Frontline of the Global Water Crisis:
Efforts to Secure Safe Water in High Need Communities

Steve Luby, MD

International WaTER Conference
Norman, Oklahoma, USA
October 27, 2009
September 11, 2001

- An estimated 5000 children died from diarrheal disease

• September 12, 2001
  - An estimated 5000 children died from diarrheal disease

• September 13, 2001
  - An estimated 5000 children died from diarrheal disease

• Since September 2001 an estimated 14 million children have died from diarrheal disease
Why do children die of enteric diseases in low income countries?

• Youngest children
  – Immature immune system
  – Less physiologic reserve

• Multiple physiologic insults
  – Malnutrition
    • Protein & calorie deficient
    • Micronutrient deficient
  – Frequent infections

• Feces contaminated environment
  – Water
  – Food
  – Physical surrounding

• Limited access to effective clinical care

Photo: Mubina Agboatwalla
How many child deaths are caused each year by unsafe water?

- Question’s premise ignores the web of causality and assumes a single cause of death
- Any such estimates require speculation of counterfactuals
- Risks pitting professional groups against each other
  - arguing for resources
  - rather than collaborating to effectively address the problem
- Child mortality from diarrhea is an enormous global public health problem and contaminated water contributes importantly.
Risk of lower respiratory tract infection following diarrhea, Ghana, 1990-91

26% of pneumonia cases may be due to diarrhea in the previous 2 weeks.

Global child deaths by cause

Impact of diarrhea on stunting at 24 months

Growth Profile of Gambian Children

Growth faltering:
- 10% attributable to diarrhea
- 30% attributable to caloric insufficiency

Tropical enteropathy

• Pathology
  – Bacterial overgrowth
  – Intestinal mucosal damage
  – Impaired absorption of nutrients

• Results
  – Impaired growth
  – Impaired cognitive development
    • Impaired economic growth

• Epidemiology
  – Widespread in tropical settings with high environmental contamination
  – Peace Corps workers
  – Resolves within 18 months of relocation to developed countries
  – More common among poor Africans than wealthy Africans

• Unknown role of contaminated water

Other Waterborne Enteric Infections

- Typhoid fever
  - 200,000 deaths per year
- Parasitic infections
  - Cryptosporidium
  - Cyclospora
  - Giardia

From: Ralph Gianella, *Salmonella*
Worldwide distribution of drinking water arsenic contamination

Garelick H, Jones H. Chemistry International 2008; 30(4)
Arsenicosis Health Impact

- birth outcomes
- child survival
- impaired immunity
- cognitive development
- hypertension
- cardiovascular disease
- diabetes
- cancer

Banglapedia
Millennium Development Goal 7
Ensure Environmental Sustainability

• Halve by 2015 the proportion of people without sustainable access to safe drinking water.
• To assess progress “safe water” is defined as “water from an improved source”
What does the phrase ‘improved water supply’ mean?

World Health Organization

– Improved: Household connection, public standpipe, borehole, protected dug well, protected spring, rainwater collection.

– Not improved: Unprotected well, unprotected spring, vendor provided water, bottled water, tanker truck provision water.
The ‘improved’ water supply in Karachi, Pakistan squatter settlements

- 10,900 colony forming units of fecal coliforms per 100 ml
- Diarrhea
  - the leading cause of death among children under the age of 5 years
  - 39 deaths per 1000 live births
Safe Water : No adverse health impacts

Improved water ≠ Safe water

• Microbiological contamination
  – Bacteria, viruses, parasites

• Geological contamination
  – Arsenic, Manganese, Fluoride

• Industrial contamination
  – Fertilizer,
  – Pesticides
  – Industrial chemicals

In low income countries:
  – 90% of public waste water
  – 70% of industrial wastes

Discharged into surface water without treatment

• Unsafe water causes substantial human disease
• How should we expect this situation to change in the future?
Growing threats to water
Population Growth

Global population, estimates and projections (billions)

1750 1800 1850 1900 1950 2000 2050

Developed countries
Developing countries

http://www.grida.no/publications/rr/food-crisis/
Agriculture Sector

• An average person consumes
  – 30 – 300 liters per day for domestic purposes
  – 3,000 liters per day to grow their food

• Agriculture is the largest user of freshwater
  – 70% of water use
  – 93% of depletion

• Decreased water availability risks increased malnutrition and famine

Turner K, et al. Economic valuation of water resources in agriculture. FAO paper reports, No. 27
• Livestock heavy user of water
  – 8% of total human water use
  – 30% if evaporated losses from feed cropland are included

• Raising livestock accounts for
  – 55% of erosion
  – Water pollution
    • 33% of nitrogen and phosphorus
    • 37% of pesticides
    • 37% of heavy metals
    • 50% of antibiotics
Between 1995 and 2025 livestock water demand is projected to:

