CLEAN DRINKING WATER FOR NORTHERN GHANA

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EFFECTS OF AN INTERMITTENT PIPED WATER DISTRIBUTION SYSTEM AND WATER STORAGE PRACTICES ON HOUSEHOLD WATER QUALITY IN TAMALE, GHANA
Tamale, Ghana

- Population: approx. 500,000
- (3\textsuperscript{rd} largest city in Ghana)
Goal 7, part c: Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation.

→ Measured by access to “Improved” drinking water sources.
IMPROVED SOURCES

Examples of Improved Sources
• Piped water into dwelling
• Piped water to yard/plot
• Public tap or standpipe
• Tubewell or borehole
• Protected dug well
• Protected spring
• Rainwater

*http://www.wssinfo.org/definitions-methods/watsan-categories/
UNIMPROVED SOURCES

Unimproved Sources*
- Unprotected spring
- Unprotected dug well
- Cart with small tank/drum
- Tanker-truck
- Surface water
- Bottled water

*http://www.wssinfo.org/definitions-methods/watsan-categories/

Photo credit: Kristine Cheng

Photo credit: Deborah Vacs Renwick
BACKGROUND

• Piped water distribution system in Tamale run by Ghana Water Company Ltd (GWCL)

• Water from White Volta River treated at Dalun-Nawuni Treatment Plant

• System upgraded 2006-2008
  • Enlarged treatment plant (5 to 11.6 MGD)
  • Expanded distribution network

• Intermittent system – water only flows to customers several hours a day, or days a week, sometimes even less frequently
INTERMITTENT PIPED WATER NETWORK

• Piped water systems are designed to be run continuously
• Positive pressure in pipes helps prevent contamination of drinking water
• Intermittent networks – pipes are dry (zero pressure) for hours/days at a time

Photo credit: Deborah Vacs Renwick
THESIS OBJECTIVES

1. Track water quality from Dalun-Nawuni treatment plant outlet to households, to identify where degradation is occurring.

2. Examine household water storage practices to explain where water quality degradation is occurring.
FIELDWORK –
HOUSEHOLD SURVEYS

• 40 surveys conducted
• Qualitative questions
  • “How often does the water flow to your house?”
  • “How do you store your water?”

Photo credit: Deborah Vacs Renwick
FIELDWORK – HOUSEHOLD SURVEYS

- Water storage practices varied

Photo credits: Deborah Vacs Renwick
FIELDWORK – HOUSEHOLD SURVEYS

• Quantitative testing
  • *E. coli*
  • Total coliform
  • Chlorine residual

Photo credit: www.camlab.co.uk
RESULTS – CHLORINE

Distribution of Total Chlorine Residual Results

- Less than 0.05 mg/L: 14
- 0.05-0.1 mg/L: 15
- 0.1-0.15 mg/L: 6
- 0.15-0.2 mg/L: 2
- Greater than 0.2 mg/L: 3
RESULTS – BACTERIOLOGICAL

Distribution of Bacteriological Results

- Low Risk
  - <1 Cfu/100 mL: 9
  - 1-10 Cfu/100 mL: 3
- Intermediate Risk
  - 11-100 Cfu/100 mL: 6
- High Risk
  - 11-100 Cfu/100 mL: 4
- Very High Risk
  - >100 Cfu/100 mL: 17

Legend:
- Total Coliform
- E. coli
RESULTS – HOUSEHOLD STORAGE PRACTICES

Types of Storage Containers Observed

- Poly Tanks: 30%
- Steel Tanks: 9%
- Jerry Cans: 8%
- Metal Drums: 17%
- Clay Pots: 15%
- Plastic Drums: 15%
- Cement Tanks: 6%

Safe containers:
Based on observation of
(i) Covered
(ii) with a spigot

Unsafe: 53%
Safe: 47%
CONCLUSIONS

• Water quality degrades between treatment plant and homes
  - lowered chlorine residual in system and households
  - 33% of *E. coli* results >0 in households

• Too little data to quantify and pinpoint where most of the degradation is occurring – in system or in households

• Room for improvement in household storage practices in Tamale (53% observed unsafe)
RECOMMENDATIONS

• **Improve household storage practices**
  - Education
  - Safe storage containers

• **Decrease intermittency of system**
  - Decrease non-revenue water
    - Fix leaks
    - Monitor illegal connections
    - Increase supply
  - Improve reliability of electricity (pumps)
RESEARCH OBJECTIVES

