Review of Evidence for Effectiveness of POU Water Treatment

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Leading Causes of Deaths from Infectious Diseases

- Lower Respiratory Infections: 3.9 million deaths (Over age 5)
- HIV/AIDS: 2.8 million deaths (Under age 5)
- Diarrhoeal Diseases: 1.8 million deaths (Over age 5)
- Tuberculosis: 1.6 million deaths
- Malaria: 1.3 million deaths
- Measles: 0.6 million deaths

Source: WHO 2004

Diarrhea may be 88% preventable by water, sanitation and hygiene.
HWTS Interventions to Improve WQ & Reduce WB Disease
What about boiling?

- Sub-optimal microbiological performance, probably due to recontamination after boiling

| Distribution of samples by TTC count (log scale) in longitudinal field studies (n=50 HH in Vietnam and Guatemala, 212 HH in India) |
|---|---|---|---|---|
| Vietnam (Clasen 2008) | 71.2 | 10.7 | 13.2 | 4.9 |
| India (Clasen 2009) | 37.0 | 38.3 | 22.2 | 2.5 |
| Guatemala (Rosa 2010) | 59.6 | 5.7 | 9.5 | 25.1 |
| Zambia (Psutka 2010) | 39.3 | 22.9 | 17.7 | 20.0 |

- Potentially high cost: US$7.99 to US$8.34 per HH per year in India; US$3.24 (collect fuel) to US$20.16 (purchase) in Vietnam
- Indoor air pollution from cooking with biomass associated with reduced birth weight, respiratory infections, anemia, stunting (Retherford 2006)
- Boiling water at home is also associated with higher levels of burn accidents (Rossi 1998).
- Other issues: Acceptability, environmental sustainability
The Need for a POU Technological Breakthrough

• Current “popular” technologies have deficiencies of various kinds

• Most are single-barrier and unable to efficiently reduce all pathogens and create aesthetically “attractive “water

• Better technologies are available in largely expensive, high-end products from specific manufacturers

• Question:

• What are the necessary and desirable properties of an optimum HWT technology?
Challenge #1: Assessing Efficacy/Effectiveness

- What are the best criteria for this?
  - Microbial
  - Heath impact

- Programmatic
- Economic

Microbial reduction performance levels achieved by HWTs
Assessing Efficacy/Effectiveness: Microbial

- What are the most appropriate metrics for microbial reduction evidence?
- EPA and NSF “6-4-3” $\log_{10}$ reductions?
- New WHO guidance for health risk-based microbial reduction evidence linked to DALYs (disability adjusted life years)
  - 3 levels of performance (3 bars)
    - Highest: meets $10^{-6}$ DALY/person/yr WHO target
    - Mid: meets $10^{-4}$ DALY/person/yr
    - Minimum: $\geq 1 \log_{10}$ reduction of each microbe class

<table>
<thead>
<tr>
<th>Rating</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>$\geq 4$</td>
<td>$\geq 5$</td>
<td>$\geq 4$</td>
</tr>
<tr>
<td>Protective</td>
<td>$\geq 2$</td>
<td>$\geq 3$</td>
<td>$\geq 2$</td>
</tr>
<tr>
<td>Minimally protective</td>
<td>$\geq 1$</td>
<td>$\geq 1$</td>
<td>$\geq 1$</td>
</tr>
</tbody>
</table>
Assessing Efficacy/Effectiveness: Health Impacts

• How reliable and robust is the health evidence from RCTs, other epidemiological studies and meta analyses?
• Diarrhea as a health outcome
  – Less reliable than mortality, child growth measures, other health outcome measures
• Lack of blinding and no placebos
• Courtesy and or participant fatigue bias
• Short study duration and declining health impact over time
### Systematic Review Evidence: Clasen et al. (2006)

<table>
<thead>
<tr>
<th>Intervention Type</th>
<th>Estimate (random)</th>
<th>% Δ (1-RR)</th>
<th>95% CI of Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source (6)</td>
<td>0.73</td>
<td>27%</td>
<td>0.53 to 1.01</td>
</tr>
<tr>
<td>Household (32)</td>
<td>0.53</td>
<td>47%</td>
<td>0.39 to 0.73</td>
</tr>
<tr>
<td>Filtration (6)</td>
<td>0.37</td>
<td>63%</td>
<td>0.28 to 0.49</td>
</tr>
<tr>
<td>Chlorination (16)</td>
<td>0.63</td>
<td>37%</td>
<td>0.52 to 0.75</td>
</tr>
<tr>
<td>Solar Disinfection (2)</td>
<td>0.69</td>
<td>31%</td>
<td>0.63 to 0.74</td>
</tr>
<tr>
<td>Flocc/Disinfection (7)</td>
<td>0.48</td>
<td>52%</td>
<td>0.20 to 1.16</td>
</tr>
<tr>
<td>Flocc/Disinfection (ex Doocy)</td>
<td>0.69</td>
<td>31%</td>
<td>0.58 to 0.82</td>
</tr>
<tr>
<td>Impr. Storage (1)</td>
<td>0.79</td>
<td>21%</td>
<td>0.61 to 1.03</td>
</tr>
</tbody>
</table>

Challenge #1: Assessing Efficacy/Effectiveness

• How reliable, robust and representative is the *microbial reduction* evidence from lab performance evaluation and field studies?

