Microbiological Effectiveness and Cost of Boiling to Disinfect Drinking Water: Case Studies from Vietnam and India

Thomas F. Clasen, JD, PhD
Department of Infectious and Tropical Diseases
London School of Hygiene & Tropical Medicine

Summary

- Background
  - Prevalence of Boiling
  - Advantages and Disadvantages
  - Previous studies
- Field Studies in Vietnam and India
  - Settings
  - Methods
  - Results
- Conclusions and future research

Potential advantages of Boiling

- Widely accepted and promoted by governments/NGOs
- Apparatus commonly available (hardware and fuel)
- Effective against all waterborne microbial pathogens
- Effectiveness not impaired by chemical and physical characteristics of water (pH, turbidity, TOC, TDS, temperature, etc.)
- Scaled up in many countries

Prior Research

- Inconsistent approach
  - 1 minute (WHO 2004, CDC, USEPA)
  - 10 minutes (Davis & Lambert 2002)
  - 20 minutes (Nnochiri 1975)
- Leading source of burns, especially in young children (Rossi 1998; Houangbevi 1981).
- Contributes to poor indoor air quality(Leigh-Smith 2004)
- Environmentally unsustainable in many areas
- Difficult to achieve adoption (Wellin 1955)

Prior Research

- Microbiological Effectiveness
  - Among 137 households in Pakistan who reported boiling as their only method for treating water, only 24 (17.5%) of samples from stored water were free of faecal coliform (Luby 2000).
  - In random sampling of 400 households in Indonesia where householders were encourage to boil, 47.5% of samples from the households were positive for *E. coli*, with 13.3% >101 CFU/100ml (high risk) and 18.0% <10>100 CFU/100ml (intermediate risk) (Handzel 2005)
  - Another study of water samples from 1027 households in post-tsunami Indonesia found that neither adequate boiling (maintaining a rolling boil for at least one minute) nor adequate boiling combined with water storage in a narrow mouthed container were associated with a decreased risk of stored water contamination (Gupta 2005).

Prior Research

- Cost
  - Gillman and Skillicorn (1985) investigated the affordability of boiling in a village in Bangladesh. Families in the lowest income quartile would have had to spend 22% of their yearly income on fuel; even those in the highest income bracket would have spent 10%. For a typical family in the lowest income quartiles, boiling of drinking water would require an 11% increase in household budget.
- Health impact
  - Pasteurization of water (70º C) in a Kenyan community using a wax indicator increased the number of households with coliform water from 10.7% to 43.1% and reduced incidence of severe diarrhoea by 45% (p=0.0016) (Iijima 2001)

Methods of Vietnam and India Studies

- Study population
  - Vietnam: 50 households (263 persons) in a one rural community
  - India: 218 households (~45 from each SEC) (1167 persons) in three peri-urban communities
- Eligibility
  - rely on surface or shallow wells for water supply, and
  - self-reportedly “always or almost always” boil their drinking water
- Study period
  - Vietnam: 3 months in winter (November-February)
  - India: 5 months post monsoon (July-November)

- Boiling Surveys (~all of households) of demographics, water sources, collection and treatment practices, definition of boiling, frequency of boiling, type of fuel used, amount of water boiled, time and method of procuring fuel, economic value of time
- Boiling Demonstrations (about 15% of households)
- Water sampling and analysis (5 rounds per household) to compare FC (India) or TTC (Vietnam) of source and household stored (purportedly boiled) drinking water using MF technique

- Fuel consumption estimated base on theoretical formula for heat energy based on type of fuel (56% efficiency for LPG, 20% for wood) verified in lab with various vessels/lids (±10%)
- Cost of fuel based on actual purchase price or economic cost of time spent collecting wood (high and low estimates)
- Other costs included economic value of time spent preparing to boil and % of time spent during boiling (50% for wood, 10% for LPG
- Percentage of monthly income based on actual reported income (Vietnam) or mean state income (India)

