Evaluation and Improvement of WASH and Industry Development Projects in Ghana

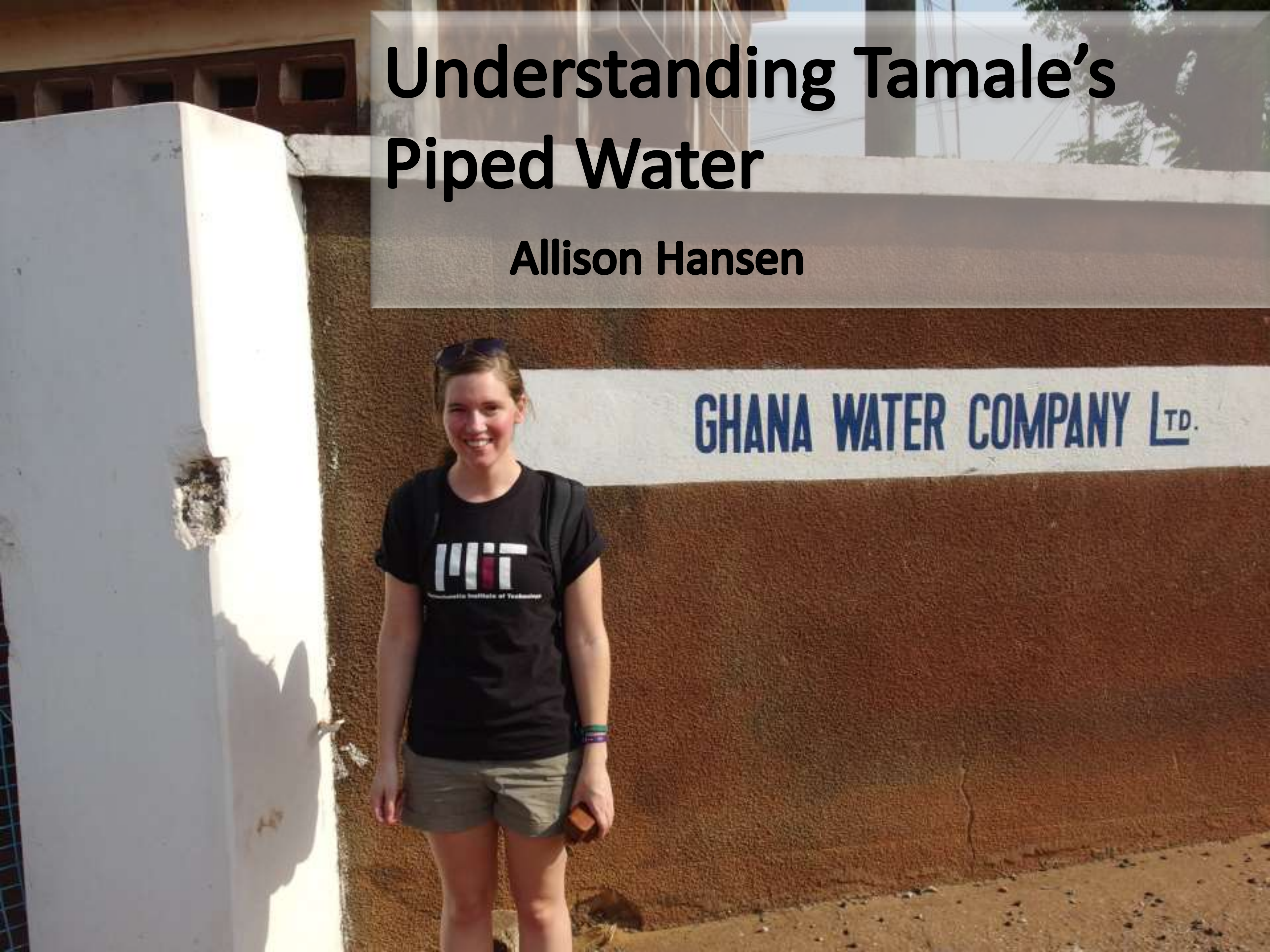

BURKINA FASO
Red Volta
0°
Bolgatanga
Black Volta
10°N
10°N
White Volta
Tamale
Oti
CÔTE D'IVOIRE
GHANA
TOGO
Sunyani
KWAHU PLATEAU
Mampong
Lake Volta
Kumasi
Akosombo Dam
Tano
Koforidua
Tema
Accra
Volta Delta
5°N
Sekondi
Takoradi
Gulf of Guinea
0
100 miles
0
100 kilometres
©Oxford Cartographers

Team Objectives

- Understanding Piped Water Supply in Tamale
- Ceramic Pot Filter Optimization
- Evaluation of High-End Household Water Treatment Product Alternatives
- Evaluation of Sanitation Innovation Projects
- Feasibility Evaluation of Fire-Brick Technology

Understanding Tamale's Piped Water

Allison Hansen



Goal

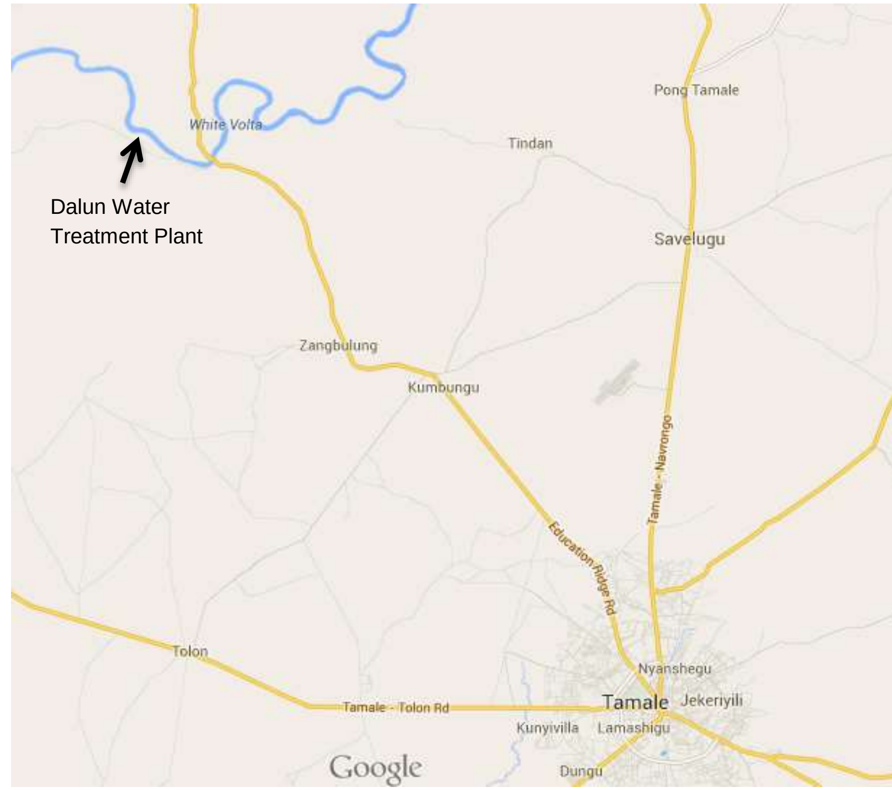
- The UN Millennium Development Goal 7.C is to "Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation"
- "Safe drinking water" is water from an "improved source"; piped water is considered improved- **but is it really safe?**
  - "Rapid Assessment of Drinking-Water Quality"

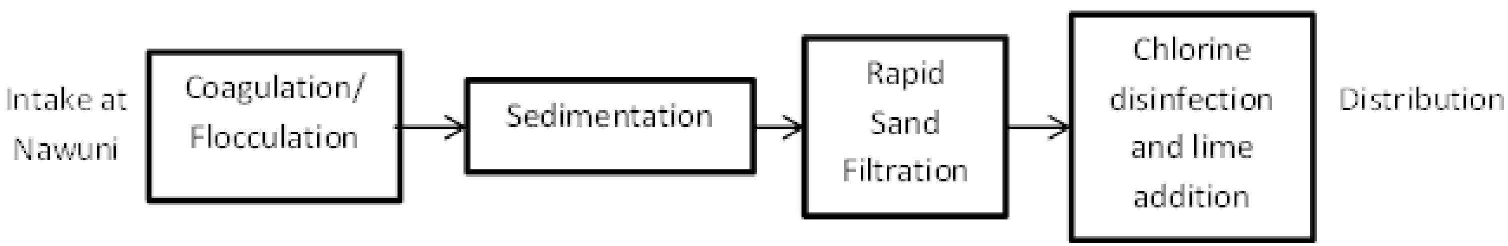
Objectives

- Continuing collaboration with Ghana Water Company Ltd. (GWCL) started last year
- Create computer database of historical water quality data from notebooks at Tamale office and analyze for trends
- Create hydraulic model of section of distribution system to look for areas of low pressure where contaminants may enter system

Background

- Tamale receives water from Dalun Treatment Plant which treats water from the White Volta River





WHO Guidelines for Drinking-Water Quality

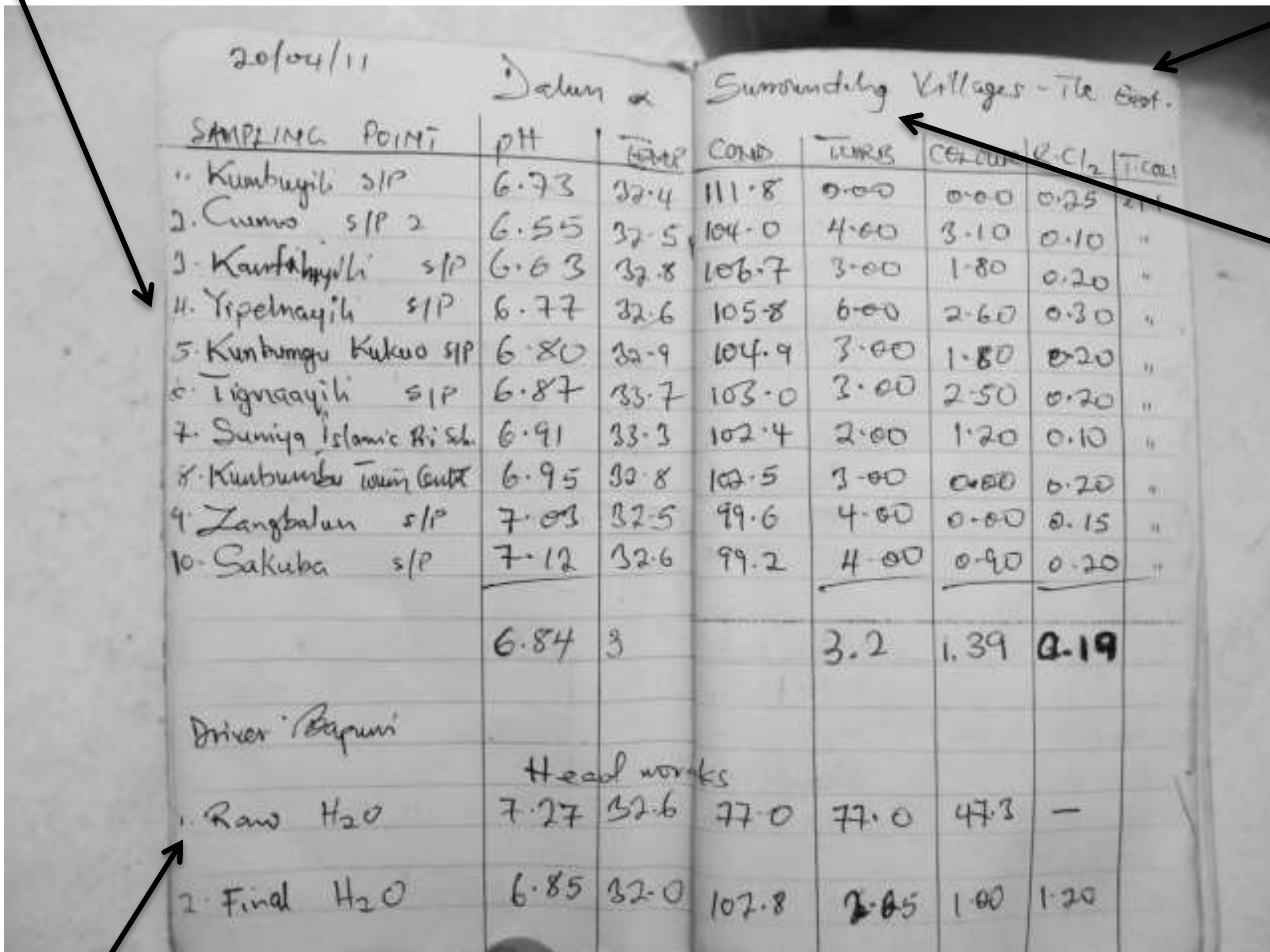
- pH: 6.5-8.5
- Turbidity: for small water supplies at least <5 NTU, if possible <1 NTU
- Chlorine residual: ≥0.5 mg/l after 30 min.; >0.2 mg/l at point of delivery
- Total Coliform (indicator bacteria): 0 counts in 100 ml sample

Water Quality Data

Sample points

District

Area



20/04/11 Dalun & Surrounding Villages - Tle East.

SAMPLING POINT	pH	TEMP	COND	TURB	COLOUR	R.Cl_2	T.COLI
1. Kumbuyili S/P	6.73	32.4	111.8	0.00	0.00	0.25	[illegible]
2. Cuma S/P 2	6.55	32.5	104.0	4.00	3.10	0.10	"
3. Kanfahiyili S/P	6.63	32.8	106.7	3.00	1.80	0.20	"
4. Yipelnayili S/P	6.77	32.6	105.8	6.00	2.60	0.30	"
5. Kunbungu Kukuo S/P	6.80	32.9	104.9	3.00	1.80	0.20	"
6. Tignaayili S/P	6.87	33.7	103.0	3.00	2.50	0.20	"
7. Suniya Islamic Pri Sch.	6.91	33.3	102.4	2.00	1.20	0.10	"
8. Kunbumbu Town Centr	6.95	32.8	102.5	3.00	0.00	0.20	"
9. Zangbalun S/P	7.03	32.5	99.6	4.00	0.00	0.15	"
10. Sakuba S/P	7.12	32.6	99.2	4.00	0.90	0.20	"
	6.84	3		3.2	1.39	0.19	

Driver Bapuni

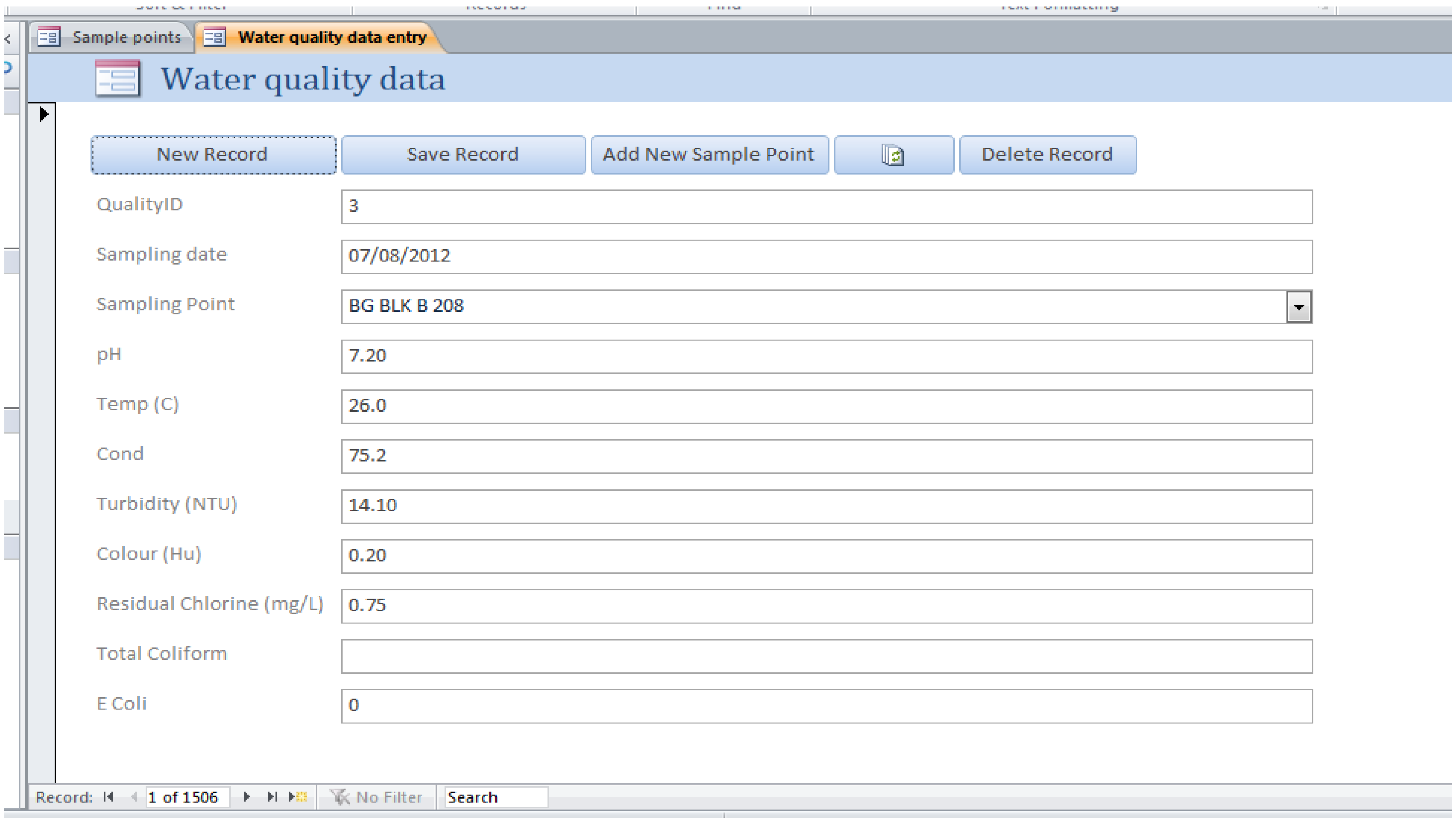
Head works

1. Raw H_2O	7.27	32.6	77.0	77.0	47.3	—
2. Final H_2O	6.85	32.0	107.8	2.65	1.00	1.20

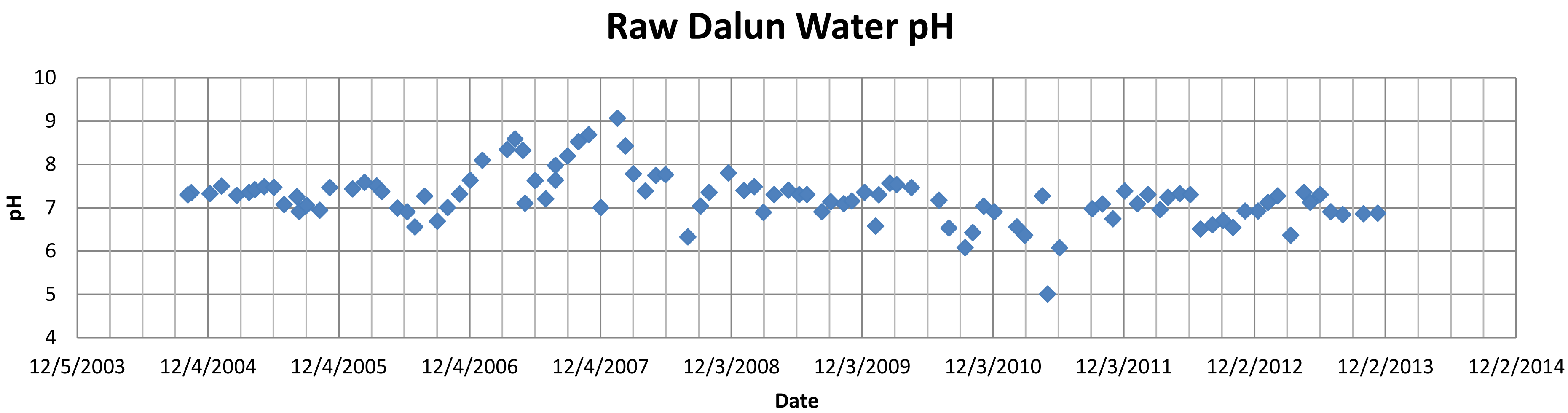
Treatment Plant

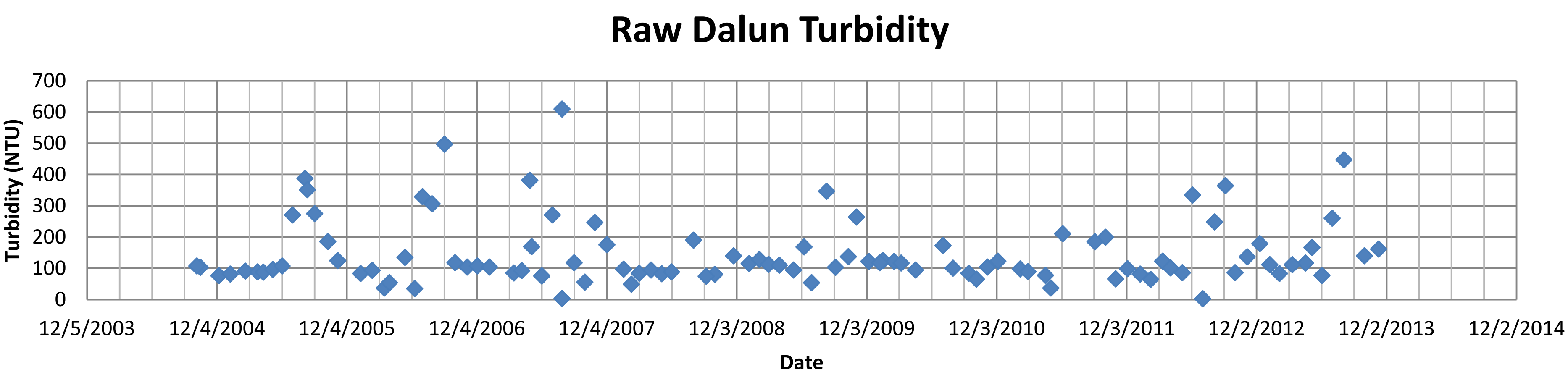
Water Quality Data

- Created Access database for GWCL



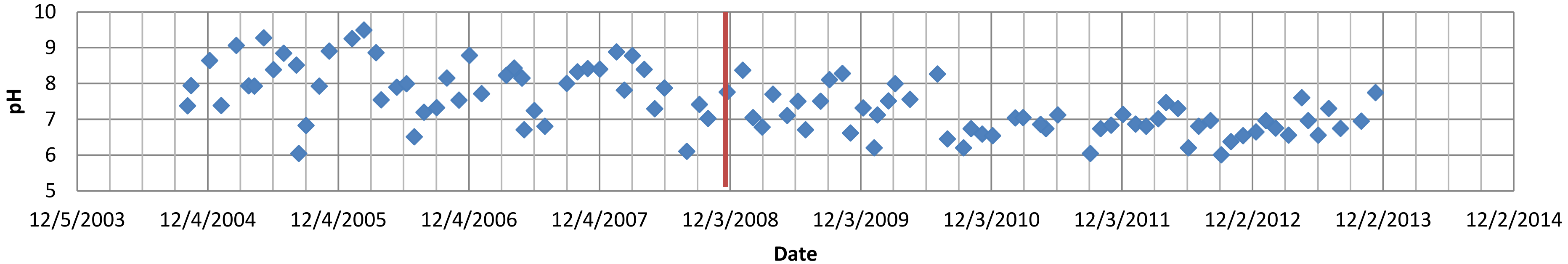
Raw Water Quality



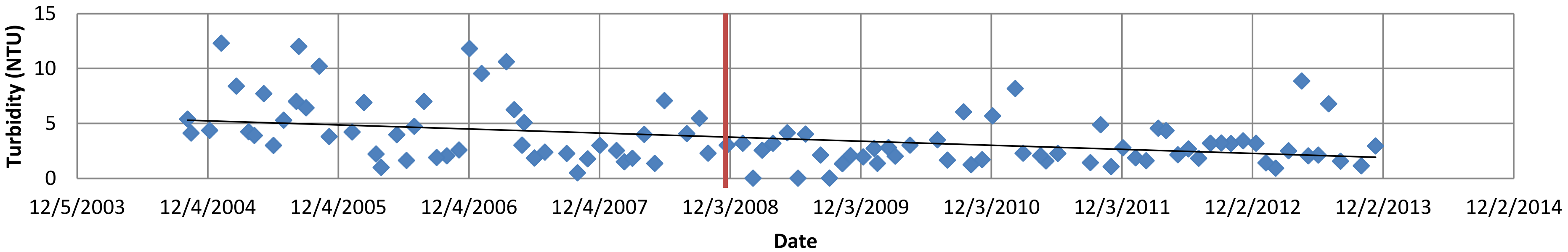


After Treatment

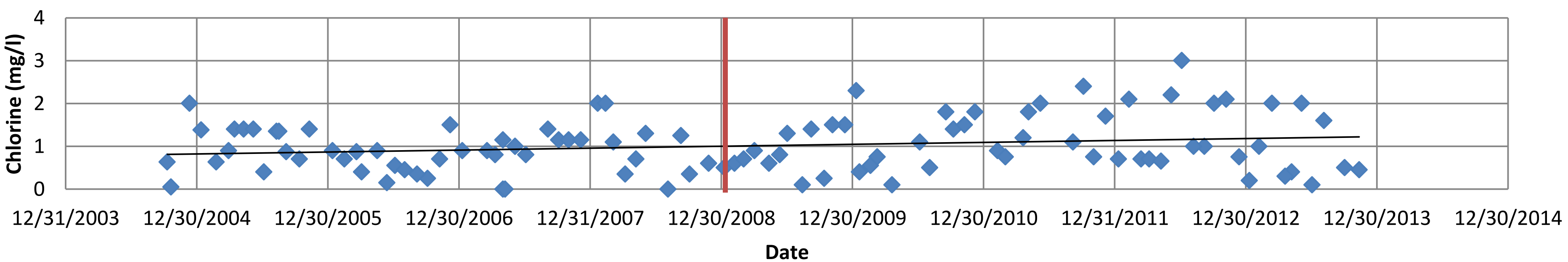
Final Dalun pH



Final Dalun Turbidity

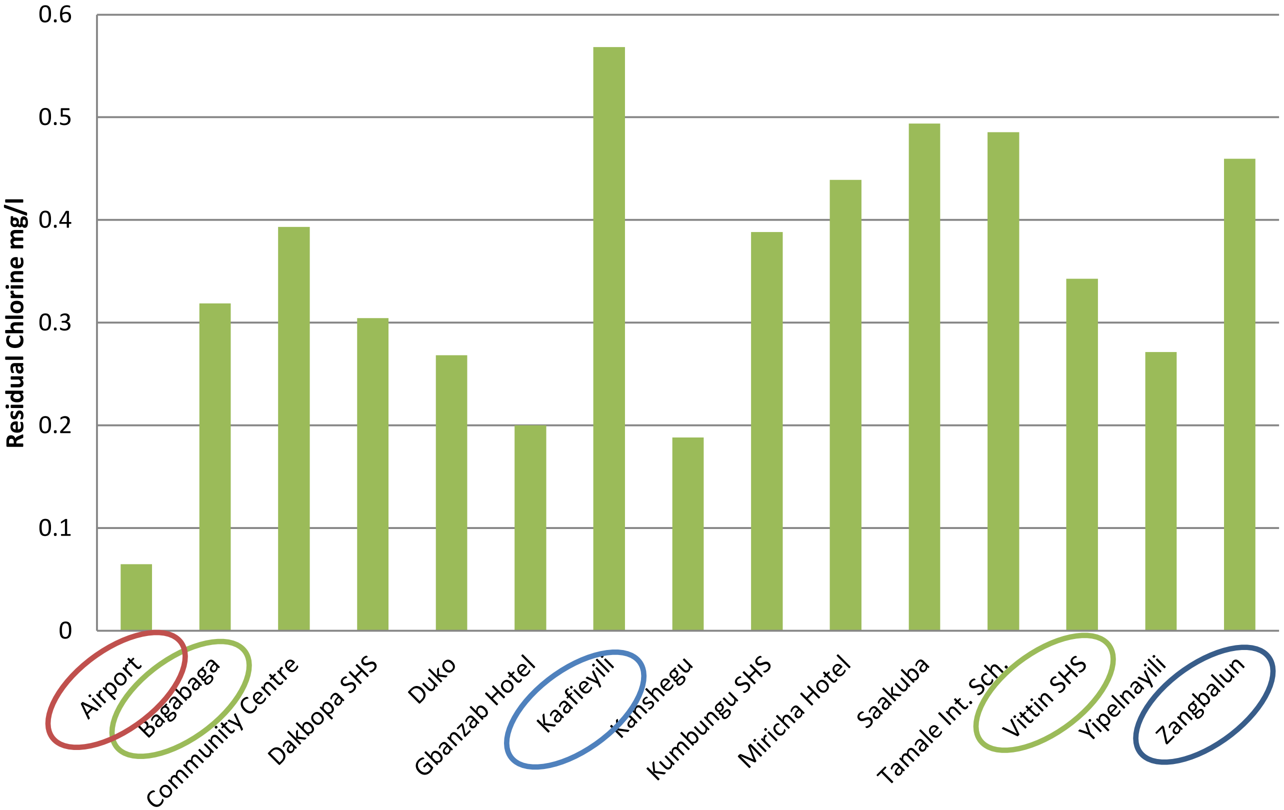


Final Dalun Residual Chlorine

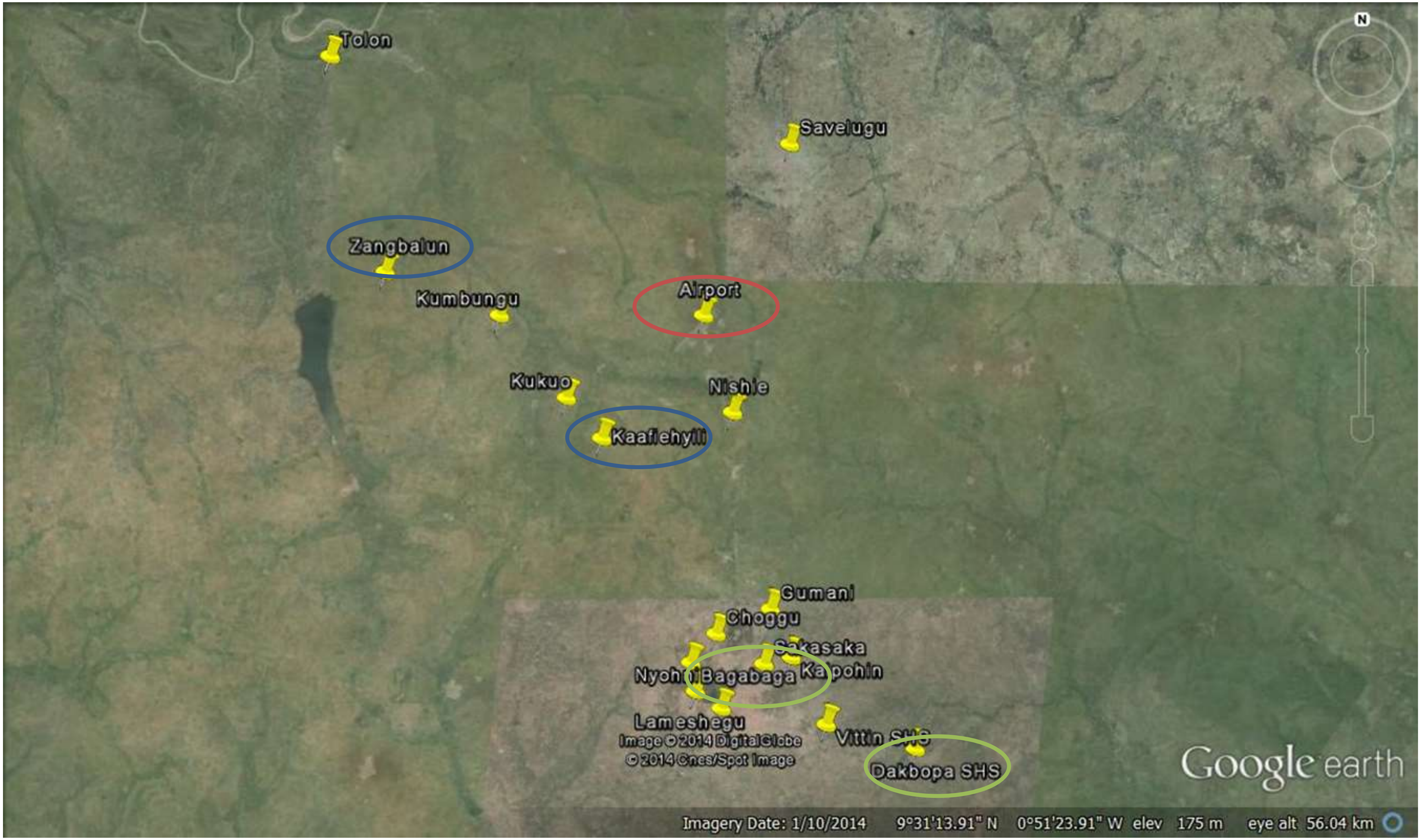


Sample Point Comparison

- Selected fifteen consistently sampled points from various areas to compare average water quality



