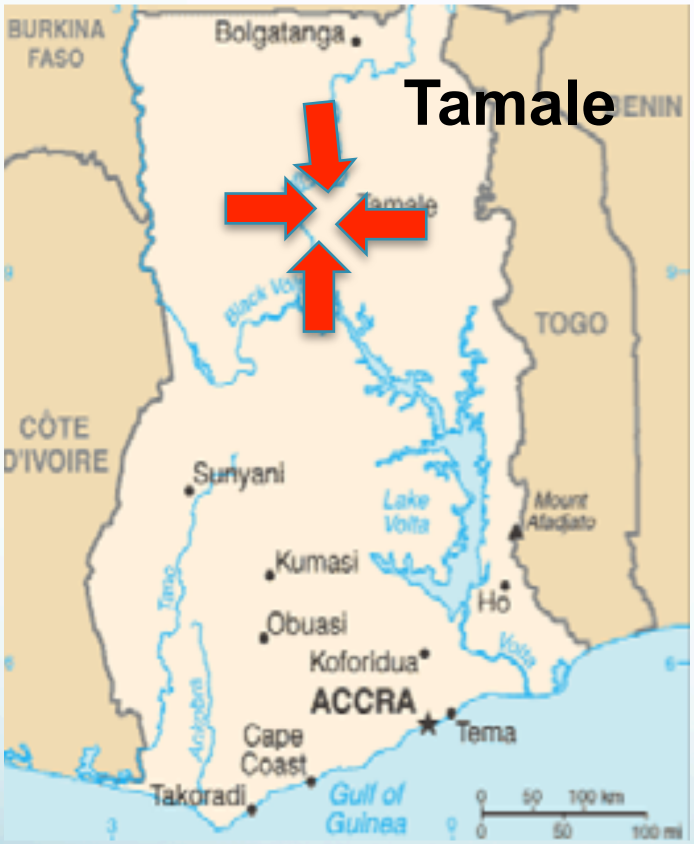
Team Ghana

Presented by Jonathan Lau, Shanti Kleiman, Joanna Cummings, Joshua Hester and Sam O'Keefe

Ghana


Tamale
BURKINA FASO
Bolgatanga
TOGO
CÔTE D'IVOIRE
Sunyani
Lake Volta
Mount Afadjato
Kumasi
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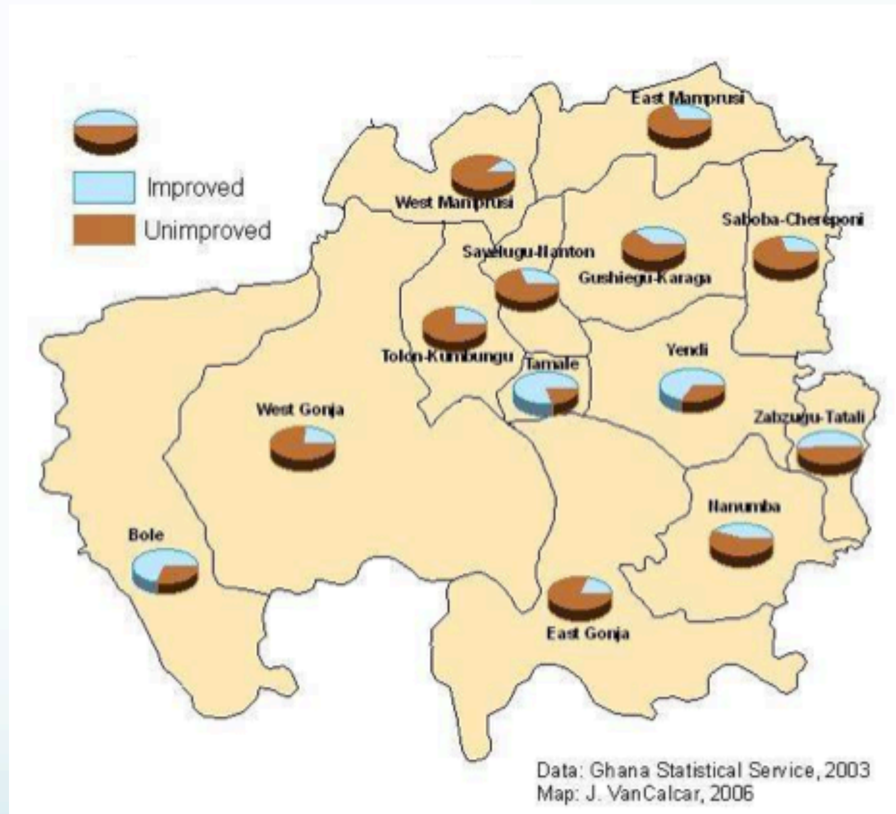
Ho
Koforidua
ACCRA
Cape Coast
Tema
Takoradi
Gulf of Guinea
0 50 100 km
0 50 100 mi


Improved
Unimproved
East Mamprusi
West Mamprusi
Saboba-Chereponi
Savelugu-Nanton
Gushiegu-Karaga
Tolon-Kumbungu
Tamale
Yendi
West Gonja
Zabzugu-Tatali
Nanumba
Bole
East Gonja
Data: Ghana Statistical Service, 2003
Map: J. VanCalcar, 2006

Pure Home Water

-A social enterprise founded in 2005

-Based in Tamale, Northern Ghana

-Focused on providing safe drinking water via household water treatment and safe storage (HWTS)

- Goal is to become locally and financially self-sustaining.

Establishing H2S Producing Bacteria as a Fecal Coliform Indicator

Presented by Samantha O'Keefe
Advisor: Susan Murcott, CEE
April 22, 2011

1) To confirm the accuracy of the 20ml H2S tests as an indicator for fecal coliform for both improved and unimproved water sources.

2) To confirm the accuracy of Easygel as a single enumerative test for fecal coliforms for improved sources.

3) To compare the effectiveness of the 20 ml H2S test used in conjunction with the Easygel enumerative methods with the standard method and provide recommendations for use.

4) Evaluation of indicator organism approval process using H2S test as a case study.

Research Objectives

Current Microbial Testing Methods

Quanti-Tray®

Photo credit: www.idexx.com

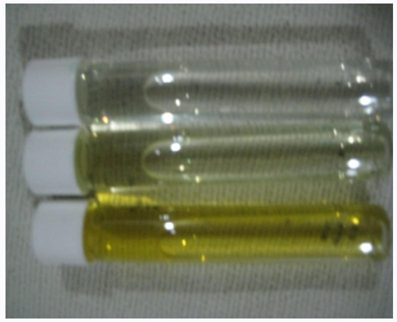
- Expensive. (Several thousand dollars)
- Subsequent test costing an additional $26
- Electricity for incubation

Membrane Filtration

- Expensive price ($1,063 dollars for a single unit)
- Very heavy
- Electricity for incubation
- Re-sterilization

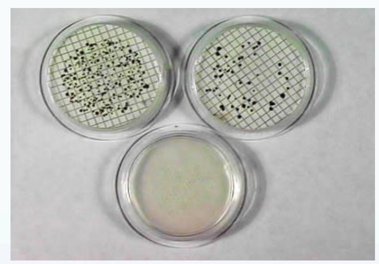
Current water testing supplies are:
1) Too complicated
2) Expensive
3) Require electricity and other resources not available in many remote areas.

10 ml Colilert Presence/ Absence Test



10 ml H2S Presence/Absence Test

1 ml Petrifilm EnumerativeTest



5 ml Easygel Enumerative Test

Water Testing Methods

Field Sampling

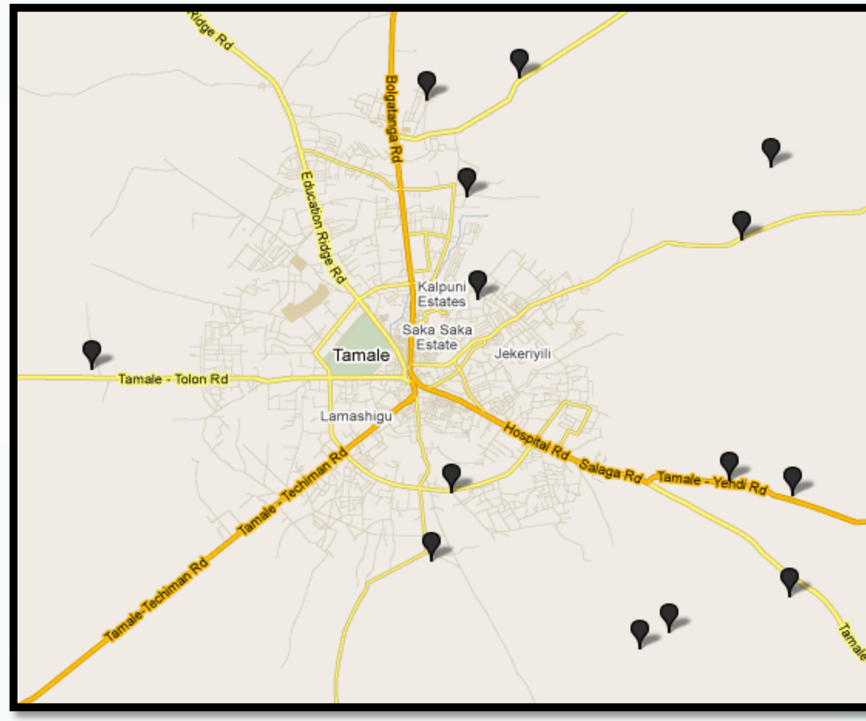
-114 Unique Water Samples

15 Villages Sampled

Field Surveying

-84 Households

Topics: Water Collection, Treatment Practices, Storage, Disease Prevalence and Hygiene



Field Work

- Contingency Tables

		Standard Method		Total
		Presence	Absence	
New Method	Presence	a	b	a+b
	Absence	c	d	c+d
Total		a+ c	b+d	**n**

- Fisher's Exact Probability

$$\Pr(a,b,c,d) = \frac{(a+b)!\,(c+d)!\,(a+c)!\,(b+d)!}{n!a!b!c!d!}$$

- Standard Methods

True Result: $(a+d)/n$

False Positive: b/n

False Negative: c/n

Sensitivity: $a/(a+c)$

Specificity: $b/b+d)$

PPV= $a/(a+b)$

NPV= $d/(c+d)$

Error= $(b+c)/n$

Data Analysis

		Quanti-Tray(*E.coli*)		Total
		Presence	Absence	
20 ml H2S Test	Presence	85	0	85
	Absence	11	15	26
Total		96	15	**111**

