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

icddr,b

CDC

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?

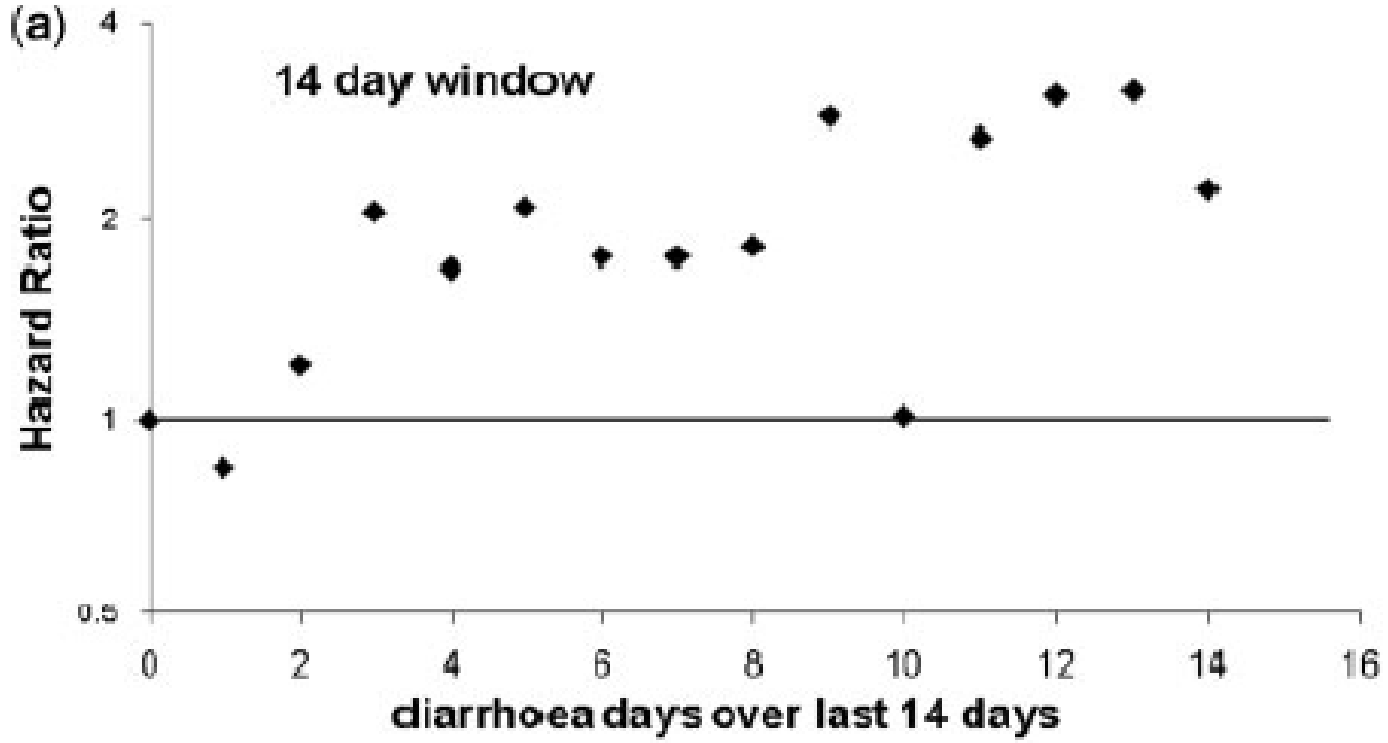
- Youngest children
  - Immature immune system
  - Less physiologic reserve
- Multiple physiologic insults
  - Malnutrition
    - Protein & calorie deficient
    - Micronutrient deficient
  - Frequent infections
- Feces contaminated environment
  - Water
  - Food
  - Physical surrounding
- Limited access 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.

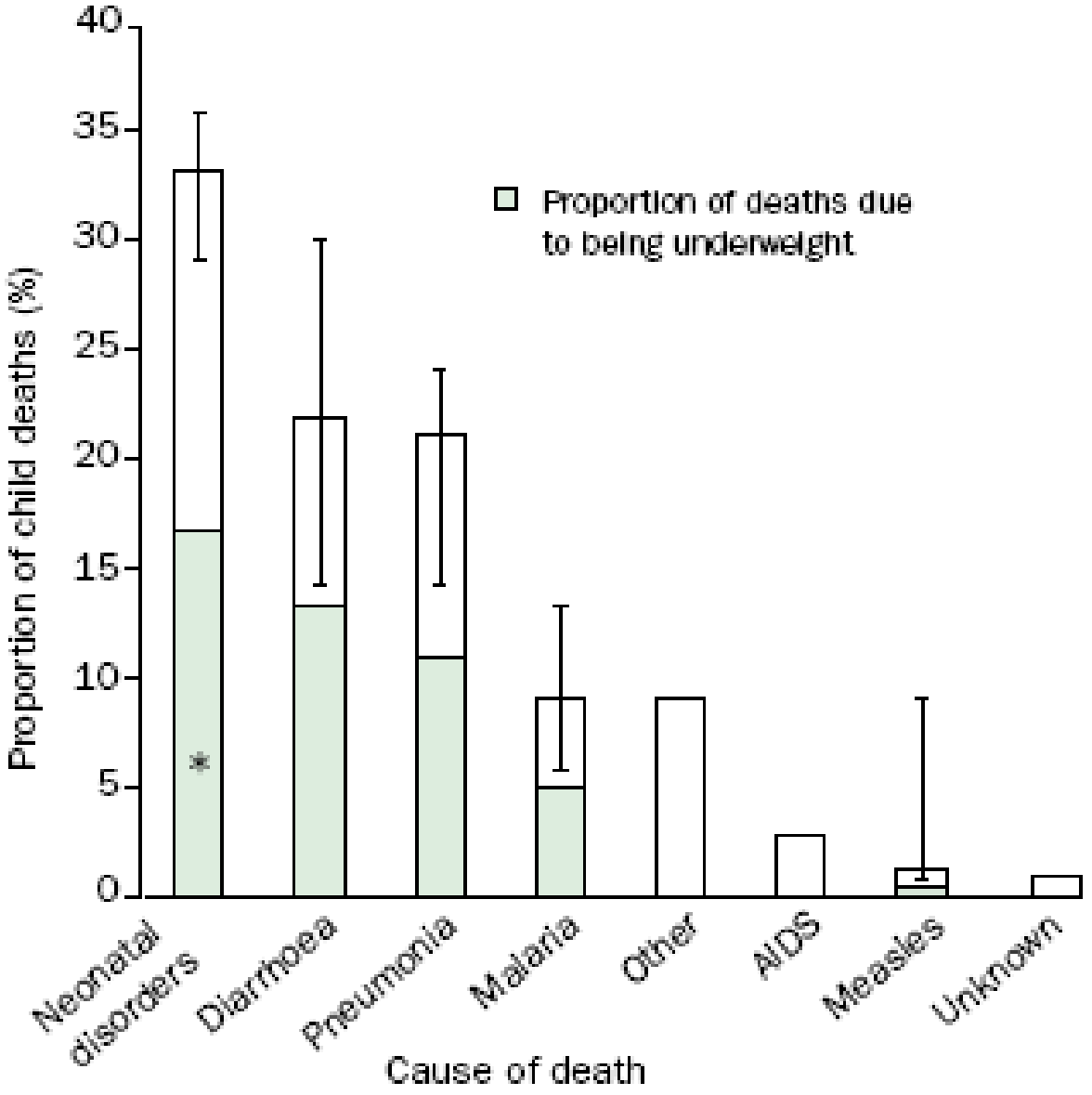
Risk of lower respiratory tract infection following diarrhea, Ghana, 1990-91



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

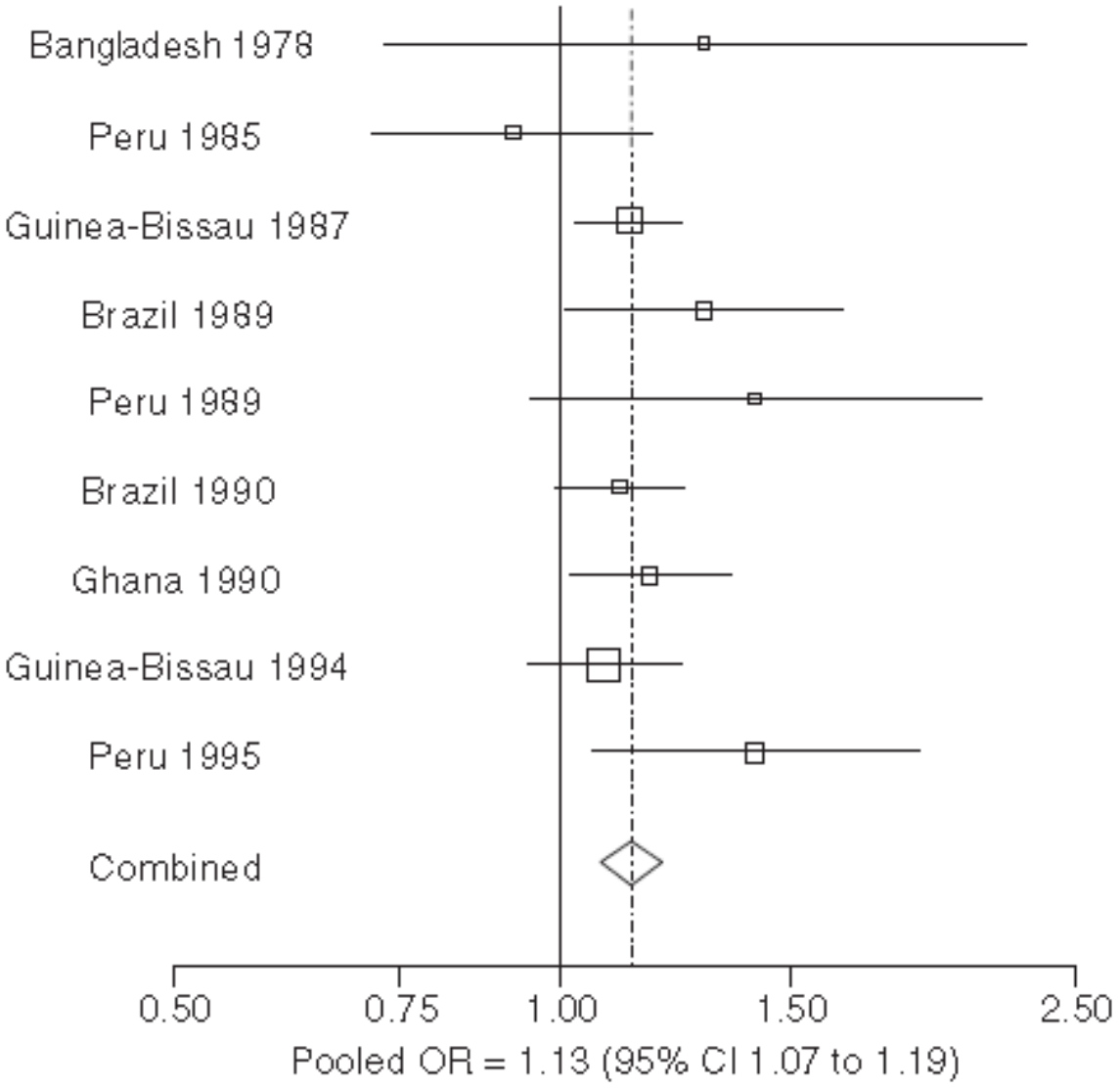
Schmidt WP, *Int J Epi*, 2009: 38(3), 766-72.

