An Evaluation of Household Drinking Water Treatment Systems in Peru: The Table Filter and the Safe Water System

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Based on Coulbert's MIT M.Eng. thesis of the same title (Feb. 2005)

Peru

★ Project Site:
La Joya, Arequipa

The Peru Team

The Water Problem

- 1.1 billion people lack access to safe drinking water
- 1.7 million people die each year from diarrheal diseases related to unsafe water, sanitation, and hygiene

Fact source: WHO, 2004

Picture source: Susan Murcott, MIT

The Problem in Peru

- 50% of Peru's 28.4 million people live below the poverty line
  - GDP per capita: $5,000
- In 2002, Peru had only 66% "improved drinking water coverage" in rural areas
  - "Improved" does *not* mean safe. It may simply indicate a household connection or protected well. (With this definition, this report evaluates almost entirely households with "improved" access to drinking water, even before treatment.)

Source: WHO Joint Monitoring Programme, CIA World Factbook

The Solution

- UN Millennium Development Goal:
  - Halve, by 2015 [as compared to 1990], the proportion of people without sustainable access to safe drinking water and basic sanitation.
- WHO International Network to Promote Household Water Treatment and Safe Storage
  - This report is part of the effort by MIT and members of the Network to seek ways to increase access to safe water for people worldwide through efforts including household water treatment systems (HWTS) and safe water storage.

The Technologies

The Table Filter

The Safe Water System

Outline

- Safe Water System
  - Tests & results from Peru
- Table Filter
  - Tests & results from Peru and the MIT lab
- Household interviews
- Cost comparison & financing options

Study of HWTS Solutions as Currently Implemented in Peru

- Field Study in southern Peru, mostly in La Joya, Arequipa
  - *January 2004*
  - Tested Safe Water Systems (household chlorination) & Table Filters in homes
  - Interviewed users
- MIT Lab Study
  - *February - July 2004*
  - Tested 2 Table Filters with different grades of sand
  - Also tested Table Filters *without* sand

Regions of Study:

Arequipa & Tacna

(focused in Cerrito Buena Vista, near La Joya, Arequipa)

Safe Water System

(Household Chlorination)

Safe Water System (SWS)

- 20-L safe storage containers (“*bidones*”)
- 0.5% sodium hypochlorite solution generated at a local hospital & distributed to towns in 200-mL bottles
- Users add “half cap” of solution to 20 L of water stored in safe storage containers and wait 30 minutes before drinking

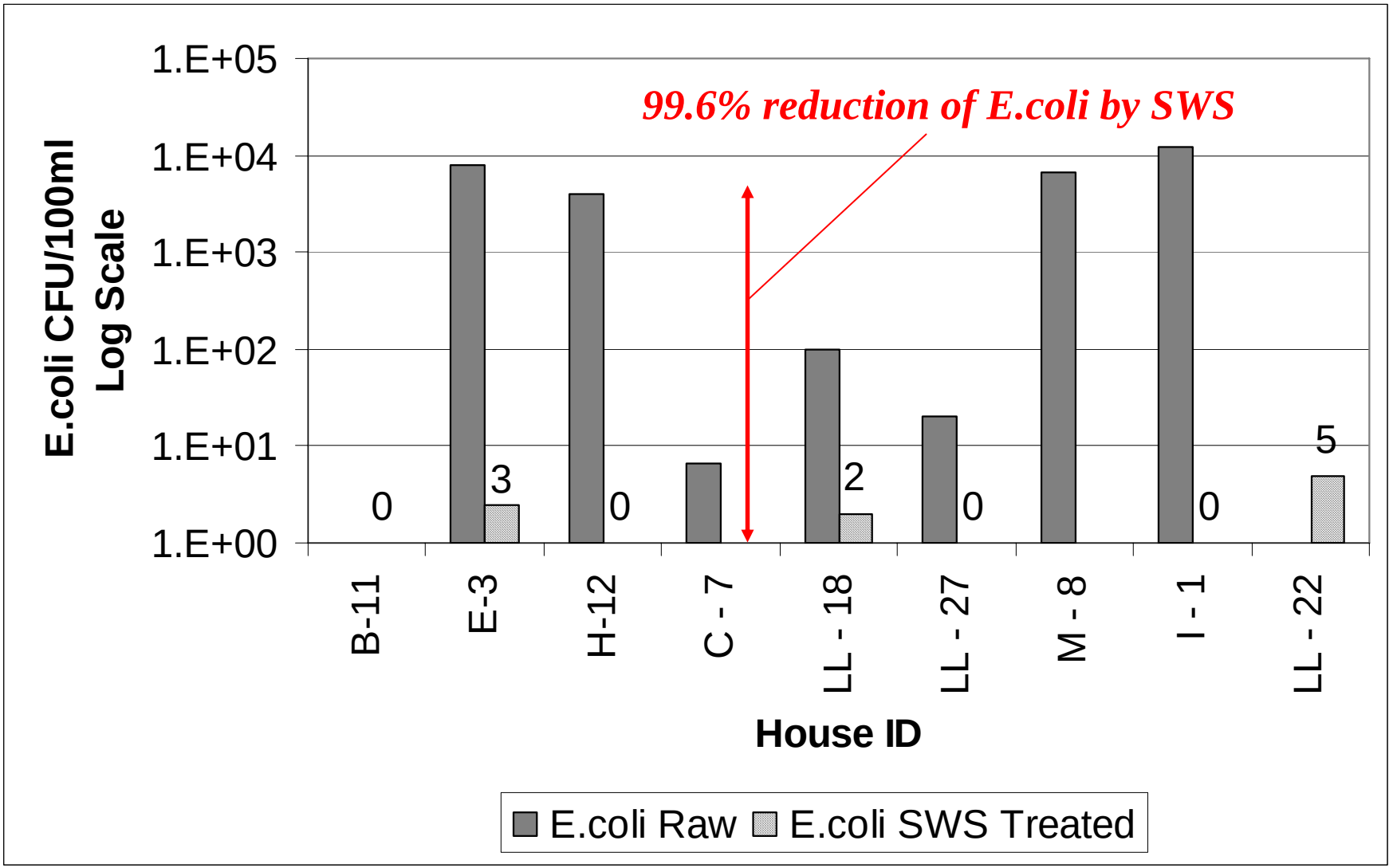
Chlorine Generator

Family in Peru using their Safe Water System

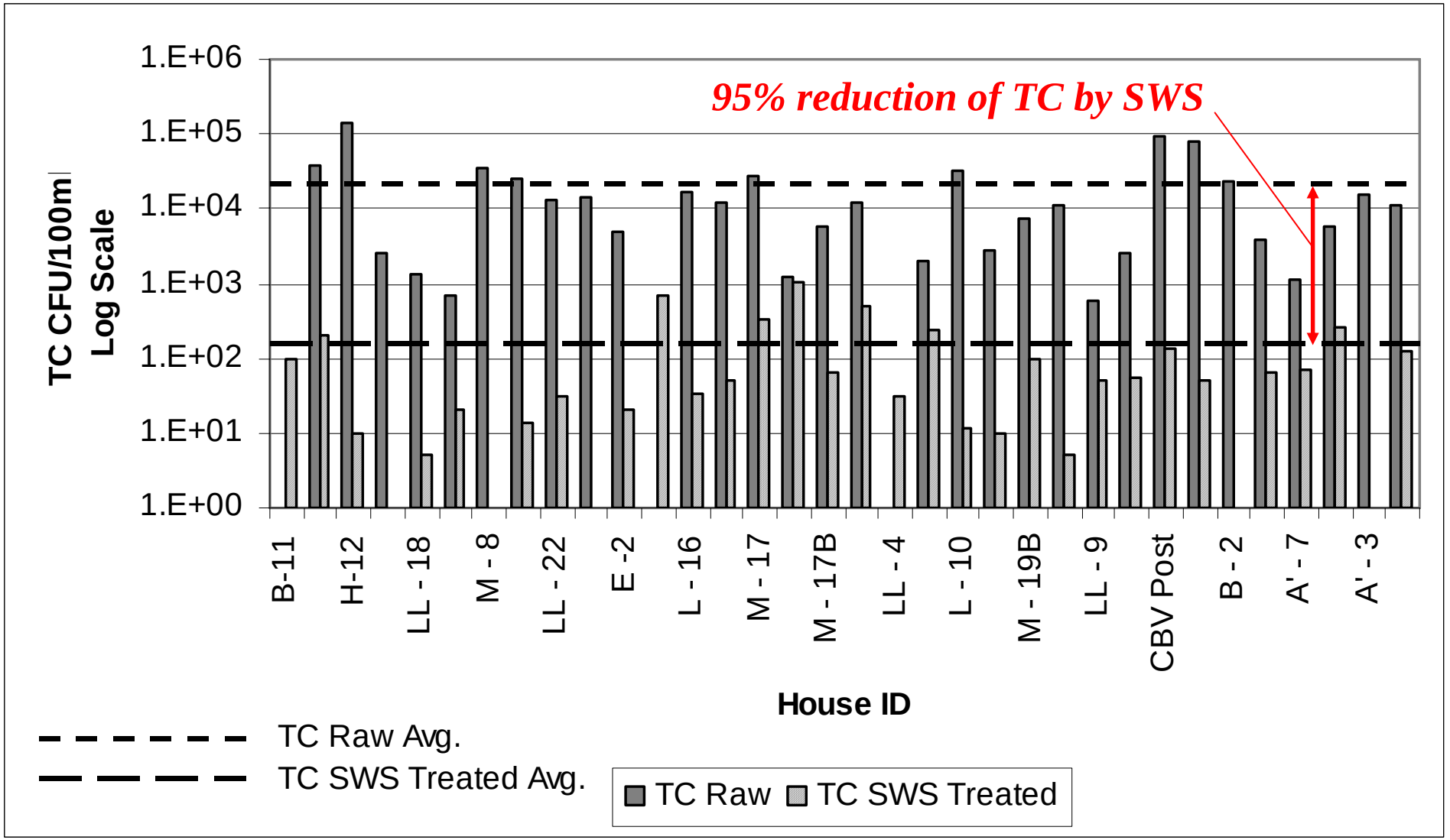
Safe Water System Tests

- E.coli & Total Coliform (TC) tests
  - These bacteria *indicate* the presence of fecal contamination, which can cause severe diarrheal sicknesses
  - *Zero* E.coli or TC “colony forming units” (CFU) should be present in any drinking water sample
- Chlorine residual tests
  - Chlorinated water sources should have a residual amount of chlorine to ensure that the chlorine dose was enough to deactivate all harmful bacteria