Results-Boiling Practices

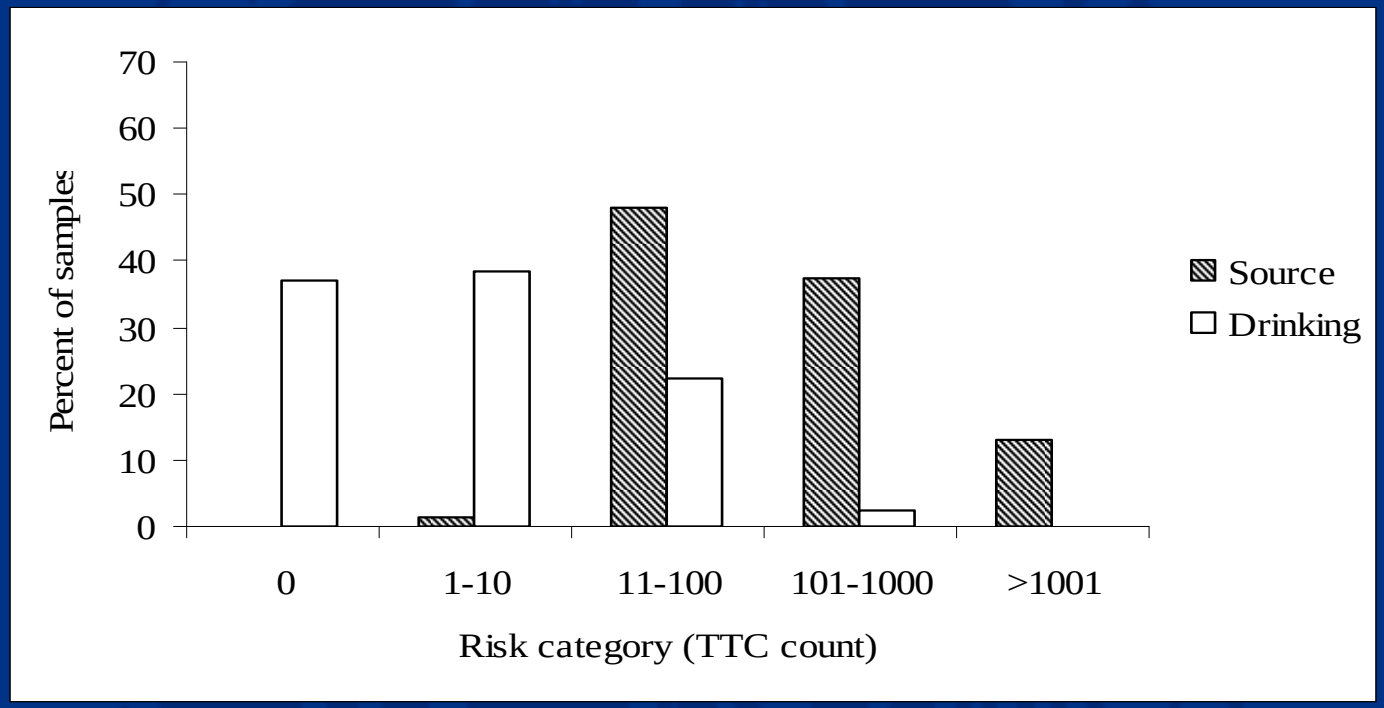
	Vietnam	India
Fuel	Collected (89.8%) or purchased (10.2%) wood	Bottled LPG (87.2%), wood (10%), electricity (1.7%), kerosene (1.1%)
Boiled until	Rolling boil (100%), but in demonstrations 73% continued for average 3.5 minutes longer	Rolling boil (80.6%), vapors (14.3%), bubbles at bottom (5.1%)
Mean quantity of water boiled daily per household	7.5L	6.7L
Mean frequency of boiling	2.6 times/day	2.0 times/day
Mean time spent boiling	38.9 minutes	44.5 minutes

Microbiological Effectiveness: Vietnam

	Source		Drinking	
	Geo Mean	**95% CI**	**Geo Mean**	**95%CI**
Round 1	164.7	(115.2; 235.5)	3.9	(2.5; 6.2)
Round 2	170.1	(111.6; 259.3)	6.5	(4.2; 10.2)
Round 3	106.1	(75.7; 148.7)	2.8	(2.1; 3.9)
Round 4	140.6	(103.2; 191.4)	4.4	(2.9; 6.9)
Round 5	132.7	(95.1; 185.3)	4.3	(2.8; 6.4)

Boiling was associated with a 1.52 log10 (97%) reduction in TTC, from 141 TTC/100ml in source water to 4.2 TTC/100ml in drinking water.