Fisher's Exact Probability: 0.0001

Extremely Statistically Significant

TR	90%	**Sensitivity**	88%	**PPV**	100%
FP	0%	**Specificity**	100%	**NPV**	57%
FN	10%	**Error**	10%		

H2S Test Initial Results

Easygel Initial Results

		Quanti-Tray(*E.coli*)		Total
		Presence	Absence	
Easygel Test	Presence	39	1	40
	Absence	4	5	9
Total		43	6	**49**

Fisher's Exact Probability: 0.0004

Extremely Statistically Significant

TR	90%	**Sensitivity**	91%	**PPV**	98%
FP	2%	**Specificity**	83%	**NPV**	56%
FN	8%	**Error**	10%		

H2S/Easygel Initial Results

Based on the WHO risk levels for E. Coli

Risk Level	**Quanti-Tray *E. coli* Result**	**H2S Result**	**Easygel (E.Coli) (Adapted for a 5ml Sample)**
Conformity	<1	Yellow	0
Low	1-10	Yellow	0
Intermediate	10-100	Black	0-4
High	100-1000	Black	5-50
Very High	>1000	Black	>50

H2S/Easygel Initial Results

		Quanti-Tray			
		Conformity/ Low	Intermediate	High/Very High	Total
H2S +Easygel	Conformity/ Low	8	1	0	9
	Intermediate	0	7	4	11
	High/Very High	0	2	27	29
Total		8	10	31	49

TR	86%	**Sensitivity**	Conformity/Low	100%	**PPV**	89%	n=8
TR(Conservative)	90%		Intermediate	70%		66%	n=10
Error	10%		High/Very High	87%		93%	n=31

Initial Recommendations

- H2S is a viable indicator test for fecal coliforms
- Easygel is a viable enumerative test for fecal coliforms
- However, the H2S and Easygel together does not appear to be better than the individual tests

Future Work

  - Comparison of Colilert and Petrifilm with Q-Tray
  - Comparison of EC-Kit with H2S/Easygel, Q-Tray
  - Trends with water origin, turbidity, pH etc. investigated

- Survey Data
  - Probing for trends in water treatment habits and quality, understanding of basic public health principles, latrine prevalence and use habits
  - Use results to assist Ghana based non-profits and Northern Regional Government in shaping water policy

Conclusion

Designing Sanitation Projects in Rural Ghana

Jonathan Lau
04/22/11
Advisor: Susan Murcott

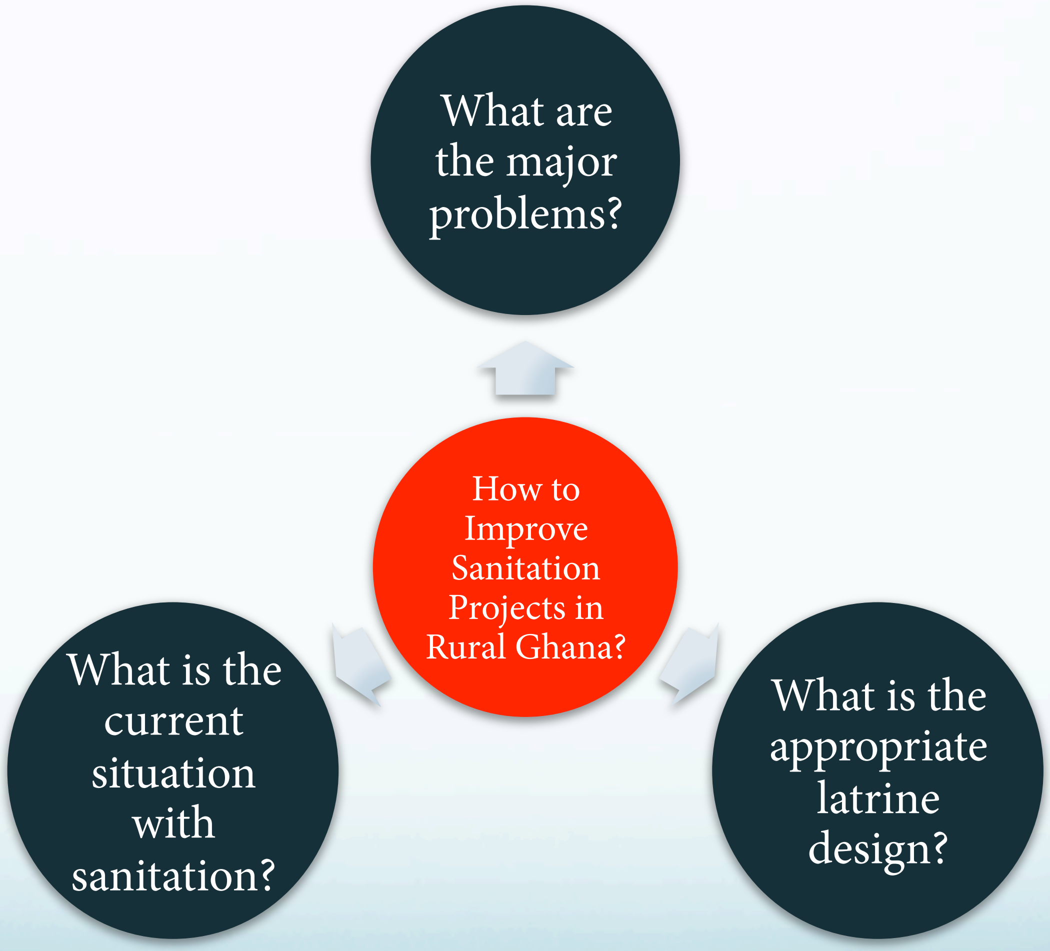
"Go to the people. Live with them. Learn from them. Love them. Start with what they know. Build with what they have. But with the best leaders, when the work is done, the task accomplished, the people will say: We have done this ourselves."

-Lao Tzu

(Chinese Philosopher, founder of Taoism,

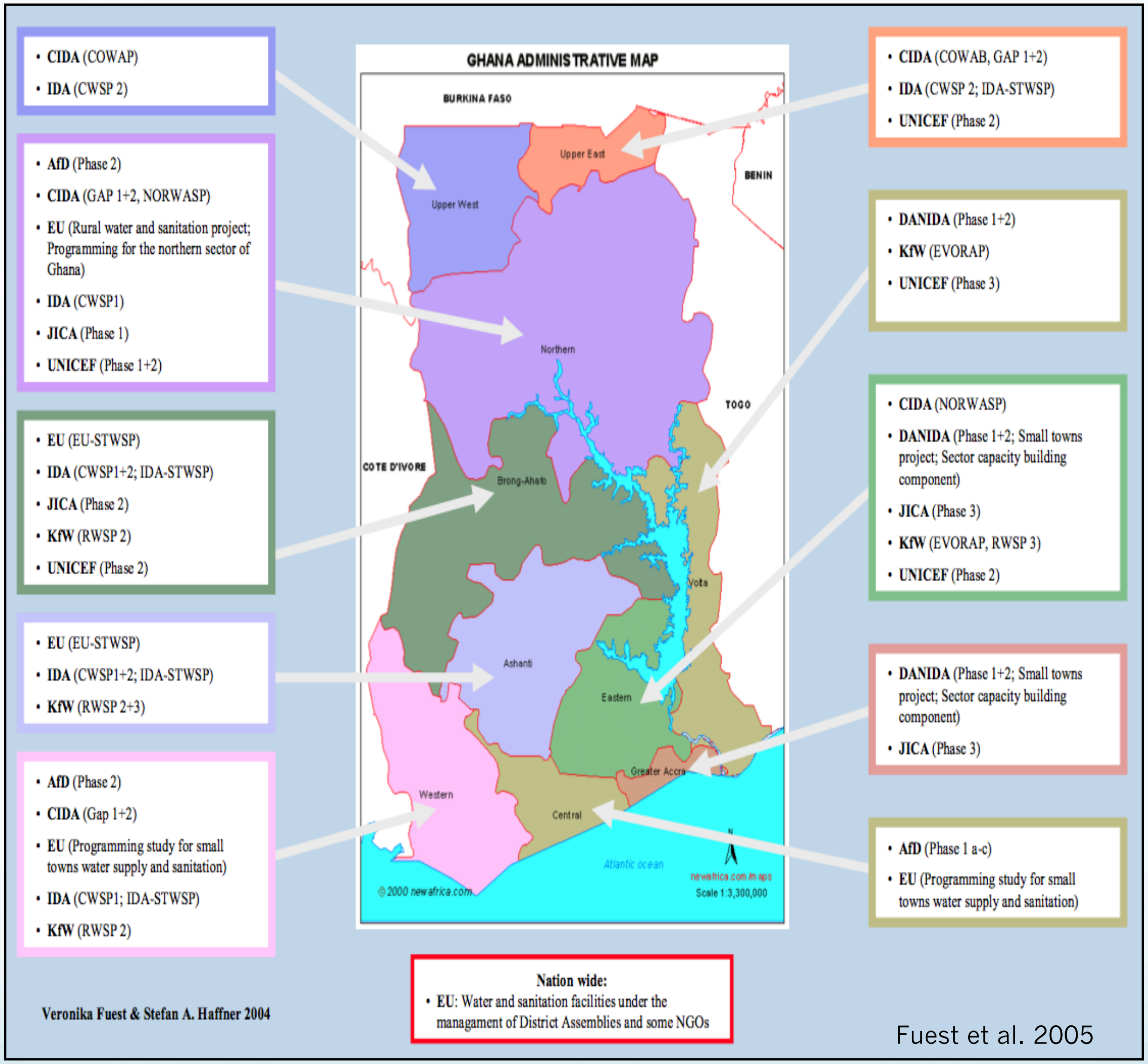
600 BC-531 BC)

