Household water treatment and safe storage and its potential for integration: evidence and opportunities

Thomas Clasen, JD, PhD

Department of Disease Control
Faculty of Infectious and Tropical Diseases
London School of Hygiene & Tropical Medicine
Department of Environmental Health
Rollins School of Public Health, Emory University

Disclosure/Potential Conflicts

- UNICEF
- WHO
- WaterAid
- DelAgua Health and Development
- Unilever/Hindustan Unilever Ltd.
- PATH
- PSI
- Medentech
- Vestergaard Frandsen
- Procter & Gamble
- USAID
- DfID
- Bill and Melinda Gates Foundation

Summary

- Background on HWTS
  - Source vs. Household Water Treatment
  - Evidence from systematic reviews
- Conditions for optimizing HWTS
  - Reaching vulnerable populations
  - Ensuring consistent use
- Opportunities for Integration
  - Leveraging on existing programs
  - Combining interventions
- Case Studies
  - Bednets and VCT in Kenya
  - Filters and stoves in Rwanda

Environmental Barriers to Faecal-Oral Transmission

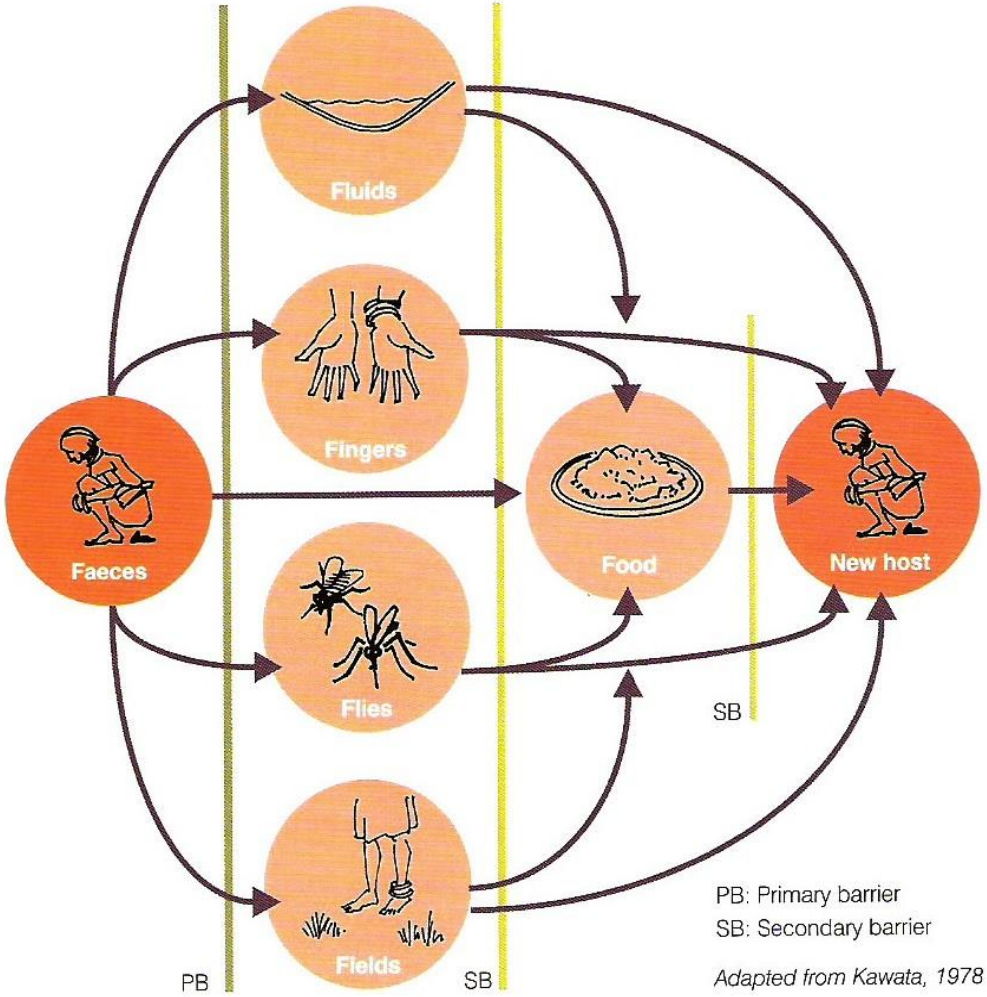


Figure 2.3.1. Transmission of disease from faeces

Primary Barrier

- Sanitation (proper excreta disposal)
- Hygiene (hand washing)

Secondary Barriers

- Water quality (treatment & safe storage)
- Water quantity (personal and domestic hygiene)
- Hygiene (especially hand washing)
- Proper cooking/food handing practices

Water Supply Coverage

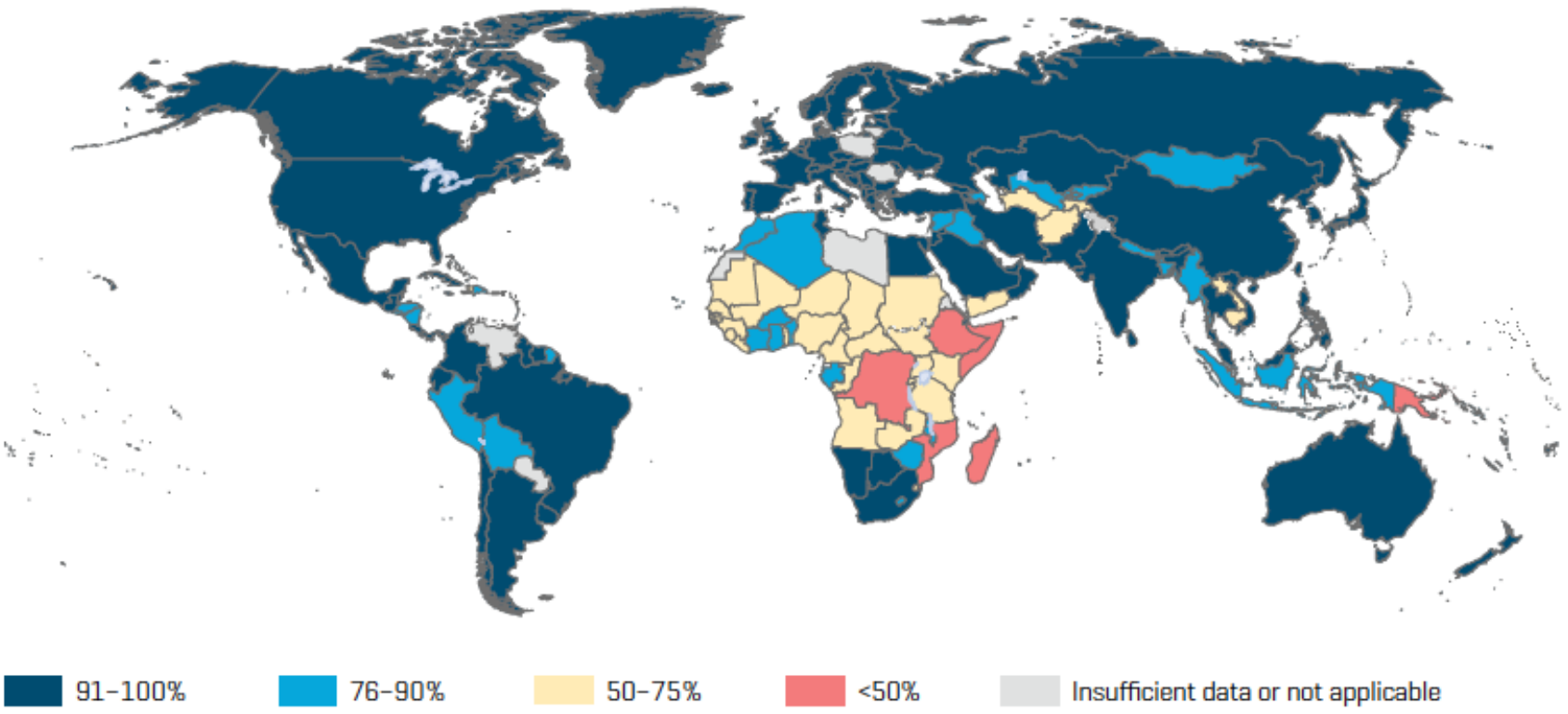


Figure 6. Proportion of the population using improved sources of drinking-water in 2011.