E.coli Concentrations
Before & After SWS Chlorination in Peru

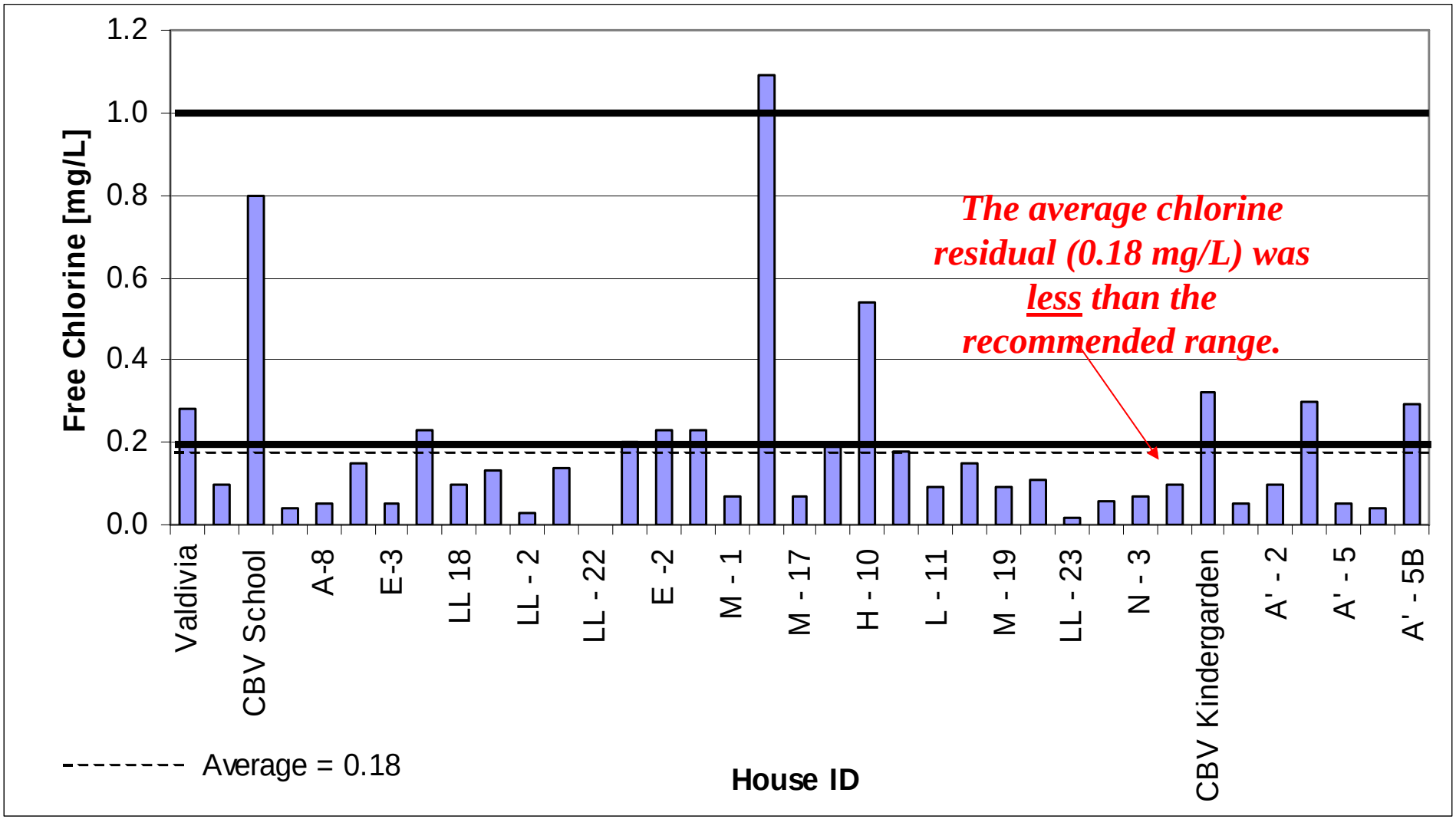


Total Coliform Concentrations Before & After SWS Chlorination in Peru



Free Chlorine Residual Measured in Bidones in Peru

(The dark black lines indicate the target concentration range.)



Pros & Cons of the SWS

Pros

- 99.6% E.coli removal
- 95% TC removal
- Very inexpensive:
  $6 container + $3/year
- Easy to use
- Local chlorine generation possible

Cons

- Less effective with turbid source water (particle removal pre-treatment is needed)
- Average chlorine residual was found to be too low
- Chlorine solution sometimes difficult to obtain due to poor technical support
- People don’t like the taste

Peruvian “Table Filter”

- Indigenous filter developed by CEPIS and the Belgian development organization, DGCI
- Filtering media: geotextile cloth, sand, & ceramic candle filters
- Made of two 20-L (5-gal.) plastic buckets

Table Filter Media

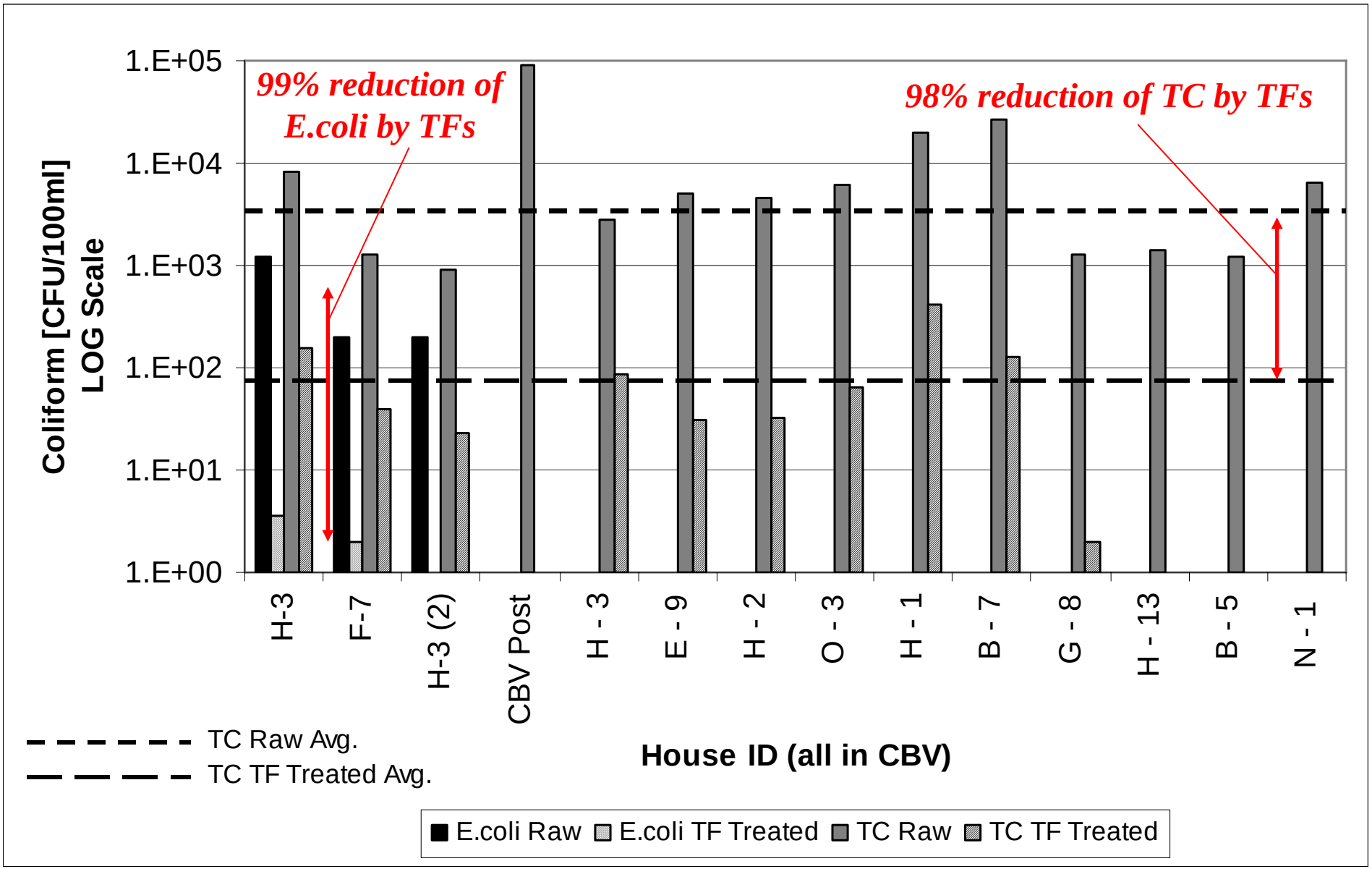
Family in Peru using their Table Filter

Table Filter Tests

- Coliform tests
  - Thermotolerant Coliform (TTC)
    - Indicates fecal contamination
  - E.coli & TC
  - Heterotrophic Plate Counts (HPC)
    - Indicates general bacteria levels
- Turbidity tests
- Flow rate tests

