Experience with Engineering Student Projects in Developing Countries

Engineers without Frontiers-USA National Conference

Cornell University

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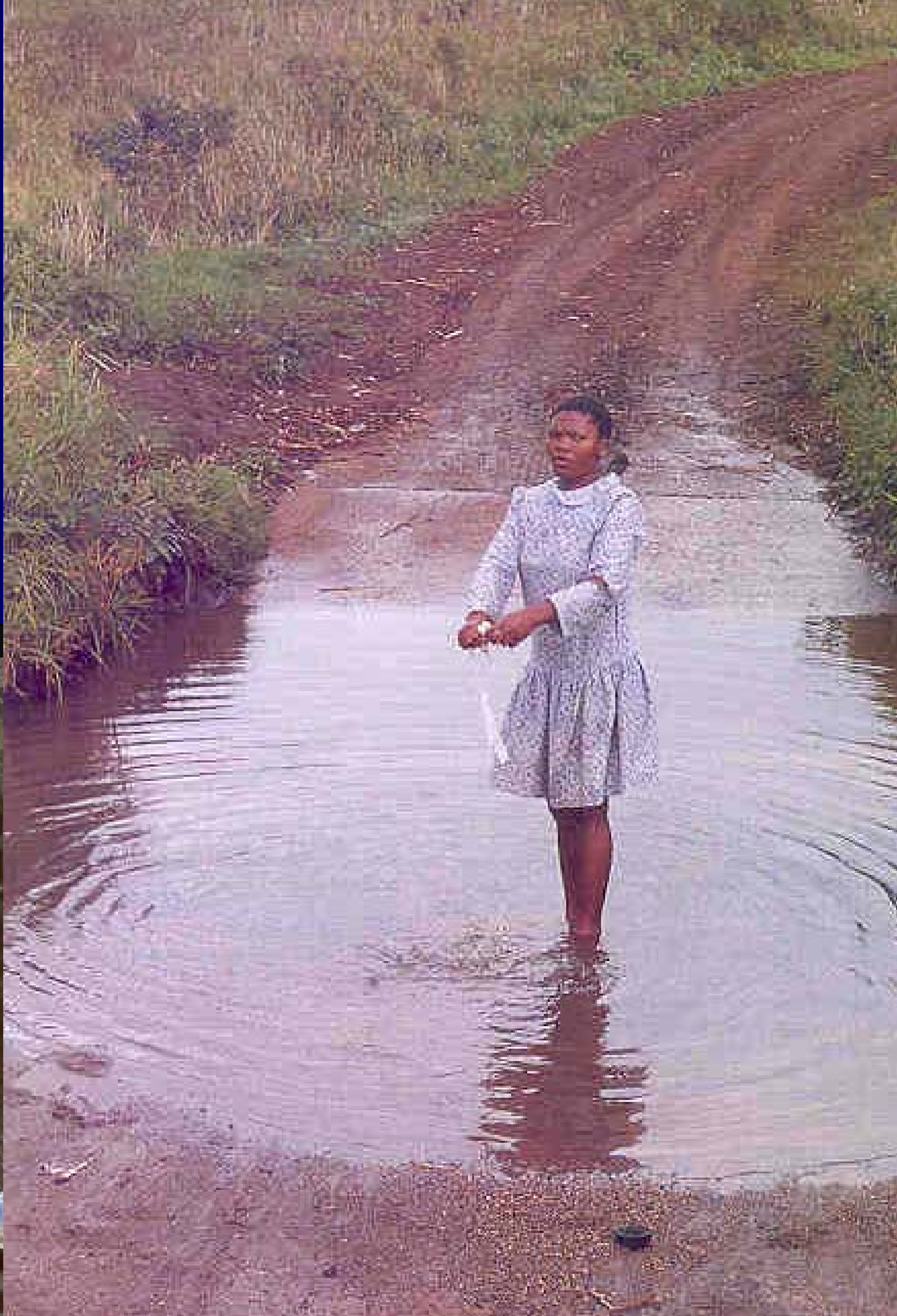
Dept. of Civil and Environmental Engineering

Water pollution and water scarcity are the 2 biggest water engineering challenges of the 21st century

Today, more than 1 billion people in the world lack access to clean, safe drinking water

This means more than 1/6th of our global family are lacking the basic foundation for human health -- safe water.



Women and children are the ones most profoundly impacted by water pollution and water scarcity.

Women and children are often the ones who carry heavy loads of water long distances each day to supply their family's needs.

Women are the primary care-takers of children and other family members sick and dying from waterborne illnesses.

Waterborne diseases are the leading cause of childhood death worldwide and are responsible for the stunted growth of 67% of surviving children in the developing world (WHO, 2000)

3.4 M people, mostly children, die each year from <u>preventable</u> water-borne diseases, more than the deaths from AIDS.

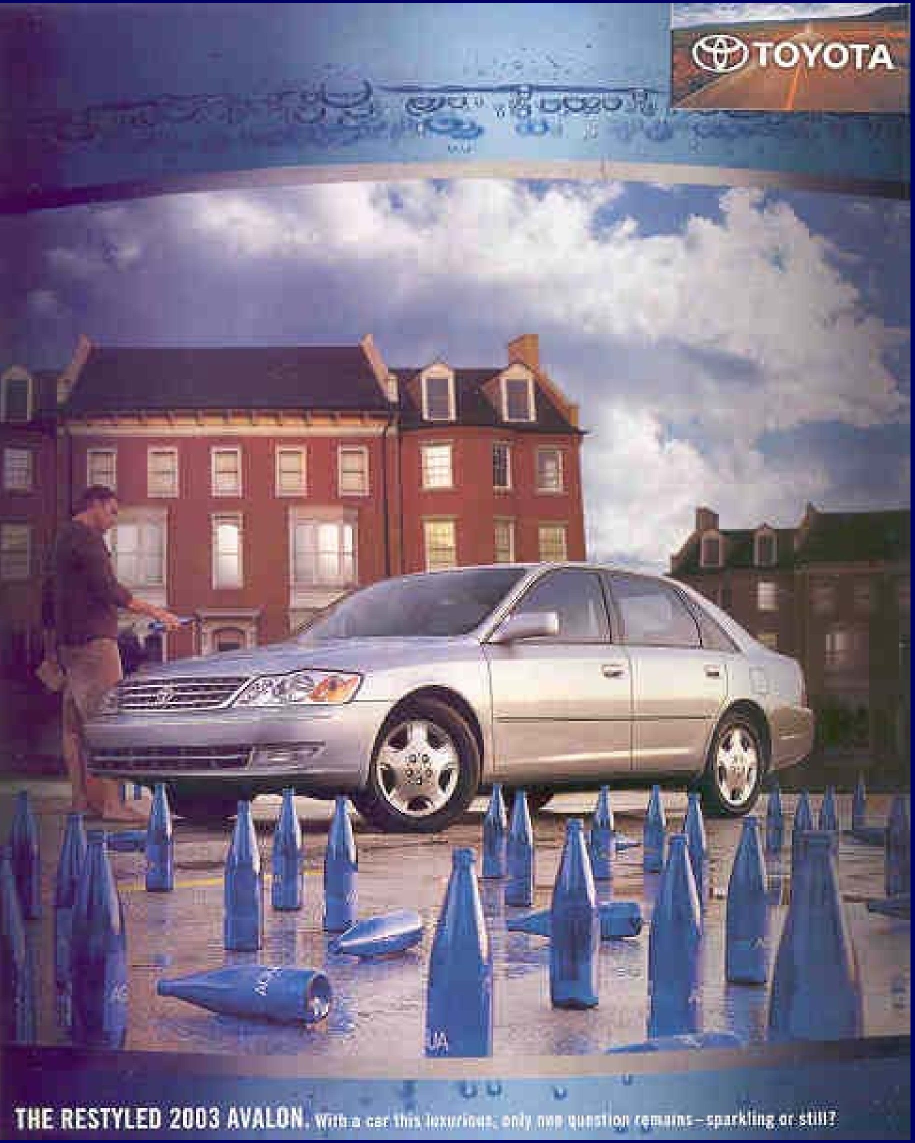
3 Global Economic Classes

Income	High > $20/day (20%)	Middle $2/day (60%)	Poor $1/day (20%)
Food	Meat, canned and packaged food, soft drinks, bottled and tap water	Grain, clean water	Insufficient grain, unsafe water
Transportation	Private cars	Bicycles, buses	Walking
Materials	Throw-aways	Durables	Local biomass