Global child deaths by cause



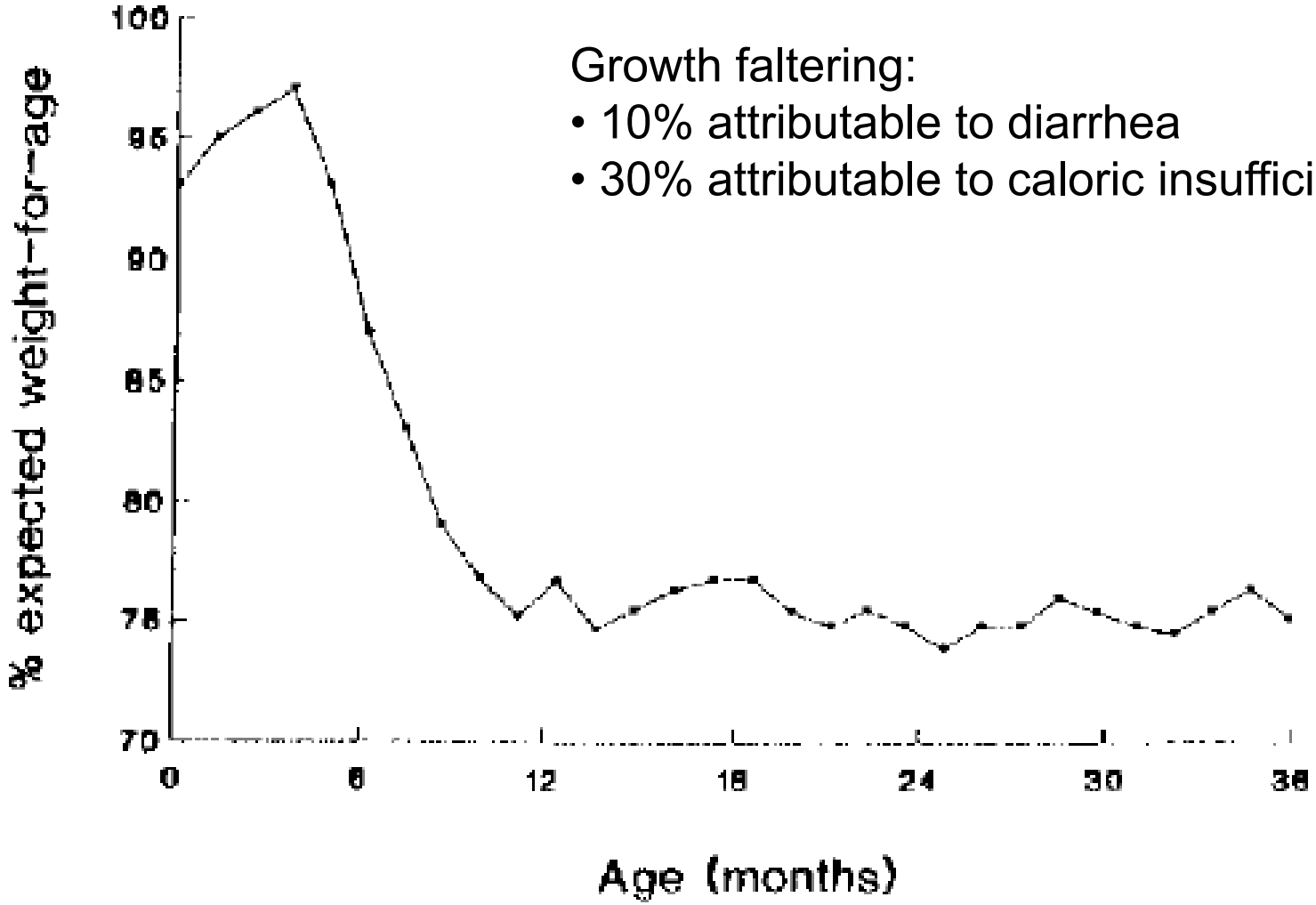
Black RE, et al. *Lancet* 2003; 361: 2226–34

Impact of diarrhea on stunting at 24 months



Checkley W, et al. Int J Epid, 2008;37:816–830

Growth Profile of Gambian Children



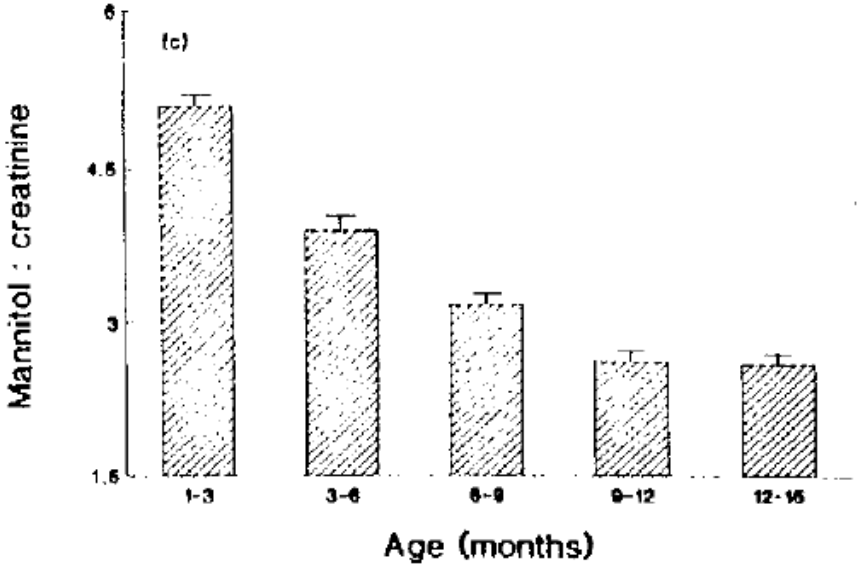
Growth faltering:

- 10% attributable to diarrhea
- 30% attributable to caloric insufficiency

Lunn PG, et al. Trans R Society Trop Med Hyg. 1991; 85:8-11

Tropical enteropathy

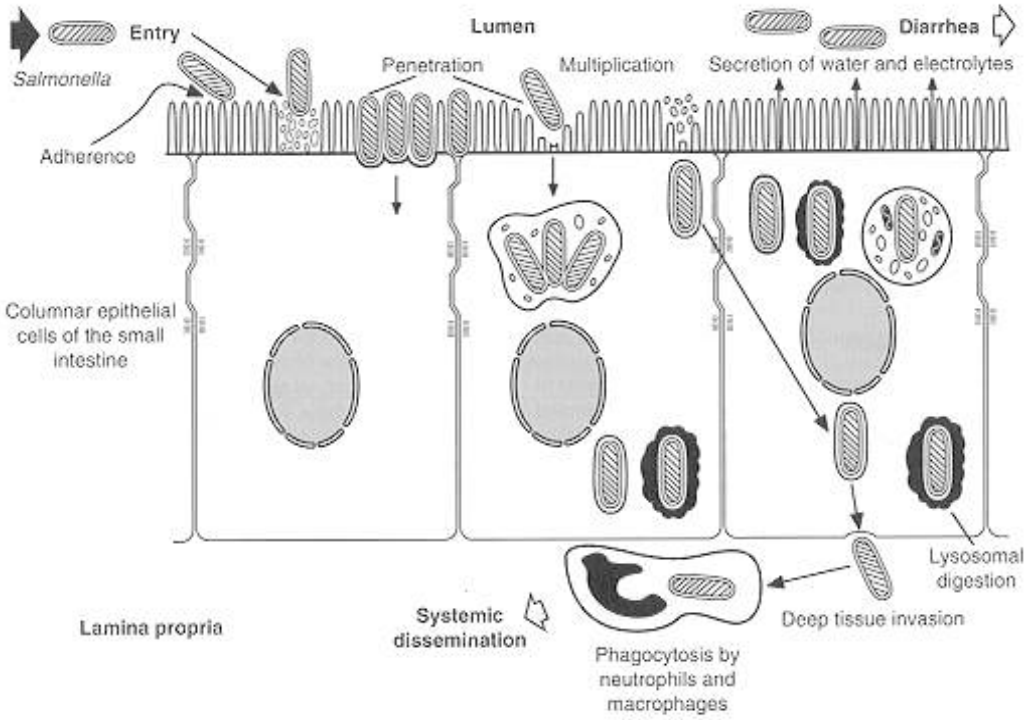
- Pathology
  - Bacterial overgrowth
  - Intestinal mucosal damage
  - Impaired absorption of nutrients
- Results
  - Impaired growth
  - Impaired cognitive development
    - Impaired economic growth
- Epidemiology
  - Widespread in tropical settings with high environmental contamination
  - Peace Corps workers
  - Resolves within 18 months of relocation to developed countries
  - More common among poor Africans than wealthy Africans
- Unknown role of contaminated water



