Innovative and Sustainable Technologies to Address the Global Arsenic Crisis

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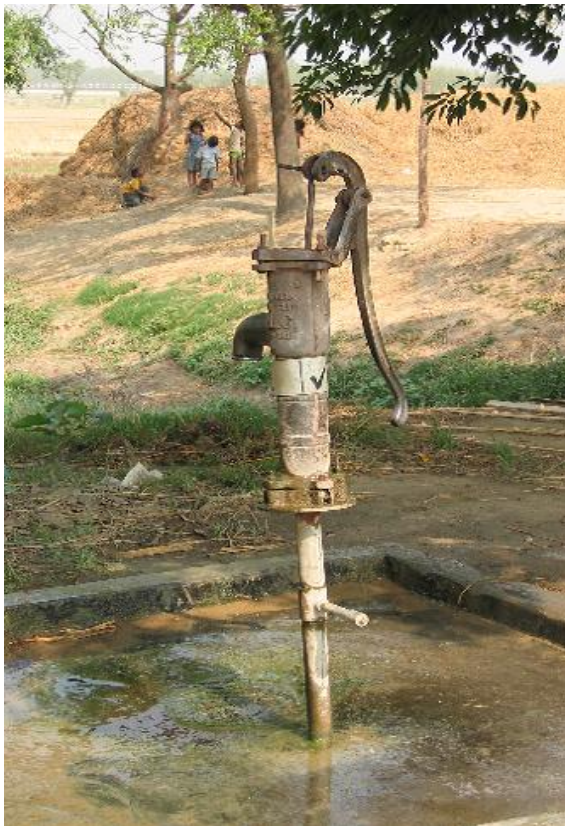
Sandia National Laboratories 2005 Vendor's Forum
Albuquerque, New Mexico
November 2, 2005



Outline

1. Global Extent of Arsenic in Drinking Water
2. Innovative and Sustainable Technologies
3. Several Implementation Efforts
4. *Kanchan*™ Arsenic Filter

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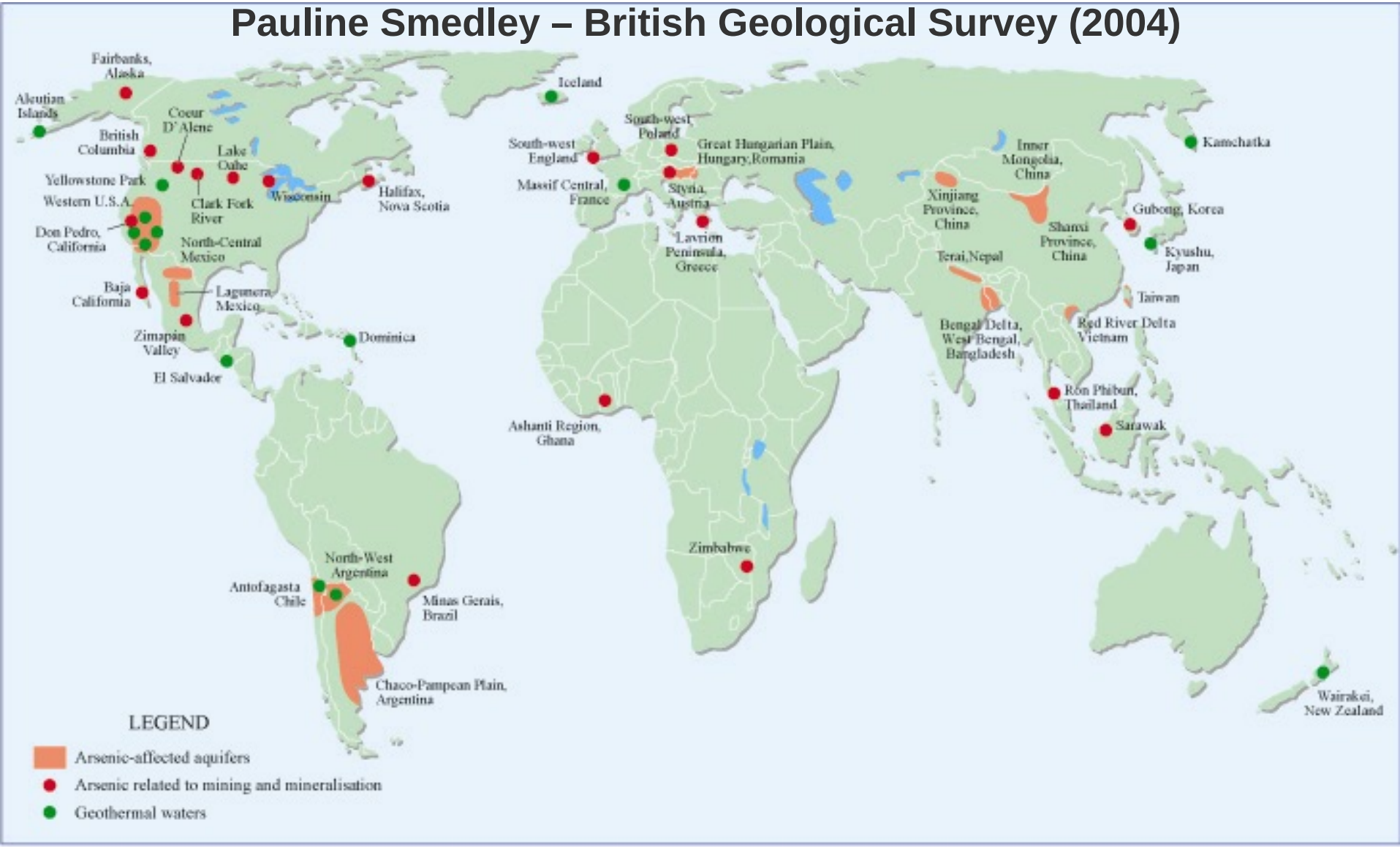
Global Extent of Arsenic in Drinking Water

Global Map of Regions with Arsenic in Drinking Water

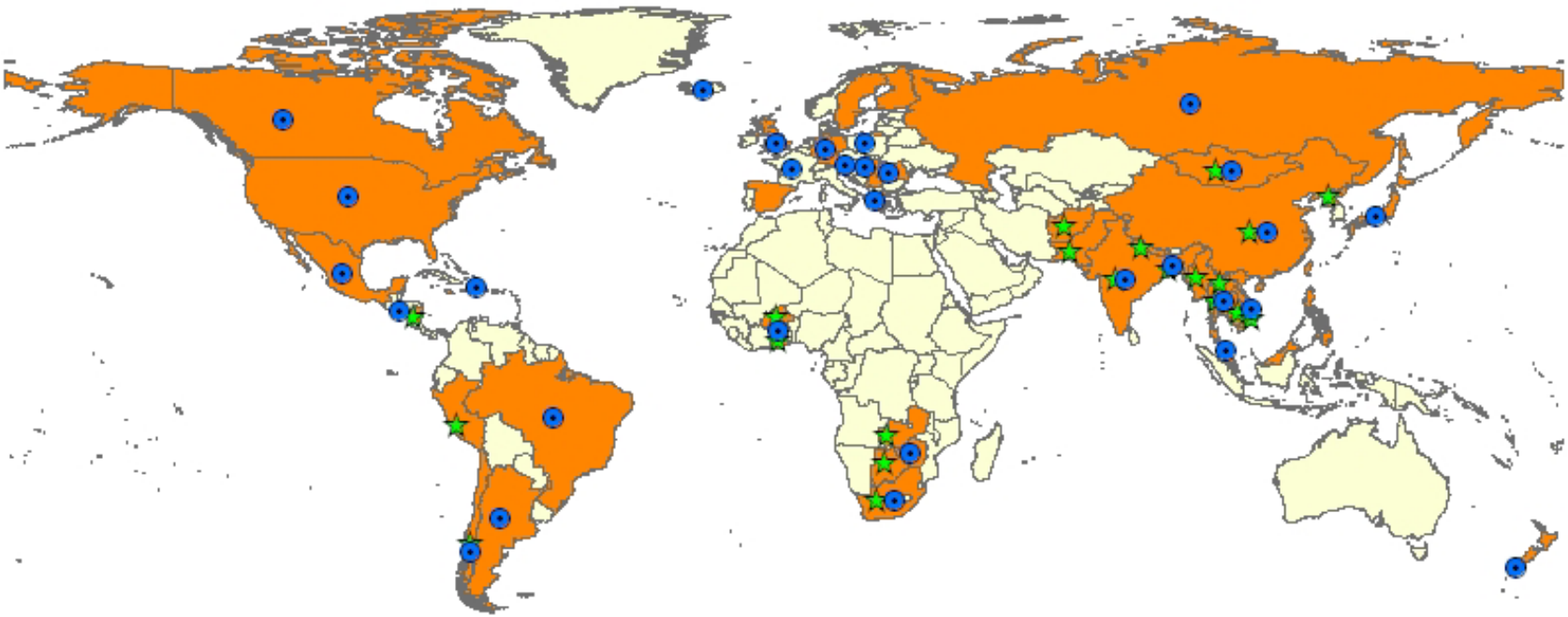
Pauline Smedley – British Geological Survey (2004)



Smedley, P. 2004. Essentials of Medical Geology Ed: Selinus, O., London: Elsevier Academic Press.

Global Map of Countries with Arsenic in Drinking Water

(from Aquifers, Mining Operations or Geothermal Waters)



★ 21 Countries Affected by Arsenic Identified by UNICEF (Ali,M., 2005)

● 30 Countries Affected by Arsenic Identified by Smedley (Smedley, 2004)

(Murcott, S. 2005)
(Map by Zheng Gong, MIT '08)

48 Countries with Arsenic in Drinking Water Identified by Murcott Literature Review (2005)

- **Africa**
- 1.Botswana
- 2. Burkina Faso
- 3. Ghana
- 4. South Africa
- 5. Zambia
- 6. Zimbabwe

- **Asia-South**
- 7. Afghanistan
- 8. Bangladesh
- 9. India (West Bengal)
- 10. Pakistan
- 11. Nepal

- **Asia-East**
- 12. China including Taiwan
- 13.Japan
- 14. Mongolia
- 15.North Korea
- 16.South Korea
- 17.Malaysia
- 18.Philippines
- 19.Russia

- **Asia – South East**
- 20. Cambodia
- 21. Lao
- 22. Myanmar
- 23.Thailand
- 24.Vietnam

- **South America**
- 25.Argentina
- 26.Brazil
- 27.Chile
- 28. Peru

- **Central America and Caribbean**
- 29. Dominican Republic
- 30. El Salvador
- 31. Jamaica
- 32. Mexico
- 33.Nicaragua

- **North America**
- 34. USA
- 35. Canada

- **Europe**
- 36. Austria
- 37. Finland
- 38. Germany
- 39. Greece
- 40.Hungary
- 41. Iceland
- 42. Poland
- 43. Romania
- 44.Serbia
- 45.Spain
- 46. Sweden
- 47. U.K.

South Pacific

48. New Zealand

Table 1. Summary of the Distribution, Nature, and Scale of Documented Arsenic Problems (>50 μg L^{-1}) in Aquifers in South and East Asia

Location	Areal extent (km^2)	Population at risk[a]	Arsenic range (μg L^{-1})
Alluvial/deltaic/ lacustrine plains			
Bangladesh	150,000	35,000,000	<1-2,300
China (Inner Mongolia, Xinjiang, Shanxi)	68,000	5,600,000	40-4,400
India (West Bengal)	23,000	5,000,000	<10-3,200
Nepal	30,000	550,000	<10-200
Taiwan (China)	6,000	(?) 10,000[b]	10-1,800
Vietnam	1,000	10,000,000[c]	1-3,100
Myanmar	(?) 3,000	3,400,000	-
Cambodia	(?) <1,000	320,000[d]	-
Pakistan	-	-	-

- Not available.
[a] Estimated to be drinking water with arsenic >50 μg L^{-1}. From Smedley 2003 and data sources therein.
[b] Before mitigation.
[c] United Nations Children's Fund (UNICEF) estimate.
[d] Maximum.
Source: World Bank Regional Operational Responses to Arsenic Workshop in Nepal, 26-27 April 2004.