Research Objectives



Ghana Sanitation Statistics

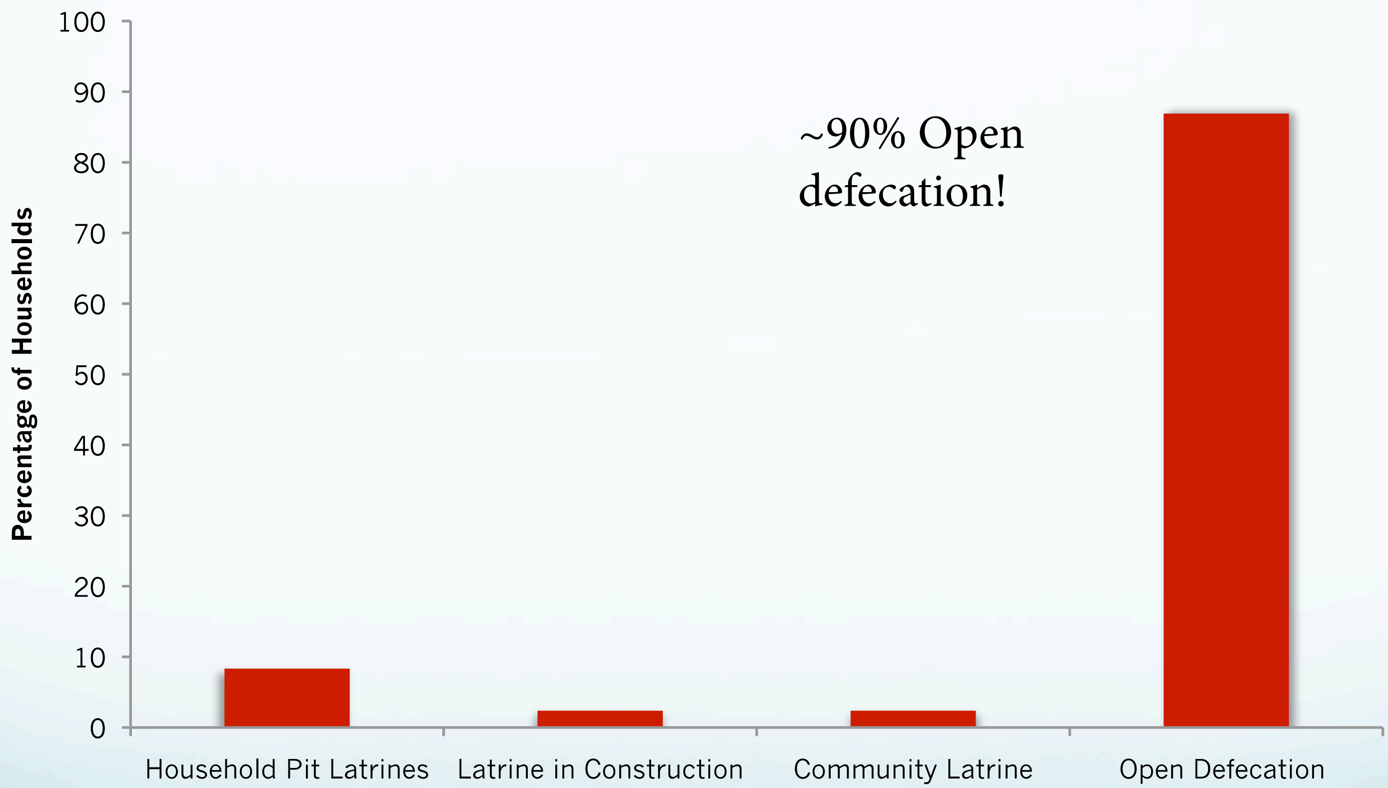
- **48%** of the population live in rural areas
- Less than **7%** of the rural population have access to improved sanitation
- The Ghanaian government spends less than **0.1%** of their annual budget on rural sanitation



Fuest et al. 2005

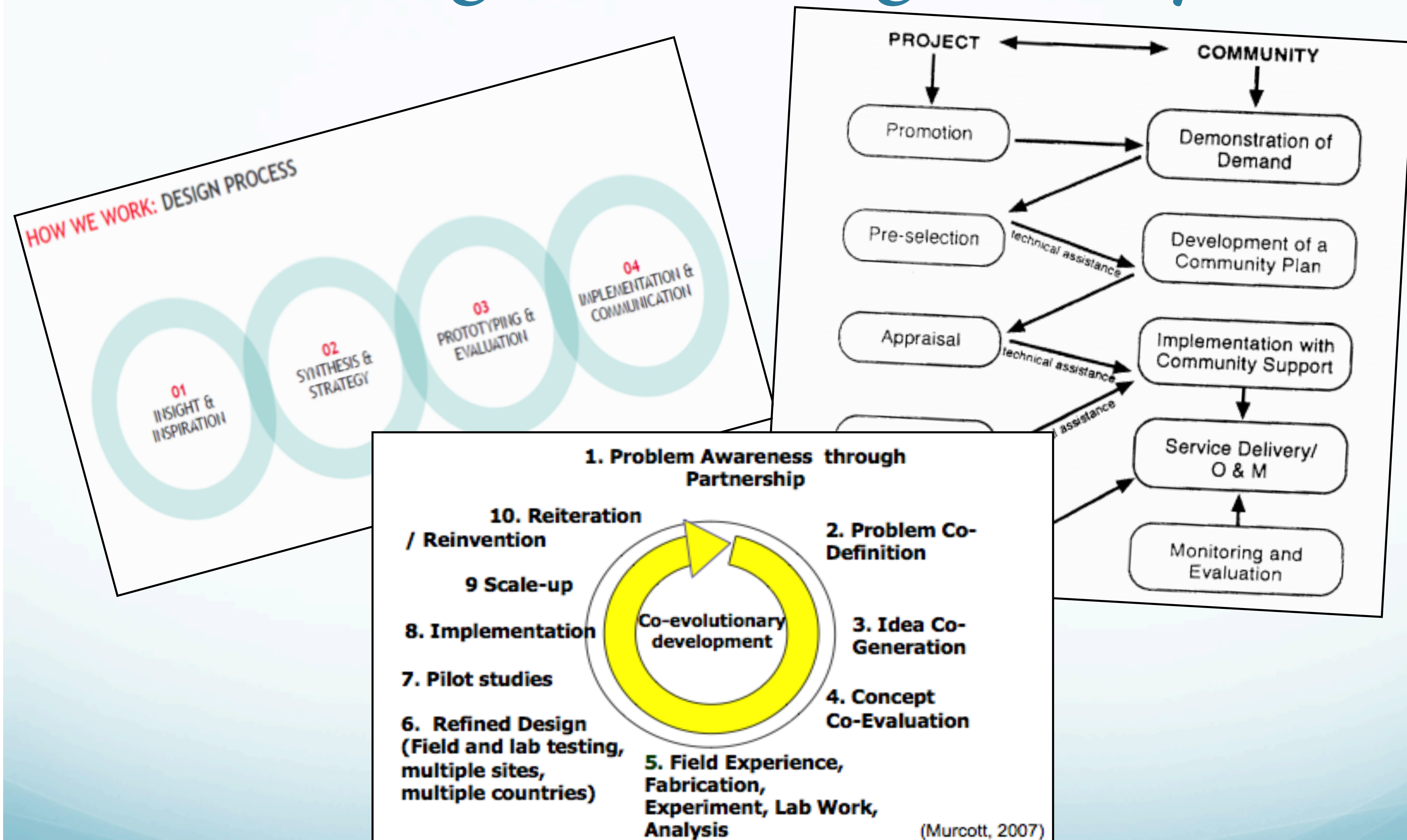
Many international organizations working in sanitation!

Informal Survey



Local Partner: REVSODEP

Design/Planning Theory



The Plan

Fall
- Research + Preliminary Design + Establish Local Partnership

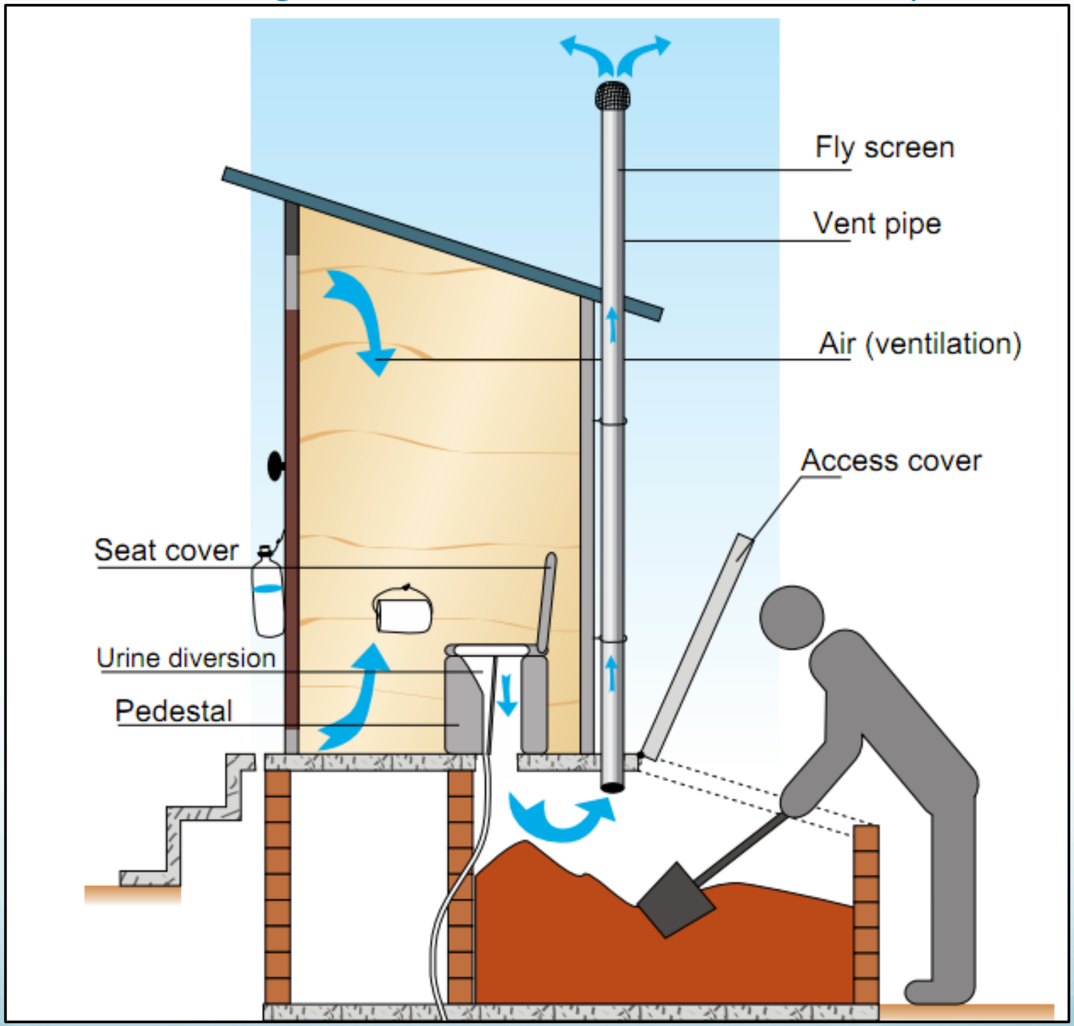
IAP
- Field Experience: Conduct Surveys and Pilot Projects

