UV Water Disinfection in Rural Households – Results from a Rigorous Evaluation

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Symposium on UV Disinfection in Developing Countries
Delft, The Netherlands, November 6th 2014
Outline:

- Context and motivation for UV disinfection
- Design of a UV system for rural households
- Field efficacy evaluation
- Adoption and sustained use evaluation
- Research and practice conclusion
Rural Mexico
2Tovar, R. et al. 2005; 3Reygadas, F. et al. 2007; Photo Credit: Moreno, E. & Fundacion Cantaro Azul
Practice Goals

• Design an effective, low-cost, and user-friendly ultraviolet disinfection system.

• Formulate an implementation program that supports the adoption and sustained use of the water disinfection system.
Research Questions

Field Efficacy
• Is ultraviolet disinfection at the household level an efficacious method for improving the quality of drinking water?
  (EPA, Colford)

Adoption and Use
• What levels of adoption and use can be achieved with ultraviolet disinfection at the household level?
  (Colford, Hunter, Luby)
Outline:

• Context and motivation for UV disinfection

• **Design of a UV system for rural households**

• Field efficacy evaluation

• Adoption and sustained use evaluation

• Research and practice conclusion
Mesita Azul: Water Disinfection at the Household Level

- Operates at fast flow rate of 5 liters / minute
- Easy to use and does not change taste of water
- Requires electricity, clear water, and safe storage

Baffle homogenizes flow

15W UV lamp
**Laboratory Efficacy of the Mesita Azul**

- **UV dose of Mesita Azul:** $1,224 \pm 66$ J/m² (95% CI)

  - Inactivates bacteria, viruses, and protozoa
  - Meets the highly protective target of the WHO guidelines for HWT
  - Delivers high germicidal dose, providing a safety margin\(^1\)

\(^1\) Brownell et al.
Mesita Azul Program

Needs Assessment

Community Presentation

Installation

Follow Up Visits
Design Process: Mesita Azul

UV dose from 900 to 1,200 J/m²
Outline:

• Context and motivation for UV disinfection
• Design of a UV system for rural households

**Field efficacy evaluation**

• Adoption and sustained use evaluation
• Research and practice conclusion
Field Efficacy Research Questions:
Is ultraviolet disinfection at the household level an efficacious method for improving the quality of drinking water?

• Do households gain access to safe water by using the Mesita Azul?

• What factors drive water contamination at the household?
Study Location
# Research Design:
Stepped-Wedge Cluster Randomized Trial

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Baseline</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
<th>Step 5</th>
<th>Step 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>0</td>
<td>X 0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5-8</td>
<td>0</td>
<td>0</td>
<td>X 0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9-12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X 0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13-16</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17-20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X 0</td>
<td>0</td>
</tr>
<tr>
<td>21-24</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>X 0</td>
</tr>
</tbody>
</table>

0 = Observation
X = Intervention

Before Intervention
After Intervention
Water Quality Analysis:
Estimated the concentration of *E. coli* with Idexx’s Colilert-18 and its Quanti-Tray 200 most probable number method
Do households gain access to safe water by using the Mesita Azul?

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Mesita Azul</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>542</td>
<td>528</td>
</tr>
<tr>
<td>Proportion of EC ≥ 1</td>
<td>0.57</td>
<td>0.29</td>
</tr>
<tr>
<td>Risk Difference (95% CI)</td>
<td>-0.28 (-0.34, -0.23)</td>
<td></td>
</tr>
</tbody>
</table>

EC = E. coli (CFU/100ml)

- EC=[0,1)
- EC=[1,10)
- EC=[10,100)
- EC=[100,9000)
Water Quality Assessment: Treatment to Consumption

![Bar chart showing water quality assessment](chart.png)
Model of Water Contamination at the Household

Source

Treatment

Hygiene

Storage

Extraction

Washing
### Model of Water Contamination at the Household: Presence of *E. coli*

<table>
<thead>
<tr>
<th>Process</th>
<th>Independent Variable</th>
<th>% of 619 Obs.</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washing</td>
<td>Used disinfected water?</td>
<td>18%</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>Used bleach or soap?</td>
<td>62%</td>
<td>1.32</td>
</tr>
<tr>
<td>Treatment</td>
<td>Does the MA work?</td>
<td>97%</td>
<td>0.26*</td>
</tr>
<tr>
<td></td>
<td>Is the operator an expert?</td>
<td>29%</td>
<td>0.61*</td>
</tr>
<tr>
<td>Storage</td>
<td>Time since filled container</td>
<td>&lt;3d=68%</td>
<td>0.81*</td>
</tr>
<tr>
<td></td>
<td>Is container covered?</td>
<td>98%</td>
<td>0.53</td>
</tr>
</tbody>
</table>