60 million at risk in Asia (estimate)

Source: World Bank. Towards a More Effective Operational Response. Vol 1. Policy Report, 2005 p. 26

Table 3. Bangladesh: Estimated Health Impact of Arsenic Contamination of Tubewells

Impact on health/ type of illness	Males	Females	Combined
Cancer cases:			
Fatal cancers/year	3,809	2,718	6,528
Nonfatal cancers/year	1,071	1,024	2,095
Total cancer fatalities accumulated over 50 years	**190,450**	**135,900**	**326,400**
Arsenicosis cases[a]:			
Keratoses	277,759	74,473	352,233
Hyperpigmentation	654,718	316,511	971,230
Cough	21,823	68,887	90,712
Chest sounds	144,831	67,025	211,858
Breathlessness	93,247	176,874	270,122
Weakness	132,927	240,176	373,104
Glucosuria	67,887	63,551	131,439
High blood pressure	94,396	88,366	182,762
Total arsenicosis cases in each year	**1,487,588**	**1,095,863**	**2,583,460**

[a] *Figures indicate average number of cases occurring in each year (not number of new cases).*
Source: Maddison, Luque, and Pearce 2004, p. 32.

Deaths/year

Cases/year

Source: World Bank. Towards a More Effective Operational Response. Vol 1. Policy Report, 2005 p. 28

Table 4. Estimated Annual Deaths from Diarrheal Disease of Children under Five

Country	Region	Annual total mortality of children under the age of five[a]	Low estimate (15% of child mortality under 5 years due to diarrhoea)	High estimate (30% of child mortality under 5 years due to diarrhoea)
Bangladesh	South Asia	323,000	48,450	96,900
Cambodia	East Asia	65,000	9,750	19,500
China	East Asia	735,000	110,250	220,500
India	South Asia	2,346,000	351,900	703,800
Lao PDR	East Asia	20,000	3,000	6,000
Myanmar	South Asia	129,000	19,350	38,700
Nepal	South Asia	74,000	11,100	22,200
Pakistan	South Asia	579,000	86,850	173,700
Vietnam	East Asia	64,000	9,600	19,200
South Asia total		3,451,000	517,650	1,035,300
East Asia total		884,000	132,600	265,200
Total		4,335,000	650,250	1,300,500

[a] Data from UNICEF website.

Deaths in Asia

Source: World Bank. Towards a More Effective Operational Response. Vol 1. Policy Report, 2005 p. 29

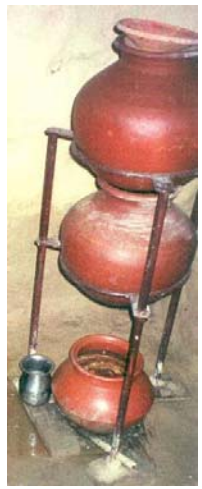
Some Observations from the Numbers

- Arsenic is a critical global public health problem;
- In Asia, 60 M people are at risk of arsenicosis
- In Bangladesh, the country currently thought to be the worst affected by arsenic contamination, the number of deaths from arsenicosis is estimated to be 6,500/year
- Yet in Bangladesh, 50,000 – 100,000 people/year, mostly children under 5, die from waterborne microbial diseases and there are 650,000 – 1.3 million deaths/year from microbial diseases in Asia. .
- With waterborne pathogens causing so many more cases of illness and death than arsenicosis (based on our best evidence we have today), it is important to integrate arsenic mitigation considerations into an overall strategy to address water-related diseases.

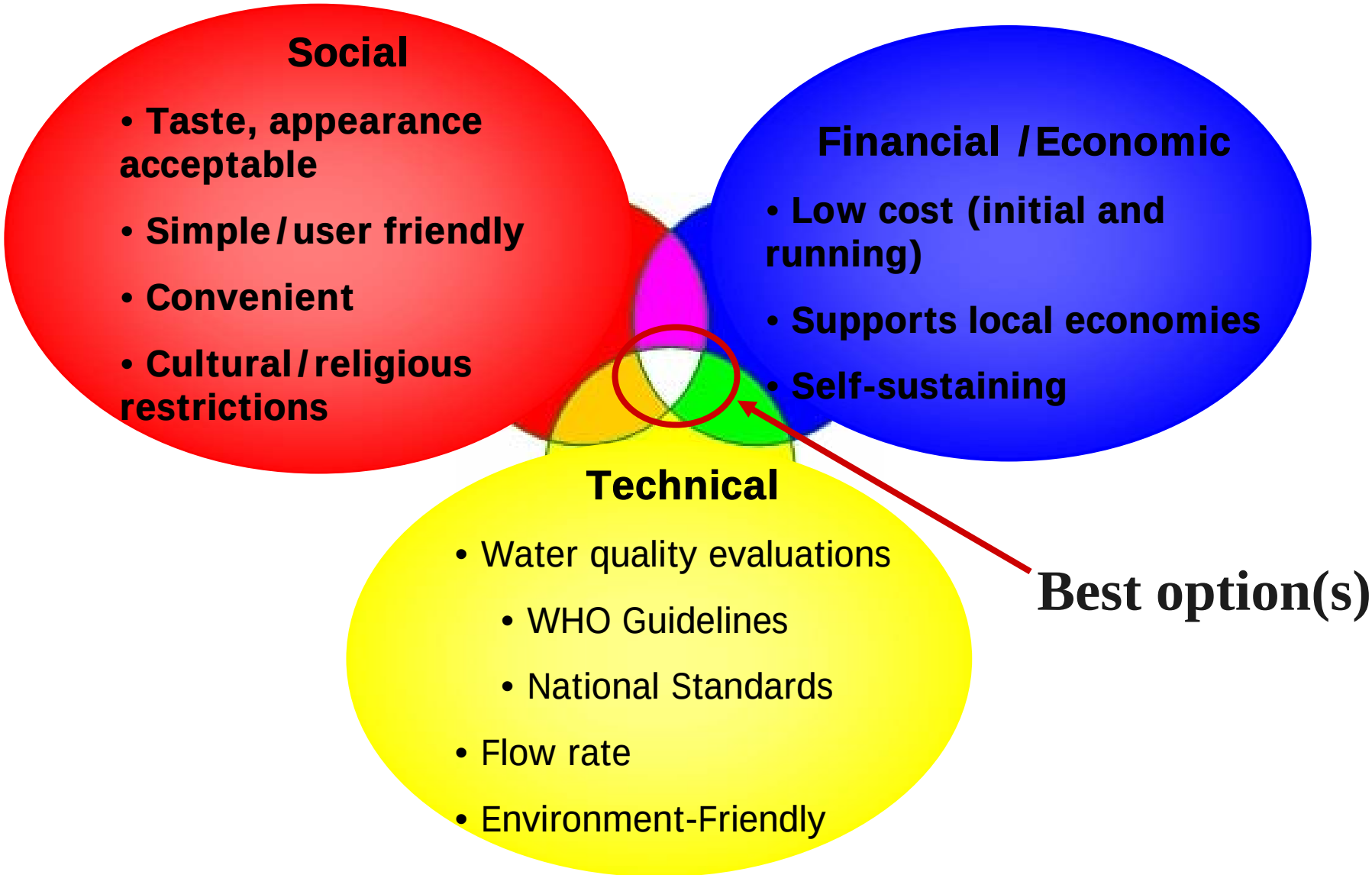
Some people affected by arsenic and/or microbially contaminated drinking water

2

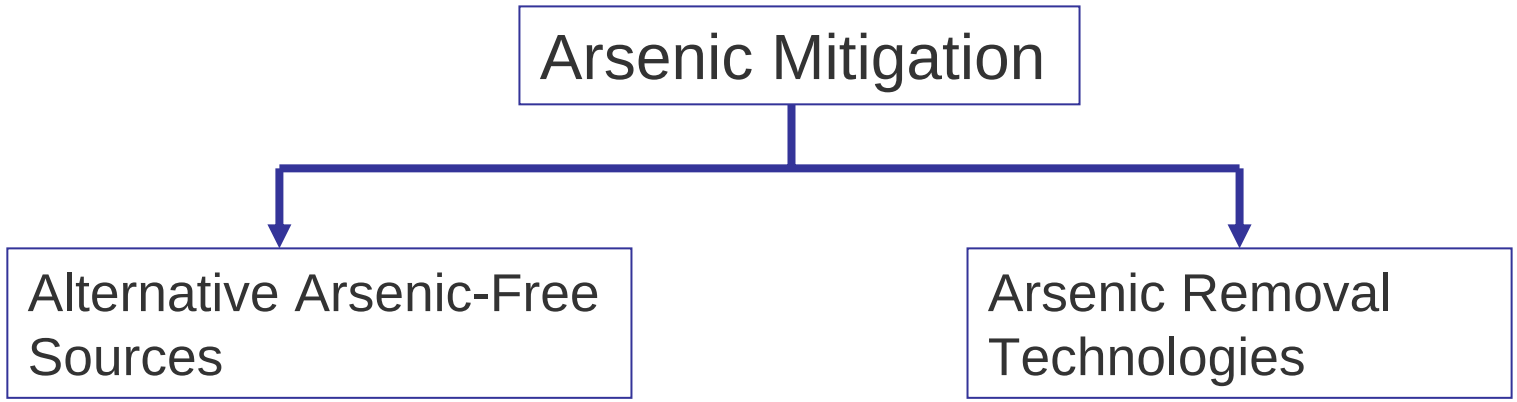
Arsenic Mitigation Options



Design for Sustainable Development



Overview of Mitigation Options



- Safe tube wells
- Improved Dug wells
- Deep wells
- Rainwater harvesting
- Surface water treatment

Safe Tube Wells

Tube wells with arsenic levels within the relevant standards

Advantage:
- Immediate solution

Limitations:
- Need regular monitoring
- Convenient?
- Customs and religious restrictions?

Cost:
- Testing cost
- (cost of drilling and installing a shallow tubewell is ~US$100 - $300

Improved Dugwells

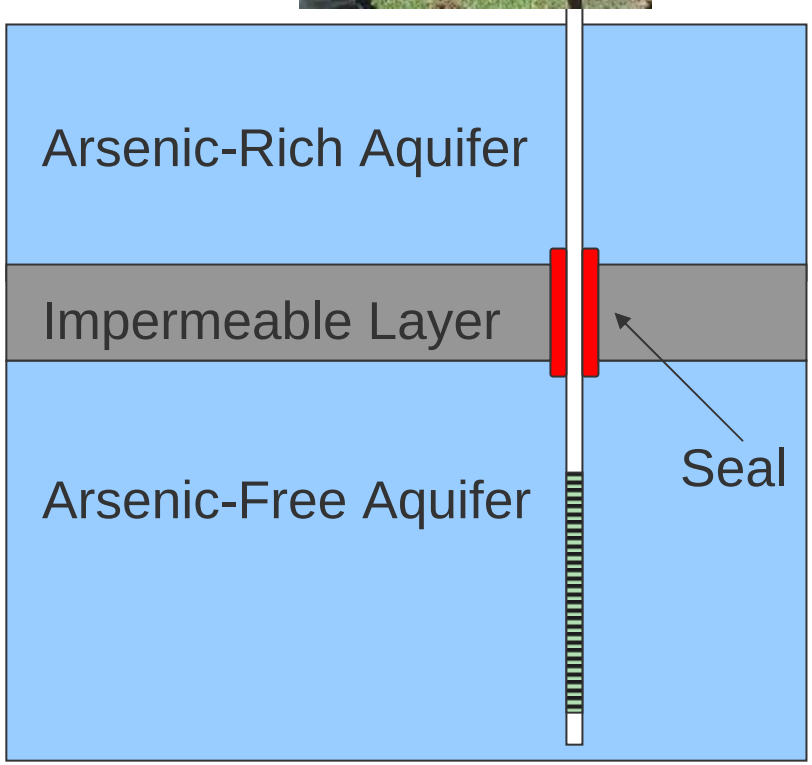
Cover existing dugwells to minimize microbial contamination

Advantages:
- Simple, well established technology

Disadvantage:
- May dry up in dry season
- Potential sewerage and agricultural chemical contamination
- Risk of arsenic contamination
- Digging not easy in some places
- Taste and odour problem

Cost:
- US$1000+ for new construction
- US$300 for rehabilitation
- minimal maintenance cost

Deep Wells



Community-level deep wells to tap arsenic-free aquifers

Advantages:
- Generally microbial-free and arsenic-free

Limitations:
- Improper drilling/sealing → contamination
- Risk of arsenic and salt in deep aquifer
- Long-term arsenic levels unknown
- Appropriate geology not everywhere
- May require a more sophisticated pump

Cost:
- US$200 to $1000+
- Minimal maintenance cost

Rainwater Harvesting

Collect rainwater from rooftop in storage containers for later use

Advantages:
- Few natural chemical contamination
- Low microbial contamination

Limitations:
- Rainfall pattern → may need large collection tank → high cost
- Water low in minerals
- Some roofs not suitable