Lunn PG, et al. Trans R Society Trop Med Hyg. 1991; 85:8-11

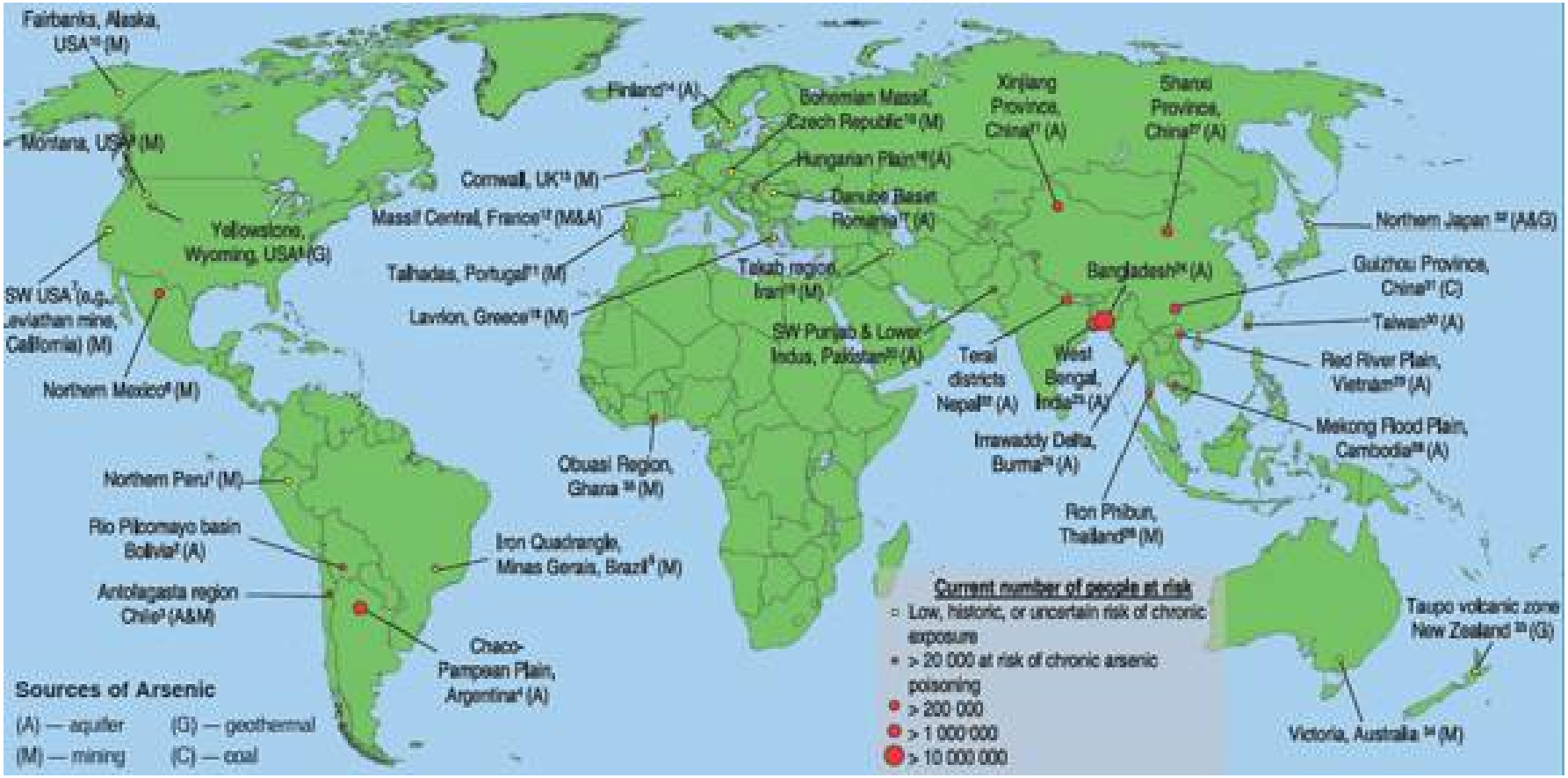
Other Waterborne Enteric Infections

- 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

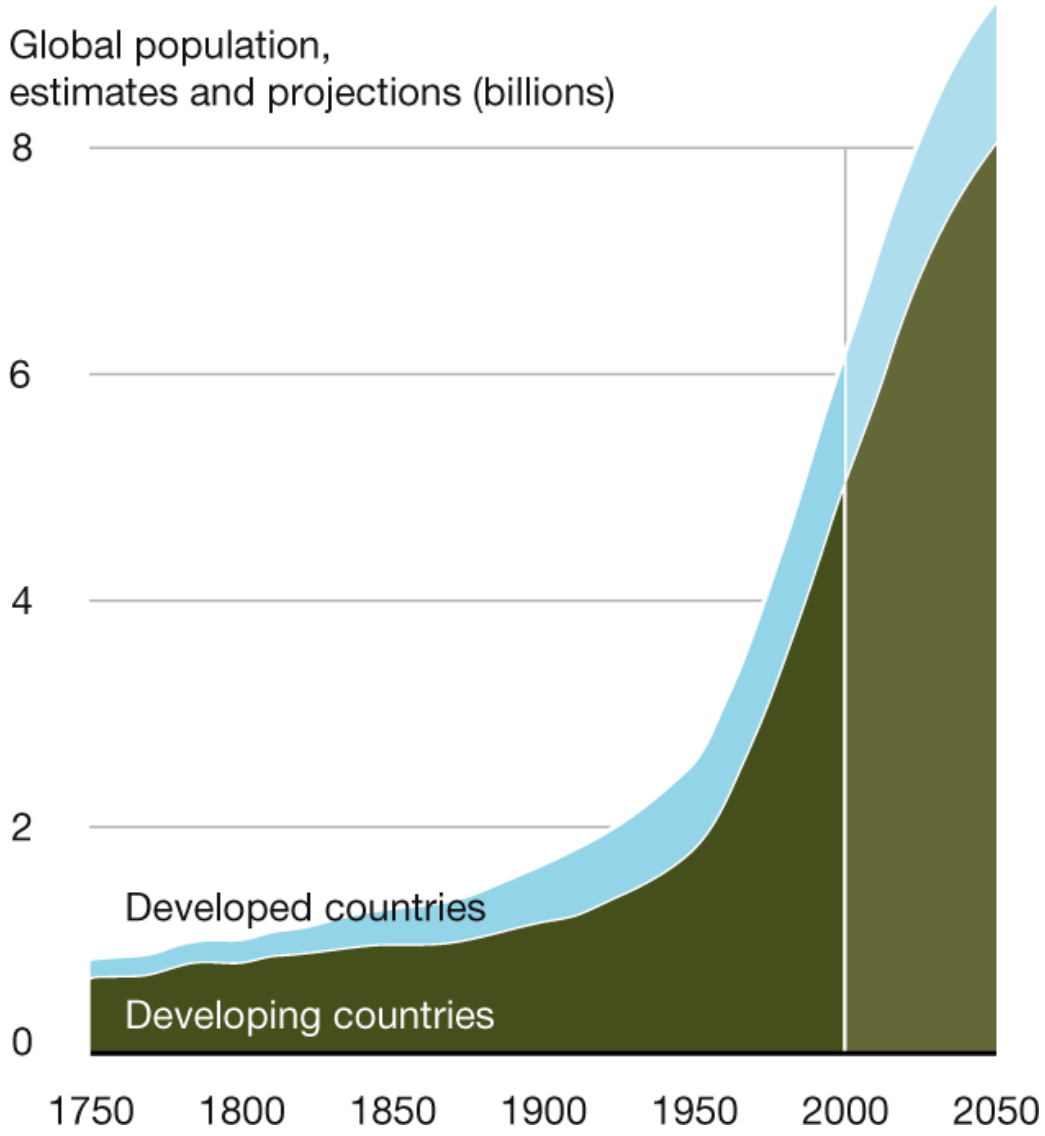
Discharged into surface water without treatment

Scieeps.com/wat

Bernstein, S. 2002, Freshwater and human population. In Karen Krchnak ed, Human population and freshwater Resources, Yale University

- Unsafe water causes substantial human disease
- How should we expect this situation to change in the future?

Growing threats to water
Population Growth



UN Population Division, 2007.

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

Agriculture Sector

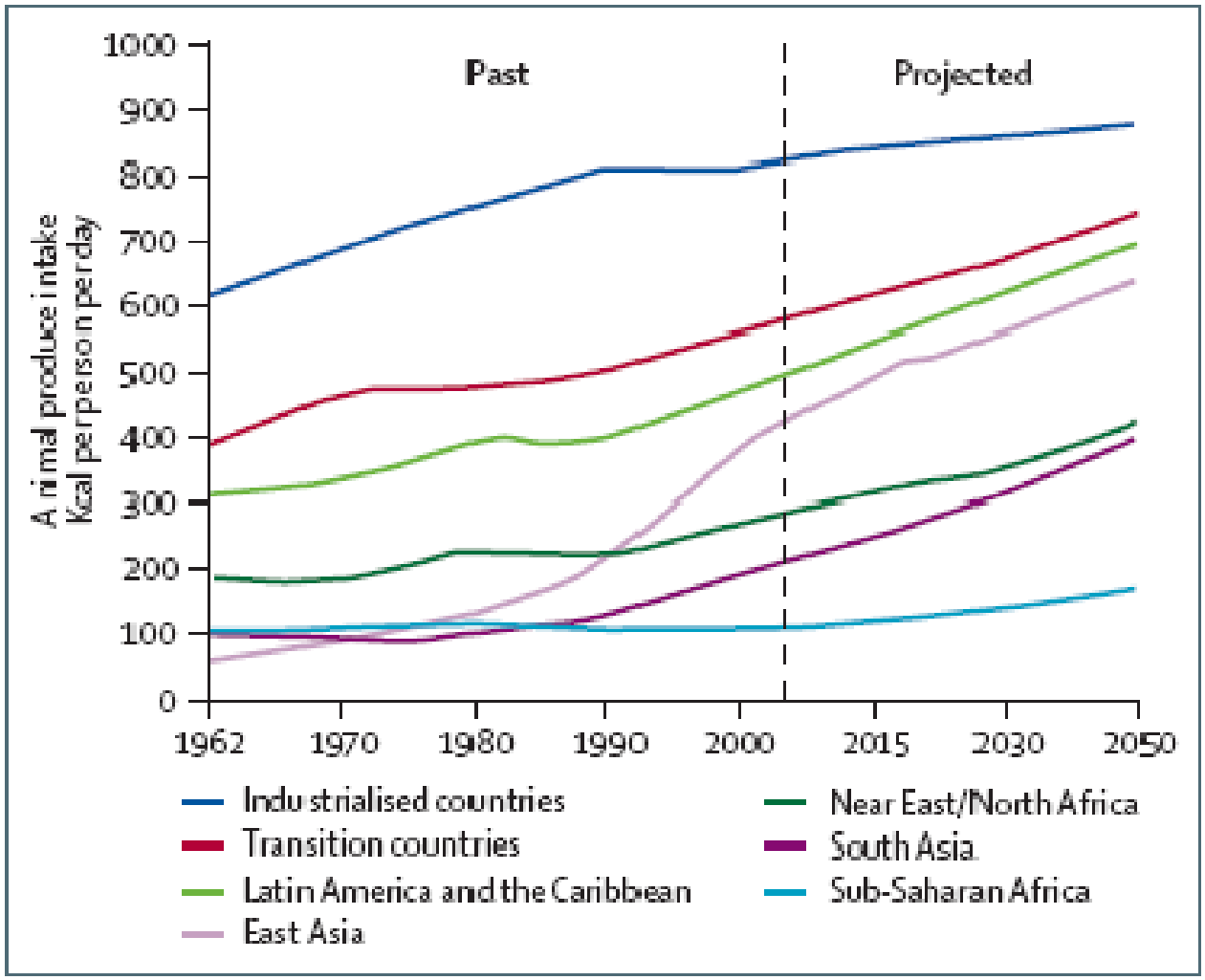
- An average person consumes
  - 30 – 300 liters per day for domestic purposes
  - 3,000 liters per day to grow their food
- Agriculture is the largest user of freshwater
  - 70% of water use
  - 93% of depletion
- Decreased water availability risks increased malnutrition and famine