Safe Water

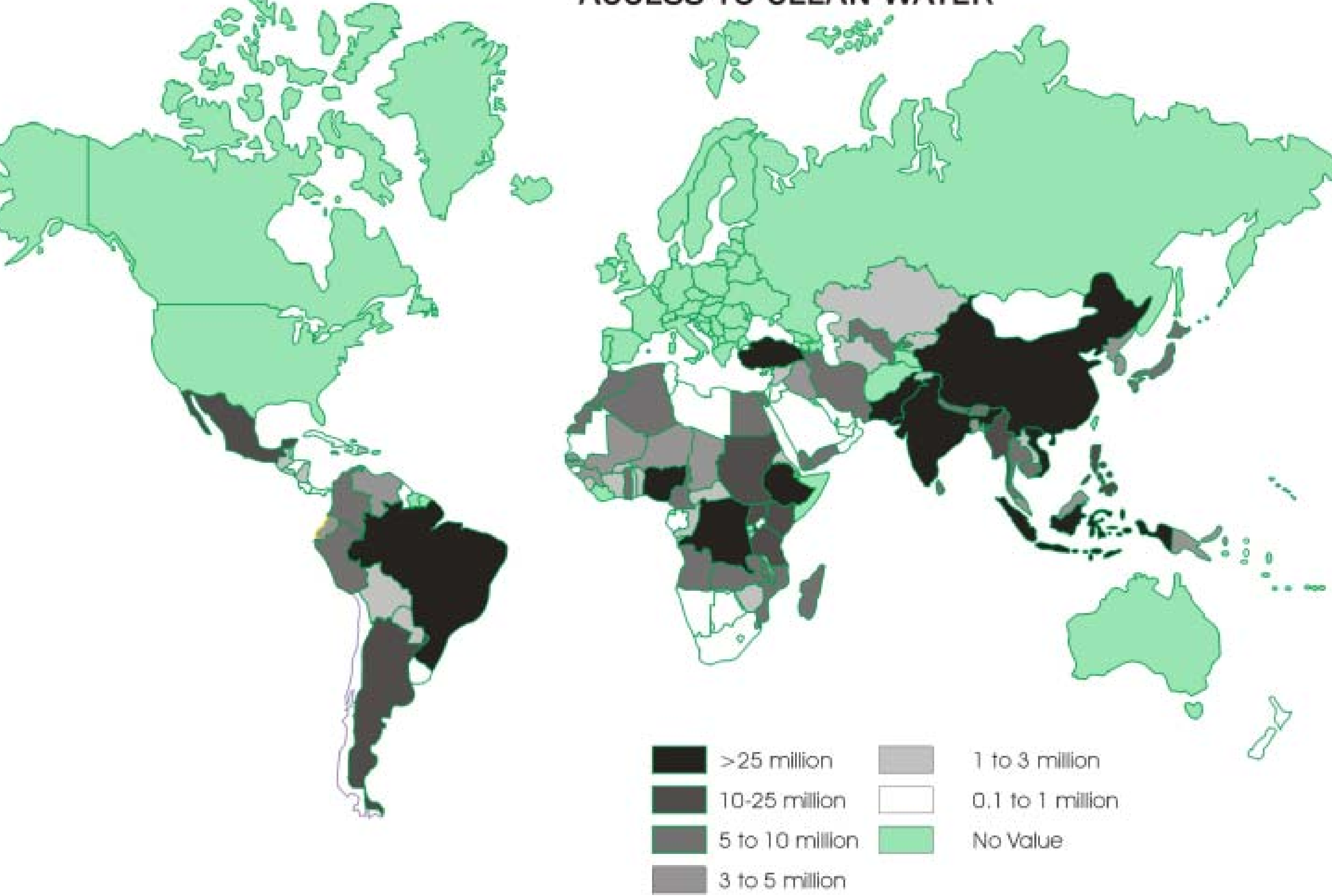
Unsafe Water

Private Cars

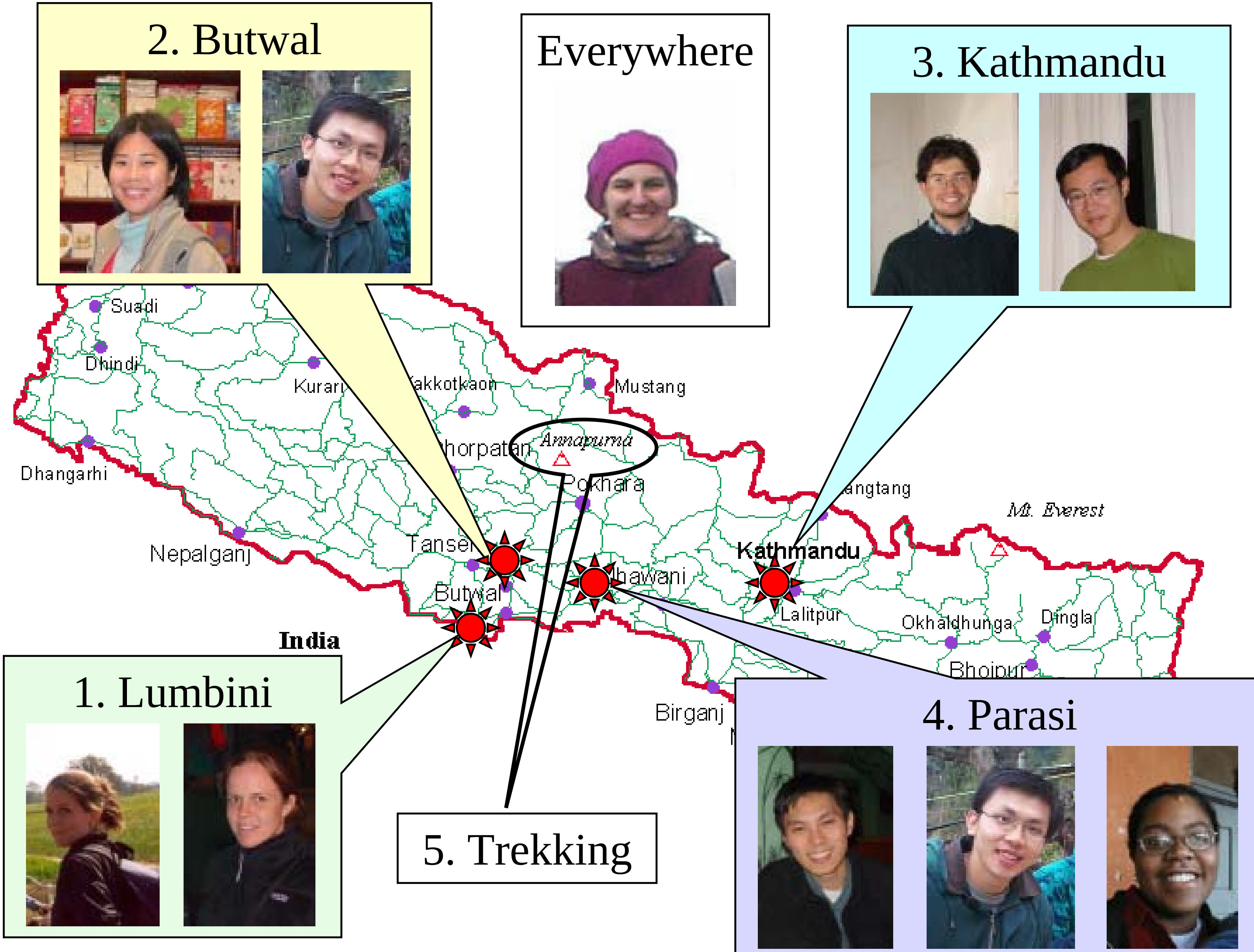


Walking

GLOBAL DISTRIBUTION OF PEOPLE WITHOUT ACCESS TO CLEAN WATER



Since 1998,
about 50 students have done
MIT Master of Engineering
thesis projects on
water and wastewater
treatment
in 4 developing countries:
Nepal, Nicaragua, Haiti, Brazil


2. Butwal
Everywhere
3. Kathmandu
1. Lumbini
5. Trekking
4. Parasi
Suadi
Dhindi
Kurari
Jakkotkaon
Mustang
Dhangarhi
Annapurna
Pokhara
Nepalganj
Tansen
Butwal
Kathmandu
Lalitpur
Mt. Everest
Okhaldhunga
Dingla
Bhojpur
Birganj
India

Nicaragua


NICARAGUA
HONDURAS
Cayos Miskitos
Puerto Cabezas
Ocotal
Somoto
CORD. ISABELLA
Matagalpa
Estelí
Jinotega
Grande de Matagalpa
Mer des Caraïbes
NICARAGUA
Chinandega
León
Lago de Managua
Managua
Boaco
Corn Islands
Juigalpa
Masaya
Granada
Bluefields
Jinotepe
CORD. DE YOLAINA
Ometepe
Lago de Nicaragua
Océan Pacifique
Rivas
San Carlos
COSTA RICA
San Francisco Libre
Managua


Filtrón

Haiti

- •Port au Prince
- •Dumay
- •Les Palmes
- •Bas Limbes
- •Ferrier


Brazil Municipal Wastewater Projects

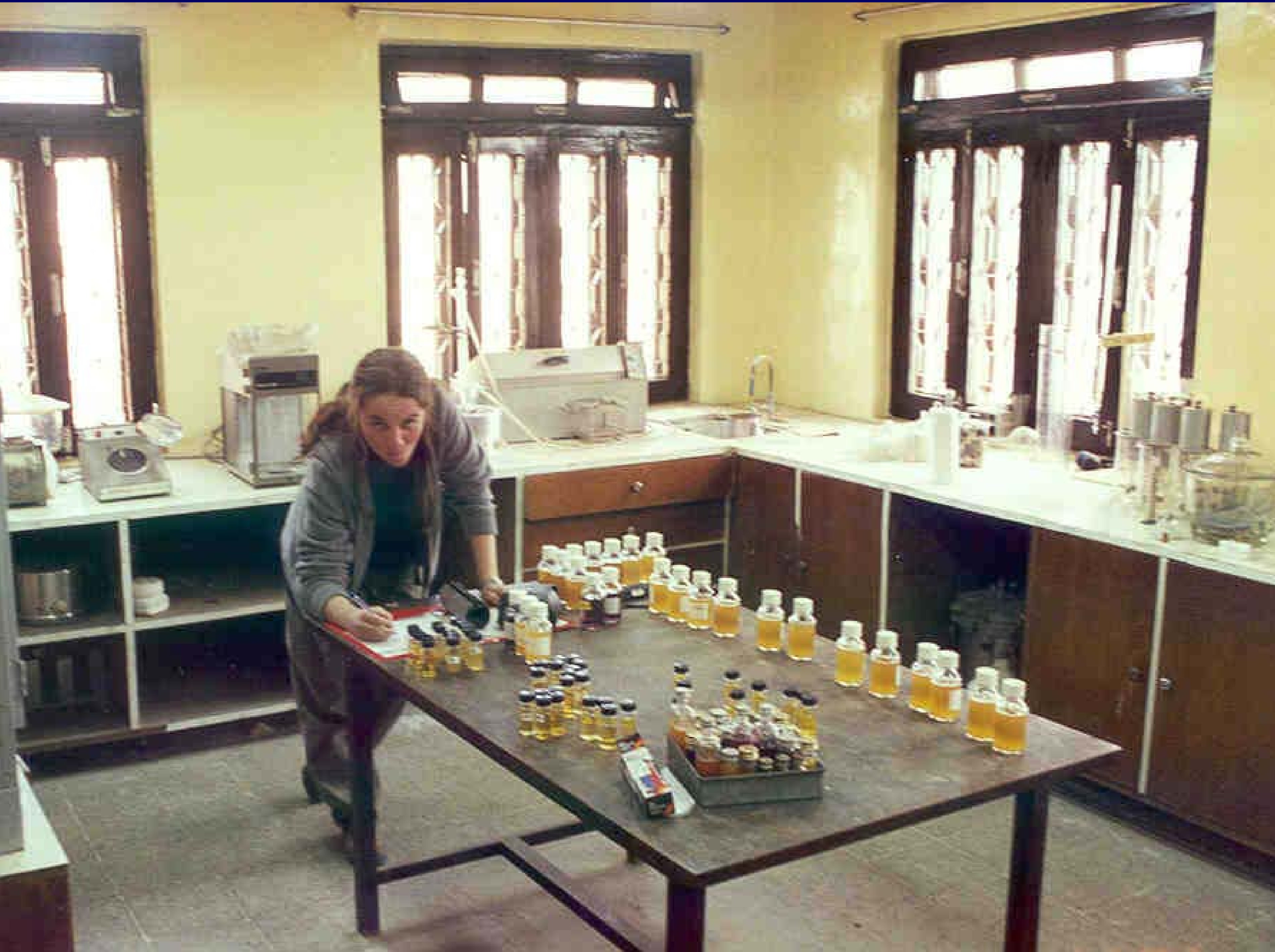
- Tatui
- Riviera
- Alfenas
- Paraty

In drinking water projects, we have had 6 areas of activity

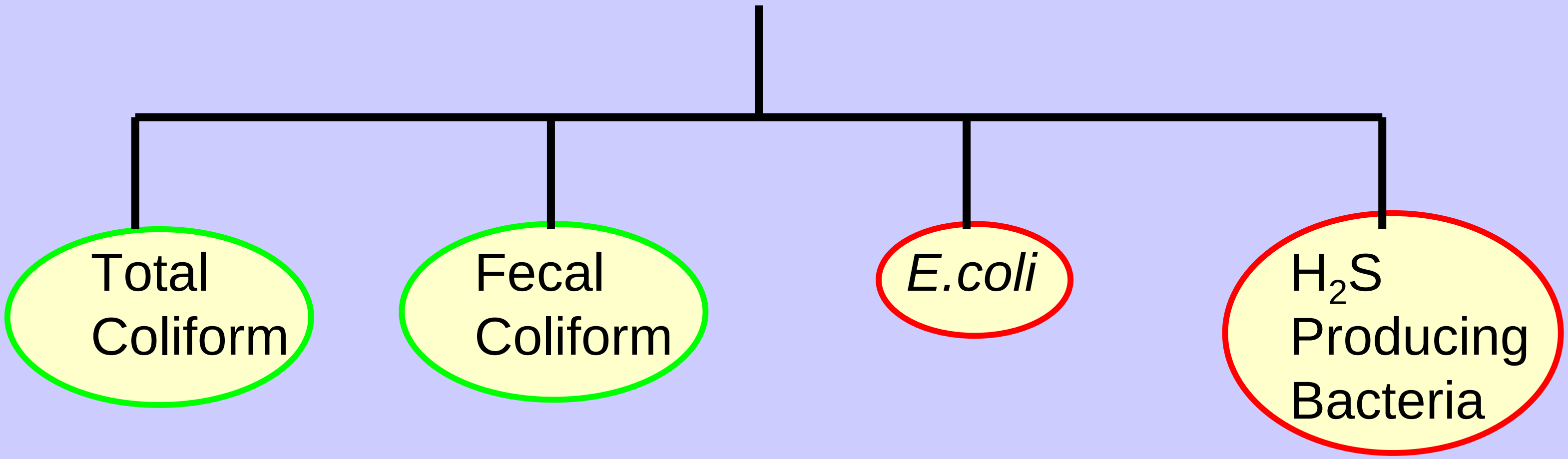
- (1) Methodological Evaluation
- (2) Site Investigation (water quality testing for microbiological contamination and arsenic)
- (3) Technology Evaluation (existing options)
- (4) Implementation programs (Biosand, chlorination pilot study, monitoring programs)
- (5) Manufacturing and Marketing
- (6) Technology Innovation

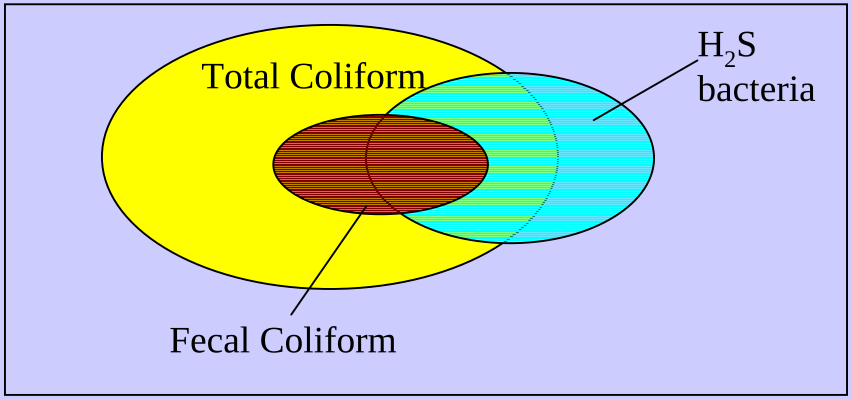
(1) Methodological Evaluations

How to do high quality lab work in developing countries?