Cost:
- US$200+ initial
- Minimal maintenance cost

Surface Water Treatment

Treat available surface water from ponds, rivers, springs, canals, etc

Water quality/quantity issues:

- Usually high microbial contamination
- Risk of agricultural and industrial chemicals contamination
- Quantity may be inadequate during certain periods

Surface Water Treatment – Community Scale

Example: Pond Sand Filtration

Community-level slow sand filter + possible chlorination

Advantages:
- Good removal of turbidity, colour, odour

Limitations:
- Incomplete microbial removal → need effective disinfection
- May not remove pesticides, fertilizers, and other chemicals
- High maintenance

Cost:
- US$300-500 initial
- Hire one technician for operation and maintenance

Surface Water Treatment – Household Scale

Example: Biosand Filters

Slow sand filter adapted for intermittent use for a household

Advantages:
- Removal of turbidity, colour, odour
- Good microbial removal
- High flow rate (15-30L/hr)

Limitations:
- Not 100% microbial removal, may require post-disinfection
- May not remove pesticides, fertilizers, and other chemicals

Cost:
- US$30-50 initial
- Minimal maintenance

Surface Water Treatment – Household Scale

Example: Chlorine Solution

Add a few drops of a pre-made chlorine solution to water

Advantages:
- Simple
- Excellent bacterial/viral removal

Limitations:
- Taste may be unacceptable
- Effectively only for low turbidity water
- Stability of chlorine solution?
- Availability in rural areas?
- Does not inactivate protozoa

Cost:
- US$10 per household per year

Surface Water Treatment – Household Scale

Example: Solar Disinfection (SODIS)

Fill clear plastic bottle with water and place under the sun for 1-2 days, UV rays inactivates pathogens

Developed in Lebanon & Switzerland

Advantages:
- Simple
- Excellent microbial removal

Limitations:
- May not remove pesticides, fertilizers, and other chemicals
- Effectively only for low turbidity water
- Small volume of water treated

Cost:
- Minimal

Surface Water Treatment – Household Scale

Example: Potter for Peace Filter

Pass water through a porous, colloidal silver soaked ceramic container. Small pores and silver traps and inactivates pathogens.

Advantages:
- Simple
- Excellent microbial removal

Limitations:
- Fragile
- Low flow (1-2L/hr)
- Requires frequent cleaning for turbid water

Cost
- US$10-15 initial
- Minimal maintenance cost

Overview of Mitigation Options

Arsenic Mitigation

Alternative Arsenic-Free Sources

Arsenic Removal Technologies

- Aeration/Oxidation
- Coagulation/Precipitation
- Adsorption
- Ion-Exchange
- Membrane

Aeration + Precipitation

Example: Arsenic Iron Removal Plant

Tube well water pumped directly into an aeration tank, then sand filtered, and collected in storage tank.

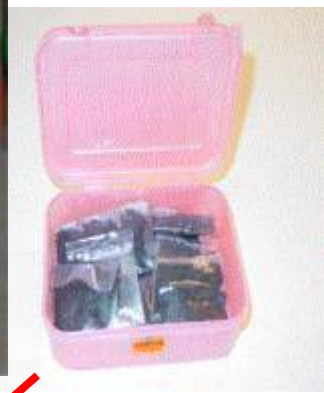
Advantages:
- Constructed with locally available material
- Excellent iron removal

Limitations:
- Microbial contamination likely
- Lack of maintenance by users
- Arsenic not effectively removed if iron is low
- Convenient?

Cost
- US$200-300
- Minimal maintenance cost

Coagulation + Filtration

Example: 2-Kolshi (sodium hypochloride, ferric chloride, ash)



Oxidizes As(III) to (V), and co-precipitate with ferric chloride and ash, then filtered

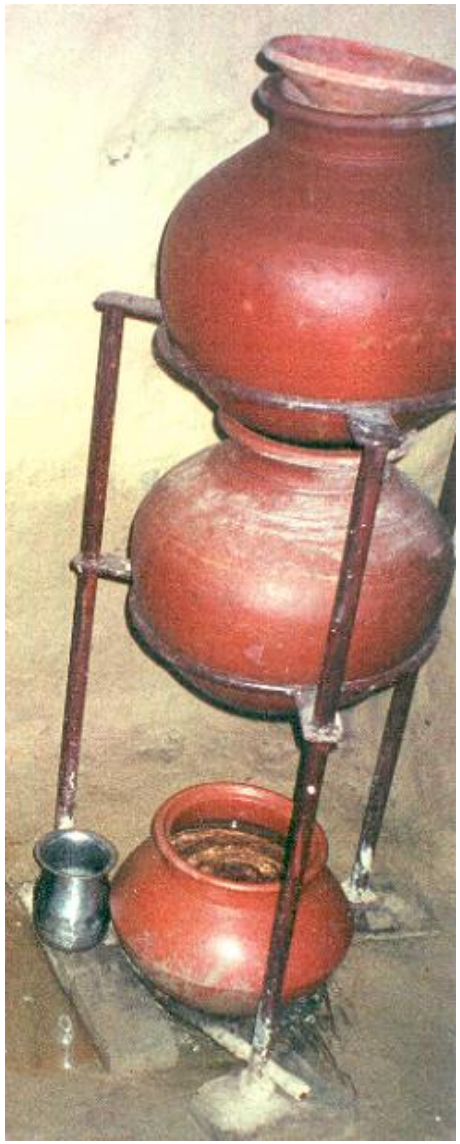
Advantages:
- Simple
- Good arsenic and microbial removal

Limitations:
- Coagulant availability in rural areas?
- Requires time & work to mix, settle, and filter
- Inferences by high PO_4 or silicate

Cost:
- US$5-10 for the equipment
- US$10 per household per year for chemicals

Adsorption

Example: 3-Kolshi (zero-valent iron)



2 kg coarse sand
3 kg iron filings

2 kg sand
1 kg charcoal
2 kg brick chips

Storage

As(III) and (V) adsorbed on iron filings

Developed in Bangladesh by Sono center and various institutions

Advantages:
- Excellent As(III) and As(V) removal
- Simple
- Indigenous materials available widely

Limitations:
- Microbial contamination likely
- Low flow rate (3-5L/hr) and clogging
- Difficult cleaning
- Fragile

Cost:
- US$5-10
- Minimal maintenance cost

SONO 45-25 (Metaliic Iron, sand)

1 Household, US$ 10

Parameters Verified	Proponent's Claim	Verified Values
Arsenic	750 ppb	≤ 750 ppb
Water Quality	None	
- Iron.	-	≤ 10 ppm
- Phosphate	-	≤ 4 ppm
- pH	-	≤ 7.5ppm
Flow Rate	18 L/hr	15 L/hr
Capacity	74,460 L	8,100 L

(Johnston, R. et al, 2004)

Adsorption

Example: Iron-oxide Coated Sand

As(III) and (V) adsorbed on iron oxide

Advantages:
- Good arsenic removal
- High flow rate
- Easy operation

Limitations:
- Manufacturing not simple (need iron nitrate, NaOH, HCl, and high oven temperature of 550C)
- Short media life (1 year?)
- Easy clogging if iron is high

Cost:
- US$10-15 initial
- replacement of sand US$5-10

Adsorption

Example: Shalpa Filter (iron oxide coated bricks chips)

As(III) and (V) adsorbed on iron oxide

Developed by IDE in Bangladesh

Advantages:
- Good arsenic removal
- Easy operation

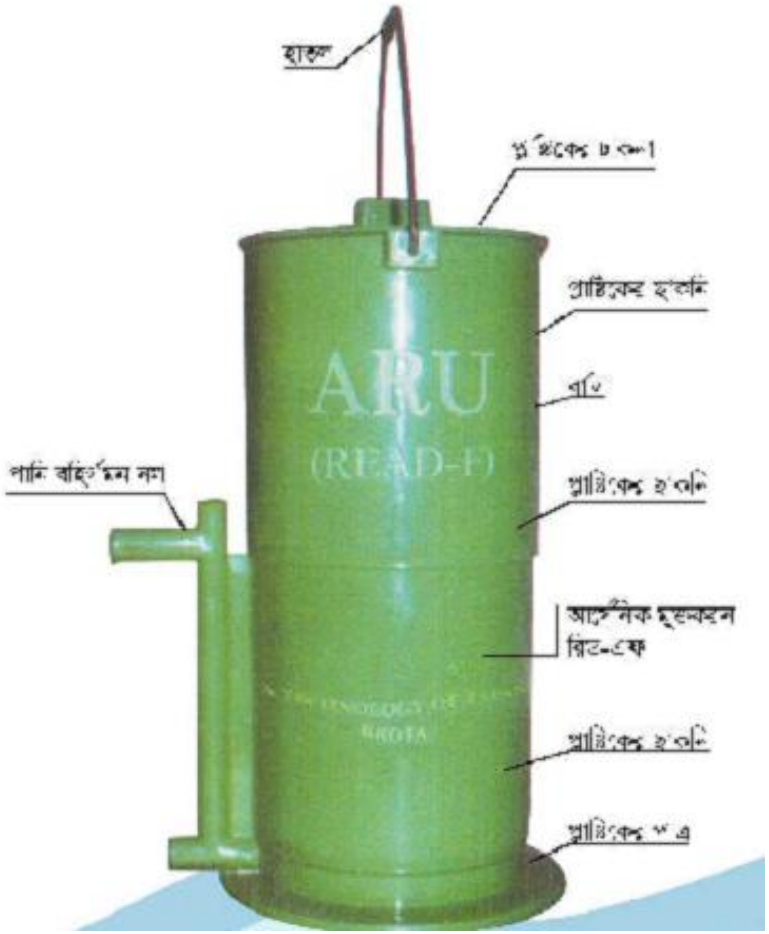
Limitations:
- Manufacturing not simple (need iron sulfate, acid, and high oven temperature)
- Short media life (3 month)

Cost:
- US$5-10 initial
- replacement of media ($10-15 per year)

Adsorption

Example: Read-F (hydrous cerium oxide)

Developed by Shin Nihon Salt Co. Ltd of Japan

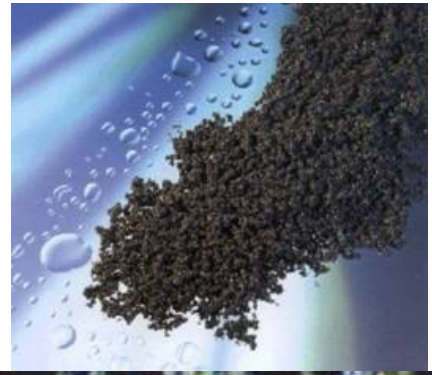


Advantages:
- Excellent As(III) and As(V) removal
- High adsorption capacity
- High flow rate
- Simple operation

Limitations:
- Media availability in rural areas?
- Support local economy?
- Easy clogging if iron is high

Cost
- US$50 per household

Adsorption
Example: Granular Ferric Hydroxide



Developed by GEH Wasserchemie GmbH of Germany and promoted by Sidko of Bangladesh and Pal Trockner of India

Advantages:
- Excellent arsenic removal and capacity
- Very high flow rate
- Spend media safe for disposal

Limitations:
- Media availability?
- Support local economy?
- May clog easily with high iron water
- Less effective at high pH

Costs:
- US$4000 each unit

Adsorption

Example: MAGC/Alcan (Enhanced Activated Alumina)

Developed by MAGC Technologies and Alcan of US

Advantages:
- Excellent arsenic and fluoride removal
- High flow rate
- Spent media safe for disposal

Limitations:
- Media availability in rural areas?
- Support local economy?

