Engineering Inputs to Increase Impact of the CDC Safe Water System Program

Daniele S. Lantagne, PE

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Mortality and Morbidity From Unsafe Drinking Water

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

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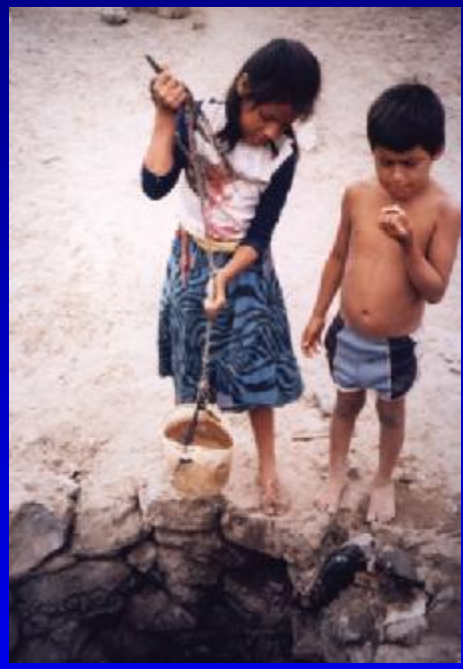
Global Burden of Unsafe Water

- Over 1 billion persons have no access to improved water sources

- Hundreds of millions more drink unsafe water from “improved” sources



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Millennium Development Goals

- Widely accepted development goals
  - Sustainable development, poverty alleviation
- By 2015:
  - Reduce in half the population without improved water
  - Requires 125,000 people per day gain access
    - No population growth or loss of access
  - World Bank estimate
    - 300,000 per day (behind in sub-Saharan Africa)

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Overarching Goal: Infrastructure

- Advantages of Infrastructure
  - Provision of reliable, quality water
  - Economic
  - Social
  - Aesthetic
  - Disease reduction
    - Increase quantity
    - Improvement hygiene
- Water as “Human Right”

Post-source Water Contamination

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CDC Safe Water System

Treat drinking water at the point of use

Dilute sodium hypochlorite bleach

Store treated drinking water safely

Narrow-mouthed, lidded vessels with spigots

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Clorin

Safe Water System Results

- Reduces diarrhea by ~50%
  - Consistently
  - Peer-reviewed literature
- Projects driven by
  - Demand creation
  - Emergency response
  - Use in non-traditional places
    - Markets in Bolivia
- Set the standard for evaluation of health impact

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Safe Water System Partners

- Funding: USAID, WHO, UNICEF, Rotary International, JICA, Procter & Gamble, DFID
- Production: Local private sector companies
- Implementation: PSI, CARE, small NGOs
- Political support: MOW, MOH
- Technical Assistance: CDC
- Evaluation: CDC, Universities

Project Partner: PSI

- Largest social marketing NGO in world
  - Condoms, bednets, birth control, water
- Scale
  - Launched 14 countries
    - 7 on deck
  - Sales of over 12 million bottles
  - 8 million bottles per year
- Social marketing, partner with NGOs

PSI Social Marketing

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Safe Water System Products

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Product Design - Historical Method

- Each country develop own dose
  - Large variation of chlorine added
  - No mechanism for comparison
- Used existing bottle/caps in country
  - Large caps (10 mL), low concentration
- Inefficient pilot project mentality
  - Madagascar
    - 0.39 USD per 500 mL bottle (0.19 subsidy)
    - 0.4% solution

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Dosing Testing Methodology

- Determine how much chlorine is needed to ensure safe water for 24 hours of storage
  - Obtain samples from each type of source used
  - Add chlorine in different concentrations
- Measure chlorine residual over 24 hours
  - Free chlorine residual: < 2.0 mg/L at 30 minutes
  - Free chlorine residual: > 0.2 mg/L at 24 hours
- Quality control critical
  - Responsibility in developing countries to do US quality work

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Mechanism to Compare: Dose Factor

$$DF = [\text{Hypochlorite}]\ (\%) \cdot \text{Amount added (20L, clear) (mL)}$$

$$\text{Dose } (mg/L_w) = \frac{[\text{Hypochlorite}]\ (mg/L_{Cl}) \cdot \text{Amount added } (mL_{Cl})}{20\ (L_w) \cdot 1000\ mL / 1L}$$

Dosage Testing Results

- Before Standardization of Testing
  - Dose Factors: 1.6 - 8.0 (median 4)
- After Standardization of Testing
  - **In 73 of 87 (84%) unchlorinated samples from 13 countries a dose factor of 3.75 (clear) 7.5 (turbid) acceptable**
    - Consistent with WHO and Clorox 'drop' recommendations
  - In 14 samples (16%) not found to be acceptable
    - Excessive turbidity 57%
    - Excessive metals 21%
    - Best treated with 1.875 or between 3.75 and 7.5 21%

