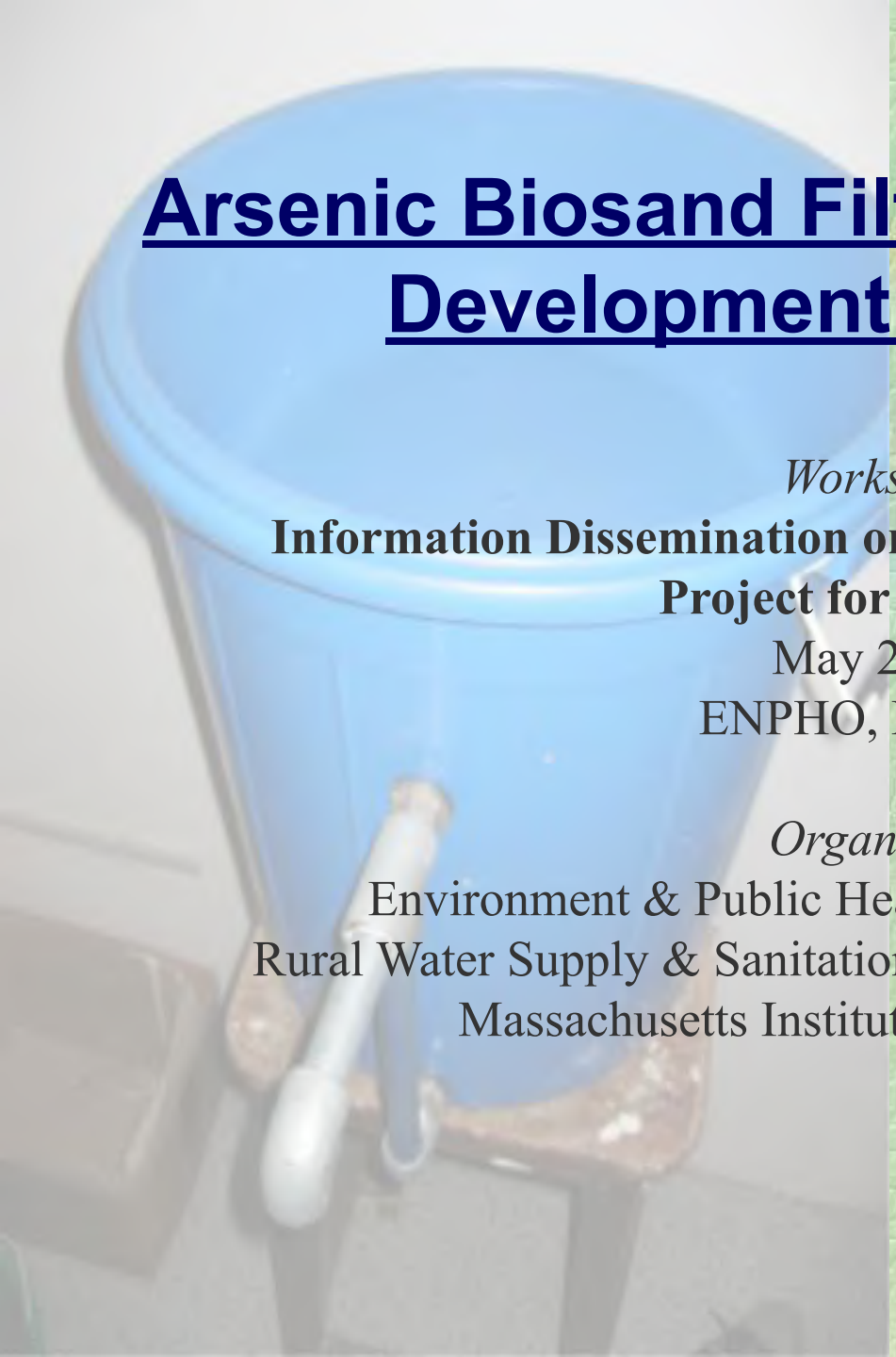


Arsenic Biosand Filter (Kanchan Filter): Development and Findings

Workshop on

Information Dissemination on Arsenic Biosand Filter (ABF)