Photo: US Fish and Wildlife Service

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

Trends in Meat Consumption



FAO. Livestock's long shadow. Rome: FAO, 2006

Between 1995 and 2025 livestock water demand is projected to

- increase 71% globally
- Double in low income countries -- from 22 to 45 km^3

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

Growing threats to water

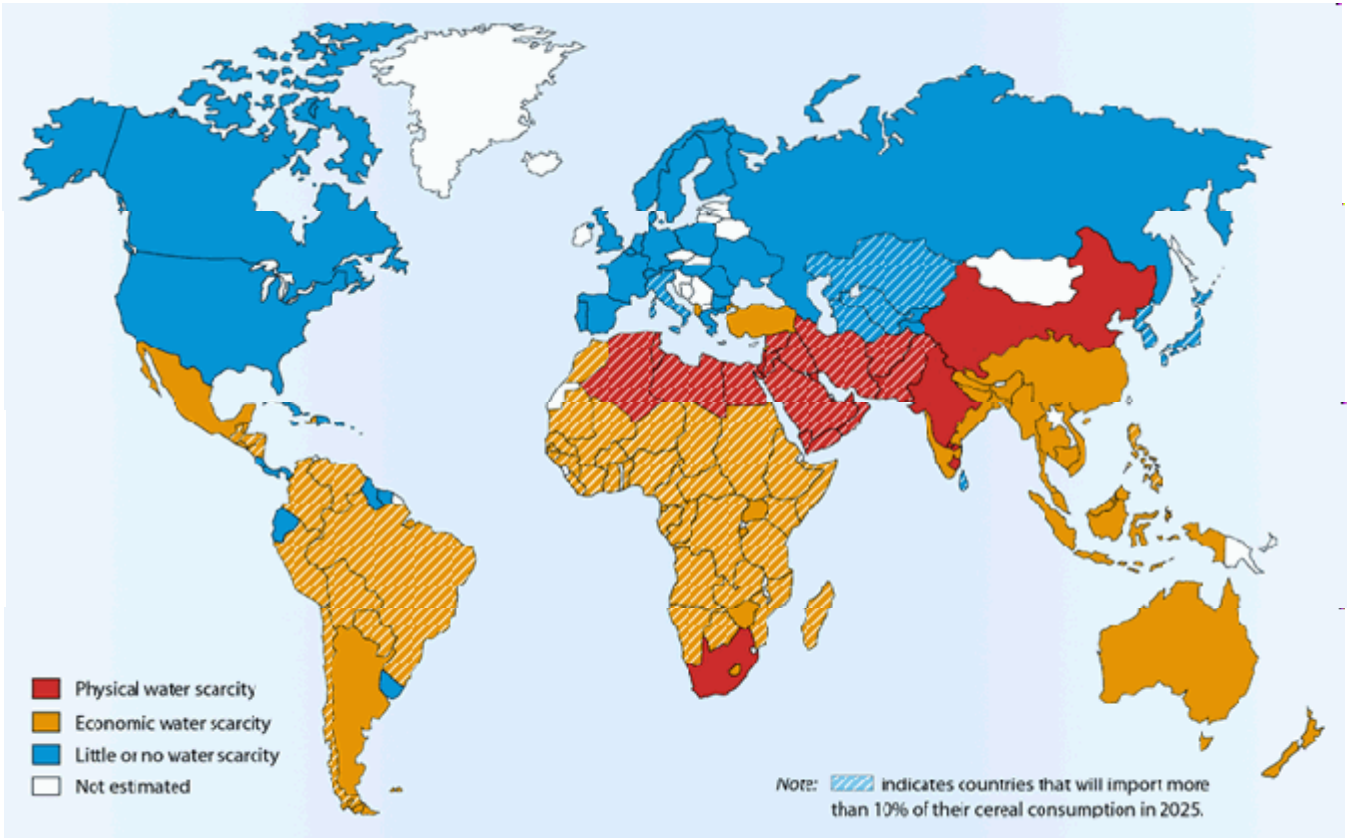
Aquifer Depletion

- Non nonreplenishable (fossil) aquifer provide:
  - Fresh water
    - Saudi Arabia 100%
    - Malta 100%
    - Tunisia 75%
    - Morocco 75%
- Rapidly falling aquifers
  - China
  - India
  - Pakistan
  - Iran

Countries Overpumping Aquifers in 2005	
Country	Population
	(million)
China	1,316
India	1,103
Iran	70
Israel	7
Jordan	6
Mexico	107
Morocco	31
Pakistan	158
Saudi Arabia	25
South Korea	48
Spain	43
Syria	19
Tunisia	10
United States	298
Yemen	21
Total	**3,262**

Brown, L. Aquifer Depletion
http://www.eoearth.org/article/Aquifer_depletion

Projected Water Scarcity in 2025



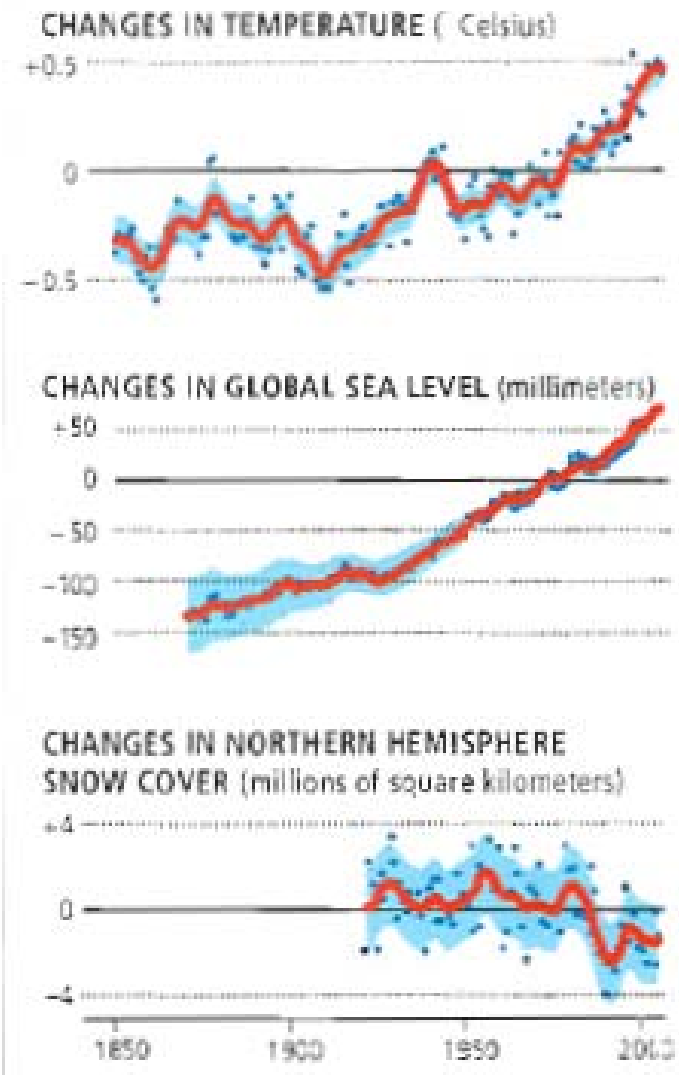
http://www.solcomhouse.com/drought.htm

- 1.7 billion people live in basins with water scarcity (less than 1000 m^3 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

Scientific American, Aug 2007, p. 68

When water is in short supply

- The poor suffer the most

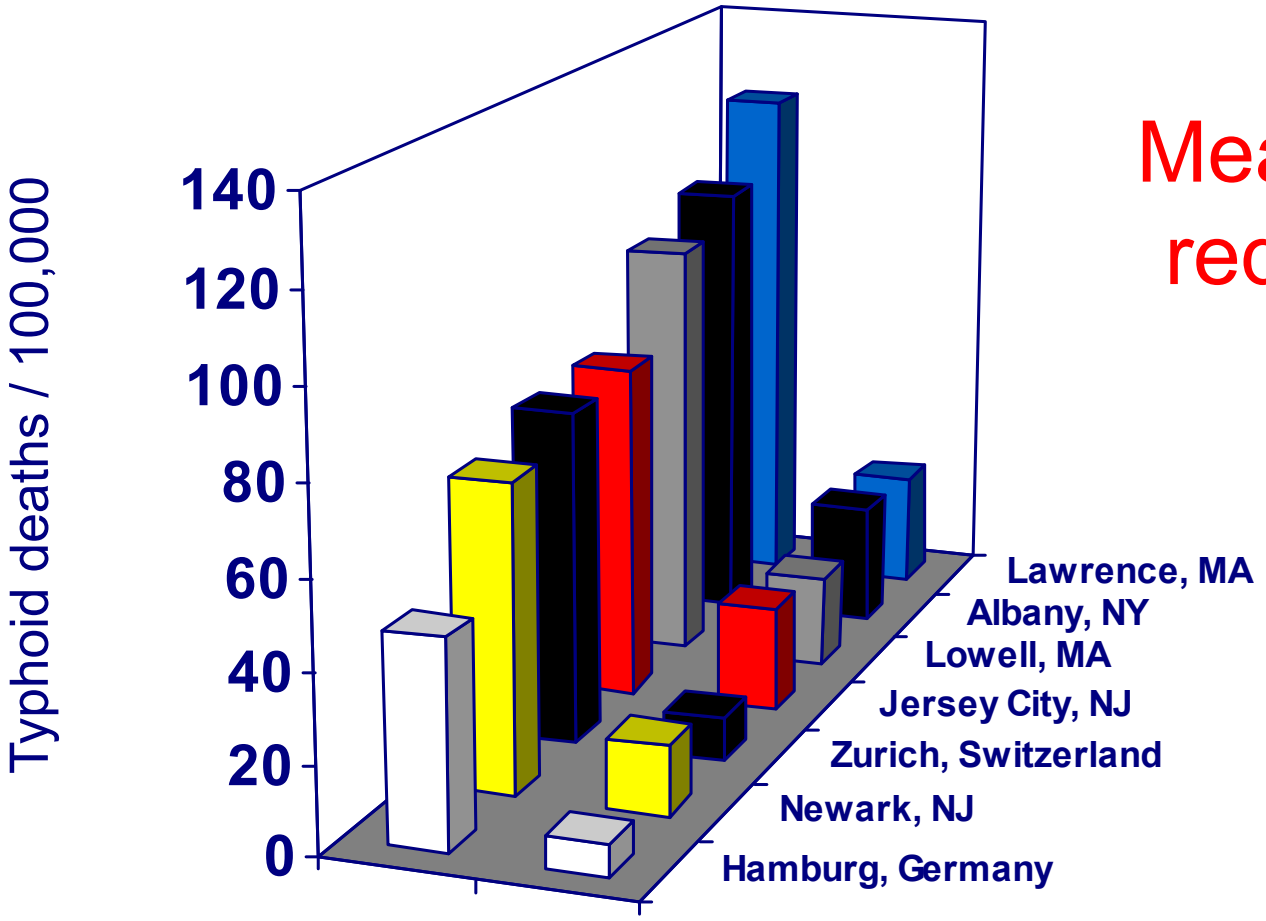
What should communities do to address the shortage of safe water?

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

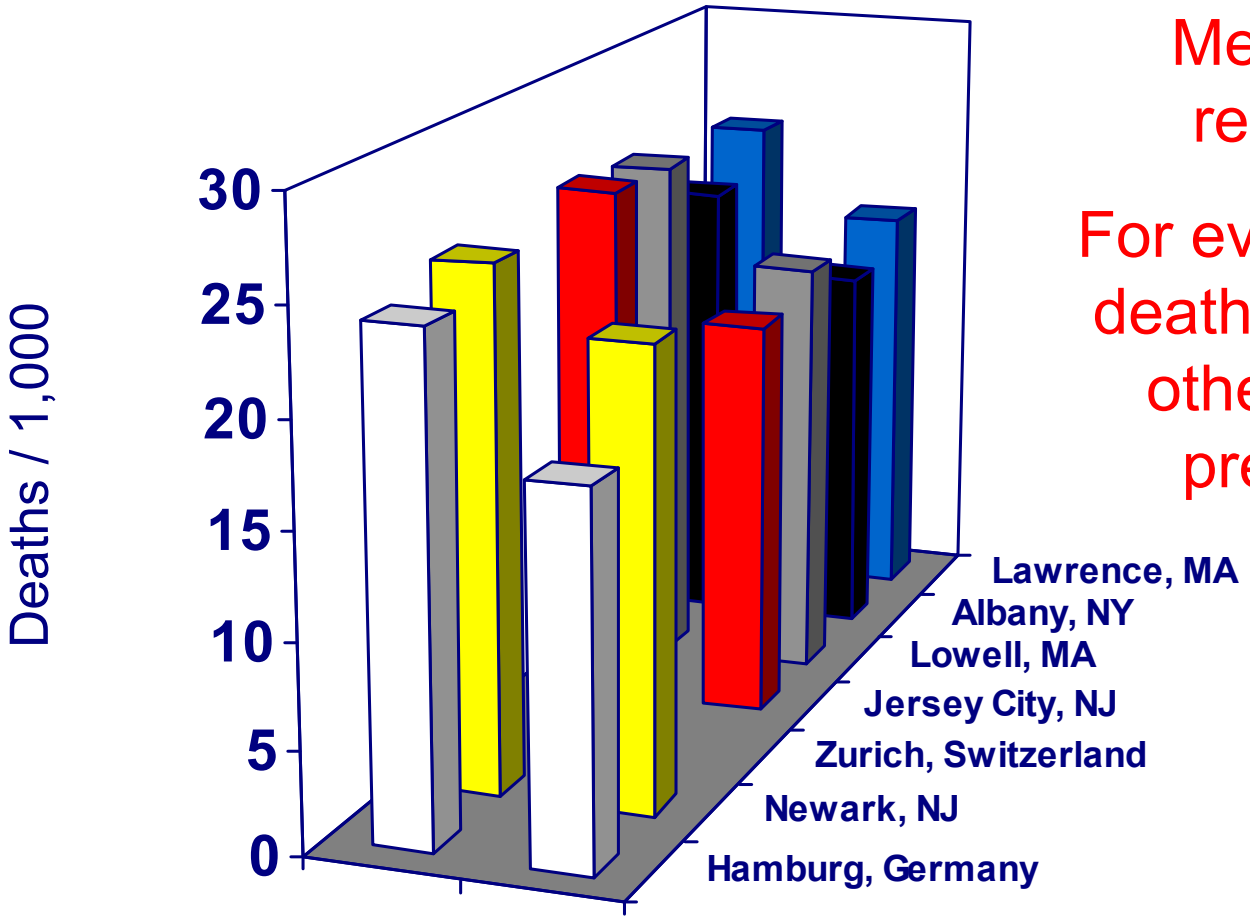


Mean 78% reduction

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
- Pay for the system by charging end users
  - Raise bonds for initial construction
  - Ongoing user fees to support maintenance

