministry of Local Government and Rural Development, 2010). The ESP specifically defines roles for the "household and communal level" and the "institutions." Under the roles for "institutions", the ESP states that "the bulk of environmental sanitation services shall be provided by the private sector, including NGOs and community based organisations under the supervision of the Public Sector." Specifically in terms of human excreta disposal, the public sector is instructed to manage septage tankers as well as operation and maintenance of sewer collection and treatment systems and the acceptable on-site sanitation facilities for the communities are described as VIP latrines and septic tanks. Additionally, the ESP states that strategic planning using sanitation assessment and audits will be carried out for urban areas and large settlements, whereas CLTS will be used for rural areas and small settlements (Ministry of Local Government and Rural Development, 2010). The NESSAP provides more detailed strategic plans for implementing environmental sanitation projects and includes the use of CLTS for populations less than 7,500 (Environmental Health and Sanitation Directorate, 2010).

Integrated Approach to Guinea Worm Eradication through Water Supply, Sanitation and Hygiene Project (I-WASH)

UNICEF and the EU implemented the I-WASH project throughout the 9 most endemic districts of the Northern Region of Ghana from 2007 until 2011. The goals of this project were focused on eradicating guinea worm disease and improving community tasks related to drinking water, sanitation, and hygiene (Decosas & Durand, 2009). The I-WASH budget showed that Result 3 (increased sanitation coverage) was allocated 16% of the total budget (€3,173,600 ($4 Million) out of €19,550,528 ($25 Million)) and Monitoring and Evaluation was provided a meager 1% (€200,000 ($252,000)). The proposal for the I-WASH project planned for a monitoring program at the district, regional, and national levels including the creation of WATSAN committees to facilitate community evaluation and mapping. Additionally, UNICEF and the EU established the following projected results to be expected in the project area (UNICEF, 2006):

- 40% (at least) decrease in the diarrheal disease among children under 5 years old
- 90% reduction of Guinea Worm cases
- 35% Increase in sanitation coverage
- 70% of the population understand the connection between handwashing and health

UNICEF also established a goal of 48,000 latrines to be constructed, however they also proposed the use of sanitation marketing "to create awareness of the importance of sanitation and hygiene and to mobilize families, civil society, religious leaders, government institutions and the private sector and others to rally behind a major push to accelerate sanitation coverage using a 'Community Led Total Sanitation' approach" (UNICEF, 2006). Proposing CLTS as a strategy and also providing a latrine construction goal is contradictory to the CLTS principle of achieving ODF communities rather than latrine coverage. According to Jim Niquette, (former) Director of the Carter Center's Guinea Worm Eradication Program in Ghana, after four years of operation (as of 2011), only 3,100 out of the projected 48,000 latrines had been built. This result means that each latrine constructed (as of 2011) required €1,000 (~$1300)[10] from the entire sanitation budget. This failure has allowed CLTS to become the priority and replace the goal of creating 48,000 latrines with increased ODF communities. However, after the author interviewed a UNICEF official it became clear that this new goal had not been achieved either (9% ODF communities out of 402 total communities was achieved as of January 2012 (Barajel, 2012))

Regardless of this result, the I-WASH Project has influenced the adoption of Community-led Total Sanitation (CLTS) throughout the District Assemblies (DA) (Niquette, 2011), which has gained considerable attention from local organizations and the Government of Ghana (GoG). The GoG group responsible for sanitation delivery, the Environmental Health and Sanitation Directorate (EHSD), created a group of key stakeholders and organizations called the National Technical Working Group on Sanitation (NTWGS) in 2008. After UNICEF implemented CLTS and supported an evaluation in 2008, the NTWGS has supported CLTS initiatives including a push for ODF communities to be achieved (Institute of Development Studies, 2011). Finally, in 2009, the Environmental Sanitation Policy was updated to include CLTS as a strategy for

[10] €1,000 = €3,173,600 (total sanitation budget) / 3,100 latrines (total constructed as of 2011)

improving sanitation in rural areas (Ministry of Local Government and Rural Development, 2010).

CLTS in Ghana

While CLTS spread fast in Bangladesh and that country is on track to meet the Millennium Development Goals set for sanitation, it has not been successful in Ghana based on the previously mentioned results of the I-WASH program and the fact that the OD percentage in rural areas has increased from 31% in 2000 to 33% in 2010 (WHO, UNICEF, 2012). After the Afram Plains Development implemented a "total sanitation" approach, which included CLTS as a corner stone (funded by WaterAid), CLTS was chosen as the potential solution to achieving the MDG sanitation target by the GoG. Between 2006 and 2007, The Community Water and Sanitation Agency (CWSA) and other NGOs began piloting CLTS in 4 regions of Ghana (Institute of Development Studies, 2011). The goal of this approach is to scale up hygiene and sanitation improvements through behavior change of communities by motivating them to become aware of sanitation issues and work together to become ODF. However, based on the author's investigations through interviews and site surveys, after the communities were inspired to act on the sanitation problem, some of them were provided with a concrete slab and latrine construction instructions. The instructions encouraged community members to line the pits they dug and also create a superstructure. However, due to the limited financial resources, most members did not line the pits so they end up collapsing during the rainy season. In addition, the superstructures are usually built of cheap materials and do not withstand heavy rain and strong winds that occur during the annual rainy season. These two factors seem to be causing community members to ultimately abandon their latrines and deem them unusable (Niquette, 2011). The author also observed that some communities were not provided with construction materials or instructions at all and told to practice "dig and bury" as a means of achieving ODF. Both of these approaches (providing concrete slabs and instruction to "dig and bury") towards implementing CLTS are not being accepted by the people. The inability for CLTS to produce positive results in rural Ghana has been a major factor in motivating the author to undertake this research and determine the reasons behind this lack of progress. The following sections present data collected and results from the author's fieldwork during January 2012 in Ghana. The purpose of this work is to determine what is hindering the advance of sanitation coverage throughout Ghana and what recommendations can be made for future sanitation improvements.

Data Collected

The author interviewed the following local officials to determine how they implemented CLTS and what results they have achieved in terms of improved sanitation coverage:

- **Isseh Baba**, Team Leader of Water and Sanitation for Tamale Metropolitan District Assembly,
- **Eric Djokotoe**, District Works Engineer for Savelugu District Assembly,
- **Ibrahim Yussif**, District Coordinating Director for Nanumba North District Assembly,
- **Chelteau Barajel**, WASH Officer for UNICEF, Ghana.

Additionally, the following 8 villages were visited and interviews were conducted with the village chiefs and community members:

- Tamale Metropolitan District
  - Bamvim Village
  - Zagyuri Village
- Savelugu District
  - Yong Village
  - Challam Village
- Nanumba North District
  - Juo-Sogon Village
  - Bincheratanga Village
  - Nakohigu Village
  - Suburi Village

The purpose of these village site visits was to evaluate the community's response to CLTS and assess the development in terms of sanitation coverage or facilities. All of the villages visited were subsistence farming communities earning less than GHS 1.10 ($0.60) per day (Ghana Statistical Service, 2008) and they did not have expendable income available for WASH investments. The following tables and figures represent the data that was collected during the interviews with local officials and site visits at the 8 villages.