Lab in La Joya, Peru

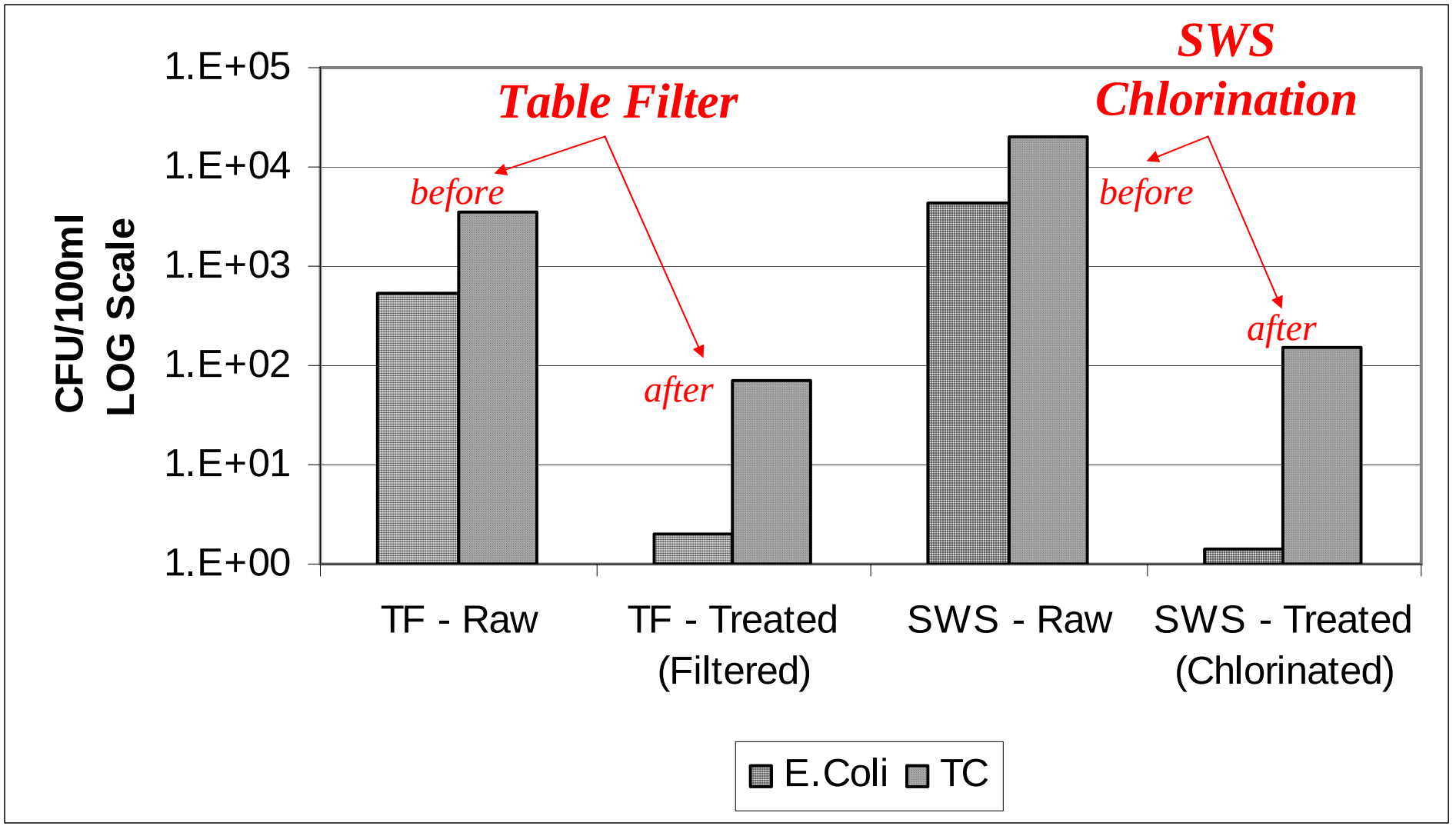
E.coli & TC Concentrations
Before & After Treatment by Table Filters in Peru



Summary Table of Coliform Tests on Table Filters and SWS in Peru

Coliform CFU/100ml	**Table Filters**			**SWS Chlorination**		
	Raw Water	Treated Water	% Removal	Raw Water	Treated Water	% Removal
E.coli	$5.3x10^2$	2	99%	$4.5x10^3$	1	99.6%
TC	$3.5x10^3$	$7.2x10^1$	98%	$2.1x10^4$	$1.5x10^2$	95%

Comparison of Average Coliform Concentrations Before & After Table Filter & SWS (in Peru)



Turbidity Concentrations Before & After Treatment by Table Filter in Peru

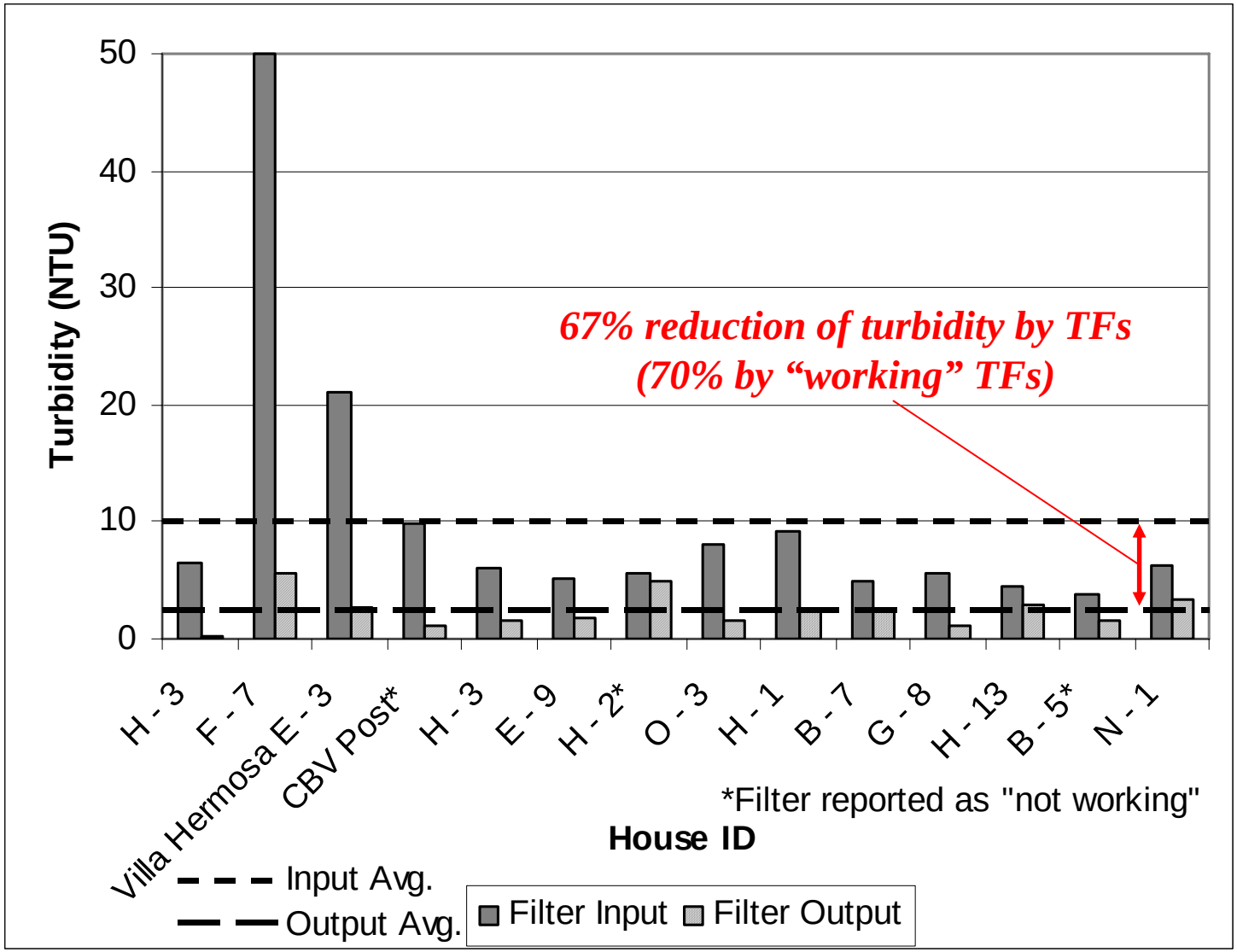
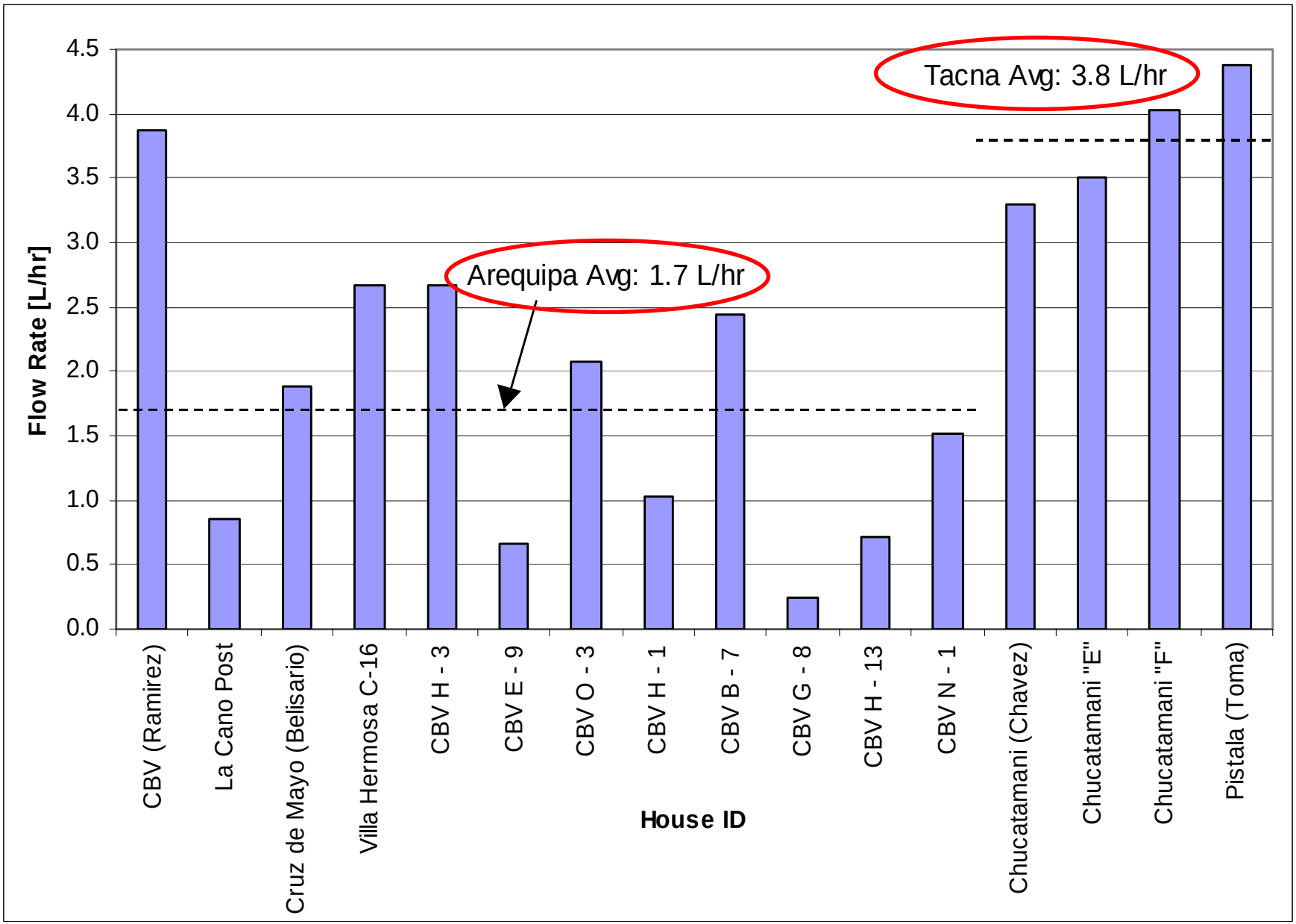


Table Filter Flow Rate in Peru

- Average: **3.1 L/hr**
  - Arequipa average: 2.3 L/hr
  - Tacna average: 3.8 L/hr