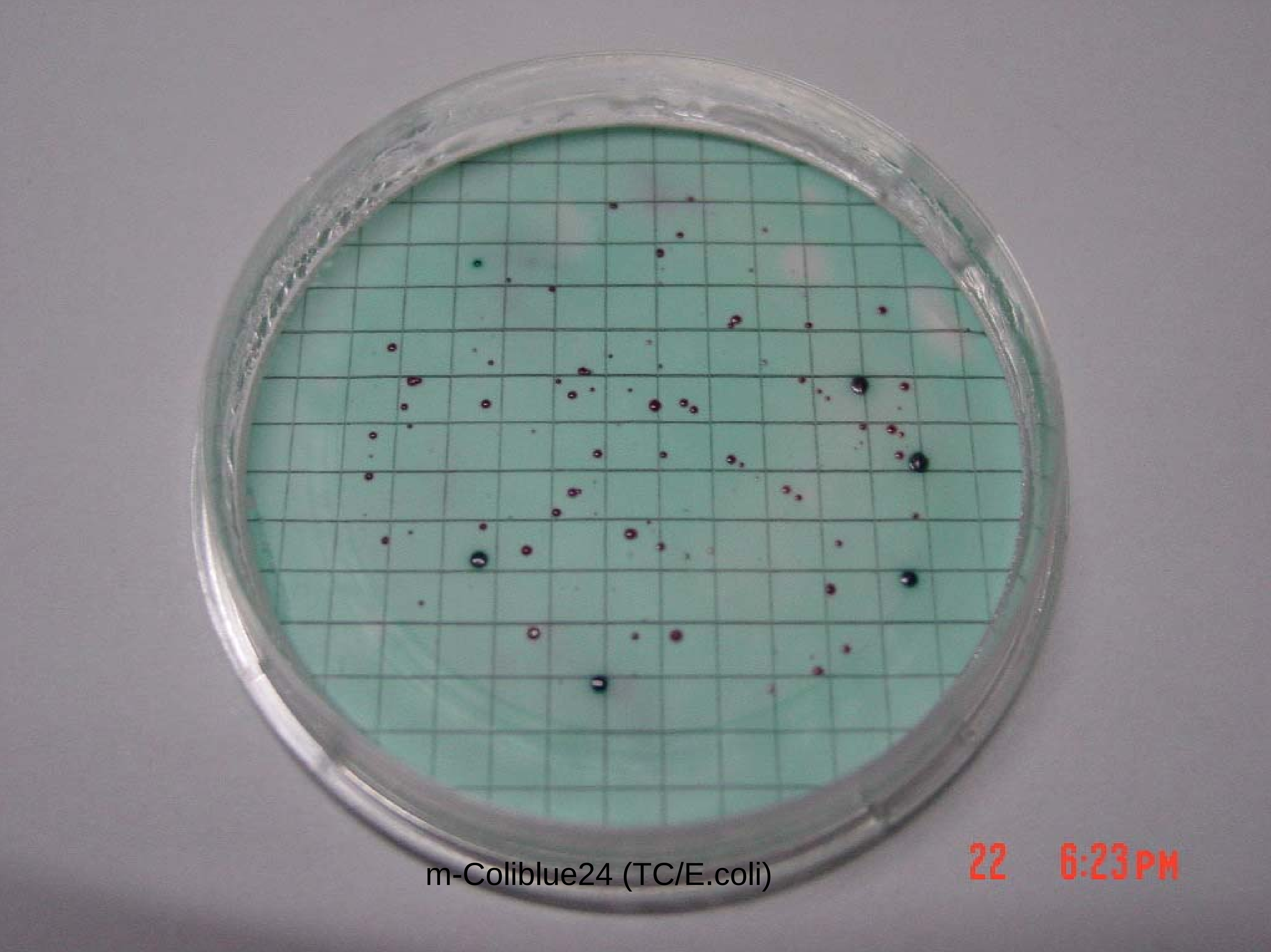
Indicator Organisms





TC/E.coli P/A results (+ TC)

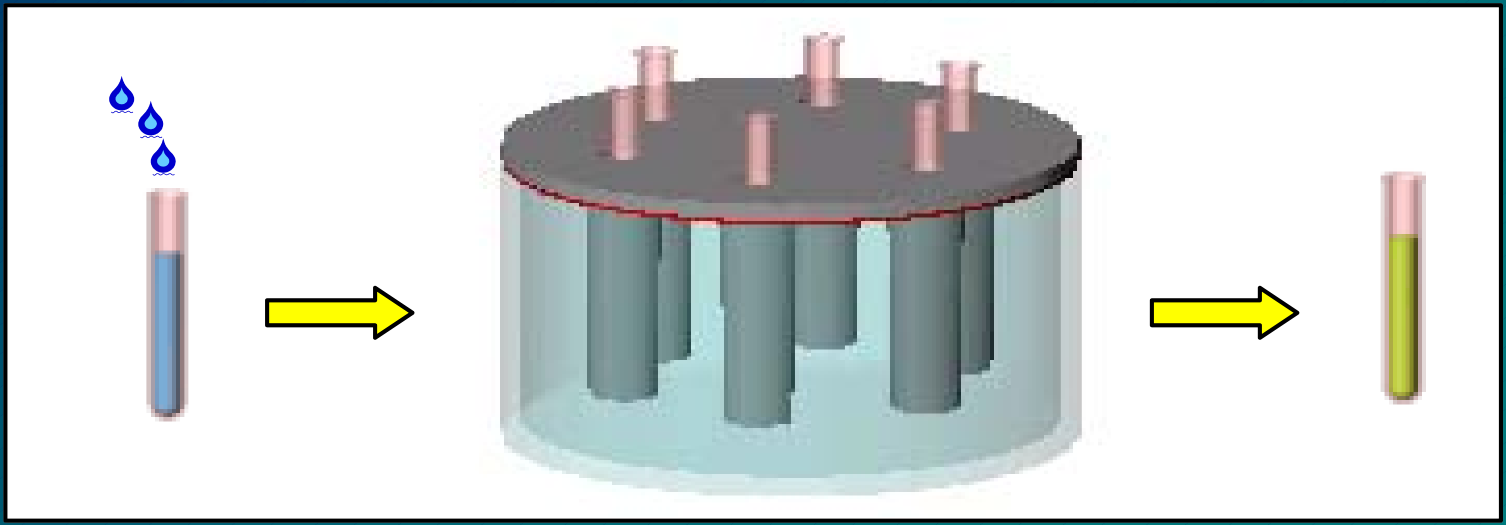
H2S P/A results



m-Coliblue24 (TC/E.coli)

nase-Change Incubator

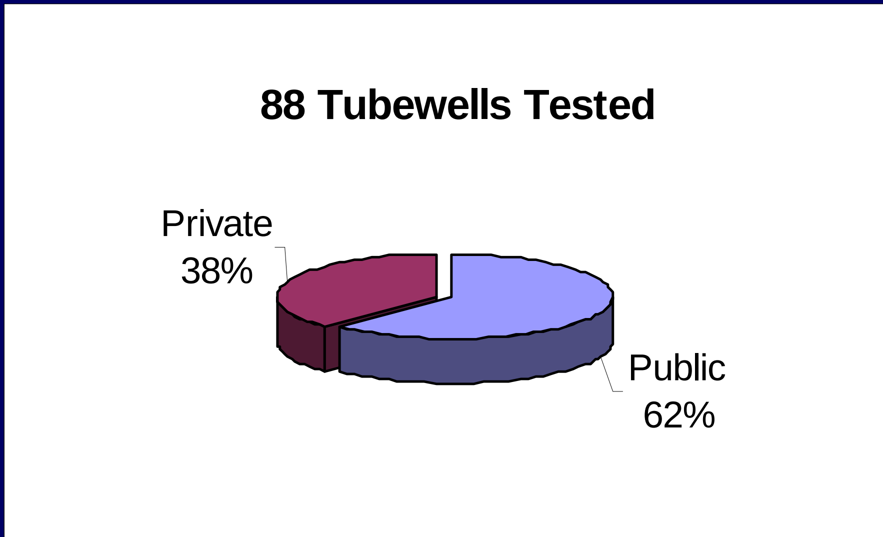
- ase-change technology maintains constant temperature
- Reliable, low cost design

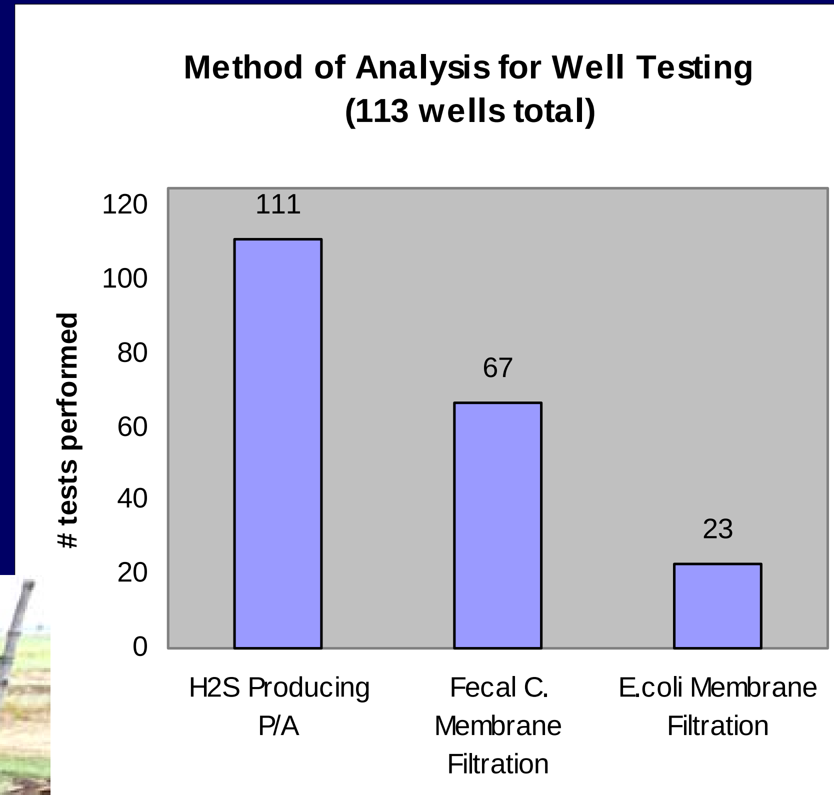



4A
6A
6D

Amy Smith's phase-change Incubator allows microbial testing in areas without electricity

(2)
Site Investigation / Water Quality Testing

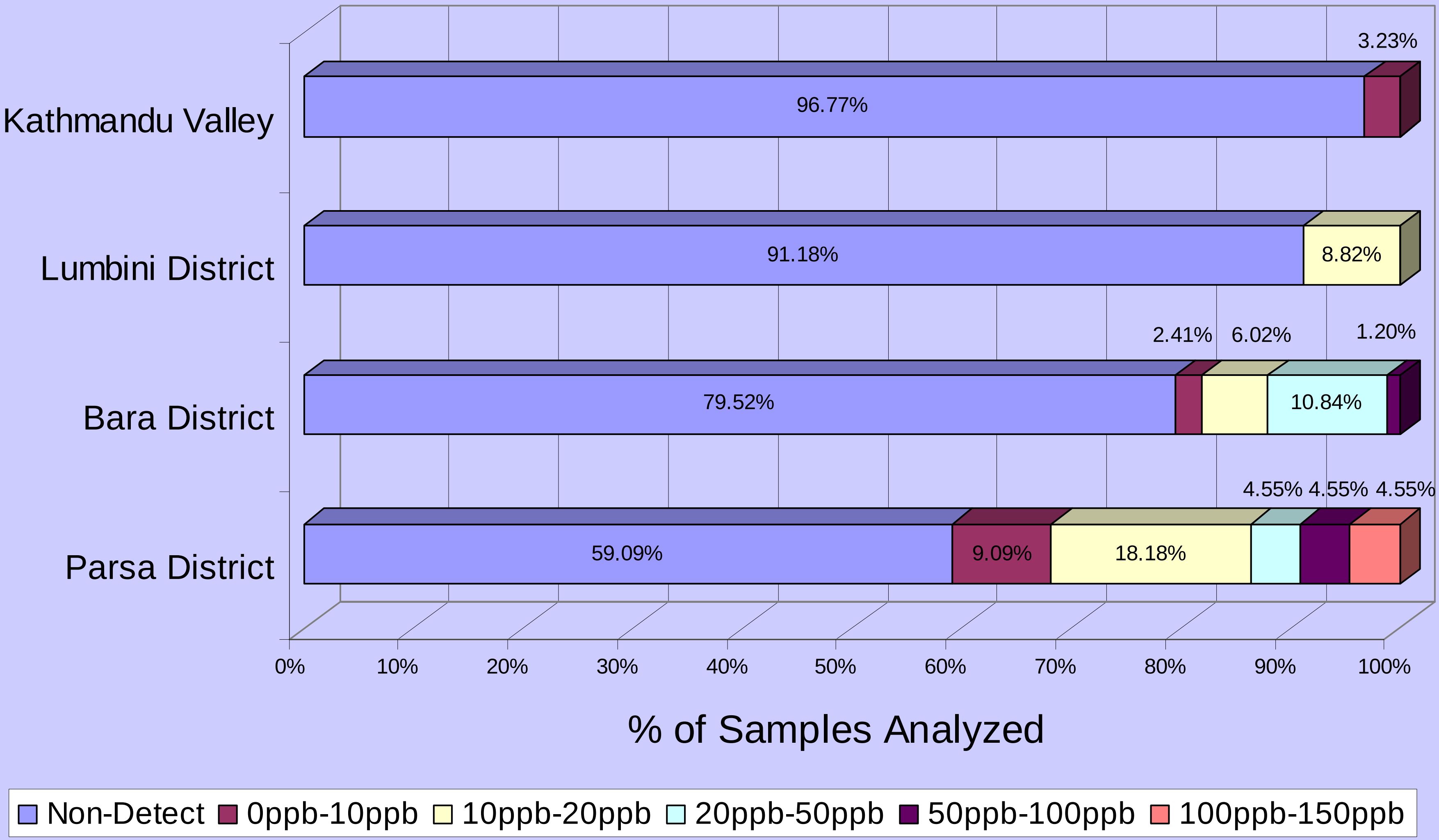

88 Tubewells Tested
Private
38%
Public
62%


Method of Analysis for Well Testing
(113 wells total)
tests performed
120
100
80
60
40
20
0
111
67
23
H2S Producing
P/A
Fecal C.
Membrane
Filtration
E.coli Membrane
Filtration