Spring
- Project evaluation
- Refine Design

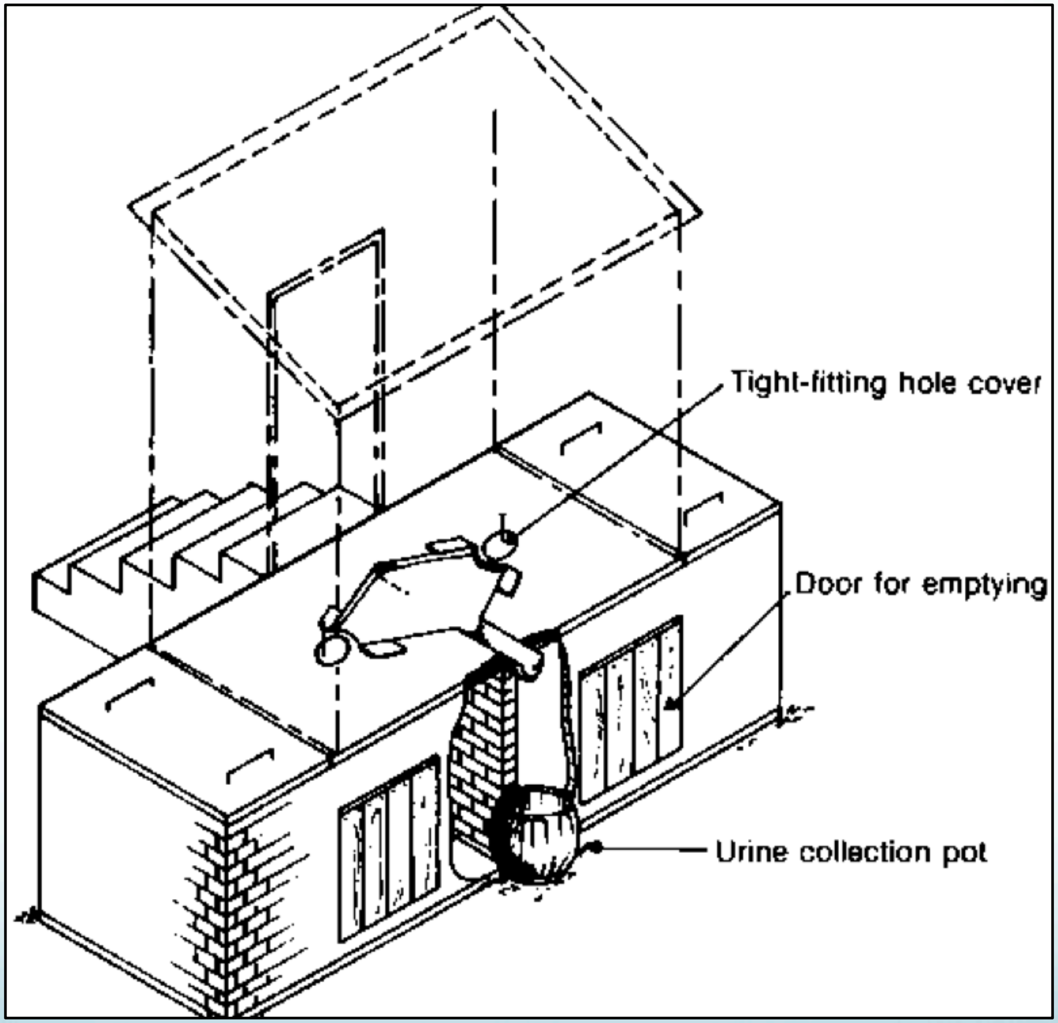
Summer+
- Additional Pilots
- Scale Up

PHW EcoSan Latrine

(A Urine-Diverting, Double-Chamber, Dehydration Latrine)



PHW EcoSan Latrine



"An ounce of action is worth more than a ton of theory"