- Faster than other ceramic filters (0.5-2.0 L/hr)
- Slower than BioSand Filter (15-30 L/hr)

Table Filter Flow Rates in Peru



MIT Lab Work -- Table Filter

February - July 2004

- Simulate conditions in Peru
  - All materials, except sand, brought from Peru
  - Charles River water & sewage added to filters to increase water contamination levels
- Two filters
  - “Medium Sand Table Filter” (MSTF): Sand size used for BioSand filter, larger grains than in Peru
  - “Fine Sand Table Filter” (FSTF): Sand size specified in Peru
- Coliform tests
- Turbidity Tests

Table Filters in MIT Lab

TTC Concentrations Before & After Treatment by the Medium and Fine Sand Table Filters

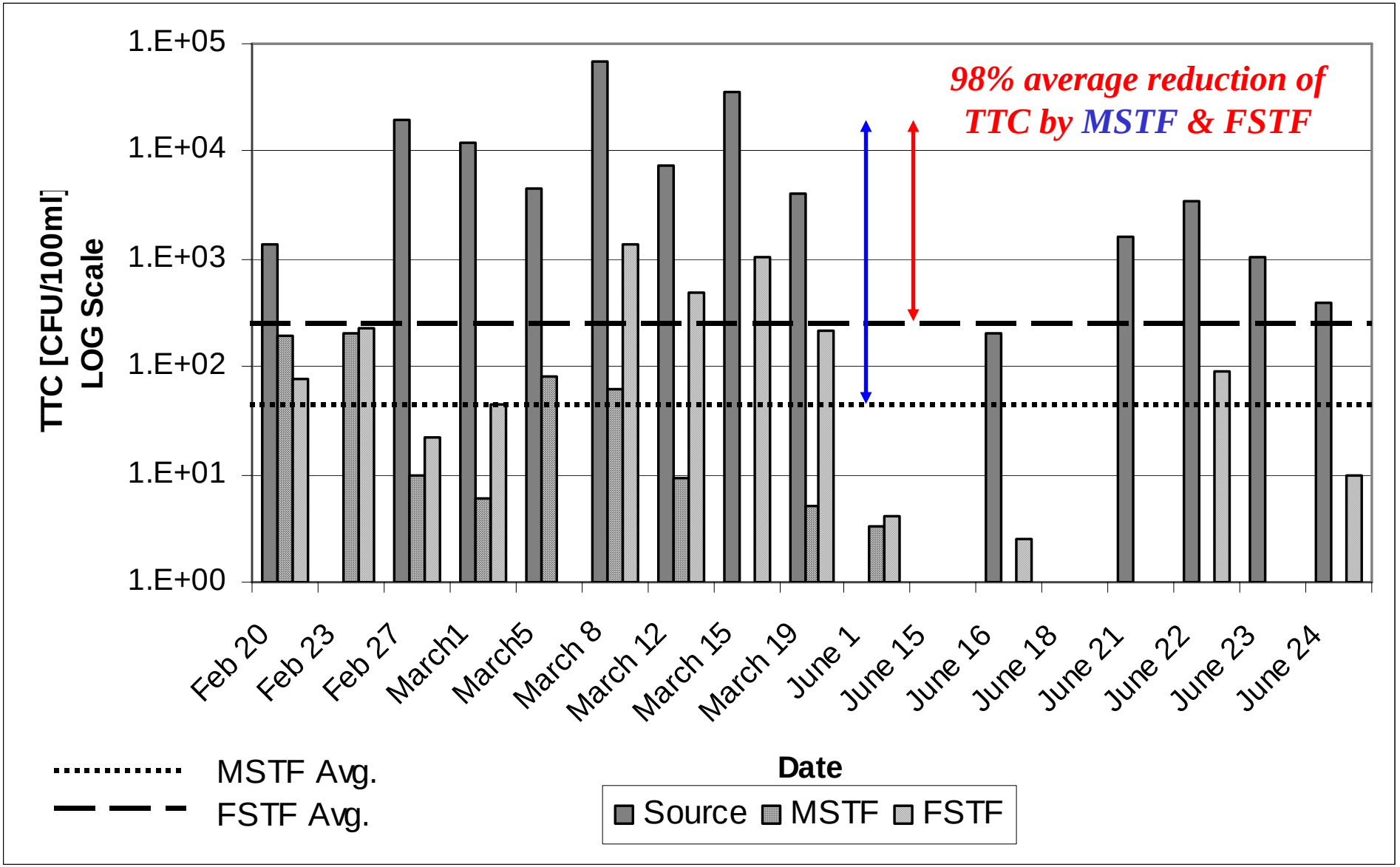
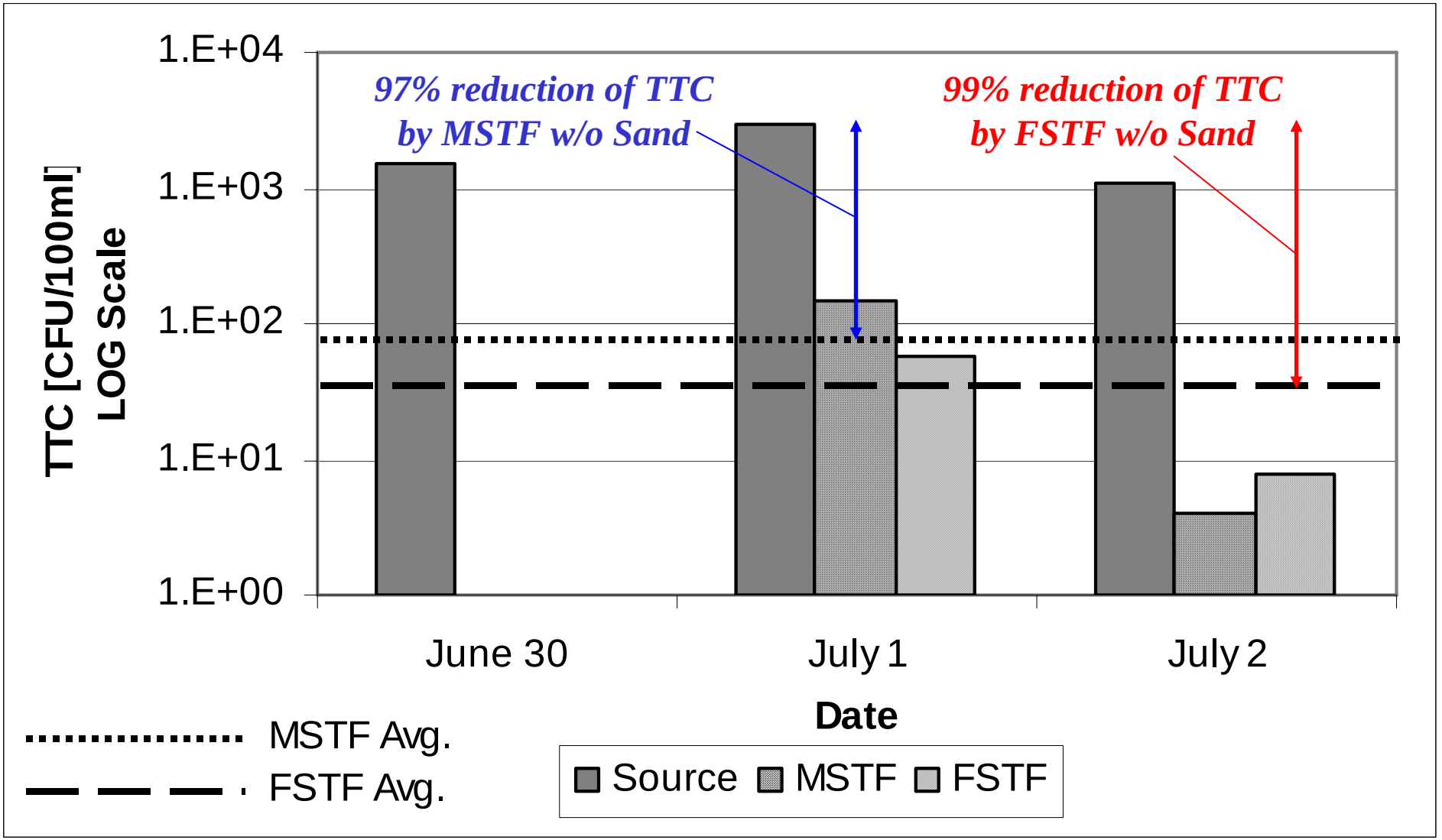


Table Filters Tested *Without* Sand

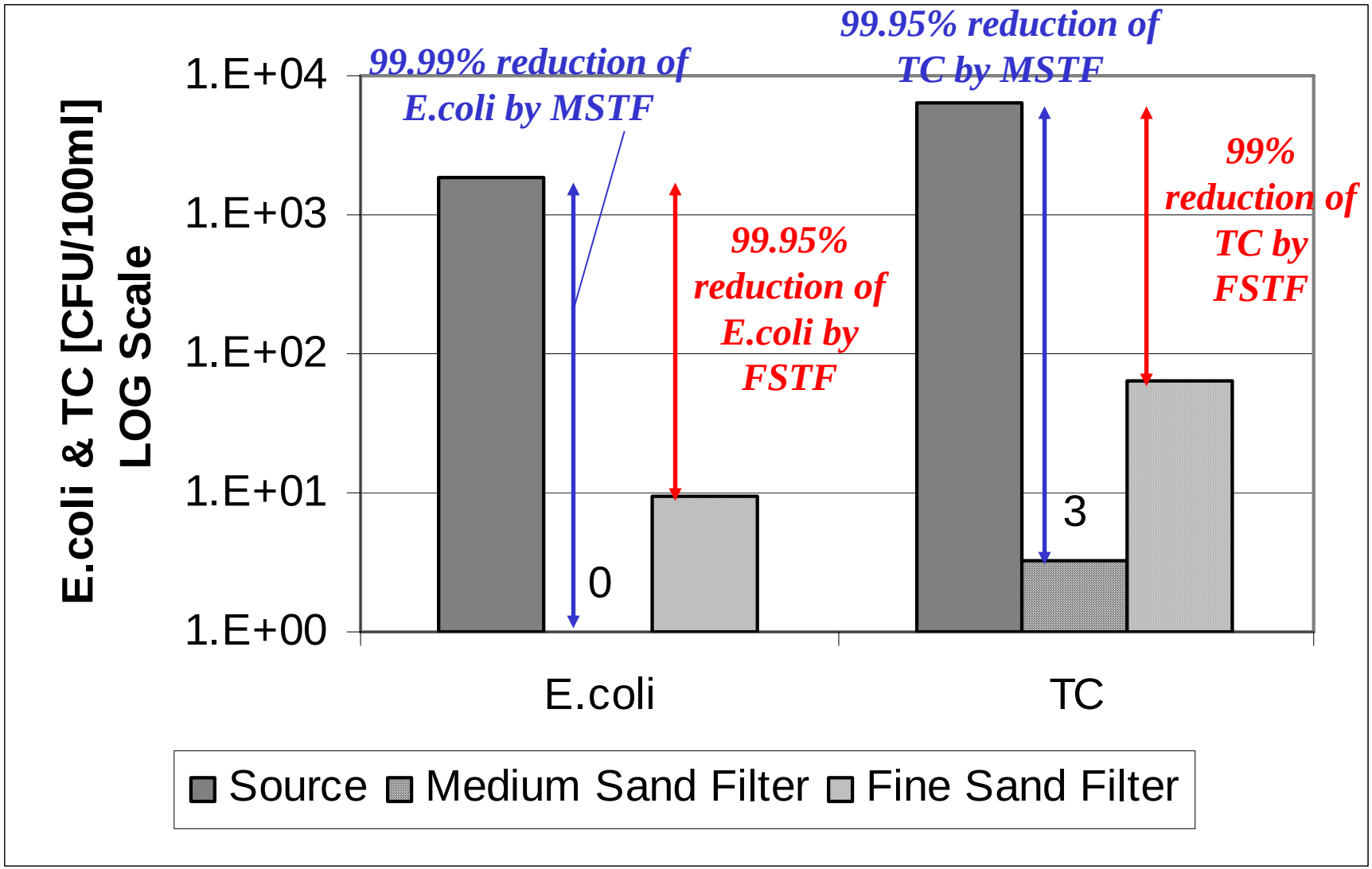
The two Table Filters showed slightly different results on average. Since sand grain size was the only known difference between the two, the sand was removed from the filters before additional testing to see if the *grain size* was the true reason for the differences in % removal (as opposed to unexpected differences in the ceramic candles).