Cost:
- US$35 per household

Adsorption

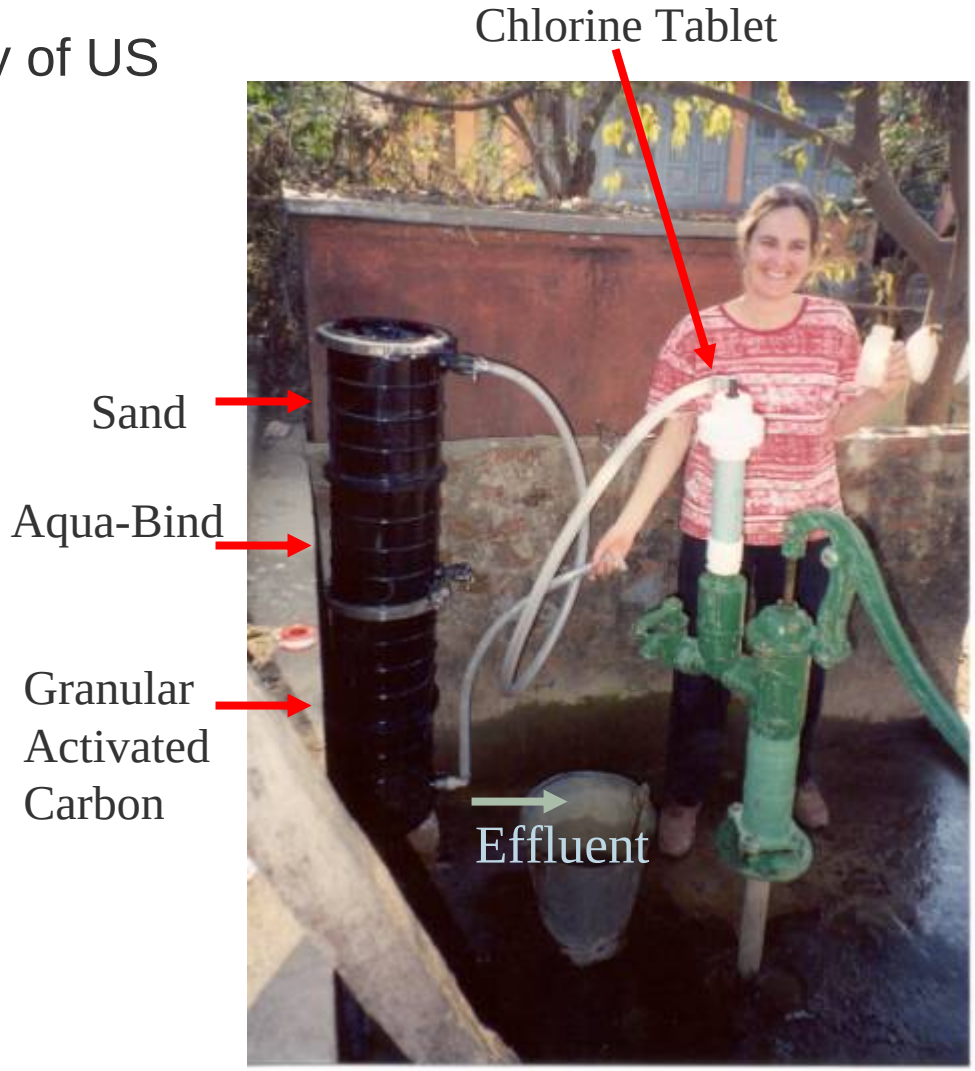
Example: Apyron Aqua-Bind (Enhanced Activated Alumina)

Developed by Apyron Technology of US

Advantages:
- Excellent arsenic removal
- Very high flow rate (100+ L/hr)
- Spent media safe for disposal

Limitations:
- Availability in rural areas?
- Support local economy?

Cost:
- US$2000 per unit



Adsorption

Example: Water Hyacinth Plant Roots (*Eichhornia crassipes*)

Dried hyacinth root powder mixed with arsenic water for 30 minutes then filtered

Advantages:
- Promising technology, 93-95% arsenic removal

Limitations:
- Technology still under development
- Where to obtain this plant?
- How to prepare the powder?
- Safe disposal?

Cost:
- unknown, but probably inexpensive

S. Al Rmalli, C. Harrington, M. Ayub, P. Haris. "A biomaterial based approach for arsenic removal from water". Journal of Environmental Monitoring. 2005, volume 7, 279-282.

Ion-Exchange
Example: Tetrahedron

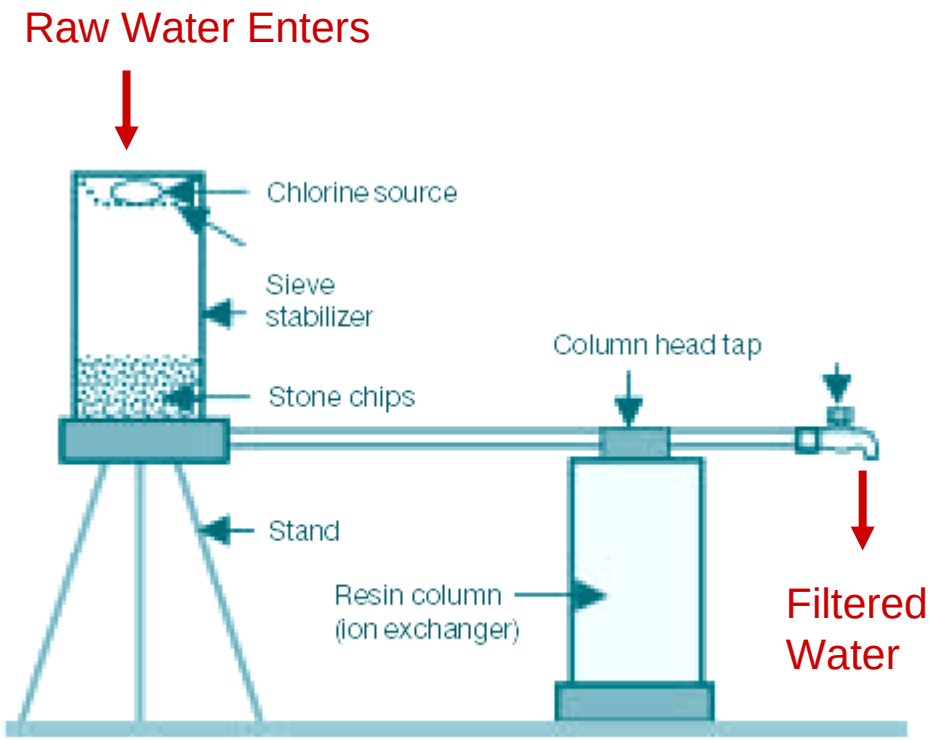
Developed by Tetrahedron Inc of US

Chlorination, stabilization, followed by ion-exchange to remove arsenic

Advantages:
- Good microbial removal
- Good arsenic removal
- High flow rate (50L/hr) for 20-50 households

Limitations:
- High initial cost
- Arsenic removal varies depending on operating conditions

Cost:
- initial cost ~US$250
- annual operating cost ~US$100



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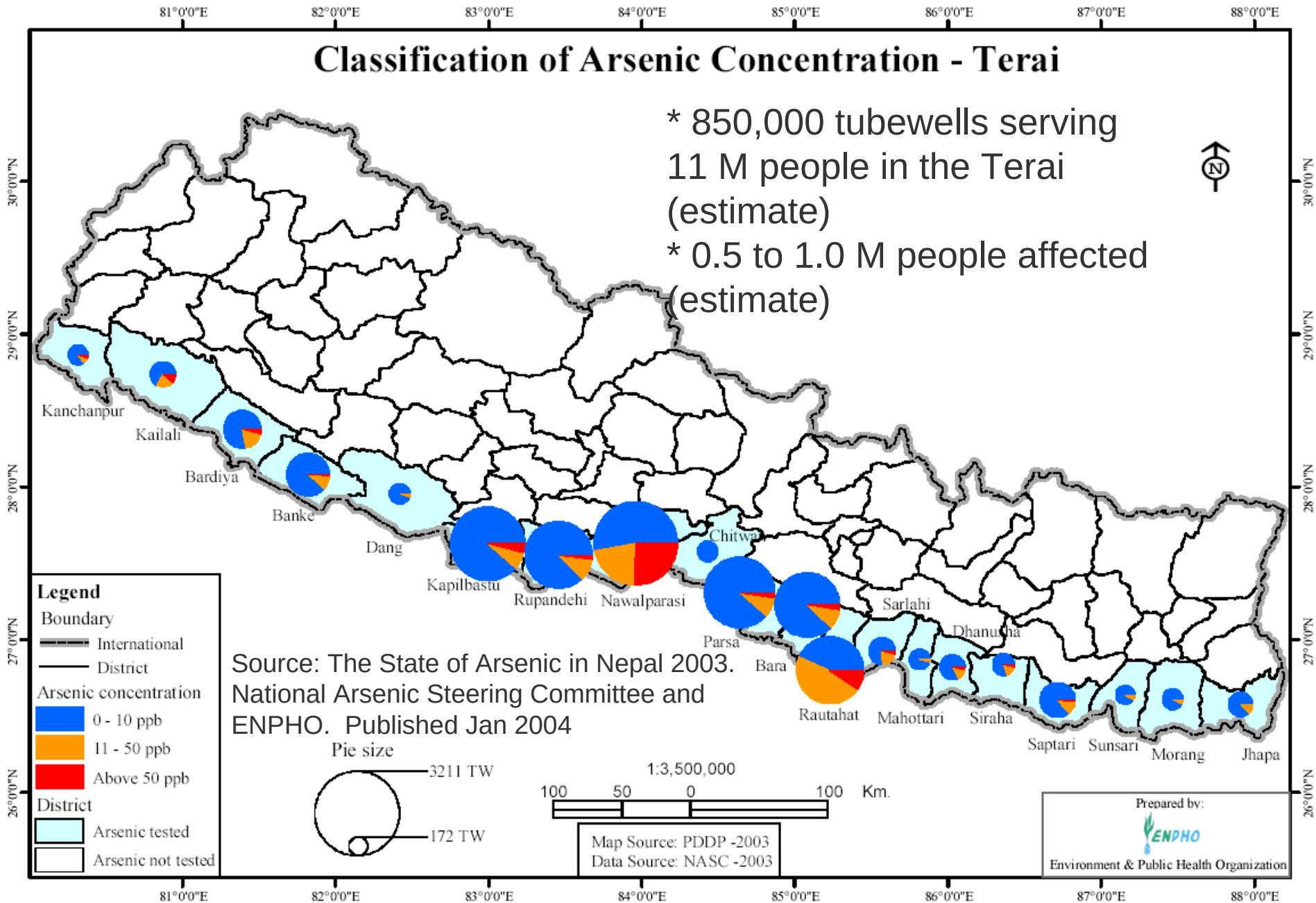
A Few Implementation Efforts

Arsenic Testing – ENPHO and National Arsenic Steering Committee



Source: The State of Arsenic in Nepal 2003. National Arsenic Steering Committee and ENPHO. Published Jan 2004

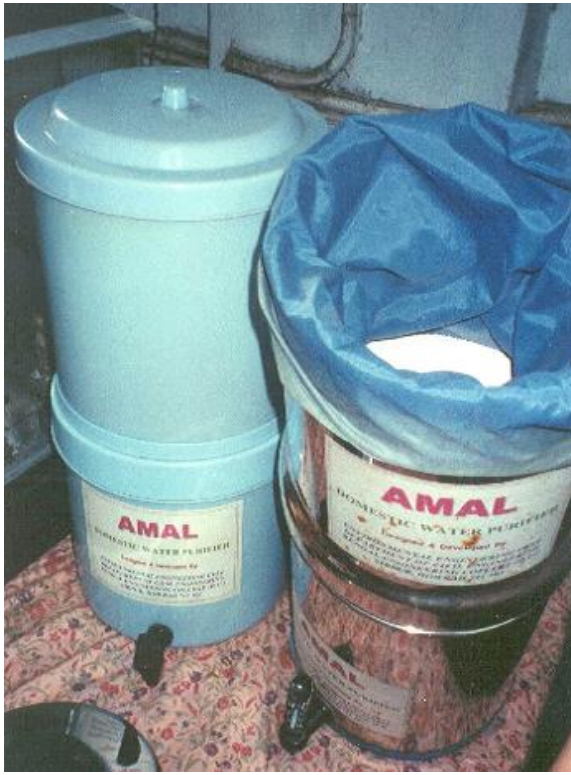
West Bengal, INDIA

AMAL (Indian-made activated alumina)

Partnership with Bengal Engineering College, Lehigh University, Water for People, Hilton Foundation, (also SolmeteX has provided media)

*140+ installed systems, locally installed by Kar Enterprises, at the rate of 40 installations/year

- Operation by a local technician
- Maintenance& backwash by BEC staff
- Good flow rate
- Excellent arsenic removal
- Cost $1500-$2000/unit



ArsenX has been installed in several units

World Health Organization and local Ministries of Health in South East Asia

* Estimated 10 M people exposed in Vietnam; 3.4 M in Myanmar

* Pilot studies underway in selected villages to determine acceptability of household treatment interventions