Sample Points/Areas



RADWQ-Style Analysis

- For each sampling date the following was recorded:
  - Area
  - Number of points sampled
  - Number of points with*…
    - pH <6.5 and >8.5
    - Turbidity >5 NTU
    - Chlorine residual <0.2 mg/l
    - No chlorine residual
    - Positive counts of total coliform

*Criteria chosen based upon WHO guidelines

RADWQ-Style Analysis

Number of Samples Complying											
	All Points	Choggu/ Jisonayili	Dalun	Gumani	Kukuo	Lameshegu/ Sawaba	Nyohni/ Zogbeli	Savelugu/ Mile 9	Tishegu/ Sakasaka	Vittin	Yendi
Points	6643	508	944	192	461	242	599	934	255	269	1883
High pH	270	18	20	15	7	0	42	13	18	33	84
Low pH	377	87	110	0	30	3	25	21	10	0	75
High Turb	1579	96	189	23	49	16	130	152	76	63	713
Low Cl	2822	100	296	116	148	112	214	549	97	119	927
No Cl	756	34	38	10	25	10	40	187	26	34	315
T. Coli	105	0	0	0	0	1	6	4	0	2	86

Percentages Complying											
	All	Choggu/ Jisonayili	Dalun	Gumani	Kukuo	Lameshegu/ Sawaba	Nyohni/ Zogbeli	Savelugu/ Mile 9	Tishegu/ Sakasaka	Vittin	Yendi
High pH	4.06%	3.54%	2.12%	7.81%	1.52%	0.00%	7.01%	1.39%	7.06%	12.27%	4.46%
Low pH	5.68%	17.13%	11.65%	0.00%	6.51%	1.24%	4.17%	2.25%	3.92%	0.00%	3.98%
High Turb	23.77%	18.90%	20.02%	11.98%	10.63%	6.61%	21.70%	16.27%	29.80%	23.42%	37.87%
Low Cl	42.48%	19.69%	31.36%	60.42%	32.10%	46.28%	35.73%	58.78%	38.04%	44.24%	49.23%
No Cl	11.38%	6.69%	4.03%	5.21%	5.42%	4.13%	6.68%	20.02%	10.20%	12.64%	16.73%
T. Coli	1.58%	0.00%	0.00%	0.00%	0.00%	0.41%	1.00%	0.43%	0.00%	0.74%	4.57%

Hydraulic Modeling Challenges

- Not enough information provided to make an accurate model feasible and helpful
  - No flow and pressure data
  - No demand data
  - Unclear where water enters and leaves system
  - Household tank storage is a very important consideration but tank data unavailable
  - Commercial software (such as EPANET) isn’t effective for intermittent system

Conclusions

- Source water has distinct seasonal trends in pH and turbidity which impact water quality at the tap
- Water quality does deteriorate as it travels through the distribution network
- Despite being an improved source, there is a fair risk that water becomes contaminated by the time it is used or consumed
- Tamale's improved source is not necessarily safe

Optimization of Ceramic Pot Filter

Shuyue Liu
Yiyue Zhang

Outline

- Project Overview
  - Problem
  - Objectives
  - Framework
- Content
  - Flow Rate
    - *Goal*
    - *Result*
    - *Comparison*
  - Bacteria Removal Rate
    - *Goal*
    - *Result*
    - *Comparison*
- Conclusion
- Recommendation

Project Overview

PROBLEM:

High Flow Rates V.S. High Bacteria Removal Rates

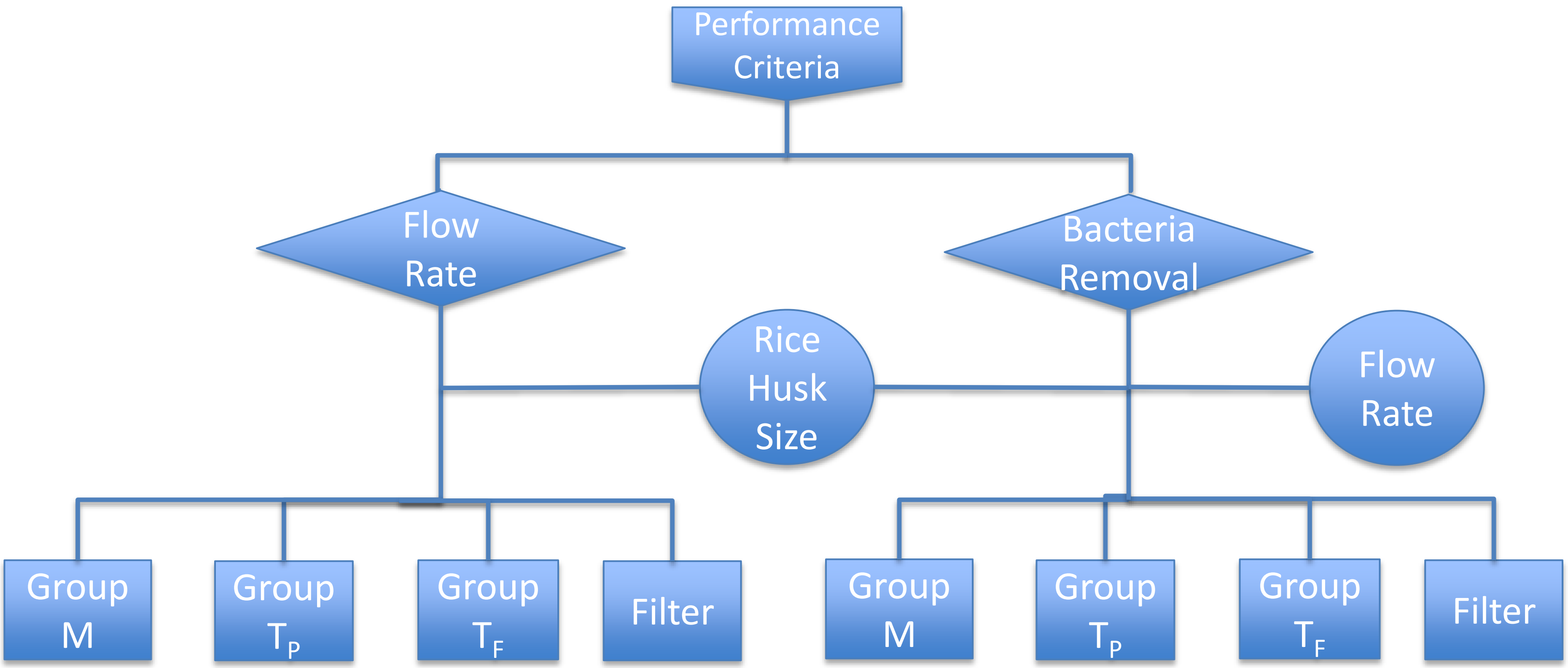
OBJECTIVES:

- Investigate impact of rice husk size on flow rates
- Investigate impact of rice husk size and flow rate on bacteria removal rate
- Recommend size of rice husk for manufacturing and future research

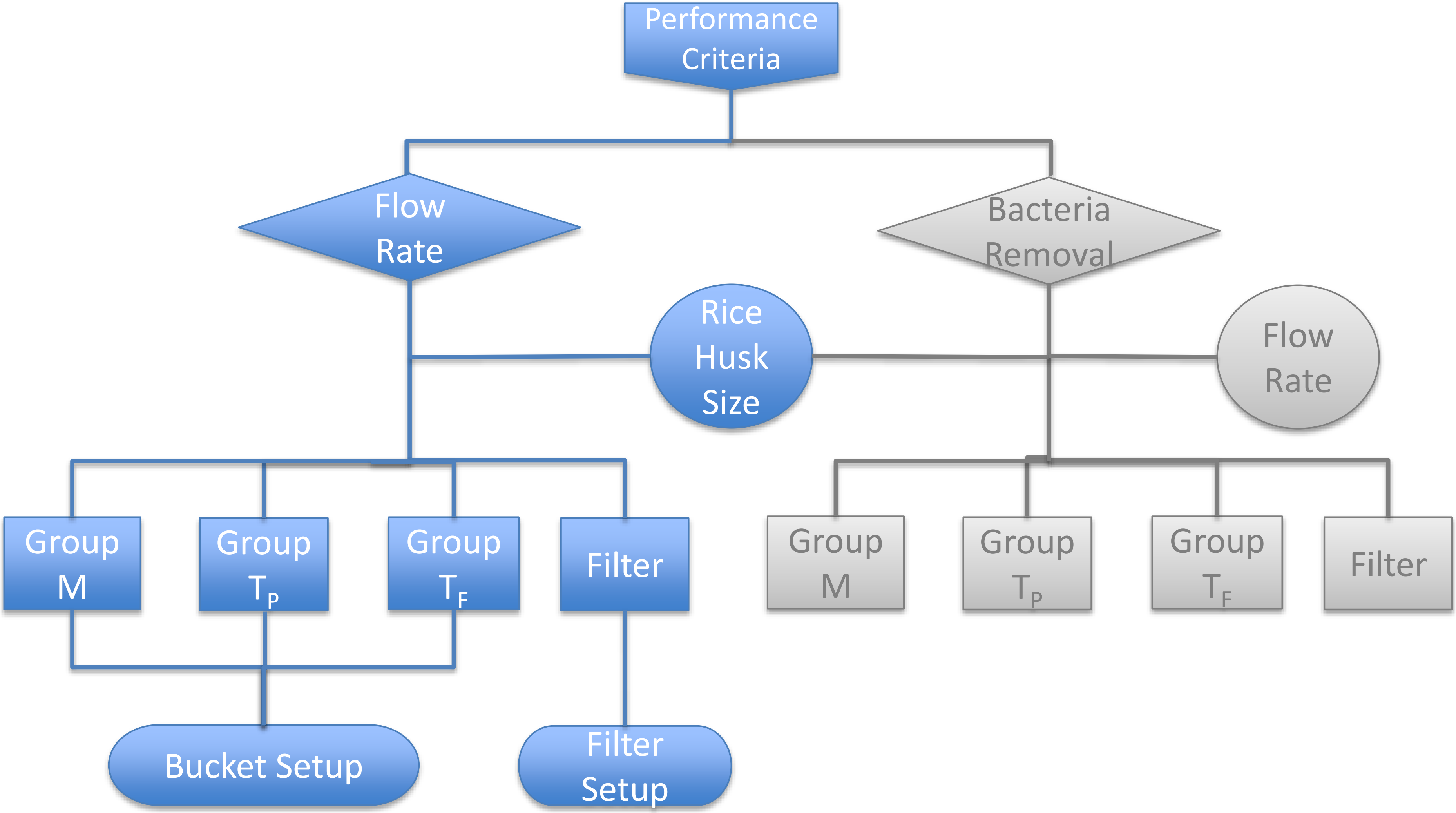
Project Overview

Size / Flow rate	350-420			420-600			600-710			710-850			850-1000		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1.5 mL/min															
1.0 mL/min															
0.5 mL/min															
0.1 mL/min															

Project Overview



Content | Flow Rate



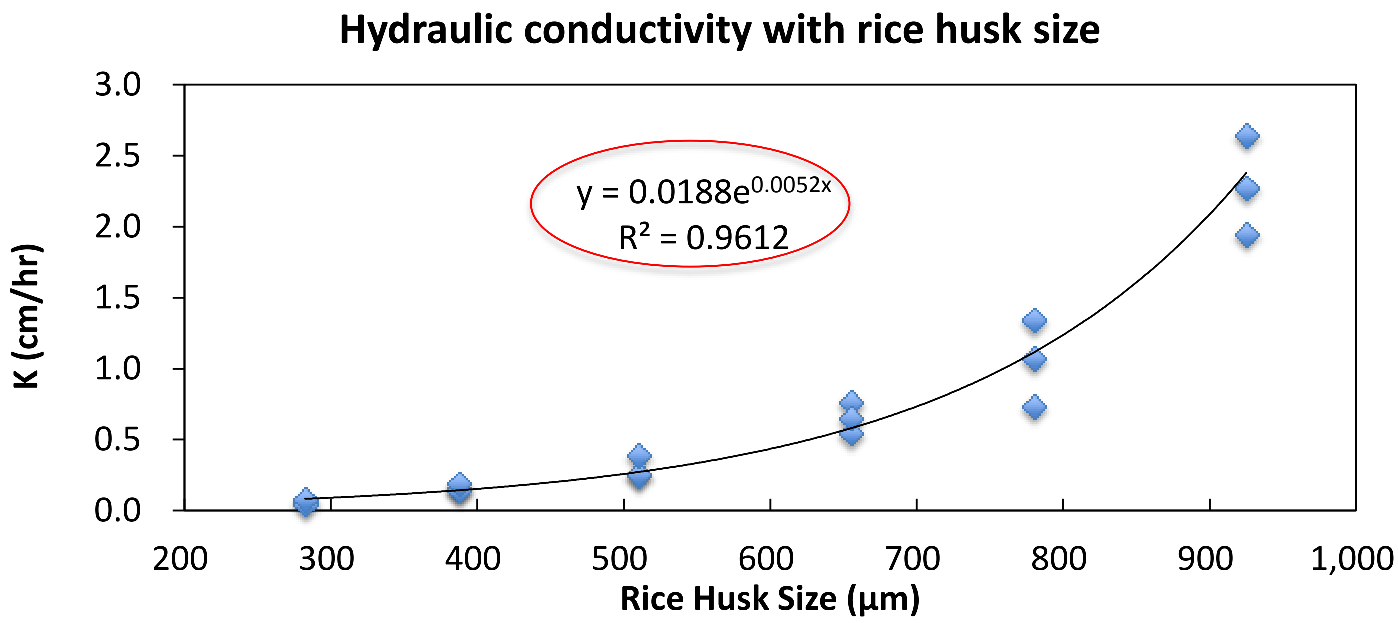
Performance Criteria 1: Flow rate

Darcy's Law: Q=(KAh)/L

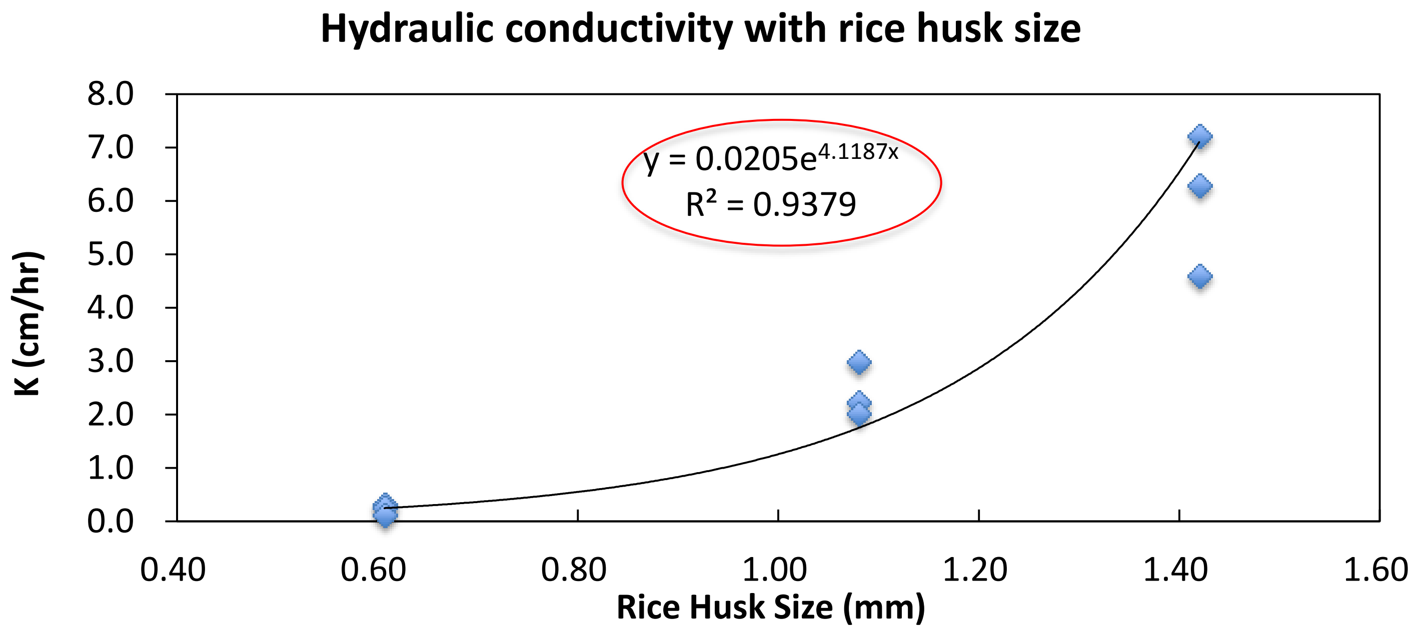
Sample Disks

Bucket Setup

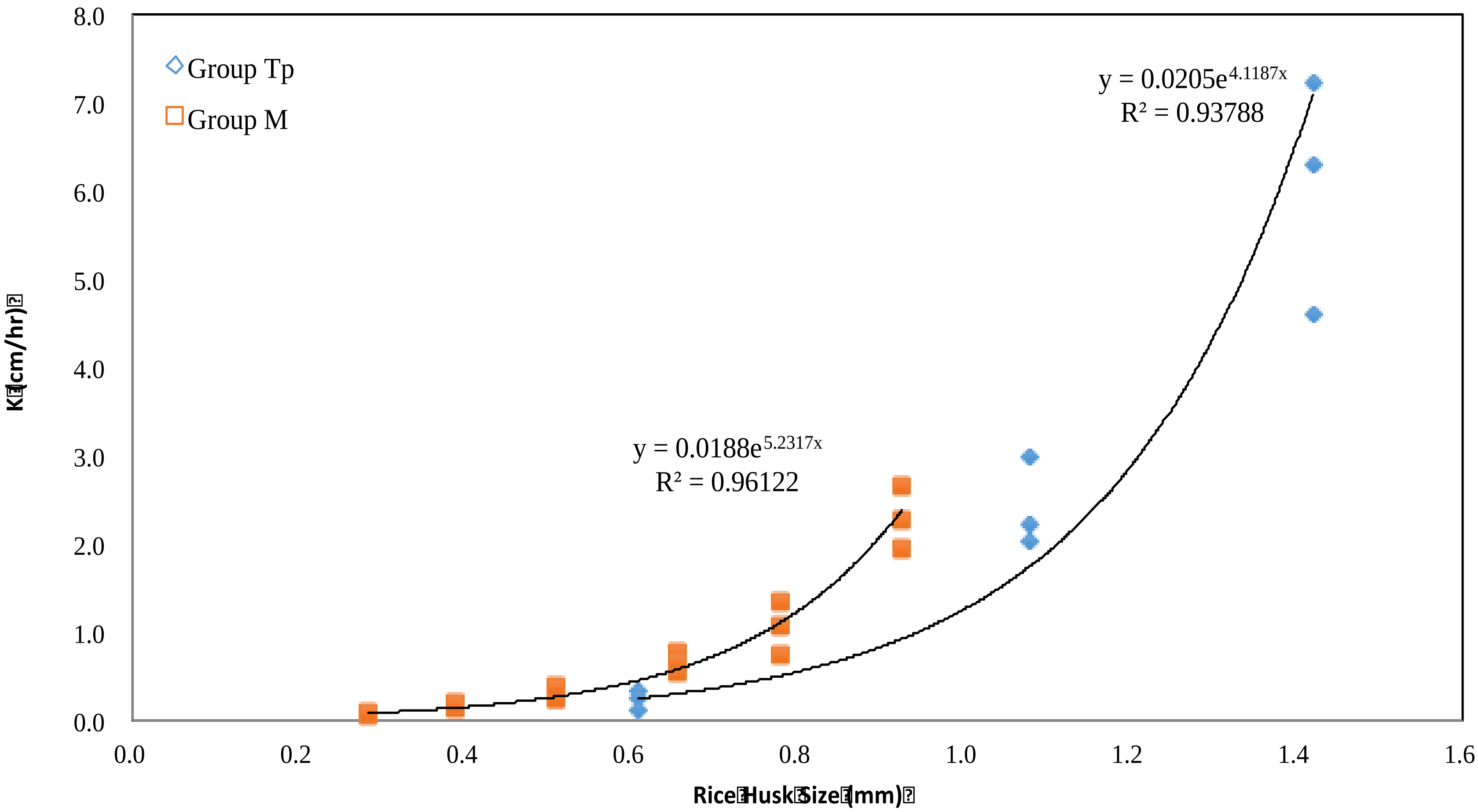
Group M



Group T_P



Comparison of K between group M and T_P



Group M > Group Tp

Modeling the theoretical flow rate of a full-size filter

$$dl = \sqrt{dz^2 + dr_z^2}$$

$$dA = 2\pi r_z dl = 2\pi r_z \sqrt{dz^2 + dr_z^2}$$

$$h = H_w - z$$

$$(R - z)^2 + r_z^2 = R^2$$

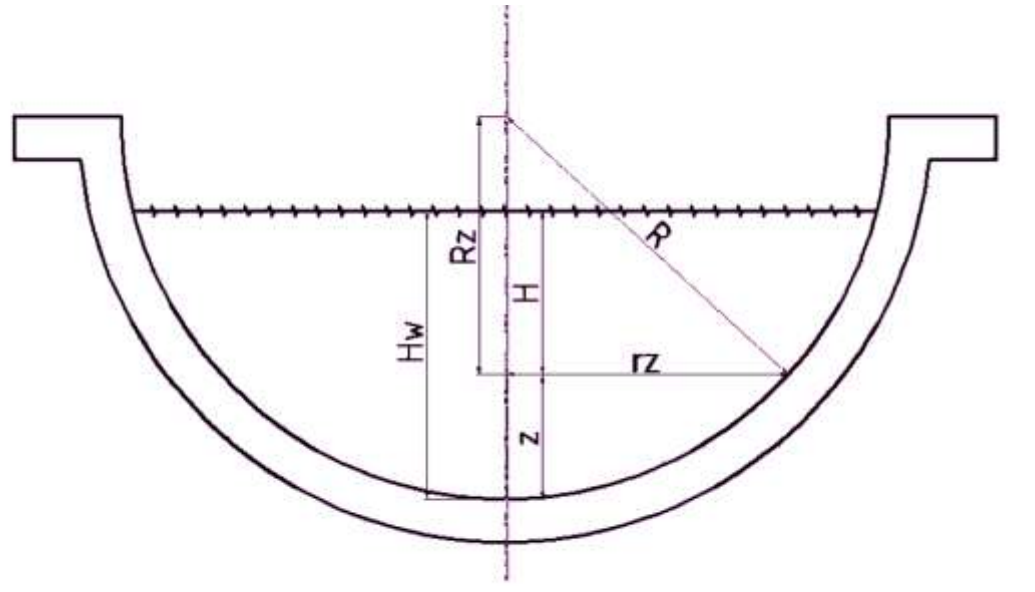
$$r_z = \sqrt{2Rz - z^2}$$

$$dr_z = \frac{R - z}{\sqrt{2Rz - z^2}} dz$$

$$dA = 2\pi r_z d_z \sqrt{1 + \frac{(R - z)^2}{2Rz - z^2}}$$

$$Q = \frac{K}{L}\int_0^{H_w} h dA = 2\pi \frac{K}{L}\int_0^{H_w} \sqrt{(2Rz - z^2)(1 + \frac{(R - z)^2}{2Rz - z^2})}(H_w - z)dz$$

$$Q = \frac{2\pi RK}{L}\int_0^{H_w} (H_w - z)dz = \frac{\pi RK}{L} H_w^2$$



Modeling the theoretical residence time for a full-size filter

$$dV = Qdt$$

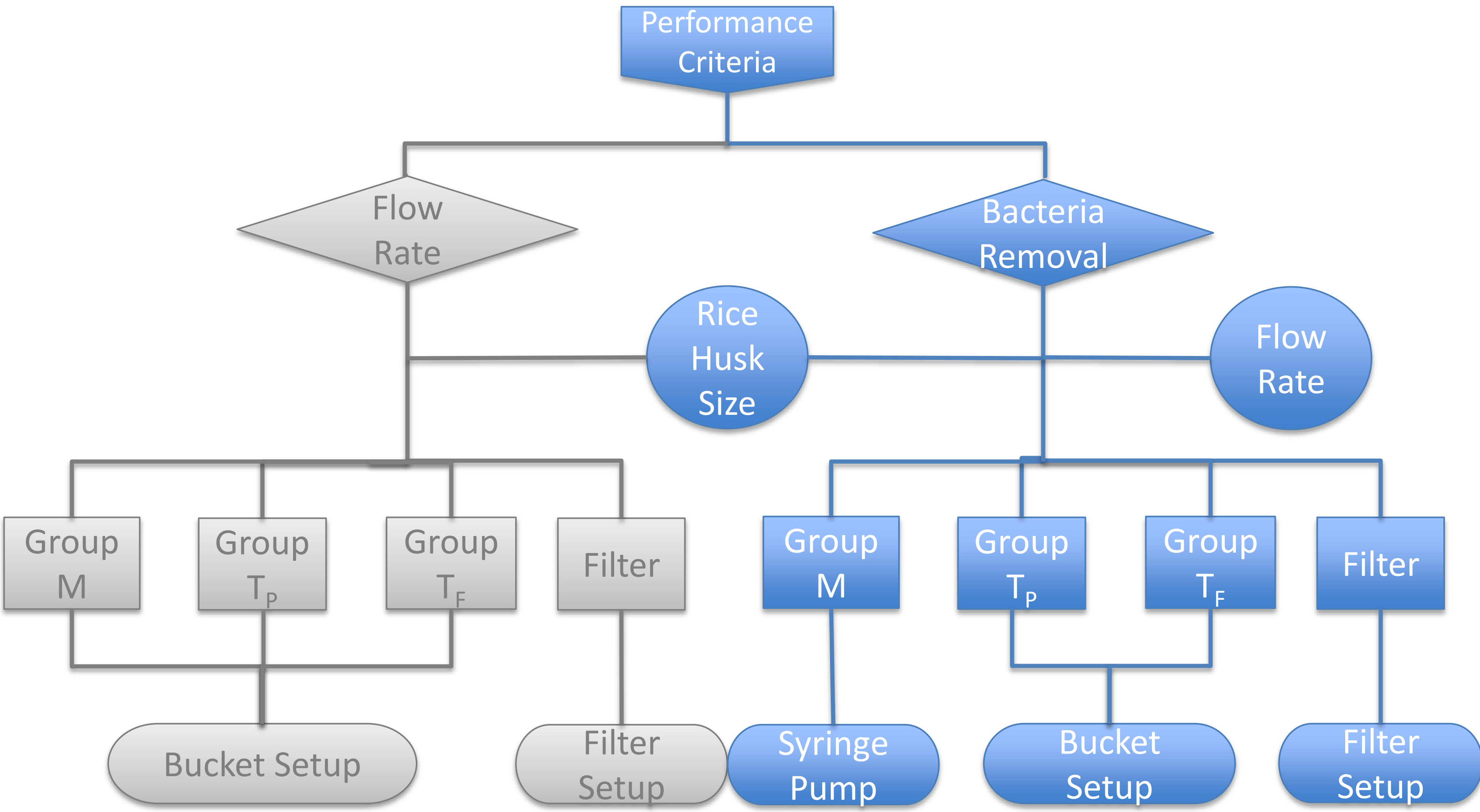
$$r_z^2 = R^2 - (R - H_w^2)$$

$$dt = \frac{dV}{Q} = \frac{AdH_w}{Q} = \frac{\pi r_z^2 dH_w}{\frac{RK}{L} H_w^2} = \frac{L}{RK}\left(\frac{2R}{H_w} - 1\right) dH_w$$

$$t = \frac{L}{RK}\int_{0.05R}^{R}\left(\frac{2R}{H_w} - 1\right) dH_w = 4.8\frac{L}{K}$$