TTC Concentrations Before & After Filtration *without Sand*

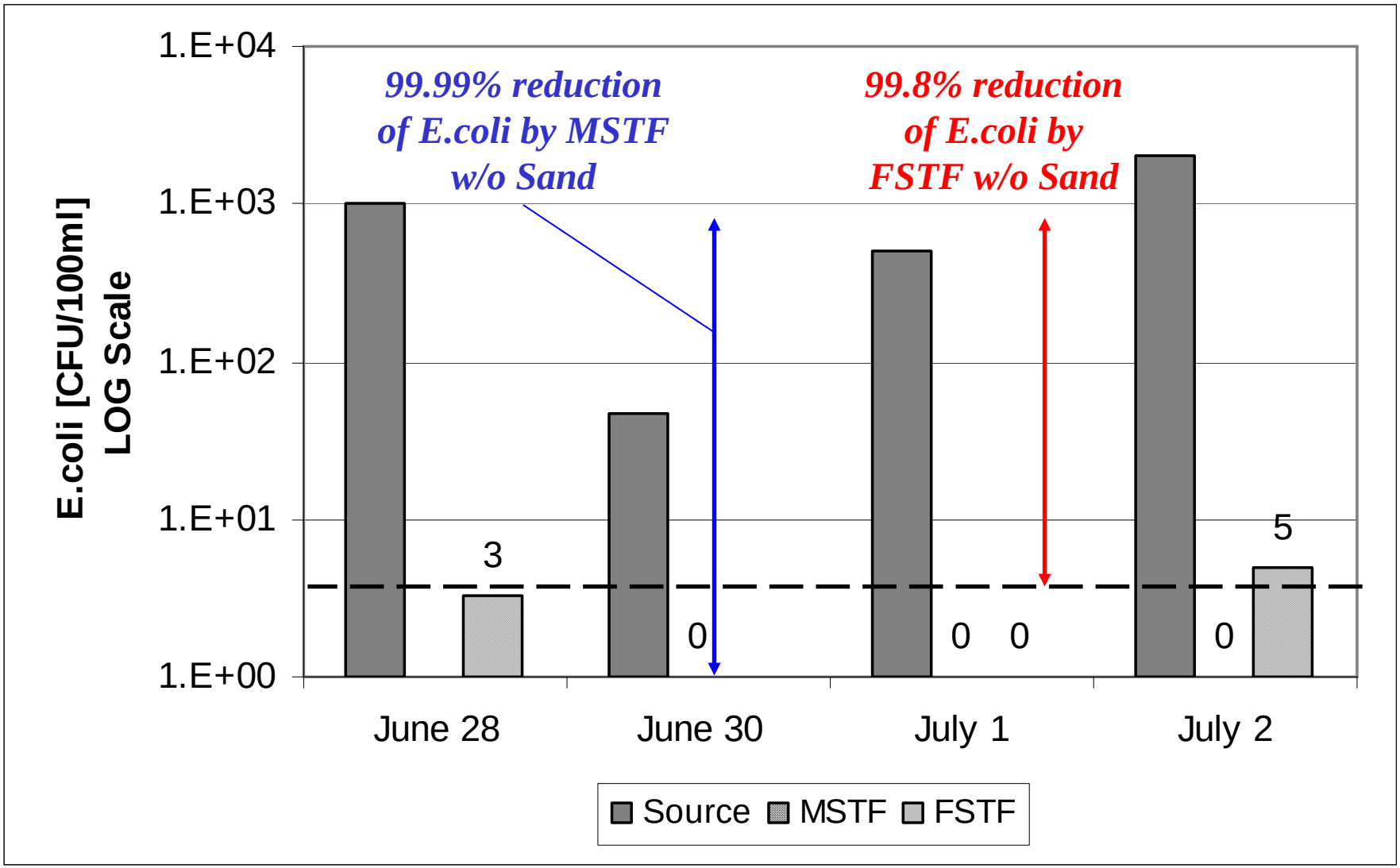


E.coli & TC Concentration Before & After Treatment by MSTFs & FSTFs

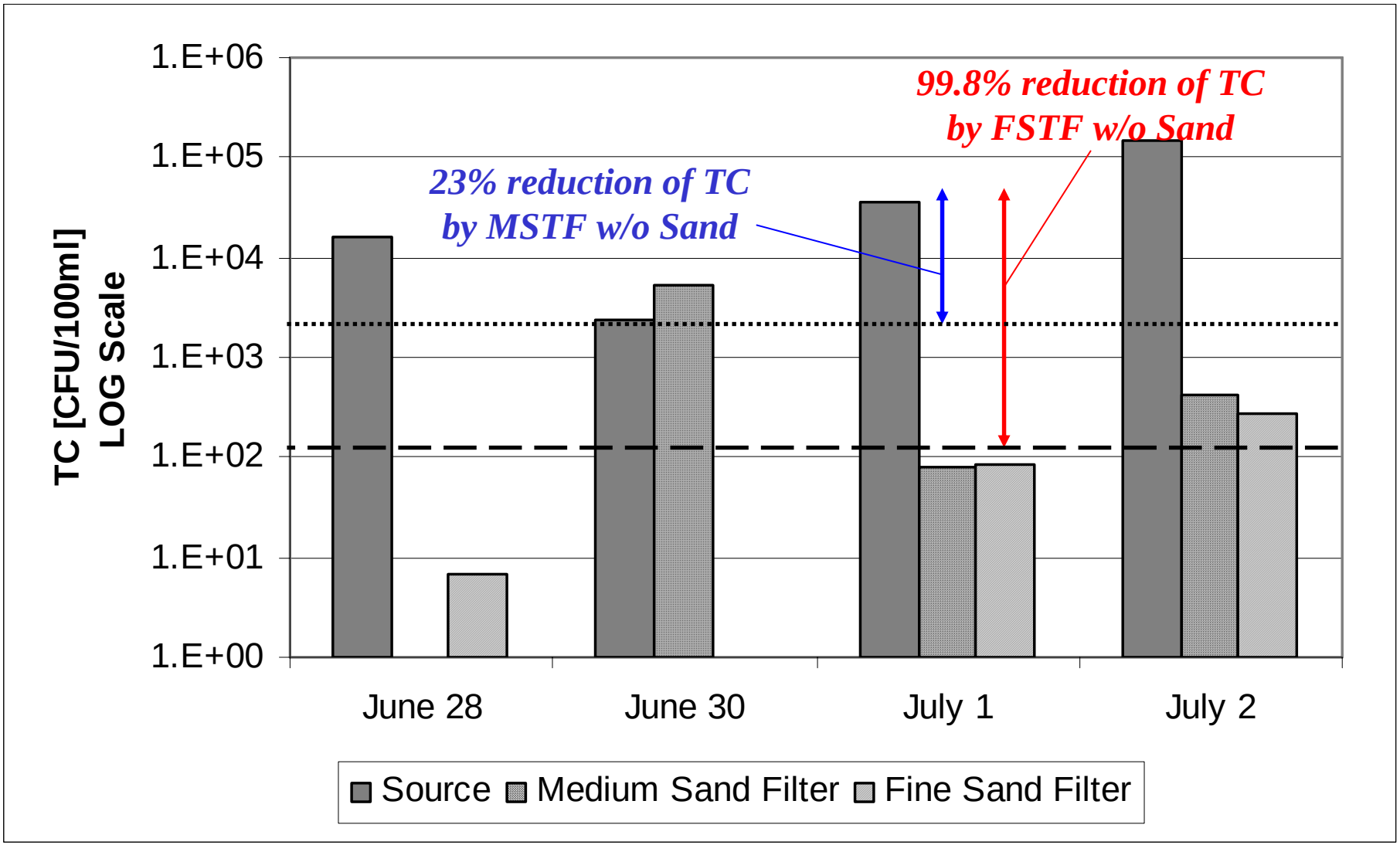
(one day of data: June 24)