• How reliable and robust is the *health impact* evidence from RCTs, other epidemiological studies and meta analyses?

• Diarrhea as a health outcome
  – Less reliable than mortality, child growth measures, other health outcome measures

• Lack of blinding and no placebos

• Short study duration and declining health impact effects and usage over time
Challenge #2: Correct, consistent use

• What are the appropriate criteria?
• How to measured in the field?
• Evidence of use decline over time for some HWTs
  – Coagulant-flocculent-disinfectant
  – Chlorine
  – SODIS
• Some filters are less prone to such use decline
  – Biosand filters: nearly 90% continued use
  – Ceramic pot filters: usually >75% use over time
    • Most disuse is from breakage and lack of replacements (supply chain deficiencies)
Compliance

• In a systematic review of all HWT intervention trials, the pooled RR was 0.46 (95% CI: 0.25-0.84) among 16 trials reporting compliance >50%, and 0.75 (0.63-0.90) among 5 trials reporting compliance <50% (Clasen 2006).

• Among intervention studies using chlorine, effectiveness against DD was enhanced among studies with a larger fraction of water samples with detectable free chlorine (Arnold 2007).

• Recent program assessment studies show very low compliance and health impact (diarrhea)

• Guatemala: chlorination and SODIS (Arnold et al.)

• Bolivia: SODIS (Mausezahl et al.)
Challenge #3: Effective and Appropriate HWTS

• Which HWTS technologies are most effective and appropriate?
• Which HWTS implementation systems are most effective and appropriate?
• Under what conditions?
• What are the criteria for these?
  – Especially to achieve high coverage and scale?
Challenge #4: Targeting the vulnerable population

- Who is most vulnerable? (children <5 years?)
- Which countries/regions are most vulnerable?
- Which countries and regions are making the most progress in scaling up HWTS?
- What are the best approaches to reach the most vulnerable where there is willingness and capacity to go to greater coverage and scale?
- What can be done to reach the vulnerables where the willingness and capacity are low?
In an evaluation of JMP household survey data from 67 low and medium-income countries, 33% of households (36.6% urban vs. 30.1%) report treating their water at home before drinking it. This is equivalent to 1.1 billion people.

Reported microbially adequate HWT-use increases with wealth

Challenge #5

Achieving long-term and sustainable uptake
Are HWTS Systems Sustainable?

• Is there continued use and effective performance over time?

• What are the appropriate criteria?
  – How can we best find out?

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**HWT Performance Scores Based Effectiveness Criteria**

<table>
<thead>
<tr>
<th>Treatment Technology</th>
<th>Water Quantity</th>
<th>Water Treatability</th>
<th>Ease of Use</th>
<th>Cost</th>
<th>Supply Chain?</th>
<th>Sustained Use</th>
<th>Overall Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free chlorine</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3, liquid 2, tablets</td>
<td>1</td>
<td>1.5</td>
<td>12.5 11.5</td>
</tr>
<tr>
<td>Coagulation/disinfection</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>SODIS</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Ceramic Filtration</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2.5</td>
<td>14.5</td>
</tr>
<tr>
<td>Biosand filtration</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>16</td>
</tr>
</tbody>
</table>

Filtration technologies score highest based on effectiveness criteria.

Score system: 3 = high, 2 = middle, 1 = low
Sustainability

Effect of POU chlorine Rx on child diarrhea by length of intervention. (Circle area reflects study weight in the random effects meta-analysis.)


Driving HWT Policy with Evidence of Impact*

• Input-based strategy for water (e.g., “improved water supplies”) has led to sub-optimal solutions in terms of performance, health impact and sustainability

• Clasen says: Do not aggravate this problem by counting HWT toward the MDG water target (“sustainable access to safe drinking water’)
  – HWT does not improve quantity and access, key antecedents to development (and health)
  – Current evidence does not demonstrate that HWT can consistently deliver “safe water” (Q: do you agree?)
    • Although safer than some conventional supplies that currently do count

• Questions: Do you agree? What if “safe” was scored?

Driving HWT Policy with Evidence of Impact

- Clasen says: HWT policy should be assessed on impact (long-term outcomes), esp. on its contribution to health (child survival)
  - *Health-based strategy* will require promoters to address key challenges (efficacy, compliance, performance, target population, sustainable uptake)
  - *Investment* (government, funders, householders) will be commensurate with demonstrable returns (Q: what kind?)
  - Position HWT policy in health (rather than water) ministry to develop clear policies that do not divert resources from optimal water solutions (household connections)
- “What gets measured, gets done.” Peter Drucker