Project for Rural Nepal

May 25, 2004

ENPHO, Kathmandu

Organized by:

Environment & Public Health Organization (ENPHO)

Rural Water Supply & Sanitation Support Programme (RWSSSP)

Massachusetts Institute of Technology (MIT)

Presentation Outline

1. Arsenic Biosand Filter concepts
2. Four different filter configurations
3. Evaluation on technical performance, implementation Issues, and cost
4. Selection of “best” design for this DM2003 Project
5. Details on filter design
6. Potential problems
7. Conclusions
8. Questions and Discussions

1. Arsenic Biosand Filter Concepts

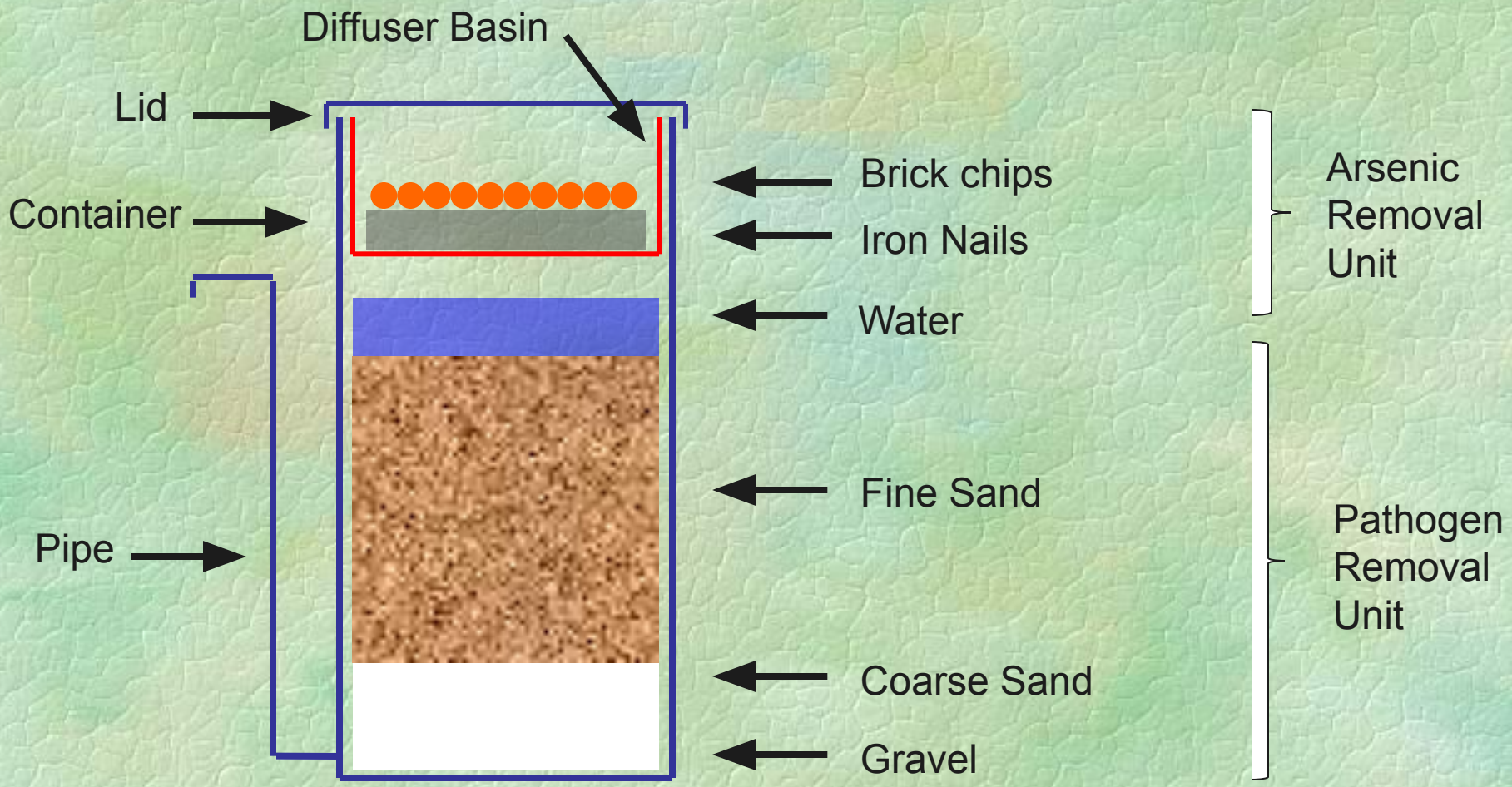
Biosand Filter

- First developed by a Dr. David Manz of the University of Calgary in Canada
- Based on slow sand filter technology for intermittent use
- Intended for bacteria removal from drinking water
- Made with easily available materials: concrete or plastic container, PVC pipe, sand, gravel, and lid