Table 1: CLTS results based on interviews

	Region	Communities Impacted	Communities declared ODF	% ODF
Isseh Baba	Tamale	2	0	0%
Eric Djokotoe	Savelugu	56	4	7%
Chelteau Barajel	Northern Region	402	36	9%

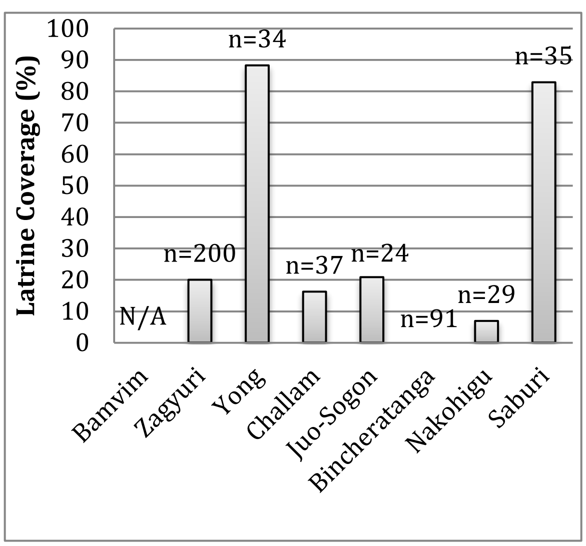

Figure 2: Latrine Coverage for Each Village (n = total number of households, latrine coverage data was not available for the Bamvim Village)

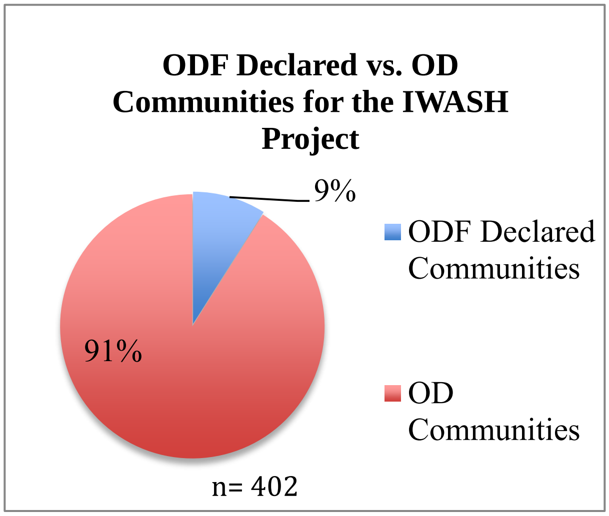

Figure 3: Percentage of ODF Communities throughout the Northern Region (Barajel, 2012)

Table 2: Observance of CLTS Action Steps in All 8 Villages

CLTS Action Step	Observance	Notes
The community discusses the impacts of open defecation with an external facilitator.	8 out of 8	This is the initial step to CLTS during the triggering exercise, so the initial conversation was conducted at all villages visited.
Together, they visit sites of open defecation.	8 out of 8	Most villagers reported visiting the sites of open defecation with the CLTS facilitators.
The community maps out areas of open defecation.	2 out of 8	The author observed two maps created, however most villages had not created defecation maps
The community works out how much human waste they produce.	7 out of 8	Most villagers reported calculating how much waste they produce
The community draws up an action plan to tackle the situation.	4 out of 8	Certain villages had created an action plan, however they were not all directed towards this action
Health and hygiene education sessions are carried out.	2 out of 8	From the conversations held, a focus on health and hygiene education was lacking among villages

The facilitator and community work on an action plan.	2 out of 8	If an action plan had been created, this step was taking place, but most villages did not have an action plan
Construction of latrines begins.	4 out of 8	Half of the villages were constructing latrines, however only one was considered ODF so the latrine coverage was minimal in the other villages
Latrines are now available to everyone and hygiene education continues.	2 out of 8	Very few villages had latrines for everyone and hygiene education was lacking to begin with
The community is awarded open defecation free status	2 out of 8	Only two villages visited were awarded open defecation free status

Discussion and Evaluation of Results

CLTS has achieved very limited success in providing access to improved sanitation facilities throughout the 9 districts of the I-WASH project in rural Northern Ghana. The original goal of the project was to improve sanitation coverage in response to the MDG, specifically to construct 48,000 latrines. After it was clear that the I-WASH program's sanitation initiative was a failure (only constructing 3,100 latrines after 4 years) a new goal of creating ODF communities was created and deemed more important. While the author believes that creating ODF communities is extremely important, he believes that UNICEF used this inferior goal to somehow translate their failure into a success. However, when the author spoke with Chelteau Barajel from UNICEF, he indicated that the I-WASH project successfully achieved 9% ODF communities out of their 402 total communities. This dramatically low number represents the ultimate failure of the I-WASH project in meeting a lower bar of ODF communities, let alone the higher bar of "improved sanitation" in rural Ghana.

The following section includes synthesis and evaluation of the data collected, conclusions, and recommendations for future sanitation initiatives. Additionally, this section below includes a discussion of the causes of the observed CLTS failure and what might be done to improve the outcome in the future.

Equitable Distribution of Sanitation interventions

The author observed tremendous inequality in distribution of sanitation resources throughout the various regions and villages in Ghana and believes that harmonization of this distribution will accelerate the provision of adequate sanitation coverage. At first glance, Figure 1 shows that Yong Village has almost 90% latrine coverage, which might lead the reader to assume that CLTS was successful in improving their access to sanitation facilities. However, the majority of this village's success can be attributed to the fact that WorldVision distributed a KVIP for free to almost every household. In contrast, the Juo-Sogon Village has only achieved just over 20% latrine coverage in their village but has been declared ODF. Juo-Sogon realized the importance of sanitation facilities and decided to construct as many latrines as they could out of local materials only. According to the WHO, this limited latrine coverage would not be deemed improved access because it requires the village to share the latrines available. Despite this classification of un-improved, Juo-Sogon represents the real success of the CLTS approach according to the project proponents.

There are many different actors in the field of international development that contribute their efforts towards improving sanitation coverage throughout Ghana. The current disconnect lies between the NGOs and the government even though they share a common goal; to provide increased access to improved sanitation facilities and meet the 2015 MDG. The GoG has updated their sanitation policy to include CLTS and has concluded that it is the most cost-effective method for providing access to improved sanitation facilities. This policy decision also means that the government will not be providing any materials or subsidies to facilitate the construction of latrines. At the same time, many NGOs, even if they claim to support CLTS, are choosing to allocate their financial resources towards latrine materials and construction (essentially the opposite strategy from the GoG). In the case of Yong, their village received both

CLTS triggering and free KVIPs from WorldVision, seemingly an ideal situation even though the provision of KVIPs contradicts the subsidy-free nature of CLTS. CLTS chooses a subsidy-free intervention because the technology can then be developed by the people themselves, forcing them to take ownership and maintain the facilities. However, when one village is provided with a subsidy-free intervention and the neighboring village is provided with free KVIPs, the former village will likely not be motivated to create their own because they will hope for a similar subsidy as the latter village was provided. Additionally, if the people do not have money or access to latrine materials/technical support, they may never develop their own technology. These inconsistencies beg for a harmonization that includes CLTS principles coupled with a plan for accessing technical support and a sanitation market.