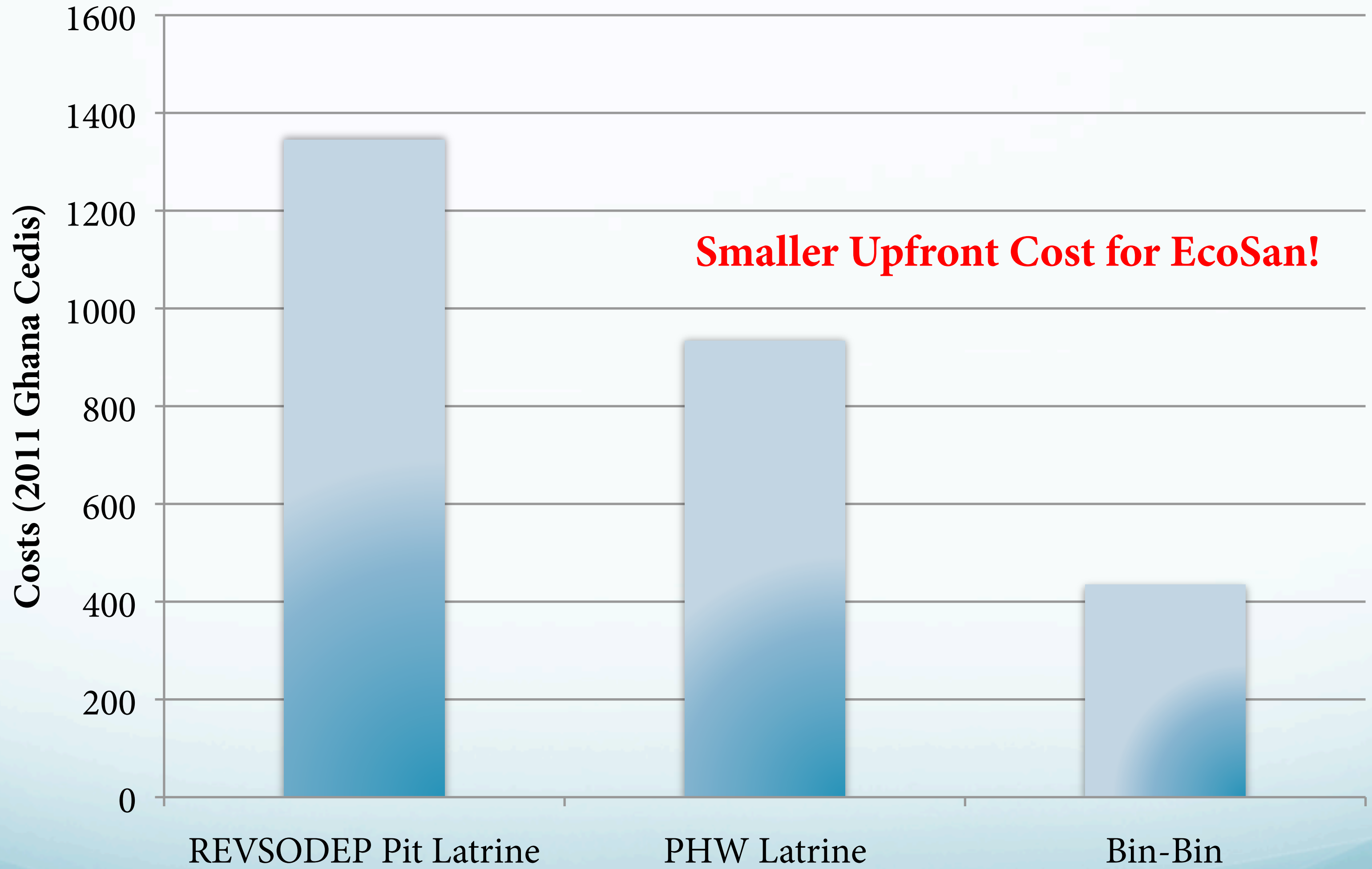
-Friedrich Engels

PHW EcoSan Latrine

MIT D-Lab Bin-Bin Latrine
New Longoro, Ghana

1. Background 2. Design Process **3. Field Experience** 4. Evaluation 5. Conclusion

Cost Comparison



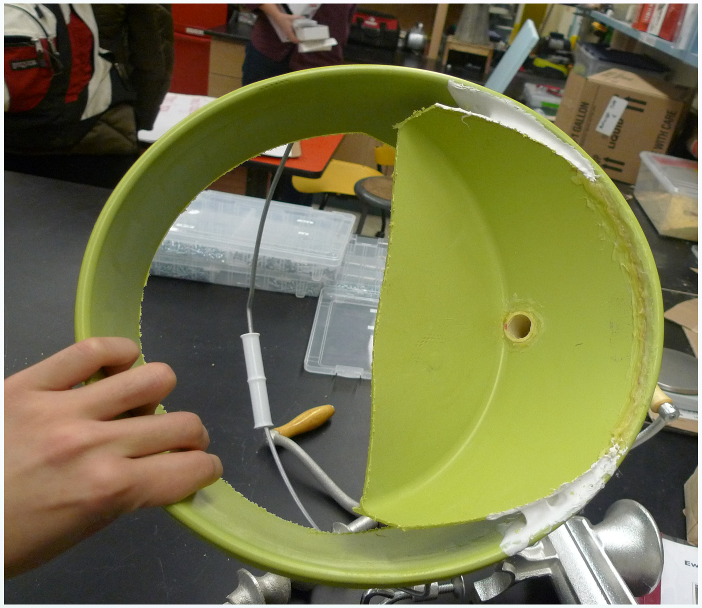
Assessment Matrix

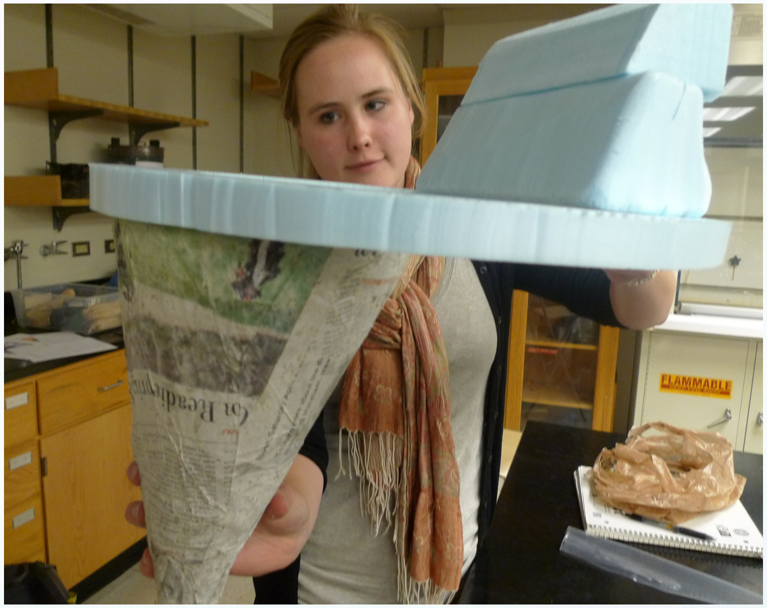
	Typical Single-pit VIP Latrine	PHW Design	Bin-Bin Design
Longevity and Durability	***	***	**
Materials Availability	**	*	*
Comfort and Privacy	**	***	***
Simple O&M	*	*	*
User/Social Acceptance	**	*	*
Scalability	*	*	*
Cost-effectiveness	*	**	***
Ease of construction	*	**	***
Total Score	**13/24**	**14/24**	**15/24**

Recommendations

1. Communicate with locals and development workers in the area
2. Investigate Low-Cost Building Materials
3. Pilot and scale-up INNOVATIVE designs
4. Education, Hygiene and Handwashing

The Future…





Thank you!

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-Lao Tzu
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Ceramic Filter Manufacturing in Northern Ghana: Water Storage and Quality Control

Shanti Kleiman

Outline

- Key Deliverables
- Rainwater tank
  - Lessons Learned
  - Cost comparison
  - Recommendations
- Quality Control
  - Results
  - Further Research and Next Steps

Key Deliverables

- Constructed 30m^3 rainwater harvesting tank
- Built 81 filter capacity saturation tank
- Calibrated T-devices, portable flow test rack, flow test station
- Trained employees in key quality control procedures

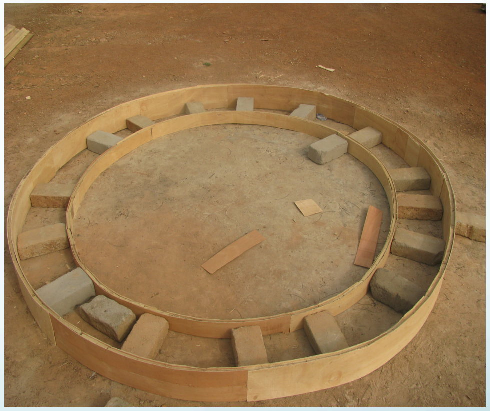
Rainwater Tank

- Capacity=30m^3
- Cost =\$4184 (\$155/m^3)
- 50% LESS capacity than originally intended!

How did that happen?

The Shrinking Tank – A Cautionary Tale

- *The 1st reduction*: 33% reduced capacity– from 60,258L to 43,568L.
  - Change in tank shape after excavation
  - Difficulty of digging through laterite and short time frame
  - Changed dimensions from 15x20x8ft rectangular tank to a 7'6" radius x 10ft cylindrical tank
- *The 2nd reduction:* Further 14% reduced capacity, to 37,565L.
  - 6" footing for tank stability - radius reduced to 7'
- *The 3rd reduction:* Further 28% reduced capacity to 26,897L.
  - Decision to turn blocks on long edge, reducing inner radius to 5' 6"



Tank Cost Comparison

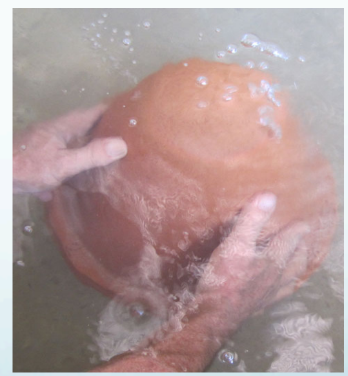
Type of Storage	Storage Capacity of System [m^3]	Cost of System [USD]	Cost per cubic meter [USD/m^3]	Notes
Plastic (5 Units-World Vision)	50	8333	167	
Concrete Block (PHW)	30	4184	155	Without Labor \$98/m^3
Ferro-cement (Presbyterian Church)	10	708	71	Does not include labor costs
Concrete Block (World Vision)	75	3500	47	**Subsidized** Amount unknown
Ferro-cement (Ludwig Estimate)	38	1641	43	Estimate – not Ghana specific

Recommendations

- Find out from World Vision by how much their $75m^3$ tanks are subsidized
- If cost without subsidy is $<\$70/m^3$ find out who their contractor it and visit tanks to assess life and quality
- Contact the Presbyterian Church to find out if they build tanks bigger than $10m^3$. If they don't, consider three $10m^3$ tanks which is still 27% cheaper per cubic meter than the current rainwater tank

Quality Control Hardware

Quality Control Training

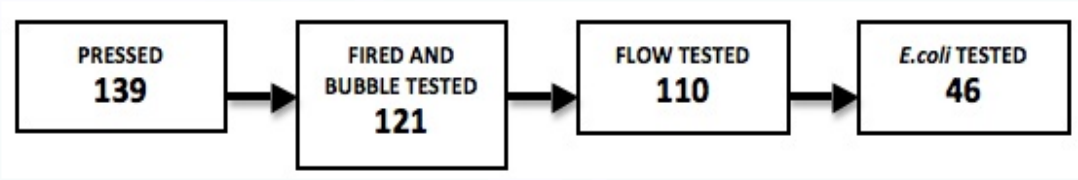


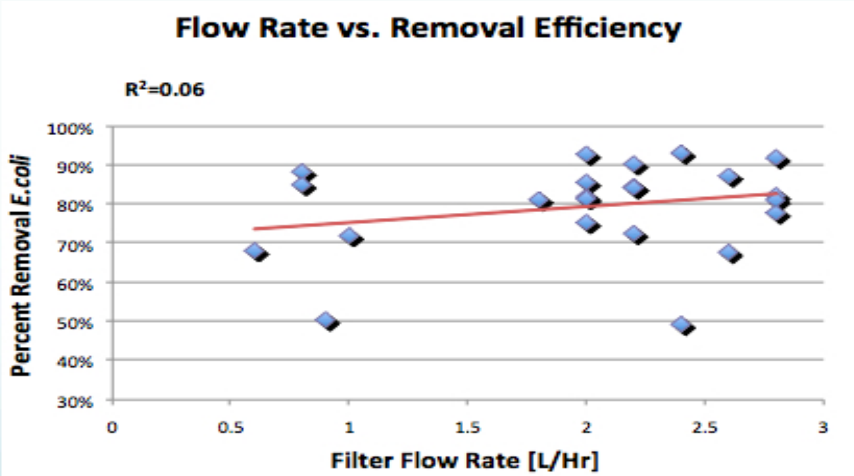
Top Priority for PHW Factory

- Establish **filter composition recipe** based on acceptable bacterial removal percentages, strength, and minimum flow rate.

Important Research Question for Developing QC Protocol

- How strong is the correlation between flow rate and removal efficiency?
  - Without silver
  - With silver applied





Impact of Relationship Between Flow Rate and Removal

- Establish the *maximum* flow rate allowable for the PHW filter based on acceptable removal efficiencies

- Develop protocol for frequency of bacterial testing
  - Regardless of the relationship to bacterial removal flow testing is still an important parameter to test every filter for because it tests manufacturing consistency and minimum acceptable flow rates. However if it is *not* a proxy for bacterial removal, removal tests will need to be performed more frequently

Additional Needs

- Soak tank connected to rainwater tank
- Free up factory floor space by setting up a testing area away from production floor
- Procuring less expensive bacterial testing media
- Purchasing time saving hardware (dry mixer, clay grinder, framed screens)
- Train more Kiln and QC staff
- Define roles and production schedule

Linking Clay Parameters to Filter Performance

Josh Hester

Key Questions

Two clay sites: Gbalahi and Wayamba

1. Is there a significant difference:
    - in the clay?
    - in the filter performance?
2. Are there significant relationships between the measured parameters?
3. What is the best clay to use?