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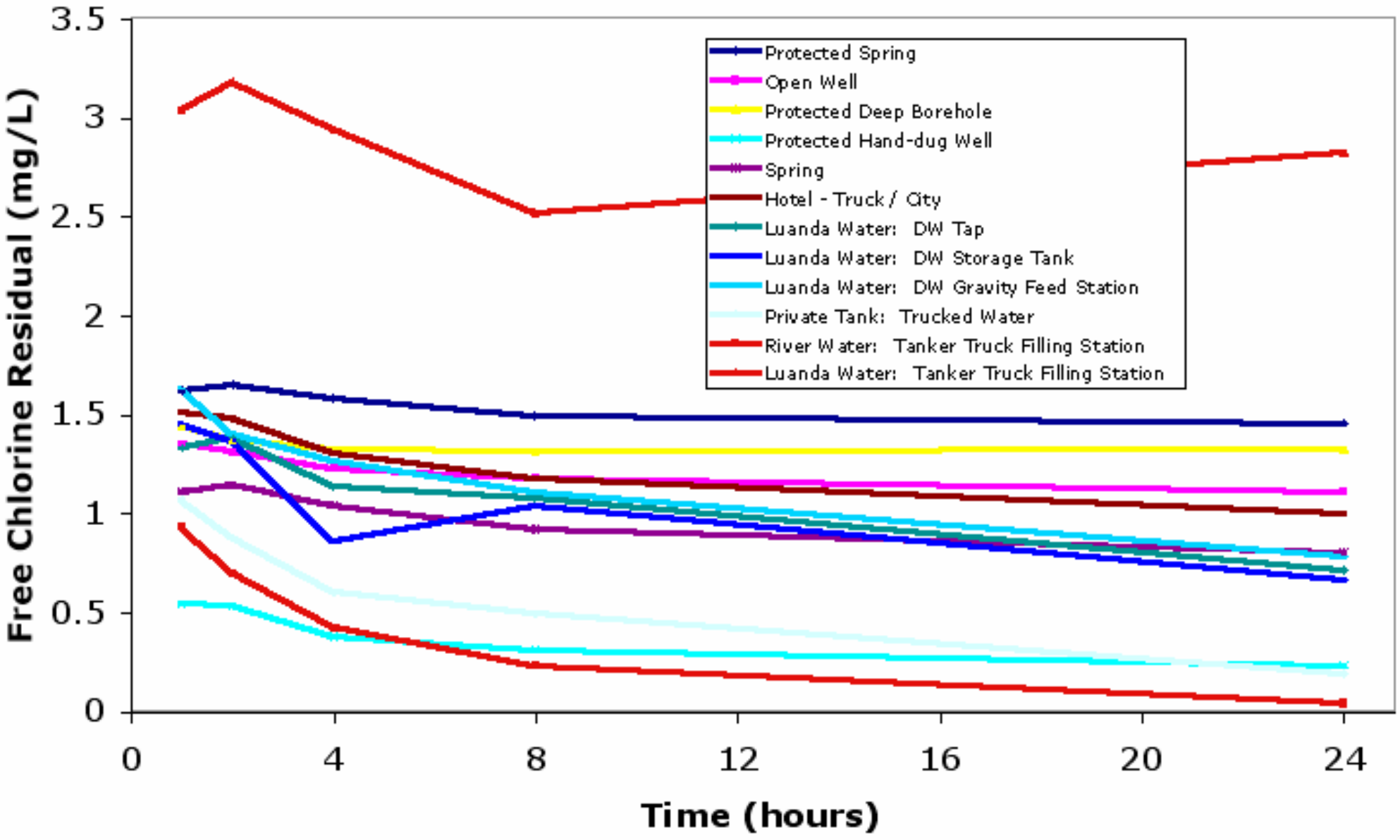
Chlorine Residual Over Time in 12 Locations



Dosing Testing - New Method

- Start with 3.75 / 7.5 regime
  - Ensure accurate
  - Do not treat each country as pilot project
  - Do not dose for one area (Kenya earth ponds / Antananarivo)

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Product Development - Variable Concept

Cap Size (mL)	Concentration (%)	Factor (one cap)	Dosing: Clear	Dosing: Dirty	Uses: 150 mL bottle	Liters treated (1 bottle)
7.5	1	7.5	1/2 cap	1 cap	40	900
3.75	1	3.75	1 cap	2 cap	40	900
3	1.25	3.75	1 cap	2 cap	50	1000
2.5	1.5	3.75	1 cap	2 cap	60	1200

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Regional Product?