WHO/UNICEF 2013

Interventions at Source

- An estimated 250,000 hand pumps installed in Africa in 1981-2000
- Surveys suggest that less than half were still in use in 2004

Harvey and Drouin (2006)

Benefits of Source-Based Improvements

- Improve water quality
  - Reduce water-borne diseases
- Improve water quantity and access
  - Reduce water washed diseases
  - Improve personal hygiene
    - Reduce reported diarrhoea by 30%-45% (Curtis 2005)
    - Reduce respiratory infections by 25% (Rabie 2006)
  - Improve domestic hygiene
  - Reduce time spent collecting water
  - Potential for productive/economic use of water

Improved Source ≠ Safe

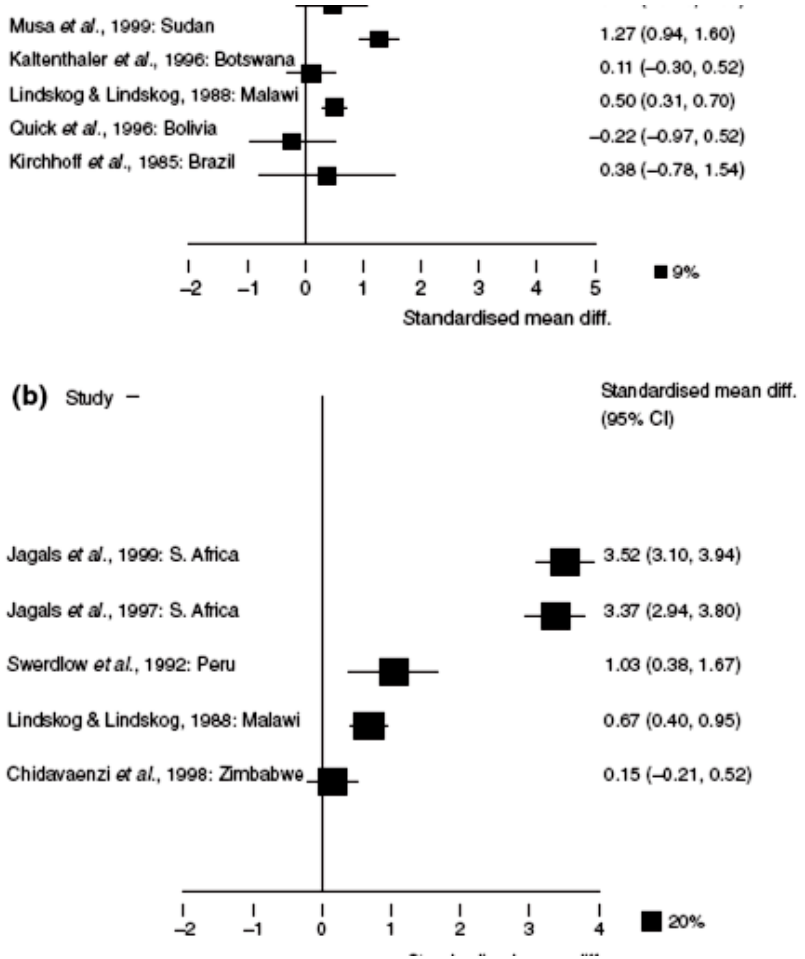
Results of multi-country

Rapid Assessment of Drinking Water Quality (RADWQ)

Percentage of samples from "improved water sources" that comply with WHO DWQG values by country and technology type (compiled from RADWQ reports)

	Utility piped water	Community piped	Boreholes/ Tubewells	Protected Springs	Protected wells	Total
Jordon	99.9%					99.9%
Ethiopia	87.6%		67.9%	43.3%	54.9%	72.0%
Nicaragua	89.9%	39.1%	45.7%		19.3%	46.7%
Nigeria	77.0%		94.0%		56.0%	75.7%
Tajikistan	88.6%			82.0%		87.2%

Recontamination in the home
Systematic Review—Wright et al.*

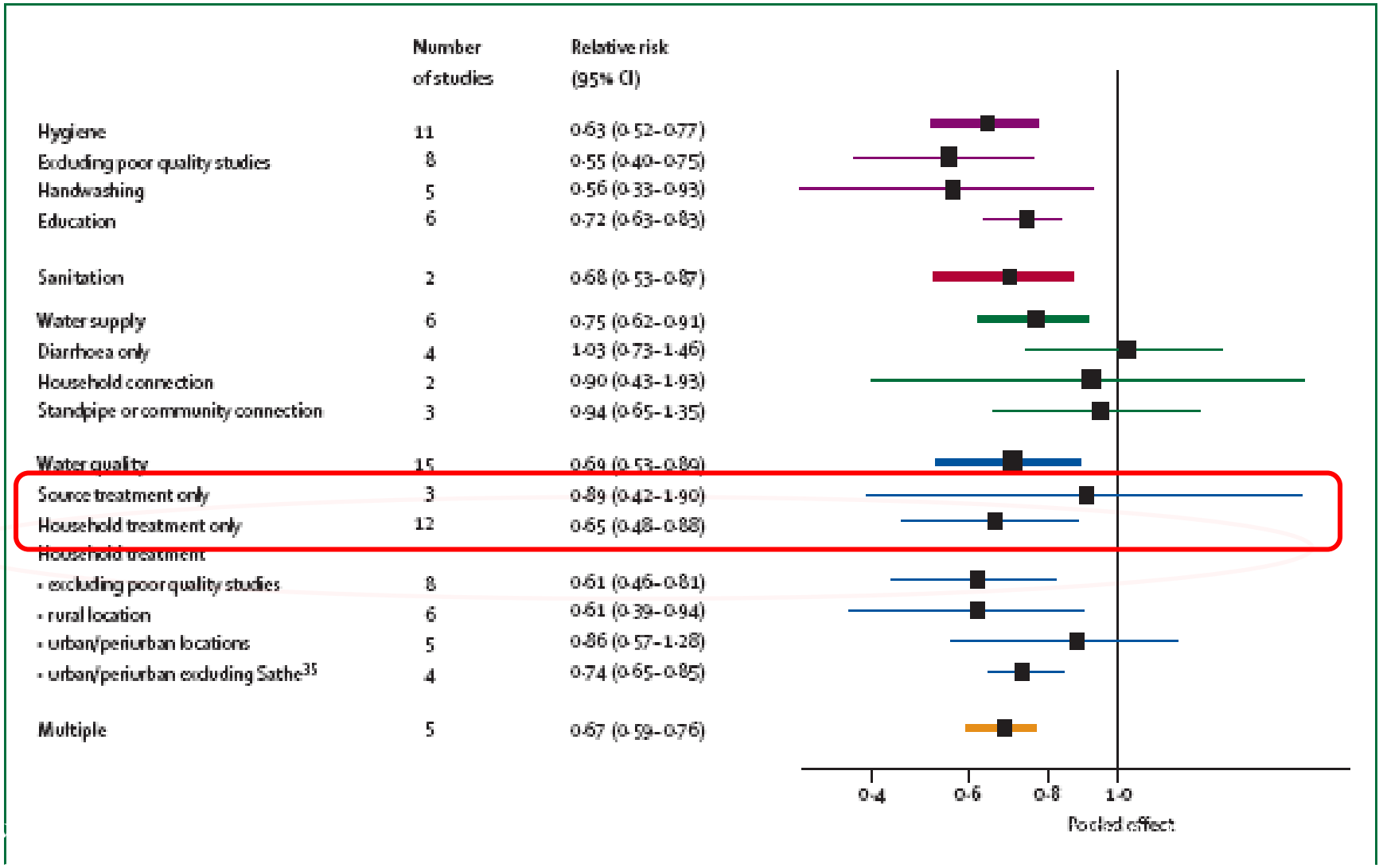


- Systematic review and meta-analysis of 57 studies measuring bacteria counts for source water and stored water in the home.
- Results: The bacteriological quality of drinking water significantly declined after collection in many settings.
- Conclusion: Policies that aim to improve water quality through source improvements may be compromised by post-collection contamination. Safer household water storage and treatment is recommended to prevent this, together with point-of-use water quality monitoring.

*Wright J, Gundry S, Conroy R (2004). Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. Tropical Med. Int'l Health 9(1): 106-117

Interventions at the Household

Impact on Diarrheal Disease
Systematic Review: Fewtrell (2005)