(* = Statistically significant association at the 95% CI level.)
## Model of Water Contamination at the Household: Presence of *E. coli*

<table>
<thead>
<tr>
<th>Process</th>
<th>Independent Variable</th>
<th>% of 619 Obs.</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extraction</strong></td>
<td><strong>Number of extractions (x10)</strong></td>
<td>≥10L=62%</td>
<td>0.84*</td>
</tr>
<tr>
<td></td>
<td>Extraction with pump?</td>
<td>50%</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>Extraction with spigot?</td>
<td>43%</td>
<td>1.43</td>
</tr>
<tr>
<td></td>
<td>Is drinking vessel used?</td>
<td>85%</td>
<td>1.91*</td>
</tr>
<tr>
<td><strong>Hygiene</strong></td>
<td>Improved hh infrastructure?</td>
<td>88%</td>
<td>0.36*</td>
</tr>
<tr>
<td></td>
<td>Good hygiene in kitchen?</td>
<td>86%</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>Hand washing station?</td>
<td>20%</td>
<td>1.38</td>
</tr>
</tbody>
</table>

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Adoption and Use Research Question:

- What levels of adoption and use can be achieved with ultraviolet disinfection at the household level?
Developed Compliance Framework that Maps Key HWT Outcomes:

<table>
<thead>
<tr>
<th>Adoption of Safe Water Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of Safe Water Practice</td>
</tr>
<tr>
<td>Access to Safe Water</td>
</tr>
<tr>
<td>Habit of Safe Water Practice</td>
</tr>
<tr>
<td>Exclusive Use of Safe Water</td>
</tr>
</tbody>
</table>

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Disaggregated Key Outcomes:

**Adoption** of Safe Water Practice
- Acquisition
- Acq. Agreement

**Knowledge** of Safe Water Practice
- Procurement
- Consumption

**Access** to Safe Water
- Procurement
- Consumption

**Habit** of Safe Water Practice
- Procurement
- Consumption

**Exclusive Use** of Safe Water
- Procurement
- Consumption
- HH vs. Community
## Adapted Compliance Framework to the Mesita Azul Program:

### Adoption of Safe Water Practice

<table>
<thead>
<tr>
<th>Procurement</th>
<th>Mesita Azul (MA) was installed in household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acq. Agreement</td>
<td>Paid contribution in full</td>
</tr>
</tbody>
</table>

### Knowledge of Safe Water Practice

<table>
<thead>
<tr>
<th>Procurement</th>
<th>Operator has minimum basic knowledge and skills in using MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td>Interviewee differentiates treated and safely stored sources from others</td>
</tr>
</tbody>
</table>

### Access to Safe Water

<table>
<thead>
<tr>
<th>Procurement</th>
<th>MA is present at accessible location and in working condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td>Water treated with MA and safely stored (SS) is present at time of visit</td>
</tr>
</tbody>
</table>

### Habit of Safe Water Practice

<table>
<thead>
<tr>
<th>Procurement</th>
<th>Uses MA to treat water at least once every five days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td>MA-SS is most common source &amp; Last glass served from MA+SS</td>
</tr>
</tbody>
</table>

### Exclusive Use of Safe Water

<table>
<thead>
<tr>
<th>Procurement</th>
<th>Not documented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td>Has only consumed water from MA-SS in past 7 days</td>
</tr>
<tr>
<td>HH vs. Community</td>
<td>Not documented</td>
</tr>
</tbody>
</table>
Outline:

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Field Efficacy Research Conclusions:

- Do households gain access to safe water by using the Mesita Azul? Yes, but there is the potential for larger gains.

- What factors drive water contamination at the household? In the case of the Mesita Azul:
  
  **Treatment**
  **Drinking Vessel**
  **Hygiene**
Adoption and Use Research Conclusions:

- What levels of adoption & use can be achieved with UV disinfection? *Adoption & sustained use significantly higher than alternatives. But also significant drop between adoption & sustained use.*
Need for a Paradigm Shift from Product to Service-based HWT Programs
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UV Disinfection in Schools and Community Kiosks
Why are issues at the intersection of water, health, and development particularly hard to solve?

• Very limited feedback on waterborne health risks
• Complex epidemiological relation between water and health
• Water touches most aspects of our lives
• Mismatch in dimensions of value between designers and end-users
Can household water treatment play a significant role in addressing these water, health, and development issues?

• HWT can empower end-users, but also transfers burdens
• These burdens have limited the sustained use of HWT products
• Narrow focus on drinking water at the HH => poor compliance
• Need new paradigm, from product to service-based HWT programs