- "Ideal Bottle"
  - 150 mL bottle, 3 mL cap, 1.25% solution
  - 50 uses (1.5 months)
  - Dose factor of 3.75 for 20 L bucket
    - One cap / two cap dosing scheme
  - Cost: 0.15-0.20 USD
  - 0.68 PYTW per bottle
  - Evolving ideal
- Potential for regional product

Regional Product

- Decision made to proceed
- Caps made and exported from Kenya
  - 12,000 USD mold
  - 1.1 US cents each ex-factory
- Bottle mold made in Kenya
  - Exported to country
- Regional - PSI
  - Uganda, Kenya, Ethiopia, Burundi, Mozambique, Tanzania, (Madagascar)
  - Vietnam, Cameroon, (Nigeria)
  - On deck: Malawi, Angola, DRC, Rwanda

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Advantages

- Simplifies program initiation
- Allows for cross-border response
- Cap economies of scale
  - 3 cents in Germany, 1.1 in Kenya
- Cost - 54% reduction
  - Madagascar (old): 0.39 USD
  - Madagascar (new): 0.18 USD

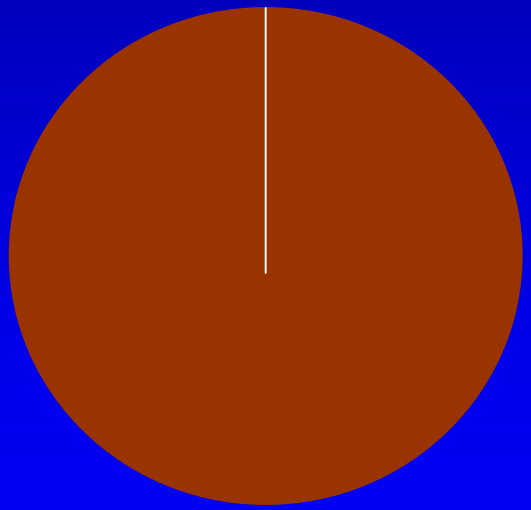
Engineering Critical Points

- Consistent water quality testing
- Analysis and comparing of results
- Industrial Design
  - User needs, label, PSI needs, transport, hand-feel, cost
  - Cap

- Allowed us to move from national to regional scale in Africa

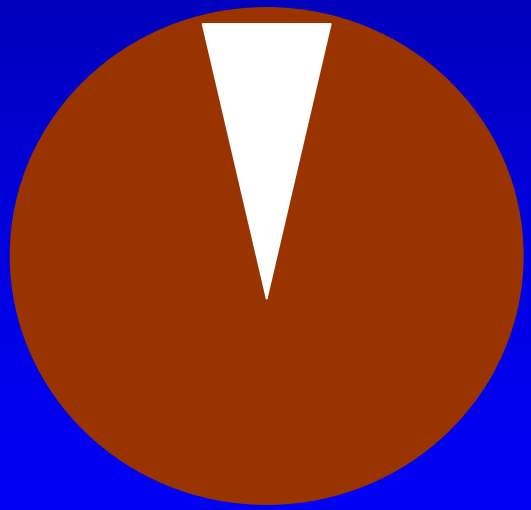
Projected Power of Partnership

Safe Water System: 2003
5 million users



Unsafe Water

Safe Water System: 2007
100 million users



PSI Expansion

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Thank you.

I am happy to take questions, and appreciate your attention and input.

Daniele Lantagne, PE CDC dul4@cdc.gov

Outline of Presentation

- Diarrheal Disease
- SWS Background
- Our Product
- Engineering Inputs
  - Dosage
  - Industrial Design
- Implementation with PSI
  - Benefits of new design
- Plans for the future