- increase 71% globally
- Double in low income countries -- from 22 to 45 km³

Rosegrant, MW, Global Water Outlook to 2025, IWMI 2002

Growing threats to water

Aquifer Depletion

- Non nonreplenishable (fossil) aquifer provide:
  - Fresh water
    - Saudi Arabia 100%
    - Malta 100%
    - Tunisia 75%
    - Morocco 75%

- Rapidly falling aquifers
  - China
  - India
  - Pakistan
  - Iran

Brown, L. Aquifer Depletion
http://www.eoearth.org/article/Aquifer_depletion
Projected Water Scarcity in 2025

1.7 billion people live in basins with water scarcity (less than 1000 m³ per person per year)

Much of the human population growth and agricultural expansion is occurring in water stressed regions

Rosegrant, MW, Global Water Outlook to 2025, IWMI 2002
Growing threats to water

Global Warming

- The glacial fed rivers of the Tibetan plateau reach 40% of the world’s population
  - Glaciers projected to disappear in the coming decades
  - China and India diverting water
When water is in short supply

• The poor suffer the most
What should communities do to address the shortage of safe water?
Wealthy Countries

- Use capital intensive technology to secure sustainable water supply
- Treat it to remove chemical and microbiological contaminants
- Distribute it to residents
- Collect and treat wastewater before discharging it back into the environment
- Pay for the system by charging end users
  - Raise bonds for initial construction
  - Ongoing user fees to support maintenance
Deaths from typhoid fever
5 years before and 5 years after improved water supplies
1892 - 1901

Data from Sedgwick WT, MacNutt JS, J Inf Dis. 1910;7(4):490-564.
Deaths from all causes
5 years before and 5 years after improved water supplies
1892 - 1901

Mean 19% reduction
For every typhoid death averted, 3 other deaths prevented

Data from Sedgwick WT, MacNutt JS, J Inf Dis. 1910;7(4):490-564.
Middle Income Countries
per capita GNP $760 - $9360 in 1998$

- Use capital intensive technology to secure sustainable water supply
- Treat it to remove chemical and microbiological contaminants
- Distribute it to residents
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Upper Middle Income Countries include:

- Russia
- Brazil
- Poland
- Argentina
Low Income Countries

- Use capital intensive technology to secure sustainable water supply
- Treat it to remove chemical and microbiological contaminants
- Distribute it to residents
- Pay for the system by charging end users
  - Raise bonds for initial construction
  - Ongoing user fees to support maintenance
Is access to sufficient safe water a right?

- Whose responsibility to supply it?
- Allows public health professionals to feel self righteous
  - We know what should be done, but people in power are too selfish, too ignorant or too unenlightened.
  - The communities are victims

photo: [Keith Kristoffer Bacongo](https://flickr.com/photos/keithkristoffer/ via flickr)
It may be more productive to frame this as a scientific challenge

• With the available constraints
  – Financial
  – Hydrogeological
  – Technical
  – Political
• The solutions offered by the experts are not supplying the poor with a sufficient supply of safe water
• Perhaps the experts should develop better interventions
Increasing water quantity

- Essential for survival
- Essential for hygiene
- Associated with improved health outcomes in cross sectional studies
- Long term sustainability underevaluated
Post-source Water Contamination

Eric Mintz, CDC
Fecal contamination of water increases with storage.


Epidemic cholera returned to the Americas in 1992

- Affected persons with both ‘improved’ and ‘unimproved’ water
- Risk factors in Trujillo Peru
  - drinking unboiled water
    (odds ratio 3.1, 95% CI 1.3-7.3)
  - drinking water from a household water storage container in which hands had been introduced into the water
    (odds ratio 4.2, 95% CI 1.2-14.9)

D. L. Swerdlow et al., Lancet 340, 28 (Jul 4, 1992)
CDC-PAHO Safe Water System
Phase 1 Trial: El Alto Bolivia

• **Objective**: Evaluate acceptability of the vessel and bleach and its effect on water quality

• **Participants**: 42 families with shallow contaminated backyard wells

• **Methods**: Interviews and water testing at baseline and every 3 weeks
  – 15 families – vessel + bleach
  – 15 families – vessel alone
  – 12 families -- control

Phase 1 Trial: El Alto Bolivia

Results

Mean \(E. \text{coli}/100\) ml

Well Water Vessel Water

Intervention Effectiveness Phase 2
Montero, Bolivia, 1994/95

• Objective: determine impact of intervention on diarrheal incidence
• Study population: 127 households in Montero Bolivia
• Study Design
  – Baseline survey
  – Randomization
  – Active surveillance for diarrhea each week
  – Active surveillance for water quality each month
• Study Duration: 5 months

R. E. Quick et al., Epidemiol Infect 122, 83 (Feb, 1999).
Episodes of Diarrhea per Household by Group
Montero, Bolivia Sept 1994 – Feb 1995