Source: Dave Fredericks, Research needs for household level treatment to remove arsenic and fluoride in drinking water in SE Asia. Presentation to the 2005 International Symposium on Household Water Management, 1-2 June 2005, Bangkok.

http://geography.about.com/library/cia/blcvietnam.htm

the International Network to Promote Safe Household Water Treatment and Storage

A Public-Private Partnership
hosted by:

World Health Organization

GHANA

New Mexico Tech Laterite System

Developed by David Norman & students at New Mexico Tech

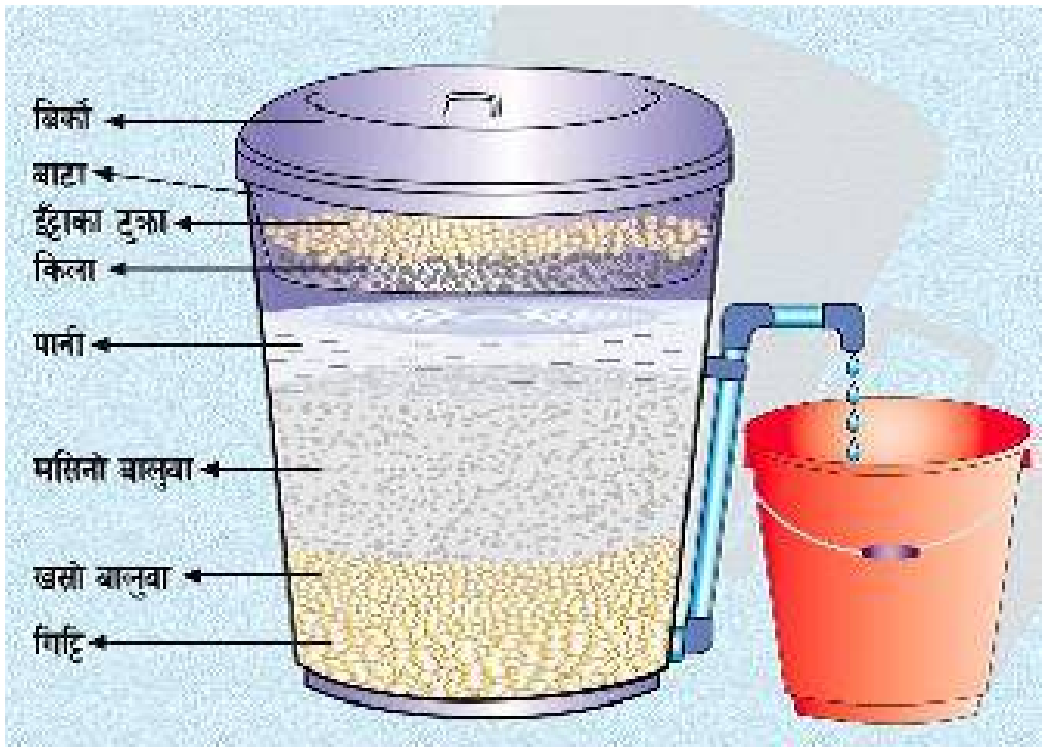
Advantages:
- Laterite is widely available in parts of the world where arsenic is a serious problem
- Good arsenic removal
- Low cost

Limitations:
- Variability in laterite media?
- Large volume of media for disposal?

Cost
- US$???

4

The *Kanchan*™ Arsenic Filter (KAF)

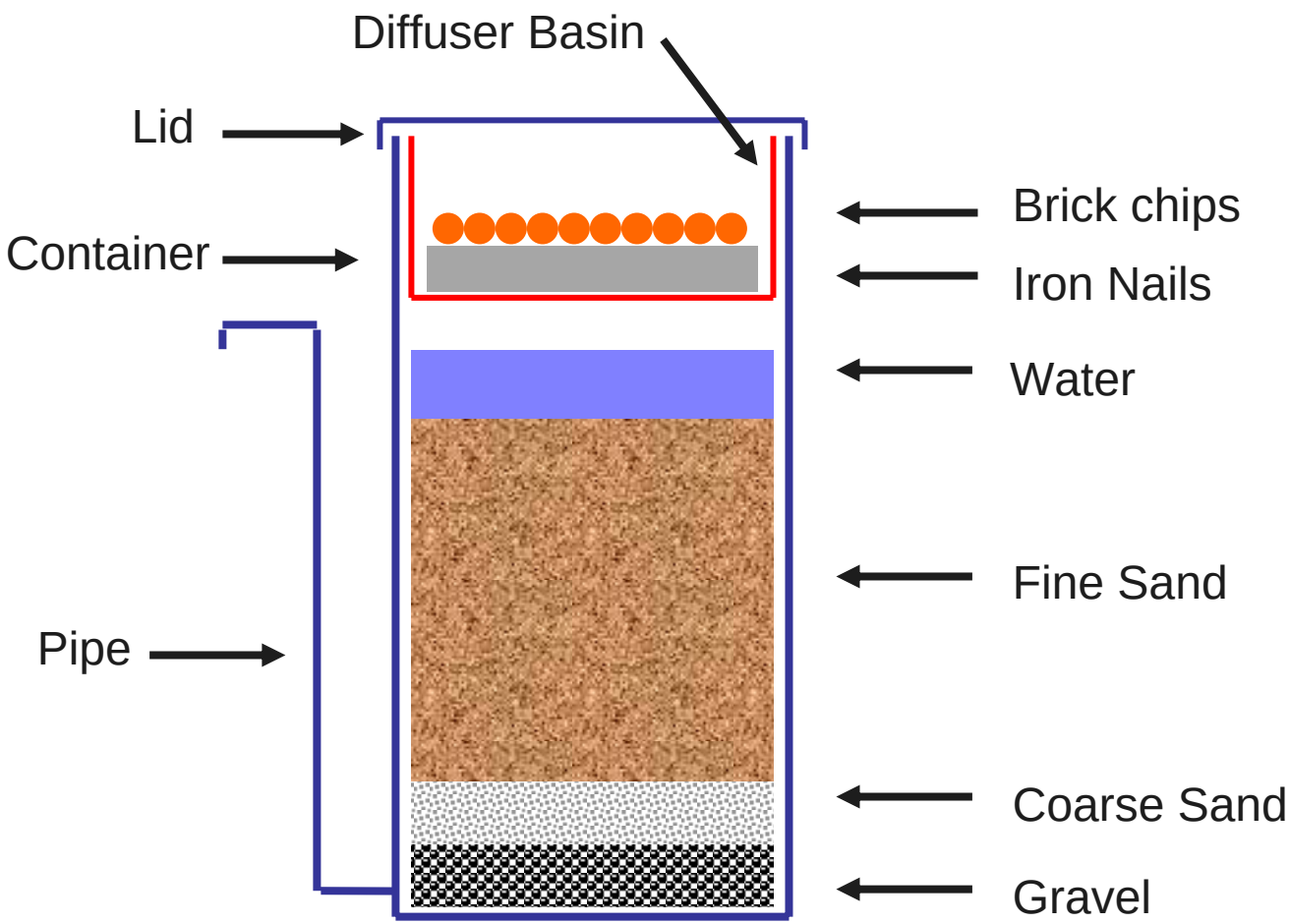


Kanchan™ Arsenic Filter

(formerly Arsenic Biosand Filter)

- Developed by MIT in collaboration with Nepal partners -ENPHO and RWSSSP
- Based on slow sand filter technology and arsenic adsorption on ferric hydroxide
- Intended for arsenic, bacteria, iron, turbidity removal
- Constructed by trained local technicians using local materials
- Good flow rate for a large family (15L/hr)
- No chemical additives
- No replacement parts except iron nails
- Easy to operate and maintain

Kanchan™ Arsenic Filter Components



Five KAF Containment Designs so far:

1. Concrete Square
2. Concrete Round
3. Plastic Hilltake
4. Plastic Bucket Gem505
5. Plastic Blow-molded

Concrete Square Filter (2002)

Concrete Round Filter (2003)

Plastic Hilltake Filter (2003)

Gem505 Filter (2004)

Filter Operation

1. Pour water into top basin. Water will pass through filter and flow up the pipe

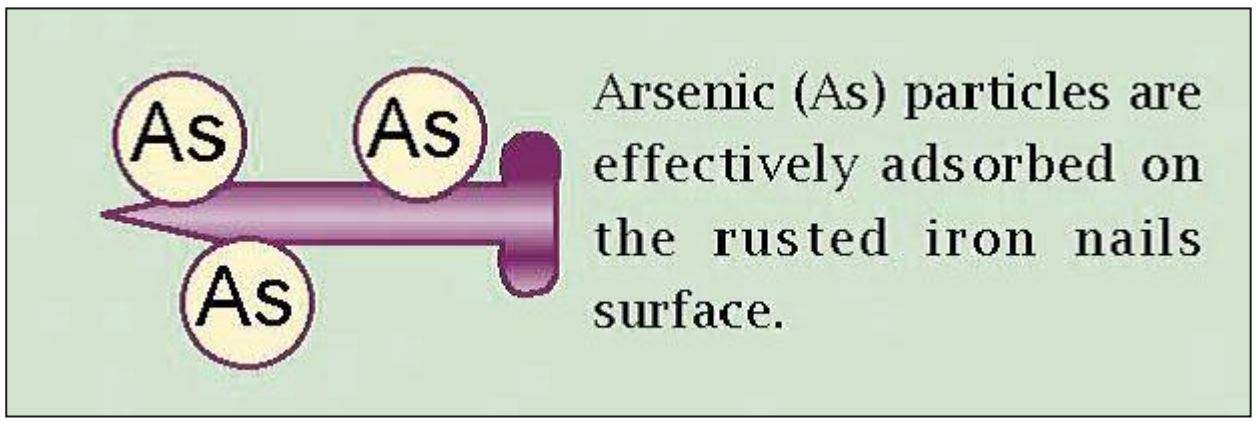
2. Collect filtered water at the pipe outlet

3. If flow rate is insufficient, then cleaning is required

Arsenic Removal Mechanism

- After contact with water and air, iron nails in the diffuser basin will quickly rust

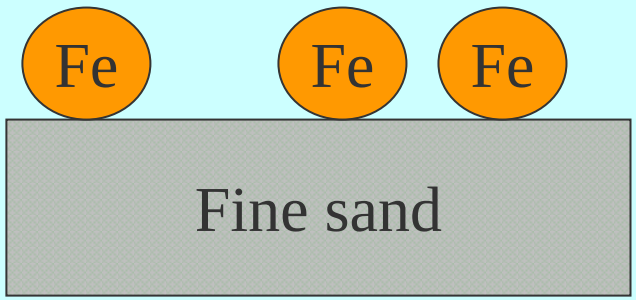
- Iron rust (ferric hydroxide) is an excellent adsorbent for arsenic



Iron Removal Mechanism

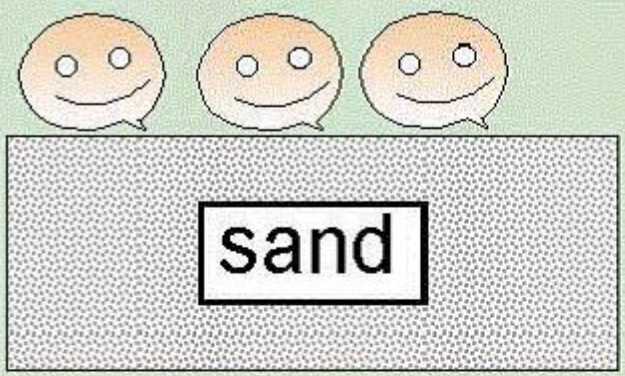
- Soluble iron(II) in raw water is oxidized in air to insoluble iron(III)

- Iron is trapped on top of sand layer by physical straining

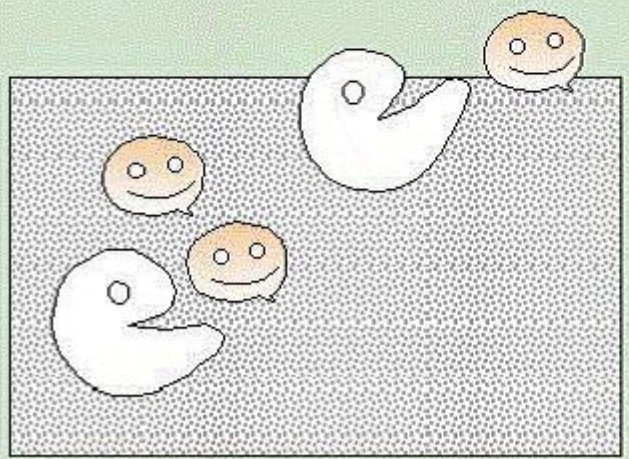


Iron particles are trapped on top of the fine sand layer by physical straining (i.e. too large to pass)

Pathogen Removal Mechanisms



Larger pathogens will be trapped on top of the sand layer by physical straining.