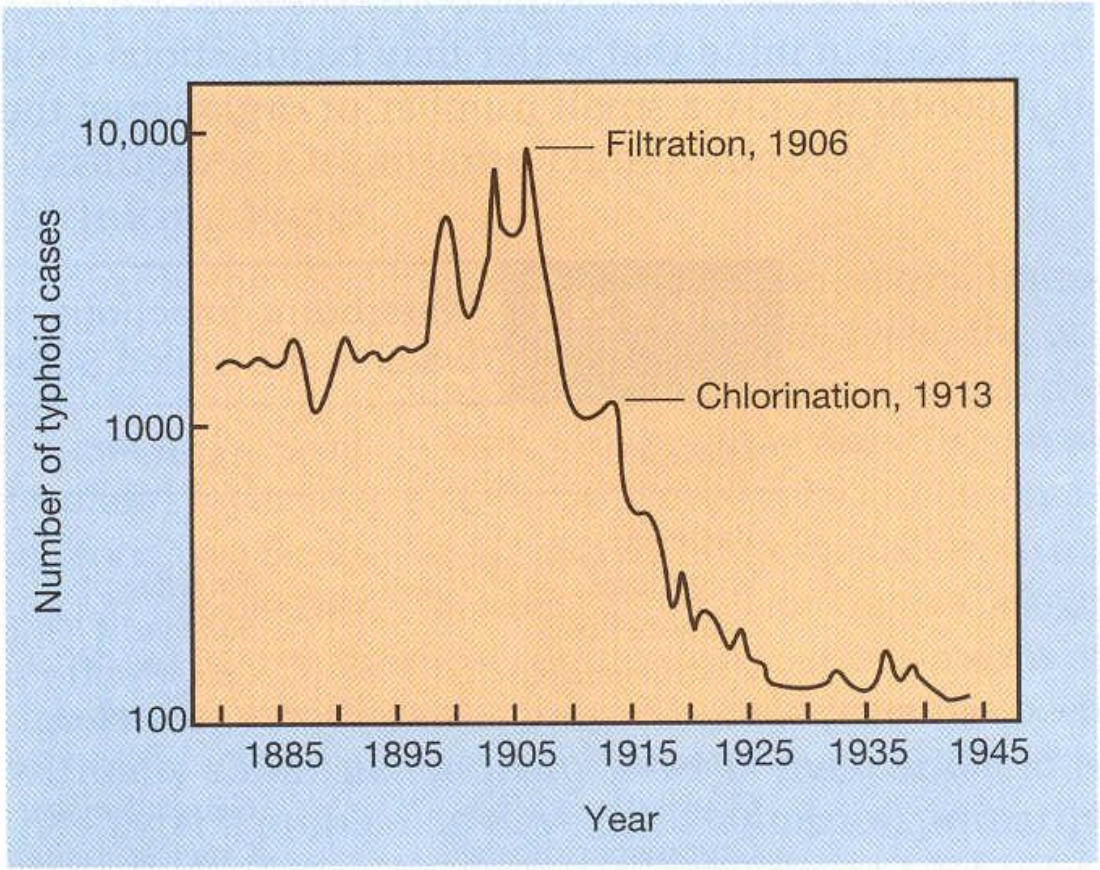
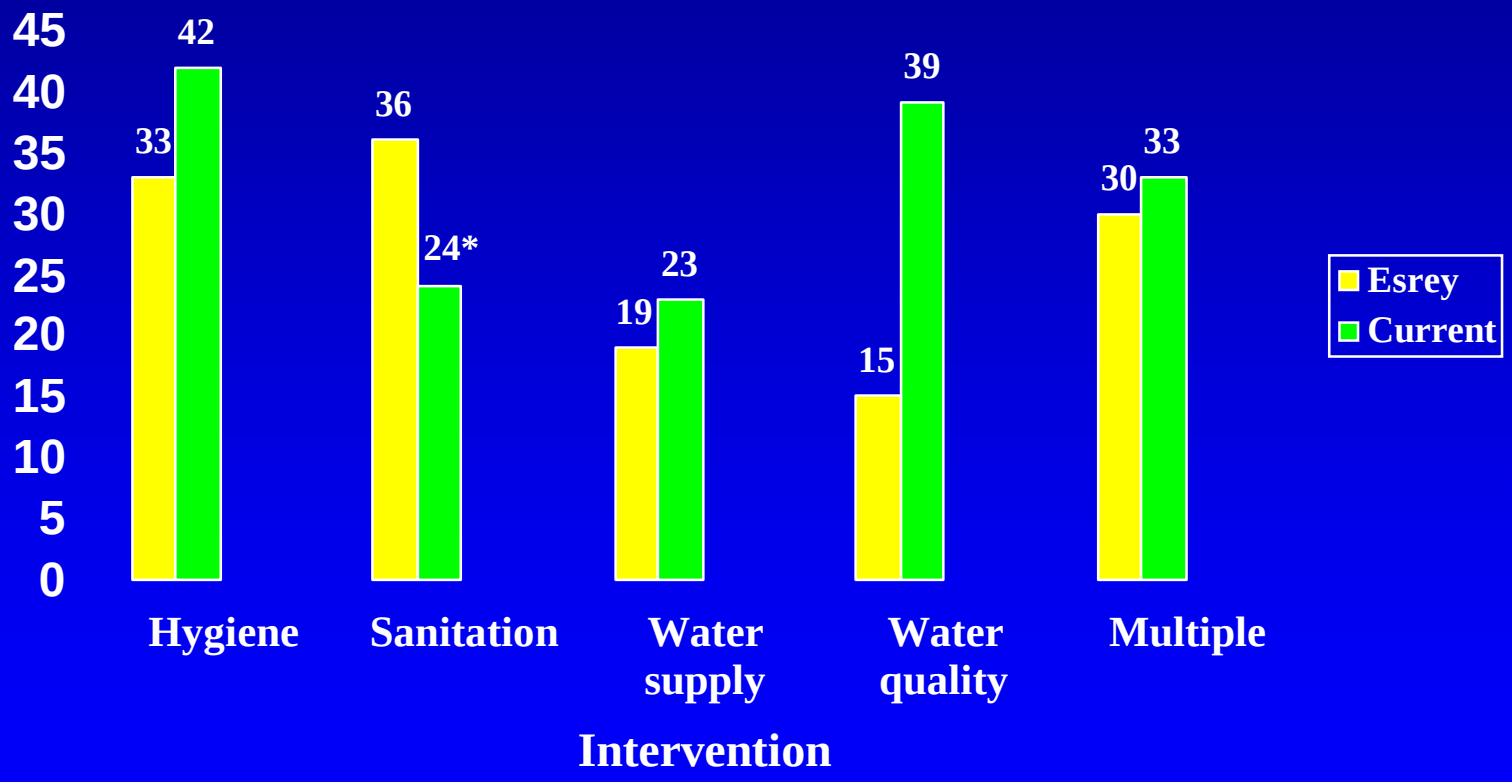


