MICROBIOLOGICAL EFFECTIVENESS OF MINERAL POT FILTERS

Phnom Penh, Cambodia - 05 June 2012

Chai Ratana, WaterSHED
Joe Brown, LSHTM / WaterSHED
Ngov Sina, WaterSHED
Alice Wang, UNC

Kaida Liang, WaterSHED
Mark D. Sobsey, UNC / WaterSHED
Outline

• Introduction to mineral pot filters (MPFs)
• Purpose of our evaluation
• Methods
• Results and discussion
• WaterSHED-Cambodia Laboratory
Mineral Pot Filter Device

- Widespread Use: Common in Cambodia & across Asia.
- Countertop Ceramic Candle Filter
- 80% of 440 retail outlets surveyed by PATH sold MPFs. This demonstrates that market penetration of MPFs greatly exceeded other HWTS options in the market (B. McLaughlin, PATH)
- Product retail cost: China & Vietnam ($15-$50), Cambodia ($21-$45).
Mineral Pot Filter

Mineral Water Pot
MWF-12

CE-S
Ceramic Filter Cartridge

MS-1
Medical Stone Filter Cartridge

MS-5
5-stage Filter Cartridge
Background

1. Dubious marketing claims:
   • Effectiveness against arsenic, pesticides, other chemicals
   • Prevents cancer
   • Boost sex drive and have other supernatural advantages

2. Unknown treatment effectiveness
   • However, they are widely used across Cambodia
   • No systematic testing, data or scientific characterization of performance available

3. Protect human health and consumers
Purpose of Evaluation

• Ability to remove microbes from water over long-term use, under realistic conditions and microbial performance testing by the WHO recommendation (WHO 2011)
- As necessary first step in a broader assessment of the potential current and future role of these uncharacterized devices
• To demonstrate and pilot our laboratory’s capacity for microbiological testing according to the new WHO testing recommendations.
Testing set up

- Used WHO (2011) performance testing recommendation in developing laboratory method (bacteria, virus, protozoa).
- 3 common MPFs in PP market in 2010 were tested in duplicate with 2 challenge waters
  - Dechlorinated Phnom Penh tap water (DTW): High quality sources with low dissolved matter.
  - Dechlorinated tap water + 1% sterile wastewater (DTWW)
- Approximately 10 liters of test waters/filter/day
- Monitoring performance over ~1500 liters total throughput per test filter.
- Reporting reductions as $\log_{10}$ reductions
Testing Procedures:

1. Daily Dosing for each filter

1. Periodic Testing of influent and effluent water

3. Weekly cleaning of filters

4. Following Treatment: daily spiking of influent water

4. Collected samples from effluent (Tues., Weds, Thurs.)
1% Sterilized Waste Water

Model Bacterium, Virus, Surrogate protozoa

SDS 100L

F1DTW  F2DTW  F3DTW

F1DTWW  F2DTWW  F3DTWW
Experiment Design
Methods

All methods as recommended by the WHO guidelines:

Membrane filtration (USEPA 2002)

- *Bacillus Atrophaeus*: Surrogate for protozoa (*Cryptosporidium* oocysts)

Plaque Assay (Adams 1959, USEPA2001)

- MS2: Coliphage Bacteriophage which size, shape and other properties are similar to human enteric viruses (Noroviruses, infectious hepatitis and enteroviruses)

Data Analysis

- Descriptive Statistics determined by a Shapiro-Wilk normality test.
- Interpretive Statistics: Using a *priori* significance level $\alpha = 0.05$
- Stata Version 8.1 (Stata Corporation, College Station, TX, USA)
What are $\log_{10}$ reductions?

- $1 \log_{10} = 90\%$
- $2 \log_{10} = 99\%$
- $3 \log_{10} = 99.9\%$
- $4 \log_{10} = 99.99\%$
- $5 \log_{10} = 99.999\%$
- And so on

WHO recommended reduction levels considered as “protective” are:

- Bacteria: $2 \log_{10}$
- Viruses: $3 \log_{10}$
- Protozoa: $2 \log_{10}$
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Filter 1</th>
<th>Filter 2</th>
<th>Filter 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dechlor tap water</td>
<td>5.6</td>
<td>4.2</td>
<td>4.7</td>
</tr>
<tr>
<td>(5.0–6.1)</td>
<td>(3.6–4.9)</td>
<td>(3.6–4.7)</td>
<td>(4.1–5.3)</td>
</tr>
<tr>
<td>Dechlor tap water</td>
<td>+1% ww</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. coli</td>
<td>49</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>4.2</td>
<td>4.2</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>(3.6–4.9)</td>
<td>(3.6–4.7)</td>
<td>(4.1–5.3)</td>
<td>(3.5–4.7)</td>
</tr>
<tr>
<td>MS2</td>
<td>28</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>3.0</td>
<td>3.1</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>(2.7–3.3)</td>
<td>(2.9–3.4)</td>
<td>(2.7–3.2)</td>
<td>(1.8–2.3)</td>
</tr>
<tr>
<td>B. atrophaeus</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>2.5</td>
<td>1.3</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>(1.9–3.1)</td>
<td>(1.0–1.6)</td>
<td>(1.3–2.0)</td>
<td>(0.86–1.5)</td>
</tr>
<tr>
<td>Turbidity</td>
<td>224</td>
<td>224</td>
<td>224</td>
</tr>
<tr>
<td>0.74</td>
<td>0.64</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>(0.67–0.80)</td>
<td>(0.58–0.69)</td>
<td>(0.49–0.66)</td>
<td>(0.57–0.68)</td>
</tr>
</tbody>
</table>
Log$_{10}$ reduction