For example, if the K value of the filter is 5.0cm/hr, the residence time of contaminated water is 4.8*2.4/5.0=2.3hr

Content | Bacteria Removal

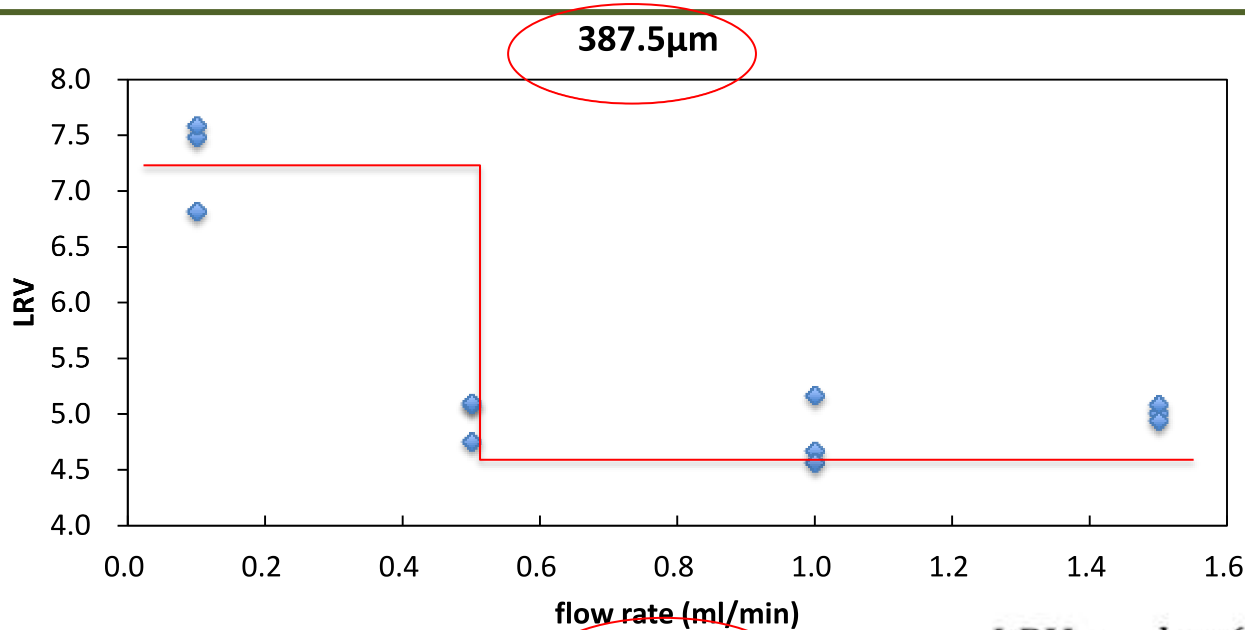


Performance Criteria 2: Bacteria Removal

Gr

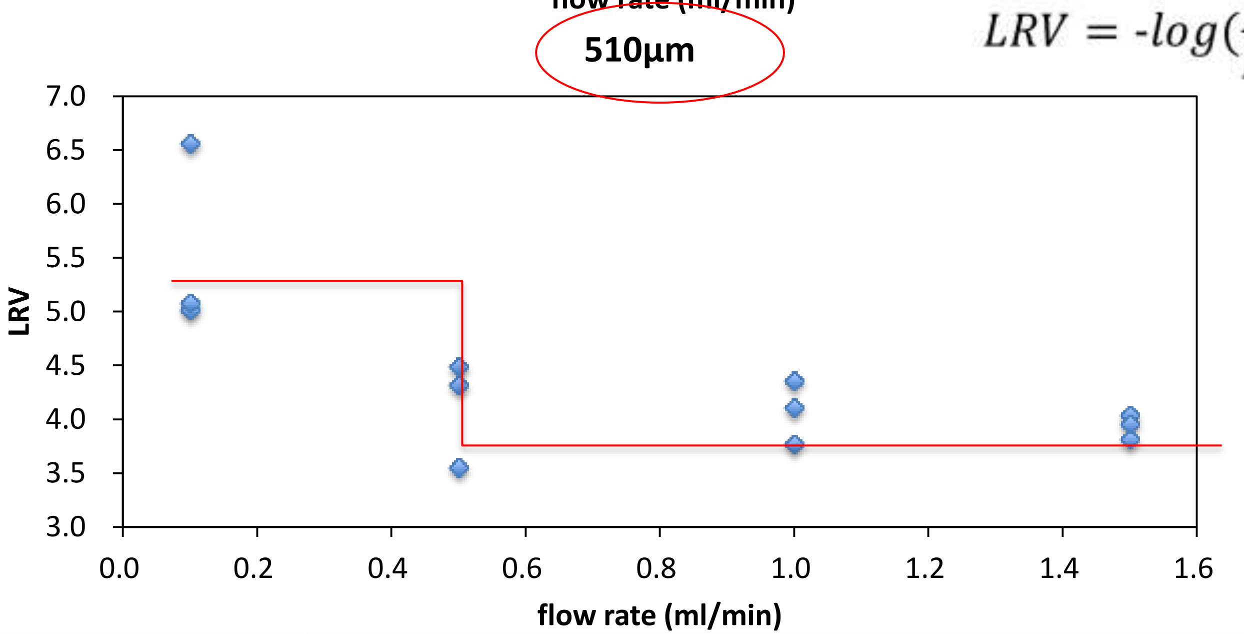
Full-Size Filter

Impact of Flow Rate on Bacteria Removal



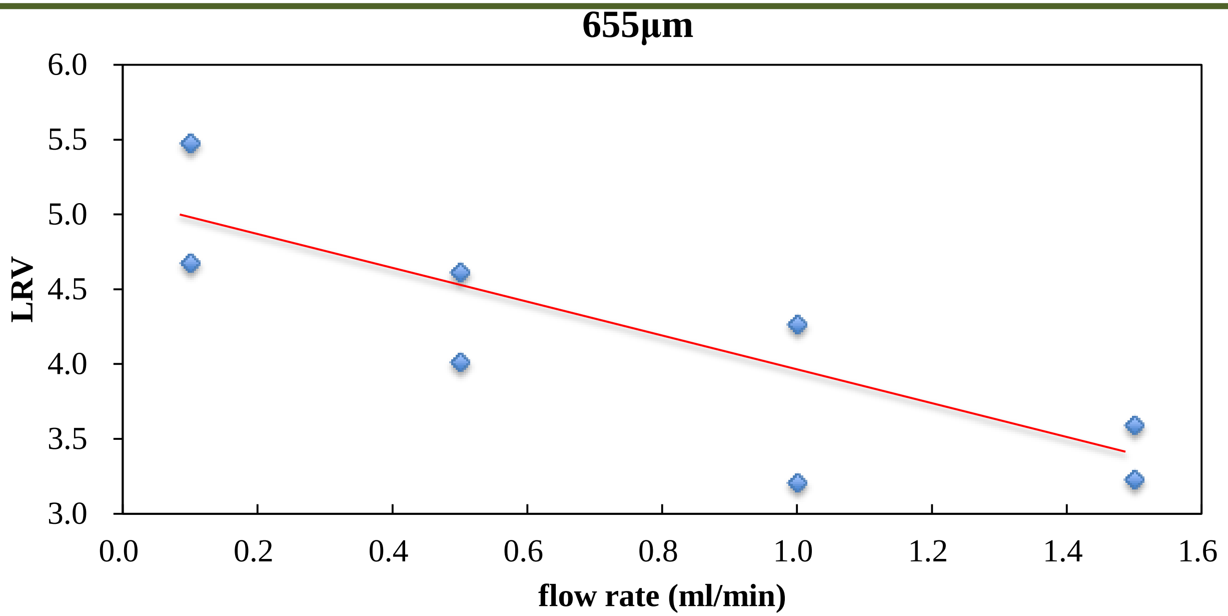
Group M

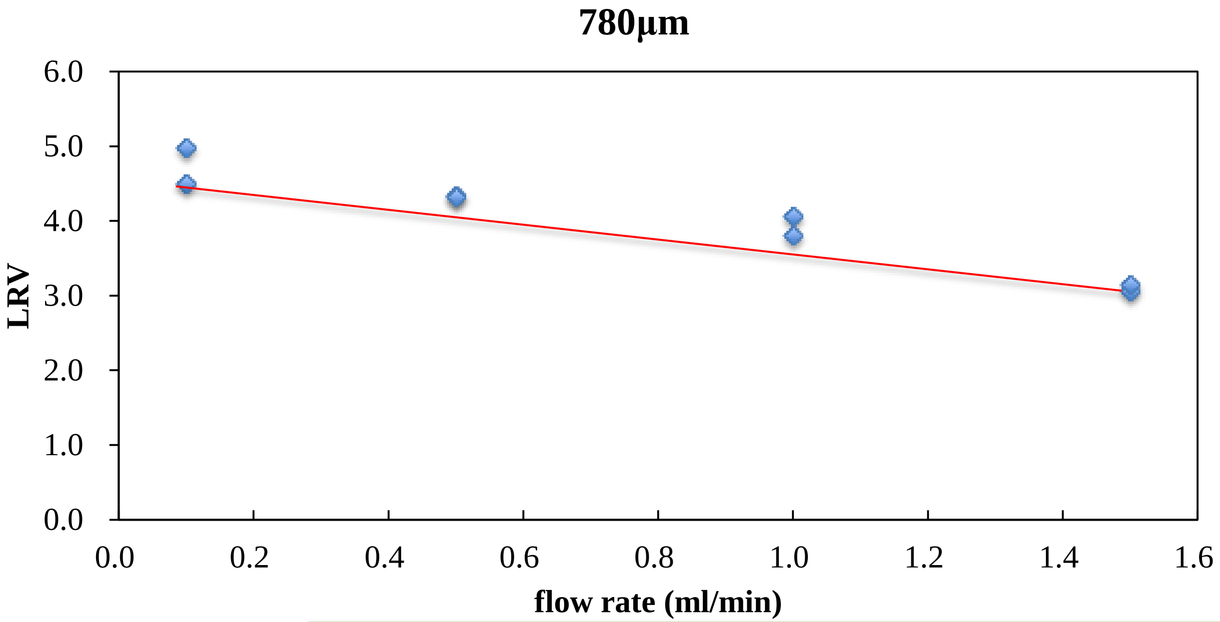
$$LRV = -log\left(\frac{Influent\ Concentration}{Effluent\ Concentration}\right)$$



Transition occurs at a flow rate of about **0.5 mL/min**.

Impact of Flow Rate on Bacteria Removal

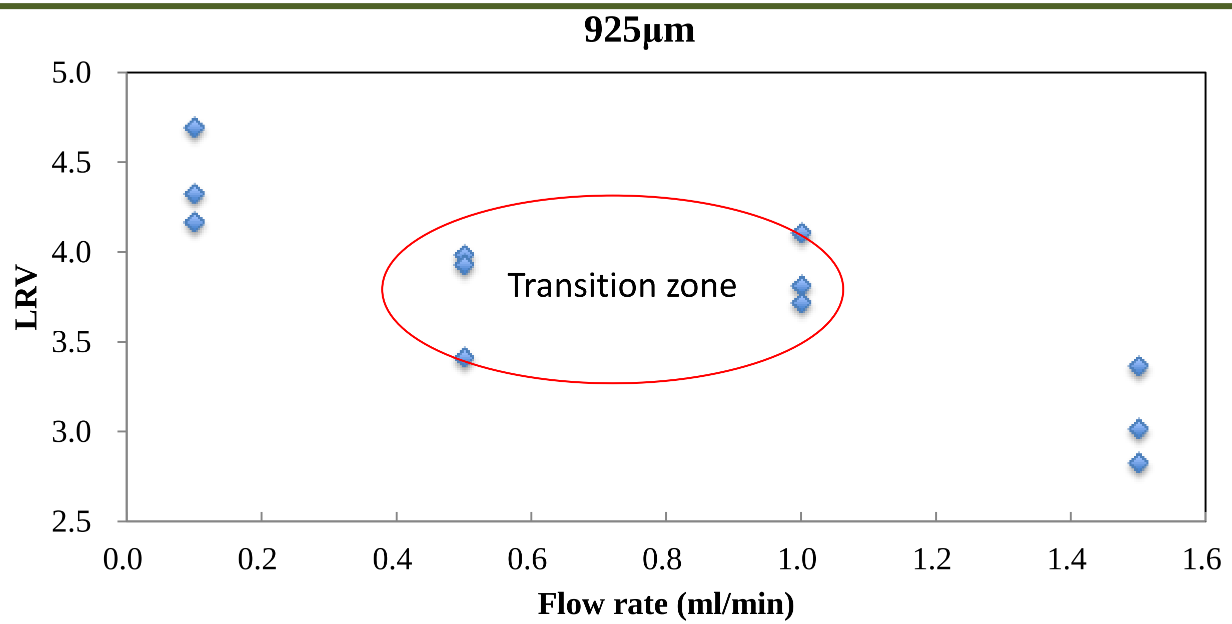


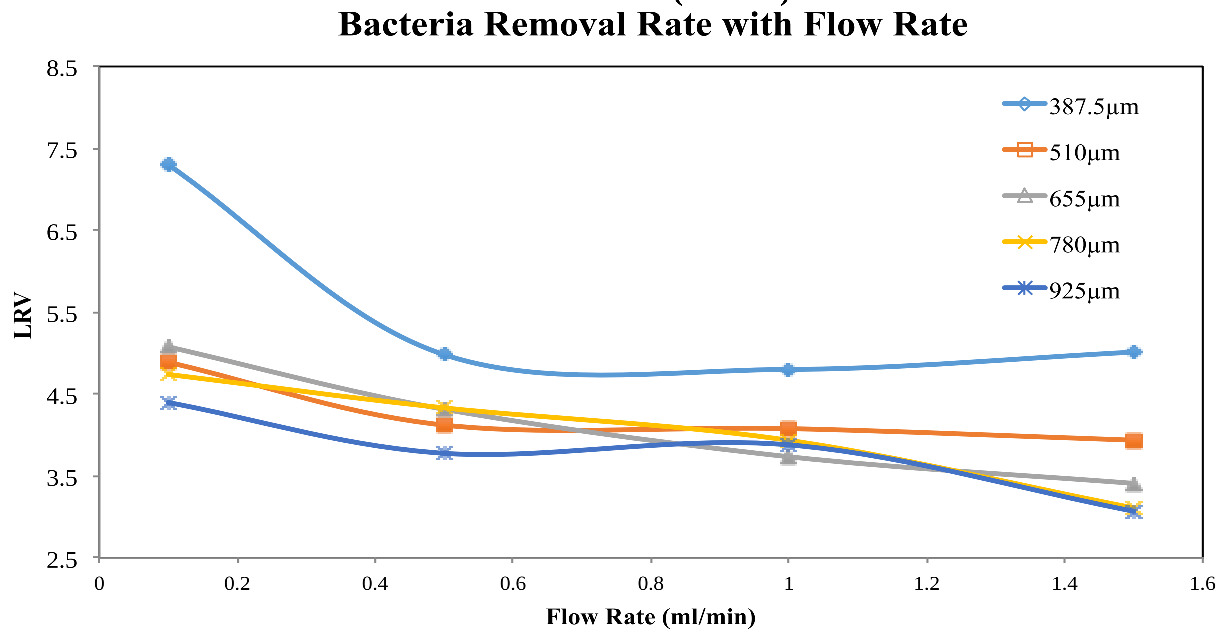


Group M

A linear correlation with a negative slope between bacteria removal and flow rate.

Impact of Flow Rate on Bacteria Removal





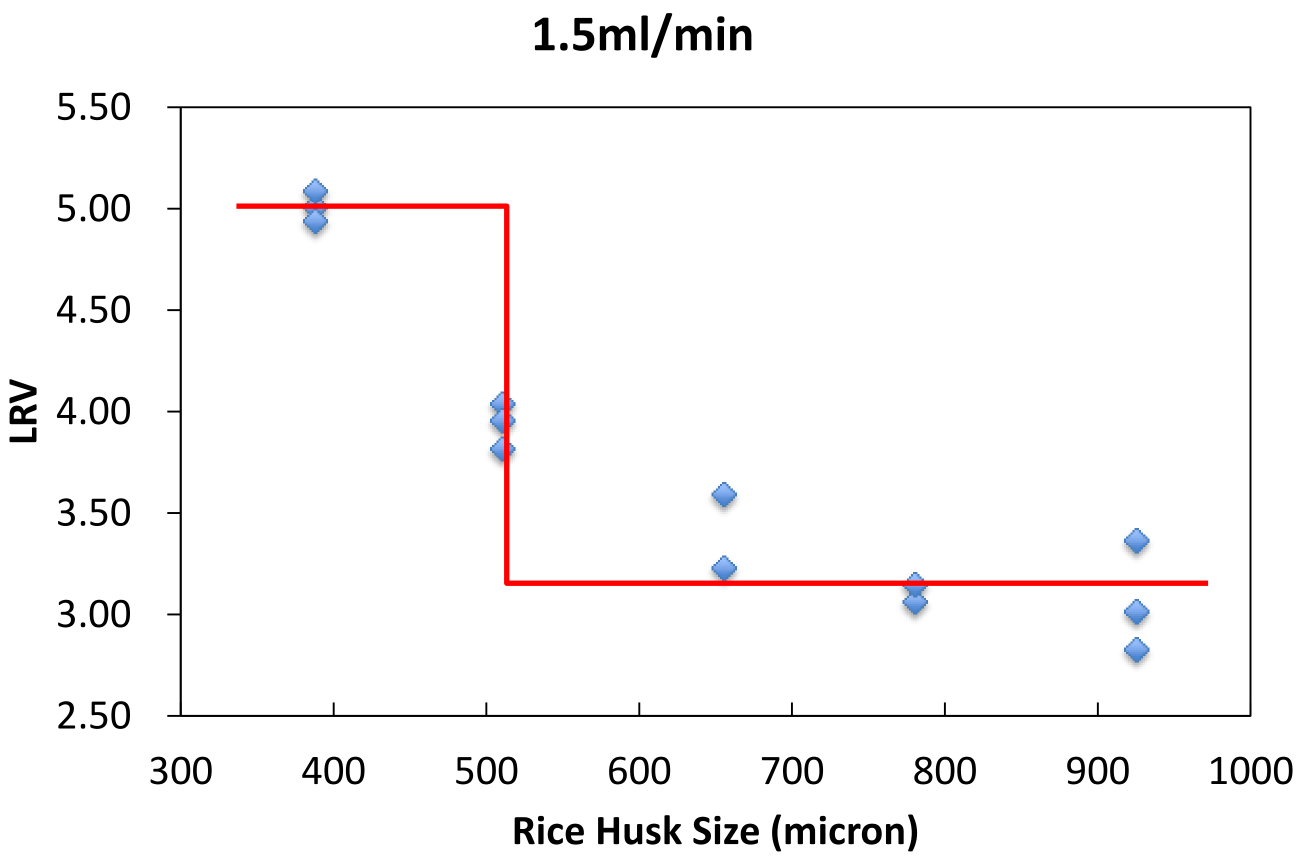
Group M

Transition zone from about 0.5mL/min to 1.0mL/min

Rice husk size is small: impact of flow rate is significant
Rice husk size is large: impact of flow rate is not significant

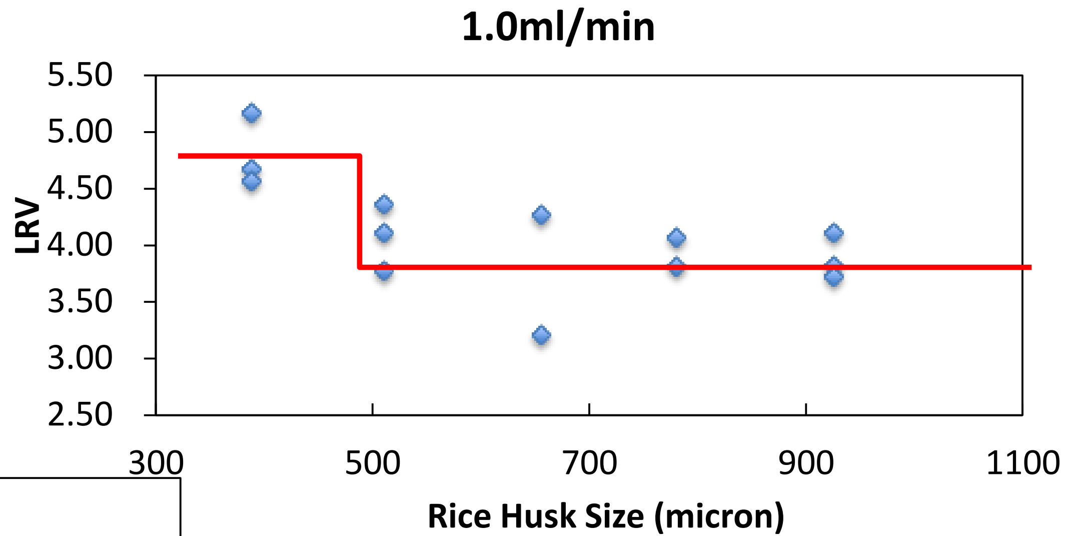
Impact of Rice Husk Size on Bacteria Removal

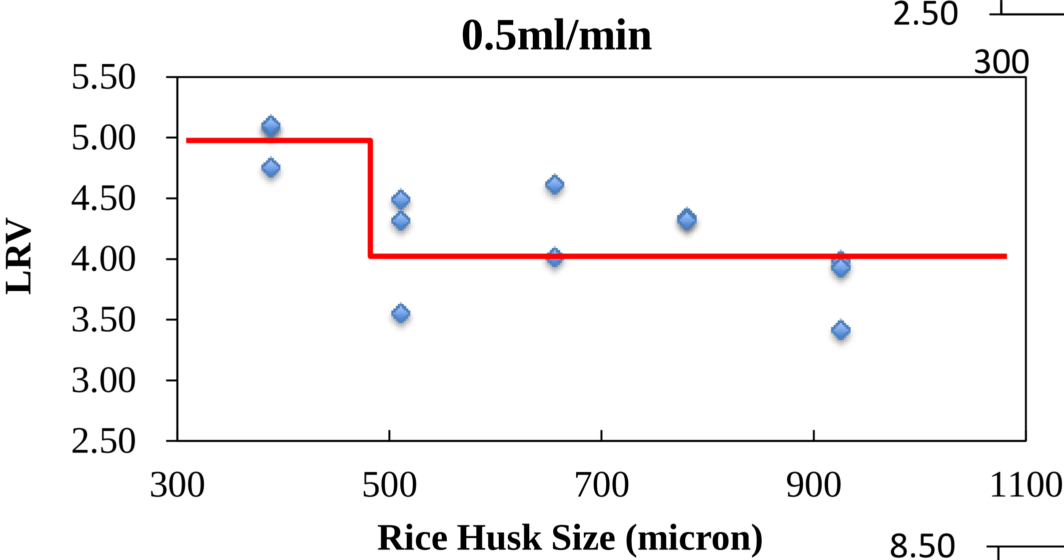
Group M



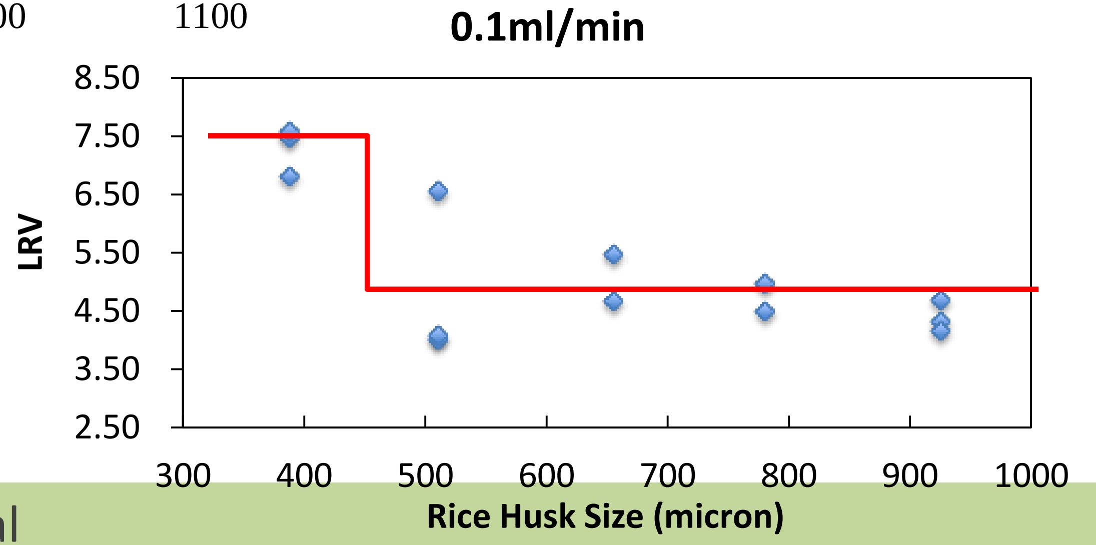
Transition occurs at a rice husk size of about **500 µm**.

