

Estimating the Effectiveness of Household Water Treatment in Reducing Diarrheal Disease Burden

Joint effects of device efficacy and behavioral use patterns

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Water Treatment and Diarrheal Disease Historical Trends

- ❖ **1980s – International drinking water supply and sanitation decade**
 - Led to interventions focused on improving water supplies
 - Results of intervention trials were equivocal
- ❖ **2000s – Shift from large scale water projects to dissemination of HWT devices**
 - Chlorination and filtration
- ❖ **2010 -WHO guidelines evaluate HWT options**
 - Health-based targets/microbiological performance specifications
 - Presents log reduction targets for viruses, bacteria, and protozoa

Water Treatment and Diarrheal Disease WHO Guidelines

Target	Log ₁₀ reduction required for bacteria	Log ₁₀ reduction required for Viruses	Log ₁₀ reduction required for Protozoa
Highly Protective	≥ 4	≥ 5	≥ 4
Protective	≥ 2	≥ 3	≥ 2
Interim	Achieves “protective” target for two classes of pathogens and results in health gains		

Summary of performance requirements for small-scale and household drinking-water treatment, based on reference pathogens *Campylobacter jejuni*, *Cryptosporidium* and rotavirus

Table reproduced from WHO publication (ISBN 978 92 4 154822 9: Evaluating household water treatment options: health-based targets and microbiological performance specifications).

Water Treatment and Diarrheal Disease

WHO Guidelines

❖ Goal

- Design guidance for producers of treatment devices
- Purchasing guidance for consumers

❖ Focus on technical features of devices

- Do not address behavioral use patterns (compliance)
 - Some people will never use the device
 - Device users will often use it inconsistently
 - People consume water outside the home
 - People may change behaviors based on risk perception

Question: How does compliance modify the effectiveness of a HWT device?

- Device decreases household exposure to pathogens
- Removal of pathogens is measured by log – removals
- Individuals not drinking treated water receive no benefits

Water Treatment and Diarrheal Disease Compliance and Risk: An Example



$$2 \text{ LR} \Rightarrow (1000 * 1/3 + 1000 * 2/3 * 0.01) = 340$$

$$3 \text{ LR} \Rightarrow (1000 * 1/3 + 1000 * 2/3 * 0.001) = 333$$

$$4 \text{ LR} \Rightarrow (1000 * 1/3 + 1000 * 2/3 * 0.0001) = 333$$

Methods – QMRA approach

- ❖ Model structure simulates following chain of events:
 - Determine concentrations of marker pathogens (rotavirus, *Giardia*, pathogenic *E. coli*) in drinking water -- sampled from gamma distributions
 - Calculate daily doses of pathogens based on their concentrations and the amount of water consumed
 - Convert daily doses to probabilities of infection (dose response function for each marker pathogen)
 - Assign infection to individuals (probabilistic)
 - Assign disease to individual (morbidity ratio)
 - Once ill an individual cannot be reinfected for 7 days
 - Process is repeated every day for a year in a defined population.

Methods – Calibration stage estimates pathogen concentrations

- ❖ Calibrate model to ensure outputs fall into one of 9 groups - all combinations of
 - 3 Baseline incidence levels (diarrhea cases/child-year)
 - High ($> 6 - 12$), Medium ($>2 - 6$), and Low ($0 - 2$)
 - 3 Etiologic fractions (percent bacteria, virus, protozoa)
 - A = (55, 30, 15), B = (55, 15, 30), and C = (40, 30, 30)
- ❖ Simulations are run under 1 of 4 source water conditions.
 - Differing magnitudes of concentration spikes

Methods – Estimation Stage

- ❖ The calibrated model is used to estimate the joint effects of compliance and device log removal
 - Three compliance types
 - α - Everyone complies perfectly or not at all
 - β – some comply perfectly, some partially, and some not at all
 - γ – Everyone complies partially
 - Log Removal values (LRV) vary from 1 to 5