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

Photo :Hossain Mohammad Shahed Sazzad

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

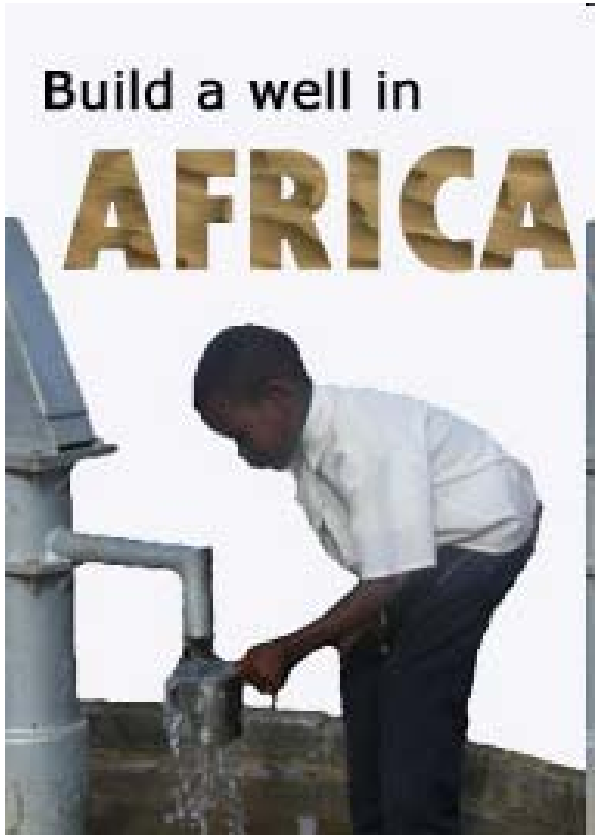
photo: Keith Kristoffer Bacongco via flickr

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



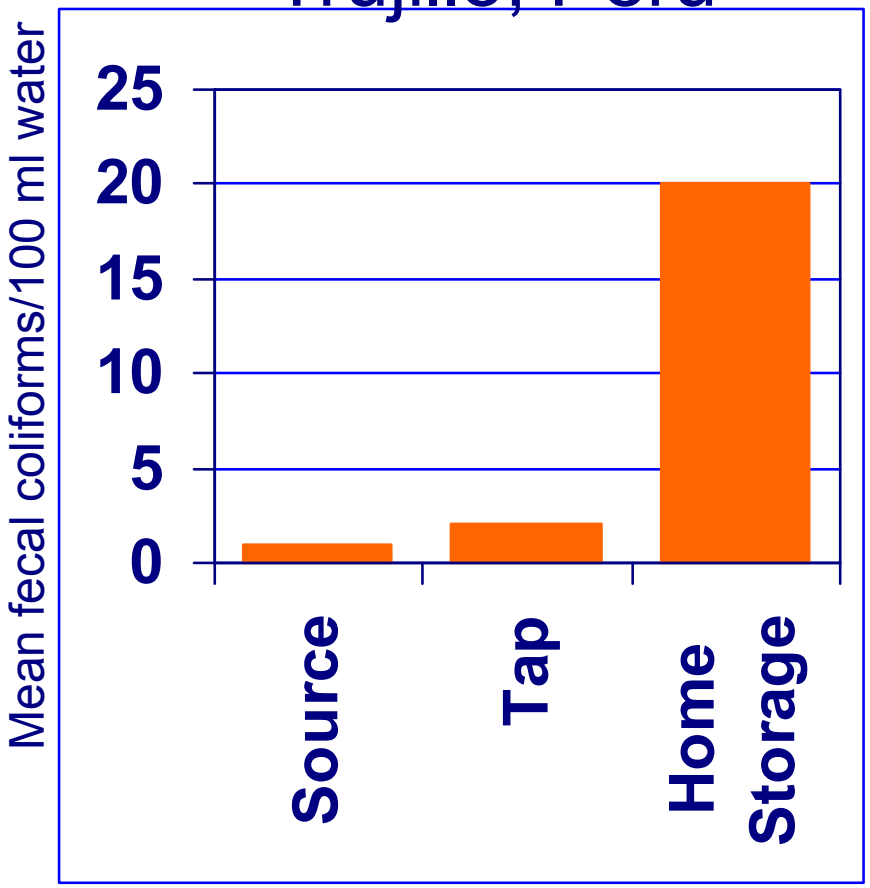
islamichelp.org.uk

Post-source Water Contamination

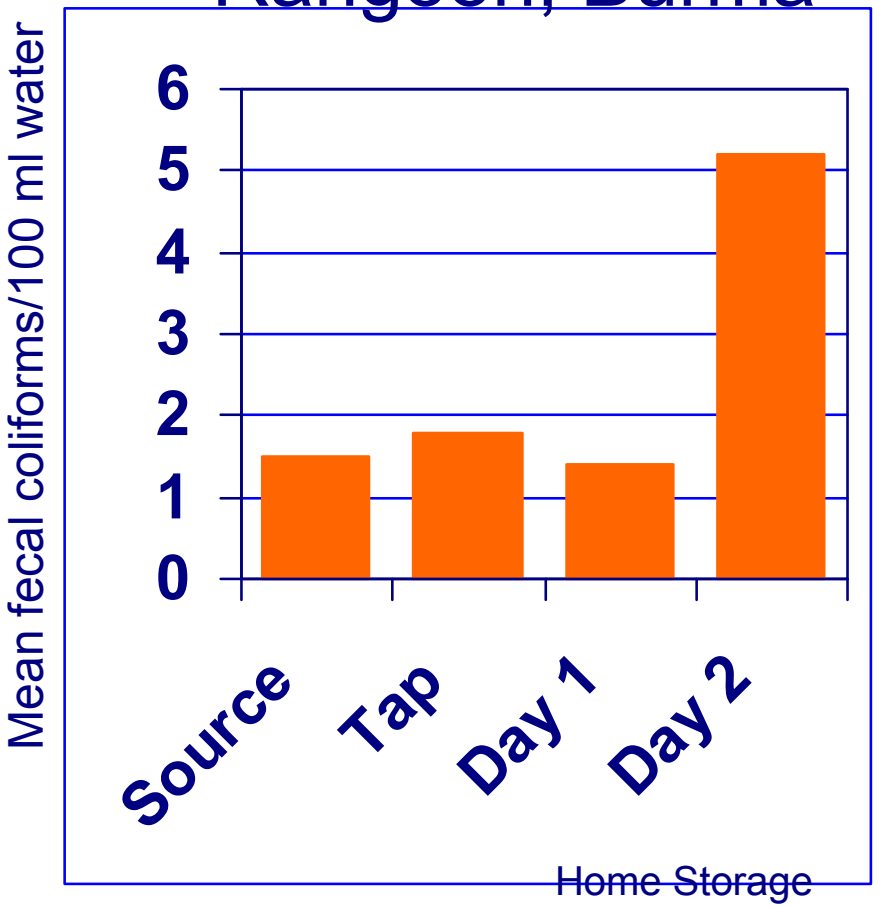
Eric Mintz, CDC

Fecal contamination of water increases with storage

Trujillo, Peru



Rangoon, Burma



Swerdlow DL, Lancet, 1992, 340:28-32.

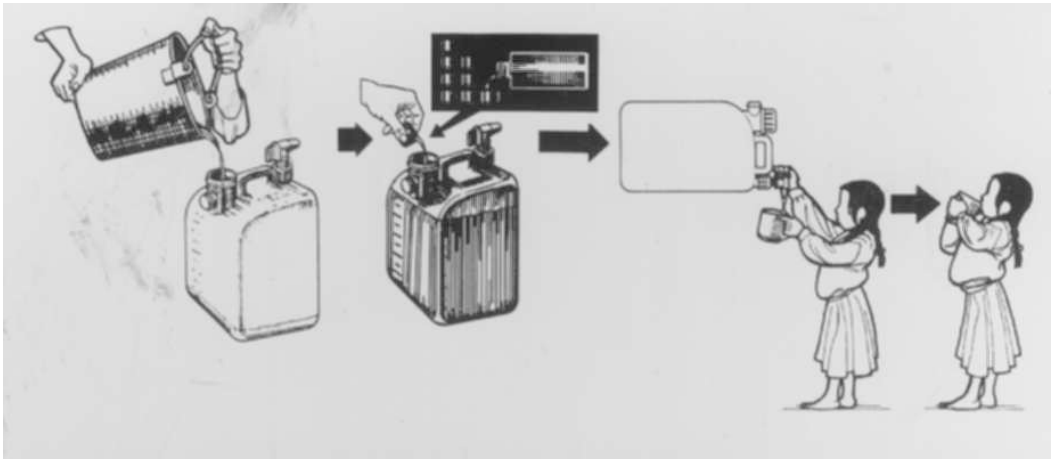
†Han AM, Trop Geogr Med, 1989, 41: 138-40.