- Adequate flow rate for a large family
- No chemical additives
- Easy to operate and clean
- Require 2 to 3 weeks to reach optimum removal of bacteria & viruses
- Over 50,000 Biosand Filters have been installed worldwide

Arsenic Biosand Filter (Kanchan Filter)

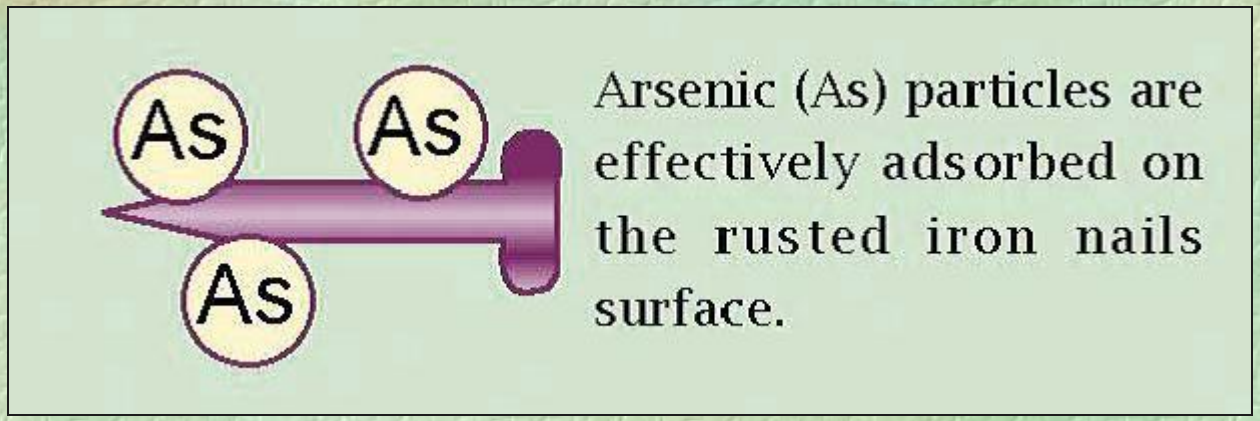
- Developed by Massachusetts Institute of Technology (MIT), Environment & Public Health Organization (ENPHO), and Rural Water Supply and Sanitation Support Programme (RWSSSP)
- An improvement on the former Biosand Filter
- Intended for bacteria and arsenic removal
- Made with easily available materials: concrete or plastic container, PVC pipe, sand, gravel, iron nails, and lid
- Adequate flow rate for a large family
- No chemical additives
- Easy to operate and clean
- Require 2 to 3 weeks to reach optimum removal of bacteria & viruses
- Immediate arsenic removal after installation