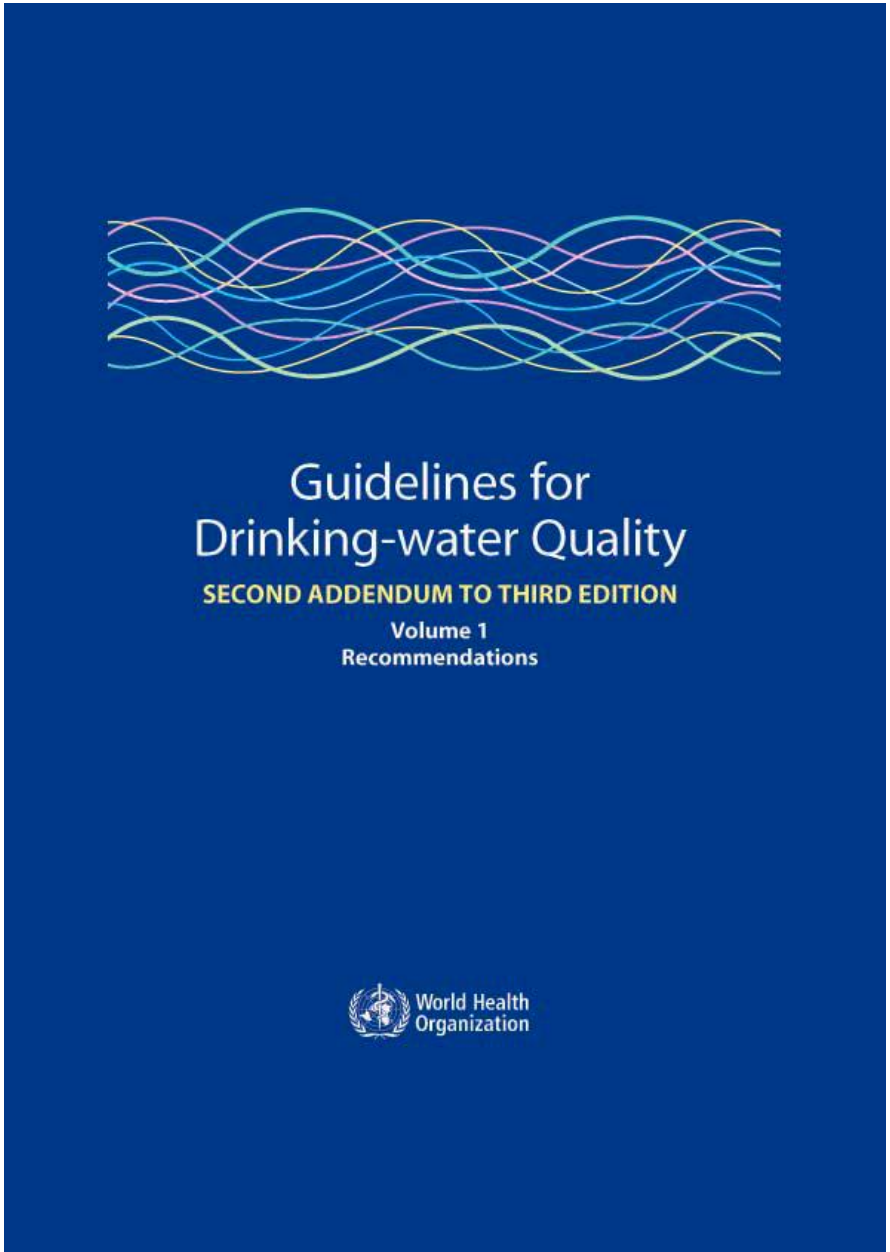
Systematic Review—Clasen (2007)

Intervention Type (no. trials)	Estimate (random)	% Δ (1-RR)	95% CI of Estimate	Heterogeneity* (Chi-square)
Source (6)	0.73	27%	0.53 to 1.01	p<0.00001
Household (32)	0.53	47%	0.39 to 0.73	p<0.00001
Filtration (6)	0.37	63%	0.28 to 0.49	p=0.56
Chlorination (16)	0.63	37%	0.52 to 0.75	p<0.00001
Solar Disinfection (2)	0.69	31%	0.63 to 0.74	p=0.73
Flocc/Disinfection (7)	0.48	52%	0.20 to 1.16	p<0.0001
Flocc/Disinfection (ex Doocy)	0.69	31%	0.58 to 0.82	p=0.08
Impr. Storage (1)	0.79	21%	0.61 to 1.03	n.a.

*Note that in a test for heterogeneity, a low p-value (eg <0.10) suggests an actual underlying difference in effect between studies that is unlikely to be attributable to chance.

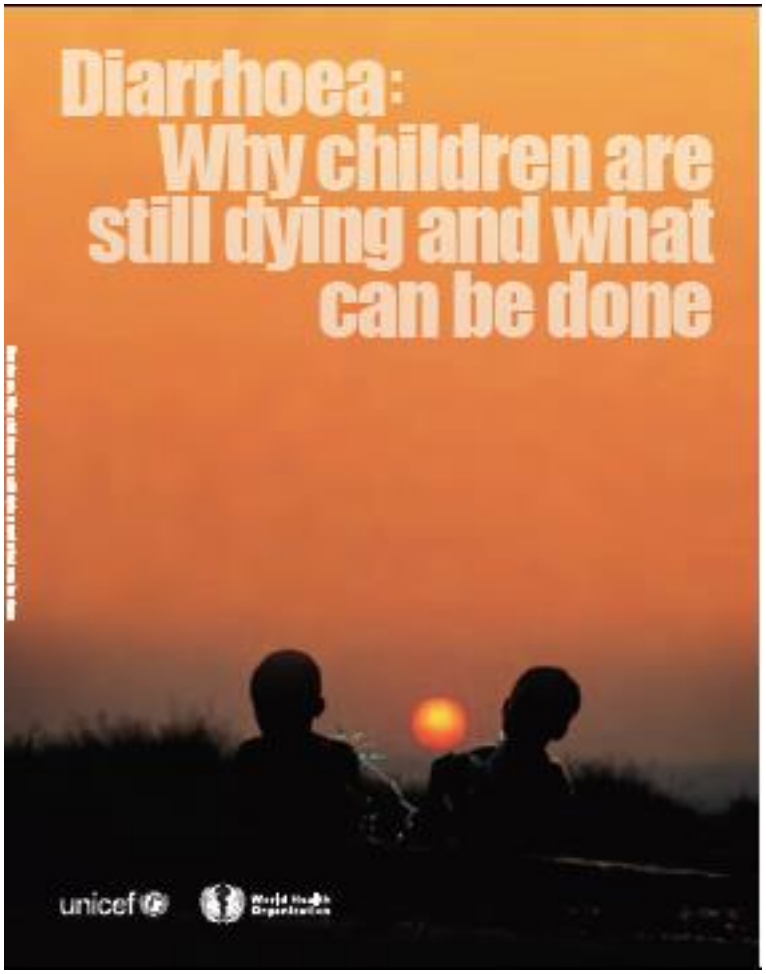
Clasen BMJ 2007

Support for HWT



"HWT technology has the potential to have rapid and significant positive health impacts in situations where piped water systems are not possible and where people rely on source water that may be contaminated, or where stored water becomes contaminated because of unhygienic handling during transport or in the home" (WHO 2008).

UNICEF/WHO 7-Point Plan for Comprehensive Diarrhoea Control



A. Treatment package
   1. Fluid replacement to prevent dehydration
   2. Zinc treatment

B. Prevention Package
   3. Rotavirus and measles vaccinations
   4. Promotion of early and exclusive breastfeeding and vitamin A supplementation
   5. Promotion of handwashing with soap
   6. Improved water supply quantity and quality, including treatment and safe storage of household water
   7. Community-wide sanitation promotion.

Unicef/WHO (2009)