Group M



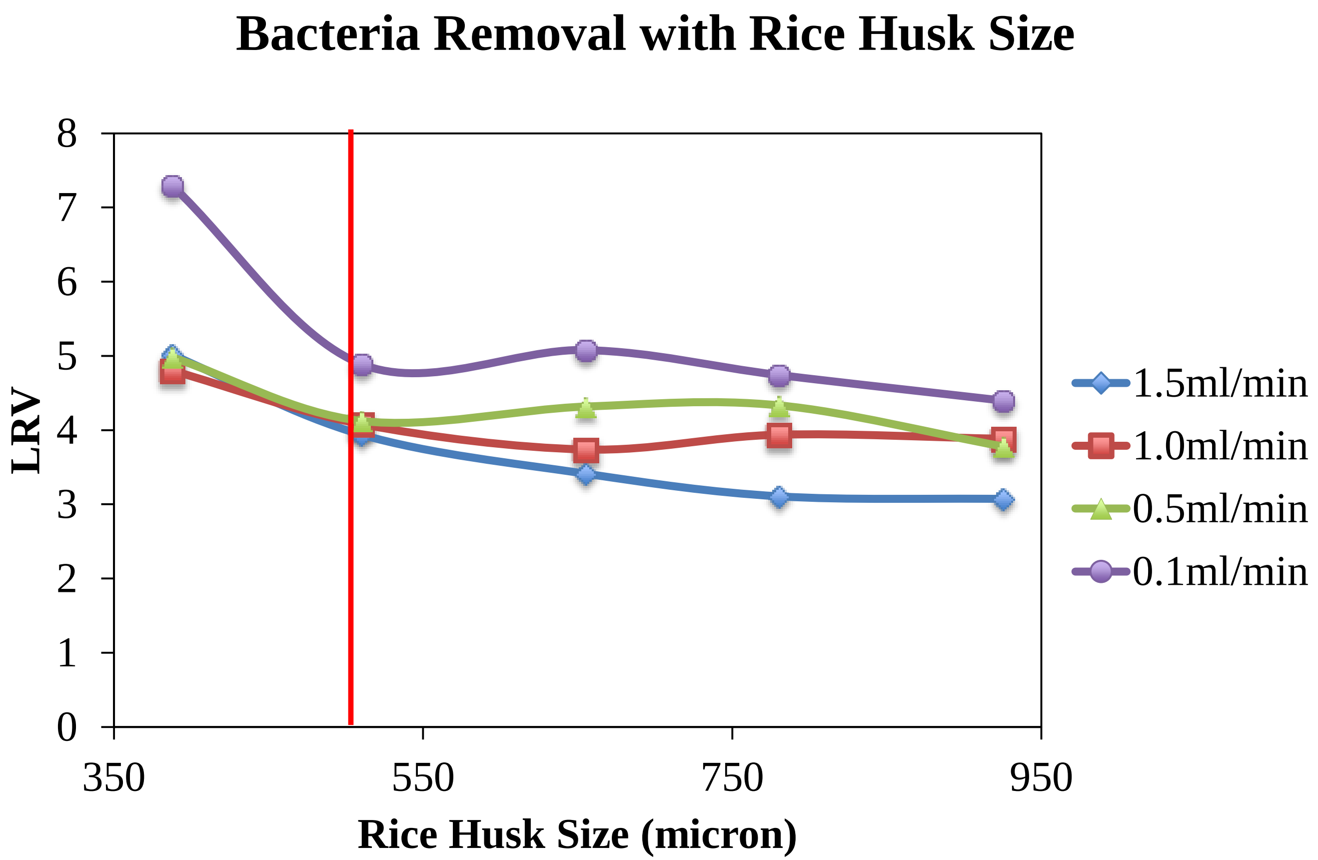


Transition occurs at a rice husk size of about **450 µm**.



Impact of Rice Husk Size on Bacteria Removal

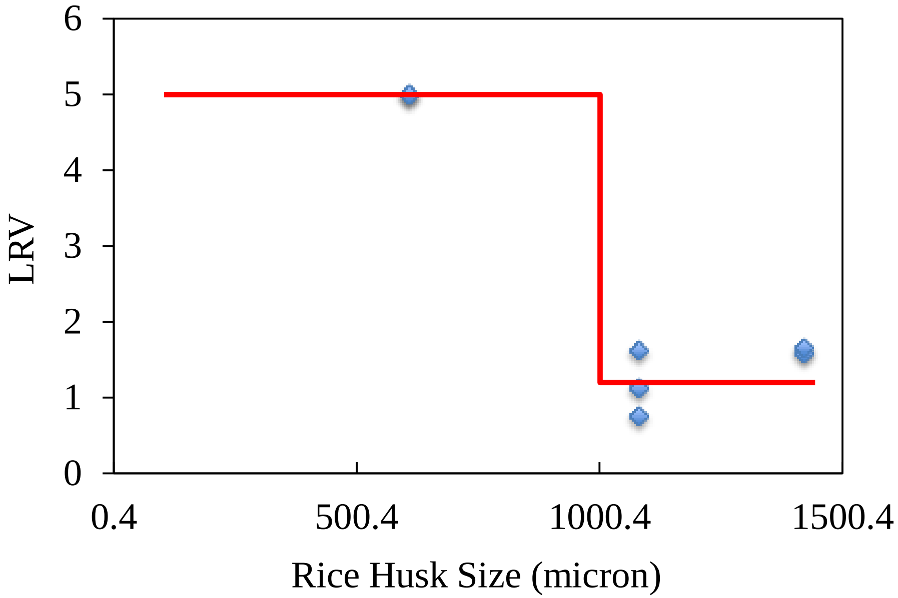
Group M



RHS<500μm, the impact of RHS is significant; 500μm<RHS<950μm, the impact of RHS is small

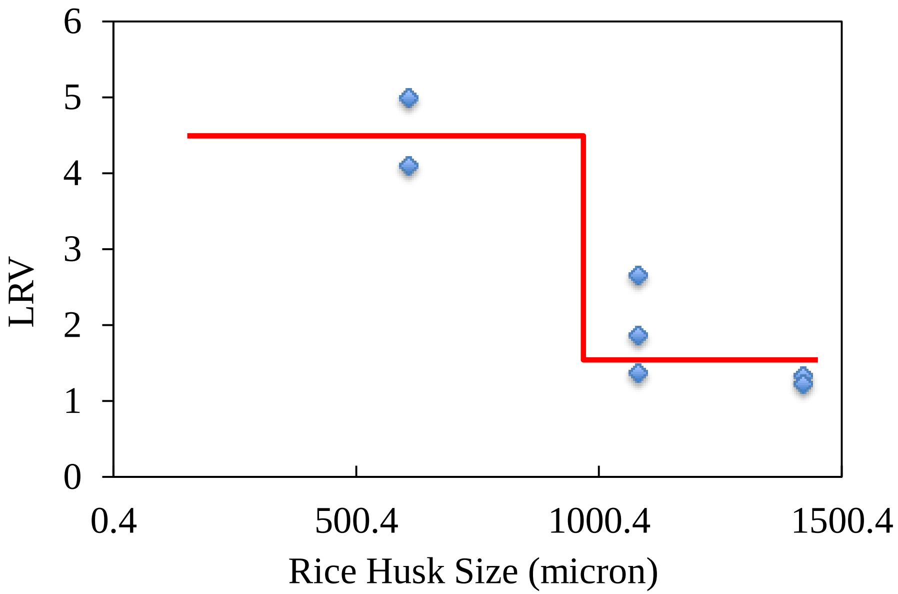
Impact of Rice Husk Size on Bacteria Removal

Group T_F



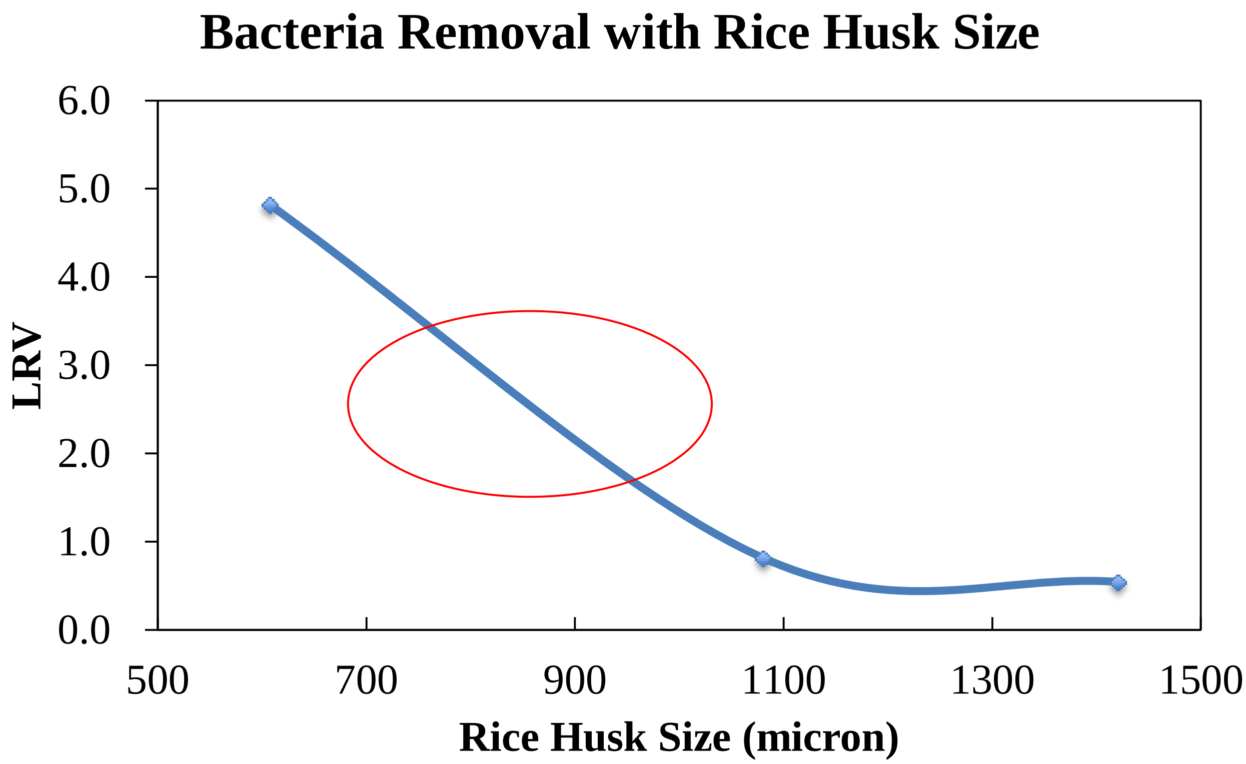
Transition occurs at a rice husk size of about **1000 μm**.

Group T_P



Impact of Rice Husk Size on Bacteria Removal

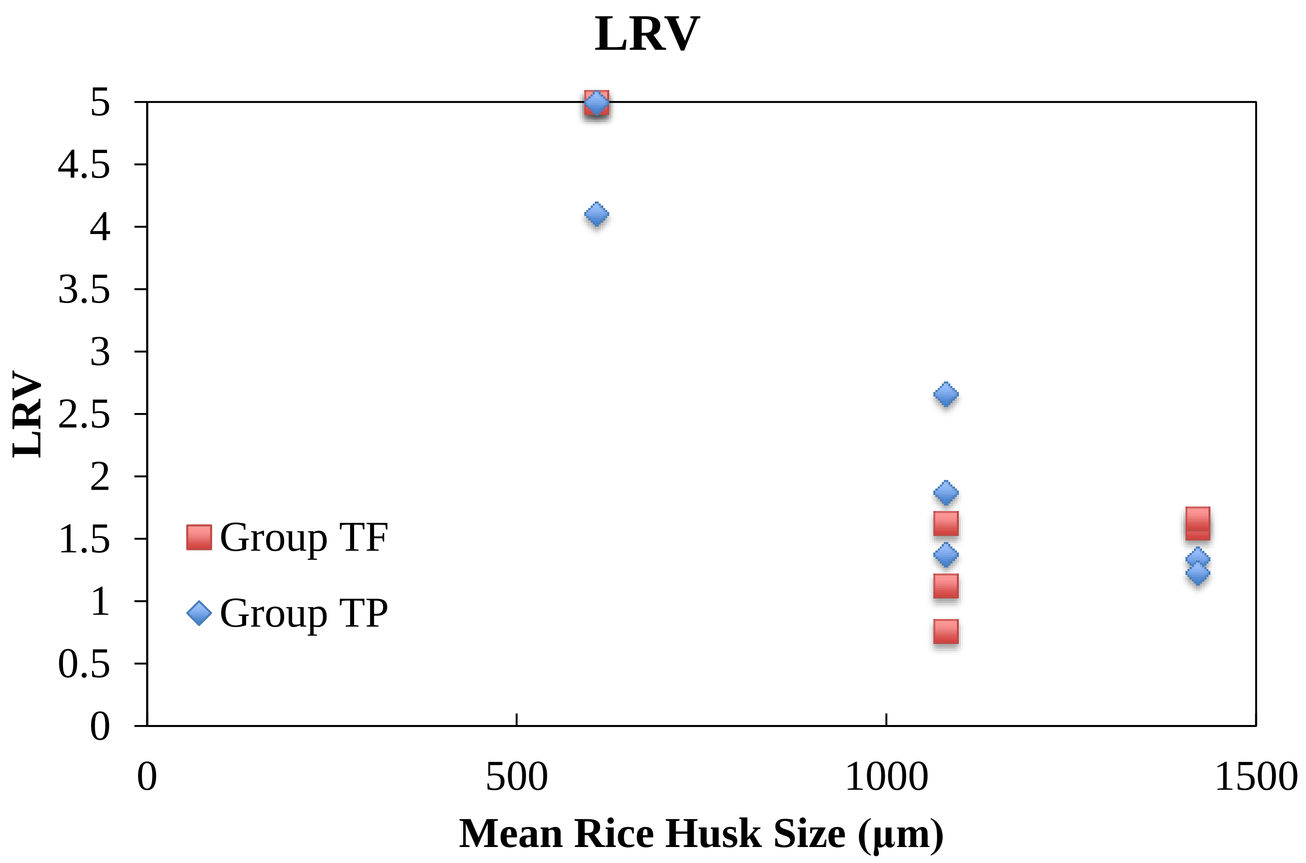
Full-Size Filter



Transition zone is between **600 - 1000 µm**

Impact of Rice Husk Size on Bacteria Removal

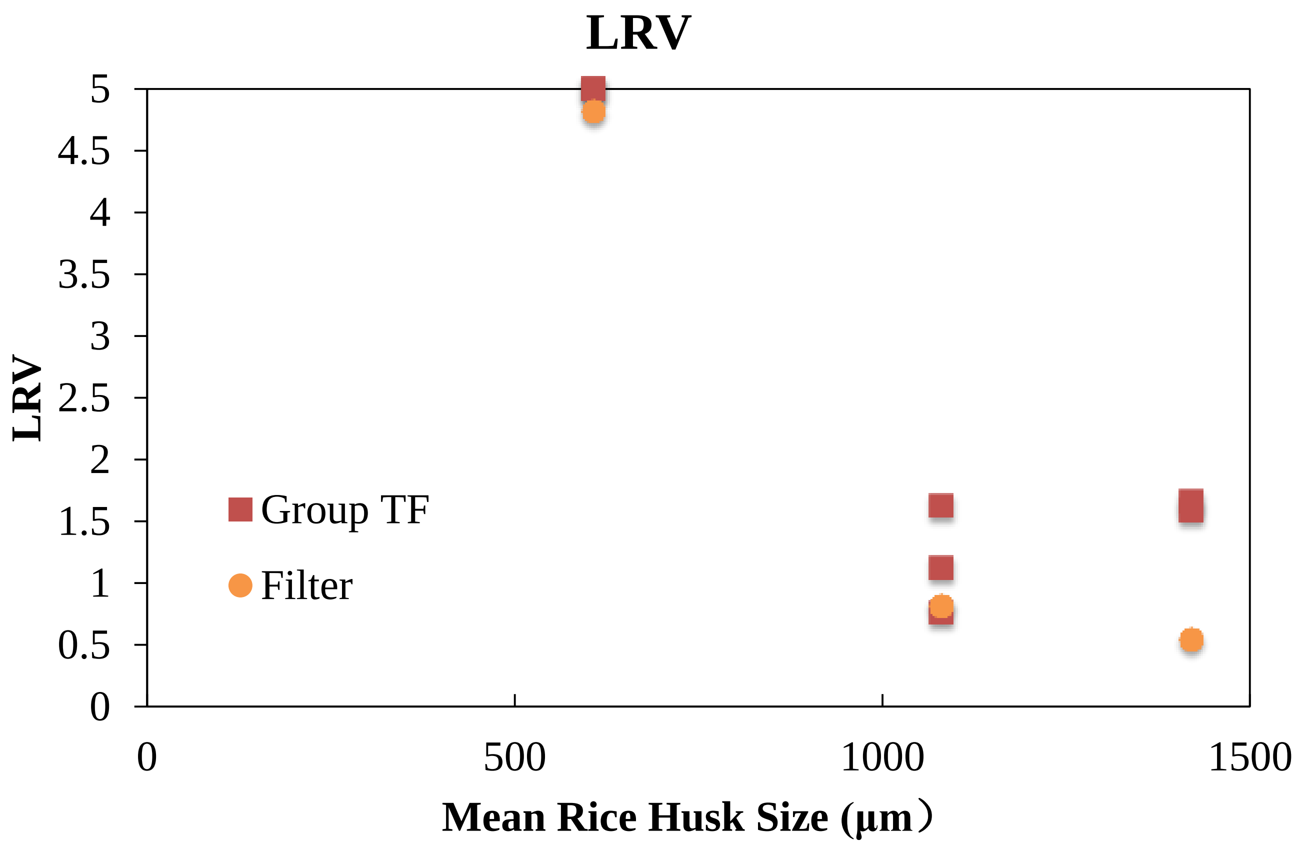
Comparison between T_F and T_P



The bacteria removal rates are almost the same

Impact of Rice Husk Size on Bacteria Removal

Comparison between T_F and Filter



As RHS become larger, the difference is more significant.

Conclusion

Flow rate:

- A positive correlation between hydraulic conductivity and rice husk size: exponential relationship
- The only factor affecting the flow rate of full size filters is rice husk size.

Bacteria removal:

- A negative correlation of bacteria removal and **flow rate**: a transition zone exists. When rice husk size is large, the influence of flow rate is not significant, and when rice husk size is small, the influence of flow rate is significant.

- Group M: When rice husk size <510μm， **bacteria removal** decreases dramatically when rice husk size increases. When rice husk size is 510-920μm, bacteria removal remains almost stable.
- Group T_P, T_F, Filter: transition happens when rice husk size is 1100μm.

Recommendation

For manufacturers:

- Use rice husks with smaller sizes. ~1100μm. Both ensure flow rate and bacteria removal.

For continuing research:

- Expand the range of rice husk size (200 to 1600μm) and find the two transitions.
- Considering the E. coli concentration of the influents, we suggest using concentration similar to real dug out water.

Household Water Treatment & Storage (HWTS) Alternatives for Ghana

Wong Teng Ke

High-end household water treatment Alternatives for Ghana

Goal

To help PHW design and develop
a new household water treatment and storage (HWTS) product
targeted at the middle and high-income family
that would generate additional capital for PHW's existing product
"AfriClay Filter".

Task

- Determine whether there is a market / need for HWTS product in middle and high-income family
- Examine consumer preference on HWTS products
- Characterize challenges to HWTS adoption

Task 1: Determine market / need for HWTS product

Qualitative questions

- “What is your main water source?”
- “How often does the water flow to your house?”
- “How do you store your water?”

Water storage devices

Quantitative testing

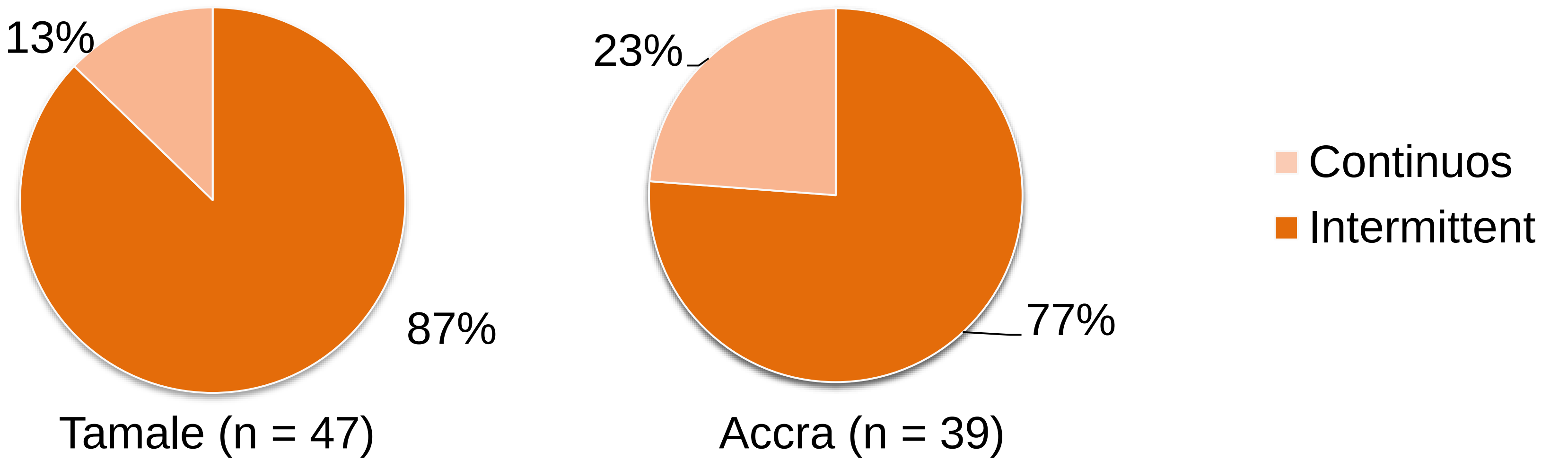
- *E. coli*
- Total coliform
- Chlorine residual

Bacteriological Test: EC kit

Hach Pocket Colorimeter II

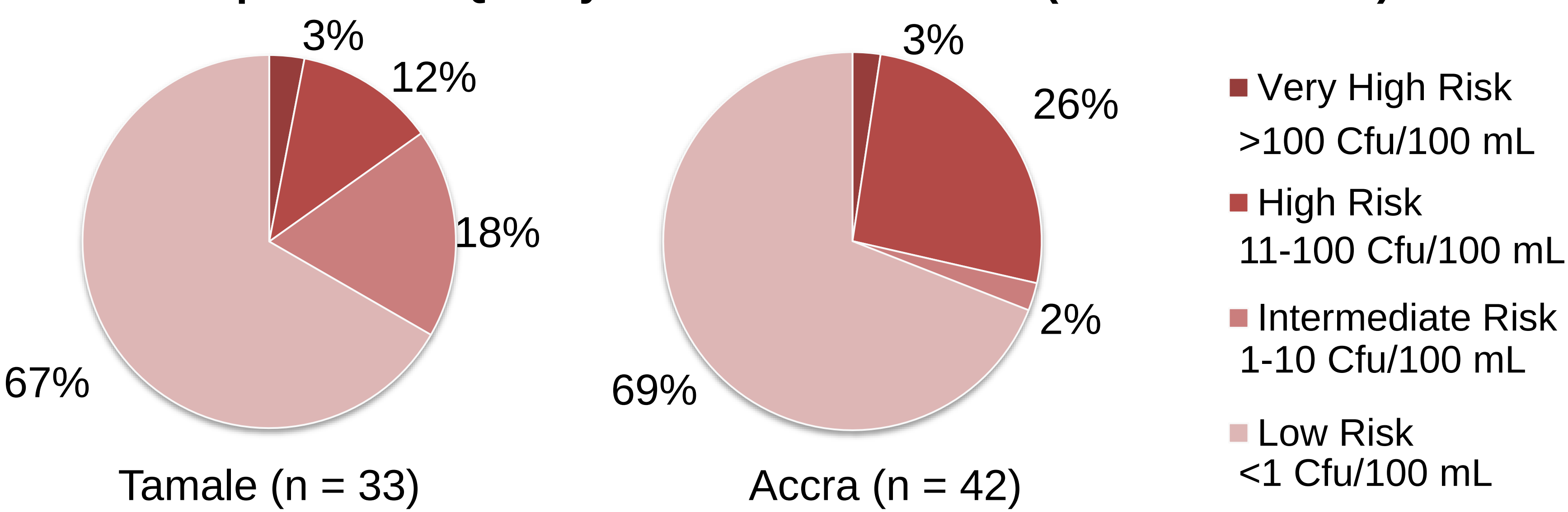
Task 1: Determine market / need for HWTS product

Piped Water Supply in Tamale and Accra (Qualitative questions)



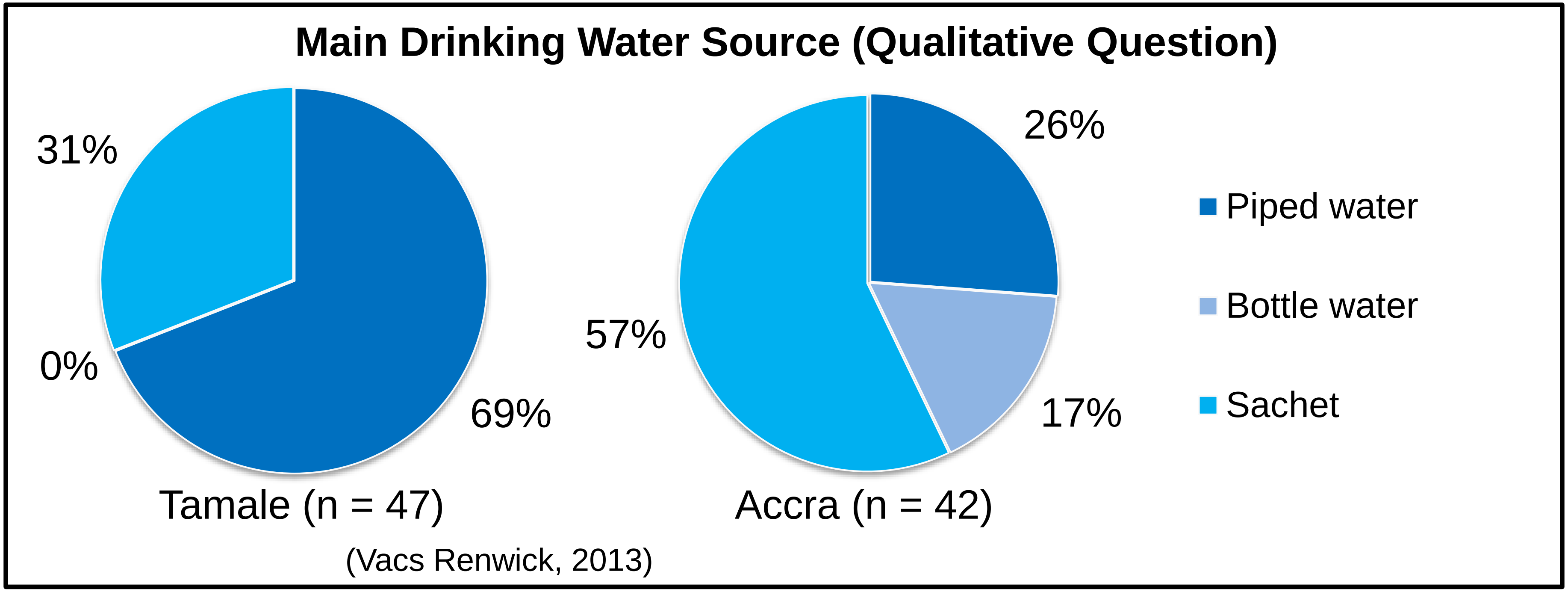
(Vacs Renwick, 2013)

Piped Water Quality in Tamale and Accra (*E.Coli* Indicator)



(Vacs Renwick, 2013)

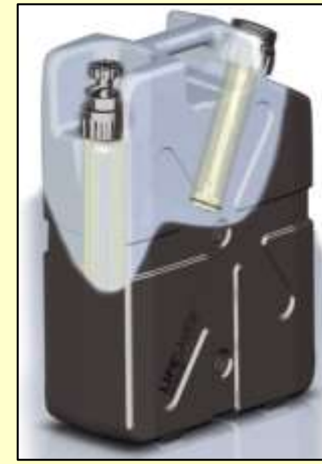
Task 1: Determine market / need for HWTS product



Sachet Water

- Cheap (USD 0.05 per 500 mL)
- Not necessarily cleaner than tap water (Okioga, 2007)
- Massive plastic waste generator
- Prevalence among users poses barrier to entry of HWTS

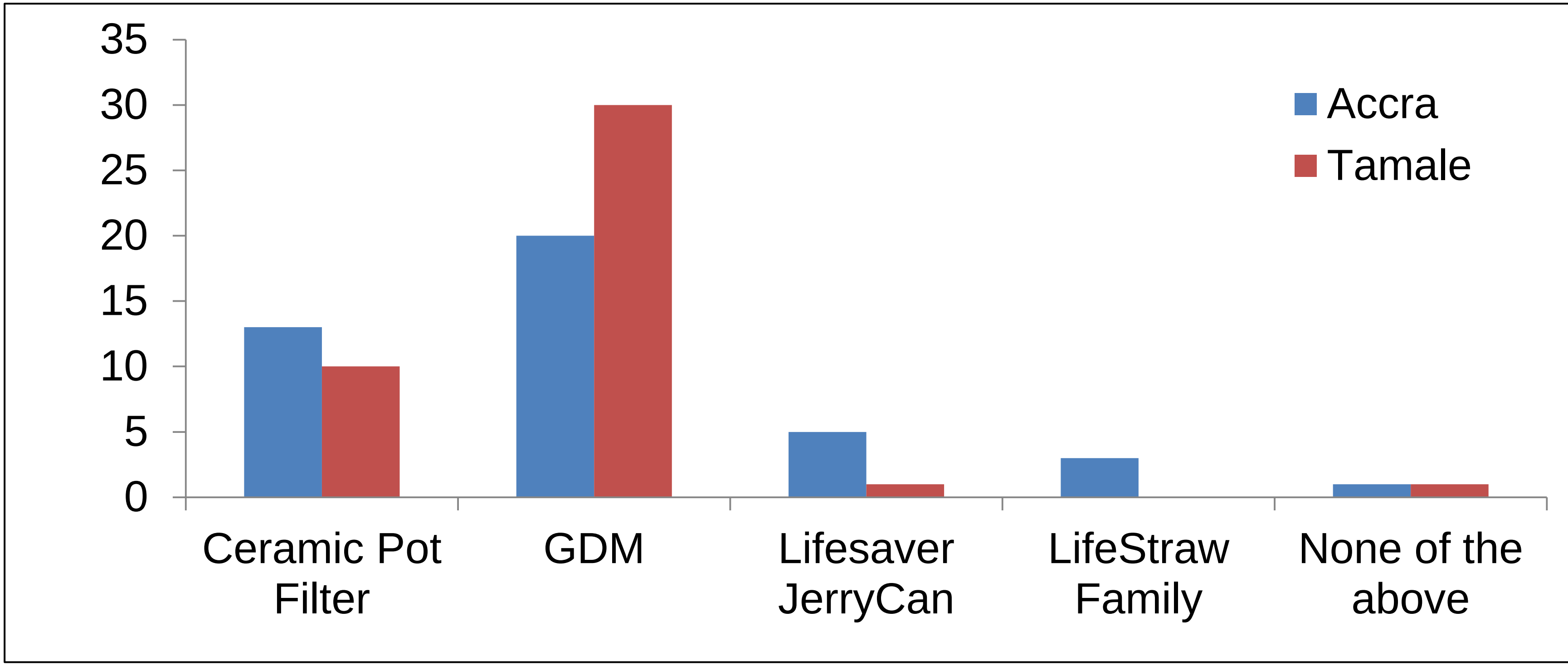
Task 2: Examine consumer preference on potential HWTS products

	(A) Ceramic pot filter	**(B) Gravity Driven Membrane**	**(C) LifeStraw Family**	**(D) LifeSaver Jerry Can**
				
Operation	Water is poured into the upper vessel and let it slowly passed through the ceramic. Weekly cleaning of the ceramic is recommended.	Water is poured into the upper vessel and let it slowly passed through the membrane . Minimum cleaning is needed	Water is poured into the upper vessel and let it slowly passed through the membrane. Daily cleaning through flushing and pumping is recommended.	Water is poured into can. Applying pressure through hand pump. Turn on the tap and use clean water from outlet. Minumum cleaning is needed.
Time to treat 1 liter	45 min ~ 1 hour	30 min	10 min	Less than 1 min
Storage capacity	5 ~10 liters	5 ~10 liters	None. Separate storage required.	None. Separate storage for clean water is required.
Life Span	1 ~ 4 years	3 ~ 4 years	2 ~ 3 years	3 ~ 4 years

Task 2: Consumer HWTS products preference

Qualitative questions

- Which product do you prefer?