Diarrheal Episodes

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>control</td>
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<tr>
<td>Dominant paradigm prediction</td>
<td>15%</td>
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Episodes of Diarrhea per Household by Group
Montero, Bolivia Sept 1994 – Feb 1995

Impact of improved water quality on diarrhea < 5 years of age

<table>
<thead>
<tr>
<th>Study</th>
<th>Risk ratio (Random)</th>
<th>95% CI</th>
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<tr>
<td><strong>Source or household treatment</strong></td>
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<tr>
<td>Garrett 2004</td>
<td>0.44 [ 0.28, 0.69 ]</td>
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Improved water ≠ Safe water

- Not surface water
- Not contaminated with sewage or hazardous chemicals
- Unimproved water → improved water
  - little effect on health
  - Contaminated water → safe water
  - marked effect on health
- 1.1 billion persons lack improved water
- ?? billion persons lack safe water
Point of use treatment options

- Safe Water System
- Biosand Filtration
- SODIS
- Ceramic Filtration
- PuR

Daniele Lantagne, CDC
Flocculant-Disinfectant (PūR®)

• Developed by Procter & Gamble
• Combines
  – Precipitation
  – Coagulation
  – Flocculation
  – Disinfection
Use Instructions

1. ADD
   - 10 Liters
   - 5 minutes

2. MIX
   - mix vigorously
   - mix again
   - Let water stand until clear and floc has grown in size.
   - Clear

3. FILTER
   - *Use a thick, 100% cotton cloth with no holes.*
   - *Discard the finished floc away from children and animals.*

4. DRINK
   - 20 minutes
   - Don’t drink the water if yellow.

-"
Low Dose Study Design
Randomized Controlled Intervention Trial

- 514 families
  - Divided into 42 neighborhood clusters
- Intervention: 2 groups
  - Control
  - Low dose flocculant-disinfectant with local vessel
- Randomized at cluster level
- 13 week duration

T. M. Chiller et al., Bulletin of the World Health Organization 84, 28 (Jan, 2006)
Longitudinal Prevalence of Diarrhea Reduction in Children

Accounting for Clustering
San Juan Sacatepéquez, Guatemala 2003

T. M. Chiller et al., Bulletin of the World Health Organization 84, 28 (Jan, 2006)
National Marketing

- PūR was marketed nationally
  - 29% of local stores in the study region sold PūR
Post-Marketing Survey

1. Measure PūR use 6 months after the efficacy trial

2. Identify characteristics associated with continued use of PūR

3. Determine if a preventive health benefit influenced continued use
Post-Marketing Use (n=462)

- Only 5% of households
  - Purchased the product within the previous 2 weeks
  - Used it within the last week
  - Had an unopened sachet
- Mean consumption was 4 sachets / week (vs. 10 / week in the trial)
- The only predictor of purchasing was belief that drinking water made one’s family sick
  - Income was not a predictor
  - Having been randomized to receive the product was not a predictor
- Similar national rates ➔ discontinued marketing
Chulli water purifier

- Home water treatment system invented and introduced in Bangladesh
- ‘Chulli’ is traditional clay cooking stove fueled by wood or cow dung
- Uses sand filtration and heat treatment while cooking
- Uses heat from chulli that would otherwise be wasted to the environment
- Costs US$ 6.00 to produce
- 114 households purchased chulli water purifiers at a subsidized price
- We evaluated 2 years later

Chulli water purifier

- **Sand filtration**
  - Bucket with sand
  - Bamboo stand
  - Plastic tubing
  - Aluminum tubing
  - Aluminum coil inside clay chulli

- **Heat treatment**
  - Opening for firewood
  - Aluminum tubing
  - Plastic tubing

- **Water output**
  - Tap affixed to stand
  - Aluminum kolshi for water collection or storage
Usage of the chulli water purifier (N=101)

- 21 (21%) respondents reported regular use of the chulli water purifier

- On repeat visits for water testing, three weeks after the initial visit, 4 (4%) respondents continued to report regular use

SODIS Evaluation – Rural Bolivia

- 11 Intervention communities
  - NGO implemented SODIS
  - 15 month intervention
    - Whole community meetings monthly
    - Household visits biweekly
    - Primary schools 3 times
  - Used demonstrations, role plays, videos to communicate
    - Importance of drinking only treated water
    - Importance of safe water storage and handwashing

- 11 Control Communities


www.ziemia.org/sodis.php
Diarrhea Prevalence by Group
SODIS Evaluation – Rural Bolivia

32% of households observed to be using SODIS

Barriers to household water treatment

• Very low demand for improved water quality, especially among the poor
• The children who suffer most from waterborne disease are the poor
• The poor are those who are least able to afford to purchase products to treat their water.
Hard questions