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

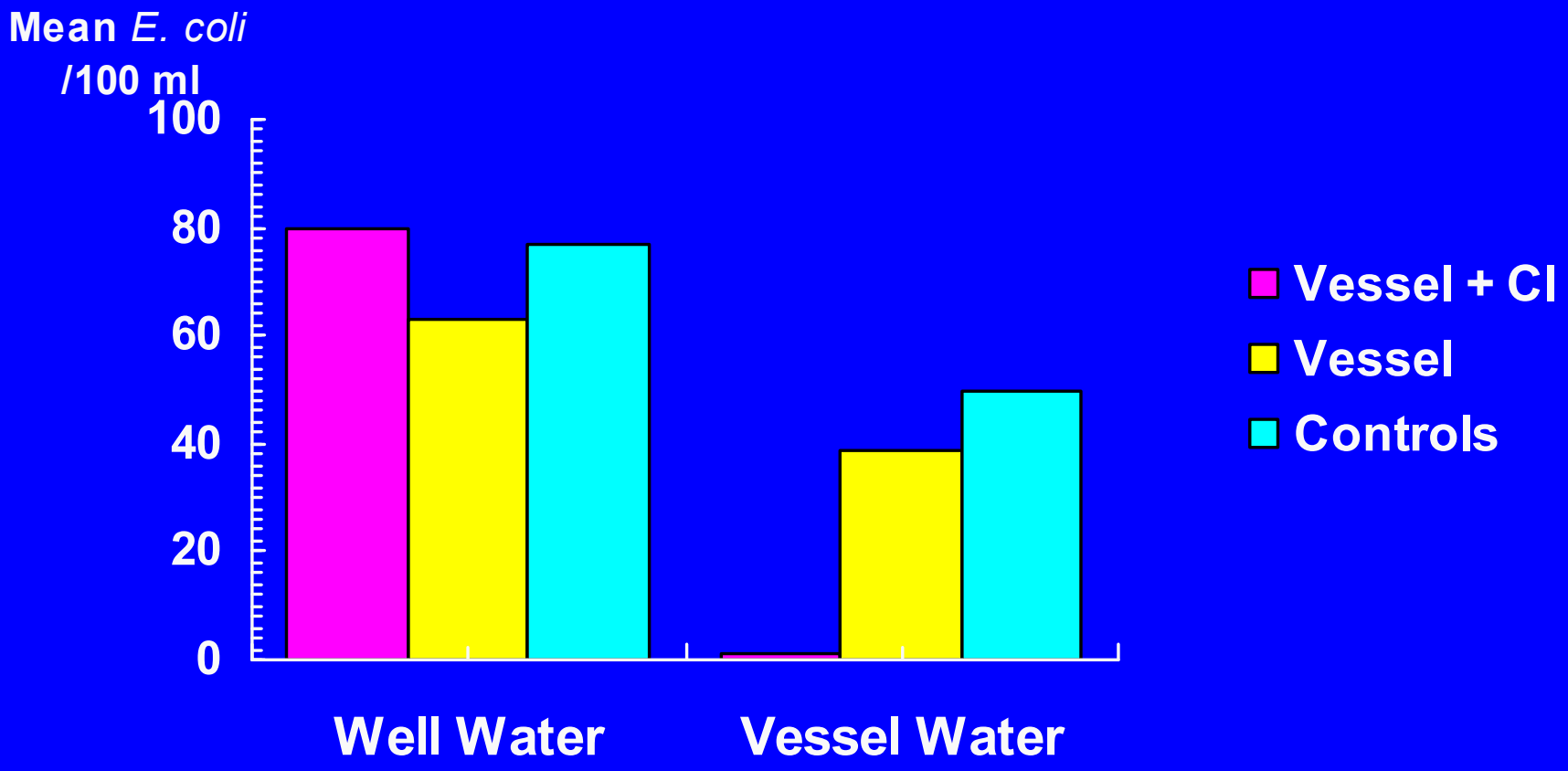


Phase 1 Trial : El Alto Bolivia

- **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

R. E. Quick *et al.*, *Amer J Trop Med Hyg* **54**, 511 (May, 1996)

Phase 1 Trial : El Alto Bolivia Results



R. E. Quick *et al.*, *Amer J Trop Med Hyg* **54**, 511 (May, 1996)

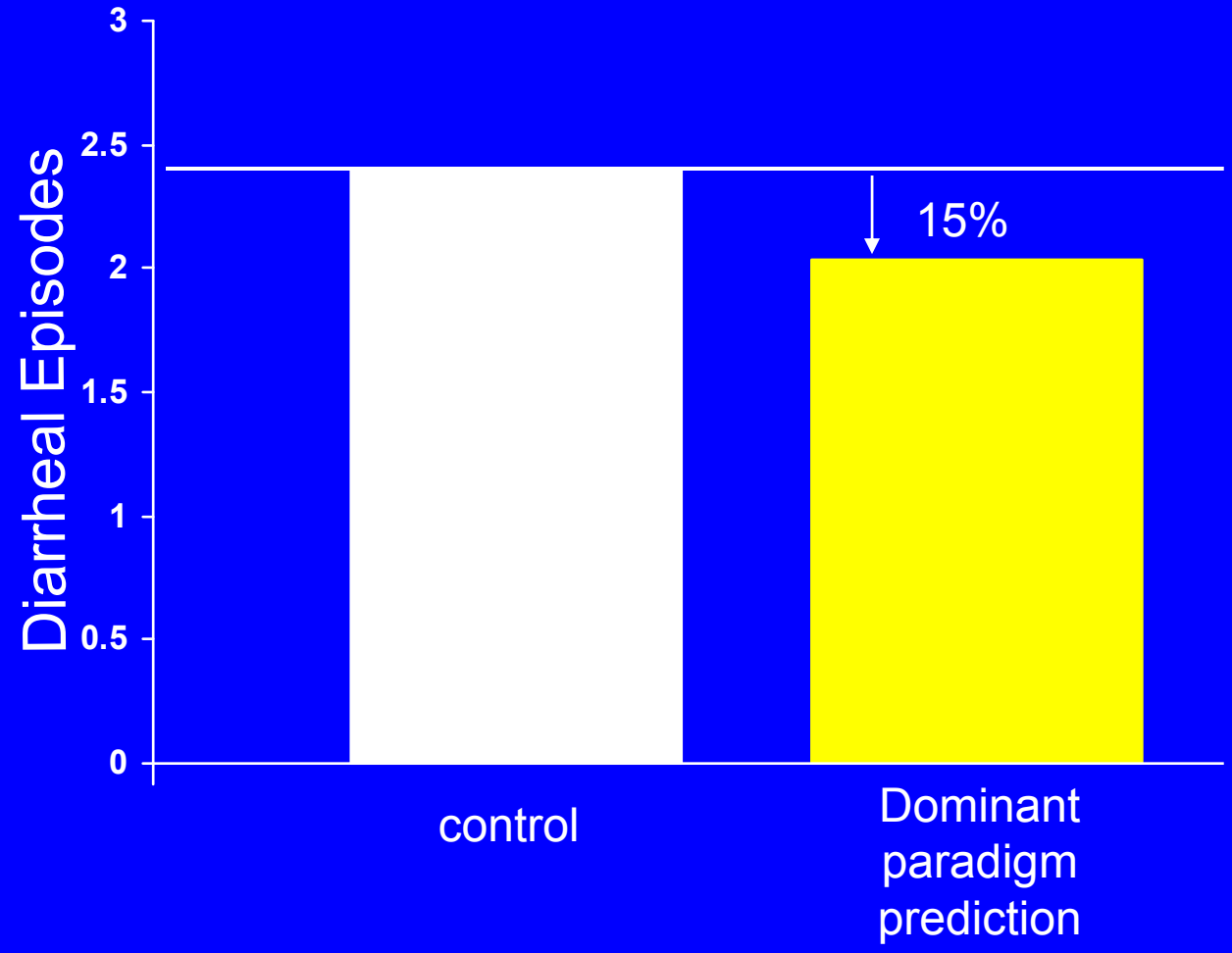
Intervention Effectiveness Phase 2
Montero, Bolivia, 1994/95

- 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



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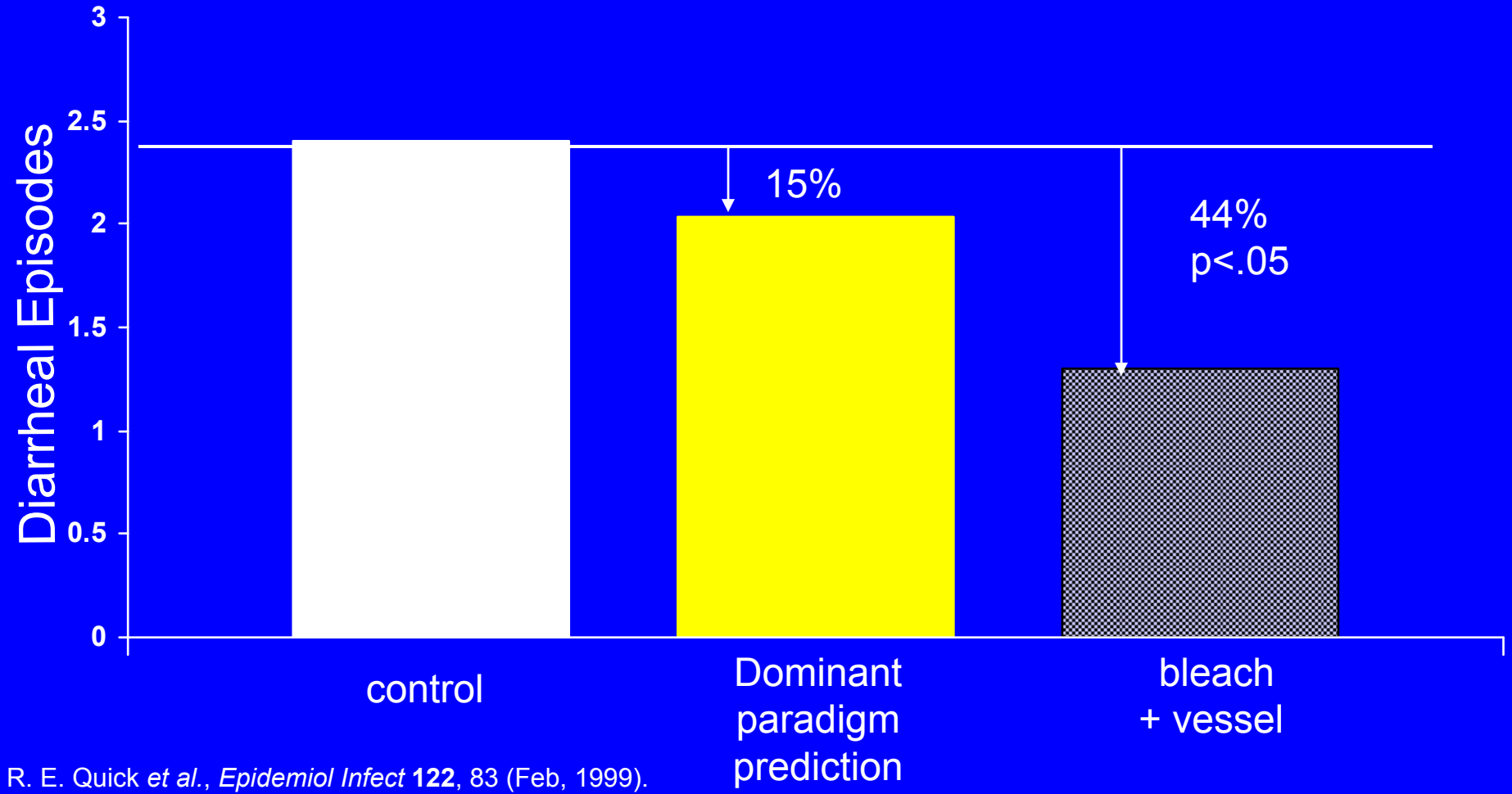
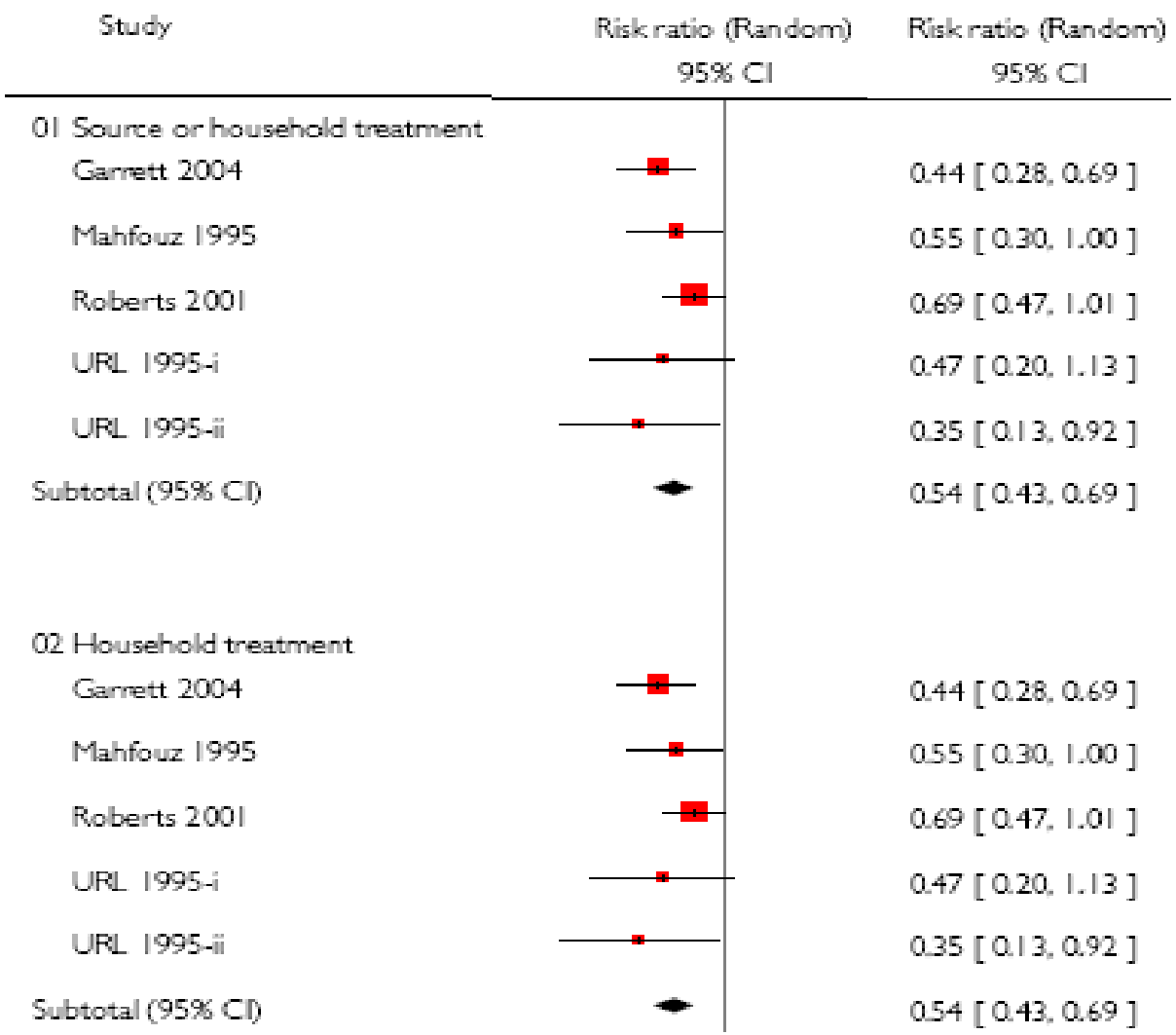