Smaller pathogens are removed by predation by microorganisms residing near the top sand layer.

Development of the Kanchan™ Arsenic Filter

- MIT Nepal Water Project

Since 1999, over 40 students and faculty have traveled to Nepal to assess water quality, to evaluate technologies, to pilot test, and to implement mitigation strategies

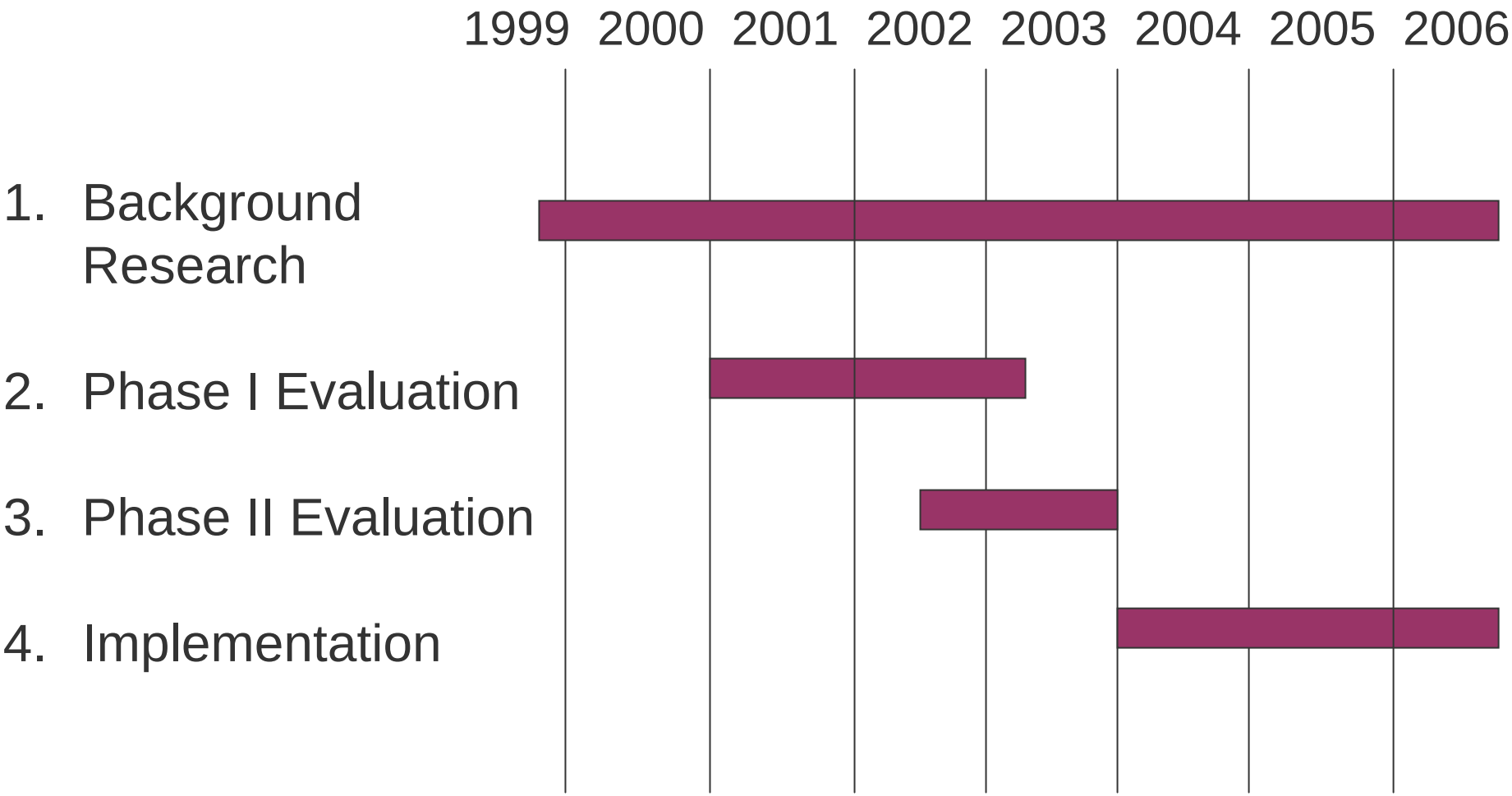
- Teams include both Master of Engineering and Sloan Business School students

Nepali Partners

Environment and Public Health Organization (ENPHO) Kathmandu

Rural Water Supply and Sanitation Support Programme (RWSSSP) Butwal

4-Steps Approach to Arsenic Mitigation



Step 1 – Background Research

Research on various mitigation options

Arsenic Mitigation

Alternative Arsenic-Free Sources

- Safe tube wells
- Improved Dug wells
- Deep wells
- Rainwater harvesting
- Surface water treatment

Arsenic Removal Technologies

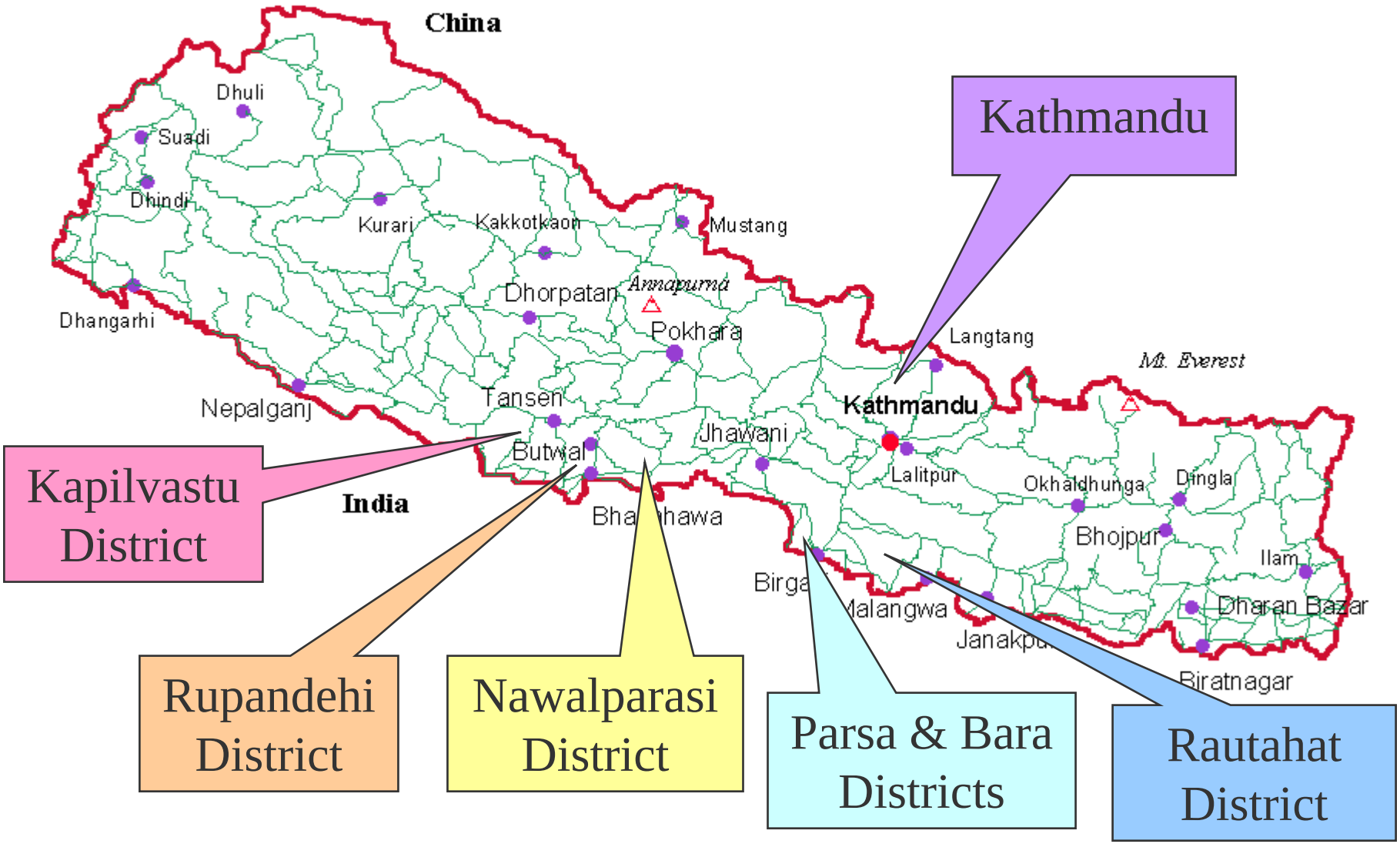
- Aeration/Oxidation
- Coagulation/Precipitation
- Adsorption
- Ion-Exchange
- Membrane

Collected information for 50+ technologies in our database

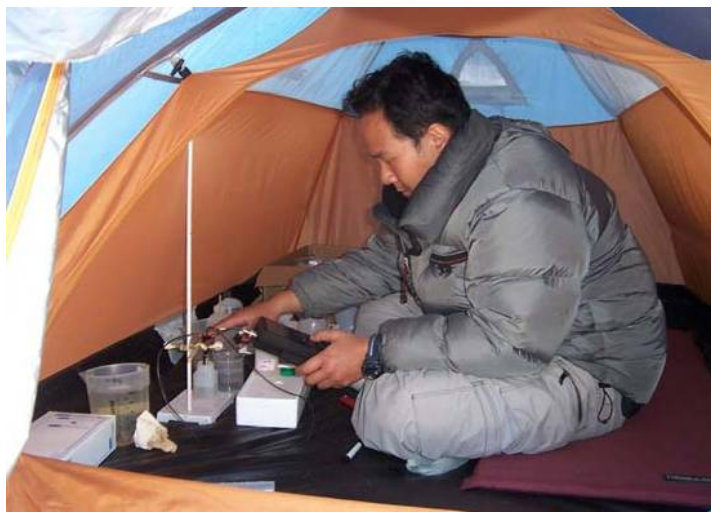
http://web.mit.edu/murcott/www/arsenic

Step 1 – Background Research

Field Visit



Step 1 – Background Research



Step 2 – Phase I Evaluation

Field Test

Screened 8 technologies from database to be field tested against following criteria:

1. Technical Performance
2. Social Acceptability
3. Low cost

Step 2 – Phase I Evaluation

Technologies Tested

3-Kolshi
a.k.a. 3-Pitcher

Jerry-Can

Iron-oxide Coated Sand

Step 2 – Phase I Evaluation

Technologies Tested

Activated Alumina Metal Oxide No.1 (Apyron)

Activated Alumina Metal Oxide No.2 (Aquatic Treatment Systems)

2-Kolshi: Coagulation/ Filtration

Step 2 – Phase I Evaluation

Technologies Tested

Arsenic Iron Removal Plant

Kanchan™ Arsenic Filter (KAF)

Step 2 – Phase I Evaluation

Summary Results

Technology	Technical	Social	Cost	Recommend for Phase II?
3-Kolshi	✓	✓	✓	✓
Jerry Can	✗	✗	✓	✗
Iron Coated Sand	✓	✗	✓	✗
Alumina #1	✓	✗	✗	✗
Alumina #2	✓	✗	✓	✗
2-Kolshi	✓	✓	✓	✓
AIRP	✗	✗	✓	✗
KAF	✓	✓	✓	✓