<table>
<thead>
<tr>
<th>Filter 1</th>
<th>Filter 2</th>
<th>Filter 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-coli</td>
<td>E-coli</td>
<td>E-coli</td>
</tr>
<tr>
<td>DTW</td>
<td>DTWW</td>
<td>DTW</td>
</tr>
<tr>
<td>Log$_{10}$ reduction</td>
<td>Log$_{10}$ reduction</td>
<td>Log$_{10}$ reduction</td>
</tr>
</tbody>
</table>
The bar chart illustrates the Log₁₀ reduction of Bacillus Atrophaeus through different filters.

- **Filter 1**: A significant reduction of 2.5 Log₁₀ units.
- **Filter 2**: A reduction of 1.3 Log₁₀ units.
- **Filter 3**: A reduction of 1.7 Log₁₀ units.

The chart compares the reduction for the same bacteria under different conditions, labeled as DTW and DTWW.
Log$_{10}$ reduction

<table>
<thead>
<tr>
<th></th>
<th>Filter 1</th>
<th>Filter 2</th>
<th>Filter 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTW</td>
<td>3.0</td>
<td>3.2</td>
<td>3.0</td>
</tr>
<tr>
<td>DTWW</td>
<td>2.0</td>
<td>2.2</td>
<td>2.0</td>
</tr>
</tbody>
</table>

MS2
Data Results

• All filters reduced turbidity significantly from pre-treatment levels although mean turbidity did not exceed 5 NTU even in DTWW. Pre-treatment water pH did not change significantly following treatment.

• No large differences in performance between the three filters: they all provided microbiologically safer water, consistently.

• The three filters were as effective or more effective than other locally available drinking water treatment options, including ceramic filters (Brown and Sobsey 2010; Brown et al. 2008) and boiling (Brown and Sobsey 2012).

• In brief, at least one filter (Filter 1) could meet WHO recommended performance levels for the “Protective” level, but not across all potential water sources.
Remaining questions

• Effectiveness against chemicals?
  – RDI/RUPP bridge students have produced a report on this: MPFs NOT effective against arsenic or fluoride

• Toxicity of mineral stone elements?
  – The filtration media remain uncharacterized

• Is regulation appropriate to limit manufacturers claims about effectiveness?

• Quality control of MPFs?

• New models on the market all the time, so cannot extend these results to ALL MPFs – continuous testing should be done
Conclusions

- MPFs are important because they demonstrate that the private sector can deliver effective water treatment products without subsidy
- The filters we tested (in the $21 - $45 range) were at least as effective as CWPs
- More research is needed to answer remaining questions
WaterSHED-Cambodia laboratory

- Lab Supervisor: Chai Ratana
- Support from USAID, The University of North Carolina – Chapel Hill and London School of Hygiene and Tropical Medicine
- In operation since April, 2009
- Services provided:
  - Comprehensive testing of household water treatment according to WHO standards
  - Microbiological testing services for water and food safety to private sector, NGO, and individual clients on a fee-for-service basis
  - Support to the water sector of Cambodia for health and well-being of the Cambodian people
Contact us!

WaterSHED-Cambodia

Address:
#39C Street 430 (corner of Street 476)
Sangkat Toul Tompong II, Khan Chamkarmon
Phnom Penh

Telephone:
Mobile: 092 923548, Office: 017 897231

E-mail: ratana@watershedasia.org
Acknowledgments

• USAID/RDMA

• Funding by UNU & GIST Joint Programme (IERC) Gwangju Institute of Science & Technology for MPF testing

• The University of North Carolina – Chapel Hill (Doug Wait – Virology Lab Manager)

• PATH: market research on MPFs
Thank You!
Q&A
Plaque Assay

1. Phage dilution
2. Top agar
3. Bacterial cells

- Pour mixture onto agar plate
- Nutrient agar plate
- Sandwich of top agar and nutrient agar
- Incubate
- Phage plaques
- Lawn of host cells
Membrane filtration

1. Original sample
2. 9 ml H₂O (10⁻¹ dilution)
3. 9 ml H₂O (10⁻² dilution)
4. 9 ml H₂O (10⁻³ dilution)
5. 9 ml H₂O (10⁻⁴ dilution)

1.0 ml
Mix with warm agar and pour.

1.0 ml

Membrane filter
on a filter support

Water sample filtered through membrane filter (0.45 µm)

Membrane filter removed and placed in plate containing the appropriate medium
Incubation for 24 hours
Typical colonies