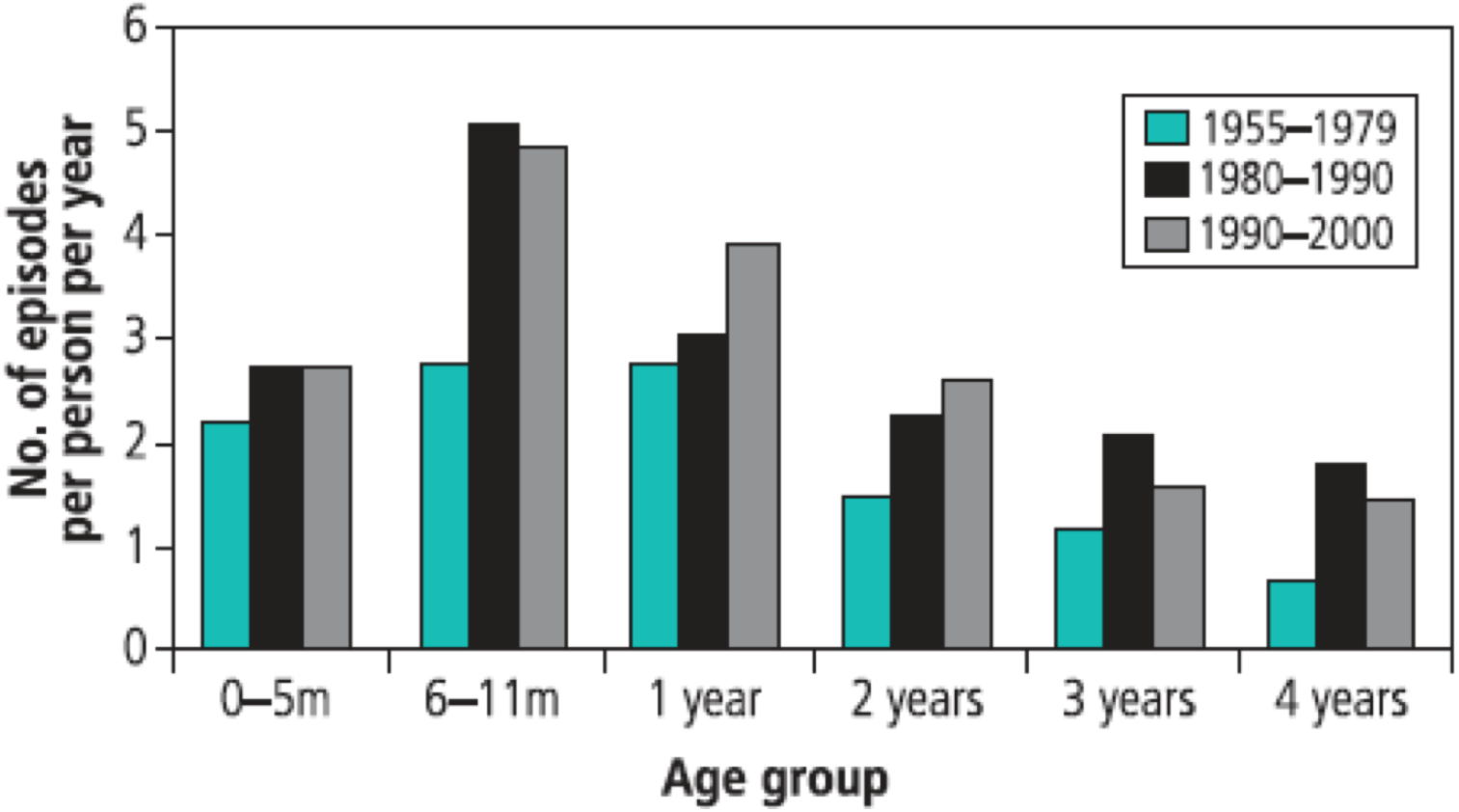
Optimizing HWTS

- Microbiologically effective solution that includes safe storage
- Vulnerable population (exposure)
- Consistent (exclusive) use
- Sustained use and accessibility

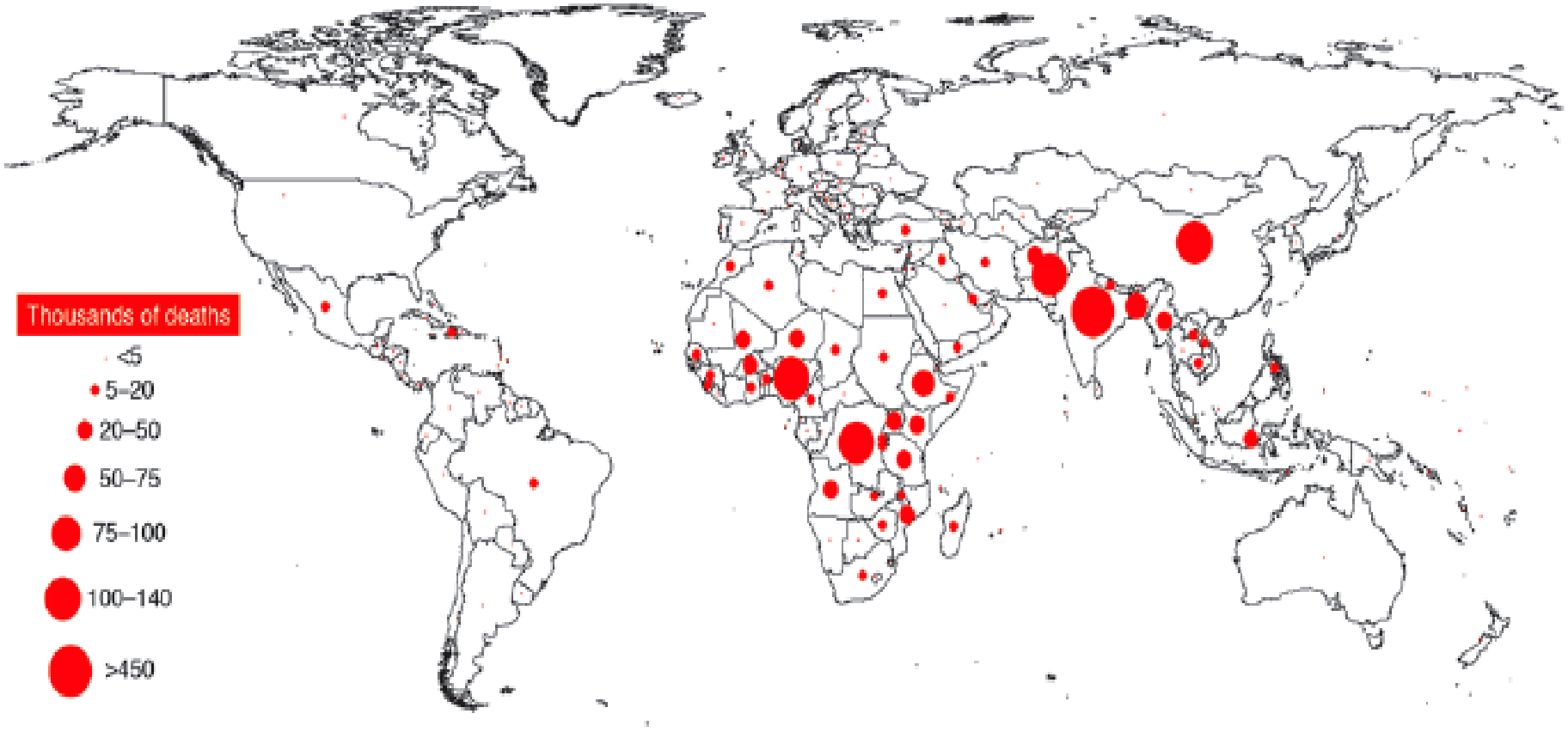
Microbiologically Effective Solutions

Vulnerable populations

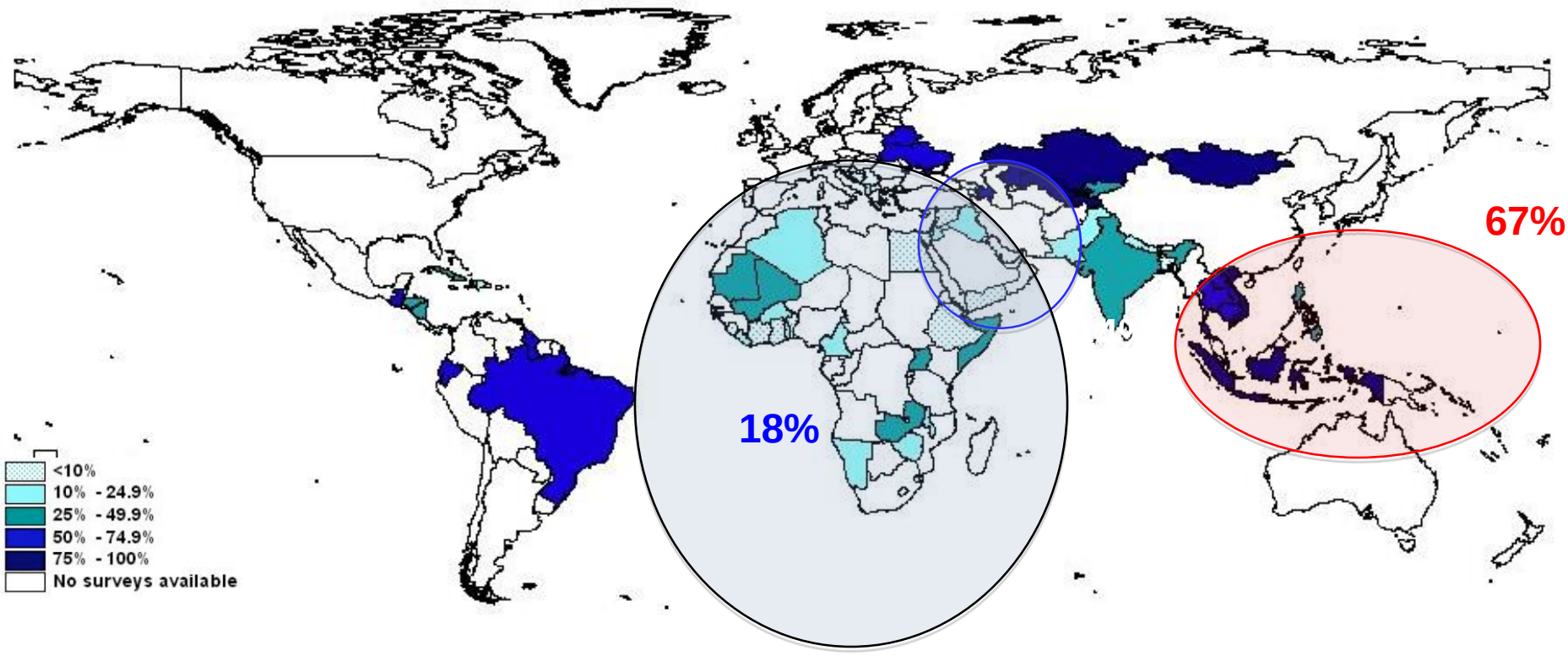
Fig. 1. **Median age-specific incidences for diarrhoeal episodes per child per year from three reviews of prospective studies in developing areas, 1955–2000**