R. E. Quick *et al.*, *Epidemiol Infect* **122**, 83 (Feb, 1999).

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



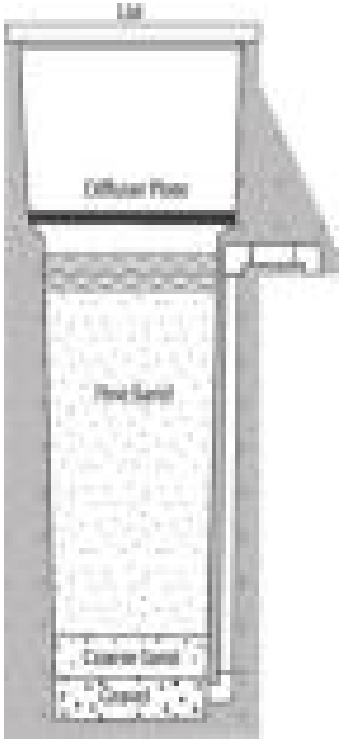
Clasen T, et al. Interventions to improve water quality for preventing diarrhoea. Cochrane Database of Systematic Reviews 2006, Issue 3. Art. No.: CD004794. DOI: 10.1002/14651858.CD004794.pub2.

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***

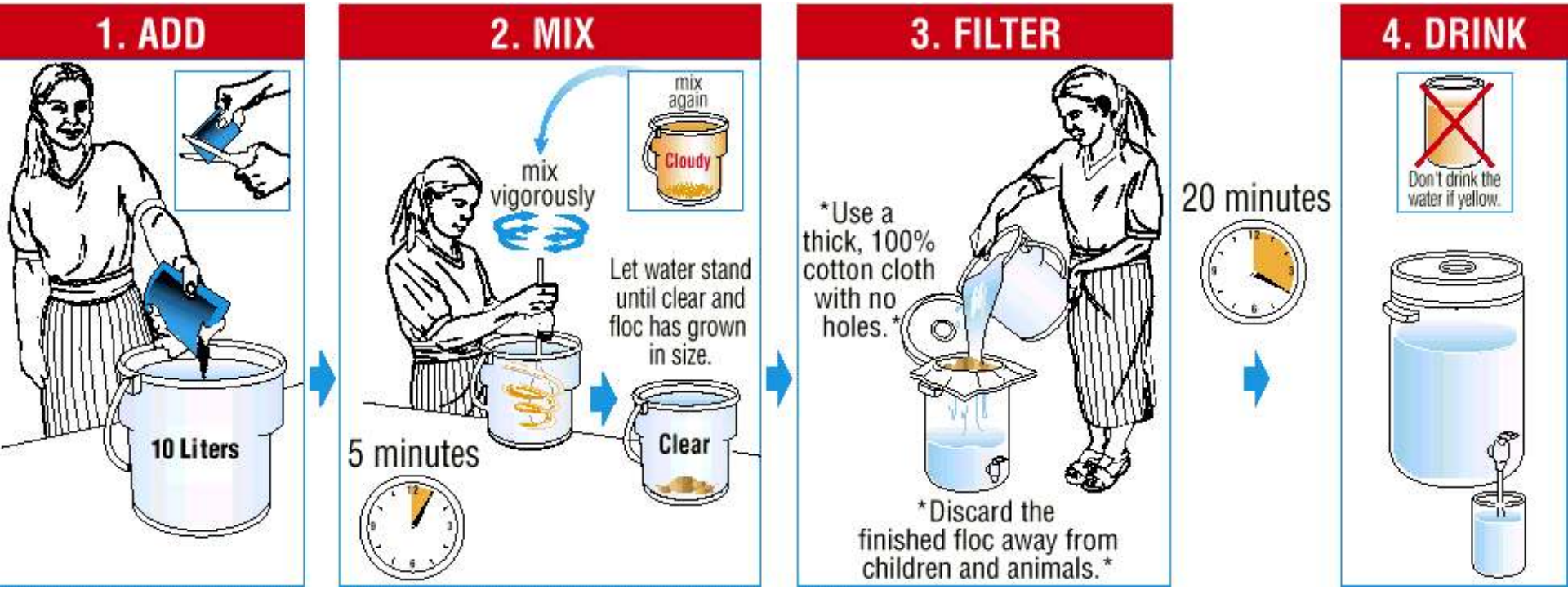


Daniele Lantagne, CDC

Flocculant-Disinfectant (PūR®)

- Developed by Procter & Gamble
- Combines
  - Precipitation
  - Coagulation
  - Flocculation
  - Disinfection

Use Instructions

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Low Dose Study Design

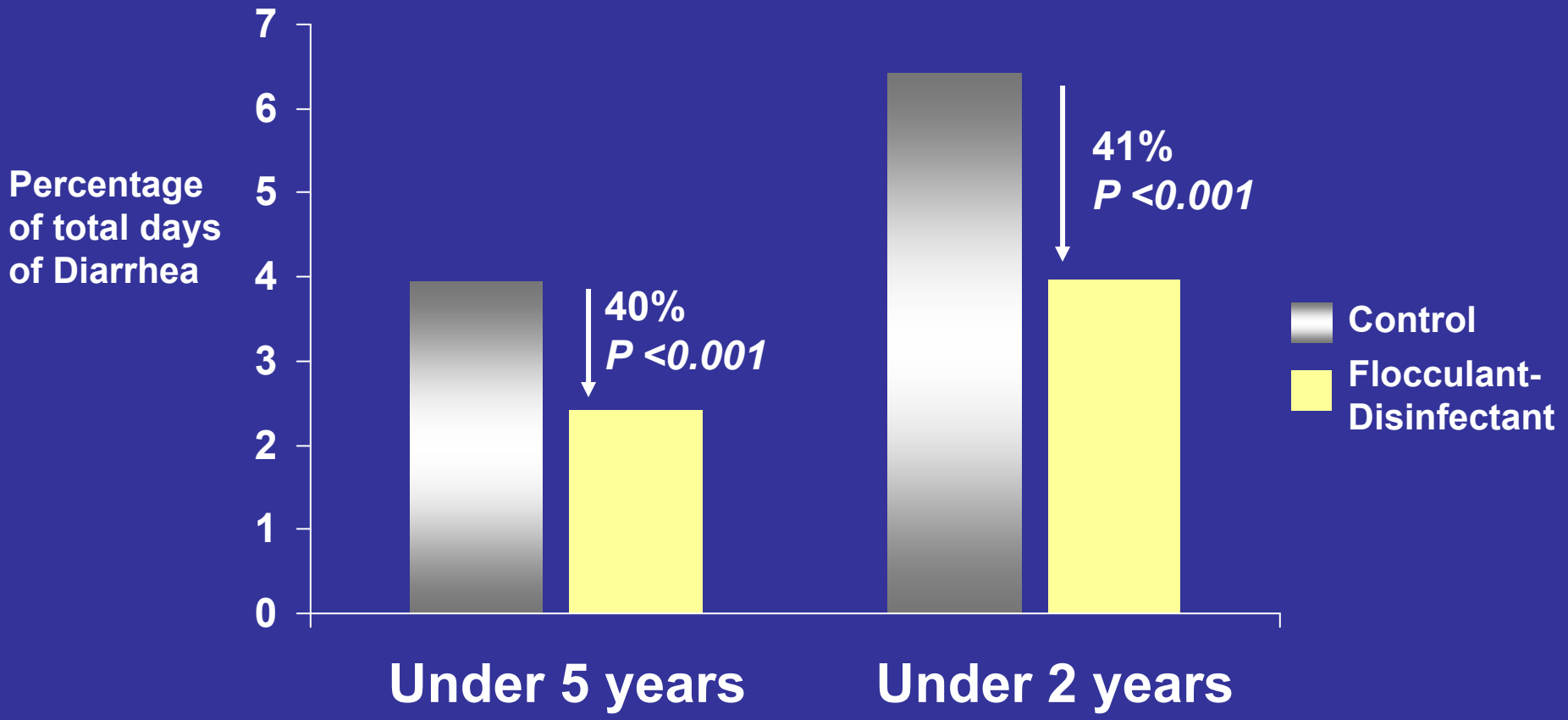
Randomized Controlled Intervention Trial

- 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)

CDC

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

Photo: Sundeep Gupta

S. K. Gupta et al. *Amer J Trop Med Hyg* **78**, 979 (Jun, 2008).

Chulli water purifier

Sand filtration
- Bucket with sand
- Bamboo stand

Heat treatment
- Plastic tubing
- Aluminum tubing
- Aluminum coil inside clay chulli
- Opening for firewood
- Aluminum tubing

Water output
- Plastic tubing
- Tap affixed to stand
- Aluminum kolshi for water collection or storage