Microbiological Effectiveness: Vietnam



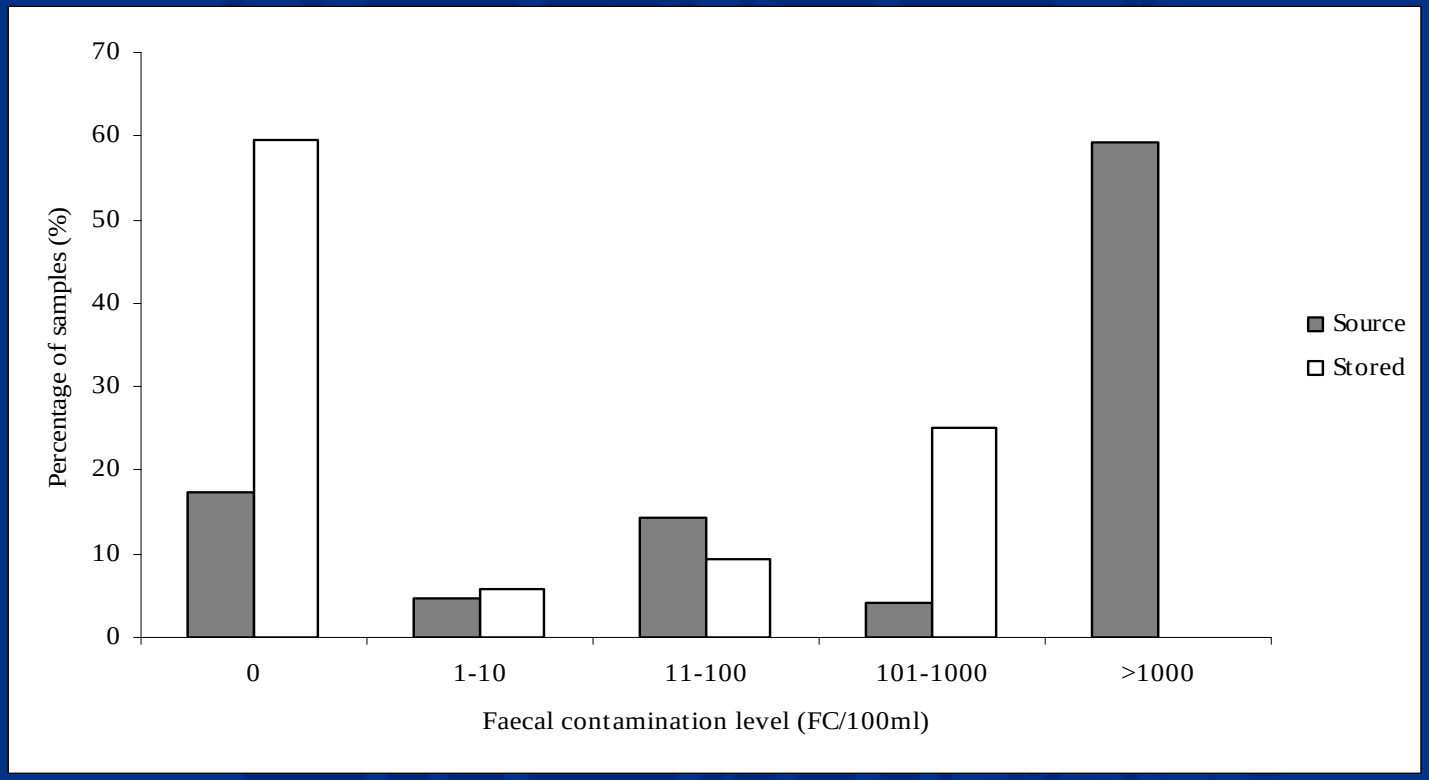
- While 98.8% samples from source water were moderate or higher (>11 TTC/100ml), 37% of drinking water samples were free of TTC and another 38.3% were low risk.
- Nevertheless, 60.5% of stored water samples were positive for TTC, with 22.2% falling into medium risk (11-100 TTC/100ml)