- Reasons given

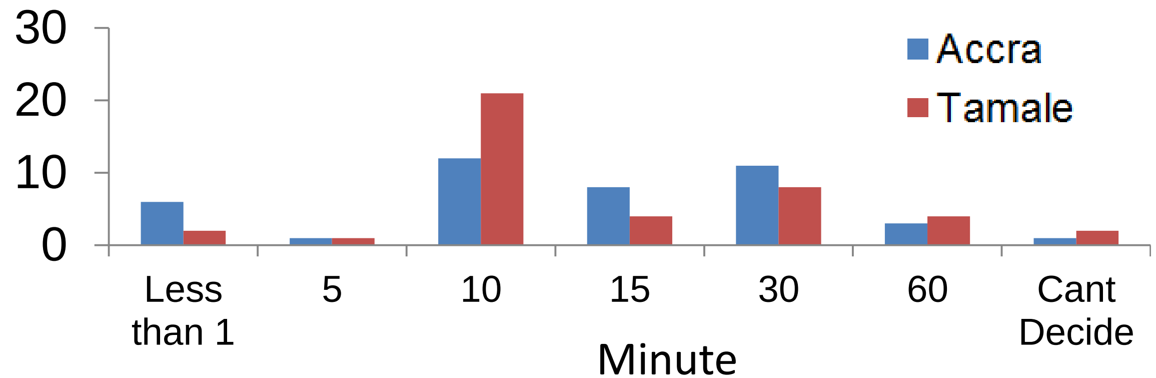
GDM : Minimum Cleaning Required; Size; Easy to use; Transparent Container; Mechanism

Ceramic Pot Filter : Frequent Cleaning; Easy to use; Size

Task 2: Consumer HWTS feature preference

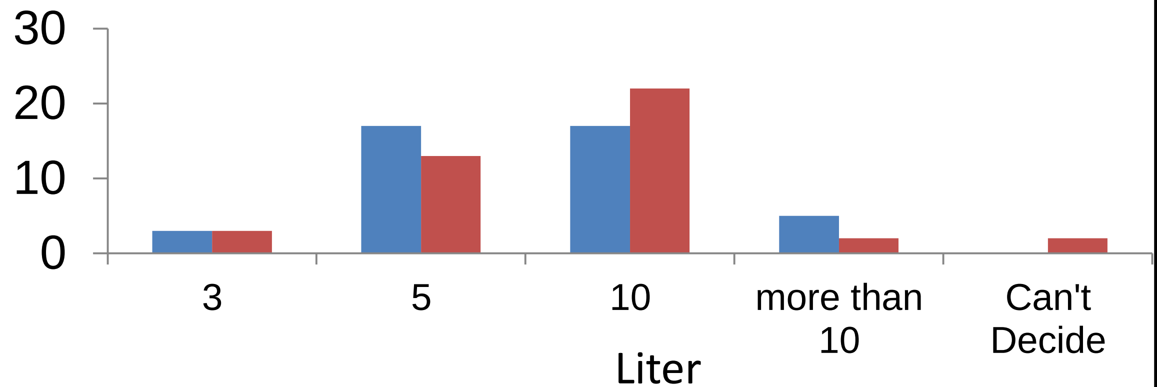
Time to treat 1L of water

Accra : 18 minute
Tamale : 18 minute



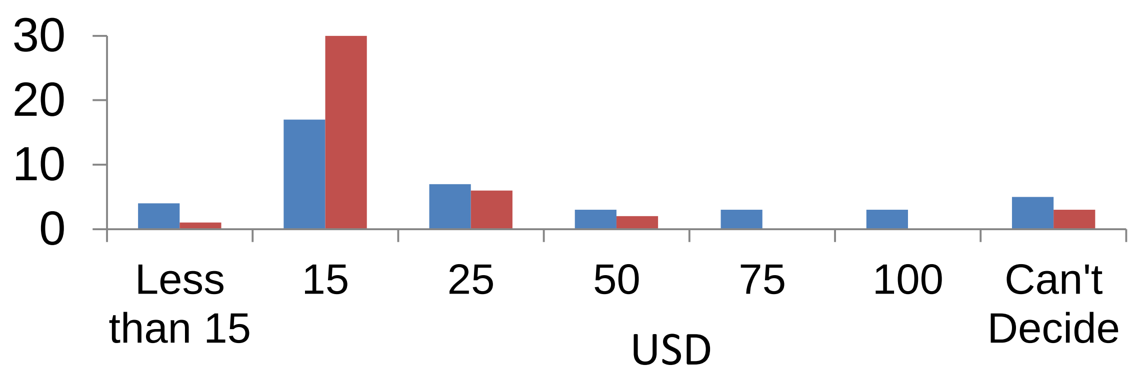
Size

Accra : 8 L
Tamale : 8 L



Willingness to Pay (WTP)

Accra : USD 30
Tamale : USD 18



Task 3: Characterize challenges to HWTS product adaption

Table 1. Unit Performance Test :Coliform Bacteria and *E.coli*

Day	Total Coliform (Cfu / 100 mL)				*E.Coli* (Cfu / 100 mL)			
	Location 1		Location 2		Location 1		Location 2	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
1	1700	0	500	0	200	0	200	0
3	1400	0	300	0	100	0	100	0
5	2000	0	700	0	0	0	200	0
7	1300	0	1000	0	200	0	0	0
20	5000	0	1200	0	0	0	0	0
21	4000	0	800	0	100	0	0	0

User Feedback

Change of water quality? No, except temperature.

Size is enough for your family? Yes, it is enough.

Willingness to Pay? User 01: USD15 → USD 50
User 02: USD 25 → USD 50

Conclusion

Task 1. Determine market / need for HWTS product

- There is a need and market for HWTS product even for middle and high income family who has access to piped water.

- However, the dominance of sachet water in the drinking water market poses a major barrier to the entrance of HWTS.

Task 2. Examine consumer preference on potential HWTS products

- GDM is the most preferred HWTS product in Tamale and Accra.
- Reasons given include: Easy to use; minimum maintenance; transparent
- Preferable features:
  Price : USD 18 ~ 30
  Time to treat 1L of water : 18 min
  Size : 8 L

Conclusion

Task 3. Characterize challenges to HWTS product

- LifeSaver JerryCan filtered contaminated water effectively.
- User willing to pay more once experienced the benefit of the product

Recommendation

PHW may either partnered with (EAWAG) selling GDM as its high-end product, or take the recommended product features forward to further develop its own product.

Product price can be set higher than 30 USD. However, payment via monthly installment with minimum initial investment is recommended to allow user to have first-hand experience and gradually grow confidence in the product.

Questions?

Sanitation Innovation Projects in Ghana

Jason Knutson

Credit: Charlie Jackson 2014

Background:
Ghana's Sanitation in Context

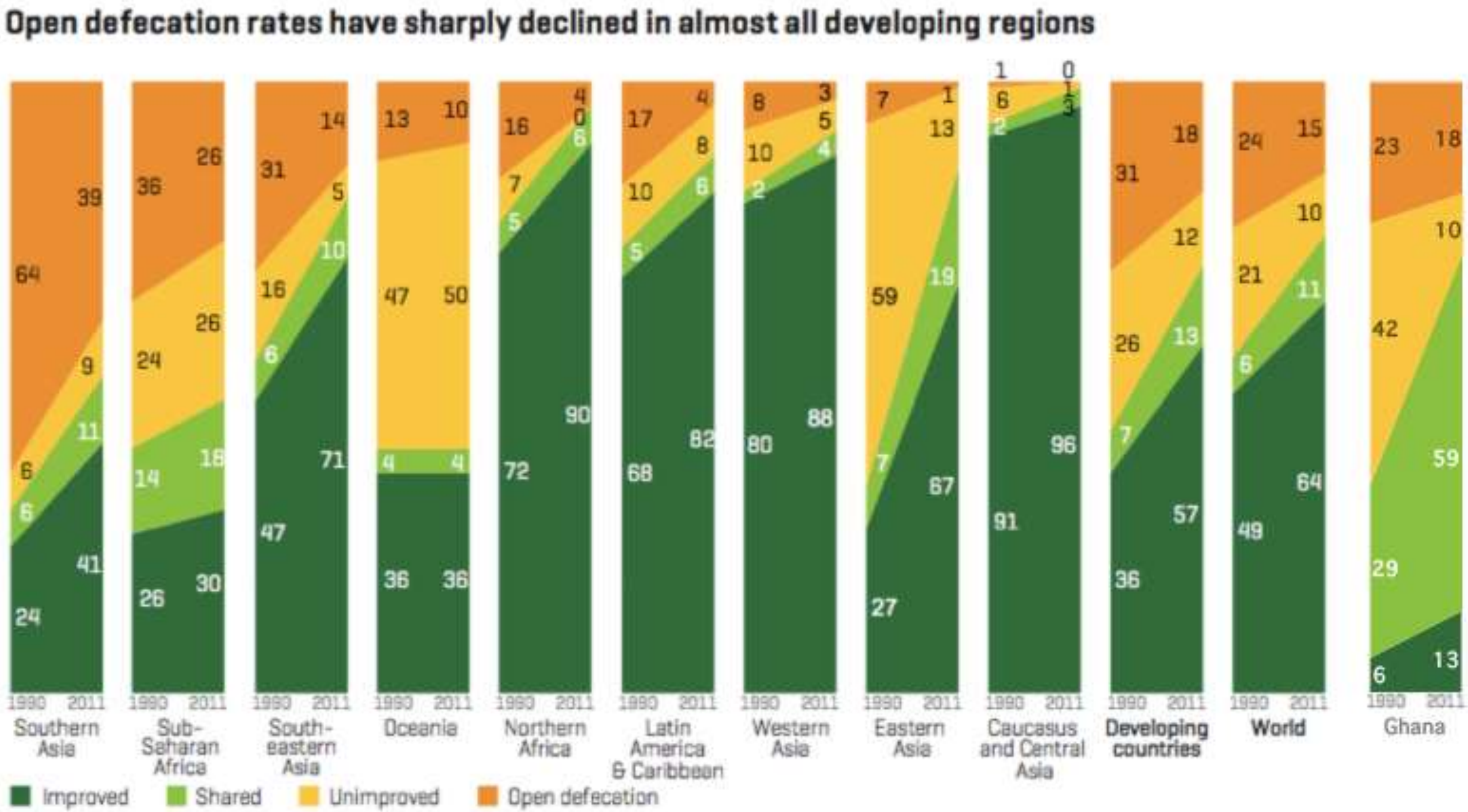


Figure 1: Sanitation coverage trends by developing regions and the world, 1990-2011 (WHO/UNICEF JMP Progress on Sanitation… 2013)

Public Toilets in Ghana

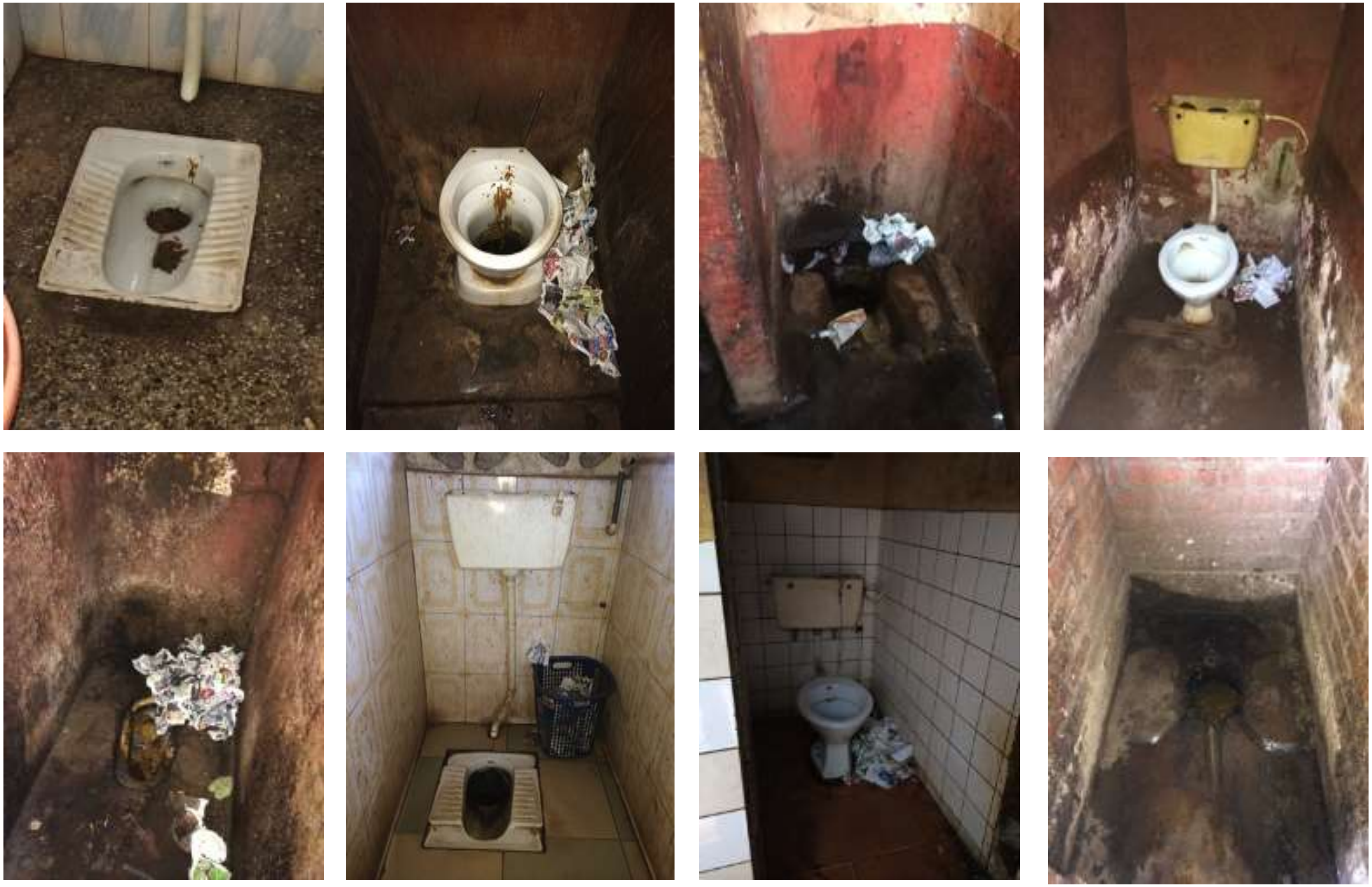
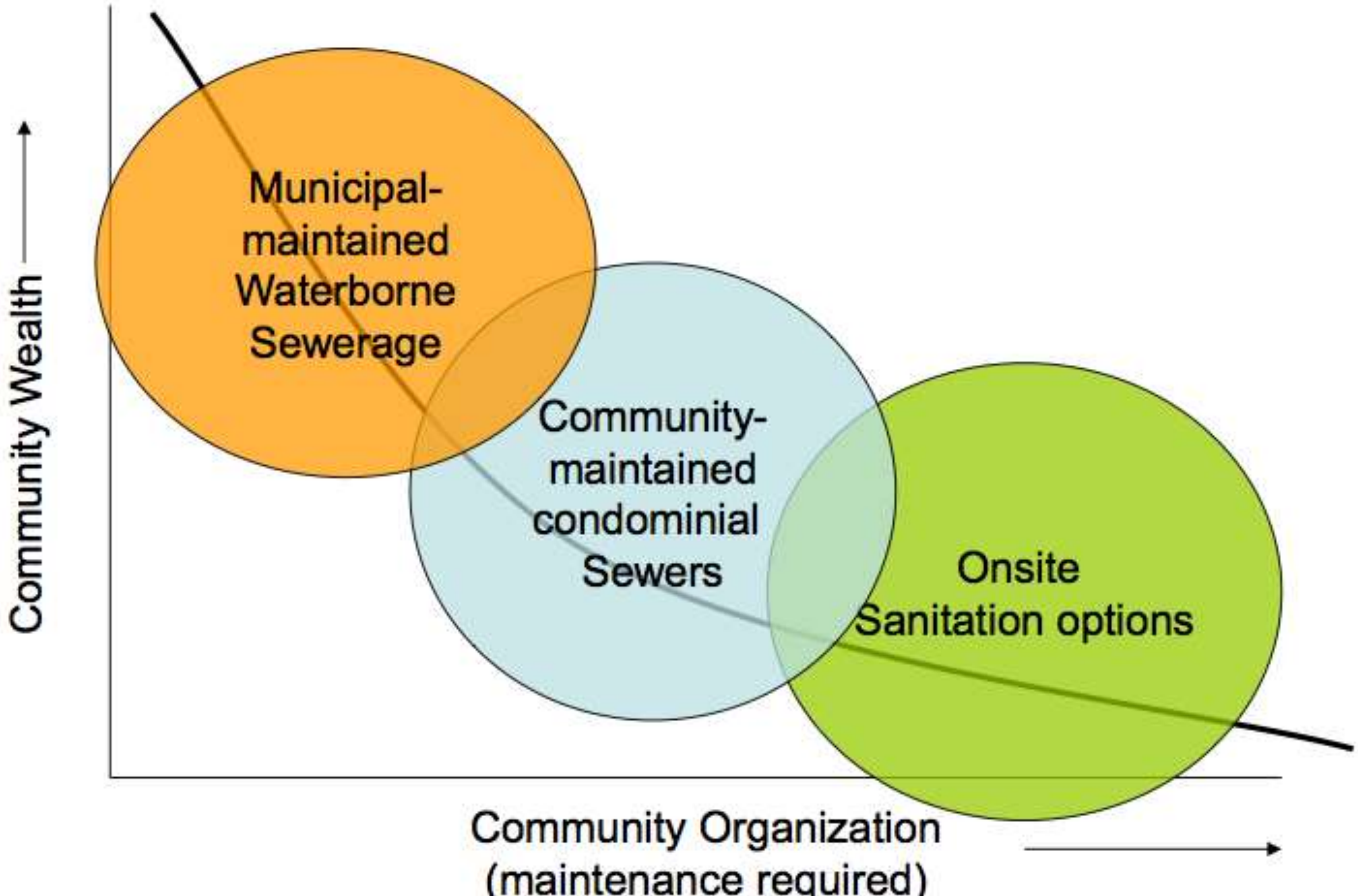


Figure 70: A look in on the condition of public sanitation in CTT's service area in Kumasi (Knutson 2014).

Concept

- Even though 82% of Ghanaians have access to some toilet (only 13% improved), most of the waste is untreated
- 90% of waste is discharged with no treatment in developing countries
- Goal: Convert waste into a resource using innovative on-site sanitation

Community Factors that affect sanitation options



Source: Murcott

Goals

- Evaluate the feasibility/scalability of a variety of sanitation innovations in terms of:
  - Sanitation Outcomes
  - Technology
  - Business Models

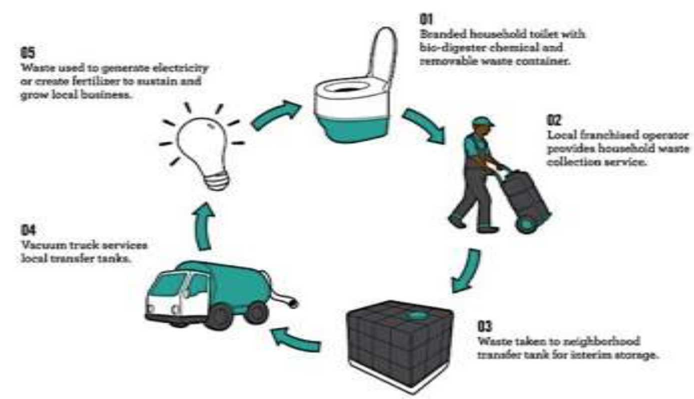
Innovative Sanitation Projects

- Microflush Biofil
- Microbial Fuel Cell
- Clean Team Toilets
- Pour Flush (Taha School)
- Fortified Excreta Pelletizer
- Anaerobic Waste Digester

A

B

C



F

Photo Credits: Keith Tanner (A, B), WSUP (C), Susan Murcott (D)

Biofil Toilet

- Price: US $1520 ($870)
- Input: 150 mL water, sewage
- Output: Humus
- Capacity: 10 uses/day
- High-end product applicable in areas with no sewer

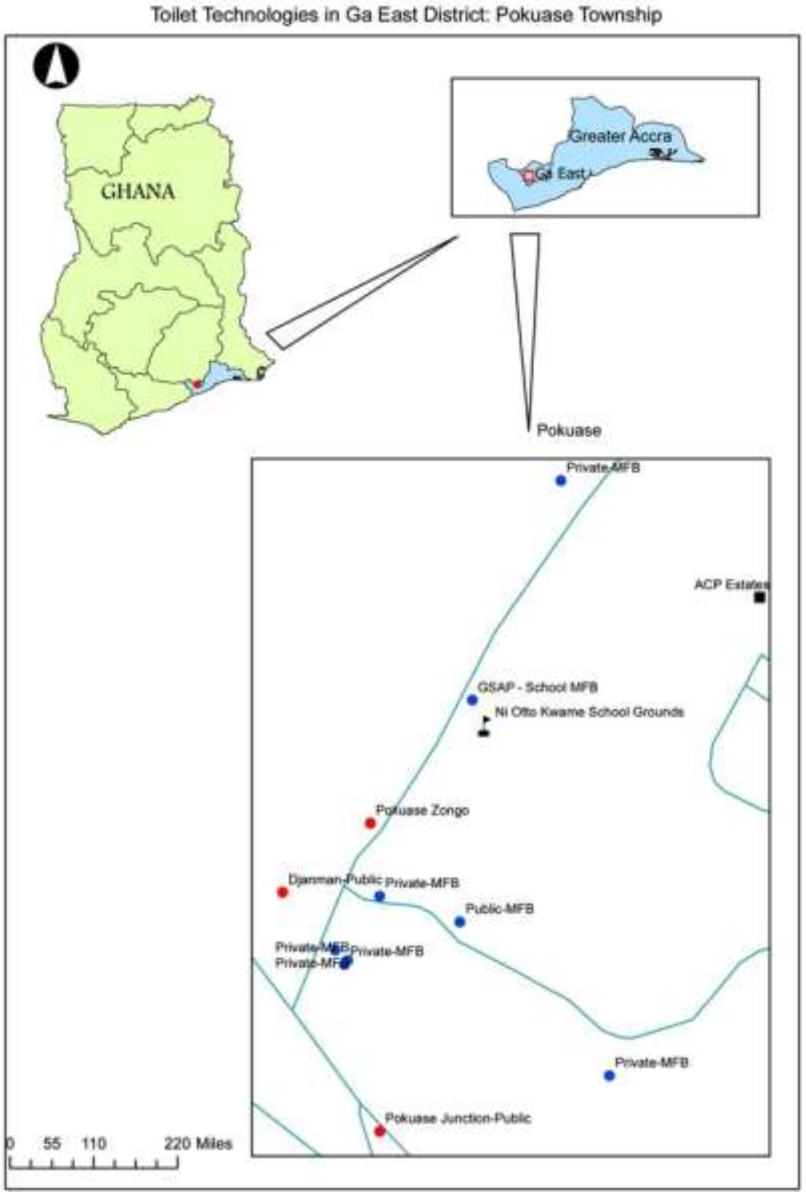
Pros	Cons
Never empty tank – need not be near road	Design not simple enough for public use
More functional, less smelly tank than MFBF	More expensive than MFBF, no loan program
Private business: 4000+ toilets, 25 employees	Requires water and education/demonstration

Microflush Biofil

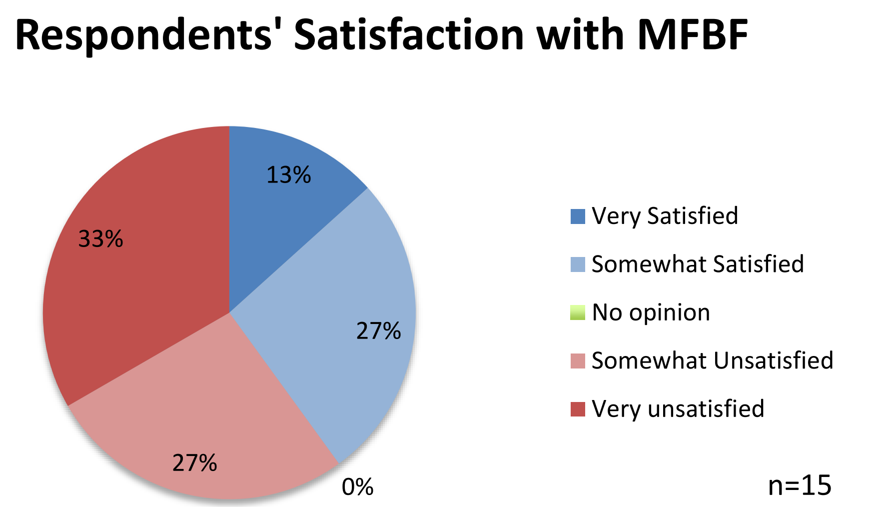
- Price: US $300
- Input: 150mL water, sewage
- Output: Humus (rarely)
- Capacity 30 uses/day
- Low/middle-end product applicable in peri-urban settings as a shared toilet

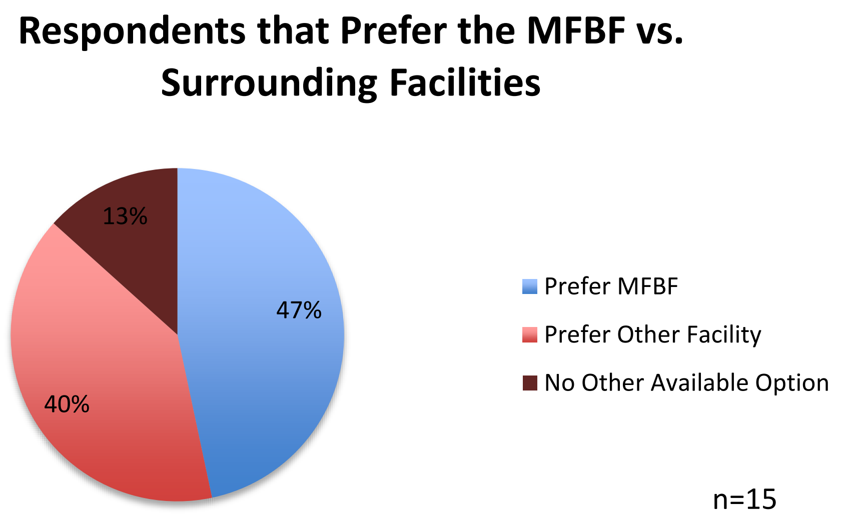
Pros	Cons
Converts waste to compost on site	Design not simple enough for public use
Flush-integrated sink promotes hand washing	Requires piped water and waste removal
Water seal reduces odors and flies	Requires education/demonstration