Arsenic Biosand Filter Cross Section



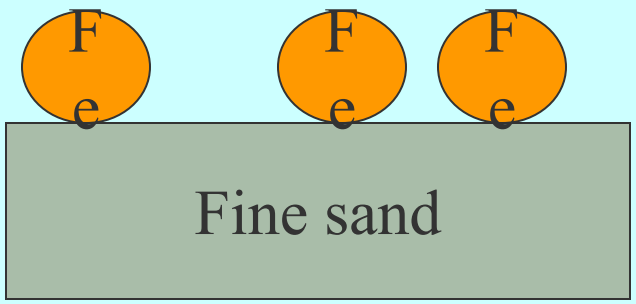
Arsenic Removal Mechanism

- 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



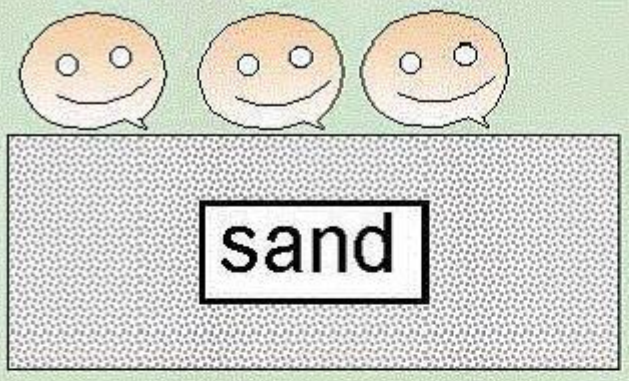
Iron Removal Mechanism

- 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

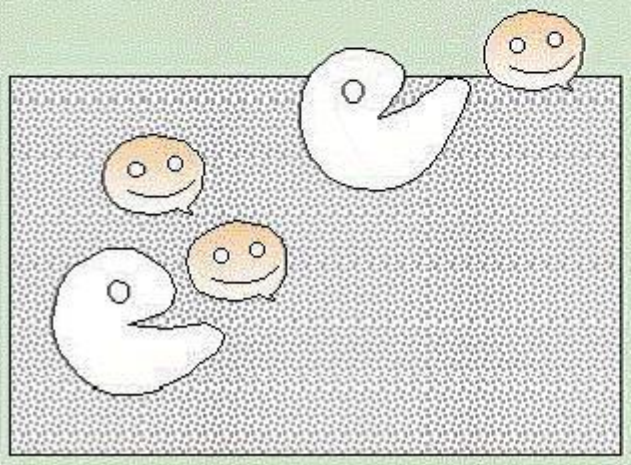


Iron particles are trapped on top of the fine sand layer by physical straining (i.e. too large to pass)

Bacteria Removal Mechanism



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.

2. Four Different Filter Configurations

Filter Design

We have developed 4 configurations for the ABF:

1. Concrete Square
2. Concrete Round
3. Plastic Hilltake
4. Plastic Gem505

Concrete Square Filter

Concrete Round Filter

Plastic Hilltake Filter

Plastic Gem505 Filter

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

Filter Cleaning/ Maintenance

Wash your hands with soap

Remove diffuser basin

Stir the uppermost ½ inch of sand with your fingers

Filter Cleaning/ Maintenance

Remove turbid water with a cup.
Replace the basin and add more water.
Repeat the stirring process for two additional time.