Technical support

When the author visited the villages, many of the members explained that they did not know how to construct latrines or did not have access to sufficient materials/laborers. The idea that CLTS will allow the people to start with dig and bury and progress up the sanitation ladder towards improved facilities is fine in theory, however in practice does not seem to be successful. A technical support program should be incorporated into the CLTS framework, allowing the people to have adequate resources when/if they decide that latrine construction is appropriate for their village. The author believes that a more appropriate alternative to the advice to dig and bury might be providing the technical support required to construct an Arborloo. This cheap technology, which is a step up from dig and bury, requires a new pit to be dug every year, however this alternative is far more advantageous to digging a hole for every act of defecation. The technical support or program provided by NGOs or local businesses could allow the people to move up the sanitation ladder and have access to knowledge/materials that is a prerequisite to do so. The following section of recommendations will provide additional detail on what this technical support framework might entail.

Access to a sanitation market

Many alternative approaches to CLTS promote a sanitation market that incorporates the needs of the community. Jeff Chapin, an international expert and designer from the design firm IDEO, explained that his team spent a considerable amount of time in Cambodia developing prototypes and learning from the people what they value in a latrine when developing an affordable sanitation technology, which is what IDEO refers to as "human-centered design." His pursuit was complemented by CLTS principles and his team's approach believes that both sanitation marketing and CLTS are necessary for the success of a sanitation project (Chapin, 2011). Additionally, Nat Paynter (MIT CEE MEng 2001), Director of Water Programs for Charity Water, stressed the importance of assessing the sanitation market in an area to determine the demand available and what seasonal changes might affect the market (Paynter, 2010). The author believes that this principle is true in Ghana as well, based on his seeing only two villages (Juo-Sogon and Nakohigu) take initiative to create their own latrines solely from local materials. There is a clear disconnect between the implementation of CLTS and the private sector developing appropriate technologies to better serve the people throughout Ghana. The author believes that a connection between these two entities is necessary and will improve the harmonization required. Jeff Chapin described an example in Cambodia where entrepreneurs began hiring representatives to sell their sanitation technology at CLTS triggering meetings, which seems to be a good representation of this connection. CLTS creates awareness and behavior change, however the people need options and access to local businesses that may provide services for them if they are not able to construct the latrines themselves.

National laws and Building code enforcement (Punishment)

The following statement is taken directly from the National Environmental Sanitation Strategy and Action Plan (NESSAP) of Ghana:

“Another dimension for improving environmental sanitation, as proven elsewhere, is the adoption of Community-Led Total Sanitation (CLTS) as a nation-wide strategy for sanitation promotion in rural areas and small towns of population less than 7,500” (Environmental Health and Sanitation Directorate, 2010).

The Ministry of Local Government and Rural Development created this updated NESSAP in March of 2010 and throughout the plan, it is clear that previous elements have been amended to include CLTS as part of the national strategy for achieving the MDG by 2015. The goals according to the NESSAP are to achieve 15% national household latrine coverage by 2010 and 90% coverage by 2035 through the promotion of CLTS and trained artisans for construction. However, they are also planning to “Support (the) installation of bio-digesters and packaged plants by private operators” (Environmental Health and Sanitation Directorate, 2010). While CLTS is prevalent in their new strategy, it seems to exist as a suggestion to complement more important strategies, which may interfere with the strictly subsidy-free intervention that it requires.

Additionally, this policy assumes that the NGOs in the area are following suit and coordinating with the local governments. There needs to be a network of NGOs working on sanitation that includes the government so that appropriate coordination can be made and that all parties are following the same policy and monitoring progress. This coordination will also ensure that overlap does not occur such as one instance observed by the author where one village was triggered twice through CLTS by the DA and an NGO, while a nearby village had never received any triggering. Including coordination and monitoring progress in an updated national policy will be necessary for future effectiveness of sanitation interventions and should also be complemented by the addition of a sanitary code when constructing new houses.

The City of Boston’s Sanitation Code 105 CMR 410.150 states that the owner of a house shall provide, at a minimum, “A toilet with a toilet seat in a room which is not used for living, sleeping, cooking or eating purposes and which affords privacy to a person within said room”. There are also stringent guidelines including washbasins and other sanitary requirements such as bathtubs and showers. Every new construction requires an inspection and if these codes are not met they are given an appropriate time to make adjustments and ultimately fined (between $10-$500) if they fail to comply (City of Boston Department of Public Health, 2007). Currently, Ghana does have building regulations established that have general requirements for sanitary provision when constructing buildings, however there is no enforcement of such regulations. Therefore, many people in Ghana choose to build extra rooms in their houses in urban areas to rent out to more people, excluding the construction of a sanitation facility. In order to enforce these codes, the people would need to be fined (a form of punishment) for not complying.

Additionally, Jim Niquette suggested that the people with existing houses would have to be given a date when sanitation facilities would be required in their existing structures. This system seems harsh, however if an adequate sanitation market was generated and people were able to access it, enforcing such a sanitary code would seem to encourage people to take action, especially if the fine outweighs any of their capital costs.

Monitoring, Re-triggering, and Goals (Incentive)

Currently, monitoring is seen as important by the DA but seems to be inconsistently carried out throughout the villages visited. As previously mentioned, only 1% of the I-WASH budget was allocated towards monitoring, which resulted in limited monitoring through the duration of the project. Certain villages seemed to be targeted more heavily and others were simply left to themselves to improve their situation. However, all of the local government officials interviewed stated that monitoring is extremely important to ensure that the people are making significant progress. Having a monitoring plan in place also allows for re-triggering as necessary to continually be convincing the villagers of their need for improved sanitation. It is important that the people know they are being observed not only so they make sure they improve between visits, but so they know there is a continual partnership with the DA. Finally, there needs to be more incentives or goals for the people than simply improving their health and lifestyle.

Currently, the incentive for communities to become ODF is that they will receive a sign upon entering their village that displays "ODF Community," which was observed by the author in the Juo-Sogon Village. While this is a great incentive, there are more incentives that could be instituted such as national recognition through radio broadcasting or television. Most people in the villages seemed concerned with how outsiders viewed their villages, so additional recognition would seem to be an appropriate incentive. To encourage the communities, there could also be friendly rivalry created between neighboring villages as they compete to become ODF. While this idea must be executed with care as to not create violence or animosity between villages, it could create a new incentive for the villagers to act quickly.

Technology Comparison

Since cost and difficulty of construction were deemed important to the villagers, the author decided to conduct both a cost benefit analysis and a cost effectiveness analysis. In order to provide users a range of choices, the following nine technologies were researched by the author and included in the analysis:

- **Arborloo (Ecosan 1)**: A form of ecological sanitation (EcoSan) that consists of a concrete ring, concrete slab, and small pit (approximately 1 meter deep). The Arborloo is used for approximately one year depending on family size and when the pit is full, the concrete ring and slab are moved to a new location. The full pit can then be left to compost or a tree can be planted inside to utilize the fertile soil.

- **Simple pit latrine (un-lined):** The simple pit latrine (un-lined) consists of a concrete slab and beam, a relatively large pit (approximately 3m deep), and a superstructure (rammed earth block was chosen for this analysis).

- **Simple pit latrine (lined):** The simple pit latrine (lined) is the same as the simple pit latrine (un-lined) however the pit is lined with concrete and concrete blocks.