Step 3 – Phase II Evaluation

Pilot Study

3 Kolshi

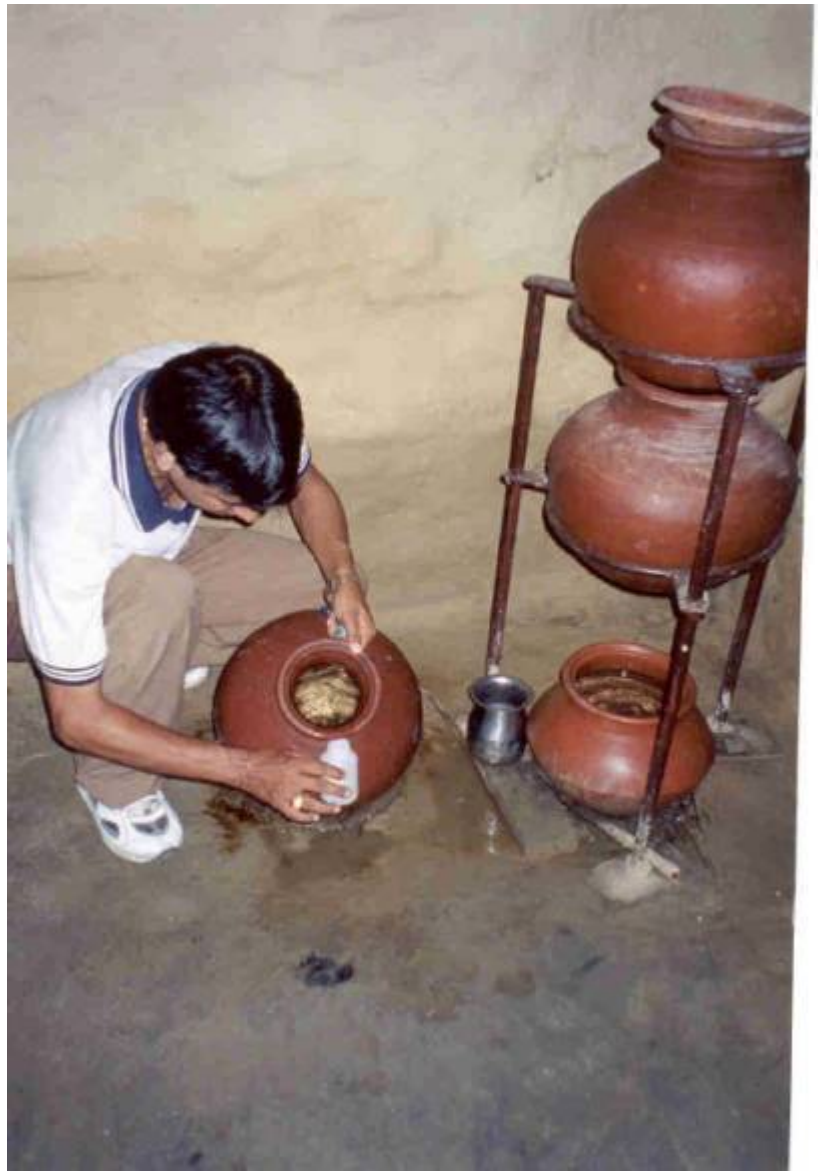
2-Kolshi

Kanchan

Step 3 – Phase II Evaluation

3-Kolshi Pilot Study

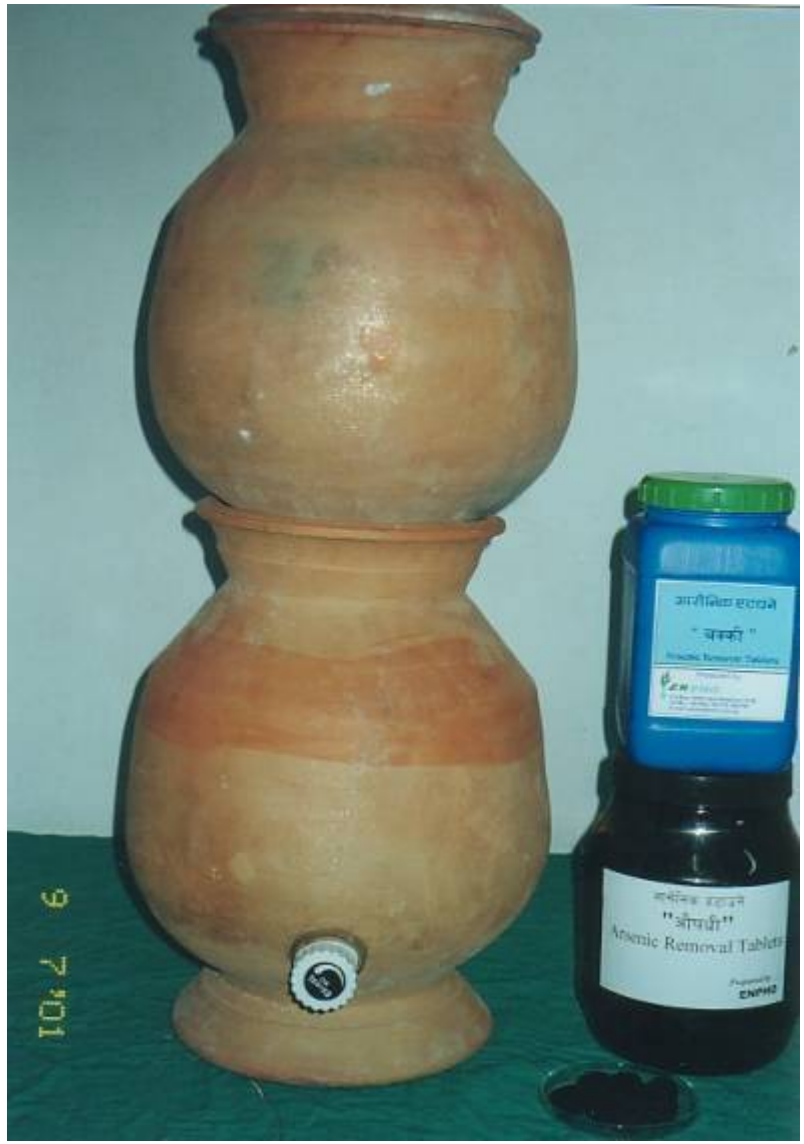
- Undertaken by RWSSSP with support from ENPHO
- 15 filters installed in two arsenic-affected villages in August 2002
- Filters were monitored monthly for 1 year



Step 3 – Phase II Evaluation

2-Kolshi Pilot Study

- Undertaken by ENPHO
- Hundreds of filters distributed in two districts in winter 2001 as a short-term immediately mitigation option
- Filters were monitored quarterly for 1 year



Step 3 – Phase II Evaluation

Kanchan™ Arsenic Filter Pilot Study

- Collaboration between MIT, ENPHO, and RWSSSP
- 16 KAF were installed in 2002
- Households were selected based on user interest and arsenic test results
- Filters were monitored every two weeks for 1 year

General Observations

1. Coagulation chemicals difficult to obtain in rural Nepal. Setup of a new distribution network is difficult and costly.

2. Similarly, access to imported media (e.g. activated alumina) is difficult.

3. Lack of capability for complicated manufacturing process (e.g. iron-coated sand)

4. Filter constructed by local technicians using locally available materials can promote local employment/economy.

General Observations

5. Color, taste, turbidity of filtered water are important determinants to the user's acceptance of a technology.

6. Technology must remove microbial contamination

7. Users tend to skip filtration if the filtration rate is too low or operation too time consuming.

8. Lack of proper maintenance is prevalent for many community-scale systems

Step 3 – Phase II Evaluation

Pilot Study Results

	3-Kolshi	2-Kolshi	KAF
Arsenic removal	95-99%	80-90%	90-95%
Flow rate	1-5L/hr	1-5L/hr	10-15L/hr
Materials availability	☀☀☀	☀	☀☀☀
Easy construction	☀☀☀	☀☀☀	☀☀☀
Simple O&M	☀☀	☀☀	☀☀☀
Minimal environmental impact	☀☀	☀☀	☀☀
Long-term sustainability	☀☀	☀	☀☀☀
User acceptance	☀☀	☀	☀☀☀
Low initial cost	☀☀☀	☀☀☀	☀☀
Low running cost	☀☀	☀☀	☀☀☀
Overall Ranking	**2nd**	**3rd**	**Best**

☀ **= poor** ☀☀ **= moderate** ☀☀☀ **= good**

World Bank DM2003 Award

Funding Source:

• Won a US$115,000 award from the World Bank Development Marketplace Global Competition 2003

Project Objective:

• To sustainably promote the *Kanchan™* Arsenic Filter as an appropriate arsenic mitigation option throughout Nepal

Project Duration:

• Jan 04 to Jan 05

Project Partners:

• MIT, ENPHO, RWSSSP

KAF Blanket Monitoring

Arsenic Removal (n=966)

Effluent Arsenic Concentration (ug/L)

Influent Arsenic Concentration (ug/L)	ND	10	20	30	40	50	60	70	80	90	100	150	200	250	300	350	400	450	500
500	5	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
450	8	1	2	3	0	0	0	0	0	0	1	0	0	0	1	1	1	3	
400	10	2	2	1	2	0	0	0	0	0	0	1	0	1	0	0	1		
350	15	3	1	3	1	0	0	0											
300	28	1	3	1	1	0	0	0											
250	27	2	1	2	2	2	0	0											
200	32	1	0	0	0	0	0	0											
150	40	1	1	0	1	0	0	0											
100	99	8	3	1	1	0	0	1	0	0	0								
90	86	6	3	0	0	0	1	2	0	1									
80	57	1	0	1	0	0	0	0	0										
70	42	3	0	3	0	0	0	0											
60	34	13	5	2	1	0	0												
50	71	5	2	0	0	0													
40	21	2	0	0	0														
30	17	0	0	0															
20	44	1	0																
10	12	0																	
ND	189																		

Unacceptable results have been found to be caused by improper installation and maintenance.

Unacceptable

Acceptable

Figure indicates number of filters

User Survey Results

Preliminary results (n= 424) as of Jan 31, 2005

	Yes	*Partially*	*No*
Filter still in operation after 1 year	85.3%	8.3%	6.3%
Users think filter operation is easy	73.6%	---	26.4%
Users can operate the filter correctly	50.2%	42.3%	7.4%
Users will recommend filter to others	82.5%	---	17.5%

	Better	*Same*	*Worse*
Appearance of filtered water	92.8%	6.9%	0.2%
Taste of filtered water	95.0%	5.0%	0%
Smell of filtered water	89.9%	11.1%	0%
Users' perceived health conditions after drinking filtered water	77.5%	22.5%	0%

Filter Cost in Nepal

	Concrete		*Hilltake*		*Gem505*	
Item	NRs	$US	NRs	$US	NRs	$US
Container, Basin & Lid	800	11.43	1390	19.86	540	7.71
Piping System	100	1.43	230	3.29	160	2.29
Sand & Gravel media	25	0.36	35	0.50	25	0.36
Iron Nails	350	5.00	350	5.00	350	5.00
Bricks	5	0.07	5	0.07	5	0.07
Piyush (disinfection)	35	0.50	35	0.50	35	0.50
Transportation	250	2.14	75	1.07	50	0.71
Labor	200	2.86	95	1.36	65	1.14
Documentation	20	0.29	20	0.29	20	0.29
Tools/ Bags	15	0.21	15	0.21	15	0.21
Cost per Unit	**1800**	**25.71**	**2250**	**32.14**	**1265**	**18.07**
Profit 10%	180	2.57	225	3.21	127	1.81
Selling Price	**1980**	**28.28**	**2475**	**35.36**	**1392**	**19.88**

Assume Exchange rate of US$1 = 70 Nepali Rupees
Cost of steel mold for concrete filter not included