Public Microflush Biofil Case Study



This map indicates the locations of each of GSAP's Microflush Biofil toilets in Pokuase (blue dots) and of other public toilets (red dots). Credit: Chipo Mubambe





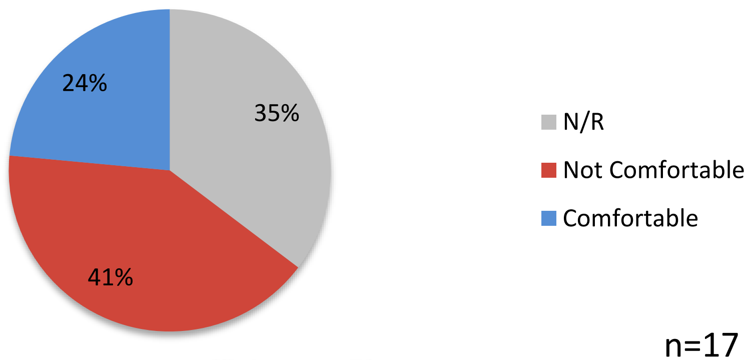
Microbial Fuel Cell

- Price: US $1900
- Input: Sewage + Wood Ash
- Output: Electricity + Humus
- In need of further development
- Most applicable in urban areas where toilet access after dark is dangerous

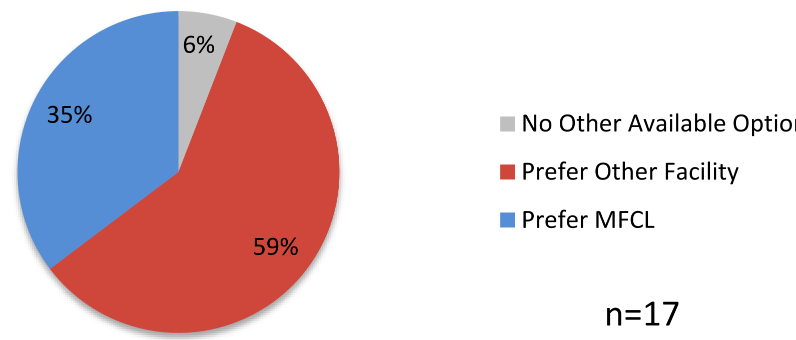
Pros	Cons
Educational pilot project	Never produced electricity (Inconsistent use)
Convert waste to fertilizer and electricity	Requires waste removal at some point
Similar to familiar KVIP or VIP units	Significant odor and nearby WCs deter users

Microbial Fuel Cell Case Study

Number of Respondents Comfortable Using the MFCL



Respondents that Prefer Another Facility



Results

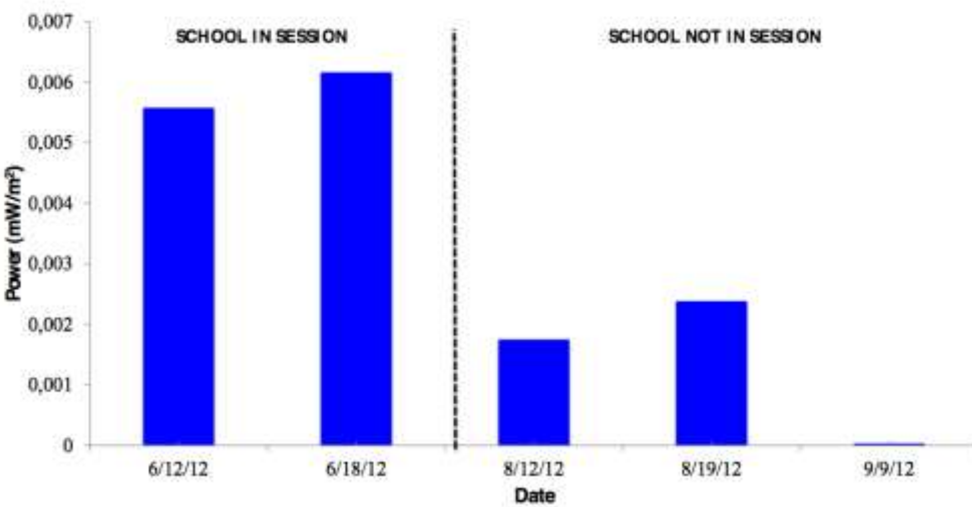
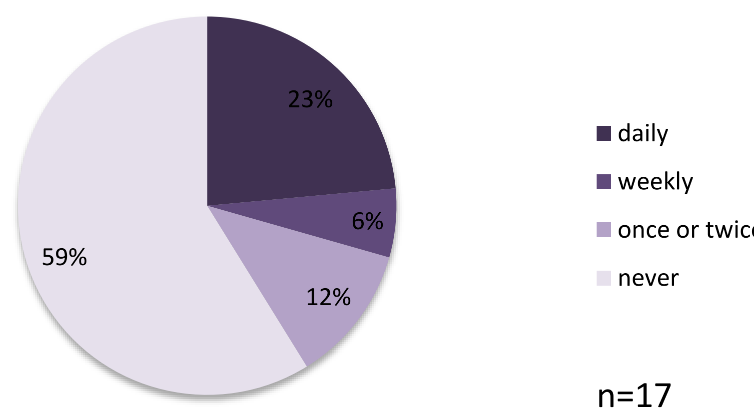


Figure 55: Power generated during the Nyastech MFCL's first three months of operation (Butler 2012). 2.5 mW were generated in a lab setting.

How Often Respondents Use the MFCL



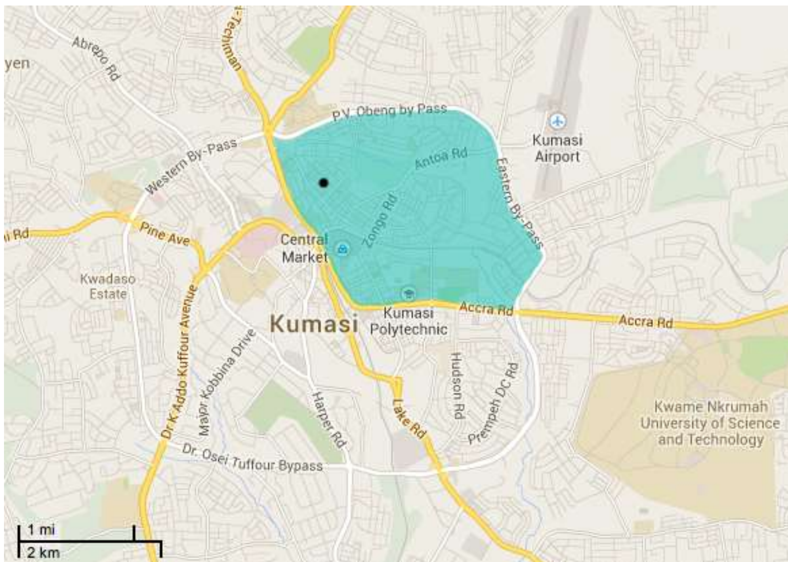
Clean Team Toilets

- Price: US$200 + labor

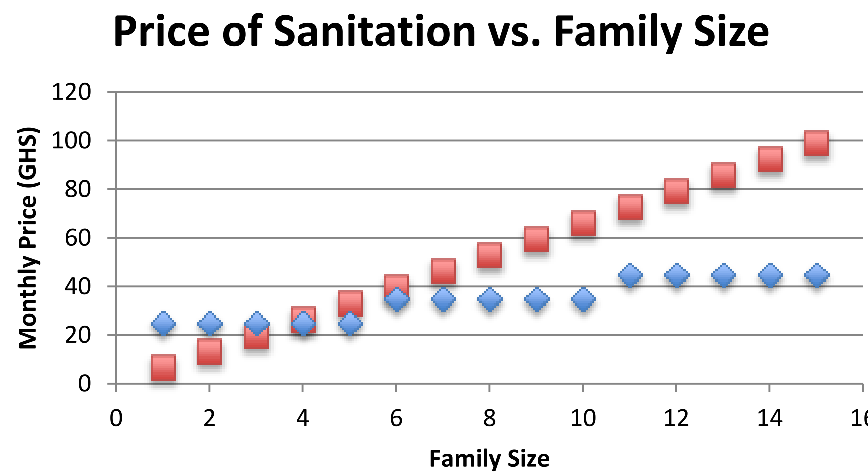
  (Subscription prices on next page)
- Input: Sewage + Glutaraldehyde
- Output: Sludge (Resource recovery in development)
- Excellent proven solution in dense urban communities

Pros	Cons
Subscription means cost distributed over time	Very labor intensive
No large on-site infrastructure	May not be affordable for low-income users
Creates respected sanitation jobs	Only feasible in dense urban areas

Clean Team Case Study



The area in teal represents the service area of CTT. The black dot is the central collection point in Ashtown.



Price of Sanitation vs. Family Size. The blue data points represent the CTT's price as a function of family size, while the red data points represent the price of public sanitation in CTT's service area.

Family Size	Collections per week	Monthly Price (GHS/US$)	Original Price (GHS/US$)
0-5	2	25 / 11.36	15 / 6.82
5-10	3	35 / 15.90	20 / 9.09
10-15	4	45 / 20.45	N/A
	Everyday	No longer available	25 / 11.36

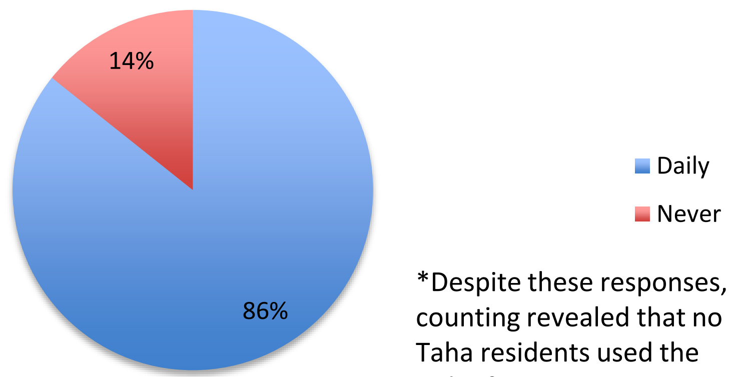
Pour Flush Toilets

- Cost: US$8,700 ($0.04/use)
- Input: Sewage
- Output: Sludge
- A common solution for communities

Pros	Cons
Standard, familiar technology	Requires Emptying
Water Seal	No resource recovery from sewage

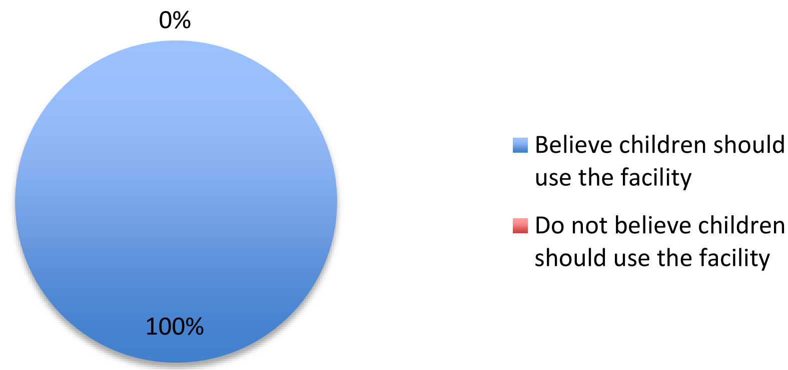
Taha School Pour Flush Block Case Study

How Often Respondents Use the Facility

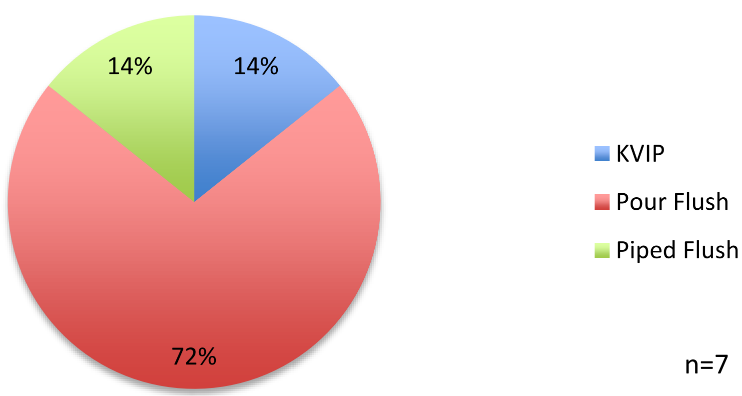


*Despite these responses, counting revealed that no Taha residents used the toilet from 6:30 AM - 11 AM.

Respondents Who Believe Children Should Use the Facility



Respondents' Preferred Toilet Types



- Observation > Interviews
- Pour Flush is most desired in Taha
- Although children do not use the PF, the community wants them to

Fortified Excreta Pelletizer

- Price: Under development
- Input: Fecal Sludge, Cassava Starch, Sawdust
- Output: Fertilizer Pellets
- Applicable in densely populated areas without sewer systems or formal waste collection/treatment

Pros	Cons
Prevents waste from being dumped in ocean	Low nitrogen content compared to inorganics
Plans to commercialize at Nungua (Tema)	Requires added inorganic fertilizer
Can serve as a solution to many toilet facilities	Fortifying starch can cause mold growth

Fortifer Case Study

Fertilizer	Nutrient wt %		
	N	P_2O_5	K_2O
Ammonia anhydrous	82		
Ammonia solution	20 - 25		
Ammonium Bicarbonate	15.5		
Ammonium Chloride	25 -27		
Ammonium Phosphate sulfate	13 - 16	20 - 39	
Ammonium Polyphosphate	10 - 11	34 - 37	
Ammonium Thiosulfate	12		
Ammonium Chloride	25 - 26		
Ammonium Nitrate	33 - 34		
Ammonium Sulfate	21		
Ammonium Sulfate Nitrate	26		
Calcium Ammonium Nitrate	20 - 28		
Calcium Cyanamide	20 - 21		
Calcium Nitrate	15		
Diammonium Phosphate	18 - 21	46 - 54	
Dicalcium phosphate		35 - 52	
Kainit			12 - 22
Monoammonium Phosphate	11	48 - 55	
Nitrogen Solution	28 - 41		
Phosphate Rock		26 - 37	
Potassium Chloride			60
Potassium Magnesium Sulfate			22
Potassium Nitrate	13		44
Potassium Sulfate			50
Slag Basic		12 - 18	
Slag Potassic			43
Superphosphate single		17 - 20	
Superphosphate triple		44 - 48	
Sodium Nitrate	16		
Urea Phosphate	17	43 - 44	
Urea	45		
Urea Ammonium Nitrate	28 - 32		
Urea Ammonium Phosphate	21 - 38	13-42	
Urea Sulfate	30 - 40		

- N-P-K Rating of Fortifer: 1.7-0.13-0.25

  (After enrichment: 3-0.13-0.25)
- Price of inorganic fertilizer: US$0.53/kg($3.12/kg N)
- Price of Fortifer to match: US$0.09/kg

Ashesi University's Small-Scale Anaerobic Waste Digester

- Price: US $60,000 for 450 users
- Input: Sewage
- Output: Methane for Cooking Gas + Water for Irrigation
- Applicable for small, private communities with central funds

Pros	Cons
Eliminates harmful effluents	Expensive capital and operation costs
Recovers gas for cooking and nutrient-rich water for irrigation	High maintenance

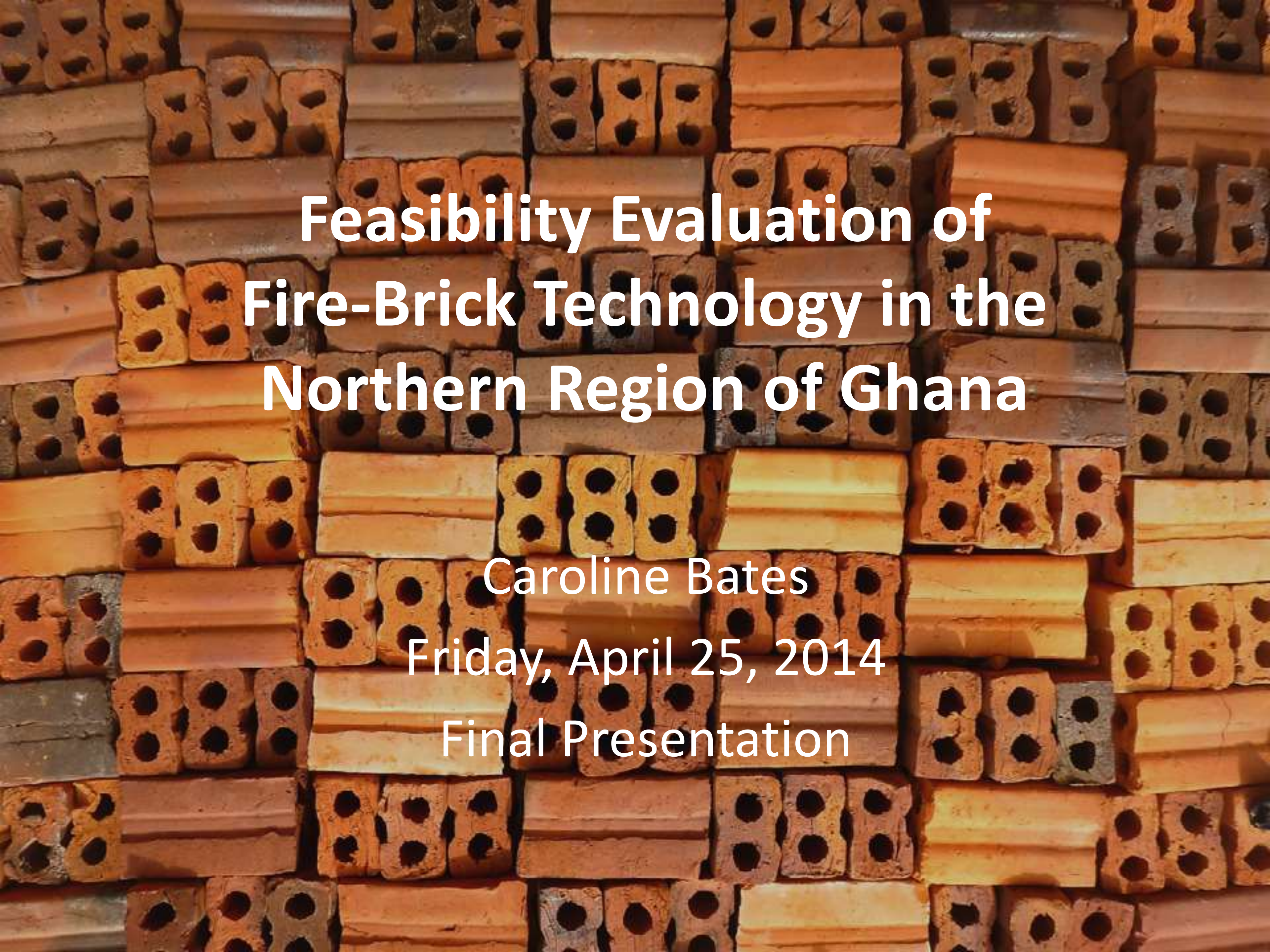
Evaluation Matrix

	Adoption	Improved	Facilitates Cleanliness	Low Maintenance	User Satisfaction	Handicapped Accessibility	Single Unit Capital (USD)	Annual Operating Costs	Profitable Re-source Recovery	Lifespan	Environmental Impact	Independent from Elec Grid	Independent from Sewer	Water Required per Flush	On-Site Waste Treatment	Resource Re-covery Efficiency	Final Score
Pour Flush	72, but few use it	Yes, Water Seal	Non-Porous, but Squat-Style	Emptying	72	Squat	1,450	0	None	~20	Not Recyclable	Except at Night	Emptying Needed	1-3 L	None	None	-5
Biofil	47	Yes, Water & Mech Seal	No Bleach, Promotes HW	Removable Parts, Emptying	40	Sitting	870	0	Very Small Amount of Humus		Not Recyclable, Imported Materials	Except at Night	No Waste	150 mL	Composting	Humus, Unknown Efficiency	4
Microflush Biofil	47	Yes, Water & Mech Seal	No Bleach	Removable Parts, Emptying	40	Sitting	300	0	Small Amount of Humus		Not Recyclable, Local Materials	Except at Night	No Waste	150 mL	Composting	Humus, Unknown Efficiency	7
Clean Team Toilets	Apparent Rapid Adoption	No, Bucket with Chem	Ownership, Regular Cleaning	Frequent Waste Collection	N/A	Sitting, in-home	200	Labor Costs	Currently None, but in Development		Recyclable Plastic, but Glutaraldehyde	Except at Night	Collection Needed, Central Treatment	None	Neutralized with Glutaraldehyde	None yet	3
Microbial Fuel Cell Latrine	35	No, Open Pit	No Bleach, Porous Surfaces	Monitoring of Technology	46	Sitting	1,900	0	Electricity Generation Unproven, Humus		Not Recyclable, Local Materials	In Theory, but Unproven	No Waste	None	Composting	Low, but in pilot phase	1

2 | 1 | 0 | -1 | -2 | N/A

- MFBF/Biofil are the highest-rated models
- CTT set to surpass them once resource recovery begins

	Type	Setting	User Group	Production Cost	Cost to Consumer
Pour Flush	Decentralized	Urban/Rural	Community	$1,667	$1,667
Biofil	Decentralized	Urban/Rural	Family (Shared)	$870	$1,520
Microflush Biofil	Decentralized	Urban/Rural	Family (Shared)	$300	$300
Clean Team Toilets	Decentralized	Urban	Large Family (Unshared)	$200	$11.36-20.45/month
Microbial Fuel Cell Latrine	Decentralized	Urban	Community	$1,900	$1,900
Fortifer	Centralized	Urban	City	?	Projected: $0.09-0.22/kg
Small-Scale Treatment/ Digestion	Centralized	Urban	Community (450)	?	$60,000



Feasibility Evaluation of Fire-Brick Technology in the Northern Region of Ghana

Caroline Bates

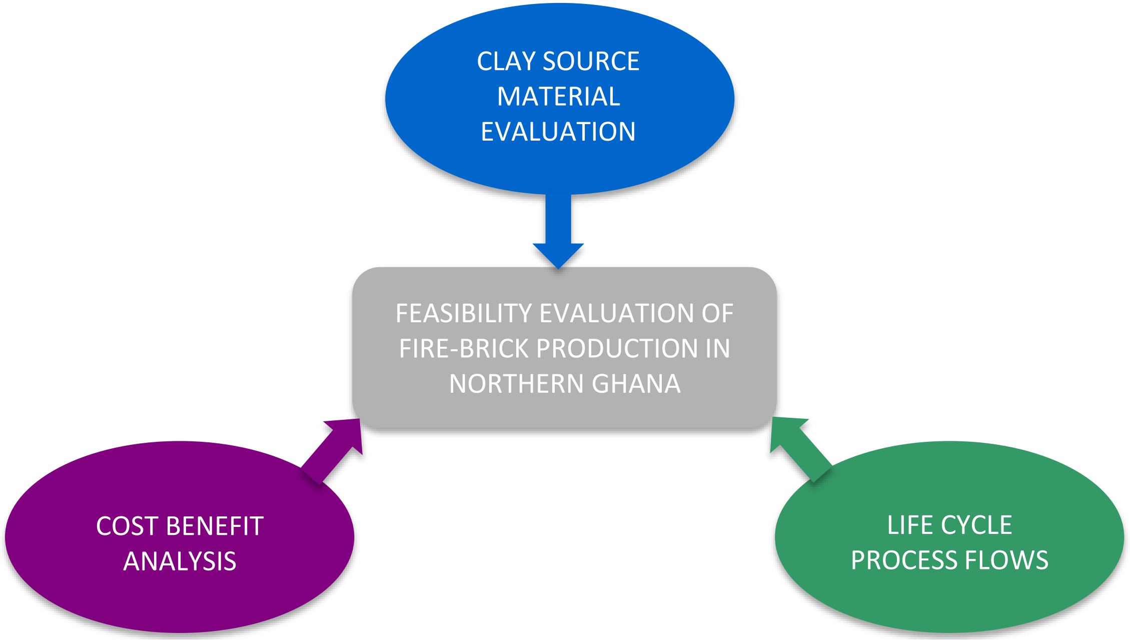
Friday, April 25, 2014

Final Presentation

Project Scope

To produce a technical recommendation on the feasibility of fire-brick production in Northern Ghana:

- *Is it sustainable?*
- *Can it be a source of revenue for PHW and the community?*



Project Context: Why focus on Northern Ghana?

- Economically depressed region
- Limited resources
  - Mineral and cocoa resources in the south
  - Offshore oil and gas reserves
- Youth unemployment
- Major deforestation (75%)
  - Soil erosion
  - Soil degradation
- Main industry is agriculture
  - One growing season
  - No irrigation
  - Limited crops

What are bricks?

SOIL + WATER —heat→ BRICKS

- Clay must be a major constituent of the soil:
  - Contributes plasticity for moulding
  - Contributes strength due to particle bonding and vitrification of silica
- Clay % and mineralogy is important

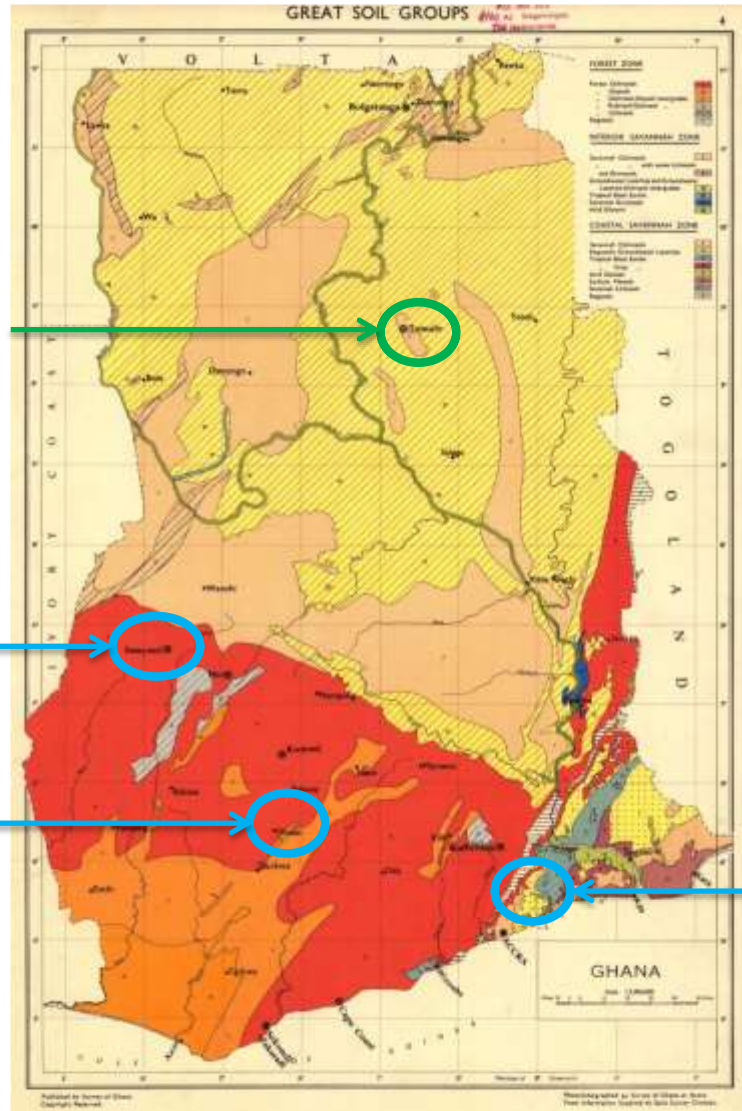
Clay Source Material Investigation

Proposed sites in Tamale

Existing Plants in Acherensua

Existing Plant in Obuasi

Existing Plant outside Accra



Source: EuDASM, 2011

Clay Source Material Investigation

4 BRICK FACTORIES

Clay Source Material Investigation

5 PHW PLOTS

Clay Source Material Investigation

HOLE ID: TP-PHW14-003

LOGGED BY: CAROLINE BATES

DATE: JANUARY 10, 2014

LOCATION: GBALAHI PLOT

COORDINATES: N: 9'26'24.85 W: 0'46'08.29

0

GRAVEL (GW)

Fine to medium, sandy to some sand, trace to some silt, trace clay, well graded, very dense, maximum particle size is 15 mm, equant, rounded to subangular, greyish brown clasts within an orangish brown matrix of fines, no odour, dry, strong cementation.

[GRAVEL DEPOSIT]

0.8 FT

G1

1

CLAY (CH)

Some silt, trace sand, high plastic, very stiff to hard, grey with orangish brown mottling, no odour, moist to dry, no discernable structure, moderate to strong cementation, very high dry strength, slow dilatancy, medium effort required to work clay.