• Develop models for flow through flower pot, paraboloid, and hemispheric filters
• Compare flow rates for different filter shapes
• Examine sensitivity of flow rate and travel times to various parameters (shape, hydraulic conductivity, etc)
METHODS-FEFLOW

• Shapefile: 2-D cross section of filter
• Mesh: automatic generation
METHODS-FEFLOW

**PROBLEM SETTINGS**
- 2-D, axisymmetric
- Steady state

**BOUNDARY CONDITIONS**
- Constant head
METHODS-FEFLOW

- Iterate through steady state solutions to find $Q(h)$
- New water level calculated based on previous $Q$

Head distribution in parabolic filter after 0, 5, and 12 hours
METHODS- LAB TESTING

Flow rate tests for hemispheric (Ghana) and flower pot (Cambodia) filters:

• Constant water level
• 4 different water heights
• Saturated conditions
RESULTS: SHAPE COMPARISON

FLOWER POT  PARABOLOID  HEMISPHERE

Head distribution in full filter (flower pot, paraboloid, hemisphere)
RESULTS: SHAPE COMPARISON

FLOWER POT  PARABOLOID  HEMISPHERE

Darcy flux in full filter (flower pot, paraboloid, hemisphere)
RESULTS: FLOW RATE VS WATER HEIGHT

For all filter types, $K = 0.234$ cm/hr
FLOW RATE VS WATER HEIGHT: VARYING K

**Flower pot**

**Paraboloid**

**Hemisphere**
RESULTS: ESTIMATING K FROM FLOW RATE

Flower pot:
- \( Q = aK h + b \)

Paraboloid:
- \( Q = cK^3 h^2 + K^2 d h \)

Hemisphere:
- \( Q = eK^4 h^2 + fh \)

Can use these relationships to estimate K from flow rate data.
Example:
Calculate K for flower pot from lab test: 1.26 cm/hr
FLOW RATE OVER TIME, HEMISPHERE

- Most flow occurs in first 3 hours
- Factory results reported as flow over first hour
- From lab tests:
  \[ Q(\text{full filter}) = 5.91 \text{ L/hr} \]
  \[ Q(1\text{hr method}) = 3.8 \text{ L/hr} \]

Zoomed in to first three hours:

\[ K=5.616 \]
\[ K=10 \]
\[ K=20 \]
CONCLUSIONS

• **Filter flow models:**
  • Can use flow rate data to estimate $K$

• **Shape comparison**
  • Hemisphere is most “efficient”

• **Parameter sensitivity**
  • Flower pot filter sensitivity to $K$ is constant for all possible values of $K$
  • Curved filters have a flow rate that is increasingly sensitive to changes in $K$ as $K$ increases
  • Sensitivity increases more rapidly for more “curved” shapes – this could explain current manufacturing issues
RECOMMENDATIONS

Recommended filter shape, based on efficiency: hemisphere

For future flow rate testing:

• 1-hr estimate does not fully describe filter performance

• 10-min test while maintaining constant water level (full) can be used to predict filter performance and estimate hydraulic conductivity
MONITORING AND EVALUATION OF THE CERAMIC HEMISPHERIC FILTER IN NORTHERN GHANAIAIN HOUSEHOLDS
INTRODUCTION

• 1st large scale distribution of hemispheric filters produced at PHW factory.

• Village of Yipelgu
  • 20 miles West of Tamale Center
  • Extremely turbid water sources
  • About 140 compounds
  • Approximately 1,000 HH’s

• Distribution logistics
  • Jan. ‘13: 700 filters distributed
  • Female beneficiary households
  • No available records
  • Feb. ‘13: Distribution completed
BACKGROUND

• **3C’s: Correct, Consistent, & Continuous Use**
  - Successful method to sustain safe drinking water consumption
  - **Correct** – appropriate training given & knowledge retained to properly use filter to best performance.
  - **Consistent** – filter used every day.
  - **Continuous** - filter used throughout entire year.

Research focuses on Correct Use based on survey responses & water quality data.
GOAL & OBJECTIVES

Main Goal:
Monitor & evaluate PHW’s *AfriClay* filter at household level.

Objectives:

(1) Identify behavioral factors from Correct Use surveys that affect filter performance.

(2) Focus on water quality data as the primary filter performance indicator.

(3) Create a baseline & provide recommendations for future M&E efforts.