- **Urine-Diverting Dehydration Toilet (UDDT) (Ecosan 2):** The UDDT is a form of EcoSan that uses the design of a ventilated improved pit (VIP) latrine by providing a pit with a vent and necessary measures to reduce flies and odor, however the waste collection chamber is constructed aboveground so that a pit is not required. A urine-diverting toilet seat is used to allow urine to infiltrate into the soil so that the chamber contains less moisture and the waste will dehydrate quickly. Additionally, for this analysis, the UDDT was assumed to contain two chambers so that one chamber can compost while the other chamber is in use, creating fertilizer after the composting is complete.

- **Micro-Flush Bio-Fill (MFBF) Toilet:** The MFBF toilet consists of a handwashing basin that drains into a concrete toilet seat base for flushing. The waste is then deposited into a pit below that uses vermiculture to accelerate the decomposition and turn the waste into valuable fertilizer.

- **Small Small Global Latrine:** The global latrine was developed by an organization, Small Small, and consists of a prefabricated polyethylene VIP latrine that is placed over two manually-dug pits. The two pits (lined with polyethylene from the prefabricated structure) allow for composting in one pit while the other pit is in use. After composting is complete, the waste can be used as fertilizer.

- **Sanivation:** Sanivation is a service-based model where the users are provided a toilet with a small waste storage chamber below and pay a monthly fee to have the waste removed. The waste is then stored in a central facility and treated inside a solar concentrator to kill off pathogens and provide fertilizer as an end product.

- **Uniloo:** Uniloo is a service-based model where the users are provided a urine-diverting toilet with a small waste storage chamber below and pay a monthly fee to have the waste removed. The urine is diverted into a plastic container or a drain and a chemical is supplied to reduce the odor in the toilet. The waste that is collected is stored in a central facility and then pumped out by vacuum trucks.

- **Sanergy:** Sanergy is also a service-based model that sells a toilet structure consisting of a urine-diverting toilet seat, superstructure, and two plastic containers to store the urine and waste to a franchisee. The franchisee then charges the users to use the toilet. Sanergy team members collect the urine and waste from the toilets and create fertilizer through composting. Eventually, Sanergy plans to generate electricity through a biogas plant.

To thoroughly evaluate the previous technologies, a cost benefit analysis was performed assuming the technology was used by a family of 10 that produced an average of 60 liters per year per person of waste. Capital costs, annual costs of maintenance, and additional annual labor

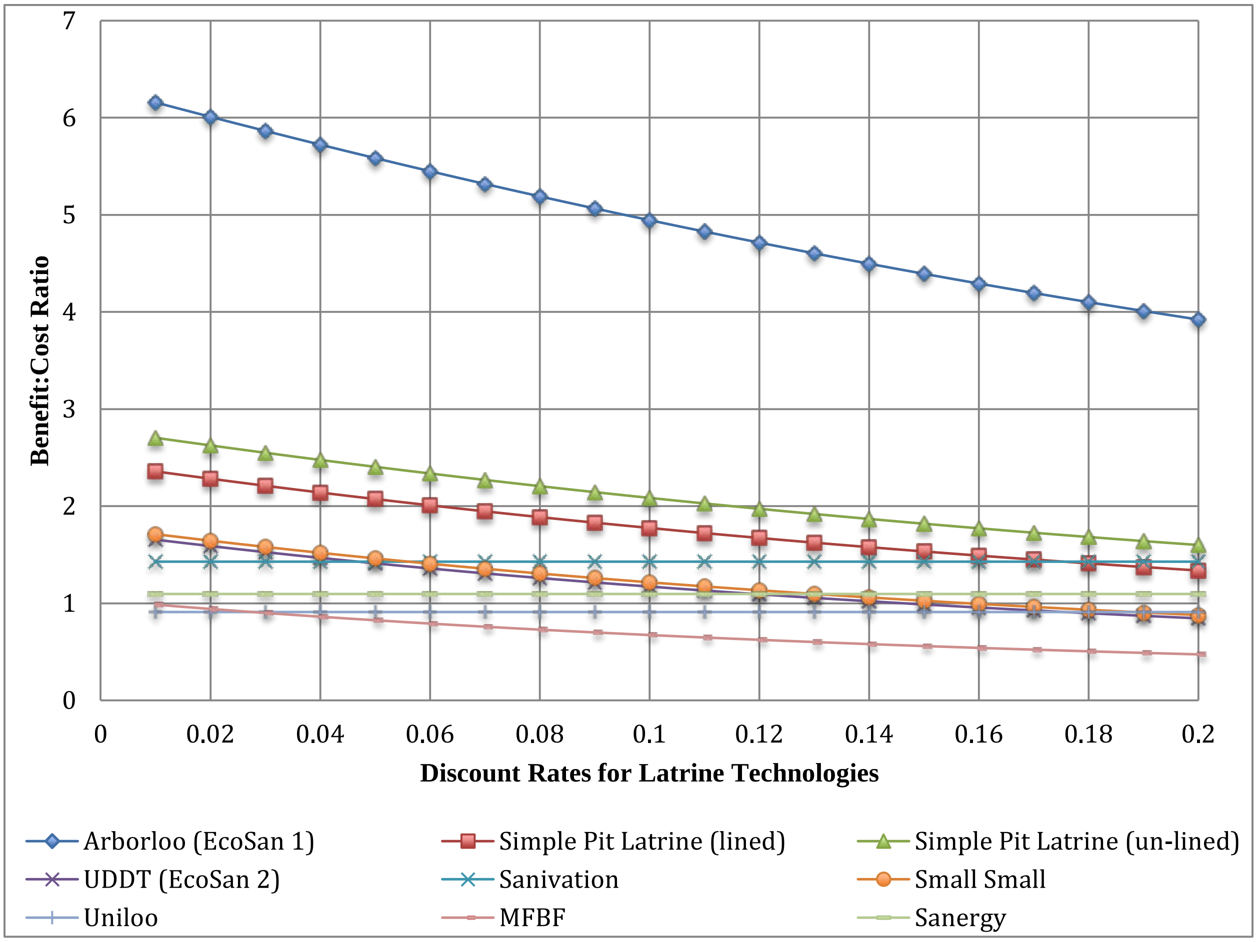

Figure 4: Benefit:Cost Ratio vs. Discount Rate for Latrine Technologies

costs were determined[11] and the Present Value of all costs was calculated for each technology over 10 years. The annual benefit was assumed to be equal for all technologies and represents the time gained from not traveling to open defecation areas, the reduction in premature deaths, the increased productivity resulting from reduced illness, and the reduction in health care expenditures. The World Bank's Water and Sanitation Program did a study to evaluate the monetary value of all such costs and determined that poor sanitation costs GHS 22 ($12) per person per year in Ghana, which is the figure used to determine the benefit (Water and Sanitation Program, 2012). These benefits were assumed for the entire family and calculated as a Present Value assuming a 10-year duration. Figure 3 shows the results of the cost:benefit analysis.