Global Distribution of <5 deaths from diarrhoea

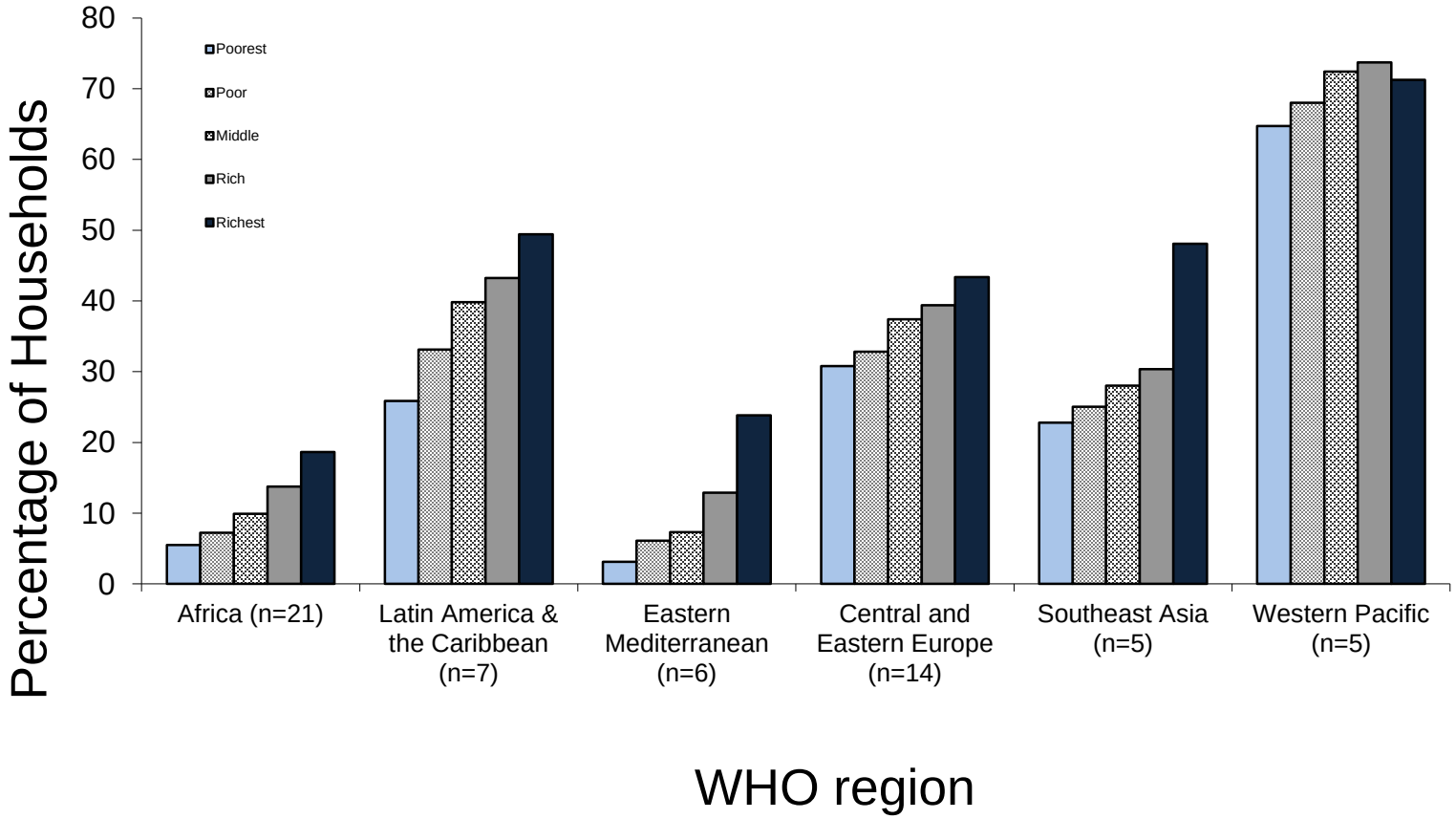


Current Scale of Reported HWT



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 microbiologically adequate HWT-use increases with wealth