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

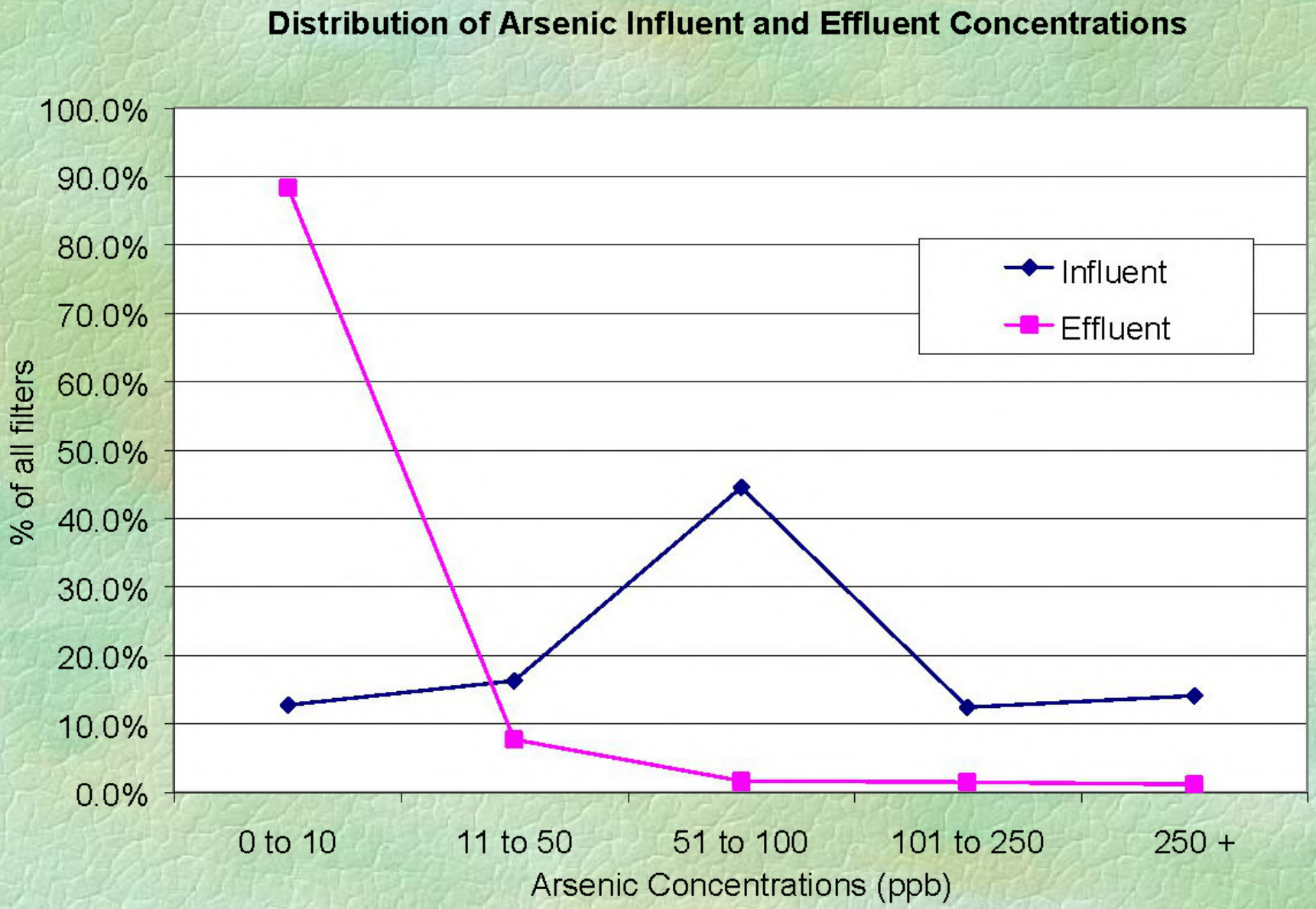
Now the filter can be used again

3. Evaluation on Technical Performance, Implementation Issues, and Cost

Technical Performance

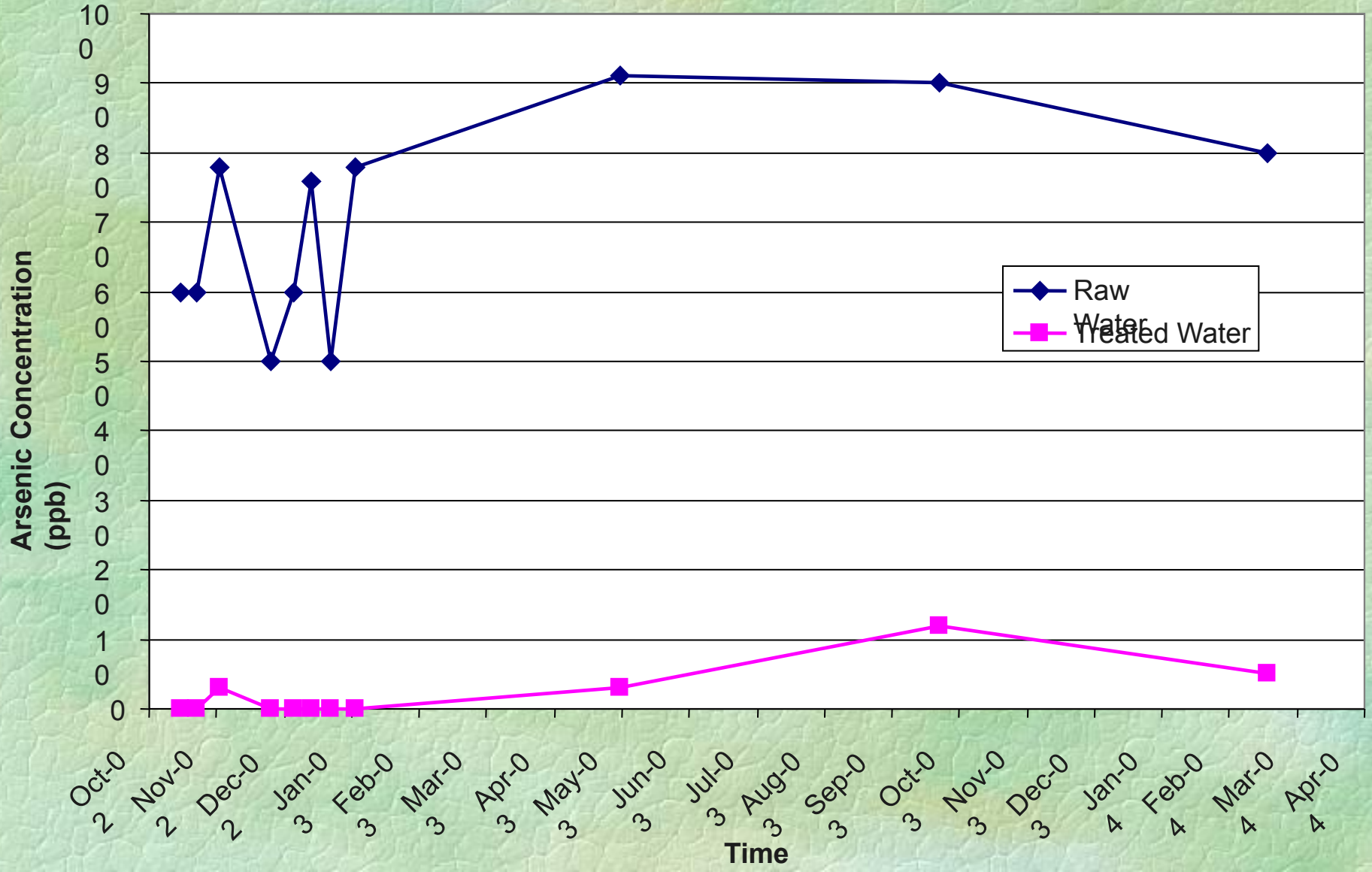
- Currently more than 900 filters are in operation
- More than 500 were distributed by NRCS, about 100 by Fund Board, about 300 by RWSSSP
- Filters were distributed starting from September 2002 until today
- We have monitored all filters between February to May 2004 on arsenic and iron removal
- The average time between filter installation date and filter monitoring date is 93 days

Filter Performance: Arsenic (n=650)