Overview

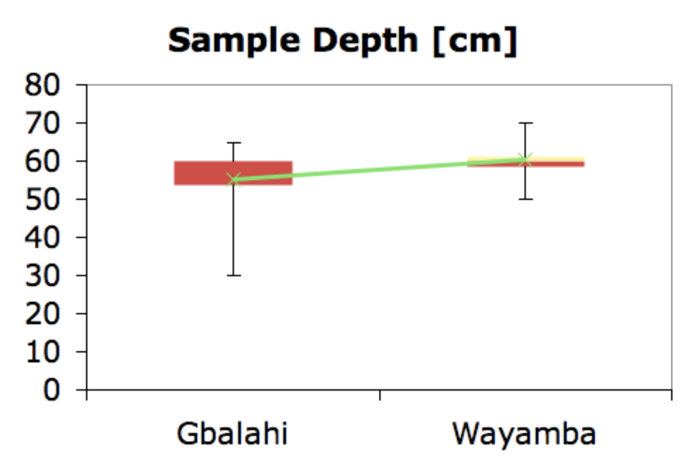
Collect Samples & Analyze Clay → Produce Filters → Evaluate Performance

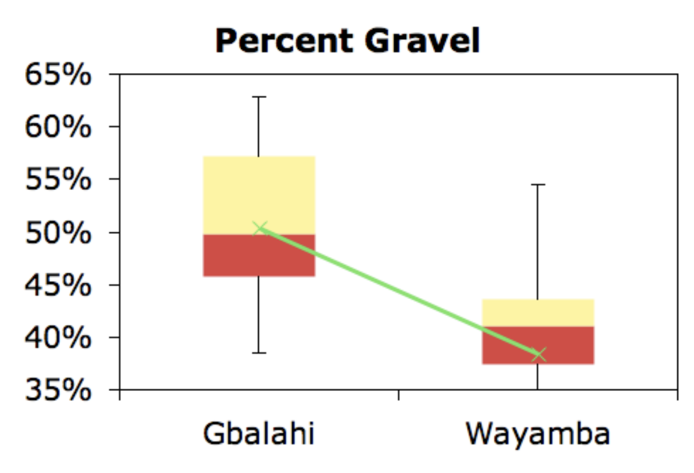
- Plasticity
- Particle size
- Sample depth

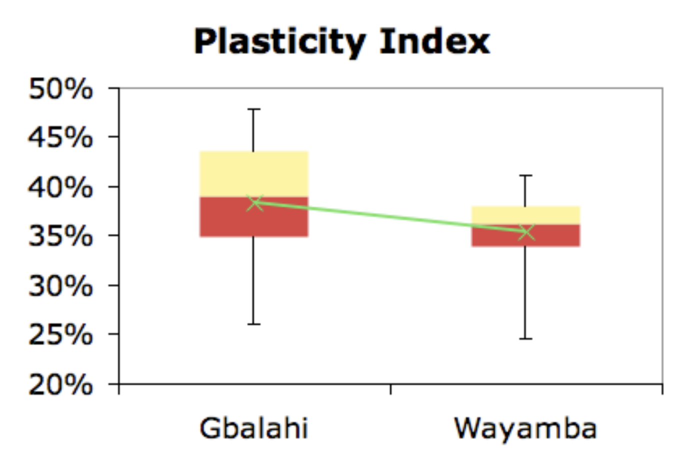
Statistical Analysis:
- Variation
- Correlation

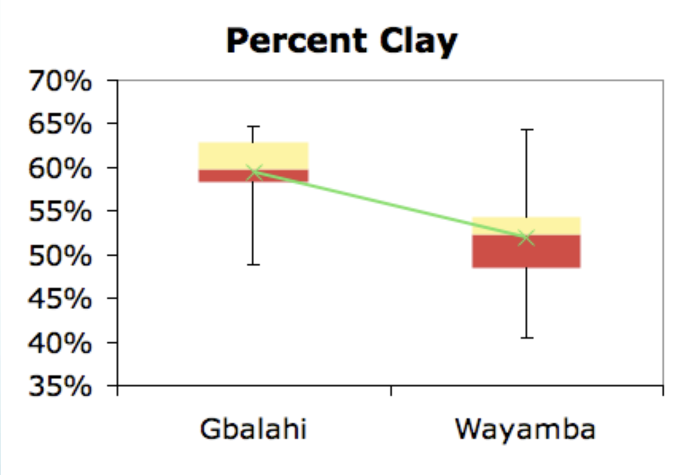
- Flow rate
- Turbidity reduction
- Coliform reduction
- E coli reduction

Results - Clay Parameters

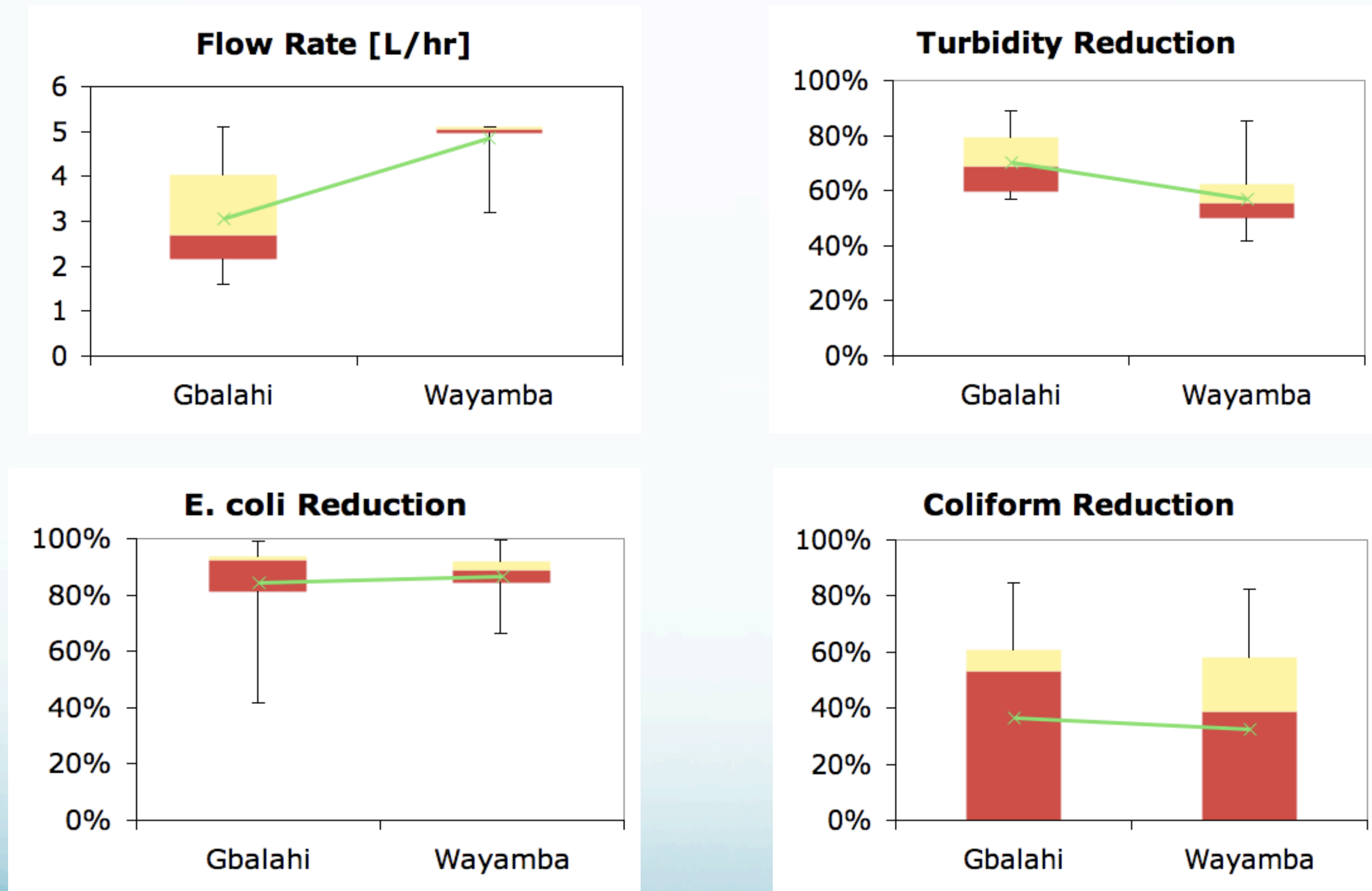








Results - Filter Performance



Statistical Analysis

- Compared population means from two sites using Student's t-test

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

$\bar{x} =$ sample average

$s^2 =$ sample variance

$n =$ sample size

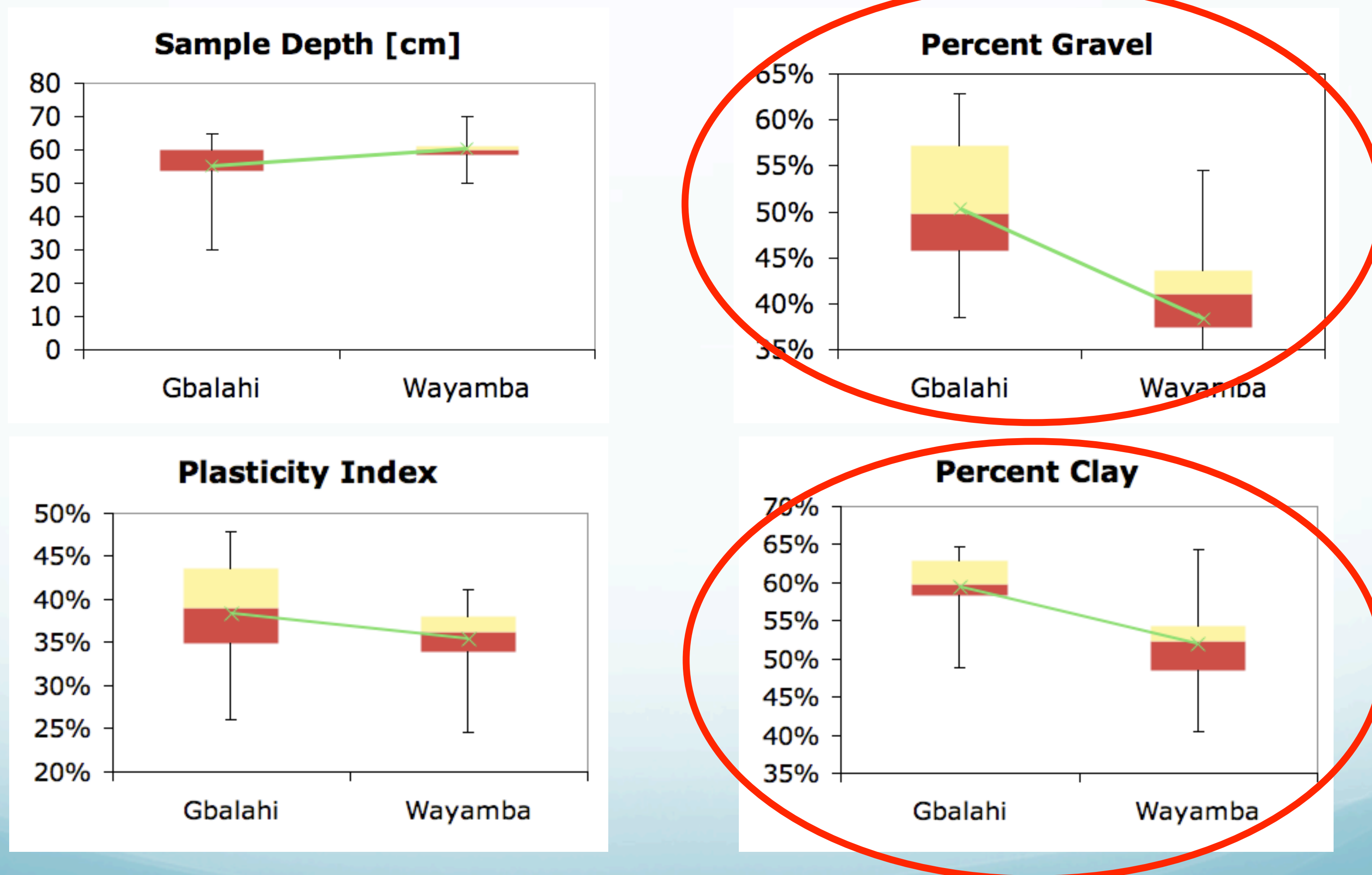
- Critical t-statistic corresponds to threshold probability that means are the same