The filters assessed are the 1st set to be examined in the field rather than tested in the factory’s quality control operations.
METHODS

• Sample size: 85 households
  • 10% MOE, 95% CI
  • 50% Response distribution

• Random sampling
  • Divisions aligned with main roads
  • Number of days assigned to quadrant; according to density
  • All beneficiary households in compound surveyed
  • Cooking/meal times, market days, & prayer schedules considered
  • Achieves geographic spread
METHODS

CORRECT USE SURVEY

• 1st M&E tool for PHW’s new design

• Components:
  • General information
  • Dry/wet season sources
  • Correct Use Checklist
    • Filter assembly
    • Treatment practices
    • Demonstration
    • Safe storage
    • Maintenance
  • Cleaning procedure
  • Filter problems/issues

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<table>
<thead>
<tr>
<th>Monitoring Observations</th>
<th>Correct Use Checklist</th>
<th>(Yes/No/NA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. All components are present (ceramic pot, safe storage unit, lid, tap, brush, sticker)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Ceramic pot installed in the plastic safe-storage unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Ceramic pot’s rim fully covers the top rim of the safe storage container</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. CPF setup components rest evenly on each other (unit how if no discrepancies noted)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. CPF setup is on level surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. CPF setup on prescribed stable base (concrete block or cemented around)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Base is approximately 1 foot high</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Tap extends beyond edge of base</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Tap shows no signs of leaking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. CPF setup located against a wall, not in middle of room</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. CPF setup located out of direct sunlight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Turbidity water undergoes settling for at least one hour before filtration*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Ceramic pot is partially full or at least damp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Ceramic pot is not overfilled. Water level remains below lip of pot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Storage unit is not filled above the bottom of the ceramic pot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Request that the respondent to pour you a cup of drinking water:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Used cup or calabash to scoop water from large “settling” container to fill filter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Cup or calabash used to fill filter is hygienic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. There is water in the safe-storage unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Lid kept in place and is securely covered, except when being filled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Safe-storage unit is clean inside and out (free of visible scum or scaling)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Out of reach of possible contaminant sources (animals, birds, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. Ceramic pot, storage unit, and tap are clean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Ceramic pot, storage unit, and tap show no visible leaks or cracks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. Safe storage unit shows no signs of stress (indicated by plastic turning white)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. Respondent never uses soap or disinfectant with the ceramic pot itself</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Instructional sticker intact on filter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Settling in household storage vessels, distinct from AfriClay ceramic pot filter (CPF) setup
METHODS

WATER QUALITY MONITORING

• 3 water quality tests
  • Turbidity – HACH 2100P Turbidimeter
  • Total coliform/E. coli – IDEXX QT
  • H₂S bacteria – Triple batch medium

• 2 samples from each household
  • Stored – 1: 100 dilution
  • Filtered – 1: 10 dilution

• 13 dry season water sources

• Blanks & duplicates
## METHODS

Drinking Water Guidelines (WHO and UNICEF).

<table>
<thead>
<tr>
<th>Level of <em>E. coli</em> contamination</th>
<th>WHO Risk Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 CFU/100 mL</td>
<td>No action required</td>
</tr>
<tr>
<td>1 – 10 CFU/100 mL</td>
<td>Low risk</td>
</tr>
<tr>
<td>11 – 100 CFU/100 mL</td>
<td>Intermediate risk</td>
</tr>
<tr>
<td>101 – 1000 CFU/100 mL</td>
<td>Very High</td>
</tr>
<tr>
<td>&gt; 1000 CFU/100 mL</td>
<td>Very High [sic]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WHO Target</th>
<th>Log(_{10}) reduction required: Bacteria</th>
<th>Log(_{10}) reduction required: Viruses</th>
<th>Log(_{10}) reduction required: Protozoa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly protective</td>
<td>≥ 4</td>
<td>≥ 5</td>
<td>≥ 4</td>
</tr>
<tr>
<td>Protective</td>
<td>≥ 2</td>
<td>≥ 3</td>
<td>≥ 2</td>
</tr>
<tr>
<td>Interim*</td>
<td>Achieves “protective” target for two classes of pathogens and results in health gains</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Log reduction value (LRV) = \( \log_{10} \left( \frac{\text{stored water sample}}{\text{filtered water sample}} \right) \)

where, stored & filtered samples are in units of MPN/100 mL
METHODS

Statistical Analysis:

(1) **Histograms** of TC and *E. coli* LRV generated to visualize the range & frequency of filter performance.

(2) **Simple linear regression** analysis can verify if there is a significant relationship between the Correct Use scores & filter performance.

(3) **Significance tests** were used to determine variables that might affect filter performance.