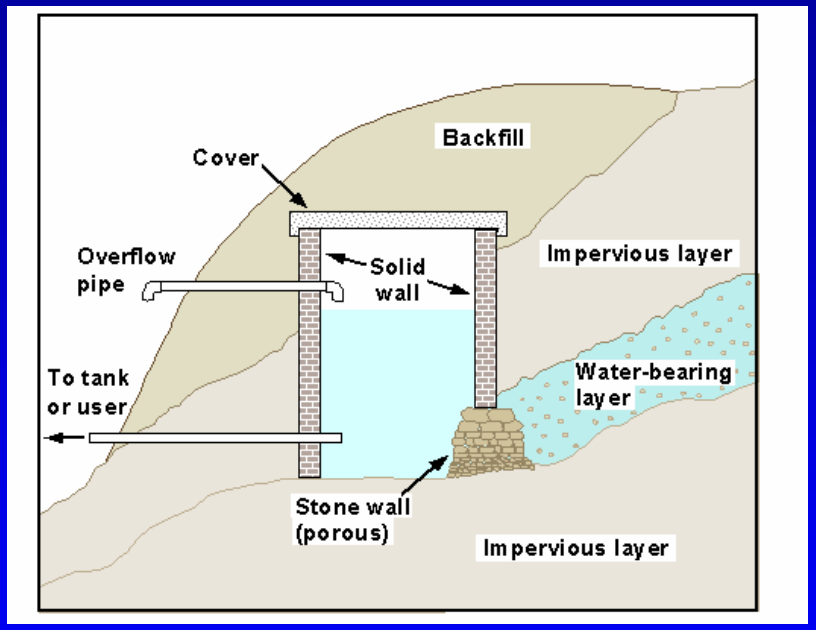
FIGURE 24.19 The dramatic effect of water purification on the incidence of waterborne disease. The graph shows the incidence of typhoid fever in Philadelphia (PA, USA) during the early part of the twentieth century. Note the dramatic reduction in incidence of the disease after the introduction of filtration and chlorination.

Goal: Health Impact



Infrastructure: Limitations

- Necessitates
  - Political stability
  - Large investment of public dollars
  - Terrain conducive
  - Population density
- Alternative options promoted
  - Supply
  - Sanitation
  - Hygiene



Other POU Treatment Options

- *PuR*
- Biosand Filtration
- Ceramic Filtration
- *SODIS*
- UV
- Multiple barrier

International Network to Promote Household Water Treatment and Safe Storage

WHO Consortium and Secretariat:

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.

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Safe Water System Results

Consistently reduces diarrheal disease incidence in randomized, controlled, published studies

Uzbekistan	**1998**	**84% overall**
Bolivia	**1999**	**44% overall, 53% in infants**
Zambia	**2002**	**48% overall**
Pakistan	**2004**	**73% overall**
Uganda	**2004**	**30% in HIV-infected persons**
Kenya (Western)	**2004**	**22%, 25% in under-1's**

Publications available from safewater@cdc.gov

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Why the SWS?

CDC Perspective

- Evaluation Matrix for POU
  - Laboratory testing, Field testing
  - **Health Impact**, Scalability
- Chlorine is:
  - Inexpensive, effective
  - Simple to make and use
  - 100 year of experience
  - Available worldwide
  - Possible to verify use in home

PSI Perspective

- Health impact gold standard
- High impact:cost ration
- Necessary Characteristics
  - Marketable
  - Transportable
  - Easy to use
  - Affordable

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Why the CDC/PSI Partnership?