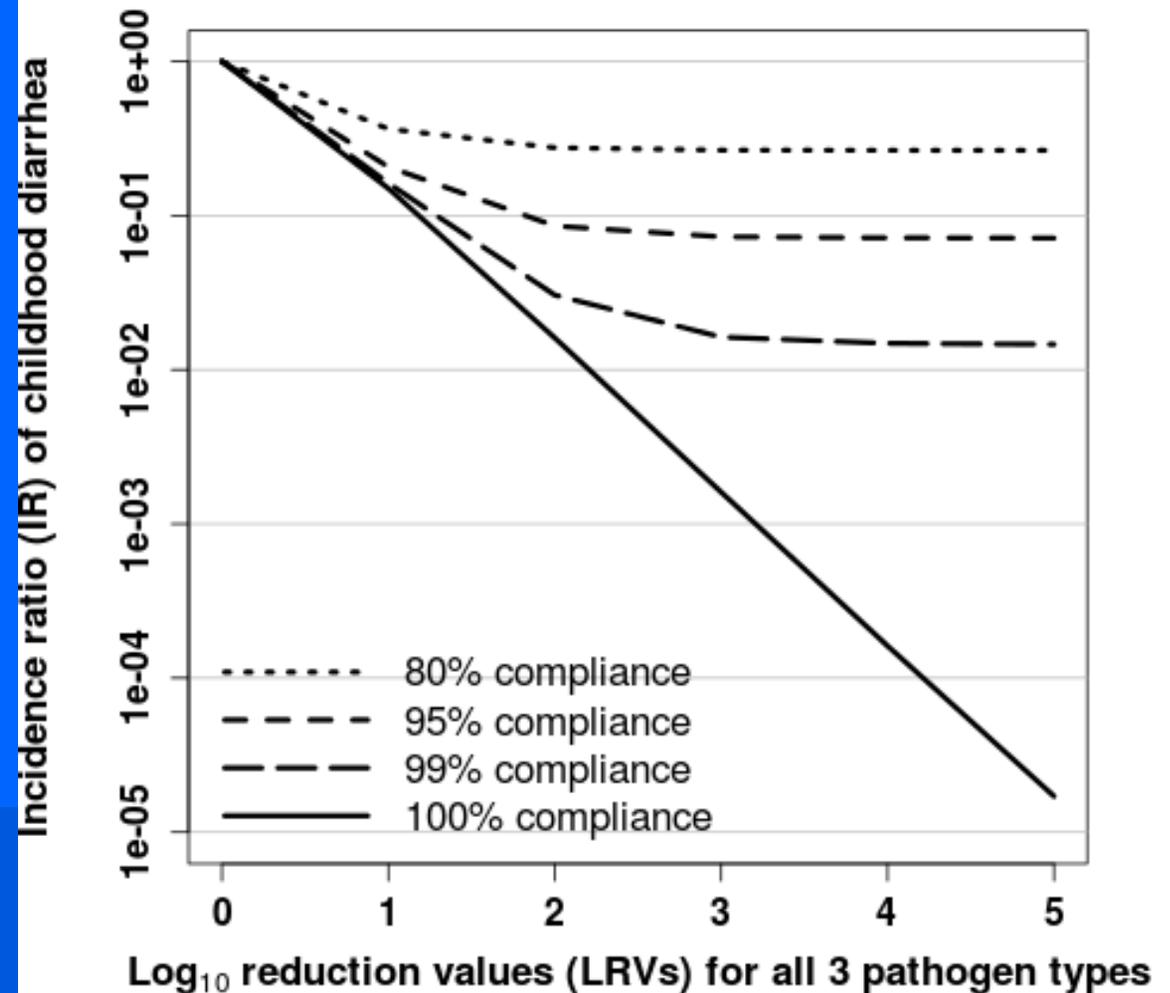
Results

Perfect compliance

Results in one log improvement in risk for every log increase in treatment efficacy

Imperfect compliance

Results in diminishing returns in health benefits for increasing treatment efficacy