To further evaluate the technologies and account for the difficulty of construction, maintenance, and waste removal, a cost-effectiveness analysis was performed. To determine the difficulty of construction and waste removal, the author rated certain aspects of construction based on difficulty level and assigned a difficulty point value for each technology. The results account for

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[11] The costs associated with each technology were calculated based on conversations with organization representatives, latrine construction manuals, and 2011 pricing from Jonathan Lau's previous research in Ghana. More details can be found in the author's MIT CEE MEng thesis, which expands on the topics in this paper.

the difficulty in digging for the specified technology as well as the difficulty in removing the waste when full. Figure 4 shows the results (High Cost-effectiveness = Most advantageous) that were calculated using the following equation:

$$Cost - Effectiveness = \frac{(Maximum\ Difficulty\ Points - Technology\ Difficulty\ Points)}{PV\ (costs)(GHS)}$$

$$Maximum\ Difficulty\ Points = 12$$
$$The\ Ratio\ was\ multiplied\ by\ 1000\ to\ create\ a\ more\ manageable\ value$$

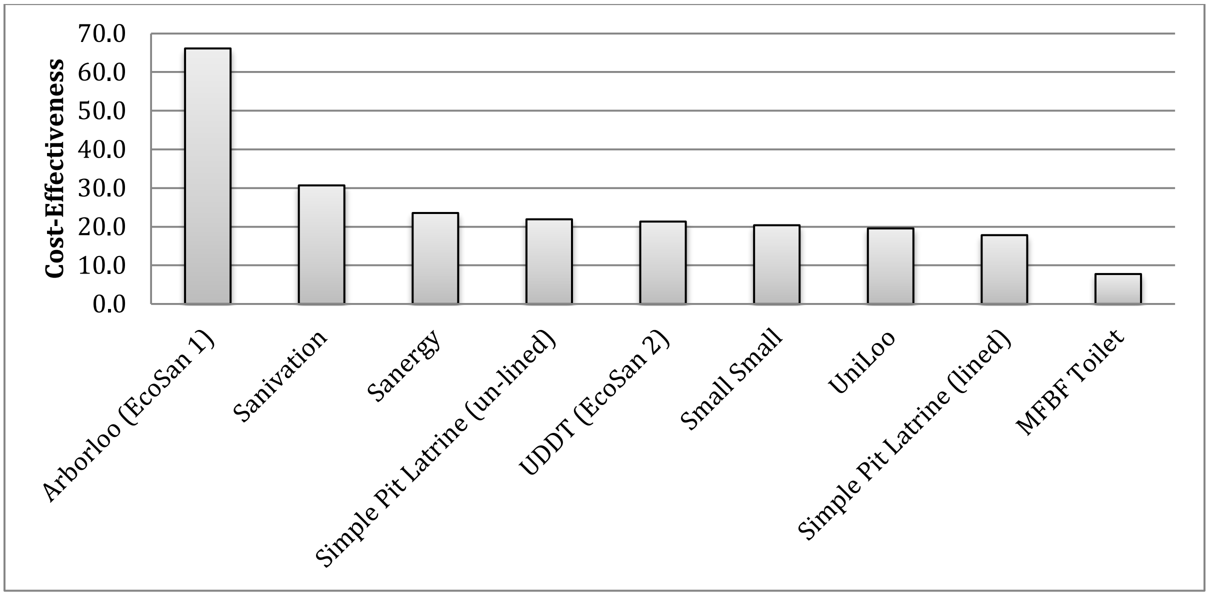

Figure 5: Cost-Effectiveness of Latrine Technologies

It is clear that the low capital cost of the Arborloo makes it advantageous in both analyses, however another important result is that Sanivation and Sanergy (two service based models) became more advantageous than other technologies in the cost-effectiveness analysis because there is no difficulty associated with their models and the monthly costs were relatively low[12].

Recommendations

Many of the current approaches towards improving sanitation fall short of their goals due to not involving the community, lack of hygiene education, promoting a single design, offering high subsidies that can not be sustained, and not reaching the poorest members (Water and Sanitation Program, 2007). Even though CLTS has been unsuccessful in Ghana, the author is still recommending using CLTS (which includes hygiene education) to involve the community as long as it is coupled with other interventions. The author is recommending that the Arborloo take the place of "dig and bury" on the sanitation ladder, however he is not promoting this technology as a single design and believes that the people need more exposure to the range of options available to them. Finally, the author is not recommending any significant subsidies

[12] The author believes that the Sanivation and Sanergy models could potentially be successful in Rural Ghana, however modifications would be necessary to ensure cultural and economical translation.

unless it will help reach the poorest members (such as subsidies for the technical support and distribution of Arborloos to encourage use and move up the sanitation ladder to a subsidy-free technology). The following sections expand on the specific recommendations for the Government of Ghana, Non-Governmental Organizations, and Pure Home Water.

Recommendations for the Government of Ghana

The current sanitation policy and strategy includes CLTS, but does not define a clear action plan that utilizes CLTS and other resources that may be provided by NGOs. It is of concern that CLTS alone was adopted as a national strategy by the GoG when it had not proved to have a high success rate in providing access to improved sanitation throughout Ghana. The author believes that sanitation in Ghana will improve drastically when the link between private initiatives (i.e. low-cost technologies or services and technical support) and CLTS is developed and sustained. Therefore, the GoG cannot simply rely on CLTS as the solution to their problems and should provide additional clauses in their sanitation policy to include:

- Coordination of key stakeholders,
- Enforcement of a sanitary code,
- More consistent monitoring.

The GoG needs to setup a network of NGOs working on sanitation in Ghana and coordinate their pursuits to prevent overlap and also to complement each other. When the DA begins to trigger a community with CLTS, they must then contact NGOs in the area to coordinate meetings with the community and offer them options after they have been triggered. Doing so will most likely increase the success of CLTS because the positive movement towards change can be harnessed into an existing technology or model and the energy and ownership of the people would hopefully transfer to the technology even if not developed solely by the people. This coordination between the GoG and NGOs will provide multiple avenues for funding to be allocated and also not violate the subsidy-free intervention requirement of CLTS, but provide alternatives. By providing alternatives, the NGOs will create a sanitation market for the people. Additionally, the GoG must enforce certain building codes and require sanitation facilities be constructed for existing and new houses.

To ensure that the people are using improved sanitation facilities, a requirement must be established and advertised that demands dry or water-based toilet facilities for each household. For this law to be successful, there must be repercussions in the form of a fee or punishment that will motivate the people to act. However, such a law's success is also determined by the existence of a sanitation market that provides alternatives to the people. This solution is ideal and the creation of the law is relatively simple, however the enforcement and monitoring will be extremely difficult, but necessary.

The GoG must ensure that enough funding is available to employ DA members in the monitoring of rural villages and enforcing the building code so the people realize this is a real threat. Additionally, having the DA present in the villages will allow them to determine if failure to succeed is related to motivation or actually having limited funds for sanitation facilities. In the latter case, the GoG would have to develop a system to subsidize or offer infrastructure for free to the poorest of the poor or else they will become increasingly burdened by the fine associated with the proposed law. The author believes that coordination between the GoG and NGOs, strict enforcement of a sanitation building code, and sufficient monitoring will provide motivation and resources for the people to construct improved sanitation facilities.