[CLAY DEPOSIT]

G2

2

At 1.75 ft; clay is darker brown with grey mottling, stiff to very stiff, moist, good clay for moulding, moderate cementation.

At 2.5 ft; clay is grey and brown mottled, slightly lumpier and takes more effort to work.

3

3.25 FT

GRAVEL (GP)

Coarse to fine, clayey, trace to some sand, trace silt, gap graded, hard soil to extremely weak rock, flat, elongated, subangular, orangish brown with layers of grey, no odour, dry to moist, mm-scale sub-horizontal laminations, strong cementation, some soil breaks down to clay with substantial effort, gravel present as corestones, extremely weak.

4

[HIGHLY WEATHERED ROCK]

5.0 FT

5

END OF TEST HOLE AT 5.0 FT

POTENTIALLY USABLE ZONE: 0.8 – 3.25 FT

NOTES:

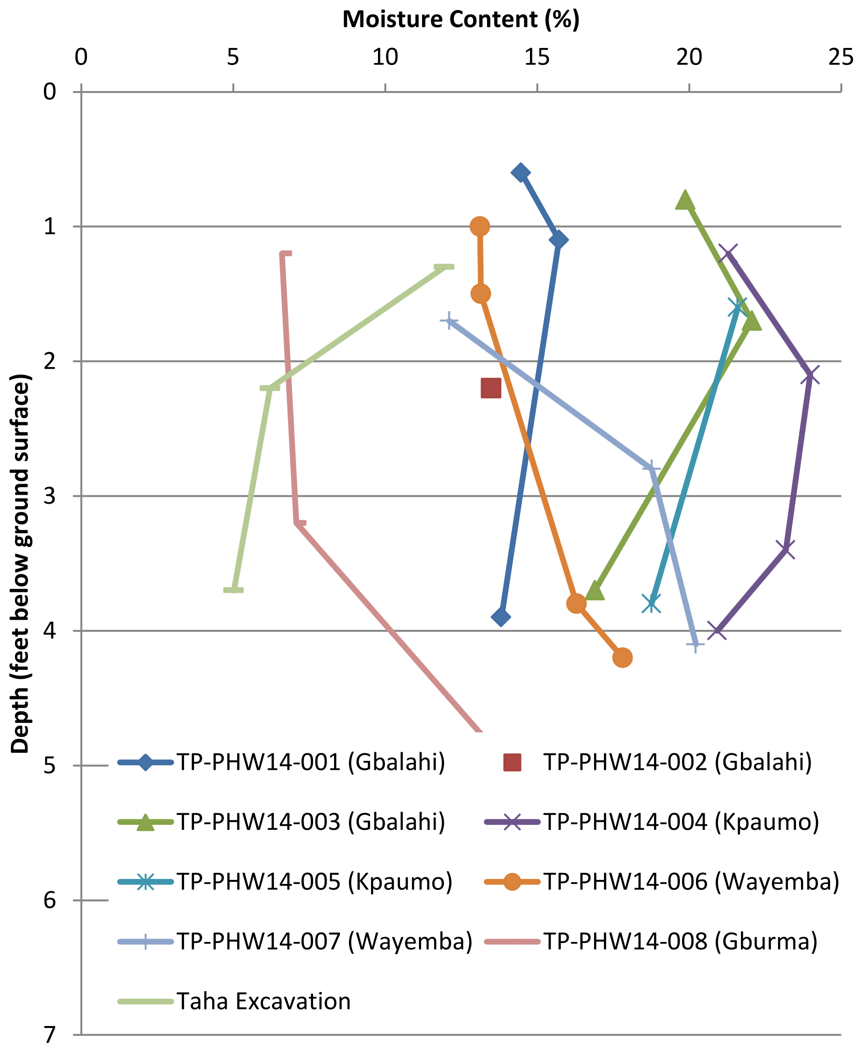
1) Hole ended due to difficult digging in unsuitable material.

2) Hole located approximately 600 ft east of TP-PHW14-002 adjacent to a dug-out clay depression.

Laboratory Testing

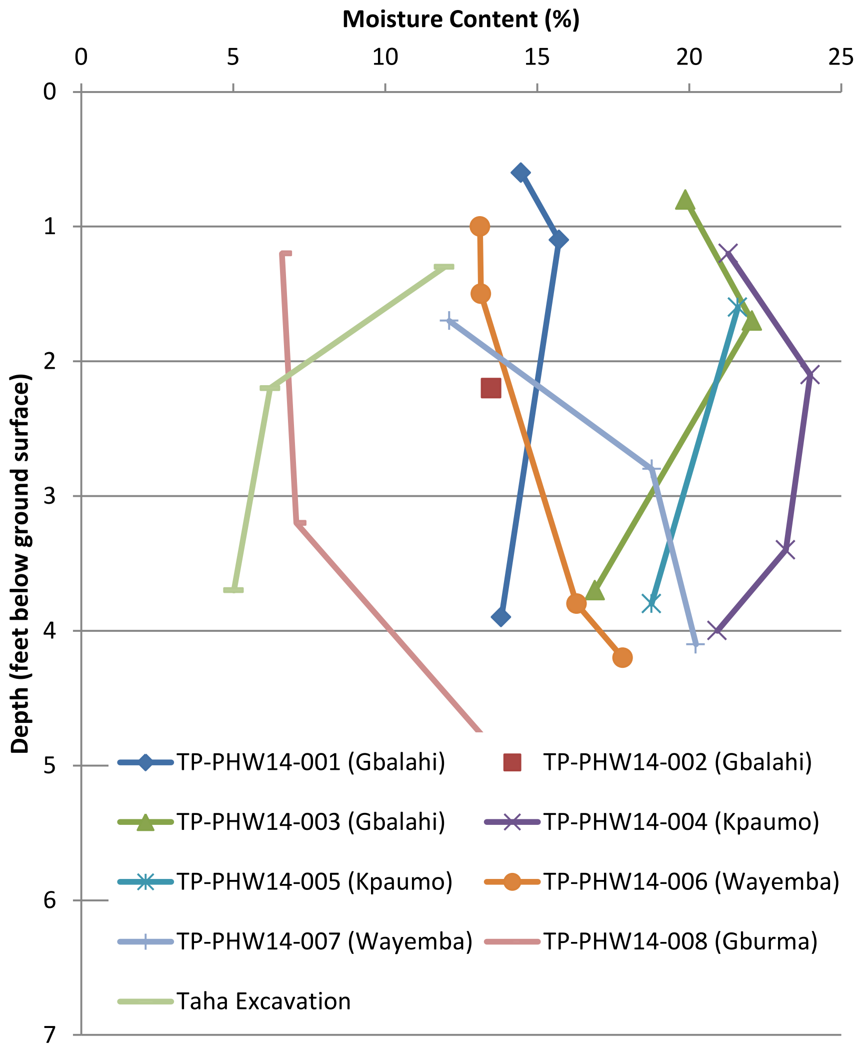
- Index Testing (# of tests)
  - Moisture Contents (30)
  - Atterberg Limits (19)
  - Simple Sedimentation (6)
- X-Ray Diffraction Testing (7 sets)
- Unconfined Compressive Strength Testing
  - Bricks from existing factories in Ghana (20)
  - Bricks made from soils of PHW plots (8)

Moisture Content



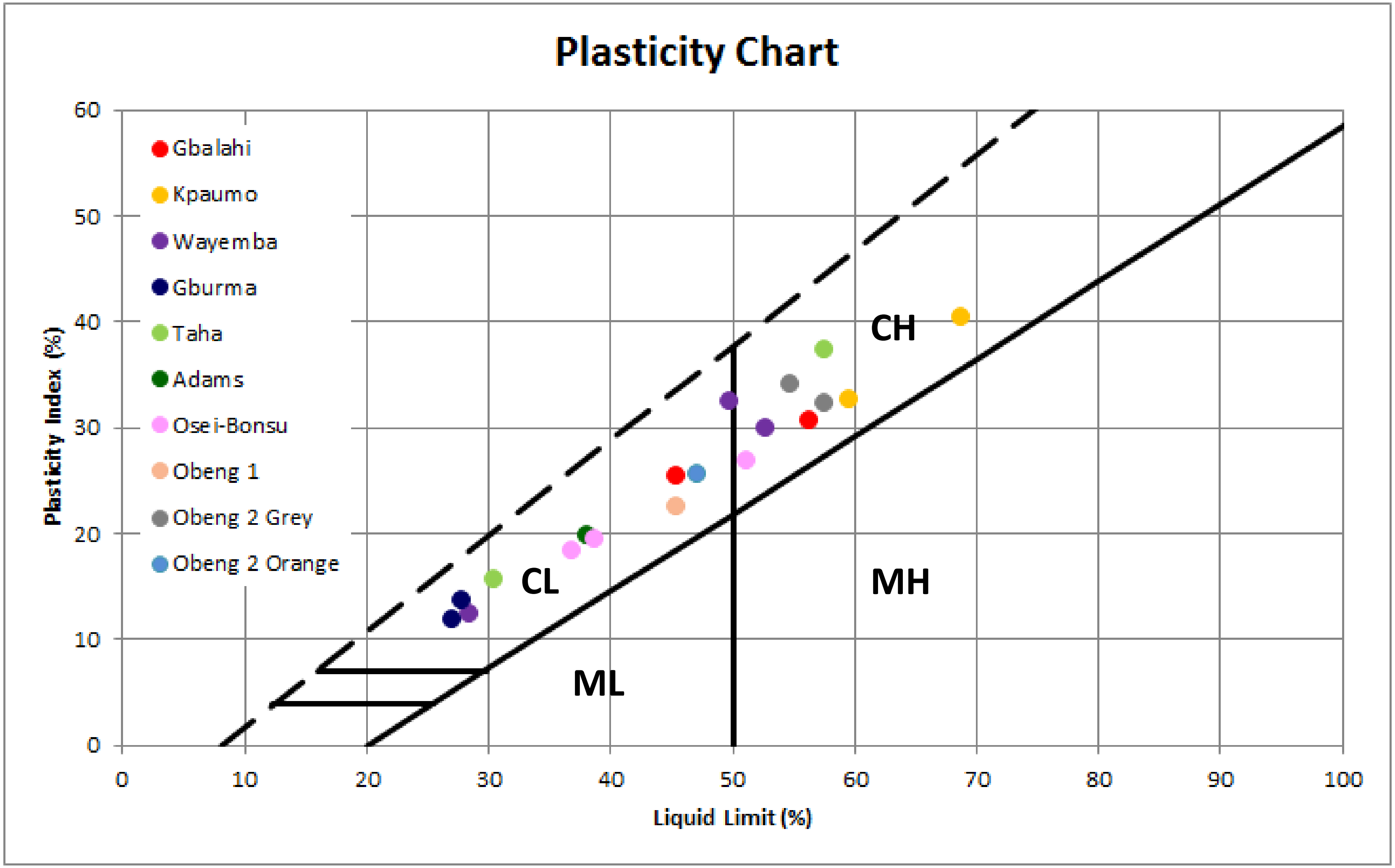
	Site	Average Moisture Content (%)
PHW PLOTS	Gbalahi	17
	Kpaumo	22
	Wayemba	16
	Gburma	9
	Taha	7
BRICK FACTORIES	Adams	32
	Obeng 1	38
	Obeng 2	30

Moisture Content

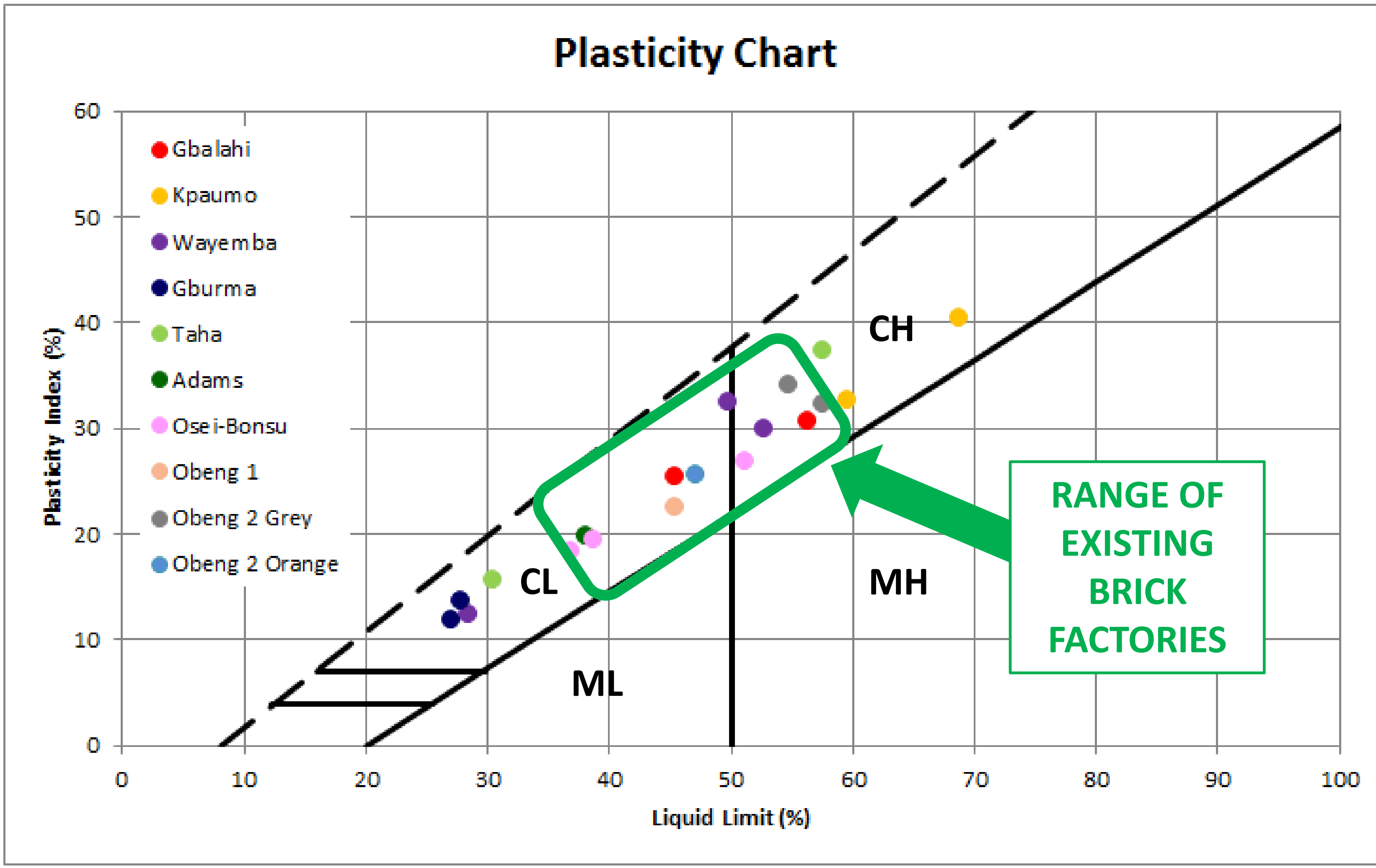


	Site	Average Moisture Content (%)
PHW PLOTS	Gbalahi	17
	Kpaumo	22
	LOWER	16
	Gburma	9
	Taha	7
BRICK FACTORIES	Adams	32
	HIGHER	38
	Obeng 2	30

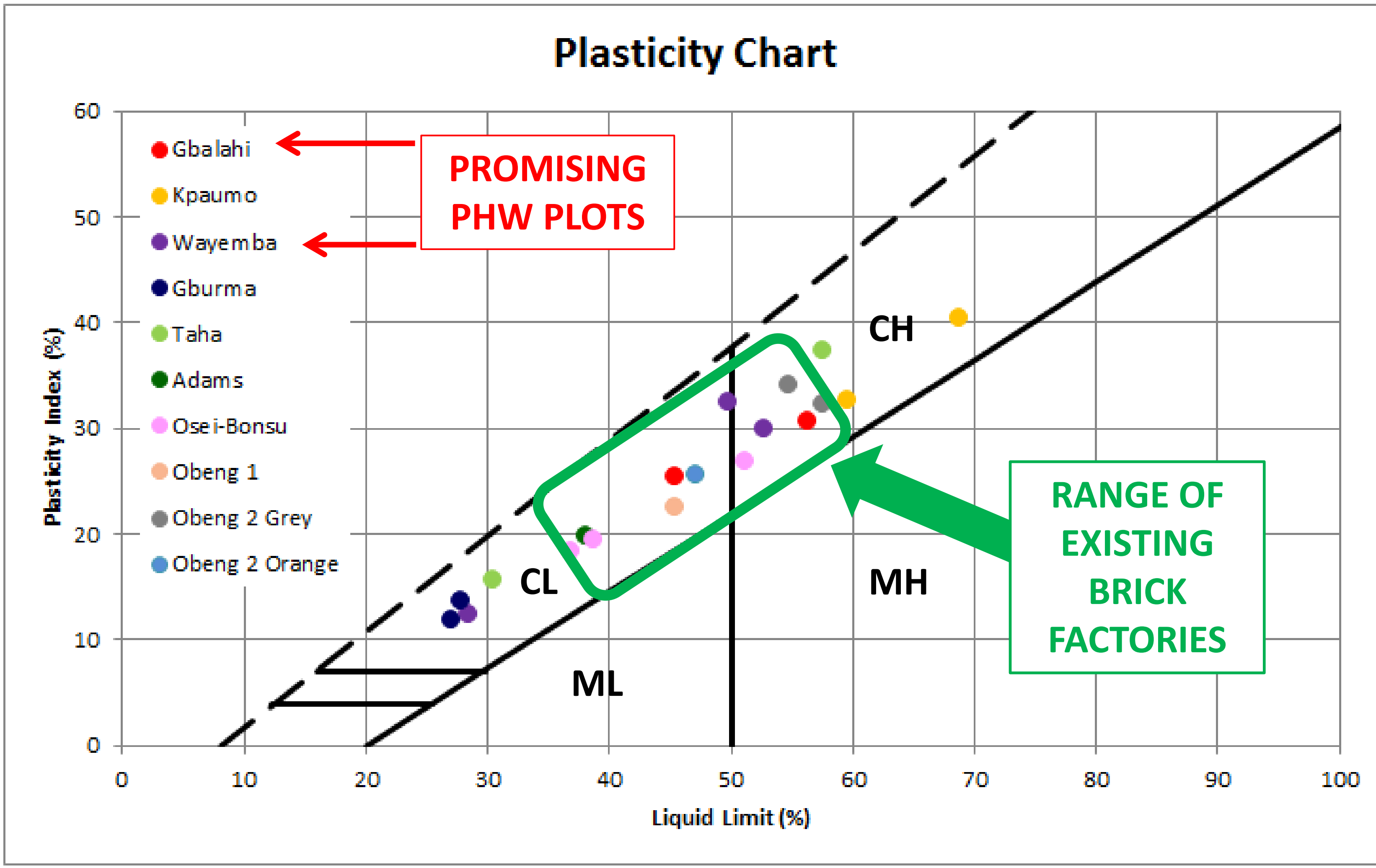
Atterberg Limits



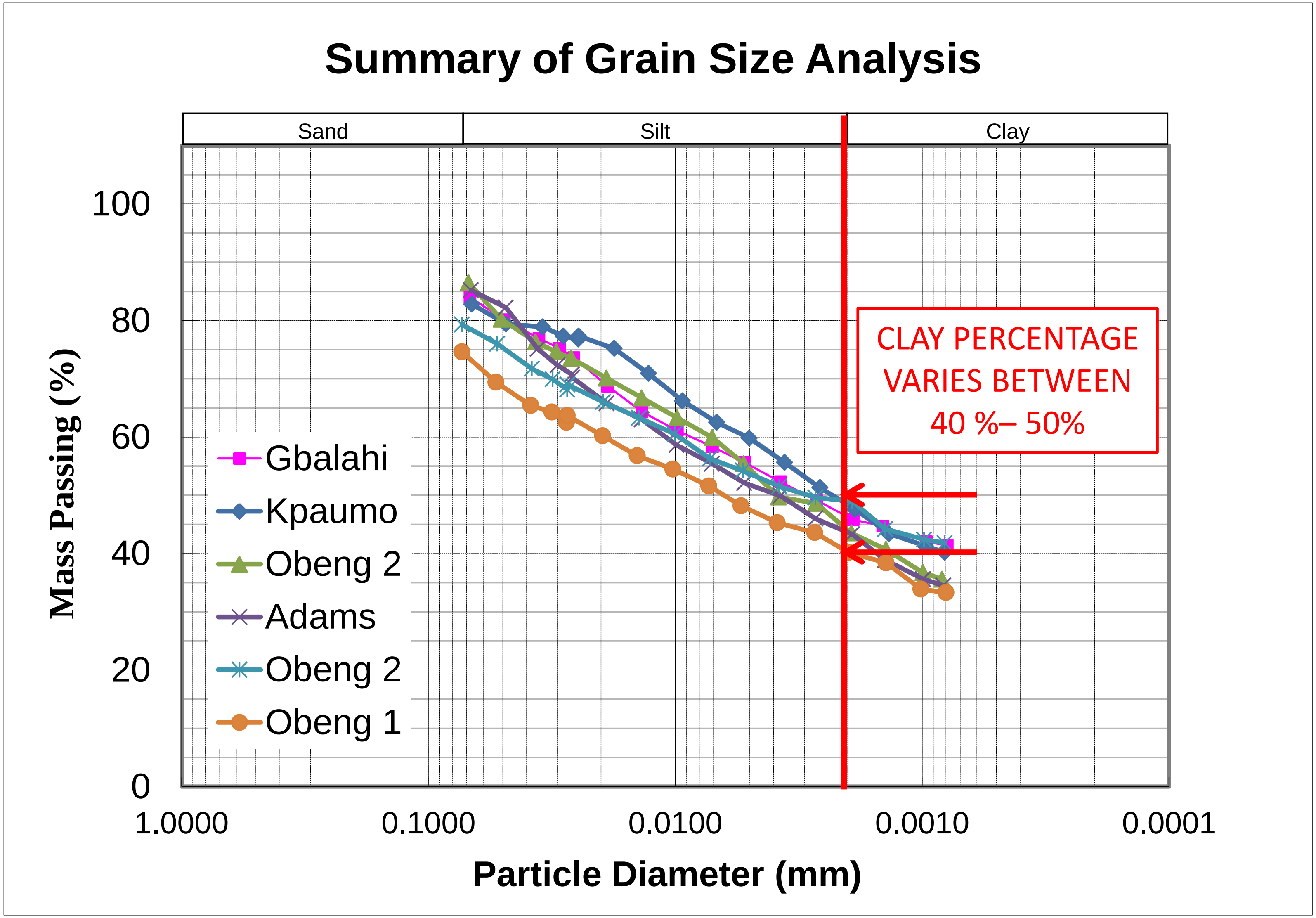
Atterberg Limits



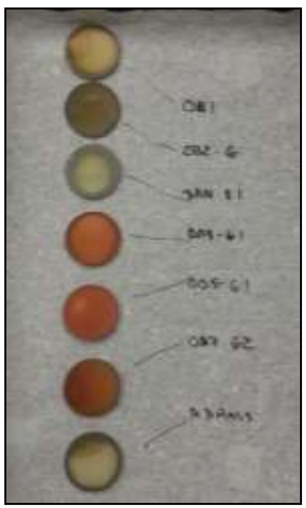
Atterberg Limits



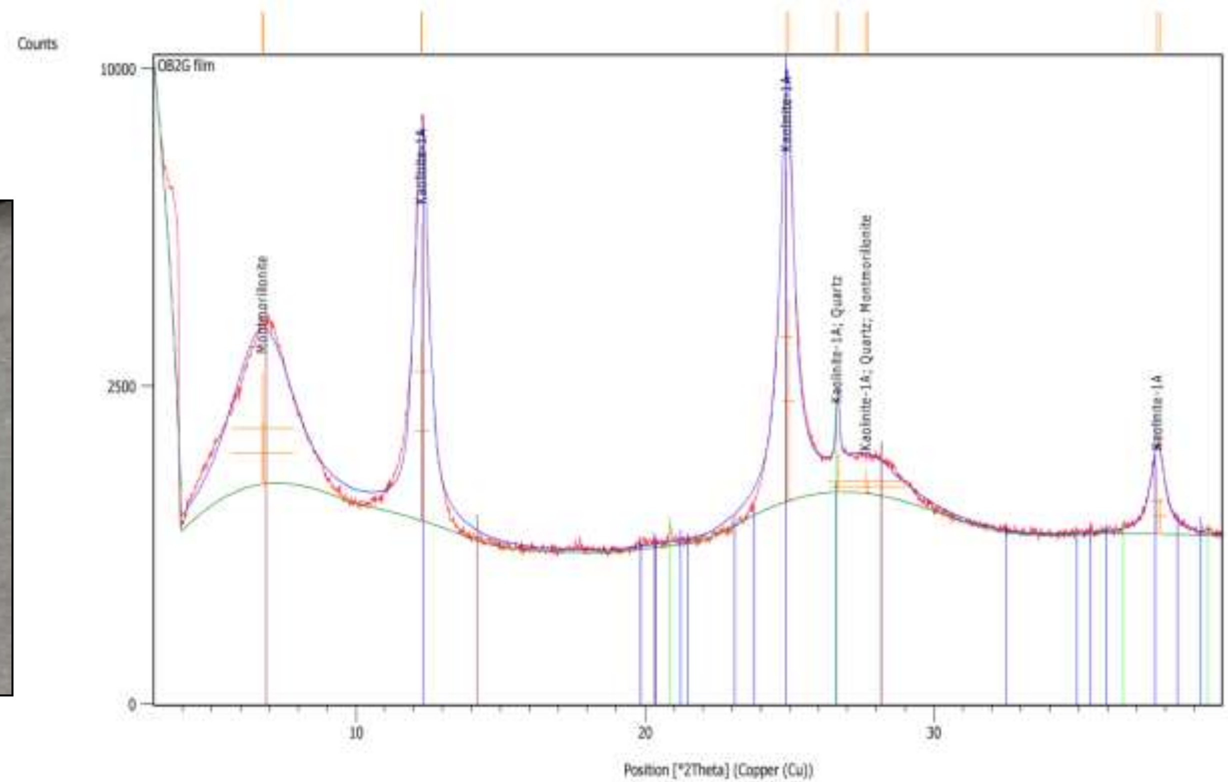
Simple Sedimentation



X-Ray Diffraction:
What minerals are present?