CDC Perspective

- Ability to go to scale

PSI Perspective

- Technical assistance

Dose Factor: Other

- Clorox
  - 3 drops of 5.25% to 1 gallon of water
  - 0.15 mL · 5.25% · 5 = Dose Factor 3.94
- WHO
  - 5 drops of 5.25% to 1 gallon (emergency)
  - 0.25 mL · 5.25% · 5 = Dose Factor 6.56

Dosing determined by CDC comparable to research completed by other agencies

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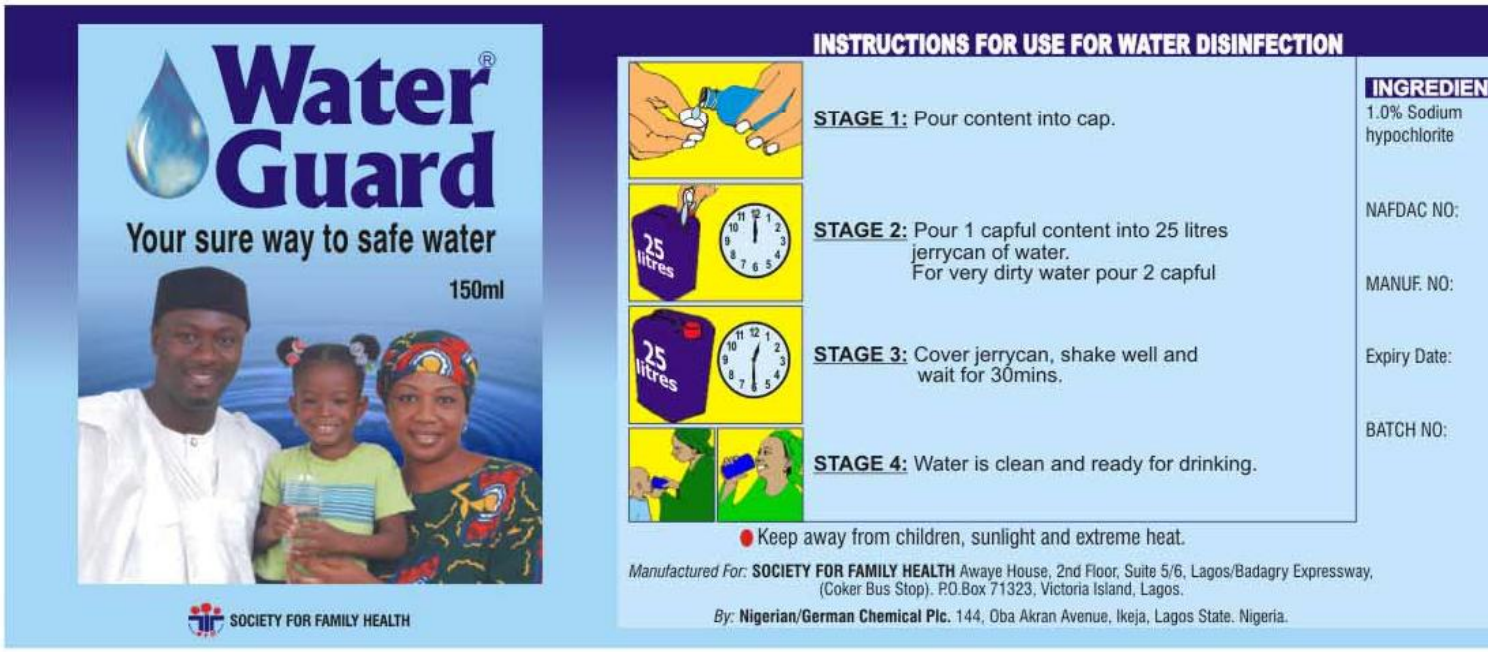
Side Note: Ways to Clarify

- Mechanisms:
  - Filtration
  - Settling and Decanting
  - Moringa/Alum
- Move water from double to single dose
- Complicates IEC messages
  - NGO partner?