T-test Results

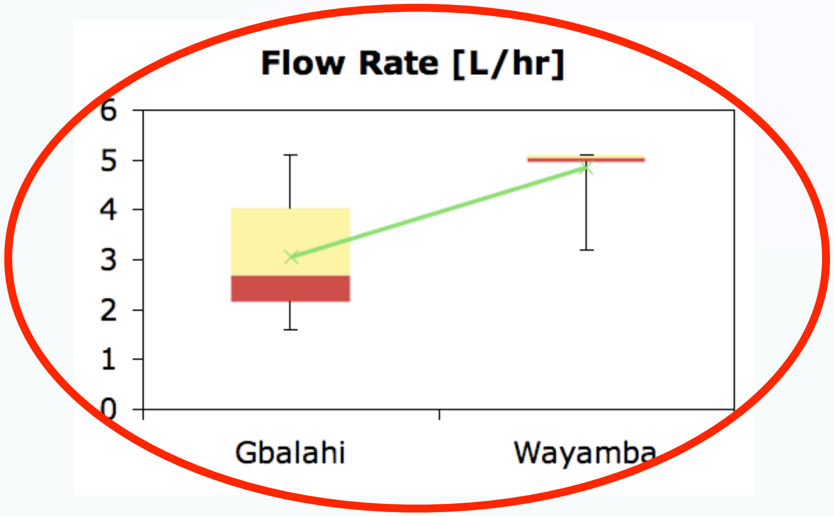
Parameter	t Stat	Two-tail P-value	Significant Variation?
Depth of sample	-1.596	0.13	No
Plasticity index	1.270	0.22	No
Percent gravel*	-2.993	0.0072	Yes
Percent clay	3.448	0.0024	Yes
Flow rate	-4.792	0.00024	Yes
NTU reduction	2.885	0.0086	Yes
E. coli reduction	-0.421	0.68	No
Coliform reduction	0.327	0.75	No

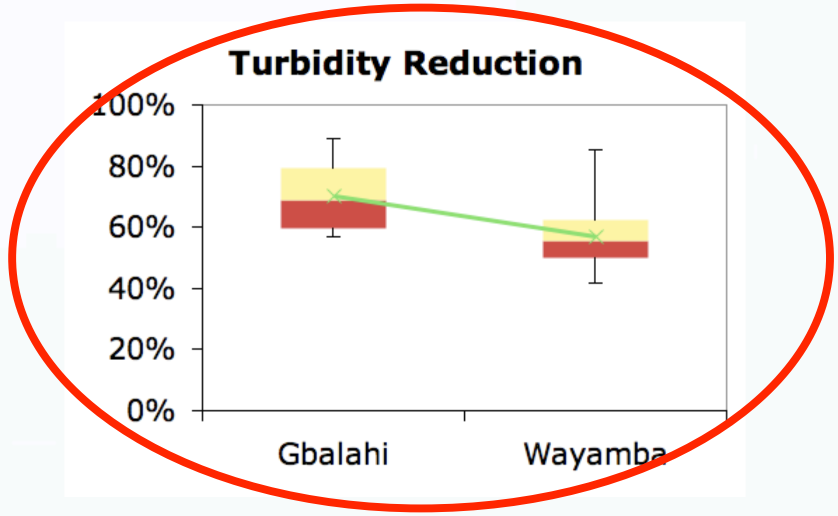
*as measured from initial sieving of samples