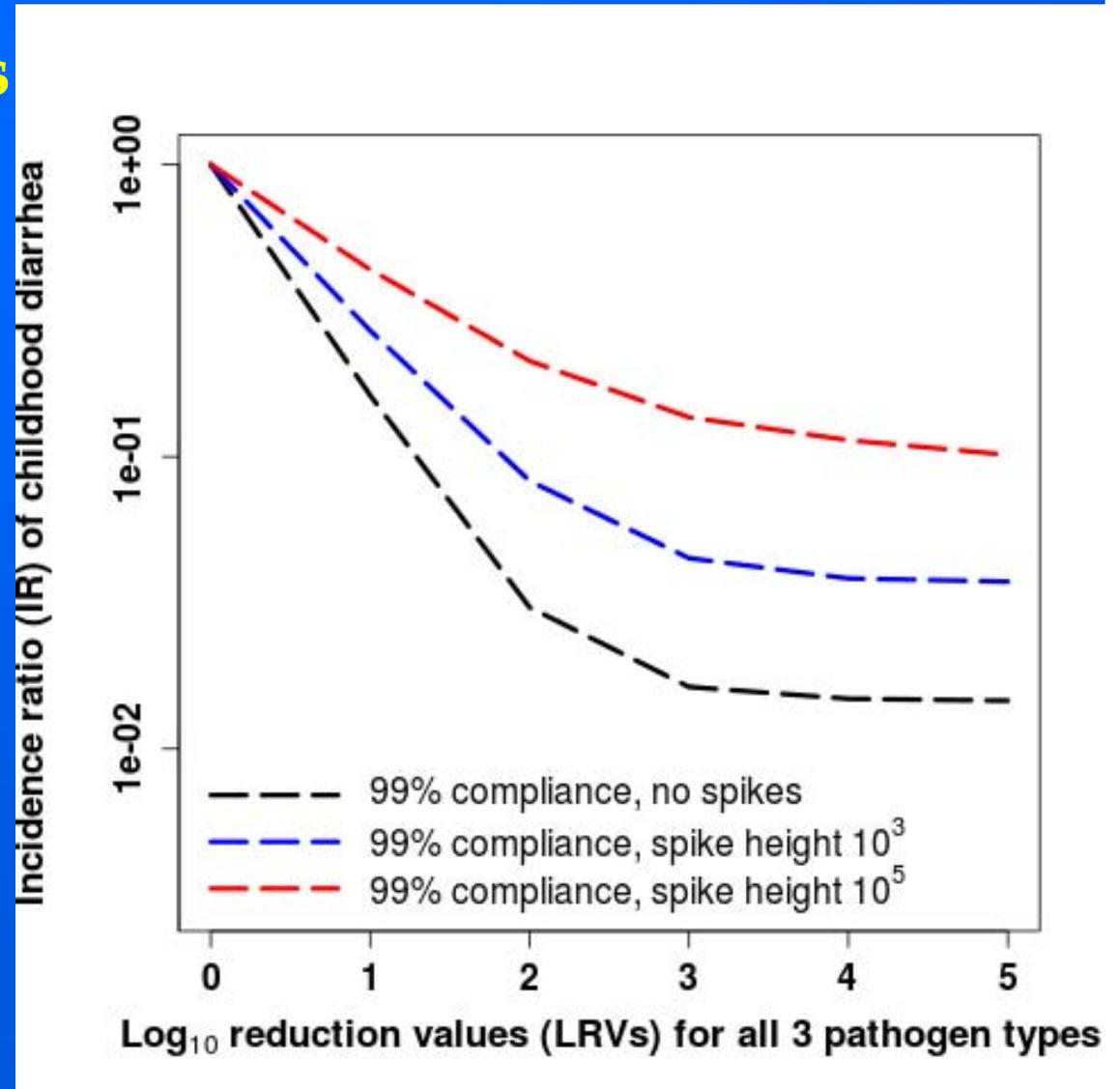
Compliance type β , no spikes, medium incidence, pathogen mixture A

Results

Contamination spikes

Increases the overall risk for a given log-removal

Diminishing returns for higher log-removal value regardless of whether or not there are contamination spikes