• Is household water treatment a failed strategy?
• Is it a fundamentally bad idea to expect the poorest people in the world to set up a personal water treatment facility in their home?
Wealthier households use household water treatment

www.aavaas.com

www.aavaas.com

www.opnan.com
School Based Water Treatment Promotion in Kenya

- Point of use water treatment integrated into the school curriculum
- Water treatment increased from 6% at baseline to 14% after the intervention.
- School absenteeism decreased by 35%

Community-based entrepreneurs selling water treatment

- **Site:** 1900 families in slum community in Dhaka, Bangladesh
- **Partner:** Dushtha Shasthya Kendra, local NGO
- **Approach:** community-based entrepreneurs
  - Peer motivation
  - Promoted household water treatment with dilute bleach
  - Sold bleach at cost
  - Paid $29 per month stipend
- **Project duration:** Sep 2004 to Dec 2006

Slide courtesy of Pavani Ram
Hardware and behavior change activities

- Hardware sold by local women
  - Sodium hypochlorite solution in dropper bottle (5.25% strength)
    - $0.13 for one-month supply
  - Water container with spigot (15 L)
    - US $2.50 paid in 6 monthly installments
    - Maintain safe storage
    - Facilitate handwashing

- Behavior change activities
  - Door-to-door mobilization by CBEs
    - Information dissemination
    - Hardware sales
    - Address individual concerns
  - Large group meetings and school-based activities
    - Facilitated by DSK staff

Community resident disinfecting her water in the storage tank

Slide courtesy of Pavani Ram
Evaluation
community-based entrepreneurs

• Aug 2004
  – Baseline
  – <1% of drinking water had detectable chlorine
• March 2006 --100 randomly selected households
  – 94% had heard of sodium hypochlorite product
  – 85% reported purchasing at least one bottle
  – 60% of households with chlorine detected
  – Median 6 bottles of water treatment purchased in last 18 months

Photo: Hossain Mohammad Shahed Sazzad

Slide courtesy of Pavani Ram
Point-of-collection Chlorine Dispenser

- Drastically cuts the cost of supplying chlorine
  - only 5% of the cost of the individually packaged bottles is for the chlorine itself
- Salience
  - Visible reminder when it’s most helpful
- Convenience
  - Dose is more precise; doesn’t get on hands
  - Don’t need to worry about passing expiration date
  - Safer than having non-tamper-proof bottle of chlorine in the home
  - Walk home provides agitation and some of wait time
- Habit formation
  - Links water treatment to existing habits associated with water collection
- Harnesses social network effects
  - Makes decision public

Slide courtesy of Clair Null and Michael Kremer
Kenya Dispenser Evaluation

• Promotion
  – Incentivized promoters, paid more if people used more
  – Hypochlorite provided at no cost

• Uptake
  – 60% of target households with free chlorine on household visits 3 – 6 months

• Long-run estimated costs
  – $0.15 per person year, ~ 1/4 - 1/3 current approach
  – < $20/DALY

Slide courtesy of Clair Null and Michael Kremer
• Failed as a commercial product in Guatemala, Philippines, Morocco and Pakistan
• But
  – Widely used for emergency treatment in response to disasters
  – Focus of P&G philanthropic efforts
  – Subsidized marketing in high need areas
  – 1 billion liters of water treated so far
  – Strong advocacy for safe water and home water treatment globally
  – Support for research
Key questions for point of use water treatment

• Can we increase demand for improved water quality among the group in highest need?
• Can we develop sustainable systems that provide point of use approaches to communities in highest need?
• Can we reduce the burden of disease, particularly among the poorest with this approach?
Improved Water Quality
political dimension

• In the 1990s Argentina allowed privatization of water supplies
• 30% of the countries municipalities embraced privatization.
• With privatization in Buenos Aires
  – More people connected to the water network
    • >580,000 new connections in Buenos Aires
    • 85% among the poor
  – 33 % reduction in child mortality
• In 2006 water privatization revoked
Key Points
Global Water Crisis

• Lack of sufficient safe water is a major contributor to child death globally
• Population growth, global warming, increasing meat consumption, and depletion of aquifers are adding additional pressure on overstressed fresh drinking water supplies.
• The greatest human cost to the water crises is borne by low income children living in low income countries
• The solutions are not simple
To Address the Global Water Crisis

• Sound and appropriate technology
• Financing models that permits sustainability
• A diversity of approaches
  – That reach the communities in need
  – That work within the culture
  – That are politically acceptable
• Able to reach billions of people
Role of Universities in The Global Water Crisis

- Historical underinvestment in research on strategies to address water quality and quantity problem in low income settings
  - a lot of basic questions incompletely answered
  - Most interventions have weak assessments
- Need a broad array of disciplines
- Need to engage students
  - So they can become intelligent participants in global discussions
  - Can work on addressing the problems
Thank you