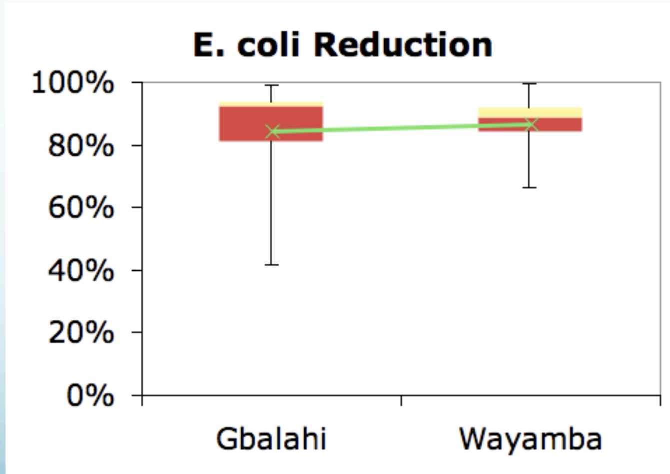
Results - Clay Parameters

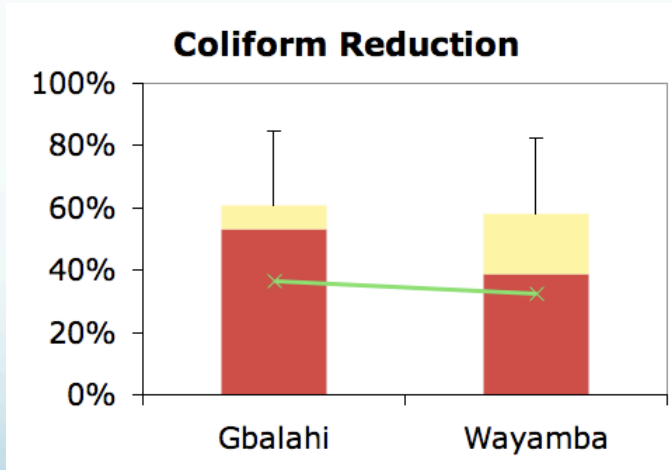


Results - Filter Performance

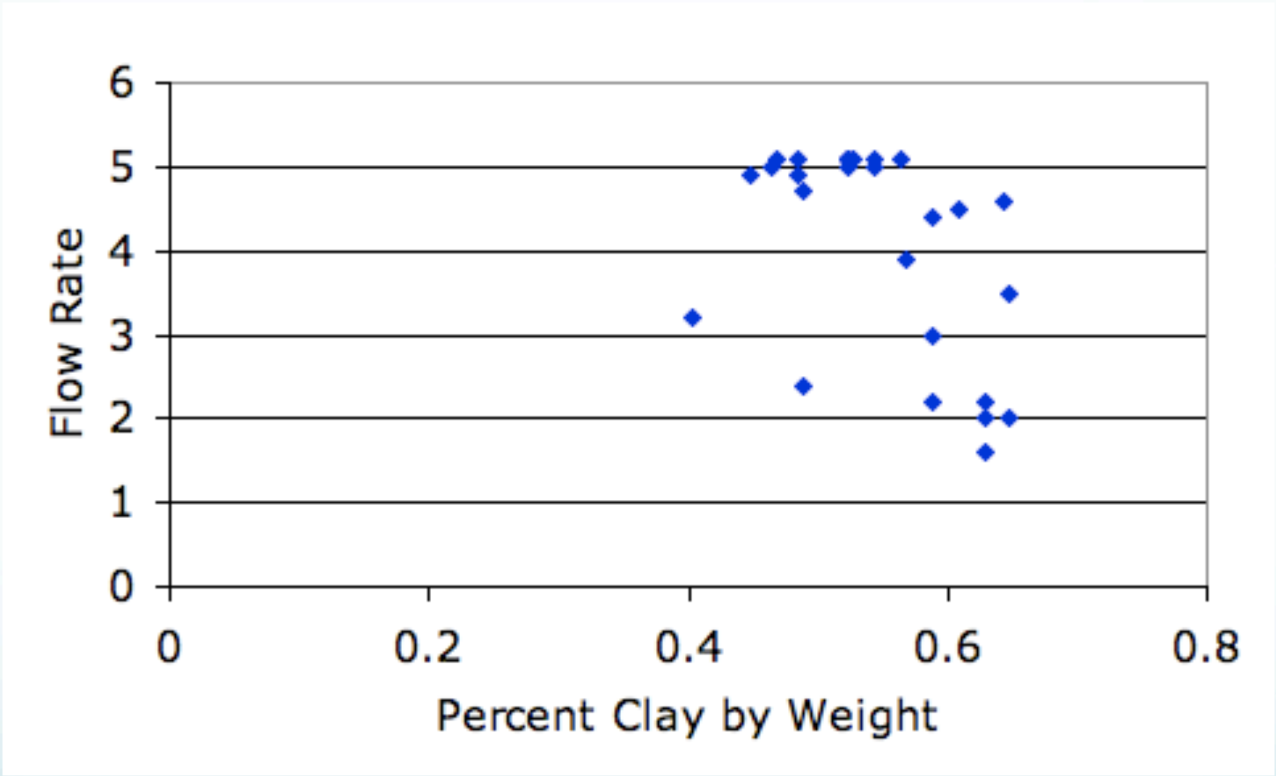




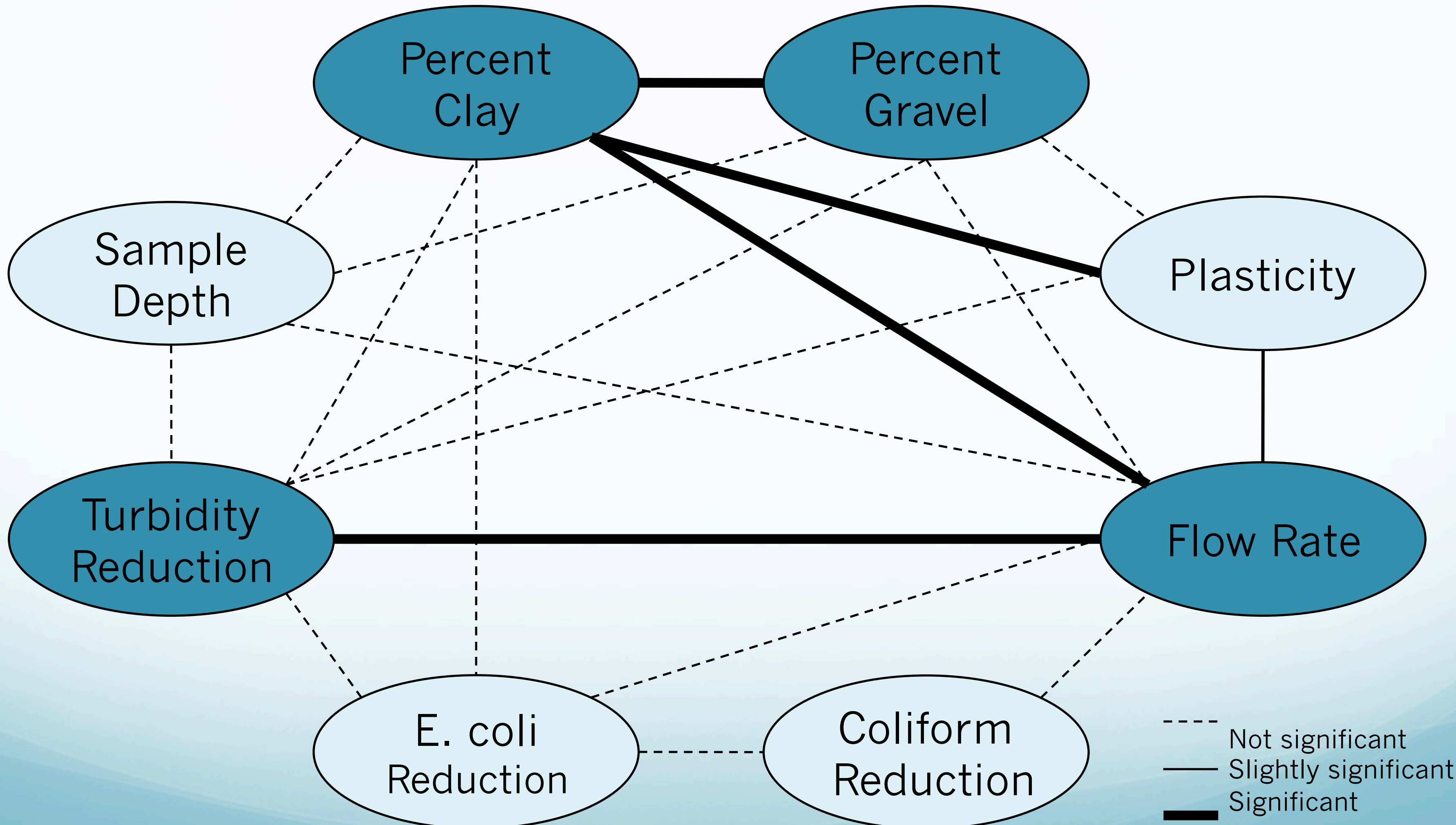




Regression

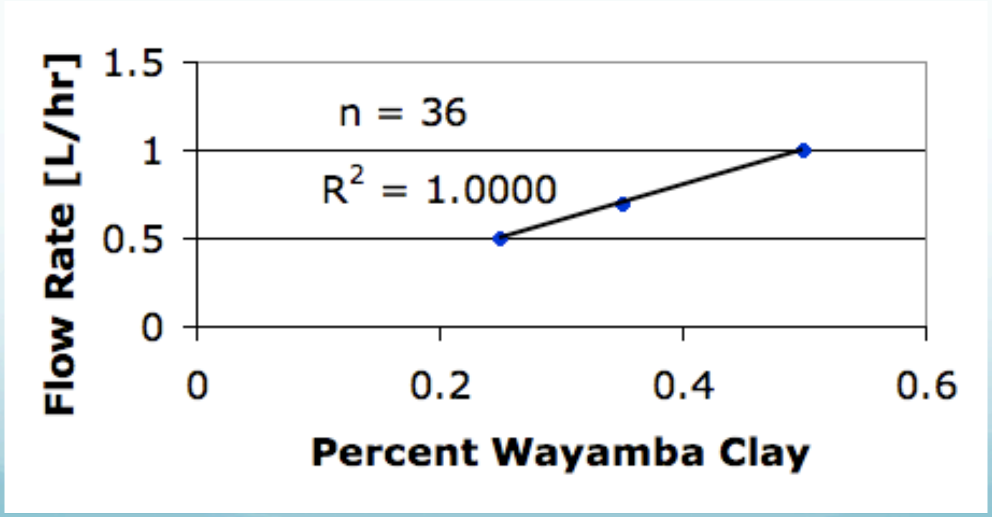


Regression Results



Work Done Since January

- Experimentation with clay recipe
- Mixes of Gbalahi and Wayamba clay
- Most significant result: strong correlation between flow rate and clay mix

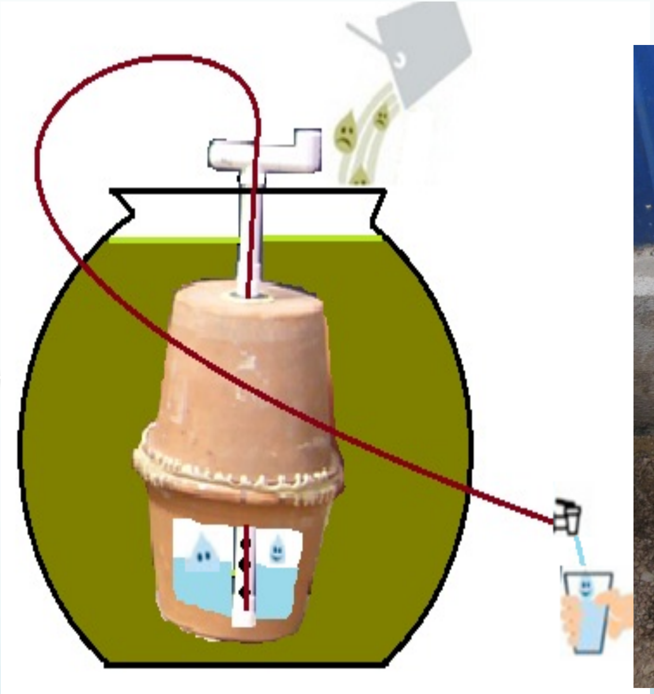


Recommendations

- If only one clay is used, Gbalahi site is recommended.
- If a mix is to be used, further experimentation is needed to find a recipe that yields optimal performance.

Kosim Water Keg:
Design Testing and Customer Study

Joanna Cummings



Project Objectives

- Evaluate Construction Technique
- Test bacterial and turbidity removal
- Measure filtration and siphon rate
- Collect customer feedback on KWK

4 weeks in Tamale, Ghana	
# of KWKs Tested	8
# of Houses surveyed	16
# of KWKs left with families	5 / 10 weeks

KWK Construction

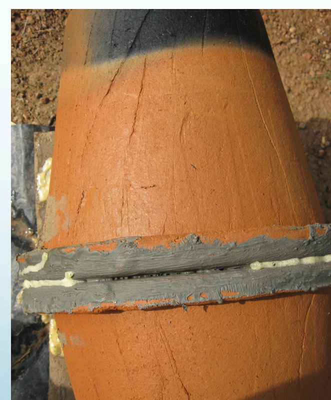
Construction of 11 KWKs





Leak Testing

Construction Problems


Bacterial and Turbidity Removal

Bacterial Removal	N	Coli forms Filtered MPN / % Removal		E. Coli Filtered MPN / % Removal	
KWK – CT	25	166.1	91.9%	6.7	96.0%
Pot Filter (PF) – CT	5	17.4	98.5%	1.2	99.4%
KWK – PHW	5	2,109	10.7%	74.7	70.4%
PF – PHW	8	1,089	65.9%	40.6	90.5%

Turbidity Removal

Filter Type Averages	n	Source NTU	Filtered NTU	% Removal %
KWK-CT	46	93.9	41.5	55%
PF-CT	6.0	142.3	18.9	83%
KWK-PHW	7.0	107.0	53.0	50%
PF-PHW	8.0	106.0	32.3	69%

Hairline crack appearing in KWK

Filtration Rate

Falling Head Filtration Rates

Time (hours)	KWK-CT-1 L/hr n=2	KWK-CT-3 L/hr n=2	KWK-CT-5 L/hr n=2	KWK-CT-6 L/hr n=1	KWK-CT-7 L/hr n=3	Average L/hr n=10
1	11.8	11.2	10.4	11.0	9.1	10.7
2	8.8	6.4	6.9	9.8	6.5	7.7
3	8.1	5.3	7.4	5.7	6.6	6.6
4	4.0	3.8	5.9	5.2	3.5	4.5

Comparison of Pot filter to KWK filter

	Pot One 1 hr Filtration Rate L/Hr	Pot Two 1 hr Filtration L/Hr	Sum of Pot Filters' Filtration Rate L/Hr	KWK 1 hr Filtration Rate L/Hr
KWK-CT-1	2.20	2.85	5.05	11.80
KWK-CT-3	3.30	2.65	5.95	11.23
KWK-CT-5	2.85	3.30	6.15	10.40
KWK-CT-6	1.77	3.00	4.77	11.04

Siphoning Rate

Total Volume Siphoned / Total Volume Filtered

Date	CT-1	CT-2	CT-3	CT-5	CT-6	CT-7	PHW-10	PHW-11
19-Jan	No			No		No		
20-Jan	No		No	No		7L / 17.1L		
21-Jan		2L / 14L	13L / 17.3L	No		1L / 15L	6L / 12.5L	
22-Jan		13L/~16			No	4.4L / ~16	No	9.7L/~15
24-Jan	8L/~15		9L / ~16	7L /~15	No	13L / ~16		

Siphoning Flow Rates
Liters/ Minute

KWK Average	PF Average
0.68	2.08
0.57	1.54
0.52	0.65


Siphon Removal System


New Pump Removal

Household Surveys

- The number and dimension of water storage vessels
- The source of water, and how often the family gathered it
- How often they cleaned their vessels
- If the family had a Kosim filter, if they used it, and who had acquired it
- Response to the KWK design
    - If the flow rate is sufficient
    - If anything broke
    - What they like / don't like

Thank you!