Compliance type β , medium incidence, pathogen mixture A

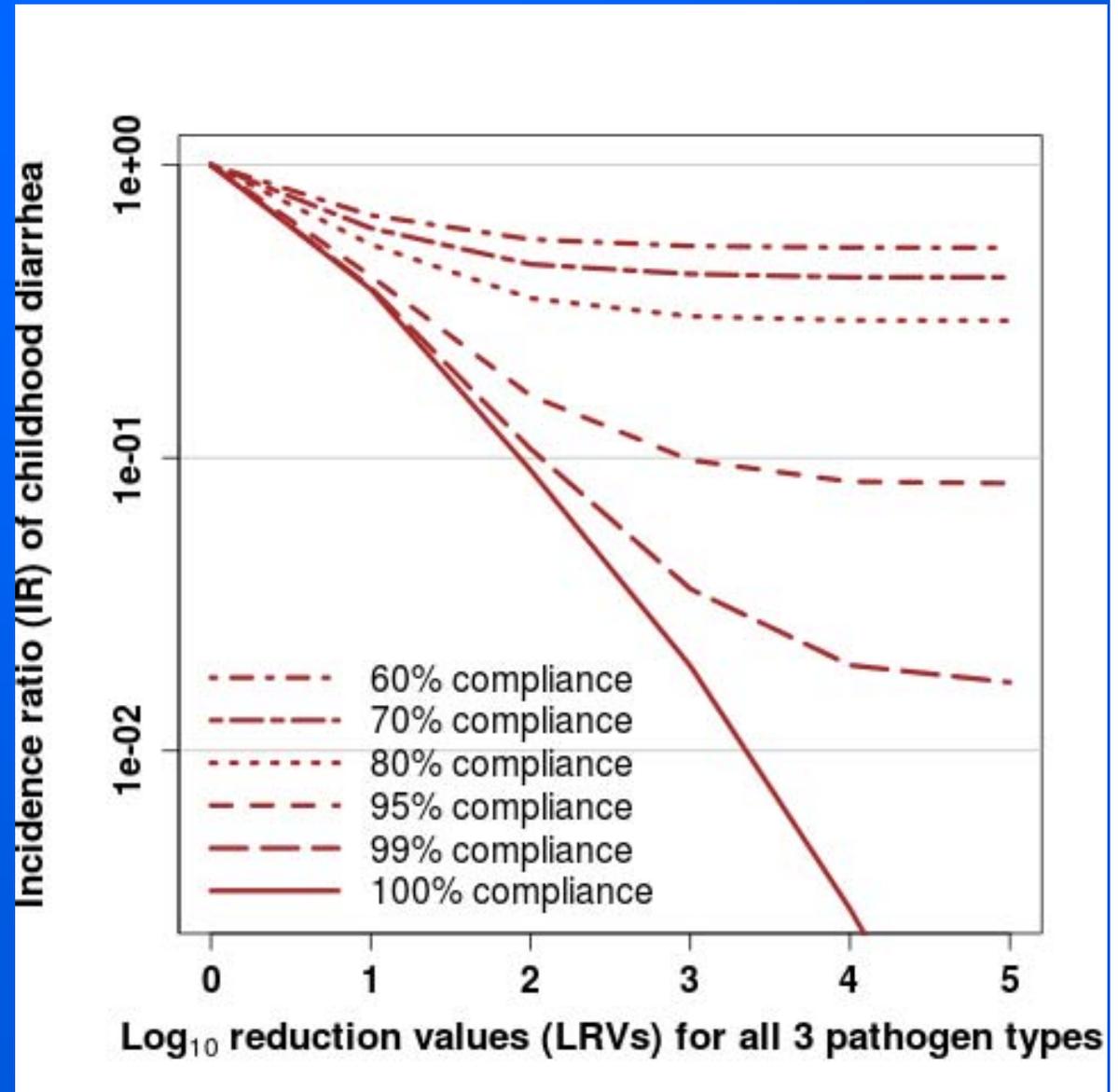
Results

Conditions where
we predict benefits
higher LRVs

When compliance
type is all or nothing

AND

Contamination spikes
are 1000 times
baseline



Compliance type α , spike magnitude = 1000x, medium incidence, pathogen mixture C

Conclusions

❖ At the individual level

- We observe benefits of high LRV with perfect compliance (100% of children drinking treated water 100% of time)
 - With each additional log removal of pathogens, there is a ten-fold decrease in incidence of diarrhea.
- When compliance decreases (even a little) these benefits of high LRV are lost.
 - Benefits are highly sensitive to changes in compliance.

Conclusions

❖ At the community level

- **Increasing from no treatment to 1 log removal**
 - Results range from 0% to 90% protection depending on the level of compliance.
- **Increasing from 1 to 2 LRV**
 - Provides increased benefits unless compliance is low.
- **Increasing beyond 3 LRV**
 - Provides little improvement unless
 - Compliance is high, at least among a subset of the population AND
 - Contamination occurs in spikes

Implications for Field Trials

- ❖ In an equivalence field trial
 - Not possible to observe a difference between a device with 2 LRV and one with higher LRV (issue of sensitivity)
- ❖ Our results are consistent with incidence reductions (20-80%) observed in field trials
 - Devices that may only have achieved 1-2 LRV of pathogens.
 - Suggests that lower compliance levels can still provide health benefits
- ❖ Health benefits from HWT are highly sensitive to the level and type of compliance.
 - Need to develop metrics to measure compliance in the field

Implications for Policy

- ❖ The WHO treatment guidelines for “highly protective” (4-5-4 LRV) and “protective” (2-3-2 LRV) HWT devices
 - Only apply to individuals that consume treated water 100% of the time.
 - Guidelines should incorporate compliance