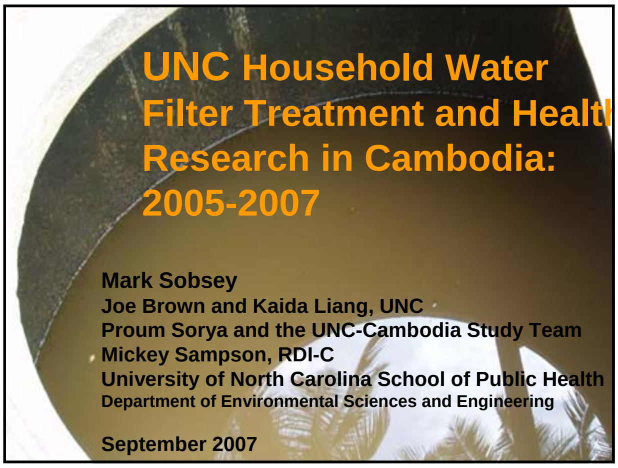

UNC Household Water Filter Treatment and Health Research in Cambodia: 2005-2007

Mark Sobsey
Joe Brown and Kaida Liang, UNC
Proum Sorya and the UNC-Cambodia Study Team
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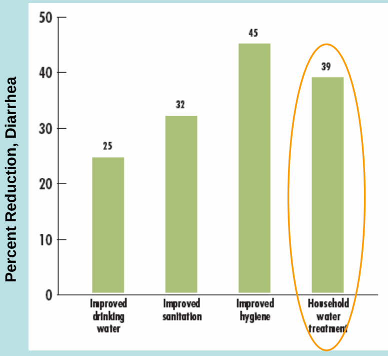
September 2007

Impacts of Water Sanitation and Health Interventions on Diarrhea: HWT Works!



Fewtrell et al. 2005, Lancet Infectious Diseases

- HWT interventions are better than previously thought
- Previous estimates put improved water quality last in diarrhea disease impact, at <20%
  - Did not include HWT studies
  - Few were studies available at the time; some had no positive effect

Technologies for Physical Treatment of HH Water: UV Radiation and Heat Inactivation of Pathogens

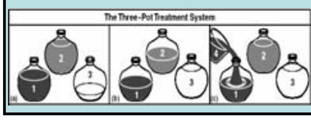
- Boiling: most widely used globally
- UV disinfection with lamps
  - "UV-Tube"
- Solar disinfection with UV + heat:
  - SODIS and SOLAIR
  - Clear UV-transparent bottle (PET)
  - Place in on dark surface for 1-2 days, depending on sunlight
- Solar disinfection with heat only:
  - black or opaque bottle or pot
  - solar cooker
  - solar reflector
  - Wax temperature indicator

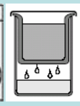


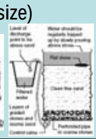


Physical Removal Processes for Household Water Rx

Treatment Method	Microbial reductions
• Plain Sedimentation	varies with microbe type
• Filtration Methods	
– Ceramic filter	High (>99%); except viruses
– Slow sand filter	High (>99% for some)
– Rapid granular media	Moderate (90-99%)
– Fabric, paper & fiber	Varies (microbe & pore size)
– Membrane filters	High, potentially (microbe and pore size)







Chemical Treatment of Household Water

- **Free chlorine (disinfectant)**
  - Liquid, tablets, granules; widely available; cheap
  - Highly effective
  - Health impact; reduces diarrhea
- Chemical coagulation (physical removal)
  - Alum, ferric salts, nut/seed polymers, etc.
  - Potentially effective but hard to properly dose
  - Best if used with filtration; available; cheap
- **Combined chemical Rx: coagulant + disinfectant**
  - Procter & Gamble PUR
    - Ferric salt, polymer and free chlorine as powder in a sachet (treats 10 liters per sachet);
  - Very effective microbe reductions; moderate cost
  - Health impact (reduces diarrhea/cholera)
  - Commercial marketing failed; humanitarian use

HWTS: roles and impacts

WHAT WE KNOW NOW

- Household-based water treatment **can greatly improve the quality** of the water people drink, providing microbially safe water where people use it: **at home**
- Interventions at point of use can **reduce diarrheal illness** by a mean of **40%**
  - Sometimes much greater

REMAINING QUESTIONS

- Is household water treatment a **long-term, sustainable solution** for access to safe water?
- What are the **limitations** of technologies?
- Under what circumstances are they **appropriate**?
- **How** are they best **implemented at large scale**?
- Can we **build the evidence base** for effectiveness of HWTS interventions in contributing to the MDGs?