Well Testing Results

	Public	Private
Positive for H_2S	36%	40%
Positive for FC	23%	35%
> 10 CFU/100ml FC	3%	18%
> 20 CFU/100ml FC	0%	18%
> 200 CFU/100ml FC	0%	12%

GFAAS Results



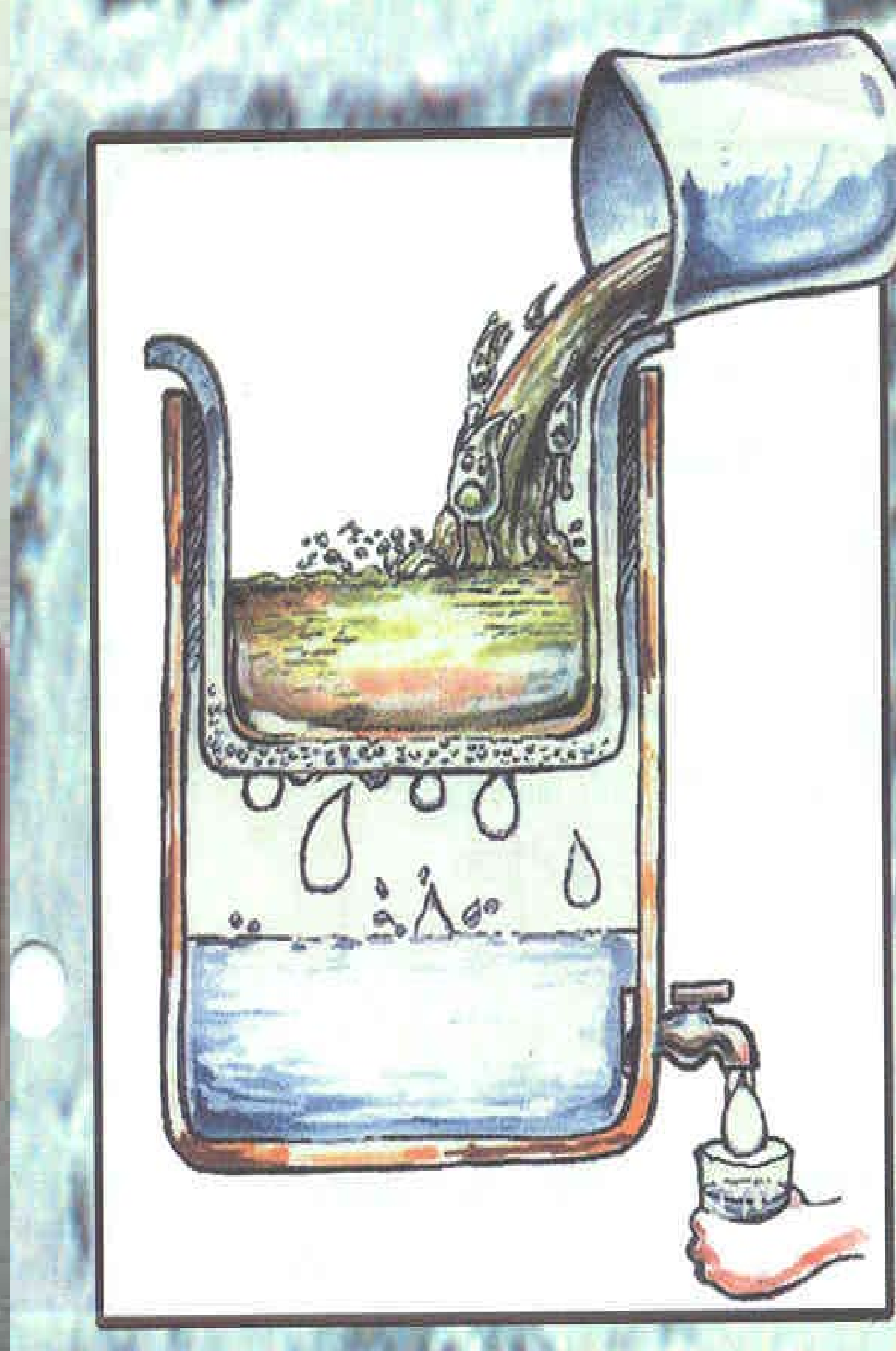
(3)
Technology Evaluations

Household Drinking Water Treatment

- Coagulation
- Filtration
- Disinfection


1 26 '00

We have looked at what household practices and systems exist in developing and industrialized country marketplaces and homes

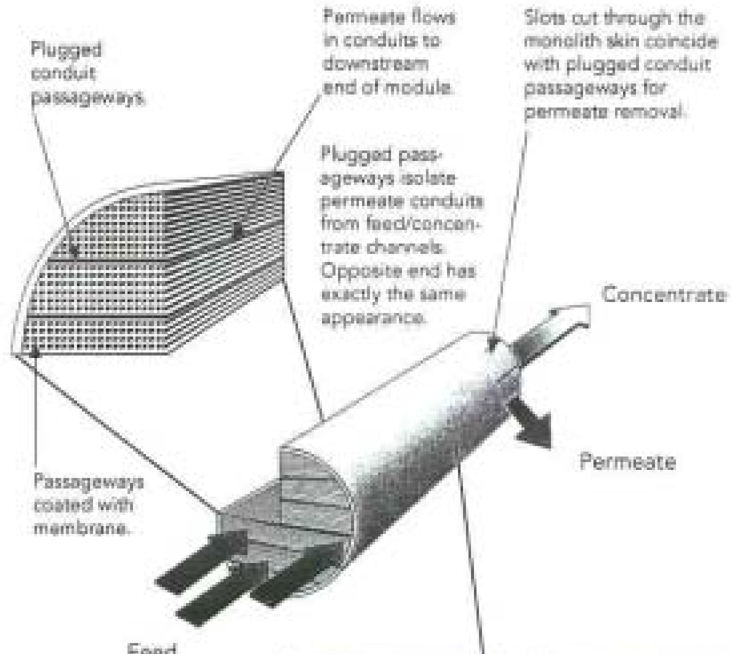
CORNING

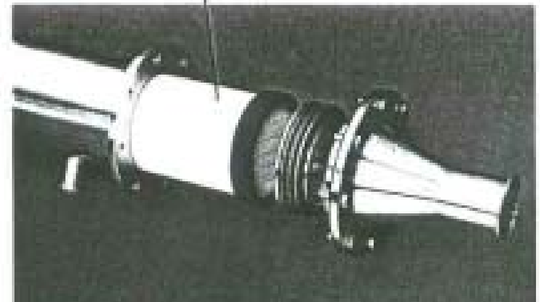
CerCor
SEPARATIONS

Liquid Crossflow Filters

CerCor Separations manufacturers and sells crossflow membrane filters with pore sizes in the Microfiltration (MF) and Ultrafiltration (UF) ranges.

These filters contain a large number of approximately 2mm square parallel passageways extending from one face to the other. A CerCor patented approach modifies the monolith support by converting some of the passageways to permeate conduits. This enables the entire filter diameter to be effectively utilized.





BioSand Water Filter


BioSand
Water Fil
Davnor Water Treatm
Calgary, Alb

Katadyn (“Ceradyn”) Ceramic Filter from Switzerland..

Hong Phuc Candle Filter – Vietnam

This system exterior is an exact imitation of the Katadyn filter. The candles are not of the same high quality. However, it only only costs $5.00

Terafil Filter

SODIS

Solar Water Disinfection

Publications
References
Conference
Cooperation Partner

What is SODIS?

- A treatment method to eliminate the pathogens which cause water-borne diseases
- Ideal to disinfect small quantities of water used for consumption
- A water treatment process depending on solar energy only
- An alternative water treatment option for use mainly at household level
- An old but so far hardly applied water purification method

The drinking water situation is precarious in numerous developing countries as more than one third of the rural population has no access to sufficient and clean water. Diarrhoeal diseases may be transmitted through contaminated drinking water and cause the death of over three million people annually. Solar water disinfection (SODIS) can contribute to improve this precarious situation.

So far, two different processes using solar energy for water treatment have been developed independently. The first focuses on solar water disinfection by radiation, and the second applies solar thermal water treatment. However, extensive laboratory and field tests conducted by EAWAG and its partners revealed that synergies, induced by the combined application of radiation and thermal treatment, have a significant effect on the die-off rate of the microorganisms. Hence, the best use of solar energy is, therefore, the combined application of the two treatment processes. Field tests also revealed that Vibrio cholerae are effectively inactivated by solar water disinfection.

How does it work?

The treatment process is a simple technolog
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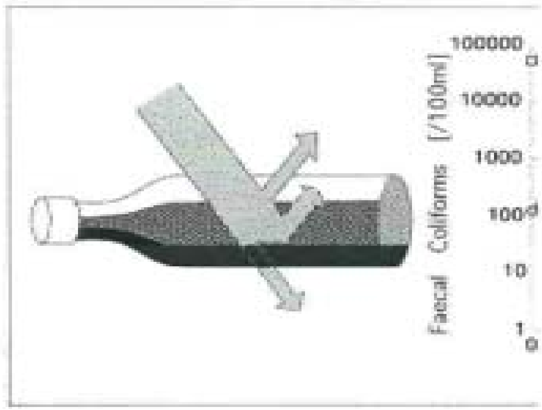
full sunlight for about five hours.



Limitations of SODIS

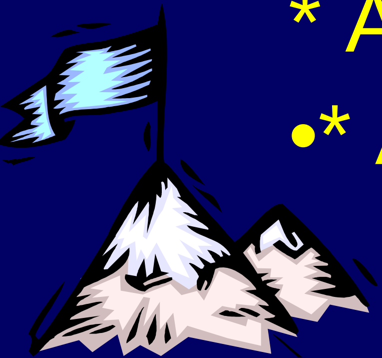
- SODIS does not change the chemical
- SODIS does not increase the water qu
- SODIS is not useful to treat large volu
- SODIS requires relatively clear water (
- SODIS needs solar radiation (exposure time: 5 hours under bright c consecutive days under 100% cloudy s

Chlorine Disinfection

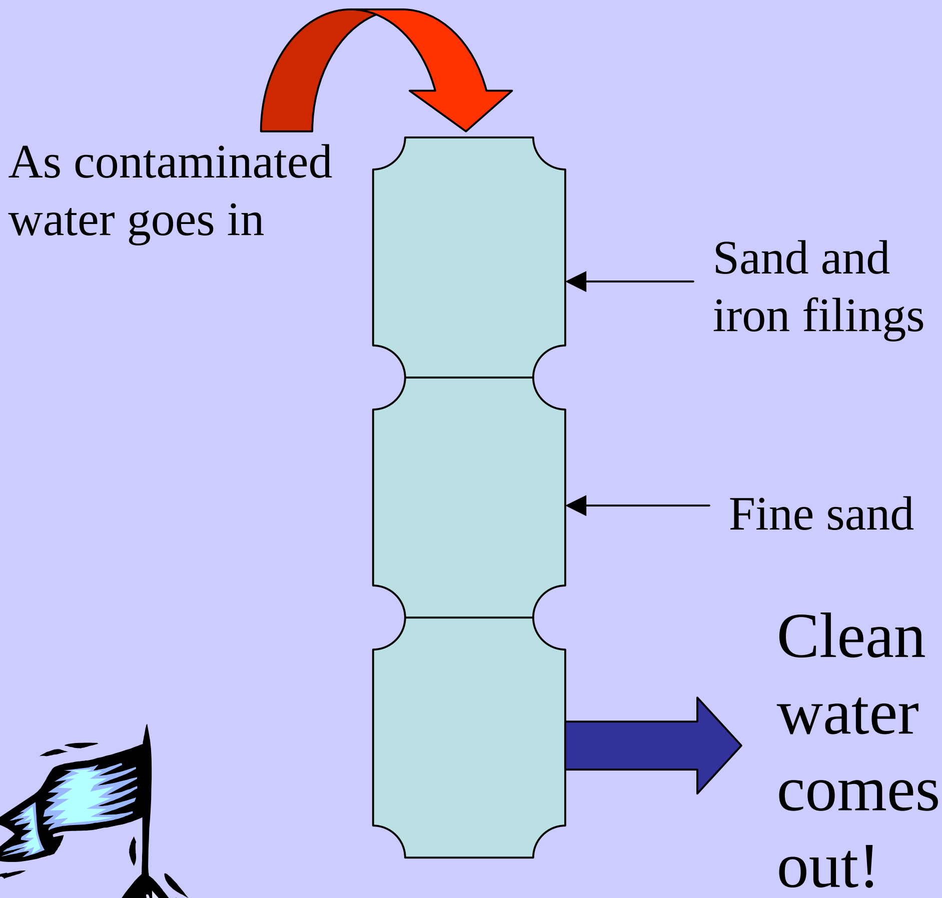
- Type of Chlorine:: $NaOHCl_2$ or CaOHCl2.

