The Safe Water System Initiative is one of the Type II partnerships that emerged from the World Summit on Sustainable Development in Johannesburg. It is an initiative that CDC helped develop, and that is now being implemented with multiple partners including WHO, CARE, USAID, and UNICEF. The Safe Water System itself is an “alternative low-cost water and sanitation solution” that has at its core “Health”, which, for CDC at least, is the most critical water issue.
Objectives

• Review current need for safe water
  – Global context

• Demonstrate options for safe water

• Talk about research possibilities
What is safe water?

• Water that does not cause morbidity and/or mortality
  – Especially in children under-5

• Engineering
  – Indicators (fecal, total coliform and E. coli)
  – Assumption that ‘protected sources’ are safe water

• Link between epidemiologists and engineers critical
An estimated 1.1 billion persons worldwide have no access to improved water sources, relying on unsafe surface sources such as ponds, streams, and shallow wells like these children are using for their water needs. In addition, hundreds of millions more collect their drinking water from “improved sources”, such as the poorly functioning municipal water system this woman has accessed, that deliver un-chlorinated water contaminated with human and animal fecal waste, and with the bacteria that cause cholera, dysentery, typhoid fever and so many other waterborne diseases. Please note that whether the source is improved or unimproved, in both photos and in hundreds of millions of families across the globe, water is collected outside and often far from the home, primarily by women and children, and that it is then carried, often in open plastic pails or buckets back to the house where it is stored, and used for drinking, washing, cooking, and bathing until another trip to the source is required.
Mortality and Morbidity From Unsafe Drinking Water

- Each year:
  - 1.7-2.2 million people die of diarrhea
- Each day:
  - 5,000 children die from infectious diarrhea acquired from unsafe drinking water
- Each year:
  - 1 billion episodes of diarrhea are caused

Each year, an estimated 1.7 to 2.2 million persons die from waterborne diseases. Most of these deaths are due to diarrheal diseases, and most occur in children and other vulnerable populations. More bluntly put, approximately 5,000 children die every day from diarrhea acquired from unsafe drinking water. The total burden of morbidity due to unsafe drinking water is difficult to estimate, but over 1 billion episodes of gastroenteritis and other infections annually are attributed to it each year.
UN Millenium Development Goals

- Widely accepted development goals
  - Sustainable development, poverty alleviation
- Water
  - Reduce in half the population w/out improved water sources by 2015
  - Requires 125,000 people per day gain access
    - No population growth
    - No loss of safe water access (conflict)
Where does fresh water come from?

• Global cycle
  – Groundwater
  – Surfacewater
  – Rainwater
  – Desalination
Water Scarcity

Projected Water Scarcity in 2025

- Physical Water Scarcity
- Economic Water Scarcity
- Little or No Water Scarcity
- Not Estimated
What contaminates water?

- Bacteria
- Parasites
  - Protozoa
  - Helminths
- Viruses
Bacteria

- Prokaryotic organisms
- Effectively inactivated by chlorine
- ~1 micron in size (filterable)
- Diseases
  - Gastroenteritis (diarrhea)
  - Typhoid fever
  - Cholera
Protozoa

• Life cycle
  – Excyst in intestines
  – Encyst in excrement, environment
• Cyst form highly resistant to chlorine
• Large (3-10 microns), easily filtered
• Diseases
  – Cryptosporidiosis, amebiasis, giardiasis
Viruses

• No DNA, noncellular
• Effectively inactivated by chlorine
• Very small (no filters)
• Less researched (engineering)
• Diseases:
  – Gastroenteritis, hepatitis, respiratory disease
Some data points from the chart:
- Polio virus: 0.03 micron
- HIV: 0.1 micron
- E. coli: 1 micron
- Protozoa: 10-100 micron

Reference points: Red blood cell = 6 micron, lower limit of human vision = 40 micron
### How do we treat water?