Recommendations for Non-Governmental Organizations

As previously discussed, the NGOs must be coordinating with the DA of their area to eliminate overlap and partner in providing improved sanitation coverage. It is the responsibility of the NGO to notify the DA of their plans and see if any combination of DA-initiated CLTS programs might be available to reinforce the NGO's existing initiative. If CLTS continues to be a national strategy, the NGOs must conduct an extensive willingness to pay/sanitation market survey before providing latrines at no cost to the villagers. Unless they are able to provide such facilities to an entire region or District, providing individual villages with free facilities will not provide incentive for neighboring villages to act on their situation. Additionally, as seen in the Yong Village that only began using donated latrines after CLTS was implemented, the distribution of free facilities may not result in increased use unless CLTS is coupled with this initiative. However, instead of instructing the villagers to practice "dig and bury", the NGO (if financially capable) might offer an Arborloo for free to all villagers so that adoption and use is sustained[13]. As time continues, and the villagers receive benefits of using the Arborloo, they will hopefully progress towards more permanent solutions that require financial contributions from the users.

Assuming the DA is actively triggering communities with CLTS, it will be advantageous for the NGOs to coordinate with the DA and attend various meetings with the villages being triggered. Towards the end of the triggering process, just as the entrepreneurs in Cambodia did with Jeff Chapin and IDEO's sanitation project, members of the NGO should present their options to the people and let them choose. The NGOs will then develop a sanitation market that will hopefully be sustained in the future due to demand for improvement up the sanitation ladder. If the NGO does not have a certain low-cost technology that they are focusing on or a financial subsidy they can provide, they should attend the CLTS-triggered village meetings and provide technical support by helping the people develop or choose a technology that is appropriate for their village.

The people realize their need for improved facilities but generally do not know how to construct the technologies or where to find assistance. When deciding what technologies or services to offer the village, the NGO must carefully consider the financial ability of the village as well as any cultural factors that may influence their decision. If a village is fed up with digging holes and refuses to do so, then a service model is more appropriate (such as Sanivation, Sanergy, or Uniloo) to offer them if they are financially capable of paying. However, if they are unable to afford such a service, then building from the Arborloo up to more traditional pit latrines or EcoSan models would be the appropriate approach. In conclusion, the NGO needs to partner with CLTS-triggered communities to offer them solutions that are applicable to their desires and culture.

[13] Assuming a village of 200 people, the distribution of free Arborloos would cost approximately GHS 3000 ($1700) or GHS 15 ($8) per person.

Recommendations for Pure Home Water

Currently, PHW is substantially involved in water and handwashing but not substantially involved in sanitation initiatives and may not be for a few years. However, these recommendations are advice in the event that PHW becomes more engaged in this field. The author believes that PHW has a variety of options in terms of improving sanitation coverage throughout Ghana. As a non-profit organization with limited human and financial resources, it is important that they partner with other organizations that focus on sanitation. The following recommendations have been developed for PHW and its potential partner organizations.

EcoSan Pod (EcoSan 3)

The author recommends that PHW research a low-cost sanitation technology that could be successful in rural Ghana. It is important that the design be low-cost and take account of the difficulty of digging in the Ghanaian soil. It will be necessary for PHW staff or future graduate students to conduct design and prototyping workshops with the villagers to assess what is important to them and determine the best design. However, the author is suggesting a potential candidate for the design: the EcoSan Pod (EcoSan 3).

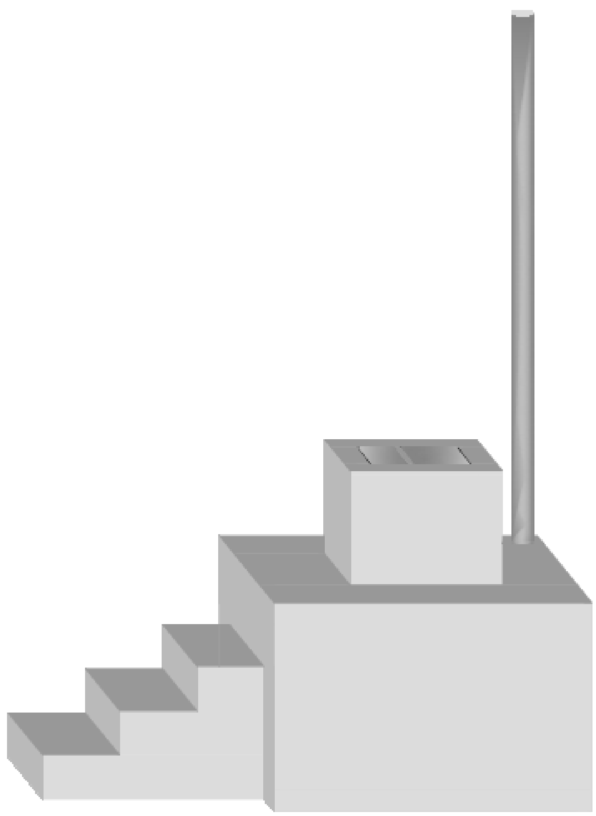

Figure 6: 3-D Model of EcoSan Pod (EcoSan 3)

The UDDT designed by Jonathan Lau (MIT CEE MEng 2011) is a great design for Ghana because it is aboveground (not requiring a pit and also advantageous in the event of a flood), it is urine diverting and dehydrating which means that the pit will not fill as quickly and will have little or no foul odor, and it offers fertilizer as an end-use of the waste. However, the dual-pit

UDDT (Ecosan 2) was very costly (GHS 943 ($520)). The EcoSan Pod (EcoSan 3) is a modified UDDT (Ecosan 2) that is 40% of the original volume and does not have a superstructure. Table 3 shows the estimated costs associated with the EcoSan Pod (EcoSan 3) that are based on the original design by Jonathan Lau (Lau, 2011).

Table 3: Estimated Costs of the EcoSan Pod (EcoSan 3)

		Quantity	Price (GHS)	Total Cost (GHS)	Total Cost (USD)
Foundation	Cement	0.6	15.00	9.00	6.43
	Aggregate	1.8	2.00	3.60	2.57
	Sand	1.2	1.00	1.20	0.86
Chamber Structure	Rammed Earth Blocks	30	0.50	15.00	10.71
	Cement	0.4	15.00	6.00	4.29
Seat	Rammed Earth Blocks	11.0	0.50	5.50	3.93
Floor Slab	cement	0.5	15.00	7.50	5.36
	1/2 inch rod	1.0	8.00	8.00	5.71
Chamber Door	2x6	1.0	12.00	12.00	8.57
	WaWa Board	1.0	18.00	18.00	12.86
	Hinge	2.00	2.00	4.00	2.86
Accessories	4" Pipe	1.00	9.00	9.00	6.43
Labor	Steel banner	0.50	10.00	5.00	3.57
	Carpenter	1.50	10.00	15.00	10.71
			Total	**118.80**	**65.27**

The costs of cement, aggregate, sand, and ½ inch rod were estimated by taking 40% of the original quantities, based on the 60% reduction in volume. The rammed earth blocks for the chamber were estimated based on approximate dimensions and the rammed earth blocks for the seat were ½ the value of the original design because there is only one seat vs. the original two-seat design. Finally, the plastic urine-diverting seat was removed from the estimate because it was very expensive. The author suggests that PHW partner with the MIT D-Lab team to build on previous research that focused on creating a urine-diverting toilet seat from a plastic bucket as well as from concrete (Andersen et al, 2011).