Microbiological Effectiveness: India

	Source		Drinking		
	Mean	95%CI	Mean	95%CI	p-value
Round 1	426.2	(261.5; 694.5)	6.1	(4.4; 8.3)	<0.001
Round 2	1031.1	(615.4; 1727.5)	6.1	(4.4; 8.3)	<0.001
Round 3	823.4	(484.8; 1398.2)	7.2	(5.2; 9.9)	<0.001
Round 4	944.9	(566.0;1577.5)	6.0	(4.4; 8.2)	<0.001
Round 5	251.8	(144.3; 439.1)	4.0	(3.0; 5.2)	<0.001

Boiling was associated with a 2.1 log10 (99%) reduction in geometric mean EC, from 612.8 FC/100ml in source water to 5.8 FC/100ml in drinking water.

Microbiological Effectiveness: India



- While 59.4% of samples from source water were very high risk (>1000 FC/100ml), 59.6% of drinking water samples were free of TTC and another 5.7% were low risk (1-10FC/100ml).
- Still, 40.4% of drinking water samples were positive for FC, with 25.1% falling into high risk (101-1000 FC/100ml)

Cost of Boiling: Vietnam

- Cost of fuel: US$0.27/month for wood collectors; US$1.68/month for wood purchasers
- Portion of income for fuel: 0.48% to 1.04%
- Value of time spent boiling: US$1.54 to US$2.40 (representing 2.12% to 3.52% of income

Cost of Boiling: India

- Householders use 13.9% of their fuel to disinfect water
- Cost of fuel: US$0.88/month for LPG (subsidized) and US$0.69/month for wood purchasers
- Value of time spent boiling: US$1.50 per month for LPG users and US$3.21 for wood users

Conclusions

- With 97% and 99% reductions in faecal contamination in actual practice by a vulnerable population, the evidence suggests that boiling may be an effective means of treating water in the home
- The microbiological performance of boiling as actually practiced is sub-optimal, but better than previously reported.
- Fuel cost is greater than hardware cost of some alternative HWTS methods, but represents a lower portion of overall income than previously reported and is probably affordable by many populations

Conclusions

- Since it is promoted and practiced so widely, boiling should be considered the benchmark against which alternative HWTS methods are assessed.
- While alternative HWTS may be more effective and cost-effective than boiling, comparisons should not be based on research-driven efficacy trials. Follow-up studies are required.

Future Research

- Additional boiling studies in Guatemala and Africa
- Use JMP data to assess
  - Size of potential market for HWTS
  - Amount of fuel consumed and potential savings (poverty reduction) from alternative HWTS methods)
  - Carbon footprint/emissions from boiling and potential environmental benefits from HWTS

Future Research

- Opportunity for economic and environmental and health benefits from improved practice in boiling (e.g., heating temperature to 70ºC only)
- Opportunity for health benefit (lower respiratory infection) from alternative HWTS
- Opportunities for synergies and for scaling up

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Papers

- Clasen T, McLaughlin C, Nayaar N, Boisson S, Gupta R, Desai D, Shah N. Microbiological effectiveness and cost of disinfecting water by boiling in semi-urban India. *Am J. Trop. Med. Hyg*. (in press)
- Clasen T, Do Hoang T, Boisson S, Shippin O (2008). Microbiological effectiveness and cost of boiling to disinfect water in rural Vietnam. *Environmental Sci. & Tech*. 10.1021/es7024802