<table>
<thead>
<tr>
<th>Processes</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source water management</td>
<td>Large-style infrastructure</td>
</tr>
<tr>
<td>Air stripping</td>
<td>Community-level systems</td>
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<tr>
<td>Coagulation</td>
<td>Point-of-use</td>
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<tr>
<td>Filtration</td>
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<tr>
<td>Sedimentation</td>
<td></td>
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<tr>
<td>Ion exchange</td>
<td></td>
</tr>
<tr>
<td>Disinfection</td>
<td></td>
</tr>
</tbody>
</table>

**Goal:**

Get the dirt and microbes out, distribute
Historical Perspective: USA

• In 1900, diarrheal disease was one of the top ten killers in the USA
  – Typhoid, NYC
• Provision of piped, chlorinated water supply eradicated waterborne disease in the US
• Although treatment methodologies have improved, chlorinated piped water systems remain the method for ensuring adequate disinfection across the developed world
Graph removed for copyright reasons.
Source unknown. "Incidence of typhoid in Philadelphia during early part of 20th century."
Ethical Question

• Is what was right for US in early 20th century right for developing world in early 21st century?
  – Counterexample: Cell phones
  – Developing: Electricity
  – ?? Water supply

• How to provide safe water to > 1.1 billion?
Large-style Infrastructure

• Provide reliable, quality water
• However, there are limitations:
  – Political
  – Necessity for large investment
  – Geographical
  – Time
  – Cultural (pop. density)
• In light of limitations, focus in developing countries has moved toward community systems
Community Systems

- Same processes as large-scale
- Can have a piped distribution network
- Have simpler process controls and maintenance
Photos courtesy of Amy Smith.
Photos courtesy of Amy Smith.
CARE, one of our Safe Water System partners, provided this striking photograph of a child in Mozambique carrying water home to his family. The bucket of water is full and open, and his hands are curled into it around the top to keep it from falling. This unavoidable hand-to-water contact means that even the purest water from the best protected bore hole well will be contaminated with any disease-causing agents that are on the water-bearer’s hands even before it crosses the threshold of his or her home.
Inside the home, things only get worse, as illustrated by this photo taken at the height of the cholera epidemic in Peru over a decade ago. In addition to the buckets used for collecting and carrying water, other containers are often used for storing water at home, but they too tend to have wide uncovered mouths. Water is removed by dipping hands and objects in, further contaminating the stored water with the prevalent fecal flora. At the time we took this photo, and in the months that followed, CDC was busy helping the Pan American Health Organization and Ministries of Health throughout the Americas try to control the raging cholera epidemic. Water from many sources was the principle vehicle for cholera transmission in each country. “Boil water” orders were issued, but most persons could not afford to comply with them, and even those who could were at risk for acquiring cholera from contamination that occurred while the boiled water was stored unprotected at home. The long-term cholera fix – extending piped, treated, safe water coverage to the entire population of Latin America was projected to cost billions of dollars and take many years to complete. So the Safe Water System was initially conceived as an inexpensive, practical alternative that would enable families to protect themselves from cholera and other waterborne diseases until more definitive solutions could be implemented.
International Network to Promote Household Water Treatment and Safe Storage

‘To contribute to a significant reduction in waterborne disease, especially among vulnerable populations, by promoting household water treatment and safe storage as a key component of water, sanitation and hygiene programmes’

• Consortium

Universities, NGO, Government, Private Sector
POU Treatment Types

1. Bottled
2. Filtration (Biosand, Ceramic)
3. Filtration & Chemical (PFP, GWI)
4. Chemical (Chlorine)
5. Combined chemical (PuR, P&G)
6. Ultraviolet
7. Solar (SODIS)
Evaluation Matrix for Household Treatment

1. Laboratory Testing
2. Field testing
   • User-monitored
   • User
3. Health Impact Analysis
4. Scalability

No one intervention is silver bullet
Bottled

- **Strengths**
  - Consumers avoid water collection and treatment
  - Safer alternative to local water sources?
  - Increased regulation for bottled water

- **Limitations**
  - Informal street vendors are prevalent
  - Consumers pay high costs for water of poor quality

- **Robustness**
  - Significant environmental impact

- **Economics**
  - 500 to 1000x more expensive than piped water
  - 0.20 - 6.00 USD per person per day
Filtration

• Strengths
  – Availability and range of filtration types
• Limitations
  – Effectiveness risk vary greatly with approach
  – Practicality, ease of use, availability, and affordability vary
  – In general, low or untested rates of disease reduction
• Robustness
  – Materials can be highly accessible
• Economics
  – Approx. $2 for simple approaches to $200 for more complex
The GWI Purifier

- Two 20 L plastic
  - String-wound Filter
  - Check Valve
  - GAC Filter

- Usage
  - 5 mL bleach, 30 minutes
  - 5 drops bleach in bottom

Remember to say chlorine is removed by GAC filter - so add 5 drops. These are made in the US and imported.
Gift of Water, Inc.