The pit's volume was designed to be approximately $0.65m^3$, which according to John Pickford, could sustain an average of 10 people for each year if not urine-separating (assuming solid production = 60 liters per person per day) (Pickford, 1995). If the user is only able to purchase a single EcoSan Pod (EcoSan 3) then after one year they would have PHW or a PHW-contracted service provider remove the waste for a small fee. However, as they progress they will be given the option to purchase an additional pod, allowing them to compost one pod for a year while the other pod is in use. Regardless, the fertilizer produced after adequate composting could be used on the user's fields, local farmers' fields, or could be collected by PHW and used on a communal garden developed on the factory site.

If PHW develops a communal garden on the factory site, they will not only be able to grow fruits, vegetables, and other plants but they will be able to model the use of fertilizer from human waste. They could hold community meetings to explain how to apply the fertilizer and show the benefits that it provides to the crops. Additionally, if PHW uses staff to manufacture the rammed earth blocks, they would generate revenue from each EcoSan Pod (EcoSan 3) sale as shown in Table 4.

Table 4: Estimated Revenue Generated from the EcoSan Pod (EcoSan 3)

	EcoSan Pod (no superstructure)	EcoSan Pod (with superstructure)
Revenue Per Latrine (GHS)	20.50	73.00
Revenue Per Latrine (USD)	11.26	40.11

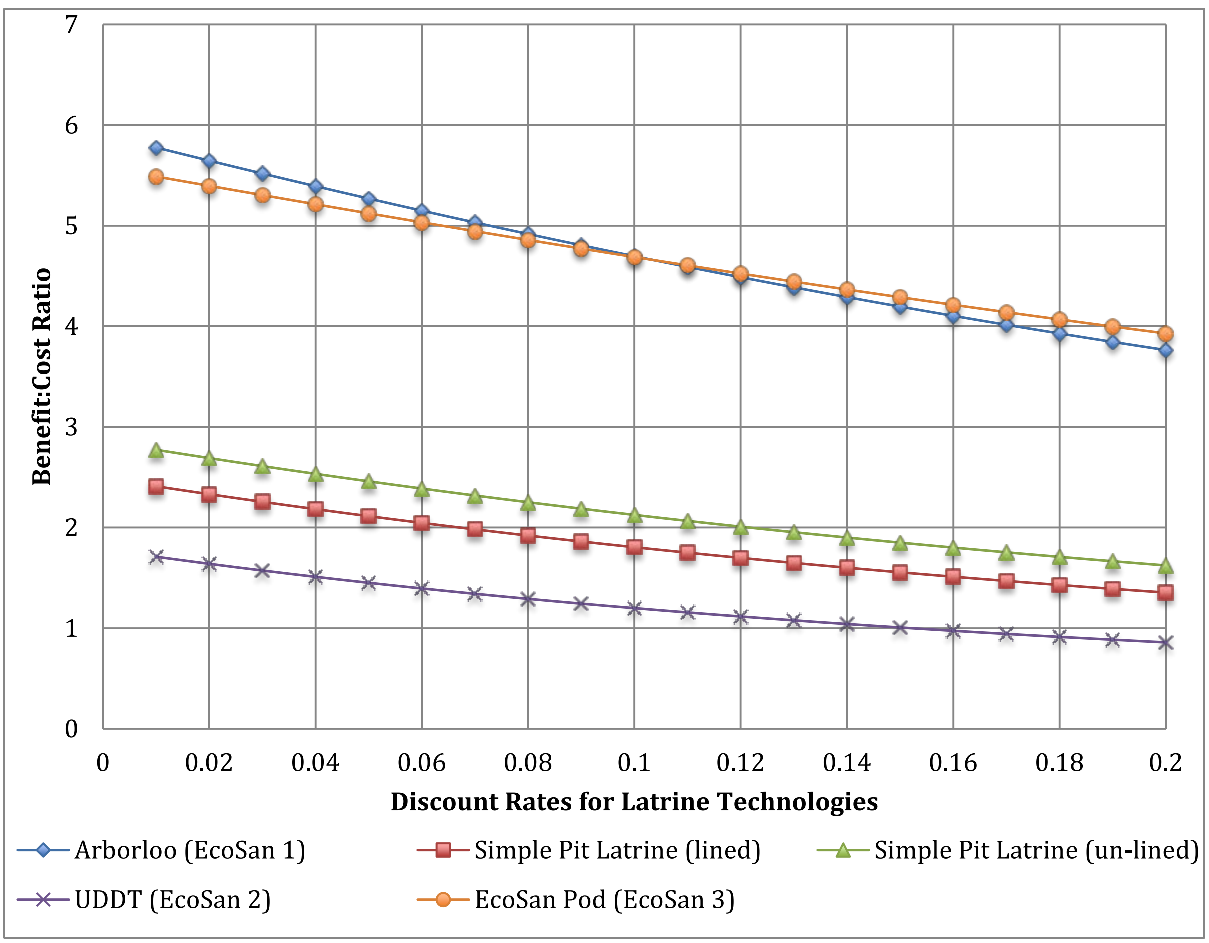

Figure 7: Benefit:Cost Ratio vs. Discount Rates including the EcoSan Pod (EcoSan 3)

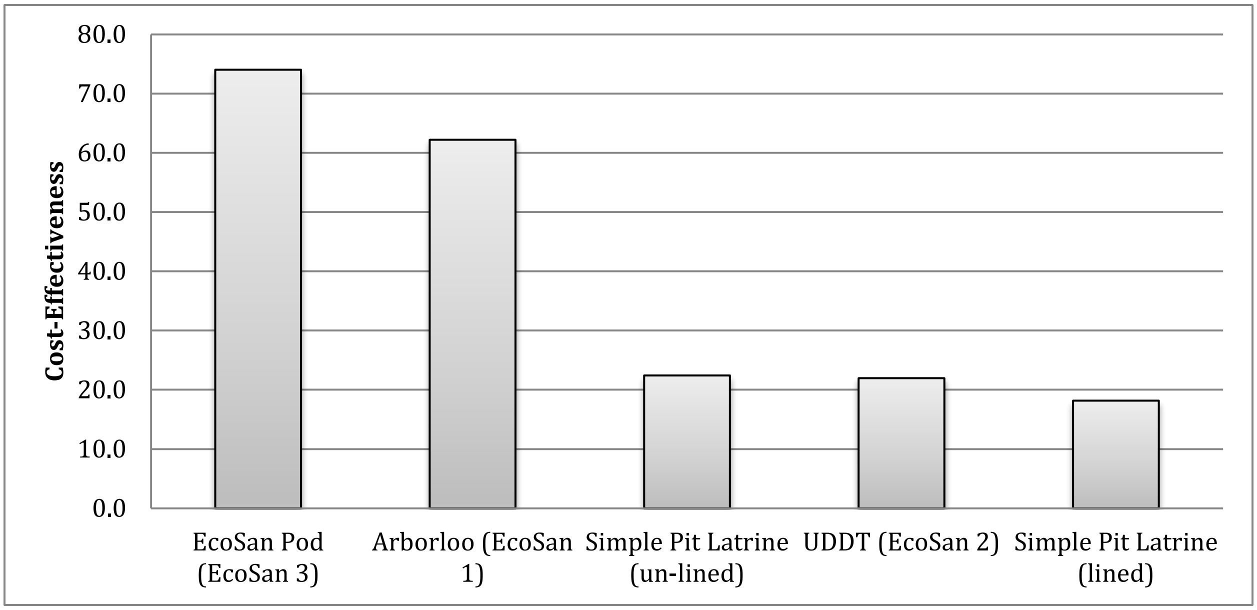

Figure 8: Cost-Effectiveness Analysis including the EcoSan Pod (EcoSan 3)

While this design is approximate, it has the potential to be very low cost, upgradeable, and when compared in a cost-benefit analysis (Figure 6) as well as a cost-effectiveness analysis (Figure 7) it proves to be advantageous.