- Chi-square test – Correct Use checklist categorical variables
- Two-sample t test – Correct Use survey interval variables
## RESULTS

### OVERALL FILTER PERFORMANCE

Geometric means of total coliform, *E. coli*, and turbidity

<table>
<thead>
<tr>
<th>Water Quality Parameter</th>
<th>Stored Sample</th>
<th>Filtered Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC (MPN/ 100 mL)</td>
<td>12,905 (9,162-18,197)</td>
<td>141 (78.7-253.5)</td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td>(N = 81)</td>
<td>(N = 83)</td>
</tr>
<tr>
<td><em>E. coli</em> (MPN/100 mL)</td>
<td>202 (133-308)</td>
<td>4 (3-5)</td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td>(N = 76)</td>
<td>(N = 85)</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>157 (122-201)</td>
<td>40 (31-51)</td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td>(N = 85)</td>
<td>(N = 85)</td>
</tr>
<tr>
<td>% TC reductions(^a)</td>
<td>--</td>
<td>99</td>
</tr>
<tr>
<td>% <em>E. coli</em> reductions(^a)</td>
<td>--</td>
<td>98</td>
</tr>
<tr>
<td>% NTU reductions(^a)</td>
<td>--</td>
<td>80</td>
</tr>
</tbody>
</table>

\(^a\)Calculated as log\(_{10}\) reduction = log\(_{10}\) influent – log\(_{10}\) effluent and subsequently the log\(_{10}\) reductions were transformed into percentages.
RESULTS

- Filter performance based on LRVs exhibit similar distribution.

- Few number performing at extremes.

- The majority achieving 1 to 2 LRV.
RESULTS

• Found a wide range of filter performance.

• Correct Use checklist variables were 1st analyzed to inform variability.

• Unweighted Correct Use score calculated for each of the 85 survey respondents.

• Unweighted Correct Use scores with either TC or E. coli LRV lack statistically significant linear relationships & correlations.

• Weighted score did not yield a favorable linear relationship & correlation either.

• Shifted focus to specific parameters rather than weighing or combining variables.
RESULTS

"COMPLIANCE"

Purpose: Shows if compliance affects LRV

Sample size: Considers only subset

Step 1: Examine Low (<1 LRV) performing filters based on TC or *E. coli* & equal # of High performing filters in upper tier

Step 2: Calculate variable compliance rates for each group & test significance

"AVERAGE LRV"

Purpose: Shows LRV improvements if compliant

Sample size: Considers entire sample size

Step 1: Divide entire sample size into compliant & non-compliant groups

Step 2: Calculate Avg. LRV for each group & test significance
RESULTS

“COMPLIANCE”

Variable: Fill frequency/day
WQ Parameter: Total coliform
Sample size: High-performing (n=20) & Low-performing (n=20) filters
Results: two-sample t test shows statistical significance; but linear regression does not.
Conclusion: Suspect lurking variables are influencing filter performance.

“AVERRAGE LRV”

Variable: Settling stored water for more than 1 hour.
WQ parameter: Total coliform
Sample size: Compliant (n=73) & Non-compliant (n=6) groups
Results: two-sample t test shows statistical significance; linear regression not possible since categorical variable
Conclusion: Emphasize settling time

<table>
<thead>
<tr>
<th></th>
<th>Compliant Group</th>
<th>Non-Compliant Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC LRV</td>
<td>2.1</td>
<td>0.7</td>
</tr>
<tr>
<td>1.4 fills/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9 fills/day</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

“COMPLIANCE”

Variable: Fills per cleaning

WQ Parameter: Total coliform

Sample size: High-performing (n=20) & Low-performing (n=20) filters

Results: two-sample t test does not show statistical significance; but general pattern noted.

Conclusion: On average, High-performing group has lower # of fills/cleaning.

“AVG LRV”

Variable: Fills per cleaning

WQ parameter: Total coliform

Sample size: Compliant (n=44) & Non-compliant (n=35) groups

Results: two-sample t test does not show statistical significance, but general pattern noted.

Conclusion: On average, those who cleaned system every ≤ 4 fills, achieved protective LRV.

High TC LRV

4.4 fills/cleaning

Low TC LRV

5.5 fills/cleaning

Low TC LRV

2.1 TC LRV

High TC LRV

1.8 TC LRV

≤ 4 fills/cleaning

> 4 fills/cleaning
RECOMMENDATIONS

• **Filter production** may hold more weight than behavior in performance because Correct Use scores did not directly correlate with LRVs.

• Emphasize stored water **settling time of at least 1 hr.** prior to filtration.

• Recommend **cleaning system every 4 fills or 2 days** to achieve protective target level as defined by WHO.