- Florida-based NGO
- Charitable organization
  - Churches in the US sponsor a village
- Installs purifiers in rural households in Haiti
  - 10 communities, ~30,000 people
- Hires local technicians
  - ~100 Haitian employees
MIT M.Eng. Theses Results

• Health Impact Study
  – 35% reduction in diarrheal disease in users
  – 51% reduction in diarrheal disease in under-5’s

• THM Study
  – 16 / 17 samples
    • Below USEPA TTHM standard
    • Below WHO TTHM guideline value

• Local hypochlorite generation recommended
  – Key to sustainability
## Community Correct Usage

<table>
<thead>
<tr>
<th>Community</th>
<th>Percent Correct Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferriere</td>
<td>100</td>
</tr>
<tr>
<td>Bas Limbe</td>
<td>20</td>
</tr>
<tr>
<td>Fon Veret</td>
<td>75</td>
</tr>
<tr>
<td>Barasa</td>
<td>90</td>
</tr>
<tr>
<td>Les Palmes</td>
<td>77</td>
</tr>
</tbody>
</table>
Factors for Program Success

- Dedicated and well-selected technicians
- Localized distribution of purifiers
- Purifiers as part of a larger community education initiative
The GWI System: Summary

Benefits
- High quality water
- Community development

Drawbacks
- Dependence on imported materials
- Sustainability / scalability
- Complexity, cost

1. Effectively reduces diarrheal disease
2. Effectively removes bacterial contamination
3. Does not pose a health risk
4. Is used correctly with TA
Potters for Peace

- Ceramic solidarity organization
  - US NGO based in Colorado
- Ceramic filter factory
  - Make filters
  - Impregnate with silver
  - Sell to NGOs
  - NGOs implement programs
Results: Lab Study

• No water sample exceeded guidelines for silver in drinking water

• All flow rates of filters sold are effective at removing bacterial indicators

• Although a majority of indicators are removed w/out silver, the 3.2% silver is necessary for 100% removal
Results: Field Studies

- 14 / 24 less than 0.5 L/hr
  - Correlated with filter age

- Microbial Testing: P/A
  - 23/24 had detectable TC
  - 19/24 had detectable H$_2$S
  - 13/17 had detectable *E. coli*

- Lab enumeration: MF
  - More contamination in finished water
The PFP Filter: Summary

Benefits
1. Silver concentrations not a health concern
2. Flow is a concern - scrubbing
3. Microbial contamination is a concern - cleaning
4. Education is vital for continued use

Drawbacks
Local production / culture
Inexpensive
Less effective in field
Breakage rate

Say important to do both lab and field studies.
Comparison

Two very different interventions

<table>
<thead>
<tr>
<th>PFP</th>
<th>GWI</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sustainable</td>
<td>• Effective</td>
</tr>
<tr>
<td>– Does not reliably reduce bacterial contamination as currently implemented</td>
<td>– Dependent on subsidies</td>
</tr>
<tr>
<td></td>
<td>– Complex</td>
</tr>
</tbody>
</table>
Biosand Filtration

Images removed for copyright reasons.
Chemical

- Strengths
  - Clinically proven
  - Residual disinfection
- Limitations
  - Does not address all contaminants
  - Chemical taste and smell
- Robustness
  - Chemical availability
  - Some storage risk
- Economics
  - $7 to $11 per family per year
The Safe Water System is simple. It provides families with the means to treat their drinking water at the point-of-use – by adding dilute sodium hypochlorite bleach - and the means for them to store treated drinking water safely – in a narrow-mouthed, lidded vessel with a spigot that can be used to collect, transport, disinfect and store drinking water in the home. A capful of the locally-produced dilute sodium hypochlorite from the 500 ml CLARO bottle is just the right amount to treat 20 liters of water in the locally-produced CLARO storage vessel. These two items were marketed together as part of the first national Safe Water System project in Bolivia in 1996.
The hypochlorite solution and the storage vessel are the “hardware” of the Safe Water System, but the most critical component is the “software”. By that I mean the messages and the methods used to induce and sustain healthy changes in behavior, including safe water handling, and improvements in hygiene and sanitation, such as handwashing. These printed materials are from Safe Water System programs in Bolivia, Zambia, and Ecuador, but our social marketing and implementation partners also reach people through radio and TV broadcasts, community mobilization campaigns, and interpersonal behavior change techniques such as motivational interviewing. We realized long ago that for the Safe Water System to have impact, it needed to be economically self-sustaining, and hence one function of the “software” is to get people to buy the “hardware”. Fortunately, the bleach solution costs very little to produce, and 10 to 25 cents worth will last a family an entire month. Safe storage vessels cost between 2 and 5 dollars, but are still within the means of many of those who can benefit from them. Increasingly, we’ve recognized that the “hardware” also helps to sell the software. In other words, people who purchase and bring into their homes a bottle of hypochlorite for water treatment and a safe water storage vessel are likely to be receptive to messages promoting simple hygiene measures like handwashing - which by the way, is a lot easier to do when your water is kept in a vessel with a spigot. The hardware empowers families to manage their household water and sanitation environment better, and this reinforces their willingness to adopt and maintain new behaviors.
Safe Water System Products