PHW's role can also include establishing a relationship with the Tamale DA and with the village chiefs in the area (many of which have already been established). PHW should coordinate with the Tamale DA to learn what villages are being triggered or plan to be triggered with CLTS, and these villages can then be selected as target villages for their sanitation partnership. Additionally, PHW might be able to use existing staff or hire new staff to assist in the monitoring of villages to ensure they are progressing. What is important is that PHW's goal of financial sustainability must be maintained through sanitation initiatives, meaning that the technology or model selected must be treated as a business. Creating a sanitation business will not only provide jobs for local Ghanaians, but it will provide sustainability instead of a one-time donation. By observing Jeff Chapin's model from IDEO, PHW can adapt a similar approach towards training local entrepreneurs to create small businesses that sell a product or service to the CLTS-triggered villages. The EcoSan Pod (EcoSan 3) could potentially be an appropriate solution to offer the CLTS-triggered communities.

"Latrine for Schools" Program

Another option for PHW is to establish a "latrines for schools" program. Since creating latrines for schools does not go against CLTS principles, the villages chosen for these projects may be those that PHW has a relationship with or knows is in serious need of sanitation facilities for their school. Again partnering with another organization
or a future MIT graduate student or team, the latrine should be designed so it can be built by the community and be relatively low-cost. PHW can focus on training the people of the village as well as the school children how to construct the latrine and teach them how they could easily

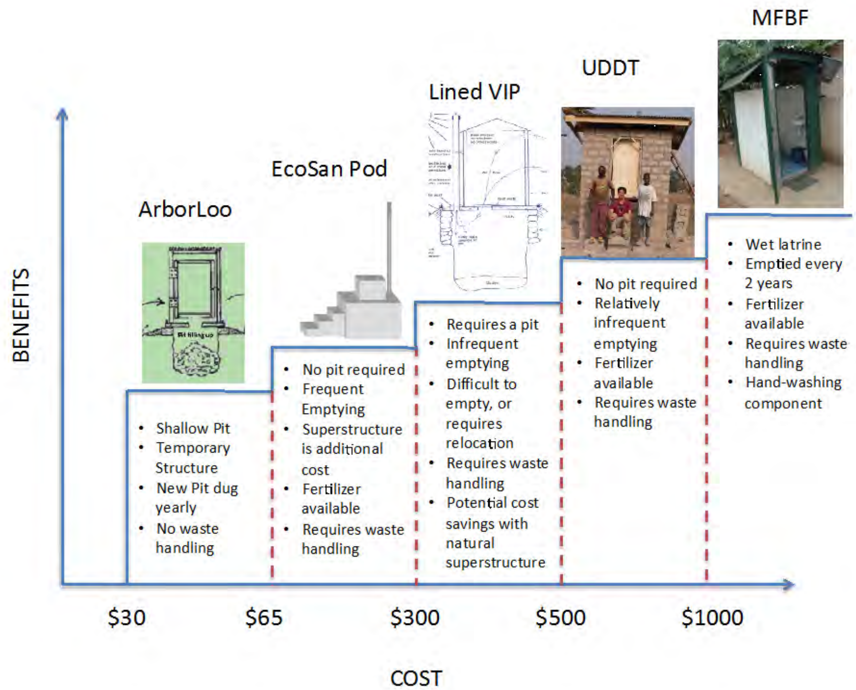

Figure 9: Latrine Technologies to be Modeled at the PHW Sanitation "Store"

construct a similar latrine for their personal household. The school children that are trained in latrine construction could then become latrine technicians and service providers and continue building and maintaining latrines throughout the community. The latrine for schools program would be a way to motivate the community and also provide examples of technologies that are available. To add to this program, PHW could also hold meetings in local mosques and churches to explain the benefits of the various sanitation technologies that exist. These meetings would also allow PHW to work with Muslims in developing a solution that is appropriate to their beliefs.

<u>Sanitation Store</u>

The final recommendation for PHW is to create a sanitation store. This sanitation store will provide a variety of latrine technologies (Figure 8) that are on display for local villagers to observe. The villagers can shop the different models and evaluate their prices and pros/cons to determine if one of them is suitable for their lifestyle. Additionally, PHW staff could also bring a model version of the "store" to CLTS-triggered villages to provide them with small-scale models of the various latrine technologies available. PHW can then provide the materials for construction, provide technical support during construction, or direct the customer to a partner NGO that is capable of providing the chosen technology. Through this process, the people will be educated about their options and this information will hopefully spread over time; creating necessary demand and excitement.

Final Remarks

As of 2010, Ghana had achieved 14% national improved sanitation coverage and is not projected to meet the MDG sanitation target by 2015 (WHO, UNICEF, 2012). There needs to be a serious restructuring of sanitation initiatives to meet this goal in the near future. The I-WASH program's attempt to improve rural sanitation coverage throughout nine districts in Northern Ghana was an ultimate failure, only constructing 3,100 latrines out of the planned 48,000 and only achieving 9% ODF communities. Community-based solutions such as CLTS cannot be solely relied on in Ghana to result in ODF communities let alone increase sanitation facility coverage. There needs to be a link between the motivating CLTS principles and the available technologies that exist and can be utilized when the villagers choose to do so. Currently, most villagers are expected to make their own plan and instructed to "dig and bury" so that the DA will not find feces around the fields and can construct an "Open Defecation Free" sign.

An alternative to this approach is advising the use of the Arborloo as a transition from OD to more permanent improved sanitation facilities. The Arborloo safely stores the waste, does not require waste handling, and is capable of providing fertilizer for fruit trees as an added incentive. Ashraf et al. showed that providing products for free can stimulate increased demand and use, therefore these Arborloos should be distributed for free to stimulate demand among the people (Ashraf, Berry, & Shapiro, 2007). Local NGOs can contribute to this distribution, or they can begin to offer more permanent solutions such as materials for simple pit latrines or the EcoSan Pod (EcoSan 3) or service models such as Sanivation, Sanergy, or Uniloo. This progression could potentially be a more promising route up the sanitation ladder for most villagers throughout the rural areas of Ghana.

If the Government creates defined roles for the DA and NGOs in the pursuit to increase rural sanitation coverage throughout Ghana, increased harmonization will result. This harmonization will reduce overlap of target villages and also create partnerships between CLTS-triggered villages by the DA and sanitation market stimulation by the NGOs. Additionally, the Government, by creating and enforcing regulations that require sanitation facilities by a certain date, will force the people with money to actually spend it on sanitation facilities or services. However, this enforcement requires that sufficient funds be allocated for monitoring so that each village is consistently reminded that they can improve their health and environment if they continue up the sanitation ladder.

Sanitation is an extremely difficult problem to tackle and the aforementioned strategies will not entirely solve the lack of coverage throughout Ghana, however their adoption has the potential to drastically improve the sanitation situation overall.

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