Sample label: Nigeria



Kenya NGO Model: SWAK

- National NGO
  - Links existing village groups
    - Trainings on legal issues, health, *water*
  - Sell PuR and WaterGuard
  - Income generating
  - Move product to areas outside market
  - Evaluation ongoing

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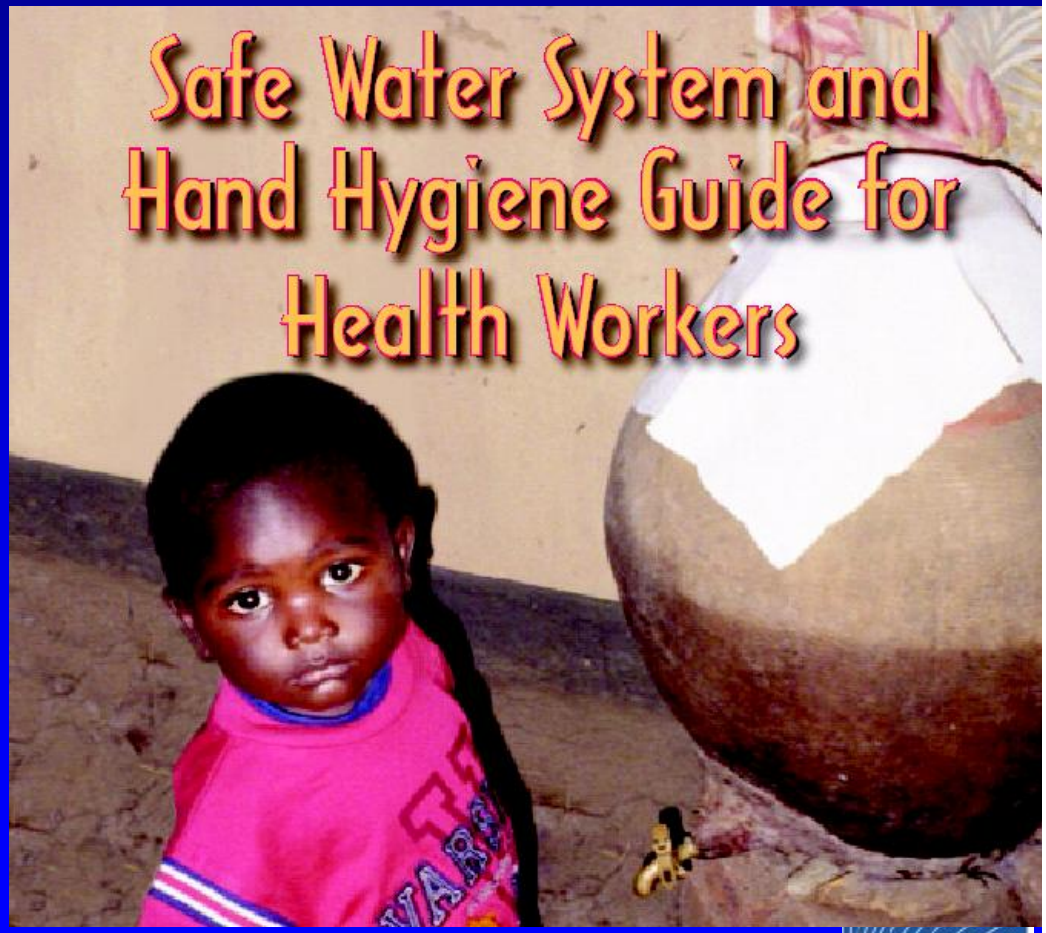
Successful Collaboration

Model Clinic Results

- >80% patients received knowledge
- Correct handwashing
  - 45% (47/105)
  - >80% 4 of 6 steps
- Chlorine Residual
  - 65% (73/112)

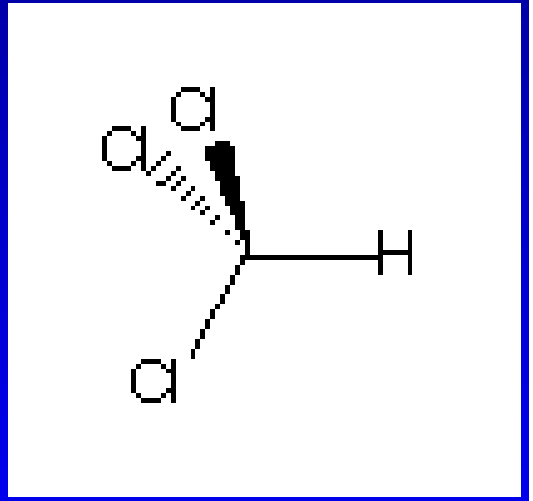


Step 10: Education on WSH World

- Esrey study
  - Meta-analysis of health impact
    - Hygiene, sanitation, water supply, water quality
    - Water quality smallest reduction
    - Informed 1980-1990 W&S decade
  - Two new meta-analysis
    - World Bank, London School
    - Water quality and hygiene most effective
- Critiques of chlorine
  - THMs, bleach safety, overdosing