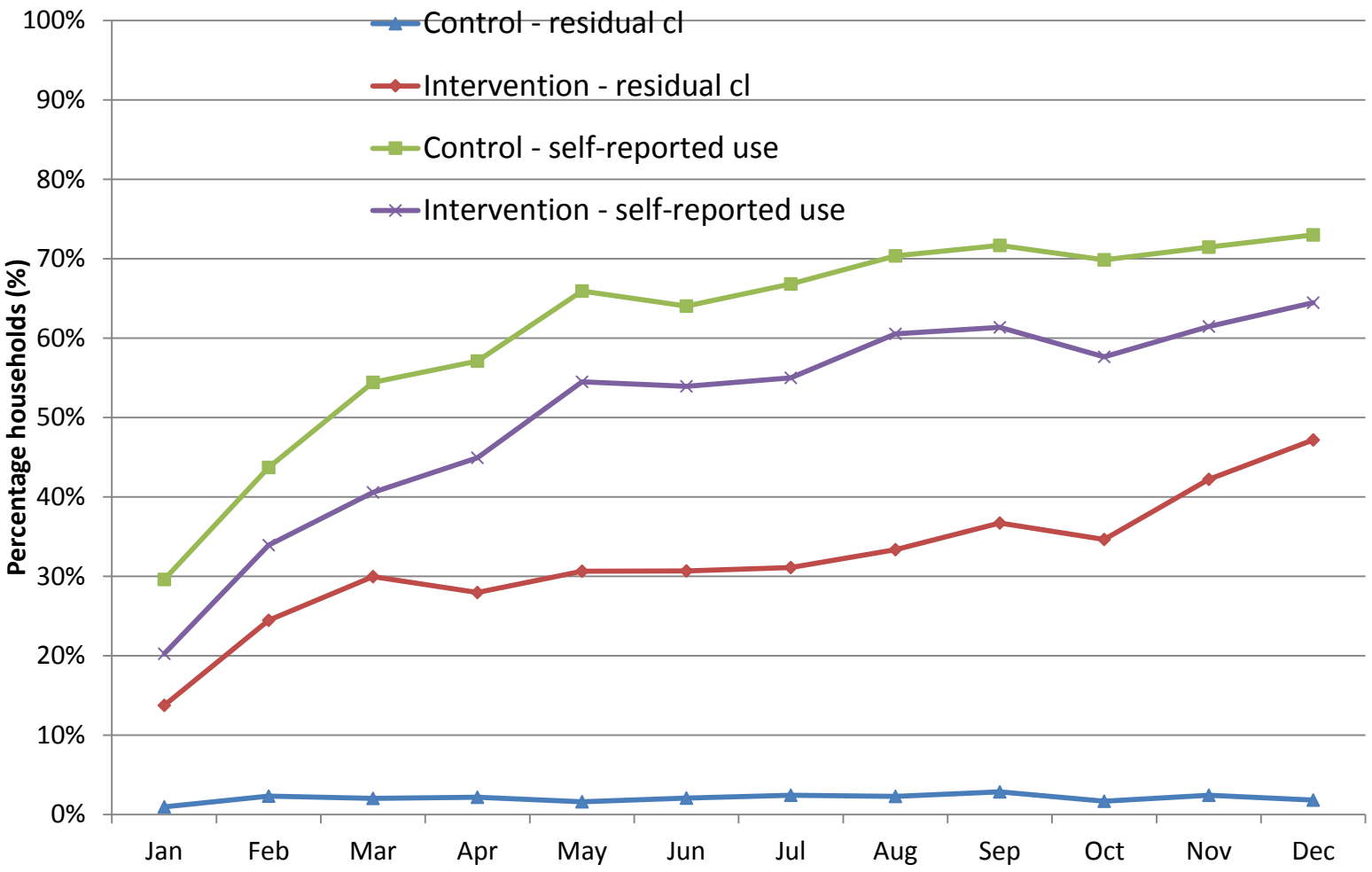


The Challenge of Securing Compliance: Aquatab Trial in Orissa

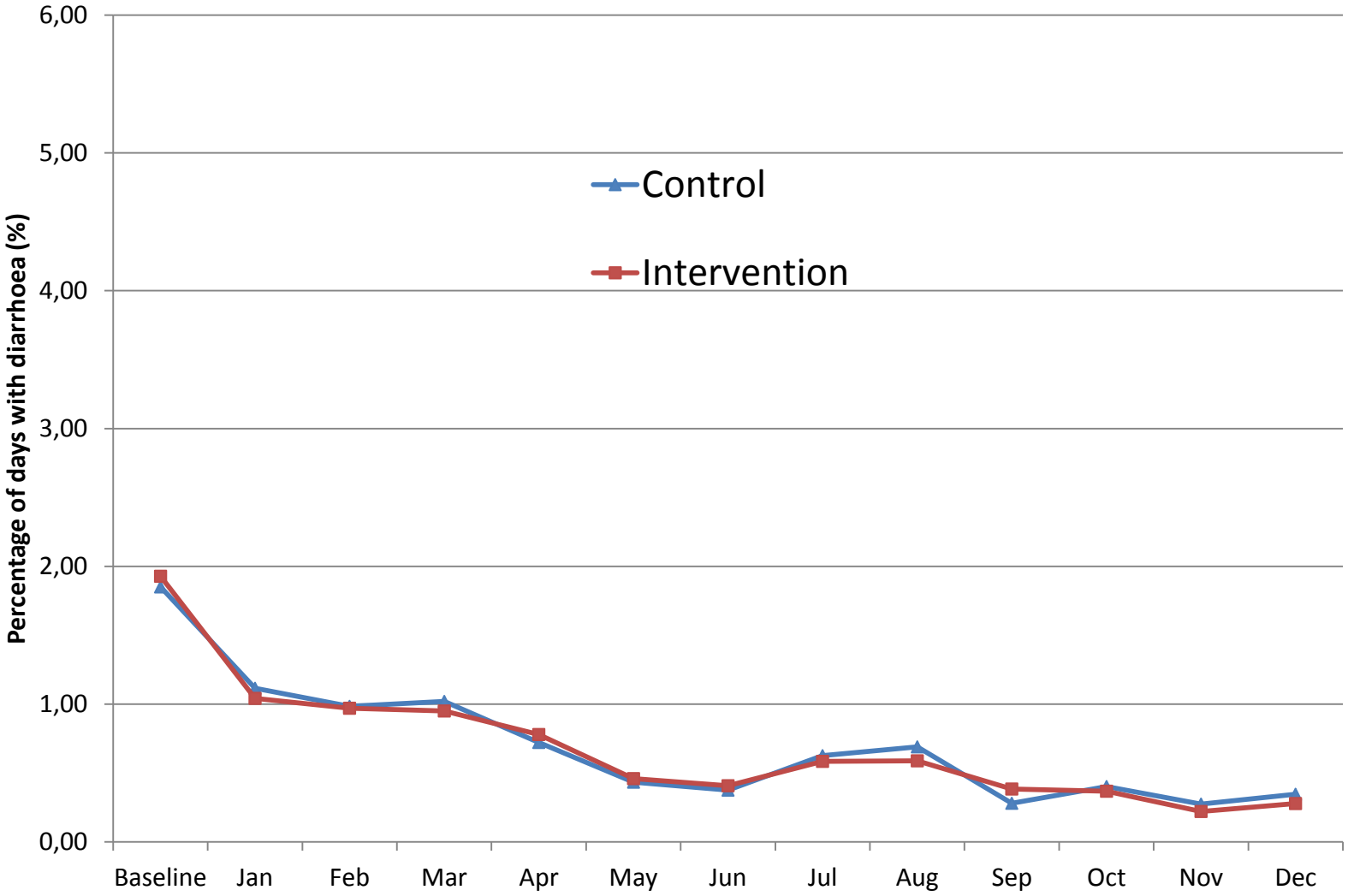
- Double blinded, cluster-randomized, placebo-controlled field trial
- Following enrollment and baseline, 2163 households (12,090 individuals) with at least one child <5 (2745 total) were randomized into intervention or control groups
- Implementation by PSI with extensive personal interaction (monthly household visits, posters, street theatre, etc.)
- 12 month follow up including water quality and RFC

Boisson et al. 2013 PLOS Med

Compliance


Control - residual cl
Intervention - residual cl
Control - self-reported use
Intervention - self-reported use
Percentage households (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Diarrhoea Prevalence by Round



Consistent Use

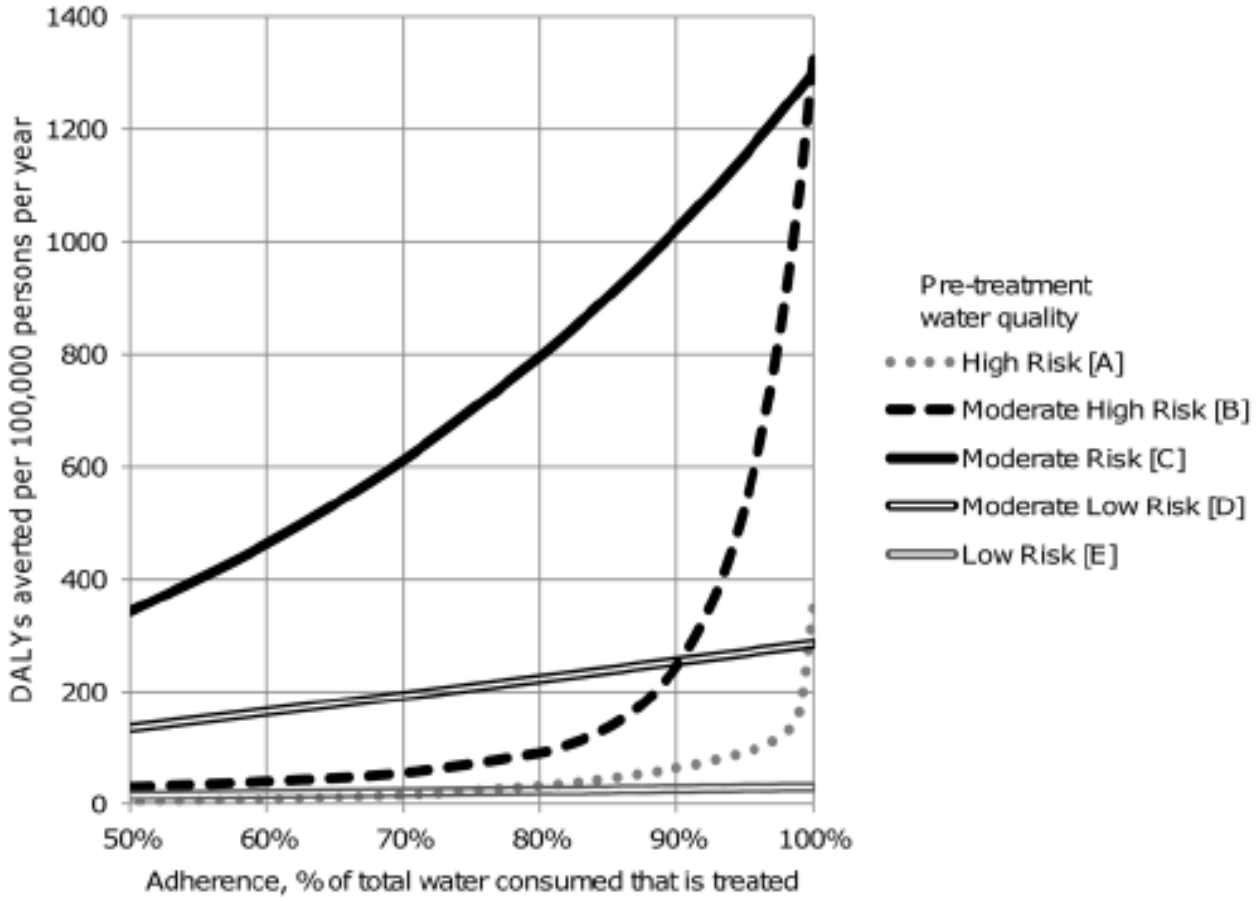


Figure 1. DALYs averted per 100,000 population, per year, based on assumptions about technology effectiveness (2 $\log_{10}$ reduction in each pathogen class), adherence, and background water quality assumptions from Table 2.
doi:10.1371/journal.pone.0036735.g001