E.coli Concentration Before & After Treatment by MSTF & FSTF *Without Sand*



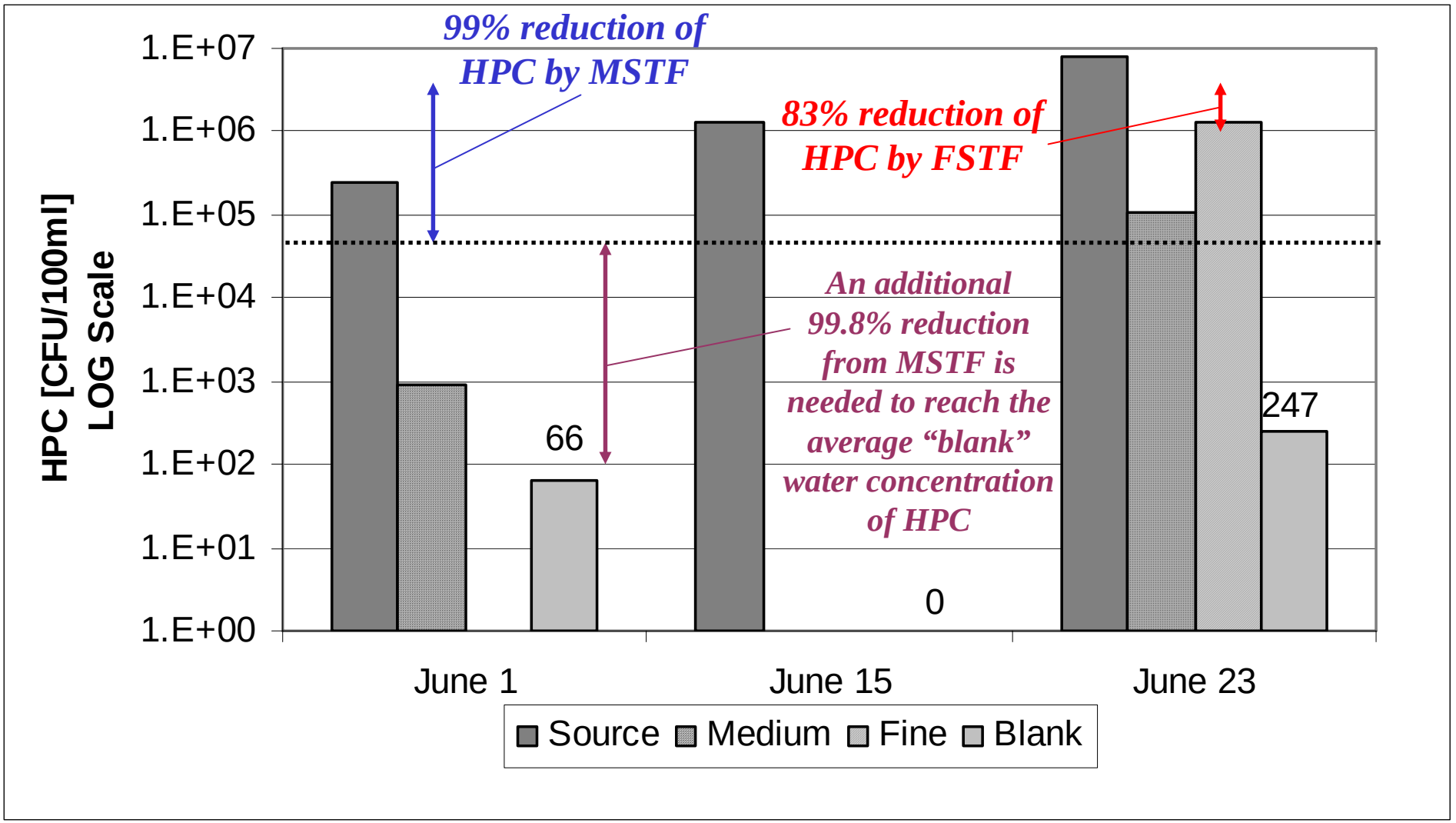
TC Concentration Before & After Treatment by MSTF & FSTF *Without Sand*



Why Only 23% Reduction of TC by MSTF w/o Sand?

The low average % removal of TC by the MSTF was caused by one day of testing which showed that the TC concentration in the *treated* water was higher than that of the *untreated* water (June 30). Valid data could not be collected from the water treated by the FSTF, so the two filters could not be compared on that day. Therefore, the average values and % removals of the two TFs without sand are not truly comparable to each other for the TC tests.

HPC (Heterotrophic Plate Counts) Concentration Before & After Treatment by Table Filters



Summary Table of Coliform Removal Rates of both Table Filters, With and Without Sand, in the MIT Lab

Coliform	Table Filter Media	Source Water	MSTF Treated Water	FSTF Treated Water	MSTF % Removal	FSTF % Removal
TTC	**Sand**	$1.2x10^4$	$4.1x10^1$	$2.2x10^2$	98%	98%
	No Sand	*$1.9x10^3$*	*$7.7x10^1$*	*$3.3x10^1$*	*97%*	*99%*
E.coli	**Sand**	$1.8x10^3$	< 1	$1.0x10^1$	99.99%	99.5%
	No Sand	*$8.9x10^2$*	*< 1*	*3*	*99.99%*	*99.8%*
TC	**Sand**	$6.5x10^3$	3	$6.4x10^1$	99.95%	99%
	No Sand	*$5.0x10^4$*	*$2.0x10^3$*	*$1.2x10^2$*	*23%*	*99.8%*
HPC	**Sand**	$3.1x10^6$	$5.3x10^4$	$1.3x10^6$	99%	83%

Sand Grain Size Theory

The coliform tests performed on Table Filters without sand did *not* support the theory that the sand grain size affected the performance of the filters.

Our Peruvian teammates sifting sand for a Table Filter

Turbidity

- Indicates amount of suspended particles in water, or its “cloudiness”
- Average % removal of turbidity by Table Filters:
  - Peru: 70%
  - MIT:
    - Medium Sand TF: 91%
    - Fine Sand TF: 92%

Pros & Cons of the Table Filter

Pros

- Average % removal of TC in Peru = 98%
- Average % removal of turbidity at MIT = 92%
- Provides relatively consistent and significantly improved drinking water
- Inexpensive: $11.40 each
- Easy to use

Cons

- Broken spigots
- Cleaning is bothersome
- Fragile ceramic candles
- Parts not easily available
- Sand sifting (during filter assembly) is time-consuming
- More expensive than other treatment methods

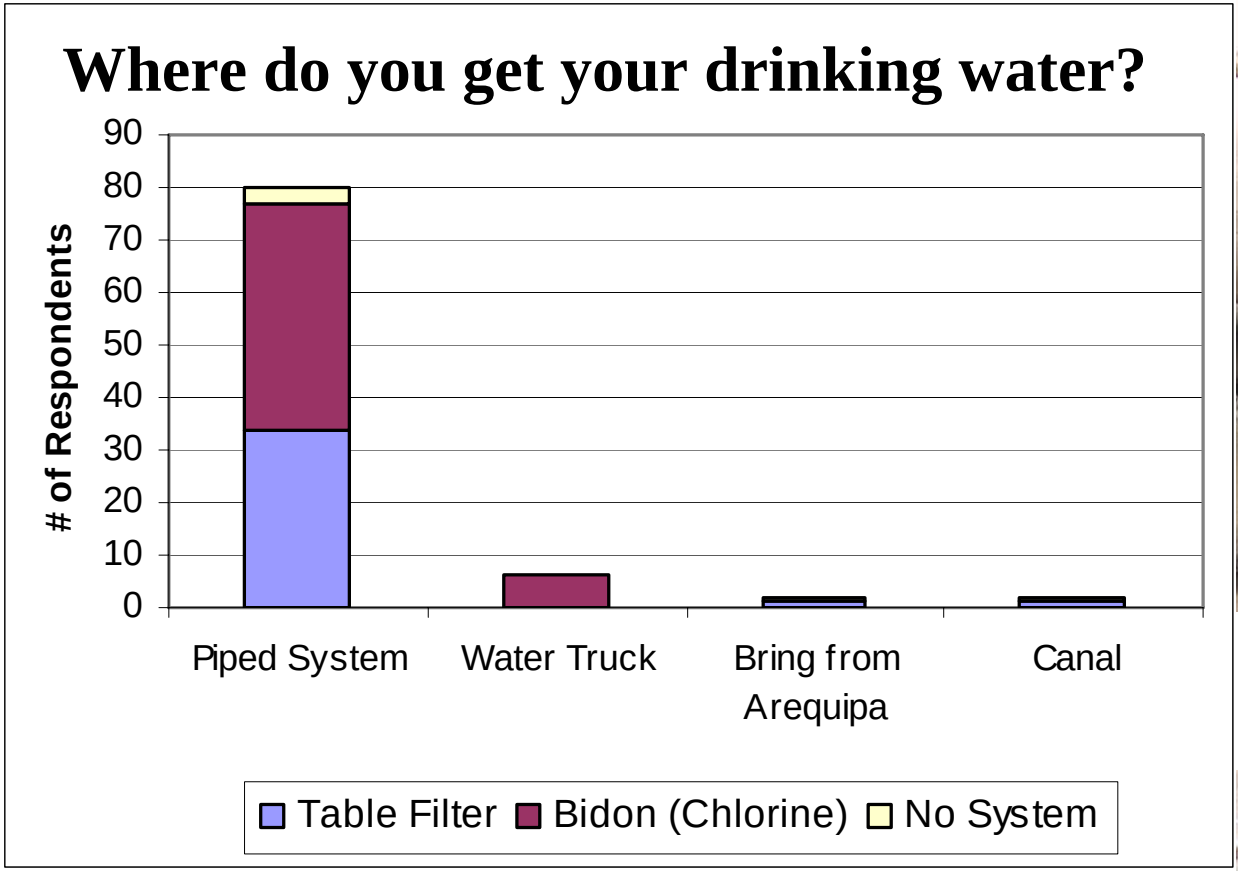
Interviews

- 89 households surveyed
  - 35 had Table Filters
  - 49 had Safe Water Systems
  - 5 had neither
- 66 were from Arequipa (57 from CBV)
- 23 were from Tacna

Interview Statistics

- Households averaged 5.2 people, including 1.3 children under the age of 5
- Average total household* spending was S/ 93 (Peruvian *nuevo soles*) per month (or $0.58 per person per day)