CLAY FILM
SAMPLES

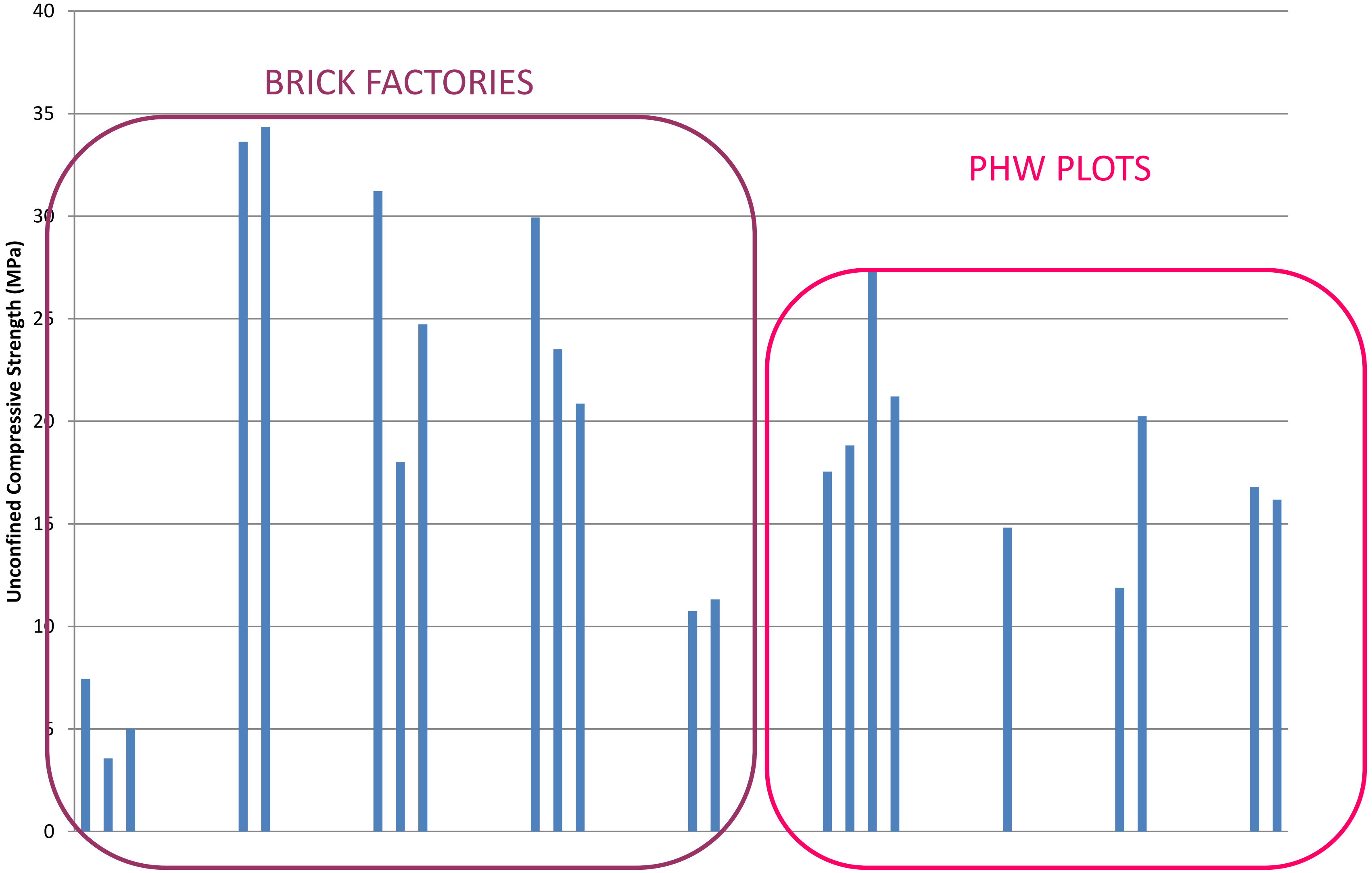


POWDER
SAMPLES

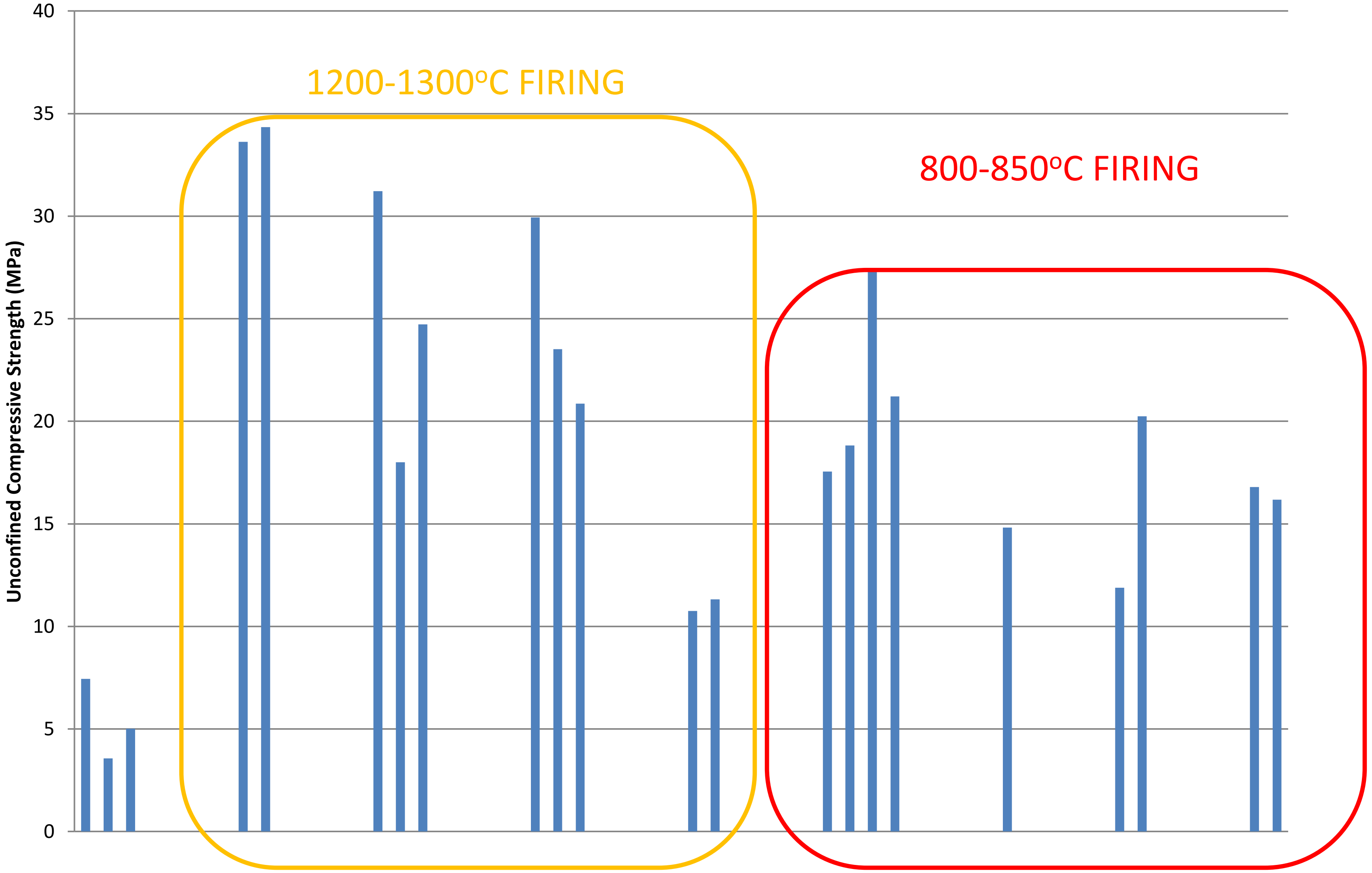
X-Ray Diffraction

	SITE	QUARTZ	KAOLINITE	ILLITE	MUSCOVITE	SMECTITE
PHW PLOTS	GBALAHI	YES	YES	YES	POSSIBLE	YES (?)
	KPAUMO	YES	YES	LIKELY	YES	YES (?)
	WAYEMBA	YES	YES	LIKELY	YES	NO (?)
BRICK FACTORIES	OSEI-BONSU	YES	YES	YES	POSSIBLE	POSSIBLE
	ADAMS	YES	YES	YES	POSSIBLE	POSSIBLE
	OBENG 1	YES	YES	LIKELY	YES	POSSIBLE
	OBENG 2	YES	YES	NO	NO	YES

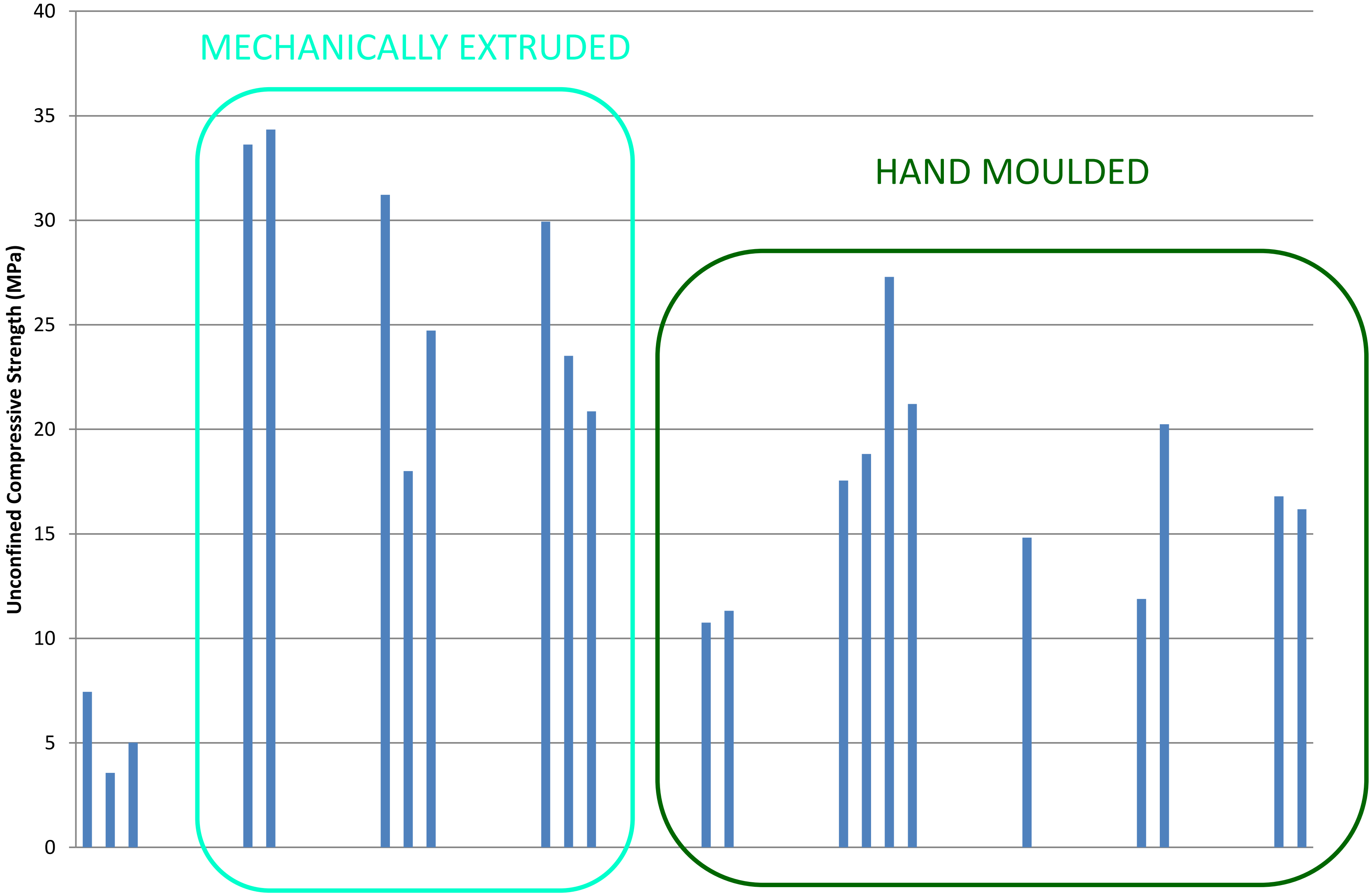
Brick Unconfined Strength Testing



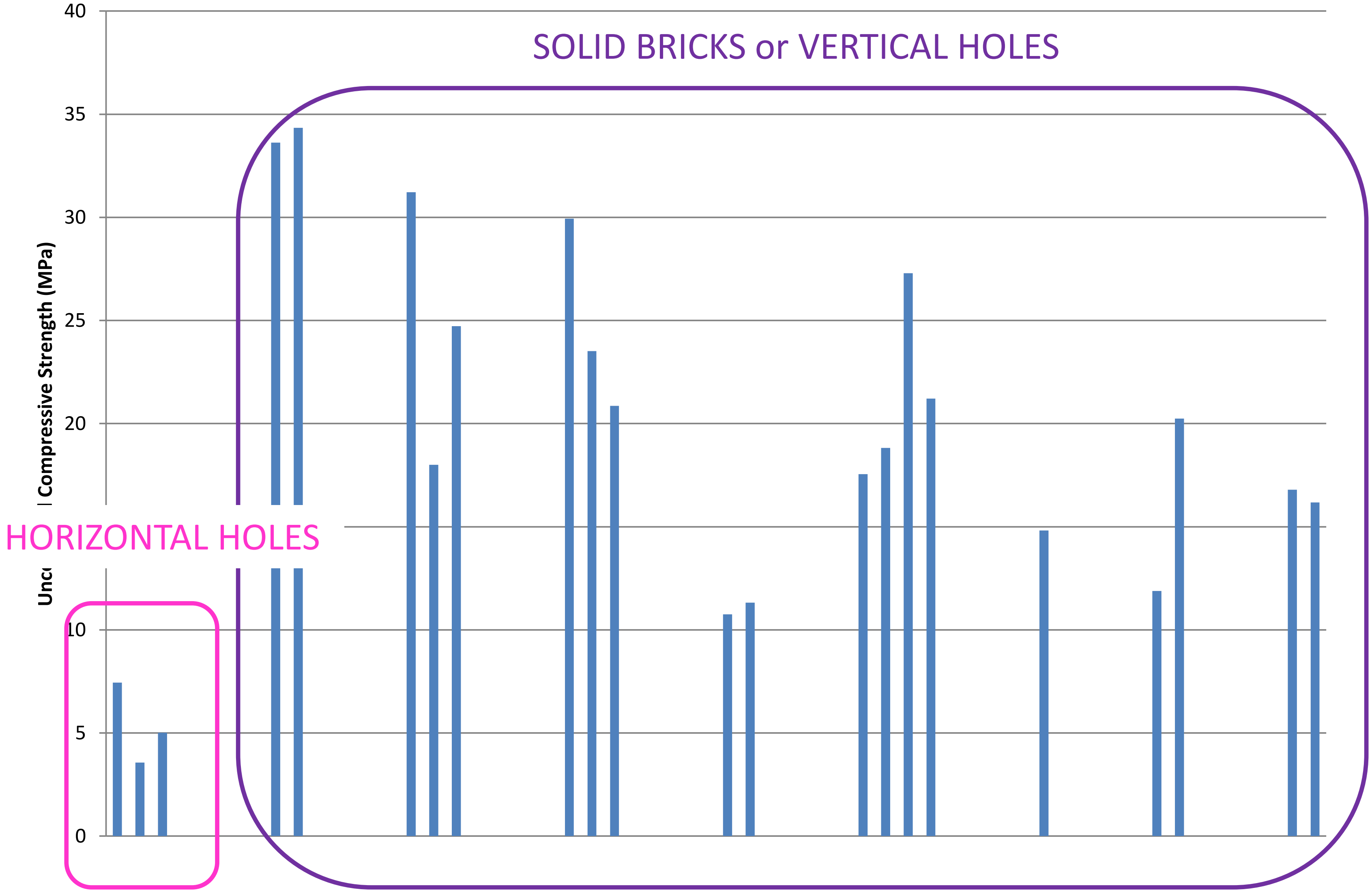
Brick Unconfined Strength Testing



Brick Unconfined Strength Testing



Brick Unconfined Strength Testing



Clay Resource Estimate for PHW Plots

	30 acres	1.5 ft. thick clay	100% coverage	1,960,00 cu.ft.
	1 acre	2 ft. thick clay	100% coverage	90,000 cu.ft.
	1 acre	2 ft. thick clay	50% coverage	45,000 cu.ft.
	10 acres	3 ft. thick clay	100% coverage	1,310,000 cu.ft.
	2.5 acres	1.5 ft. thick clay	50% coverage	80,000 cu.ft.

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Evaluation of PHW Plots for Brick Production

SITE	SOIL SUITABILITY	EASE OF BRICK PRODUCTION	APPROPRIATE LAND USE	RESOURCE SIZE	RESOURCE DEPENDABILITY	SCORE	RANK
GBALAHI	HIGH (3)	HIGH (3)	HIGH (3)	HIGH (3)	LOW (1)	13	1
KPAUMO	MEDIUM (2)	MEDIUM (2)	MEDIUM (2)	LOW (1)	HIGH (3)	10	2
WAYEMBA	HIGH (3)	MEDIUM (2)	MEDIUM (2)	LOW (1)	LOW (1)	9	3
GBURMA	LOW (1)	LOW (1)	LOW (1)	HIGH (3)	MEDIUM (2)	8	4
TAHA	LOW (1)	--	LOW (1)	LOW (1)	HIGH (3)	6	5

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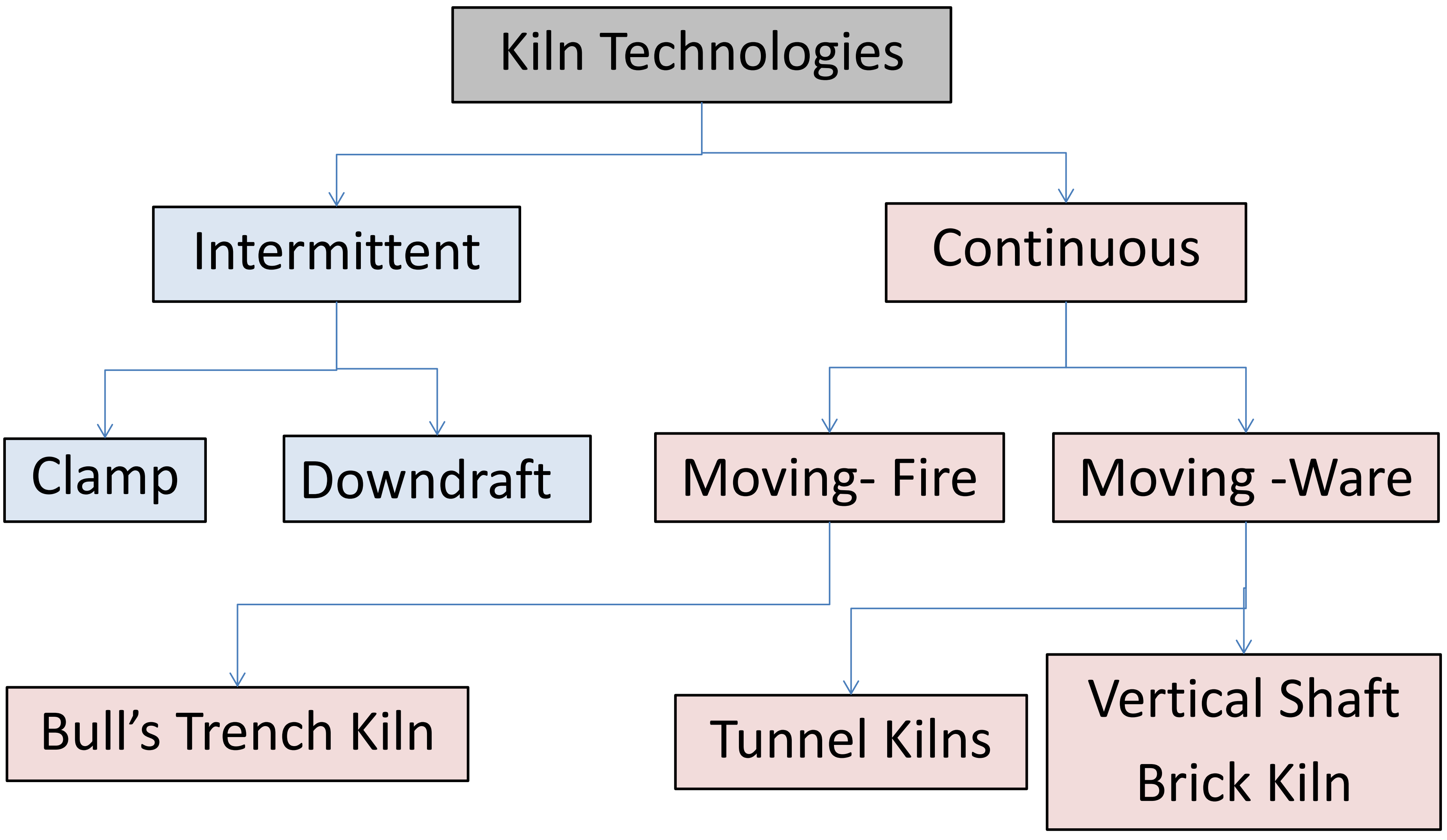
TAHA	LOW (1)	--	LOW (1)	LOW (1)	HIGH (3)	6	5

Evaluation of Brick Technology

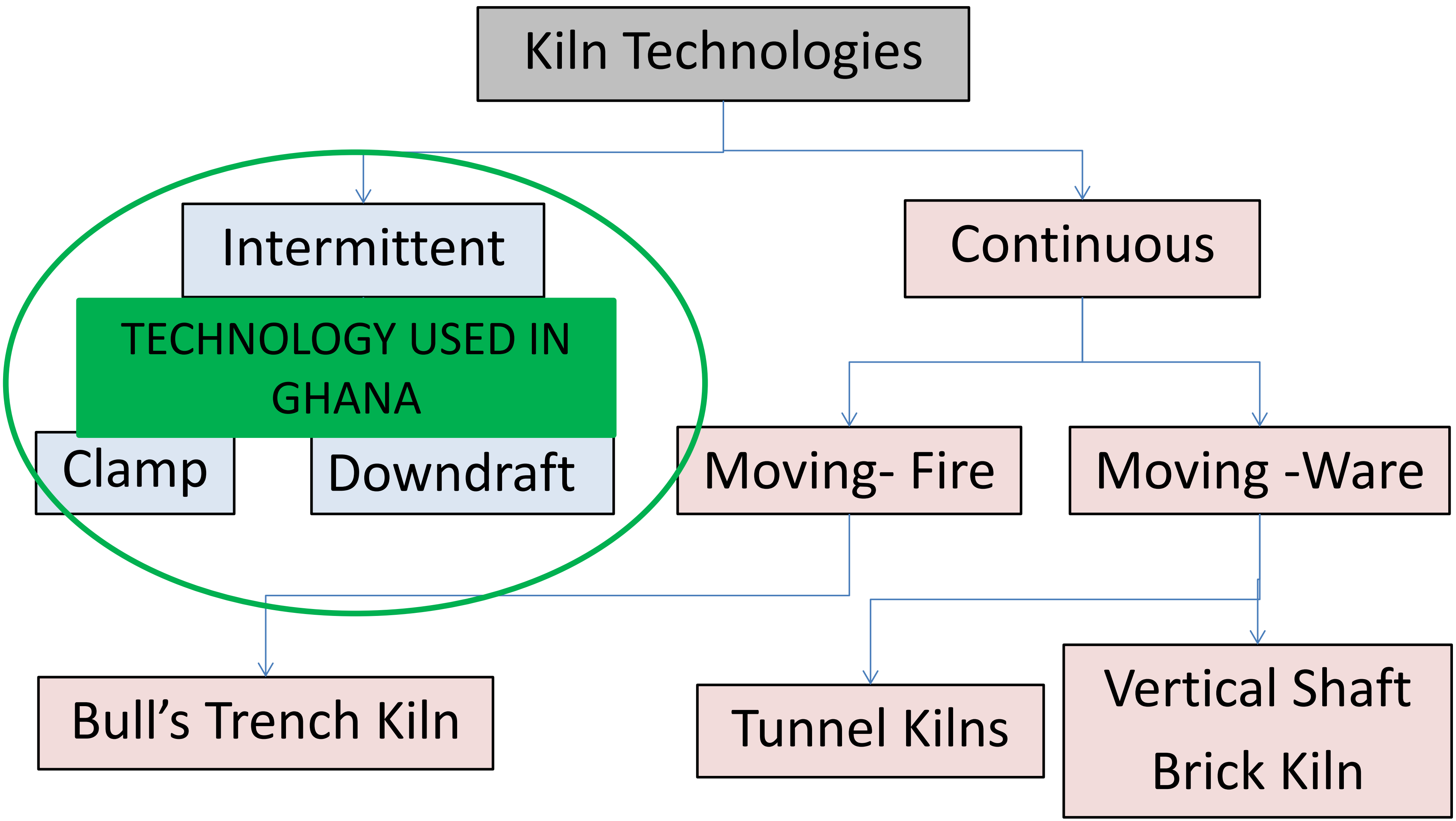
- *Advantages*:
- Excellent construction material
  - Durability
  - Insulation
  - Versatility in shape, size, and colour
  - Aesthetic appeal
- Makes use of locally available materials
- Simple technology

- *Disadvantages*:
- Energy Intensive
- Surface erosion
  - Water quality issues
  - Stripping of agricultural topsoil
- Labour intensive
  - Drudgery

Evaluation of Brick Technology



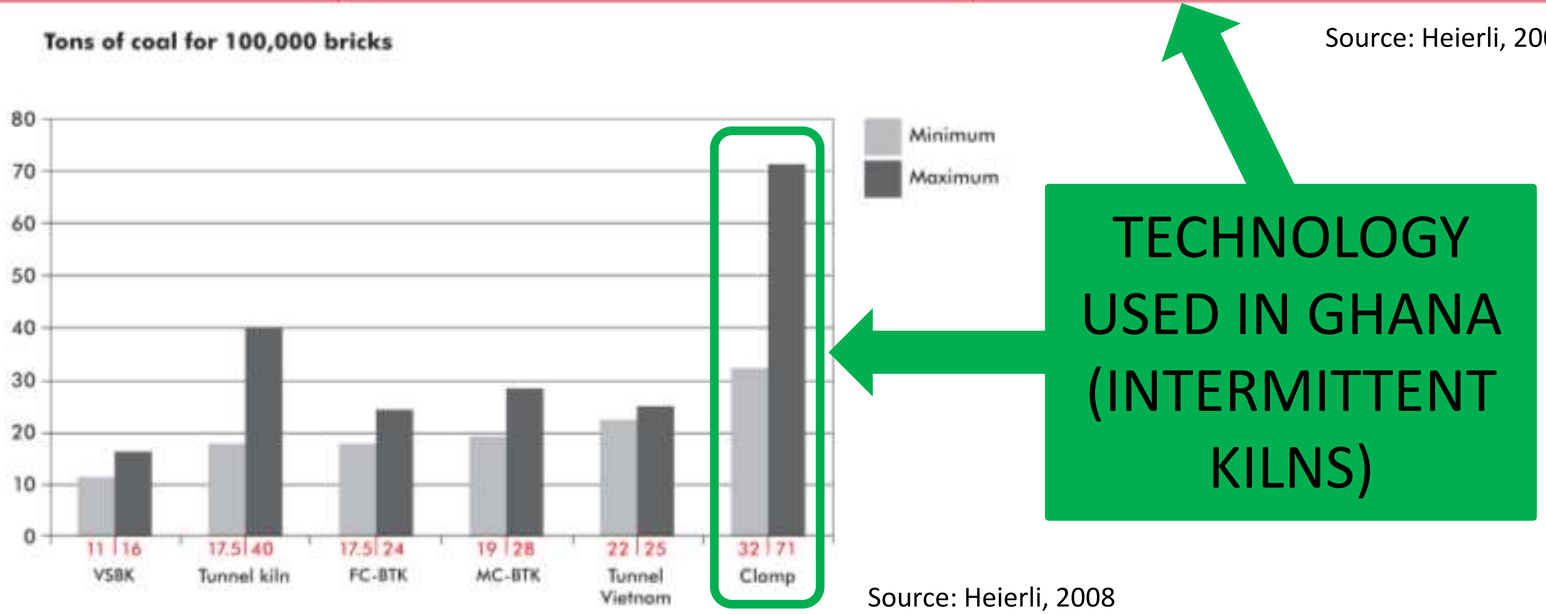
Evaluation of Brick Technology



Comparison of Kiln Technologies

Type of kiln	Specific Energy Consumption (MJ/kg of fired brick)	Specific coal consumption (tons/100,000 bricks)
VSBK (India, Nepal, Vietnam)	0.7-1.0	11-16
Fixed chimney BTK (India)	1.1-1.5	17.5-24
Moveable chimney BTK (India)	1.2-1.75	19-28
Tunnel kiln (Nam Dinh, Vietnam)	1.4-1.6	22-25
Modern tunnel kiln (Germany)	1.1-2.5	17.5-40
Clamp and other batch kilns (Asia)	2.0-4.5	32-71

Source: Heierli, 2008



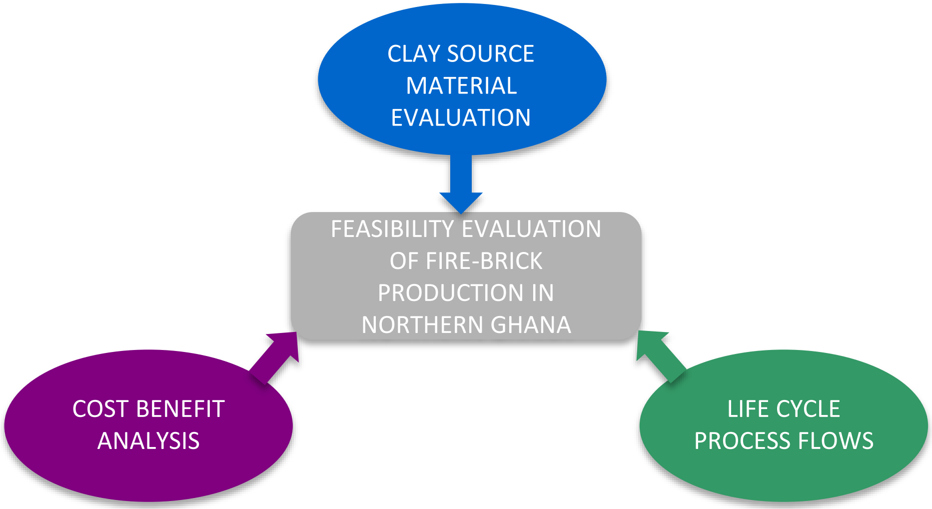
Source: Heierli, 2008

Economic Considerations

- Promising :
  - Existing brick factories are profitable and demand exceeds supply
  - Tamale is growing and there is a need for construction material
  - Substantial existing infrastructure and knowledgeable workforce at PHW Factory
- Concerning:
  - Brick industry in southern Ghana is in decline: why?
  - Capital intensive industry
  - Bricks are not used extensively in Ghana; will require marketing, education, and time to establish

Conclusions

- Clay Source Evaluation
  - Soil appears to be suitable for brick making
  - Very large borrow source of most promising soil
- Environmental and Social Considerations
  - Currently used intermittent kiln technology in Ghana is not sustainable for long term
  - Need to look towards more energy efficient kiln design
  - Reduce drudgery and manual labour by mechanizing several steps of brick making process
- Economic Analysis
  - Cautiously optimistic



Questions?

Thank You!