Brown and Clasen 2012

Sustainability

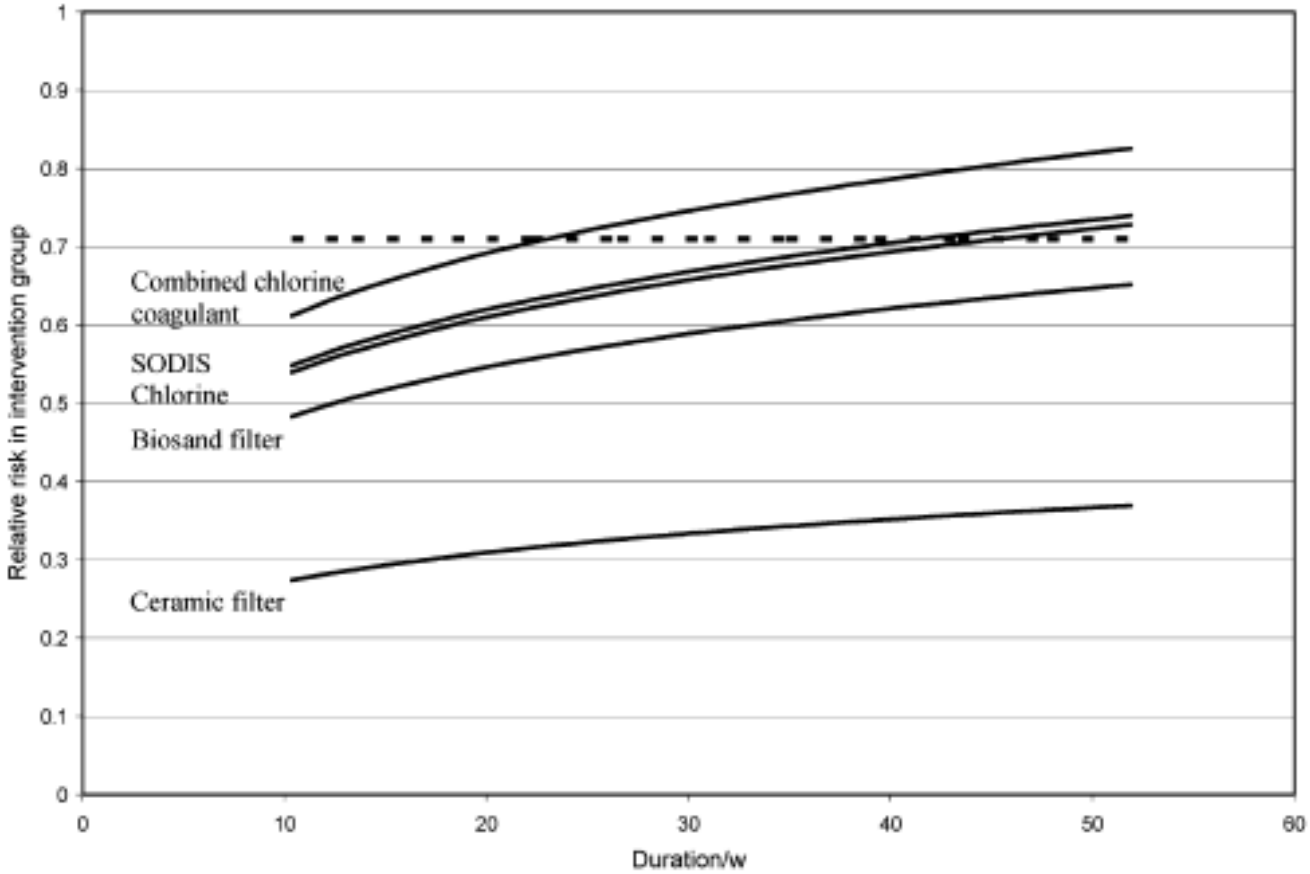


FIGURE 3. Impact of duration of follow-up on effectiveness of the different intervention types unblinded and the midpoint estimate of the likely impact of reporting bias due to lack of blinding.

Hunter P (2009). Household water treatment in developing countries: comparing different intervention types using meta-regression. Environ Sci Technol. 43(23):8991-7

Opportunities for Integration

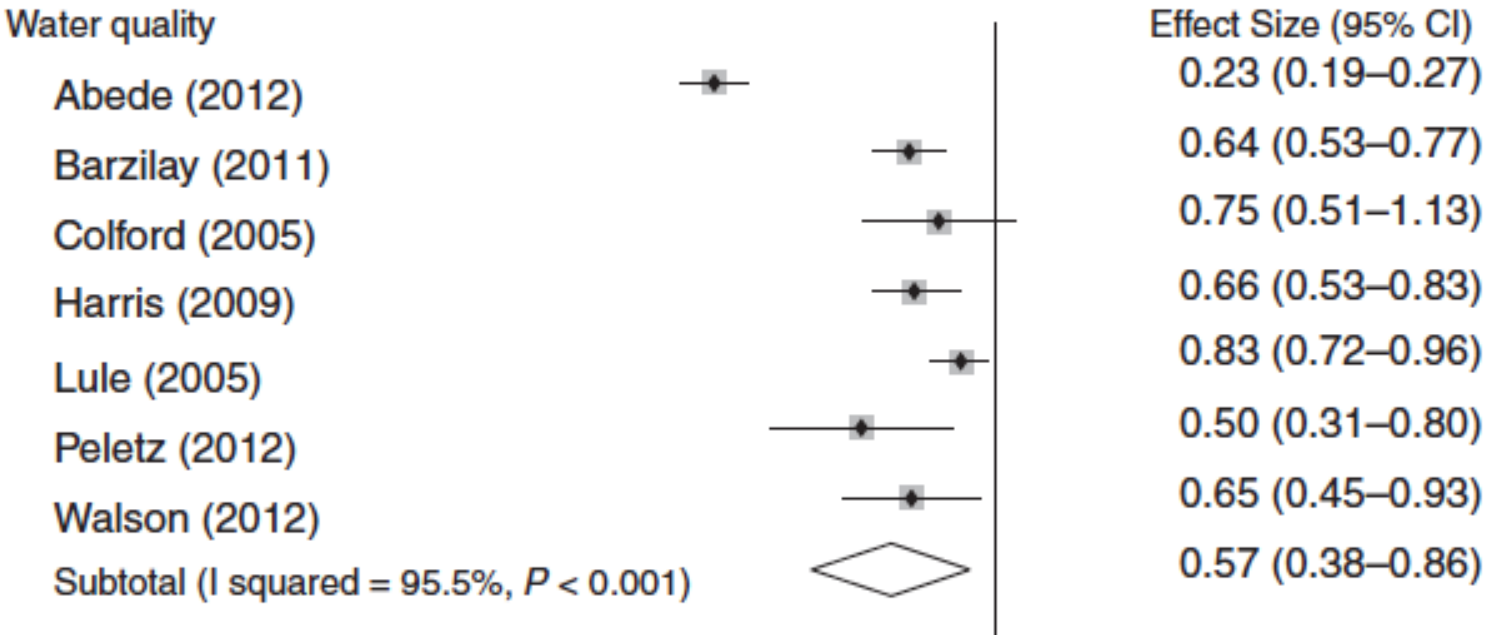
- Program Integration*
  - Child survival
  - Nutrition
  - People living with HIV/AIDS
  - Emergency and outbreak response
  - Schools and health clinics
  - Improving water storage to minimize breeding sites for disease vectors
- Intervention Integration
  - Bednets and VCT in Kenya
  - Stoves in Rwanda

*WHO (2013). Considerations for Policy Development and Scaling-Up Household Water Treatment and Safe Storage with Communicable Disease Prevention Efforts

HWTS among PLHIV

- People living with HIV/AIDS (PLHIV) are especially vulnerable to infection and disease associated with unsafe drinking water and poor sanitation and hygiene:
  - Four to seven times more likely to suffer from diarrhoeal disease (Mermin 2004)
  - Increased risk of enteric infections including *Cryptosporidium* spp., Microsporidia, *Isospora belli*, *Cyclospora*, *Entamoeba histolytica Salmonella*, *Shigella*, and other pathogens transmitted through the faecal-oral route, particularly in low-income settings (Tumwine 2005)
  - Gastrointestinal infections may increase the progression of HIV and lead to environmental (tropical) enteropathy (Mellors 1997, Humphrey 2009)
  - Household members of PLHIV including young children born to HIV-positive mothers may experience increased health risks (Filteau 2009)

Systematic Review of WASH Interventions and HIV



- 7 studies that reported on water quality diarrhoea
- Pooled RR of 0.57 (95%CI: 0·38-0·86), representing a 43% reduction