Independent Assessment of Ceramic Water Purifier – Cambodia

- Ceramic Water Purifier (CWP)
- *Potters for Peace* design
- gravity-flow porous ceramic microfiltration, with rice husk burnout material
- Food-grade plastics, local materials and manufacture
- Effective for bacteria & protozoa, less effective against viruses

Cost: US$ 8

- **Study led by Joe Brown**

Overview of Cambodia CWP Assessment

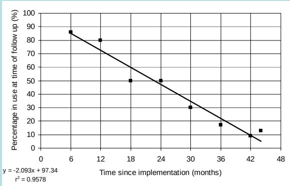
- **Independently assessed** CWP implementations in Cambodia by 2 NGOs (RDI and IDE) over previous 5-year period
- Study 3 provinces, 13 villages, several implementation strategies with an evolving technology
- Assess continued **use**, microbiological **effectiveness**, and **health impacts** of CWPs
- Study Design:
  - **cross-sectional** for continued use (sustainability)
  - **Longitudinal prospective cohort** for effectiveness and health impact (on diarrhea)

Results: cross-sectional study

- **~2% of filters fall into disuse per month** post implementation
- Two-thirds of disuse caused by **breakage** of filter hardware
- Factors associated with **continued use**:
  - **Knowledge/practice of wat-san-hygiene** safe behaviors
  - Use of **surface water** source
  - **Cash investment** in the technology (any amount)
- Factors associated with **disuse**:
  - Use of **deep well water** and **time** since implementation

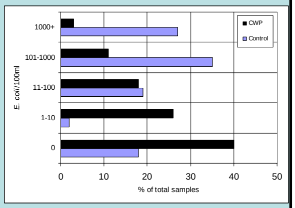
Decline in filter use over time

(~2/3rds breakage)



Results: longitudinal study

- Filters reduced *E. coli* levels in treated water by a **mean 95.1%**
  - Potential underestimate; filter effectiveness up to 99.99%
- **Two-thirds** of filtered water samples were <10 *E. coli*/100ml (WHO **low risk**)
  - Similar to stored boiled water
- **No discernable trend** in microbial efficacy **over time** in use; stable
- Filters associated with mean **46% reduction in diarrheal disease** in user versus non-user homes
  - Positive, weak relationship between *E. coli* level and diarrheal disease rates



Quality of household drinking water at time of visit

Numbers correspond to WHO risk level categories

Summary

- **CWP significantly improves quality of water**
  - consistently for a long period of time
  - if it doesn't break and is being used properly
- Filters use declined at a rate of about **2%/month** after implementation
  - constant rate across location, time, and implementer
  - mostly due to breakage
- **Recontamination of water is a real problem**
- Filter use **reduces diarrheal prevalence by nearly half**
  - among the most effective interventions available

Recommendations to increase sustainability

- Make **parts and replacements** available and accessible
  - Demand exists and filters will break over time
  - Users need to know about distribution points
- **Prevent recontamination** through appropriately designed **"software"** - essential!
- **Support with related WSH messages/interventions** and **education;**
  - **engage and empower the community; change behavior**
- **Sell filters** to users

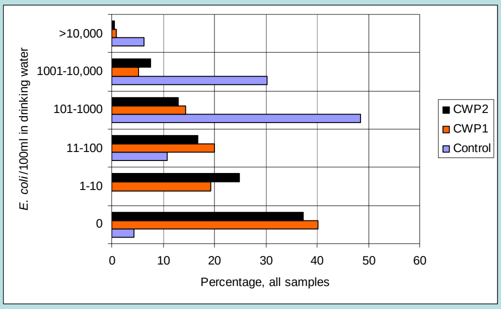
Randomized Controlled Trial of Standard and Iron Oxide CWPs: Design & Data Collection Overview