• **Overstress filters** in PHW factory or lab to find “breaking point.”
NEW PRODUCT DEVELOPMENT
INTRODUCTION

1. Household Water Treatment and Storage (HWTS) product as a supplement to piped water system
   1. Microbial and chemical contamination in intermittent distribution system
   2. An added barrier/protection from contamination is needed
   3. HWTS: ceramic water filters

2. New product development
   1. PHW’s goals
      1. Reach people most in need of safe drinking water, sanitation and hygiene in Ghana
      2. Become financially and locally self sustaining
   2. High-end water filter, targeting at middle and high income households
GOAL AND OBJECTIVES

Goal: develop a new HWTS product in Ghana, which PHW will brand as “AfriClay Deluxe Filter”

Objectives:
1. Consumer Preferences Characterization
2. HWTS Products Documentation
3. New Product Features Recommendations
4. Concrete Mold Making Documentation
## APPROACH

**Concept development**

1. Idea screening
2. Concept selection

<table>
<thead>
<tr>
<th></th>
<th>Production</th>
<th>Transportation</th>
<th>Aesthetics</th>
<th>Breakage</th>
<th>Water Taste</th>
<th>Overall Cost</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic Container</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>Hard to break</td>
<td>OK</td>
<td>OK</td>
<td>✓</td>
</tr>
<tr>
<td>Ceramic Container (locally)</td>
<td>Difficult</td>
<td>OK</td>
<td>OK</td>
<td>Easy to break</td>
<td>Good</td>
<td>High</td>
<td>✗</td>
</tr>
<tr>
<td>Ceramic Container (from Outside)</td>
<td>OK</td>
<td>Difficult</td>
<td>Good</td>
<td>Easy to break</td>
<td>Good</td>
<td>OK</td>
<td>✗</td>
</tr>
</tbody>
</table>
ALTERNATIVE PRODUCT DESCRIPTIONS

Super Tunsai, Cambodia

C1 Common Interface, China

Ecofiltro, Guatemala

AfriClay Classic Filter, PHW
APPROACH, CONTINUED

Field research

1. Consumer surveys
   1. Household water situation
   2. Customer preferences
   3. C1 Common Interface (Reference prototype)

2. Visits to local plastics manufacturers, WTP, and GWCL
RESULTS-SURVEY

1. Primary water source:
   1. Piped water (39%)
   2. Tanker Truck Water (39%)

2. Consumer preference for HWTS products
   1. Health impact (44%)
   2. Time to treat water (23%)
   3. Filter size (13%)

3. Price willing to pay
   1. $15~$20

4. Preference distribution channel (sales method)
   1. Door to door (45%)
   2. Shop (31%)
RESULTS-PRODUCT ASSESSMENT

<table>
<thead>
<tr>
<th>Cr</th>
<th>Pr</th>
<th>Pe</th>
<th>Pr</th>
<th>Us</th>
<th>Hc suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

Table 5: Products Assessment Matrix (design constraints)

<table>
<thead>
<tr>
<th>eight factor</th>
<th>Super Tunsai</th>
<th>CI Common Interface</th>
<th>AfriClay Classic</th>
<th>Ecofiltro</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

**Overall:**
- Super Tunsai: 9
- CI Common Interface: 9
- AfriClay Classic: 7
- Ecofiltro: 7
RESULTS-PRODUCT ASSESSMENT, SECOND ROUND

Table 6: Product assessment matrix (financial feasibility)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weighing factor</th>
<th>Super Tunsai</th>
<th>C1 Common Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit</td>
<td>33%</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Requirement of initial investment</td>
<td>33%</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Return on investment</td>
<td>33%</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Total score</td>
<td>Maximum score = 10</td>
<td>6</td>
<td>5.3</td>
</tr>
</tbody>
</table>
CONCLUSIONS

1. Super Tunsai represents a better model vs C1 Common Interface for PHW to adopt

2. PHW’s proposed business model resembles that of Hydrologic’s, the manufacturer of Super Tunsai

3. WIP ...
   1. Vision Statement
   2. Mold Making Documentation
RECOMMENDATIONS

1. If PHW were to directly use the design of Super Tunsai
   • Needs the design license from Hydrologic (Cambodia)

2. If PHW were to modify Super Tunsai design, or develop a completely new model
   • Maintain the hemispherical filter element
   • An exterior consists of multiple components and can be disassembled
   • Provide customers with options for sizes, transparencies and colors
   • Incorporate a filter stand that provides tap clearance