8 Arsenic Remediation Technologies

* 3-Kolshi System
* Jerry Can
* Arsenic Treatment Unit
* AM/BPI3
* Iron Oxide Coated Sand
* 2 Kolshi
* Arsenic Biosand Filter
•* Arsenic Treatment Plant



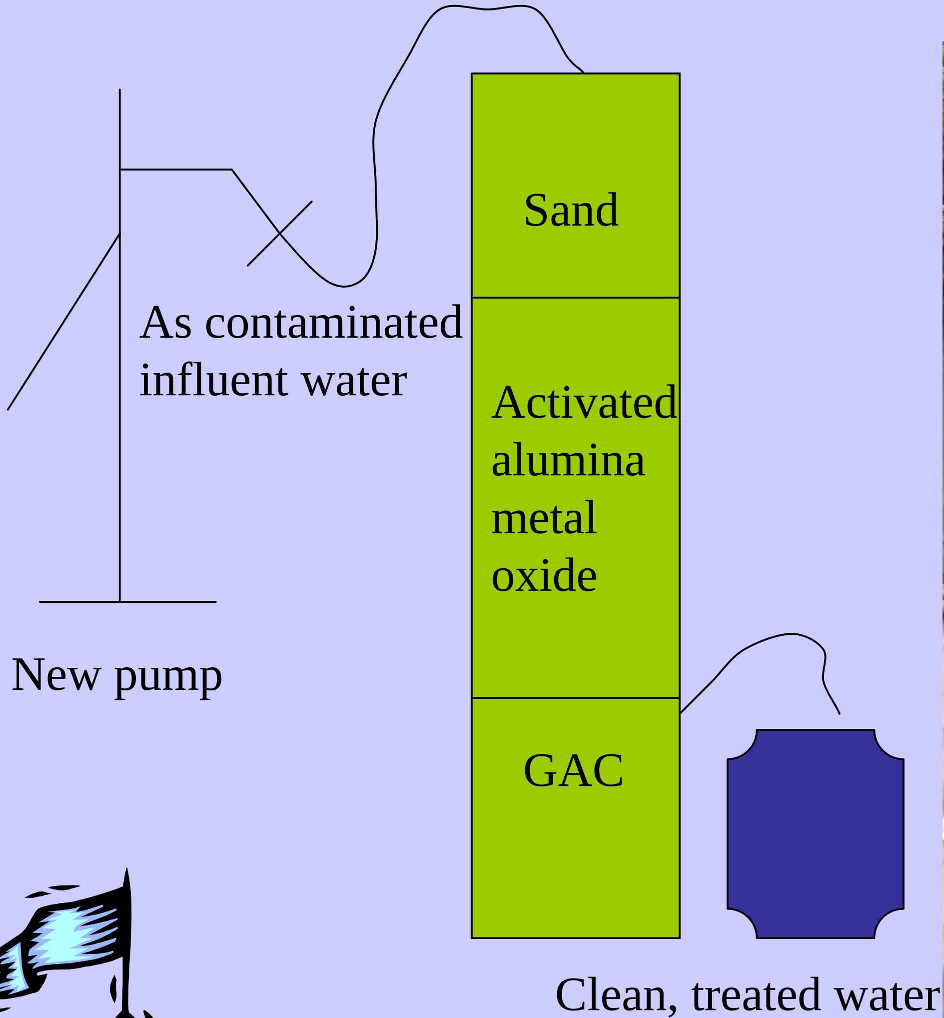
Three-Kolshi System



The real thing!

The Nepal Project

1st World Arsenic Treatment – Apyron Technologies = $2000



(4)

Pilot Programs and Monitoring

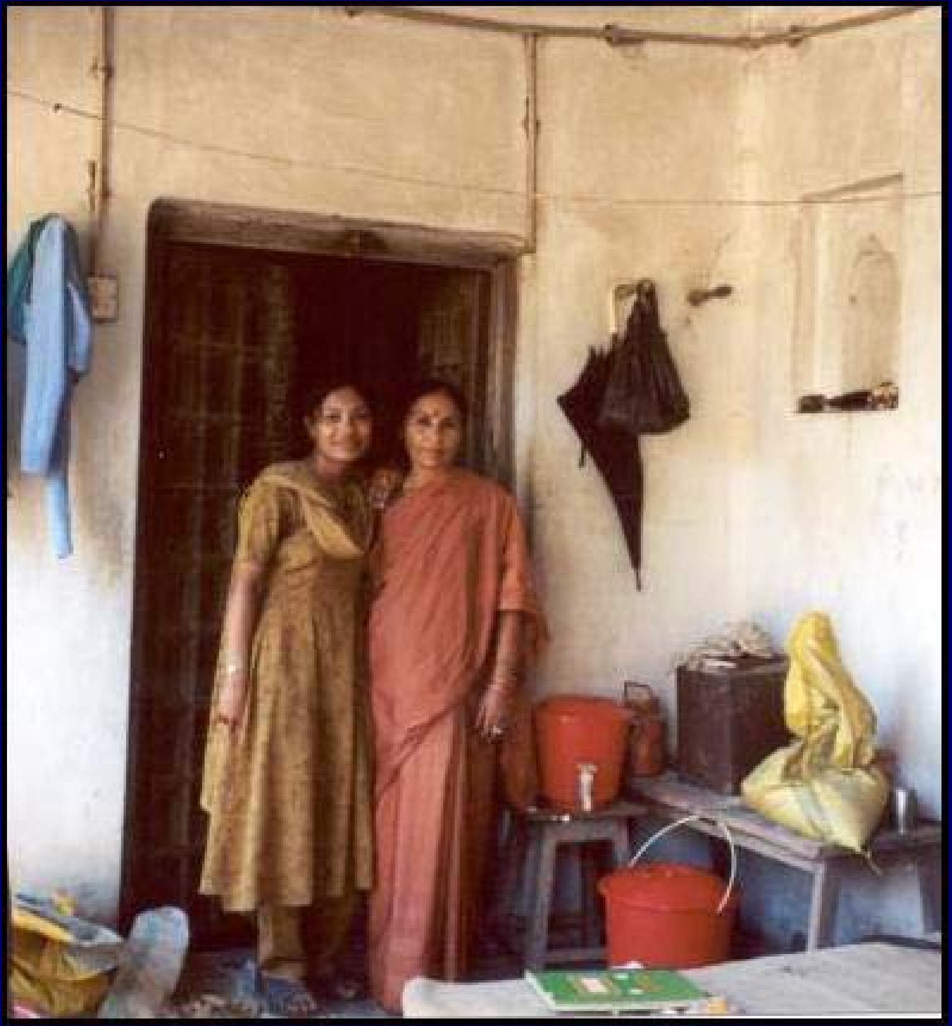
The Safe Water System Approach

- **Point-of-Use Treatment** using locally produced and distributed sodium hypochlorite solution.

•**Safe Water Storage** in plastic containers with narrow mouths, secure lids and dispensing spigots to prevent recontamination.

•**Education:** Influence hygiene behaviors and increase awareness about the dangers of contaminated water and waterborne disease.

Household Chlorination Pilot Study (1/2001 – 1/2002)



GOALS

- Provide Safe Water to a portion of the Lumbini population
- Test the acceptance of household chlorination in Nepal

Based on CDC Safe Water Systems

www.cdc.gov/safewater


Castro

(5)

Manufacturing and Marketing

The Objective

PRODUCE A CHLORINE DISINFECTANT

&

ESTABLISH MICRO-ENTERPRISE PROGRAM

<u>Piyush</u>

Imported bleaching powder

↓

Sodium hypochlorite

on-site generation

Chlorine Generator

* 113 g available Cl/h
* 0.8% chlorine
* 5.5 kW / kg chlorine
* 4.1 kg, 18 X 100 cm
* 2 year warranty
* $2000

Ceramics Filter Manufacture


(6)

Technology Innovation

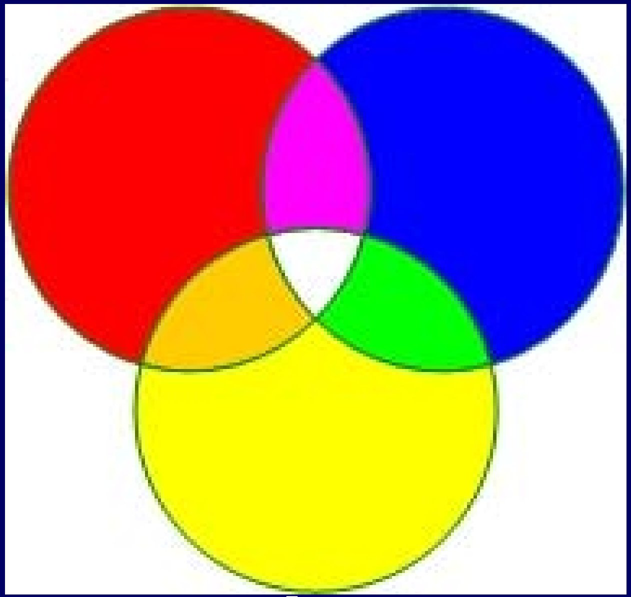
Design Principles for Appropriate Technology

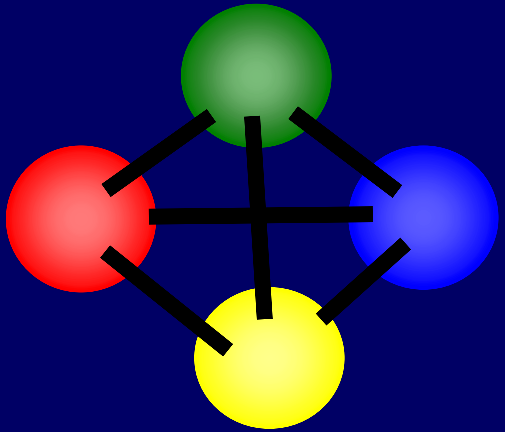
(E.F. Schumacher: Small is Beautiful, 1973)

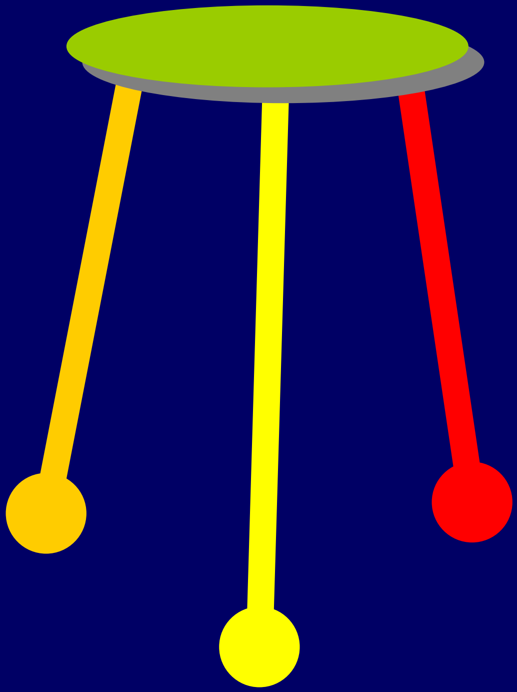
- 1. Simple design & production
- 2. Inexpensive
- 3. Use local materials for local use
- 4. Rural focus

“Sustainable development” has 2 widely accepted meanings:

Balance: economic, social, environmental aspects



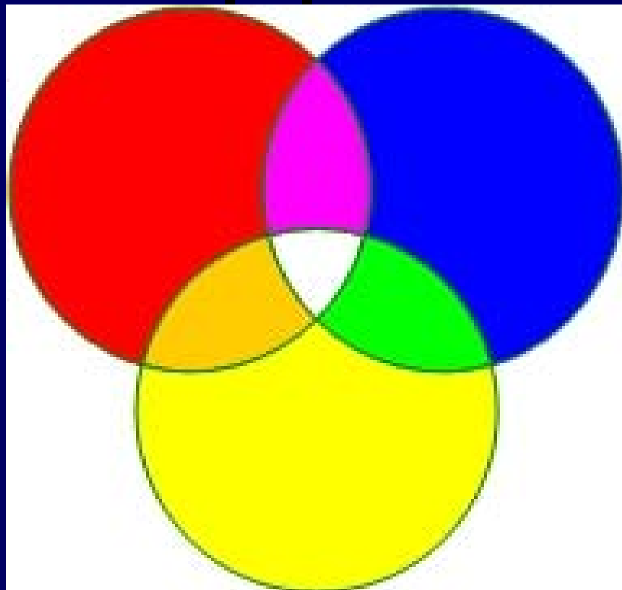




Equity…”meeting the needs of the present without compromising the ability of future generations to meet their own needs.”