- Led by Joe Brown
- Identified 300 households (previous NGO survey)
- Recruited 180 eligible HHs; random selection
- Collect baseline data
- Randomize to 1 of 3 groups:
  - CWP1 (standard), CWP2 (iron oxide-amended), control (none)
- Follow all 180 HHs for 22 weeks
  - **Water quality data**:
    - *E. coli*/100ml & turbidity
  - Score for **diarrheal disease** (7-day recall)

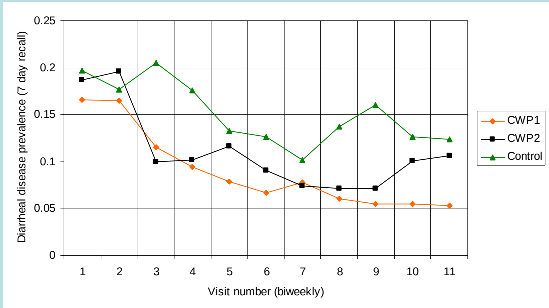
RCT Results Overview

- CWP1 & CWP2 reduced *E. coli* concentrations in treated water by a **mean 1.7 $\log_{10}$ (98%)**
  - Filter effectiveness up to 99.9999%
  - Similar to boiled water samples (**98.2% reduction)**
- **Two-thirds** of effluent water samples from filters were <10 *E. coli*/100ml (**low risk**)
  - Similar to data for stored boiled water
- Filters associated with a mean **45% reduction in diarrheal disease** in users versus non-users
  - Positive but weak relationship between *E. coli* concentrations and diarrheal disease

E. coli in drinking water
stratified by group

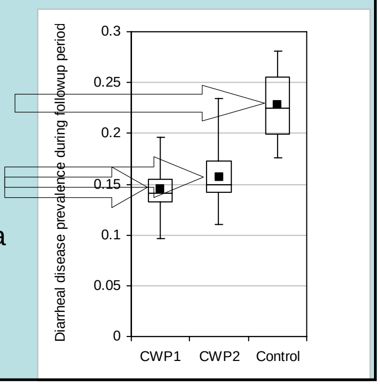


Longitudinal prevalence of diarrhea by study group



Household Diarrhea Prevalence

- Diarrhea prevalence in control group
- Diarrhea prevalence in filter groups
- Lower diarrhea prevalence in filter groups



Summary of principal findings

- **CWP significantly improves quality of water** users drink
  - A promising option for water treatment in Cambodia
  - But is it enough?
    - Some *E. coli* contamination is still present in water
- **Recontamination in use is a real problem**
  - Subject of a previous study here
  - Proper use is critical
  - People clean water vessel with a krama (dirty!)
- Use of the filter **can reduce diarrheal prevalence by about 40%**
  - Makes it among the most effective HWT interventions available
- A **weak but positive association** was observed between diarrhea and *E. coli* in drinking water
  - <10 E. coli lower diarrhea rate
  - >10 E. coli higher diarrhea rate

Principal findings, cont.

- **No significant confounding by other factors (<10%)**
- **No difference was observed** between filters with and without iron oxide
  - In health impact (diarrhea disease reduction)
  - In effectiveness against *E. coli in water*

Independent Assessment of Biosand Filters - Cambodia

Kaida Liang, Mark Sobsey, Proum Sorya, the UNC Cambodiam Study Team, Mickey Sampson

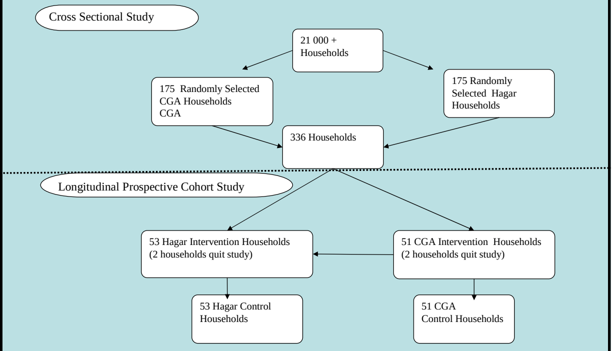
Background of BSF in Cambodia

- 1999: BSFs introduced in pilot villages
  - Hagar (local NGO) began building and implementing BSF projects in Kompong Thom and Kratie
  - Supported by Samaritan's Purse (SP) and the Canadian International Development Agency (CIDA) since 2000
  - CGA another implementer whose filters were studied