Critique: THM's

- THM's are disinfection by-products
  - Created by rxn of chlorine, organic material
  - Regulated by EPA and WHO
  - One of four is known cancer-causing agent
- Major critique of chlorination
- Risk
  - 1 in 100,000 will get cancer after 70 years
  - Compare to risk of diarrhea in under-5's
- Fact Sheet(s) on CDC web site



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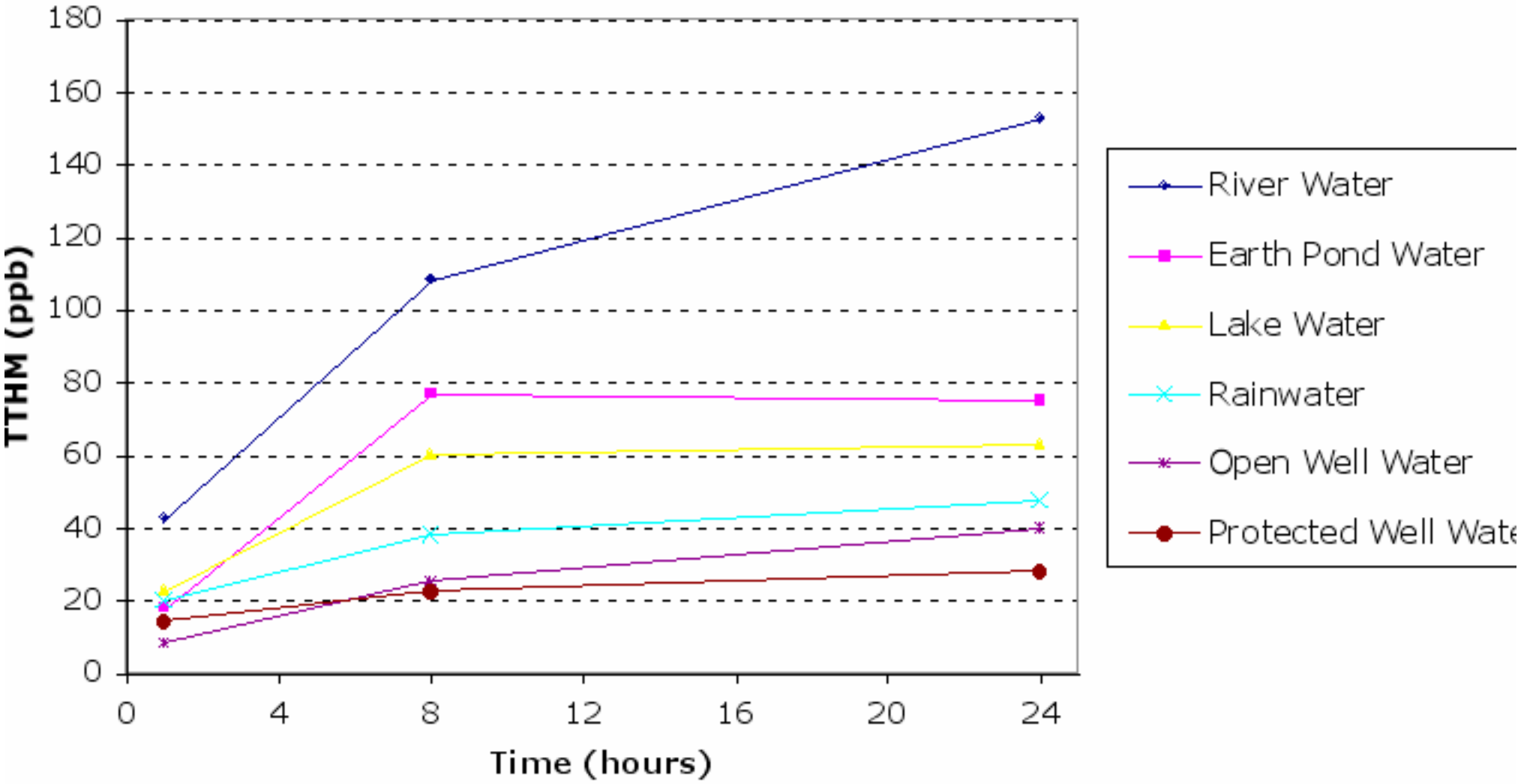
TTHM's versus Time in Plastic Containers Chlorination Only



Critique: Bleach Safety

- Safety of bleach in house
  - Concern: children drinking
  - Racciopi, et al study
    - Poison Control Centers in Europe
    - “minor, transient effects on health”
  - Bad taste
- Risk of overdosing water
  - Danger is THMs (risk low)
  - Bad taste (won’t drink)
  - Marketing risk

Common SWS Misconceptions

- Contraceptive
  - Picture of family (Nigeria)
- Decrease in libido
- Assume it's drinking water
  - Use to cook rice
- Medicine