\- Our Common Future, 1987

A sustainable technology



Economic:

* cost-effective
* Supports local economies
* self-sustaining

Environmental

* Environmentally friendly
* Low energy requirements
* Recyclable waste
* Using local materials

Social

* convenient
* ussd-friendly
* socially acceptable

1. The Ceramic Disk Filter (also known as the “Lily Filter”)

2. Melanie Pitcher Slow Sand Filter

3.Tommy’s Arsenic Biosand Filter

4. Xanat’s Semi Continuous Solar Disinfection

Ceramic Disk Filter
(the “Lily Filter”)

Water storage is ancient and ceramic filters might be ancient too. Here is an antique ceramic disk filter from Spain that is about 100 years old.

Our ceramic filter work began with Junko Sagara, from Japan, in 1999

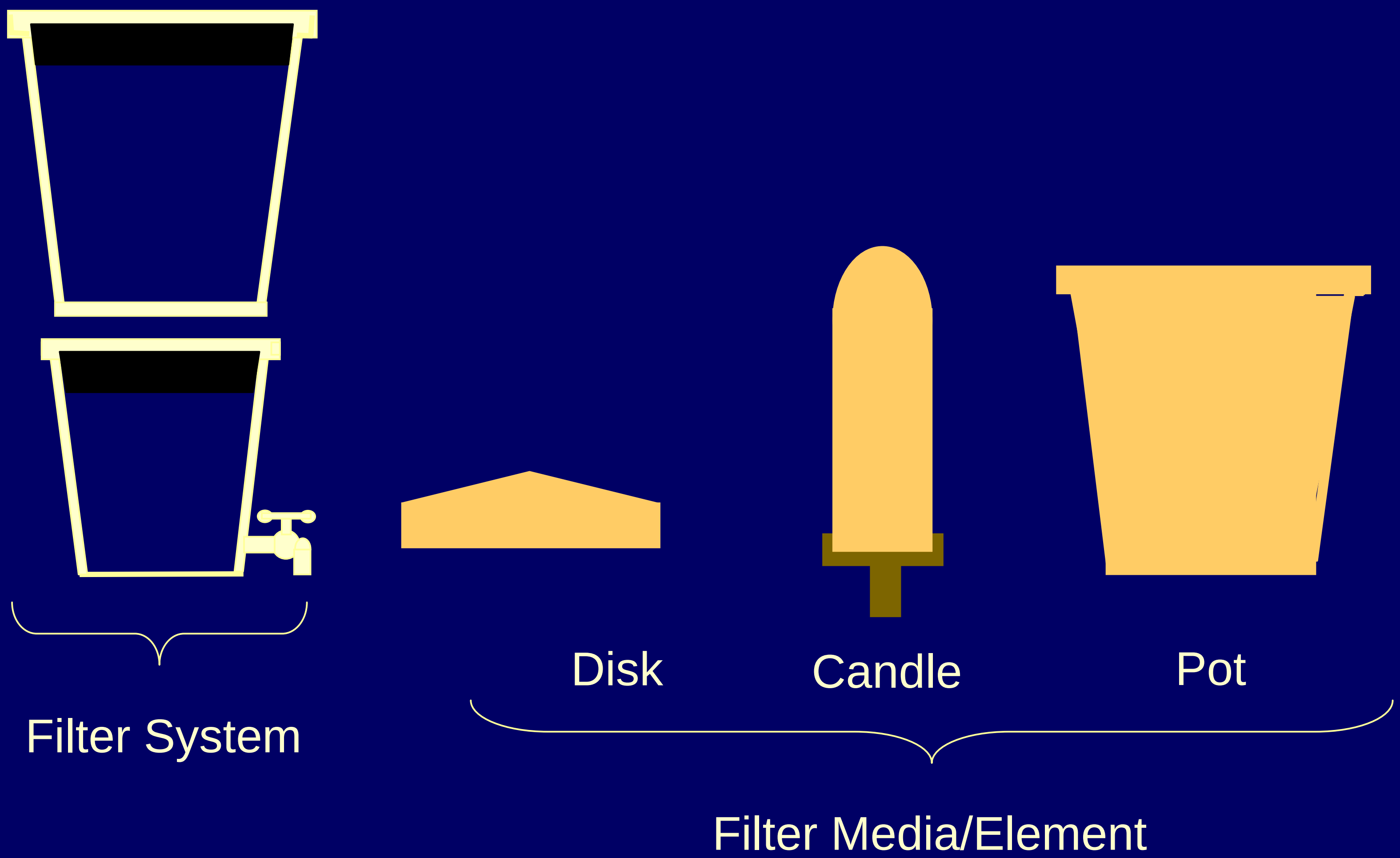
Junko met with potters who made filter candles like this at Madyapur Clay Crafts Thimi, Nepal

Candle

Ceramic Water Filters come in many shapes and sizes

The 3 most common types of filtering elements are: disk, candle and pot

Ceramic Water Filter Types



Disk

Here is Jason Low, making ceramic disk filters at Madyapur Clay Crafts, Thimi, Nepal

Filter Manufacturing Process

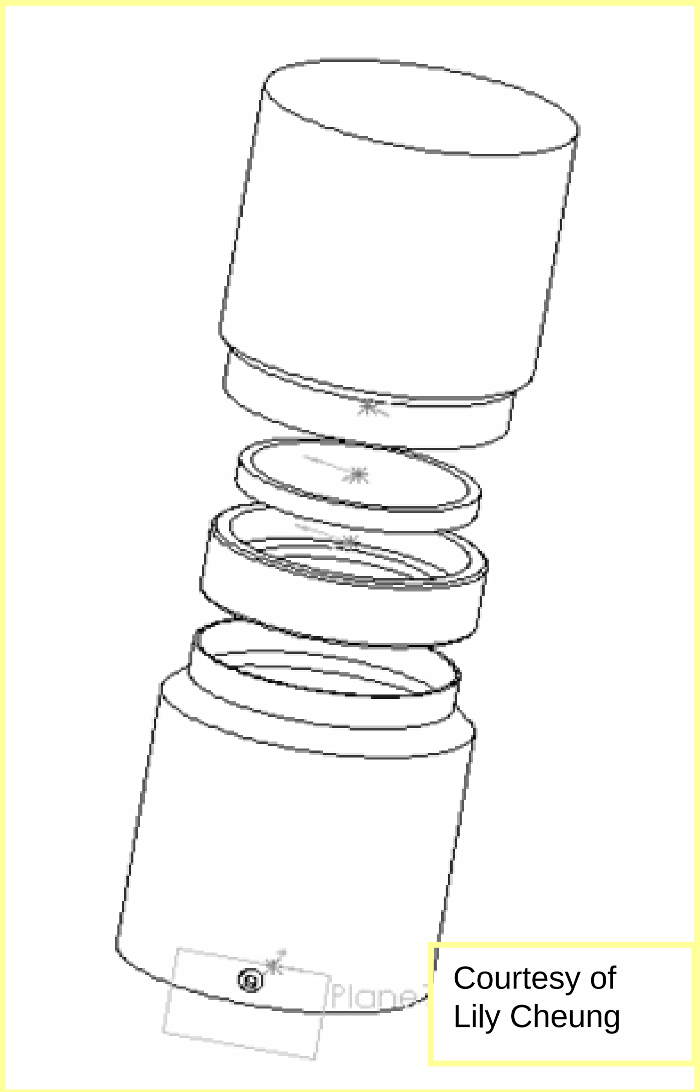
* Prepare raw materials.
* Mix by hand or in mixer
* Press in mold or filter press
* Dry (5-7 days).
* Fire (1000°C).
* Cement into ceramic/metal containers.
* Dry (2 days).


Our Prototype Ceramic Disk Filter

The "CeraMIT" team has come up with a terracotta clay filter disk system for treating drinking water.

“Lily” Filter

- We have also come up with a prototype of a plastic filter system to contain a ceramic disk.
- This system allows the user to remove the centerpiece disk easily, for cleaning or replacement.
- We call it the “Lily” filter because it was designed by Mech.Eng. student Lily Cheung
- We expect this system to cost about $6.00



Courtesy of Lily Cheung


Class of

Melanie Pitcher Filter

Here's Melanie at her filter testing field site in Lumbini, Nepal.

MIT students have been studying slow sand filters and BioSand Filters in Nepal and Nicaragua since 2000.

Slow Sand Filters

The concept of slow sand filters has also been around for over 100 years.

- Relies on natural biological, physical and chemical mechanisms to purify water
- Uses local materials – sand, gravel, concrete
- Loading rate (0.1-0.2 L/hr)
- Simple and inexpensive
- Easy to operate and maintain
- Treated water quality is good

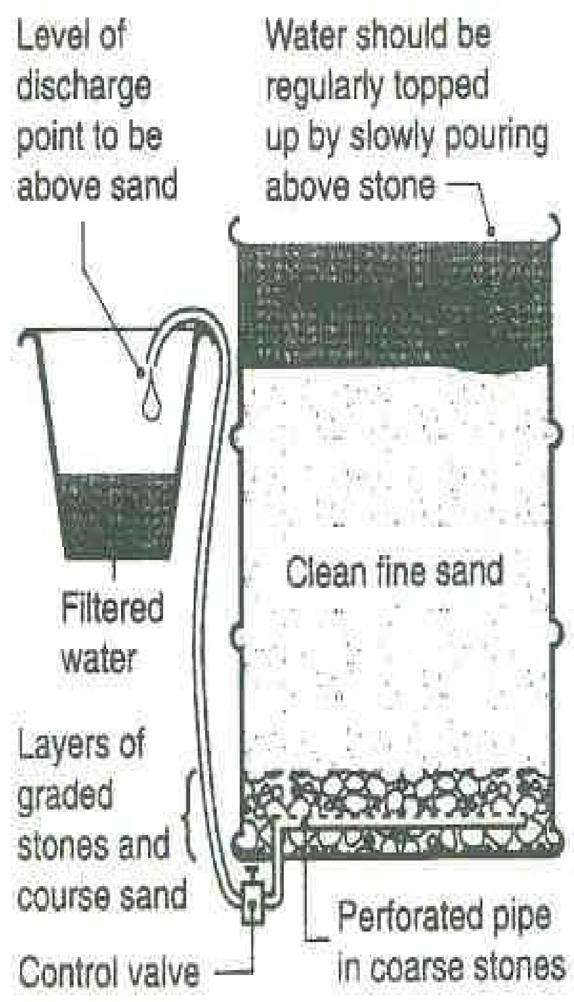
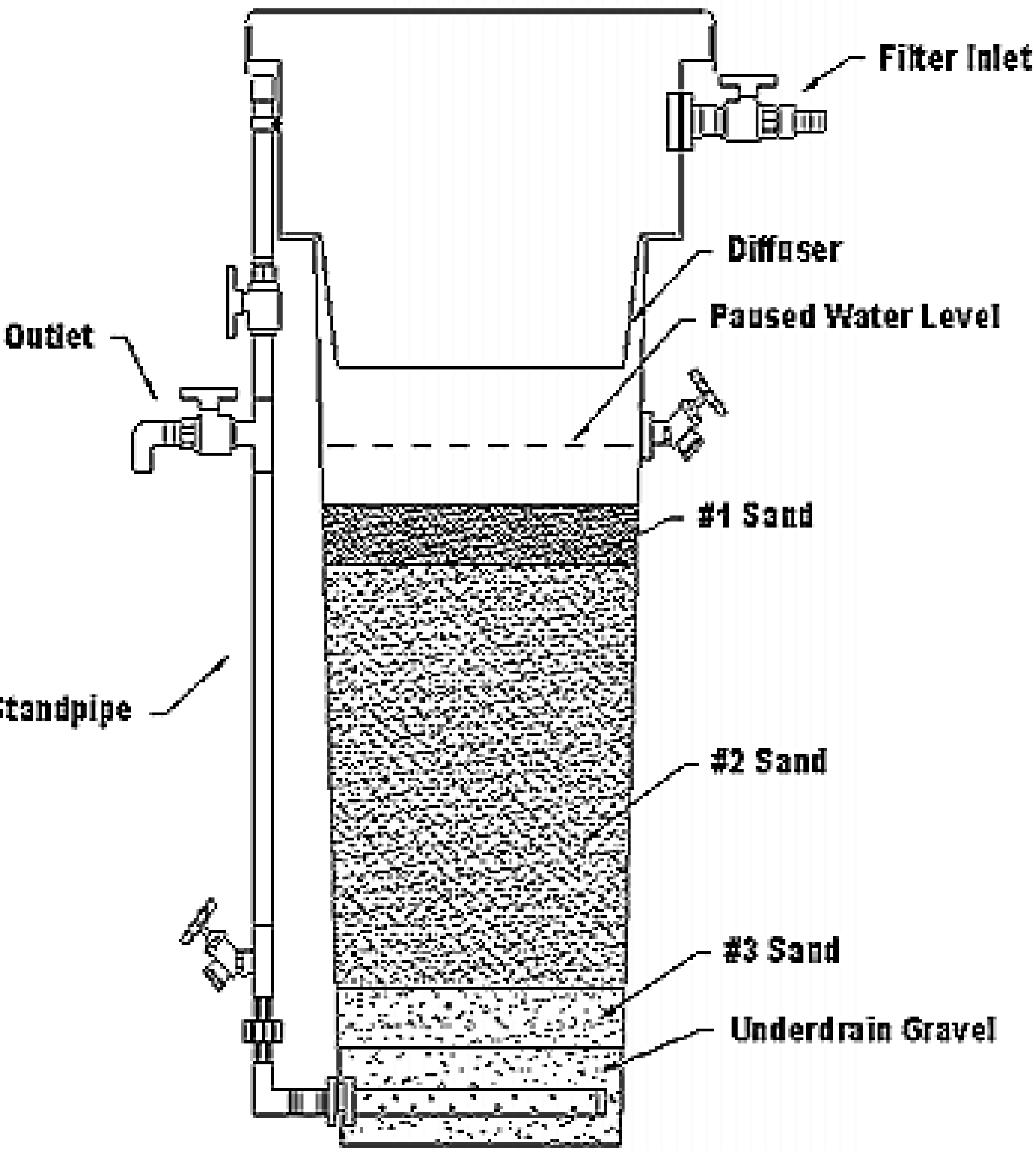