Cambodia Global Action and several other NGO's (FHI, AOC, WV, CAMA, SDA, etc.) began BSF projects in 2002 after receiving training from Hagar

- Hagar installed over 19,9557 BSFs since 2001 and CGA installed over 2668 since 2002, largest implementers
- Cambodia has the largest number and concentration of BSFs in the world

Study Design and Household Enrollment



Cross Sectional Study: Data Collection

- Initial visit of 336 households during December 2006-January 2007
- Khmer field staff conducted interviews with households (usually adult woman)
- Collected data on water handling practices and use, filter use and maintenance, sanitation and hygiene and income surrogates

Cross Sectional Study: Filter Use

- Filters had been in use from 0- 8 years
- Measured for continued use at time of visit (binary outcome)
- Quantification and comparison of filter use and non-use as the main outcome
- Statistical analysis:
  - Filter use survey data
  - determine possible predictors of filter use/disuse

Longitudinal (Prospective Cohort) Study: Health Outcome

- Monthly visits (5 months) to over 200 households
  - 50 intervention households from each organization and matched control households
- Data on diarrhea disease rates (7 day recall) computed for each group
- Diarrhea cases per person-week stratified by group, age and province
- Statistical analysis
  - Regression models applied to determine predictors of diarrheal illness
  - Reported odds ratios and 95% and CIs

Longitudinal Data Analysis: Water Quality

- Monthly sampling of raw, treated and stored water
- Water quality data for concentrations of *E. coli*
- Drinking water quality in BSF and non-BSF households were statistically analyzed and compared
  - *E. coli* concentrations and $\log_{10}$ reductions
  - Turbidity and turbidity reductions

Cross-sectional Survey: Results

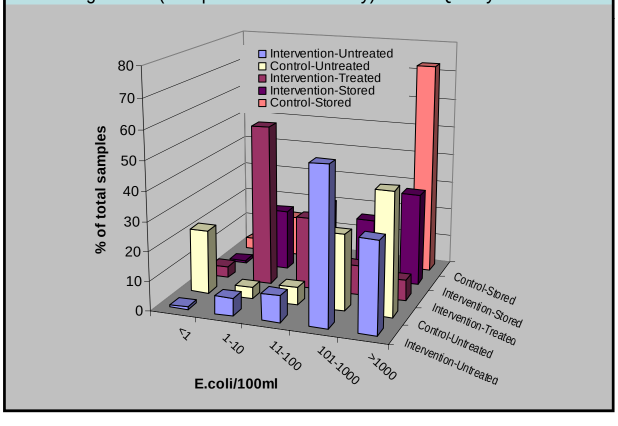
- 336 households enrolled in survey
- 1964 individuals, average of 5.86 people per household
- 50.7% of participants were female
- Number of enrolled households/province: 136 from Kandal, 30 from Kompong Speu, 53 from Svay Rieng, 59 from Kompong Thom, and 58 from Kratie
- 294 (87.5%) households reported still using the BSF, 42 (12.5%) households no longer using the filter
- Some filters included in the study had been in use for up to 8 years since implementation

Cross-Sectional Study Results:

Odds Ratio Significantly >1 for continued filter use

- Reported receiving training on BSF operation and maintenance: **2.04 (95%CI 1.0-3.9)**
- Observed method of drawing water for drinking, using a dipper: **3.1 (95%CI 1.6-6.1)**
- Using a deep well for water source: **2.6 (95% CI 1.3-5.4)**
- Reported cleaning water storage container: **14.6 (95% CI 1.29-164.7)**
- Treating water always or often: **30.6 (95% CI 3.3-281)**

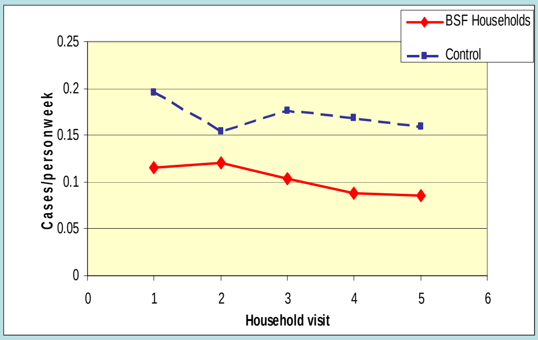
Longitudinal (Prospective Cohort Study): Water Quality Results