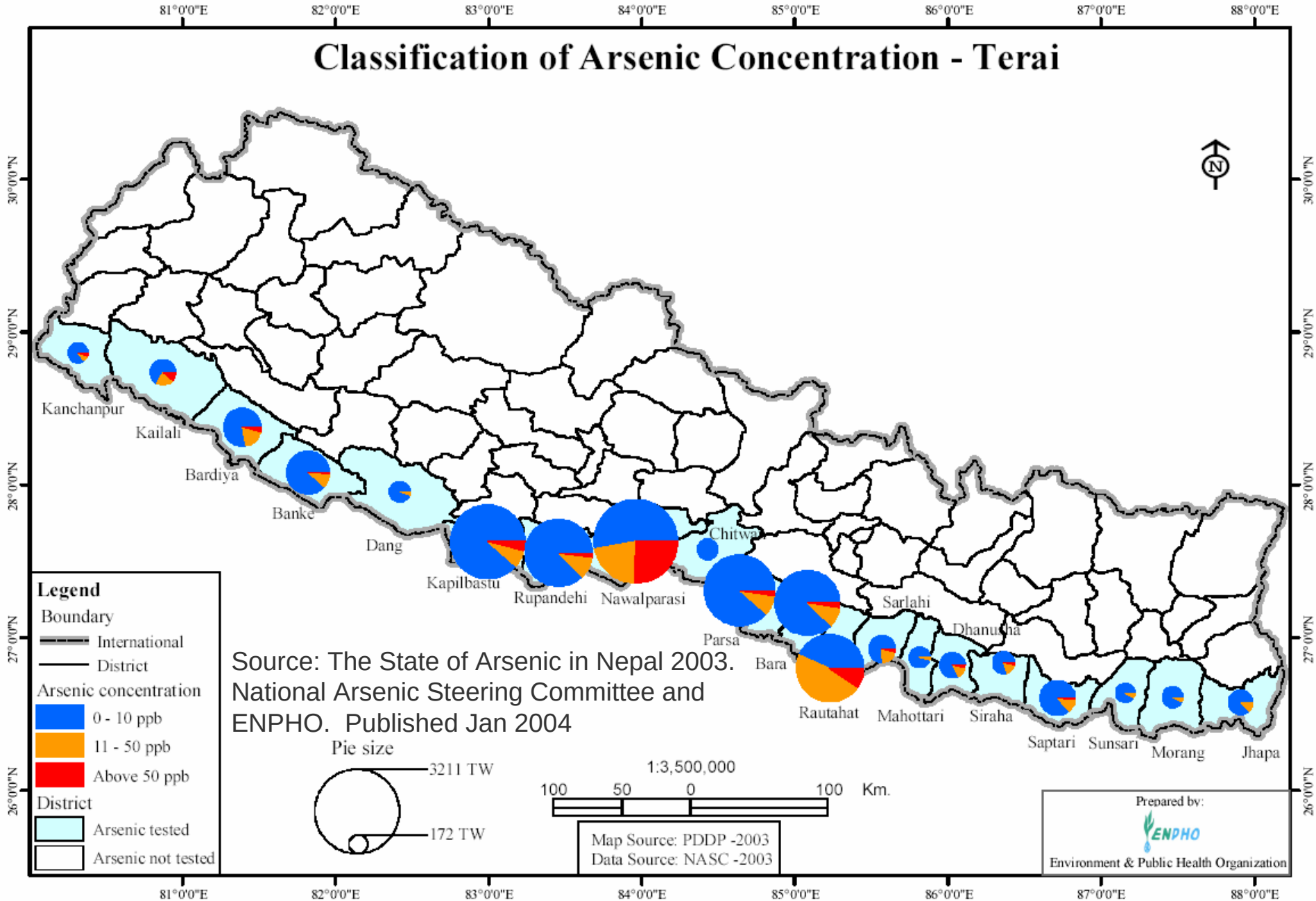
Michael Doret

Wall Street Journal

Innovation Technology 2005 Award – Environment Category

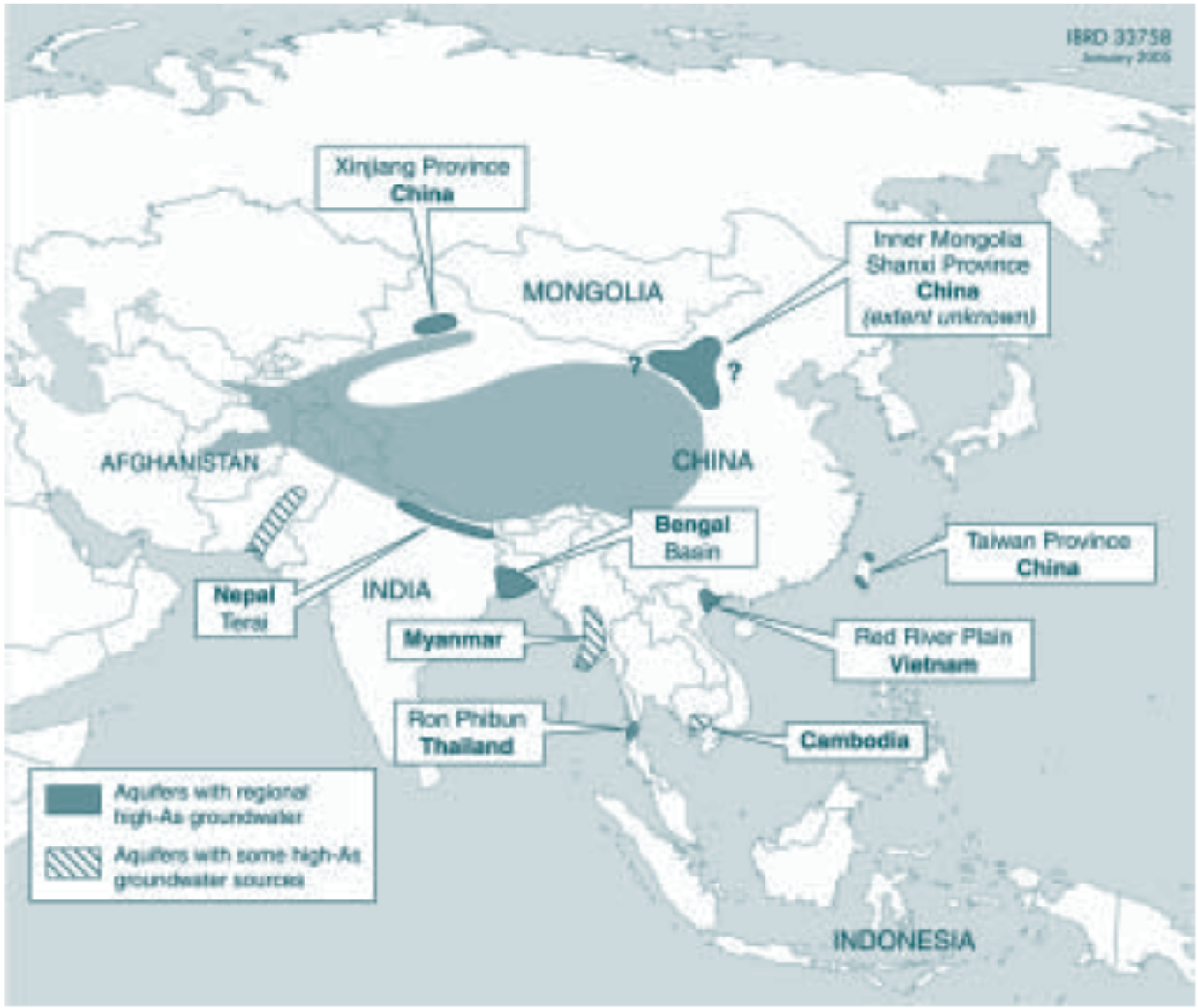
- The MIT team's water-filtering system won in the environmental technology category.
- Though decidedly a low-tech solution, it was praised by judges for addressing an important problem in an original fashion.
- However, even at $20, the price may be too high for the poor households it's targeted for.
- "Clean water is not sexy, and $20 a year won't make anyone rich," says Robert Drost, a scientist at Sun Microsystems Inc. "But 3rd World challenges in water, food, shelter, and basic medical care are much more important than innovations in first-world entertainment."

Next Steps – Expansion of Kanchan in Nepal



Next Steps – Expansion into South / S.E. Asia

Figure 2. Map of South and East Asia Showing the Locations of Documented High-Arsenic Groundwater Provinces



Source: World Ba

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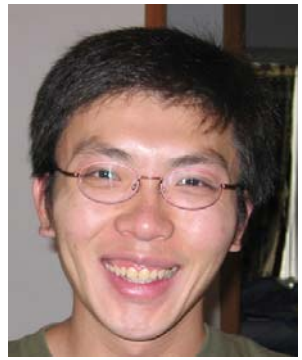

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Website:
http://web.mit.edu/watsan

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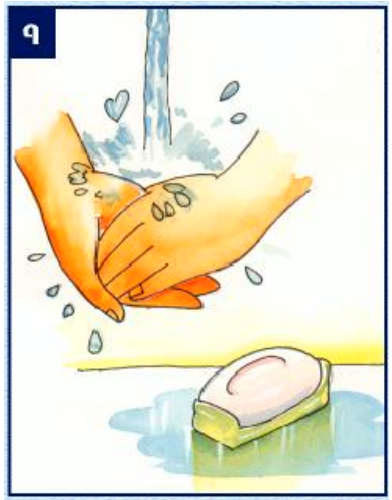
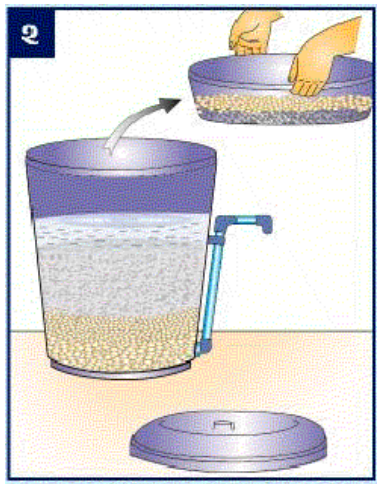
Ngai, T., Walewijk, S. (2003). "*The Arsenic Biosand Filter Project - Design of an Appropriate Household Drinking Water Filter for Rural Nepal*". Research Report. Massachusetts Institute of Technology.

Filter Cleaning/ Maintenance



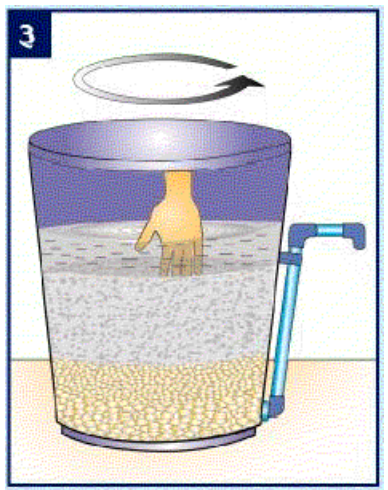
साबुन पानीले हात राम्रो संग धुने ।

1. Wash your hands with soap



किला राखेको बाटा बाहिर निकाल्ने ।

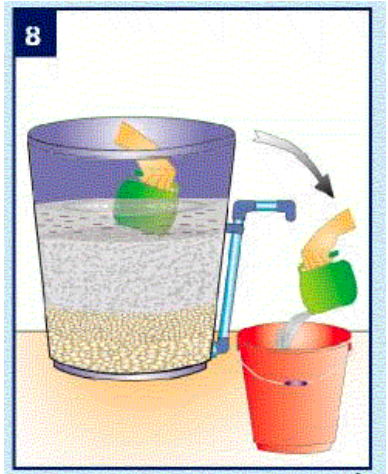
2. Remove diffuser basin



बालुवाको माथिल्लो सतह बाट आधा इन्च जति भित्र सम्म हात छिराएर राम्रो संग बालुवालाई चलाउने ।

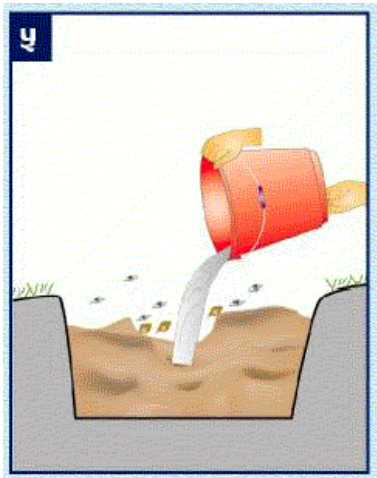
3. Stir the uppermost ½ inch of sand with your fingers

Filter Cleaning/ Maintenance



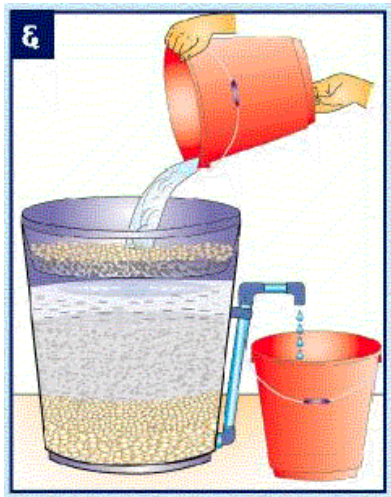
एक छिन चलाएपछि बालुवामाथिको फोहर पानी मगले बाहिर बाल्टिनमा निकाल्ने । पुन: बाटा राखेर पानी खन्याई दुई पटक सम्म चसरी नै सफा गर्ने।

4a. Remove turbid water with a cup.
4b. Replace the basin and add more water.
4c. Repeat the stirring process for two additional times.



सफा गर्दा निस्केको फोहर पानीलाई खाल्डो खनी थुपारेको गोबरमा फ्याल्ने ।

5. Discard the turbid water in a dug hole with some cow dung in it



बाटा लाई पहिले जस्तै गरी फिल्टरमा मिलाएर राख्ने । त्यसपछि पानी खन्याई फिल्टर प्रयोग गर्न सकिन्छ ।

6. Now the filter can be used again