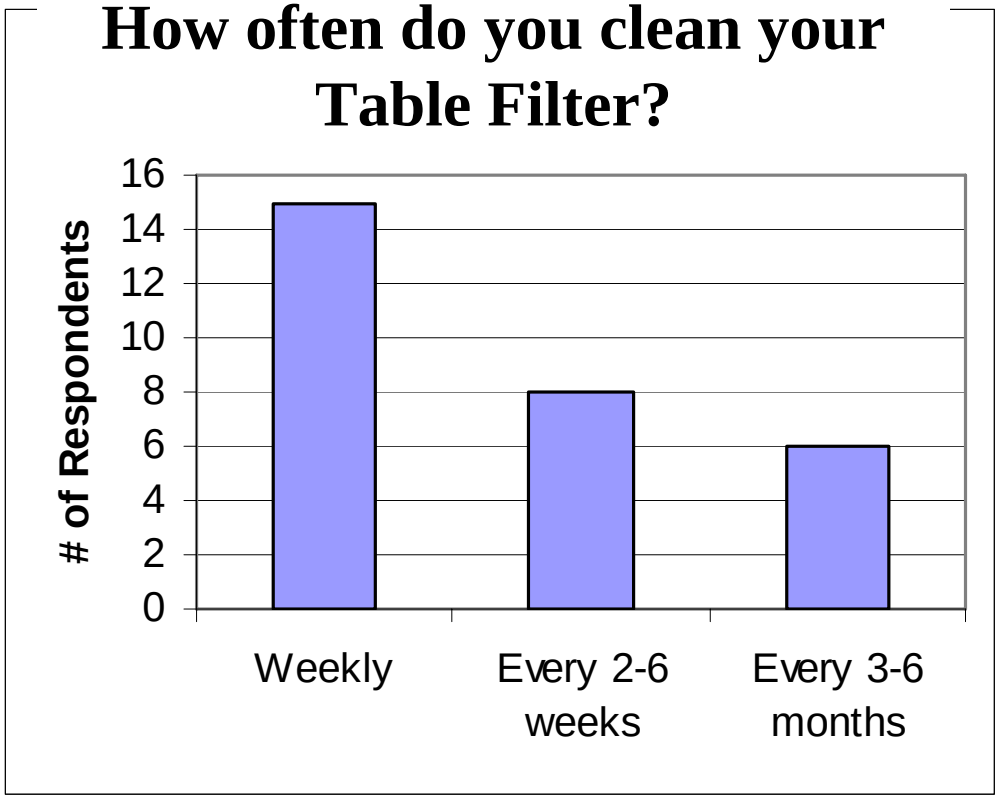
** Of the 84 households with government-sponsored water treatment systems*



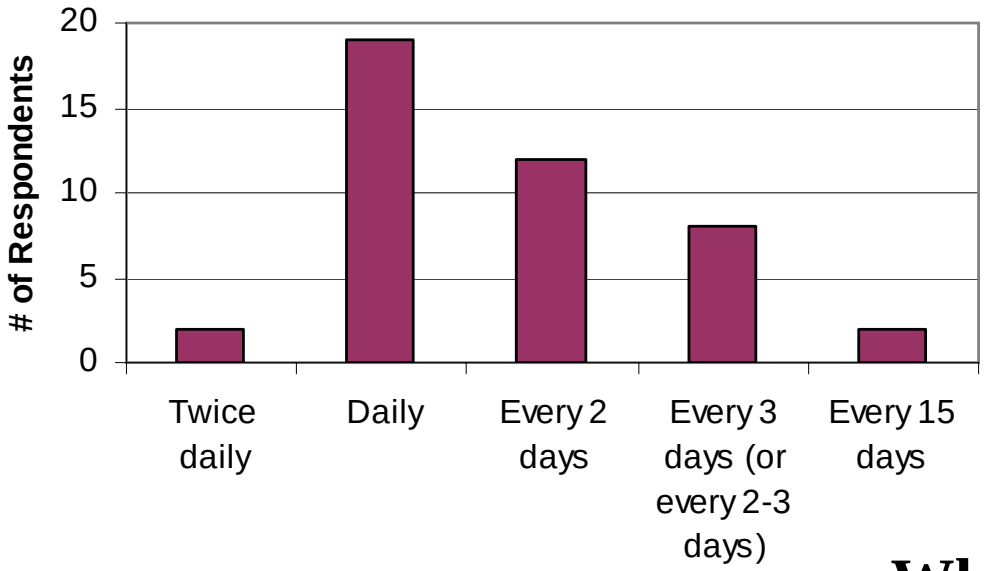
Water Vending Trucks

Irrigation Canals

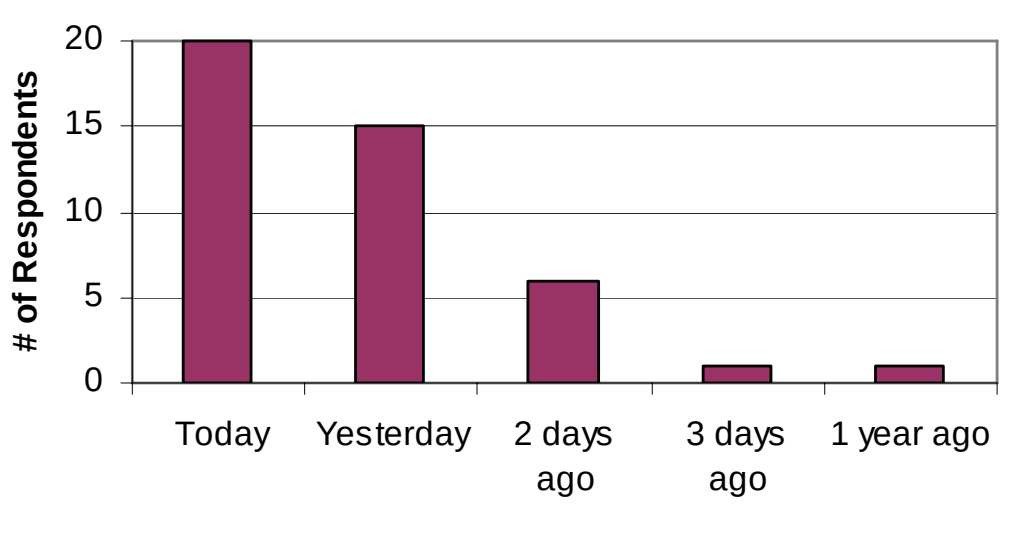
Piped System to Household Taps & Storage Devices


How often do you clean your Table Filter?
# of Respondents
16
14
12
10
8
6
4
2
0
Weekly
Every 2-6 weeks
Every 3-6 months

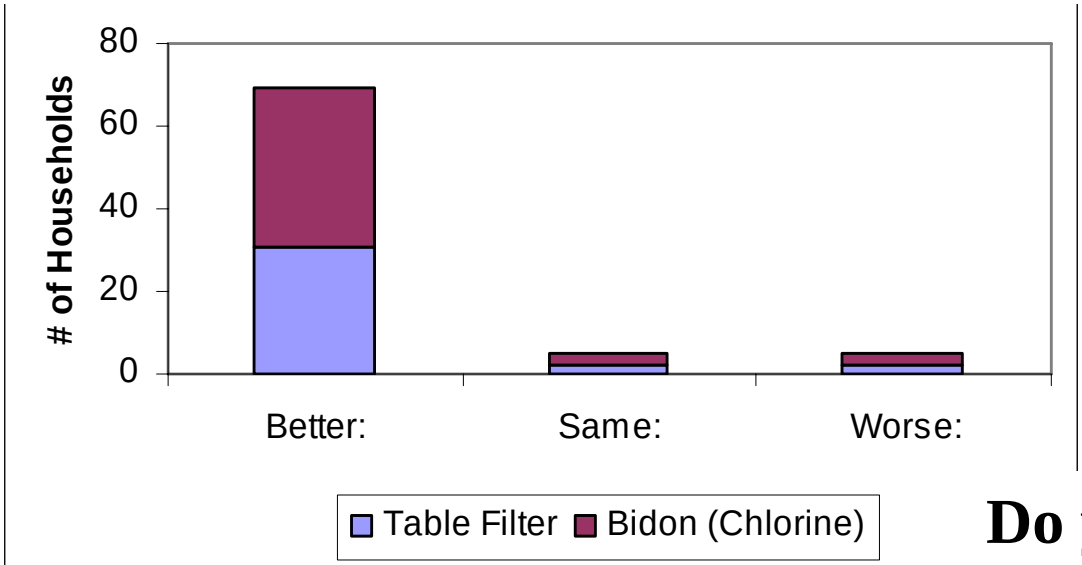
How *often* do you add disinfectant solution to your SWS bidon?



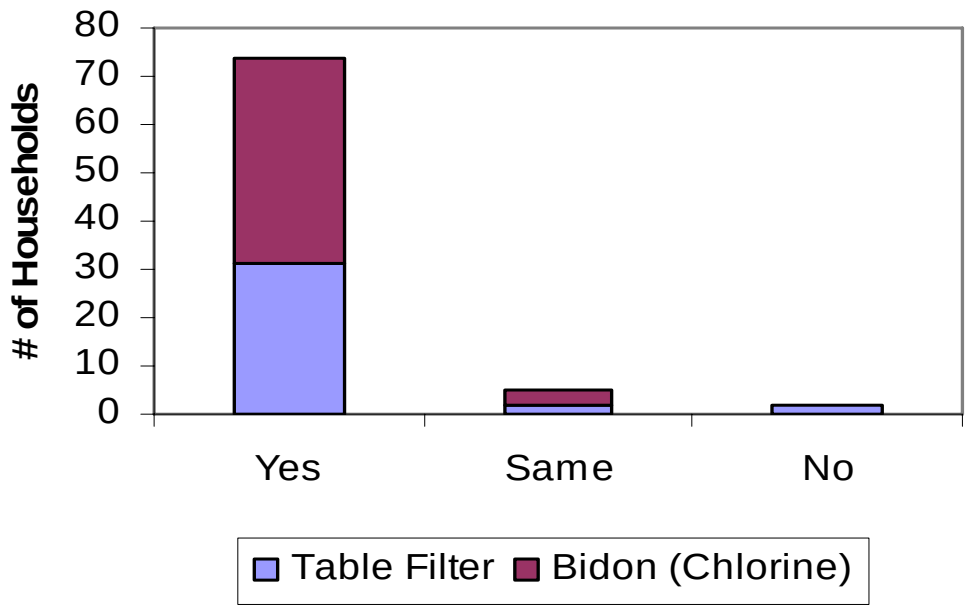
When did you *last* add disinfectant solution to your SWS bidon?



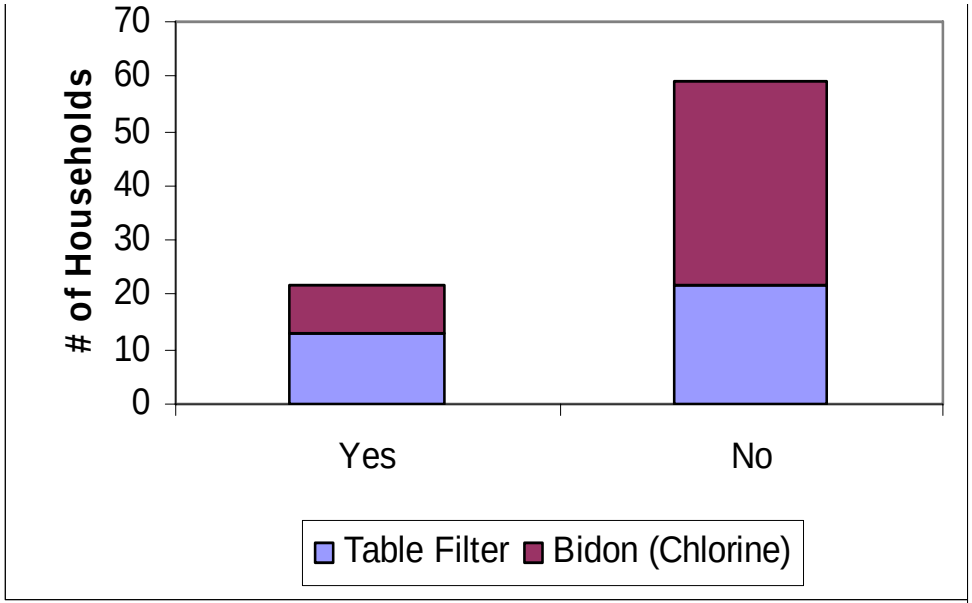
Does the water taste better or worse now that you use a treatment system?