Longitudinal Study Results: Water quality

- Filters reduce *E. coli* concentrations in treated water by a mean of 95% (1.3 $\log_{10}$ reduction value)
  - Up to 4 log (99.99%) observed
- 55% of effluent water samples from filters were <10 *E. coli*/100ml (low risk)
- 82% reduction of turbidity from untreated to treated water (Mean untreated 12 NTU turbidity)

Diarrhea disease cases/person week



Diarrheal disease impact of filter

Group	Odds Ratio	95% CI
All Ages	0.56	0.49 – 0.85
<5	0.68	0.5 - 0.9
5-14	0.54	0.4 - 0.8
15>	0.49	0.38 - 0.6
Age adjusted:		
0-2	0.89	0.63 - 1.2
2-4	0.56	0.42 - 0.76
5>	0.54	0.41 - 0.60
Age adjusted for (<5, >5)	0.58	0.50 - 0.58
Age adjusted for (<2, 2-4, >5)	0.57	0.49 - 0.66
Sex:		
Male	0.53	0.43 - .66
Female	0.58	0.40 - .60
Province:		
Kandal	0.62	.49 - .78
Kompong Speu	0.59	.39 - .88
Svay Rieng	0.41	.28 - .61
Kompong Thom	0.69	.50 - .94
Kratie	0.48	.34 - .68

Longitudinal Study: Health

- Filters associated with a mean 44% reduction in diarrheal disease in users versus non users (OR=.56, 95% CI 0.49-0.66)
- Group experiencing most protective effect, ages 2-4 (46% reduction for filter users)
- No significant protective effect for ages 0-2 (OR=0.89, 95% CI 0.6-1.2)
  - Southeast Asia children typically not weaned until ages 2-3; so probably not/less exposed to filtered water

Summary of principal findings

- BSF has high rate of sustained usage, 87.5% still in use
  - Long lifespan and low breakage rate
- Filter can improve microbiological quality of water for drinking, 1.3 $\log_{10}$ *E. coli* reduction
- 44% reduction of diarrheal disease in filter users
- Strong association filter use with reduction of diarrheal disease in households, especially for children between the ages of 2-4 years old, 46%
- Recontamination is a challenge for achieving improved and safer drinking water at the household level

Comparison of Biosand Filters with Ceramic Porous Pot Filters in Cambodia

Water quality:
- achieve similar reductions of *E. coli*, both approximately 95%
- both filters subject to recontamination of stored water

Health impact:
- both associated with about 45% reduction of diarrheal disease

Sustained use:
- Initial usage rates between 86-88% for both filters
- BSF usage rates did not decline for filters in use up to 8 years
- Ceramic filter usage rates decline steadily to ~10% after 3-4 years, ~ 2% per month after installation; due to breakage

Brown and Sobsey, 2006 “Independent Appraisal of the ceramic water purifier”

Conclusions

- BSFs have sustained use in Cambodia
  - Higher sustained usage rates than ceramic pot filters, chlorine, P&G PUR and SODIS
- Filter use achieves improved water quality (1.3 $\log_{10}$ or 95% reduction of *E. coli in* raw water*)* and reduced diarrheal disease (44% compared to matched non-filter households)
- Results comparable to other HWTS interventions
- Need to prevent recontamination through appropriately designed software (behaviors) and hardware (containers)
  - integrate with health behavior/education (software) programs
  - Encourage use of safe storage containers and water dispensing

Recommended Next Steps

- Encourage, design and evaluate scaled-up of implementation of CWPs and biosand filters in Cambodia and the region
- Examine the feasibility and evaluate the performance of large scale implementation of the plastic housing biosand filter
  - Lightweight, stackable, transportable
  - Easily assembled on-site
  - Design and performance similar to concrete filter
- Examine large scale implementation systems
  - Hardware deployment
  - "Software" (education and behavior change) systems
  - Marketing and distribution models
  - Performance evaluation: initially and post-implementation