Figure 1. A simple sand filter

Waterlines April 2003 V. 21 #4

BioSand Filter



A variation on this concept is called the "biosand filter." The biosand filter has these characteristics:

- **Intermittent slow sand filter for household use**
- **Invented in the 1990s by Dr. David Manz of Alberta, Canada at the University of Alberta.**
- **Uses of local materials – sand, concrete or plastic**
- **Flow rate (3 - 30L/hr)**
- **Somewhat expensive for low income countries ($25)**


BioSand
Water Fi
Davnor Water Treatm
Calgary, Alb


Melanie Pitcher Filter

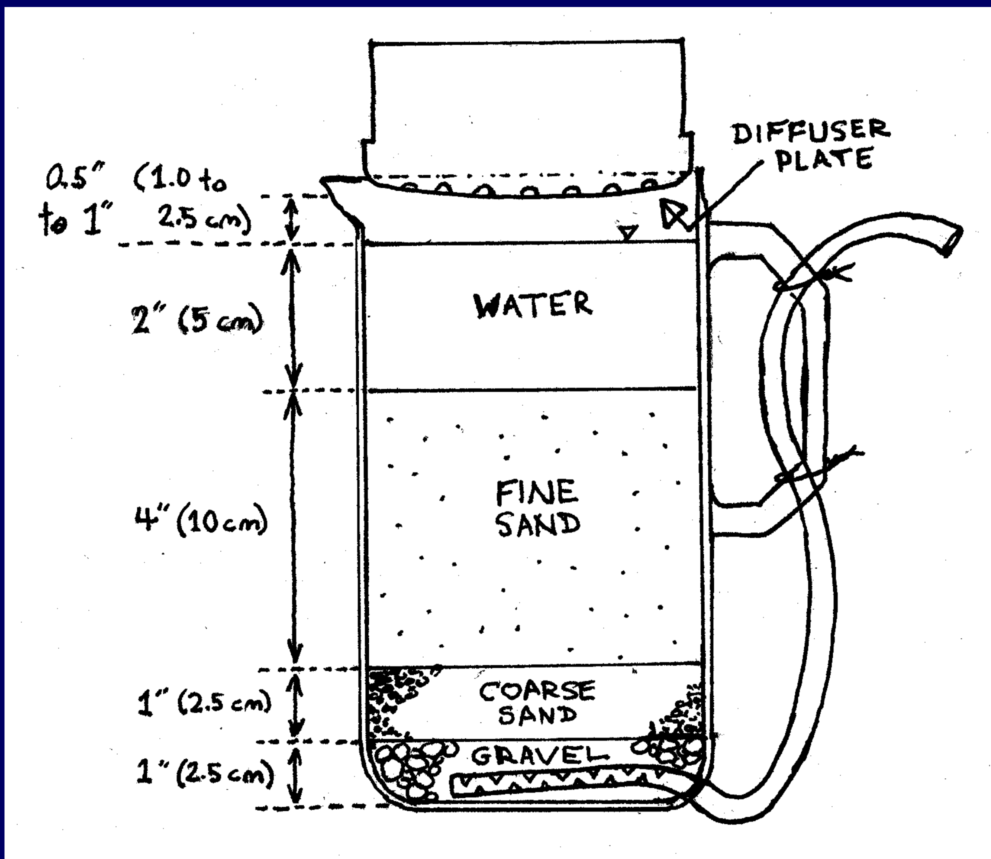
- The Melanie Pitcher Filter is a smaller, portable alternative to the BioSand filter.

- Costs only $1.00!

-It is a potential interim measure for poorer households until they can afford a larger capacity water filter.

- Field and laboratory experiments comparing the Melanie Pitcher Filter with the concrete and plastic biosand filters gave good results!

Melanie Pitcher Filter



- Microbial (*E. coli*) removal of pitcher filters comparable to existing BioSand filtration technology.

	Nepal	MIT
Pitcher filters	80% 86%	97% 97%
BioSand filters	81% 87%	95%
Ripening period (d)	8-10	30-40

- Strong correlation between biofilm maturation periods & source water quality.

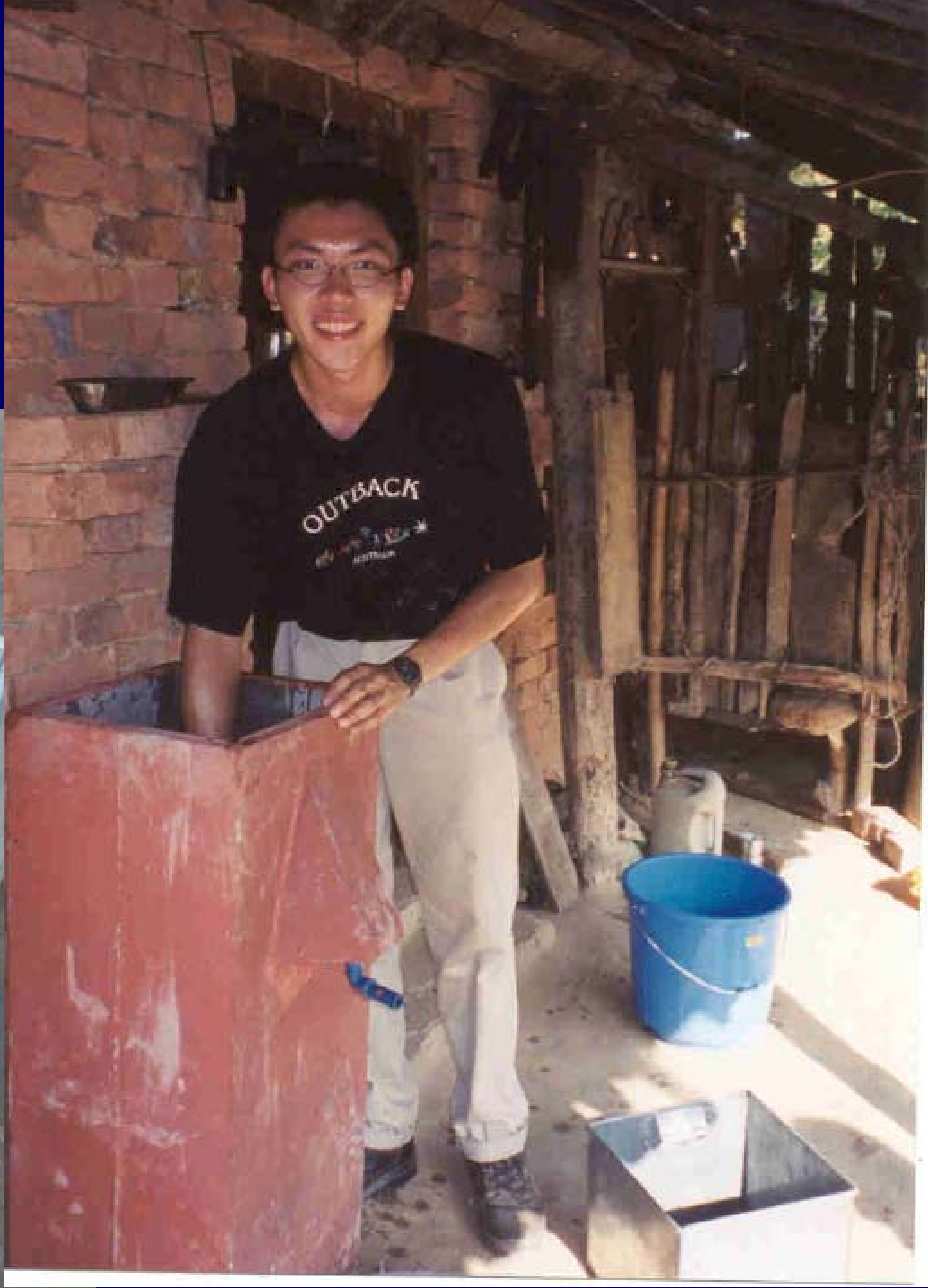
Arsenic Biosand Filter

(the “Tommy Filter”)

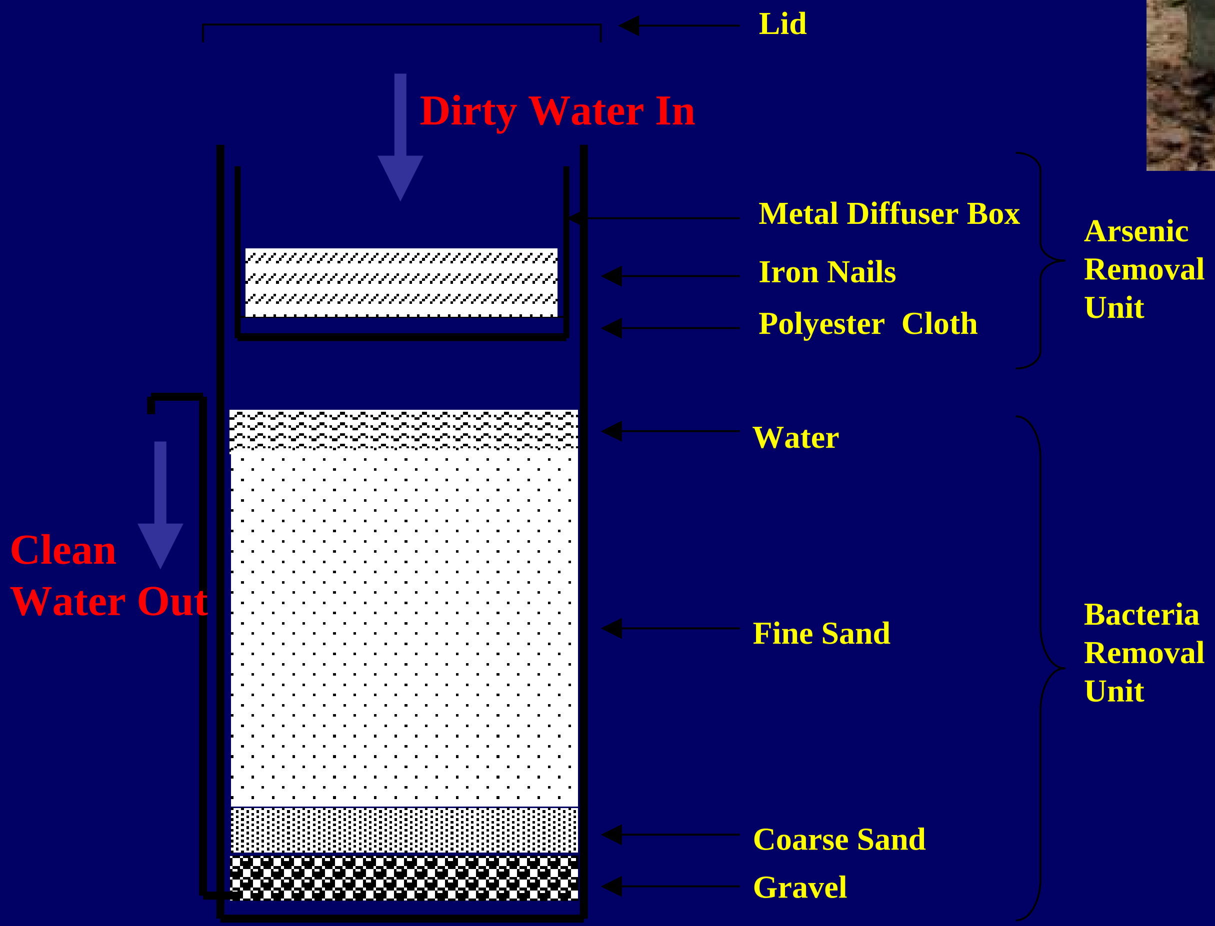
Tommy's Arsenic Biosand Filter

- Invented by Tommy Ngai (M.Eng.2002)
- Won MIT IDEAS Design Competition (2002)
- Concept: Arsenic filter combined with microbiological filter
- Arsenic removed by adsorption to iron nails; bacteria removed by sand filtration and biological means
- Pilot scale studies in Fall 2002 to Spring 2003
- Scale-up to 1,200 units in '03-'04

“The Tommy Arsenic Biosand Filter.” Here’s Tommy installing his filter



Arsenic Biosand Filter Setup



Tommy doing experiment

MIT Nepal Water Project Team Member, Sophie Walewijk (Stanford PhD student), testing Tommy's Arsenic Filter

Technical Performance
(16 Filters Pilot Study)

Technical Indicators	Average Results
Arsenic Removal	93 %
Total Coliform Removal	58 %
E. Coli Removal	64 %
Iron Removal	93 %
Flow Rate	14 L/hr

Social Acceptability
(16 Filter Pilot Study)

Most users like the high flow rate, simple operation, and minimal maintenance of the filter. In addition, the clean-looking and good-tasting filtered water is appealing. While health improvements may take months or years to appear, these favorable "observable" water qualities (e.g. clarity, color, taste, iron removal) may promote quick acceptance of the filter. Most users think the ABF (the "Tommy Filter") is a durable and appropriate solution to arsenic and pathogens contamination. Researchers in Nepal regard the ABF as the best technology available in Nepal.