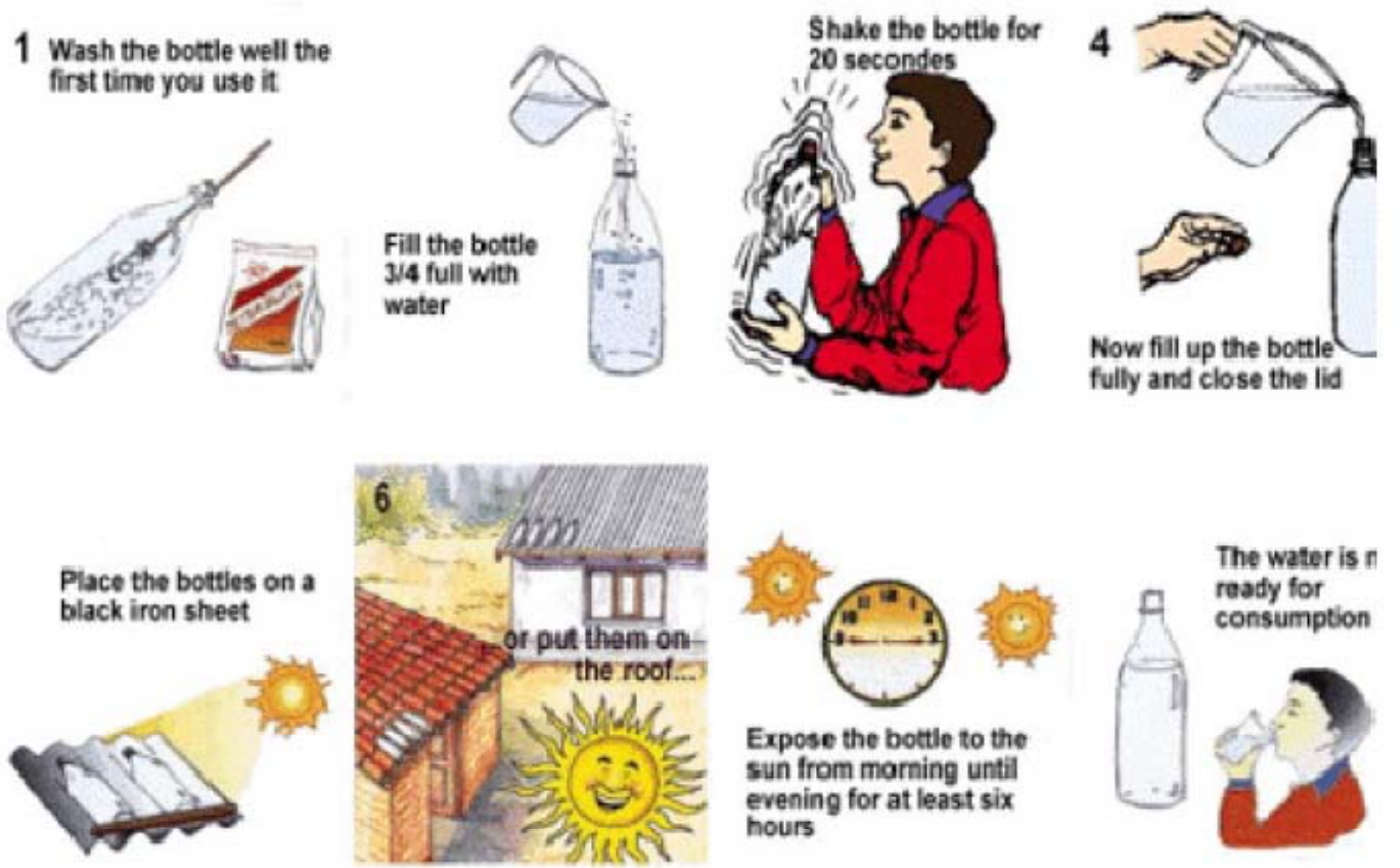
Usage of the chulli water purifier (N=101)

- 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

S. K. Gupta et al. *Amer J Trop Med Hyg* **78**, 979 (Jun, 2008).

SODIS – Solar Water Disinfection



www.sodis.ch

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

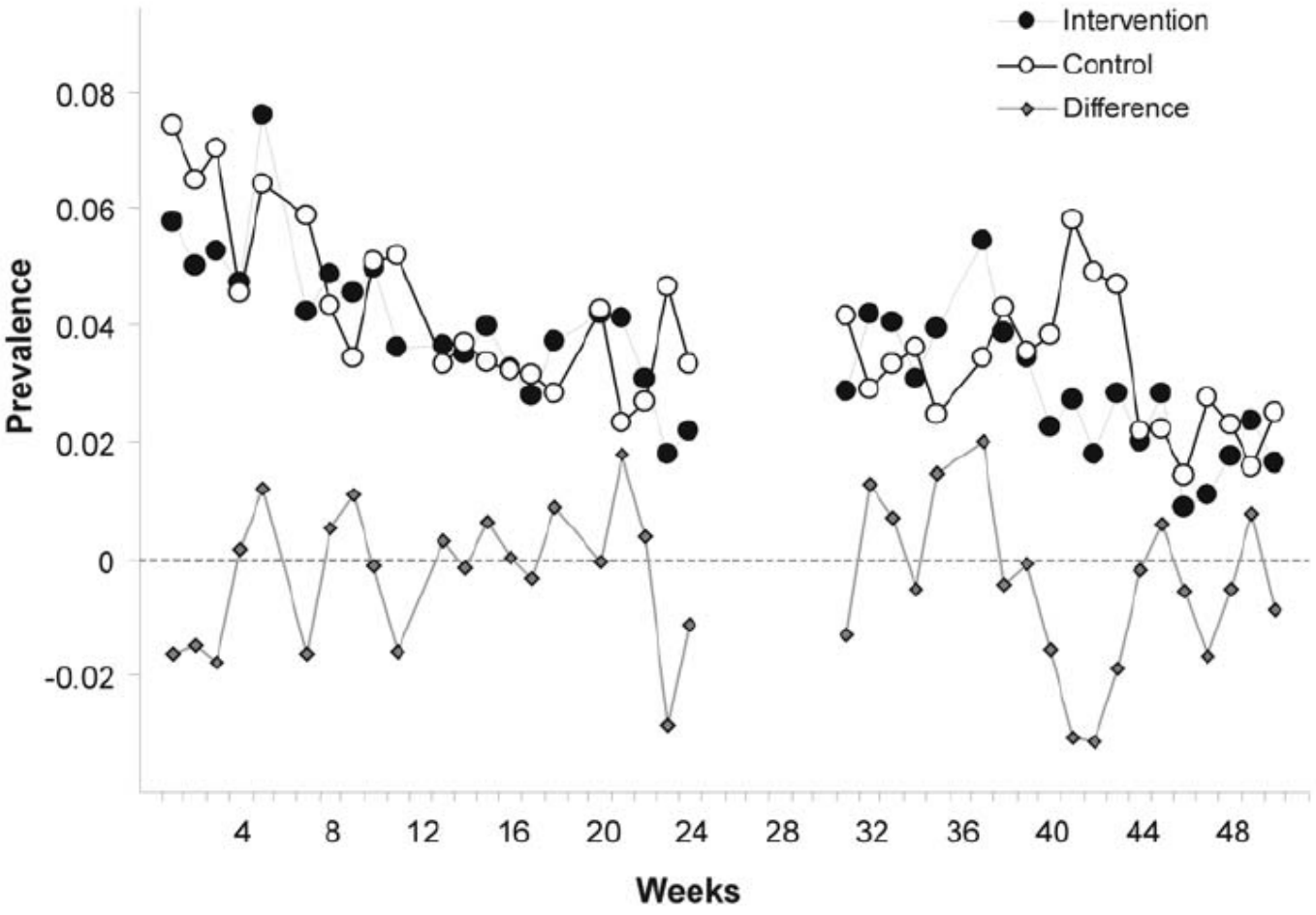
www.ziemia.org/sodis.php

D. Mausezahl *et al.*, *PLoS medicine* **6**, e1000125 (Aug, 2009).

Diarrhea Prevalence by Group

SODIS Evaluation – Rural Bolivia

32% of households observed to be using SODIS



D. Mausezahl *et al.*, *PLoS medicine* **6**, e1000125 (Aug, 2009).

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.opnan.com

www.aavaas.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%

Photo from Rob Quick

O'Reilly, CE et al. Epidemiol Infect 2008 Jan;136(1):80-91.

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

Community based entrepreneurs training session

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

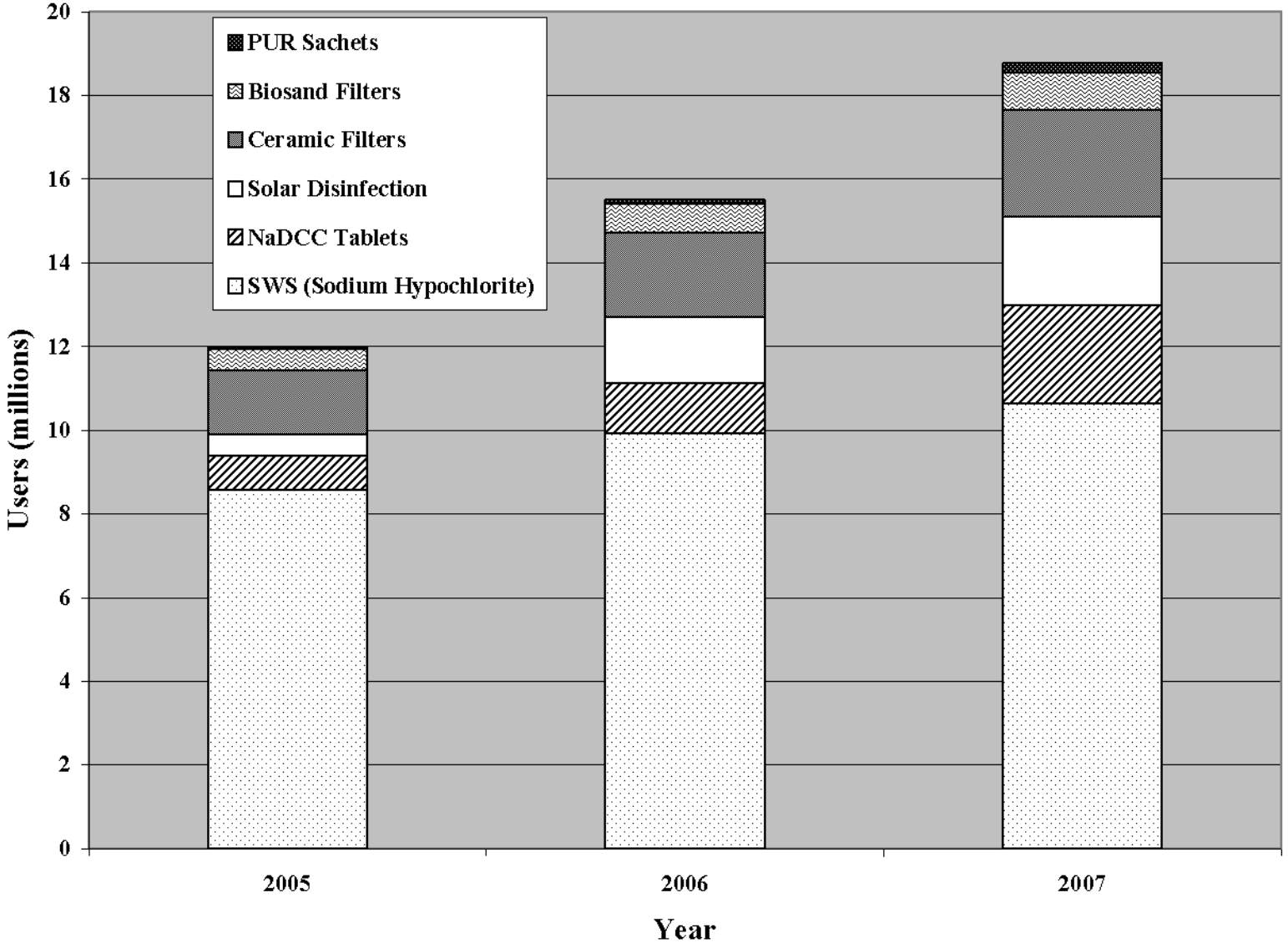
Kenya Dispenser Evaluation

- 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

Combined estimate of home water treatment products



T. Clasen, “Scaling Up Household Water Treatment Among Low-Income Populations” (World Health Organization, 2009).

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