This is a simple picture of the actual the water treatment solution bottles that are sold under different brand names in 7 countries, Bolivia, Peru, Zambia, Uganda (in yellow), Kenya, India, and Madagascar.
SWS Implementation Plan

• Work with in-country partners
  – Establish products
  – Begin pilot project
• Complete evaluation of pilot project
• Establish distribution network and market product
  – Social marketing
  – Community health motivators
  – Motivational interviewing

Evaluate and modify plan as needed
Safe Water System Results

• Consistently reduces diarrhea by ~50%

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolivia*</td>
<td>1994</td>
<td>44% overall; 53% in infants</td>
</tr>
<tr>
<td>Uzbekistan*</td>
<td>1996</td>
<td>85% overall</td>
</tr>
<tr>
<td>Zambia*</td>
<td>1998</td>
<td>48% overall</td>
</tr>
<tr>
<td>Guatemala</td>
<td>2001</td>
<td>25% overall</td>
</tr>
<tr>
<td>Madagascar*</td>
<td>2001</td>
<td>95% against cholera</td>
</tr>
<tr>
<td>Kenya</td>
<td>2001</td>
<td>55% in children &lt;5 years old</td>
</tr>
<tr>
<td>Madagascar</td>
<td>2002</td>
<td>63% overall</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2002</td>
<td>49% overall</td>
</tr>
<tr>
<td>Uganda</td>
<td>2003</td>
<td>~30% in HIV-infected persons</td>
</tr>
</tbody>
</table>
But as good as that makes us feel, when we leave our logarithmic scales behind and examine our progress on a pie chart representing the billion plus persons without safe water, we see immediately how much more needs to be done. So how are we going to capitalize on the tremendous opportunity that this situation presents us with? Several exciting new prospects have recently emerged …
Global burden of unsafe water

>1.1 billion persons

Safe Water System: 2003
5 million users

Safe Water System: 2007
100 million users

We believe that the Safe Water System can help us reach the goal, and have projected a figure of 100 million regular users by 2007 if we can find the resources to support our proposed 20 country expansion.
PuR

- Procter & Gamble Product
  - Reverse engineering from water treatment plants to POU solution
- Strength
  - Clinically proven by CDC
  - Residual disinfection benefits
  - Visual clue of treatment - addresses turbidity
- Limitations
  - More steps required for treatment
- Robustness
  - Well suited for emergency situations
  - Private sector involvement
- Economics
  - 0.20 USD per family per day
Ultraviolet

• Strengths
  – Addresses some hard to treat contaminants
  – Treats large quantities quickly

• Limitations
  – High initial costs for materials
  – Contaminant reactivation over time
  – Ineffective with some common contaminants

• Robustness
  – Electricity availability; solar options exist

• Economics
  – Electricity cost is minimal
  – UV Waterworks $800 initial cost, plus $200 for solar
Solar Disinfection

• Strengths
  – Clinically proven
  – Does not address color, taste, odor

• Limitations
  – Weather dependency
  – Contaminant reactivation over time
  – Ineffective with some common contaminants

• Robustness
  – Material availability
  – High level of oversight required

• Economics
  – Little to no initial cost with recycled plastic bottles
  – Approximately $1 per family per year
Opportunities for Research

• Each step of process
  – Focus on end goals: feasibility, impact

• Research in developing countries
  – Give something back
  – Not an excuse for poor quality control
  – Modified laboratory testing
  – Cross-major collaborations critical
College Groups

- Engineers without Borders
- Engineers without Frontiers
- Guest Speakers
- Amnesty International
Thank you!

Daniele Lantagne