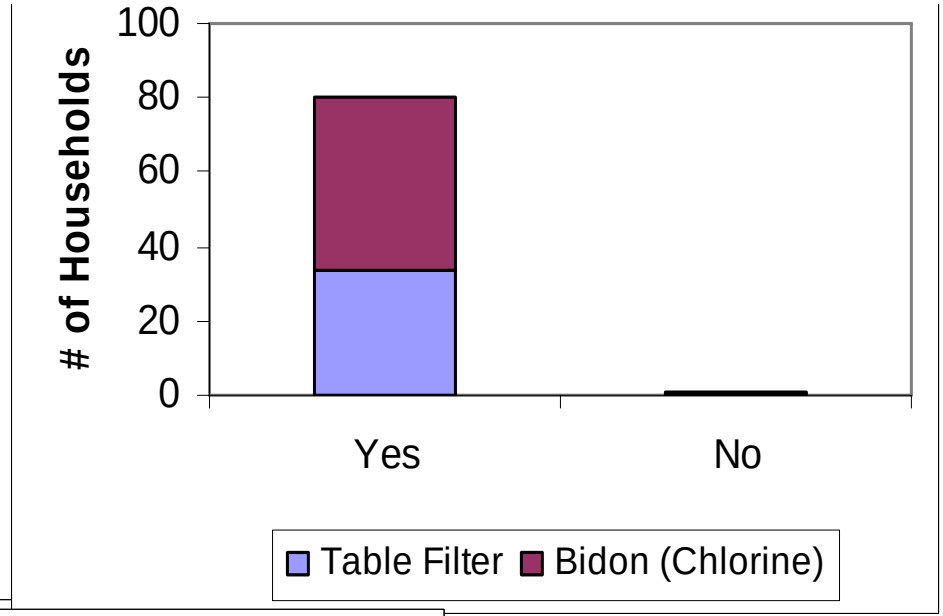
Do you feel better now that you use a treatment system?



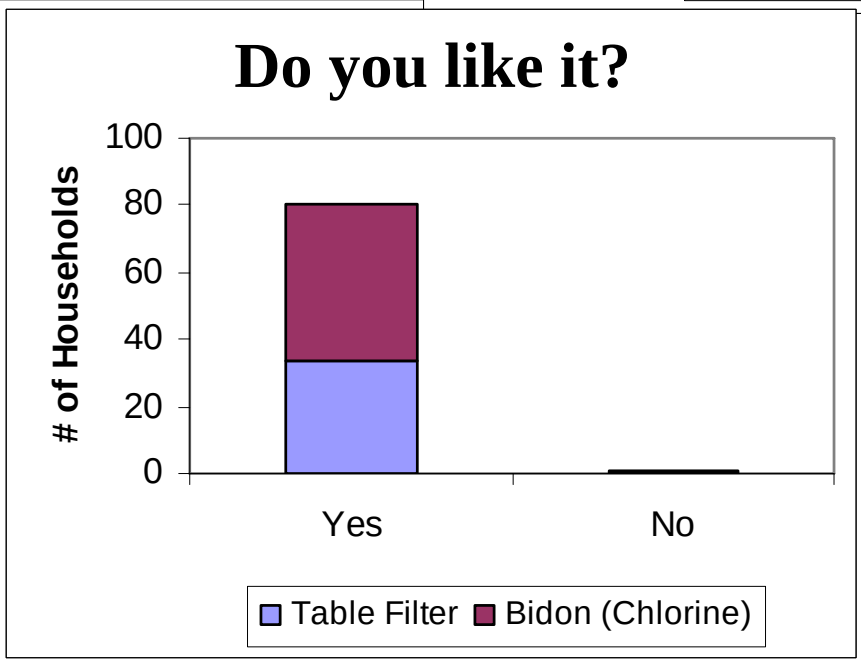
Do you have any problems/complaints about the treatment system?



Is the treatment system easy to use?



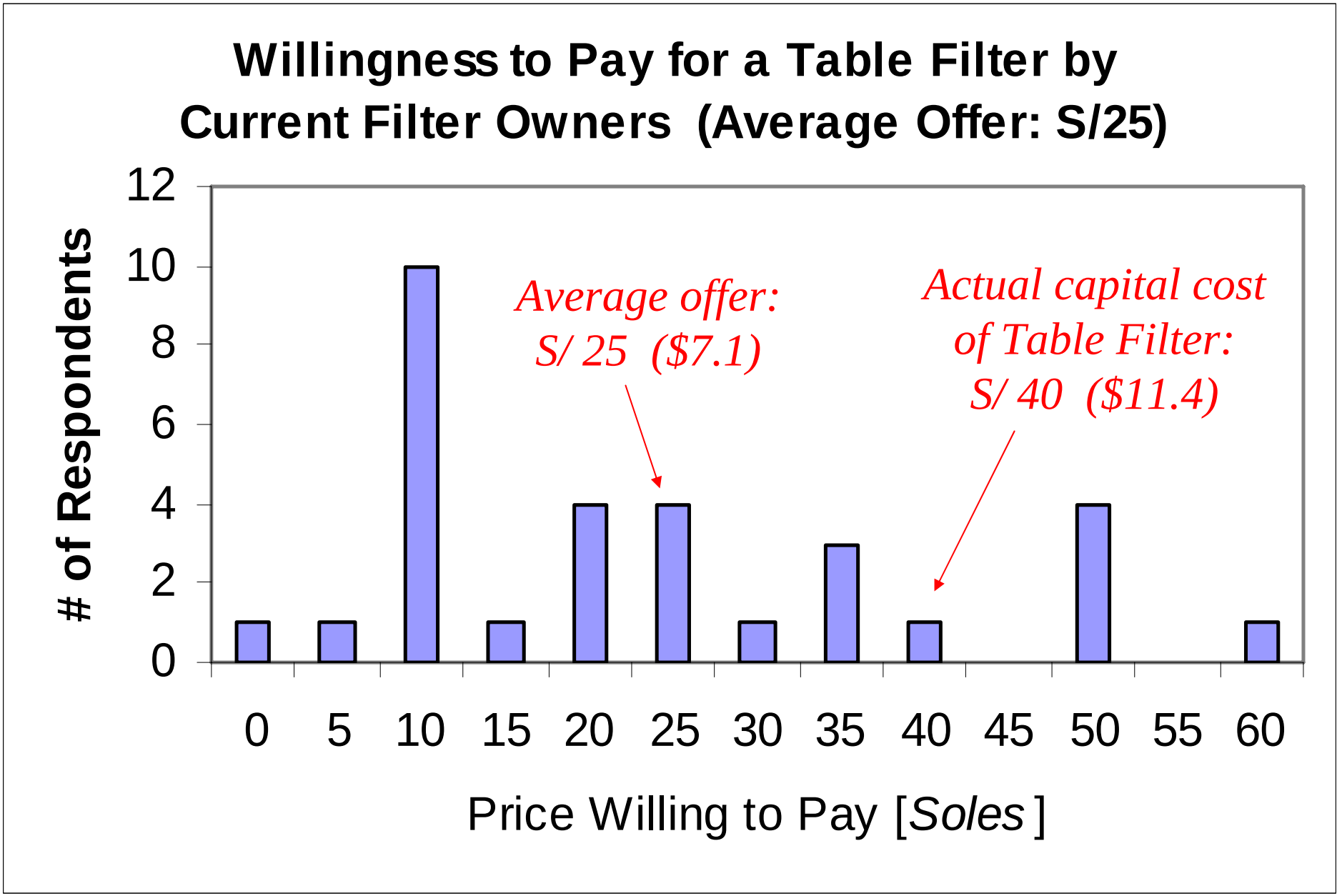
Do you like it?



Cost Comparison of Each Treatment Option

Water Treatment Option	**Capital Cost**	**O&M Costs / year**	**Total 10-Year Cost**
Table Filter	$6.40	$5	$56
Safe Water System	$9.80	$3	$40
Table Filter + SWS	$16.20	$8	$96
Water Treatment Plant (w/ piped system, per family of 5)	$475	$36	$835

The capital cost of a Table Filter is low because the initial purchase of ceramic candles is included in the O&M costs.


Willingness to Pay for a Table Filter by Current Filter Owners (Average Offer: S/25)
# of Respondents
12
10
8
6
4
2
0
Average offer: S/ 25 ($7.1)
Actual capital cost of Table Filter: S/ 40 ($11.4)
0 5 10 15 20 25 30 35 40 45 50 55 60
Price Willing to Pay [Soles]

Willingness-to-Pay

- Household surveys indicate that the target population may be willing to pay about *half* the capital cost of each system
- How does the program then cover costs?

Recommendation for Payment and Financing Options

- Government (Ministry of Health) and/or outside aid organizations contribute some % of cost or pay for large initial costs (like a $1,400 chlorine generator)
- Cheaper treatment options are explored or implemented (e.g., chlorine or SODIS)
- HWTS recipients pay in monthly installments

Proposed Monthly Payment Plan for Each Treatment Option

(assuming each user must cover 100% of capital and O&M costs)

	Monthly payment over 12 months	**Monthly payment over 24 months**	**Approx. monthly O&M after capital is paid off**
Table Filter	S/ 3.5 ($1)	S/ 2.5 ($0.7)	S/ 1.5 ($0.4)
Safe Water System	S/ 4 ($1.1)	S/ 2.5 ($0.7)	S/ 0.9 ($0.25)
Table Filter + SWS	S/ 7 ($2)	S/ 4.5 ($1.3)	S/ 2.5 ($0.7)

Recommendation: Filtration *plus* Chlorination is best!

- Filtration by a Table Filter helps remove the turbidity in water that would make chlorination less effective
- Chlorination and safe water storage by the Safe Water System kills any bacteria that remain after filtration and protects against recontamination