Xanat's Semi Continuous Solar Disinfection

Semi- Continuous Solar Disinfection

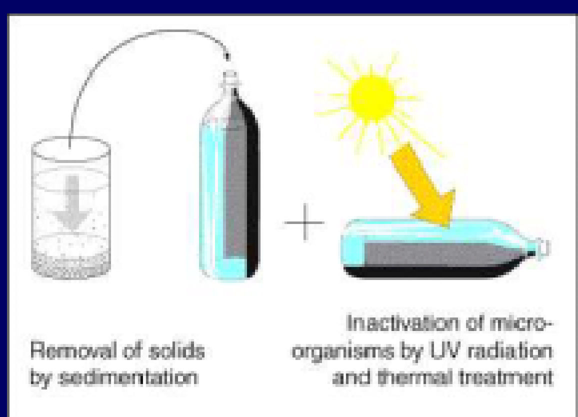
MIT environmental engineering student, Xanat Flores, from Mexico, developed a semi-continuous solar disinfection system!

It costs about $1.00!

But before we explain Xanat's system, we need to explain SODIS.

What is SODIS?

- PET plastic bottles exposed to solar radiation for 1-2 days to disinfect drinking water
- Variations:
  - Exposure time
  - Clear, black or reflective surface



SODIS
Solar Water Disinfection

Publications
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Conference
Cooperation Partner

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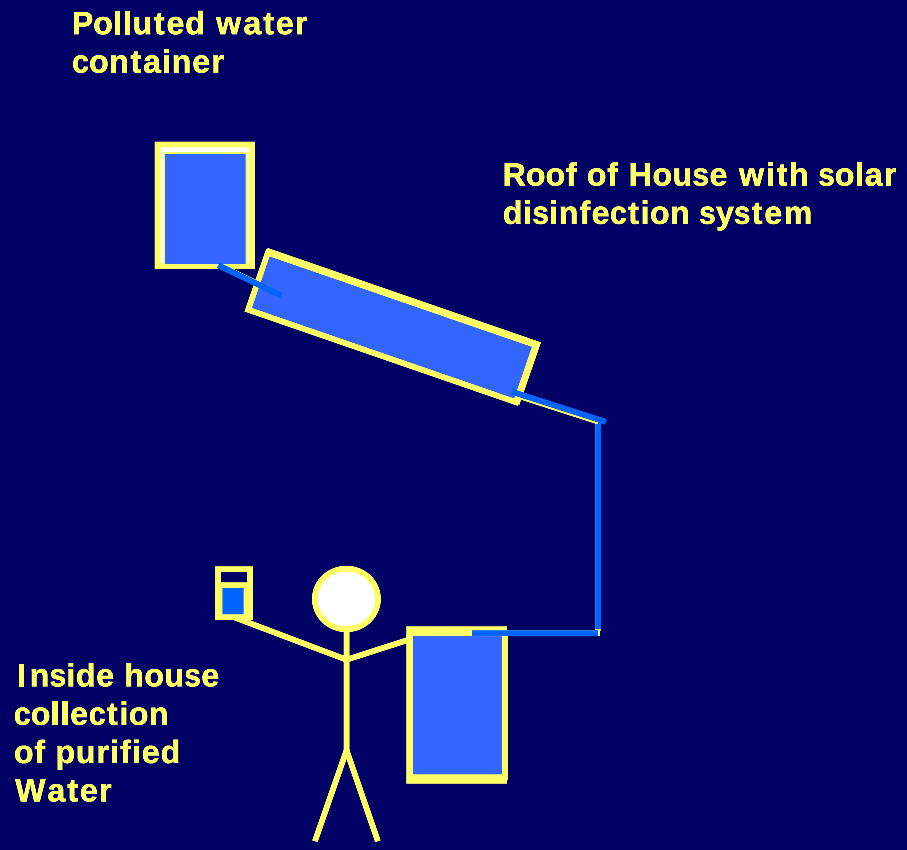
- SODIS requires relatively clear water (
- SODIS needs solar radiation (exposure time: 5 hours under bright c consecutive days under 100% cloudy

SODIS

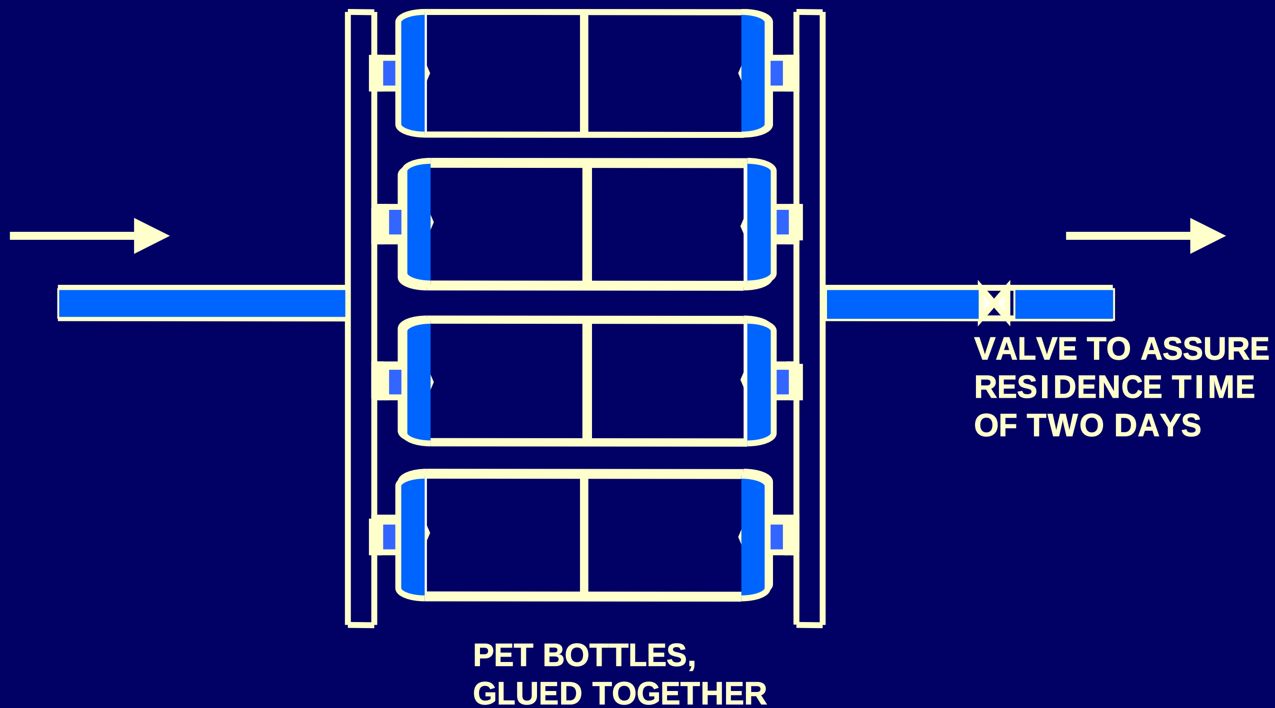
- SODIS was invented by Prof. A. Acra *et al.* of American University of Beruit, Lebanon in 1982.
- Researchers at the Swiss Federal Institute of Environmental Science and Technology (ETH-EAWAG/SANDEC) took up extensive studies of SODIS beginning in 1991.
- MIT students have investigated SODIS in Nepal and Haiti since 1999.

Here’s Amer Khayyat, also of Lebanon, studying SODIS in Nepal in January 2000

What is Semi-Continuous SODIS?



SEMI-CONTINUOUS SODIS

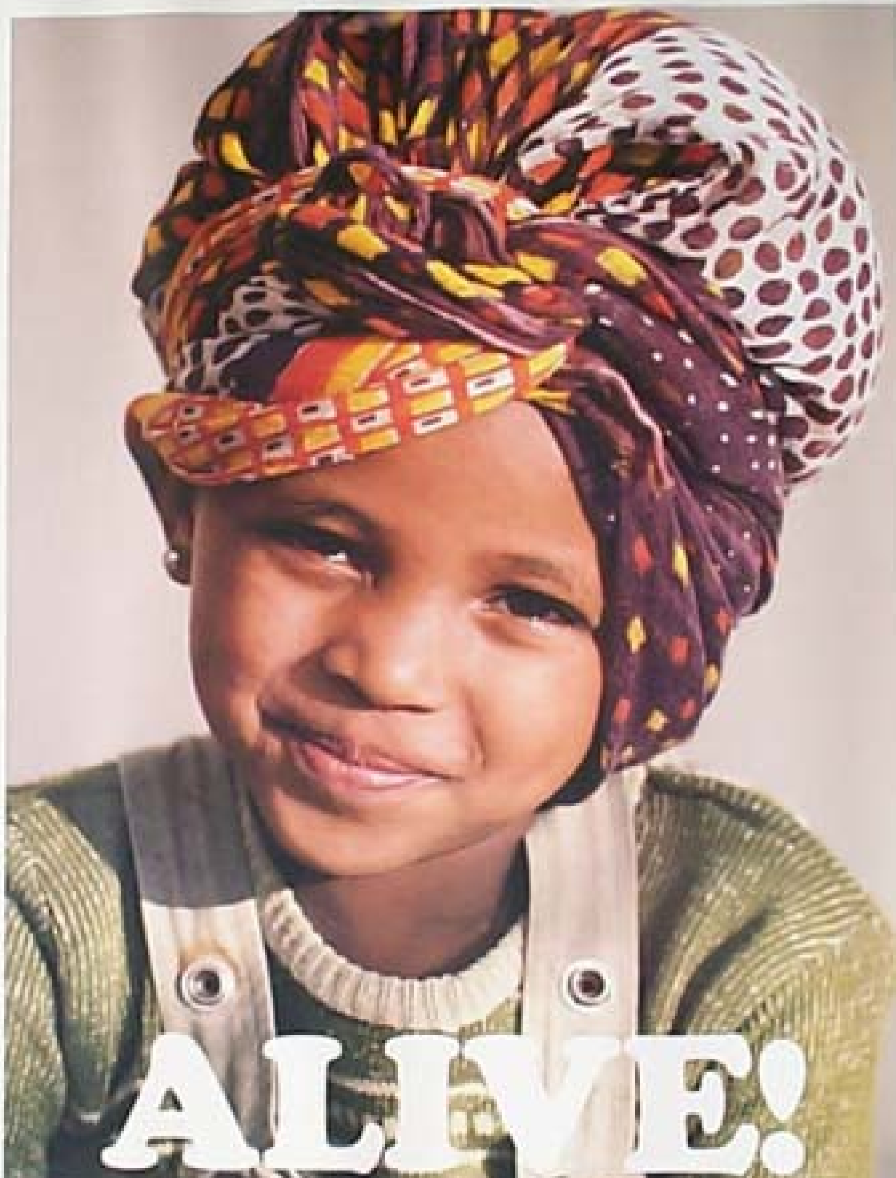


Xanat performs Semi-Continuous SODIS experiments Lumbini, Nepal -- January 2003

Semi-Continuous SODIS

- Uses recycled clear, plastic bottles (PET) bottles, cut in 2 and glued together.
- Disinfects water by 2 means:
  - Solar Radiation and the Sun's Heat
- Simple

What Would You Like to be When You Grow Up?



Questions?