Peltz et al. AIDS 2013, 27:2593–2601

Integrating Interventions

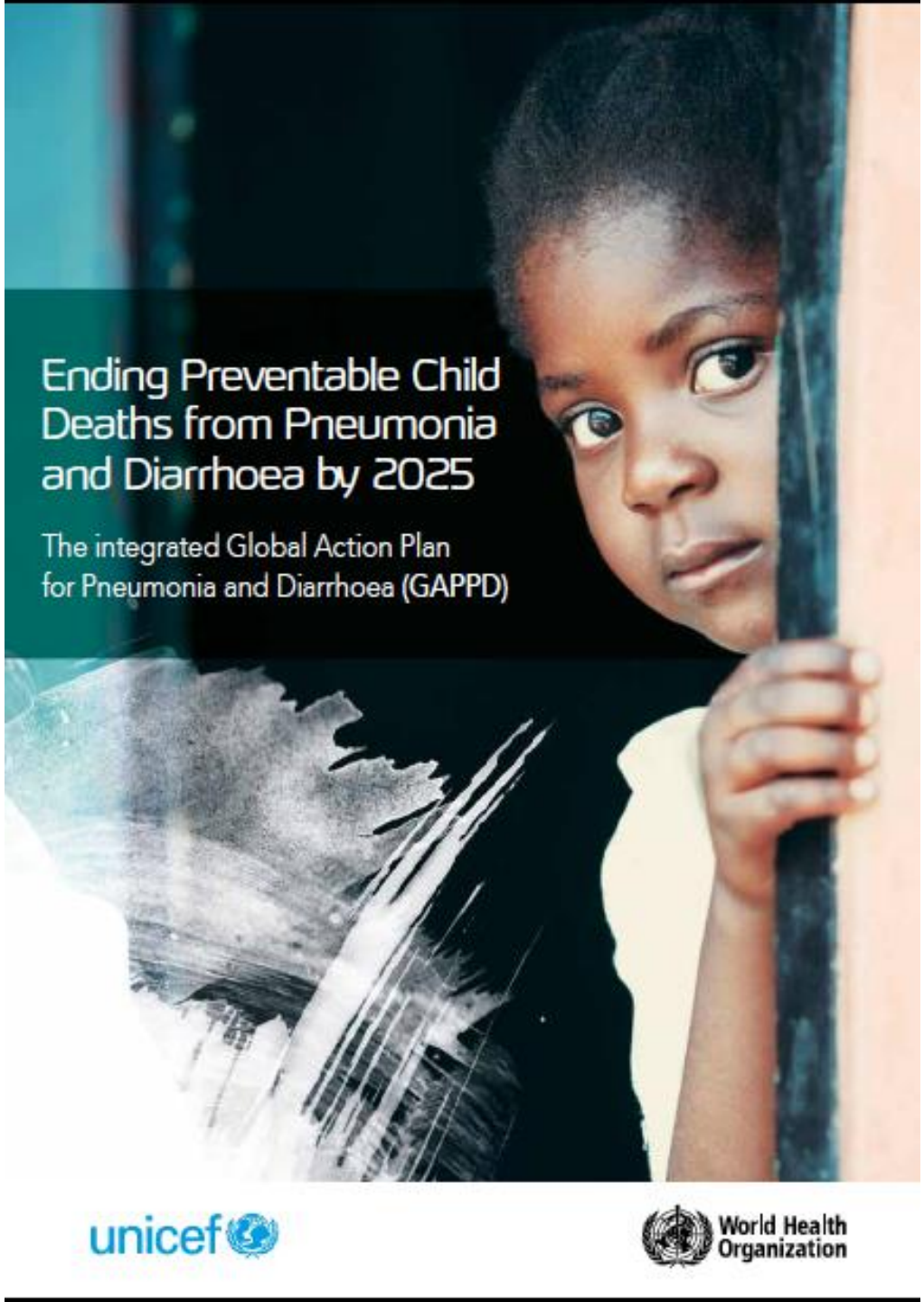
Kahn et al. 2012


INTEGRATED

Results

- 47,311 people participated over 7 days, representing 96% of target population (ages 15-59)
- 99.7% were tested for HIV; 4% tested positive
- Intervention coverage after 2 months:
  - 91.8% for bednets
  - 89.7% for condoms
  - 75.3% for water filters
  - 80.0% for cotrimoxazole for HIV infected persons.
- Cost savings of $16,015 per 1000 persons
- $20 per DALY averted

Lugada 2010; Kahn 2012



- Diarrhoea and pneumonia responsible for 6.9M deaths annually
- Implementation of WASH and 14 other designated interventions could reduce diarrhoea mortality by 95% and pneumonia by 75% by 2025
- Marginal cost is <$3B

The Lancet Diarrhoea and Pneumonia Interventions Study Group 2012

Integrated Filter-Improved Stove Project in Rwanda

- 80% of the population lives in rural areas and is engaged in agriculture.
- Improved water coverage is 65% (JMP 2012).
- Most common communicable diseases are malaria, HIV/AIDS, acute respiratory infections, diarrhoeal diseases and tuberculosis.

Phase I Evaluation: Uptake and Exposure

- 5-month household randomized controlled trial
- 566 households from 3 villages
- Randomized by public lottery to half of village households
- Five monthly follow-up visits to households
  - Observations and survey questions on use
  - Water quality sampling for TTC
  - Air quality monitoring for PM2.5 and CO in cooking area
  - SWEETSense monitoring of filter and stove use

Rosa G, Majorin F, Boisson S, Barstow C, Johnson M, et al. (2014) Assessing the Impact of Water Filters and Improved Cook Stoves on Drinking Water Quality and Household Air Pollution: A Randomised Controlled Trial in Rwanda. PLoS ONE 9(3): e91011.

Rural Water Sources

Intervention 1: Filters

- Vestergaard-Frandsen LSF 2.0, combining nanofiltration with safe storage
- Lab testing demonstrated 6-5-3 microbiological performance over 18,000L design life (Clasen 2007).
- Field studies of LSF1.0 in Zambia (Peletz 2012) and Congo (Boisson 2009).

Traditional Cooking on 3-Stone Fire

Intervention 2: Cook Stoves

- Eco-Zoom stove designed in USA and manufactured in China
- Evaluations for USAID by the Berkeley Air Monitoring reported fuel savings of 39% to 54% compared to open fires;
- Evaluations also shown to cook meals faster, and preferred stove by 96% of households.

Thomas et al. 2013


EcoZOOM
ZOOM DURA STOVE

Thomas ES&T 2013


3AUA00
2408
2389

Filter Use and Water Quality

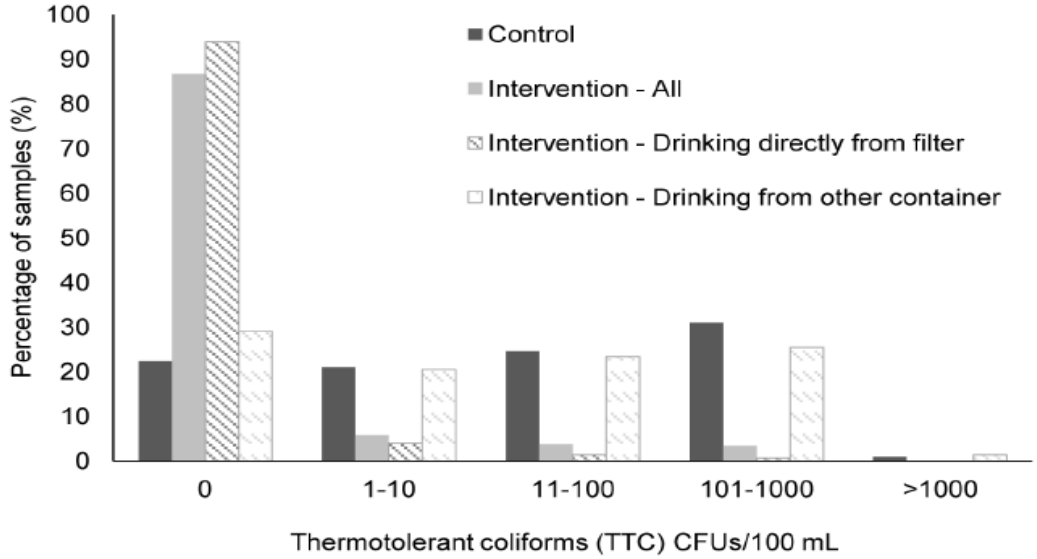


Figure 2. Percentage of water samples by level of contamination (TTC/100 mL).

- High compliance overall (89.2% use), but 25% reported drinking from other sources at least once during 5 visits
- Effective, 96.6% of drinking water samples collected directly from filters were free of TTC
- Overall, a 97.5% reduction in mean faecal indicator bacteria (Williams means 0.5 vs. 20.2 TTC/100 mL, $p<0.001$)

Stove Use and Air Quality

- Compliance
  - 66.7% of intervention households identified the intervention stove as their main cooking stove.
  - Only 23.3% of intervention households reported that their main cooking area was outdoors.
- Exposure
  - Overall, the intervention was associated with a 48% reduction of 24-h PM2.5 concentrations in the cooking area (0.485 mg/m3 and 0.267 mg/m3, $p = 0.005$).
  - Reduction was 37% for those cooking indoors ($p=0.08$) and 73% for those cooking outdoors ($p<0.001$)

Conclusions

- HWTS can be an effective intervention
  - Microbiological effectiveness (including safe storage)
  - Vulnerable population
  - Consistent use
  - Sustainable strategy
- No substitute for improved water supply
- Opportunities for integration
  - Programmatic integration (nutrition, schools/clinics, emergencies, vector control, PLHIV)
  - Combined interventions, especially household environments (bed nets, stoves, safe storage)

Acknowledgements

- CDC (S. Luby, R. Quick J. Crump, T. Chiller, E. Mintz, D. Lantagne)
- WHO (B. Gordon, A. Pruss)
- UC Berkeley (J. Colford, B. Arnold)
- University of Wales (L. Fewtrell)
- University of East Anglia (P. Hunter)
- University of North Carolina (M. Sobsey, J. Bartram)
- LSHTM (S. Cairncross, , T. Rabie, G. Rosa, L. Smith, W. Schmidt, S. Thomas)

- Special Thanks: IWRDC (H.J. Overgaard)