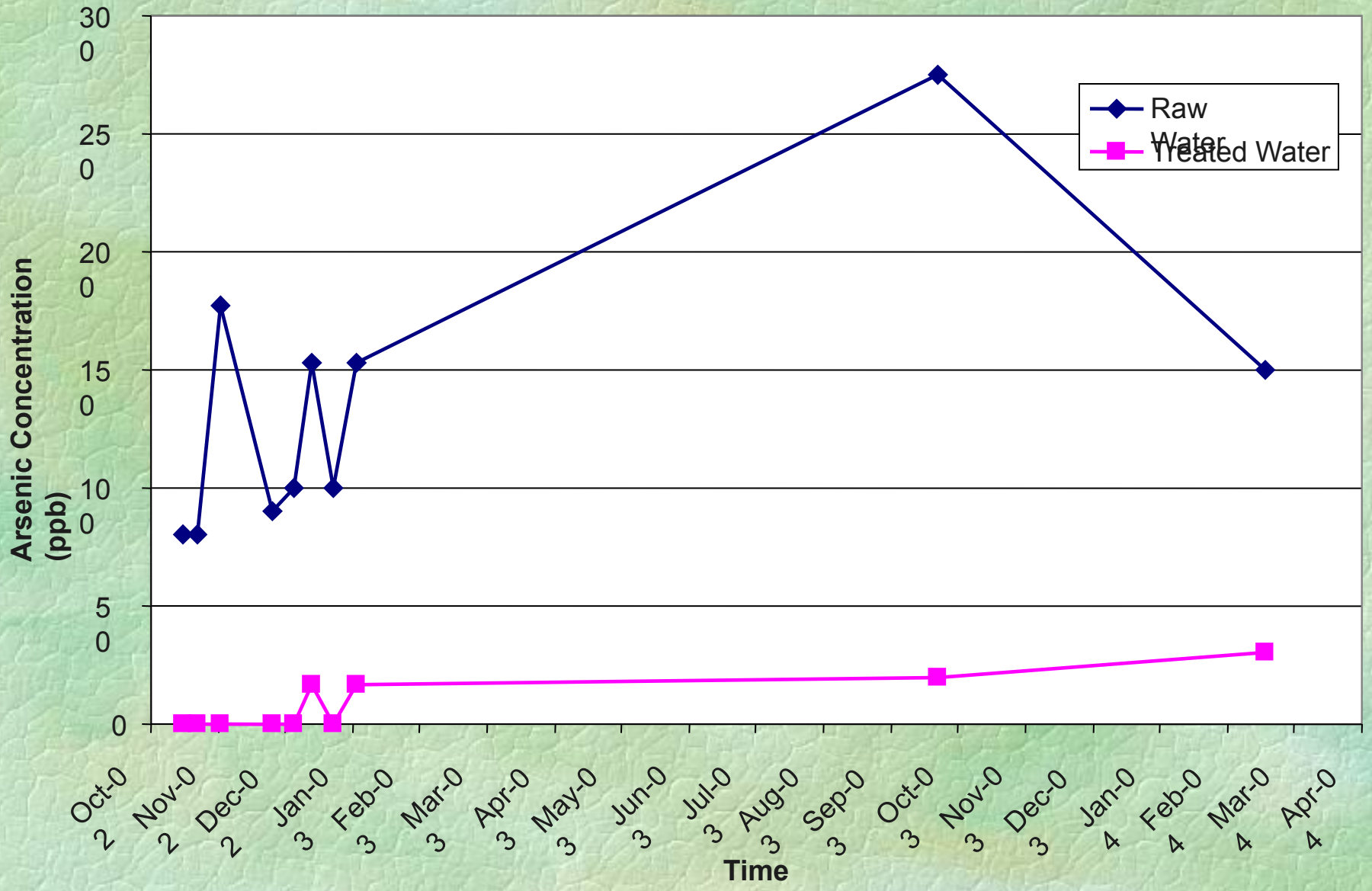
1.5 Years Arsenic Monitoring on Filter A

(Nim Narayan Chaudhary)



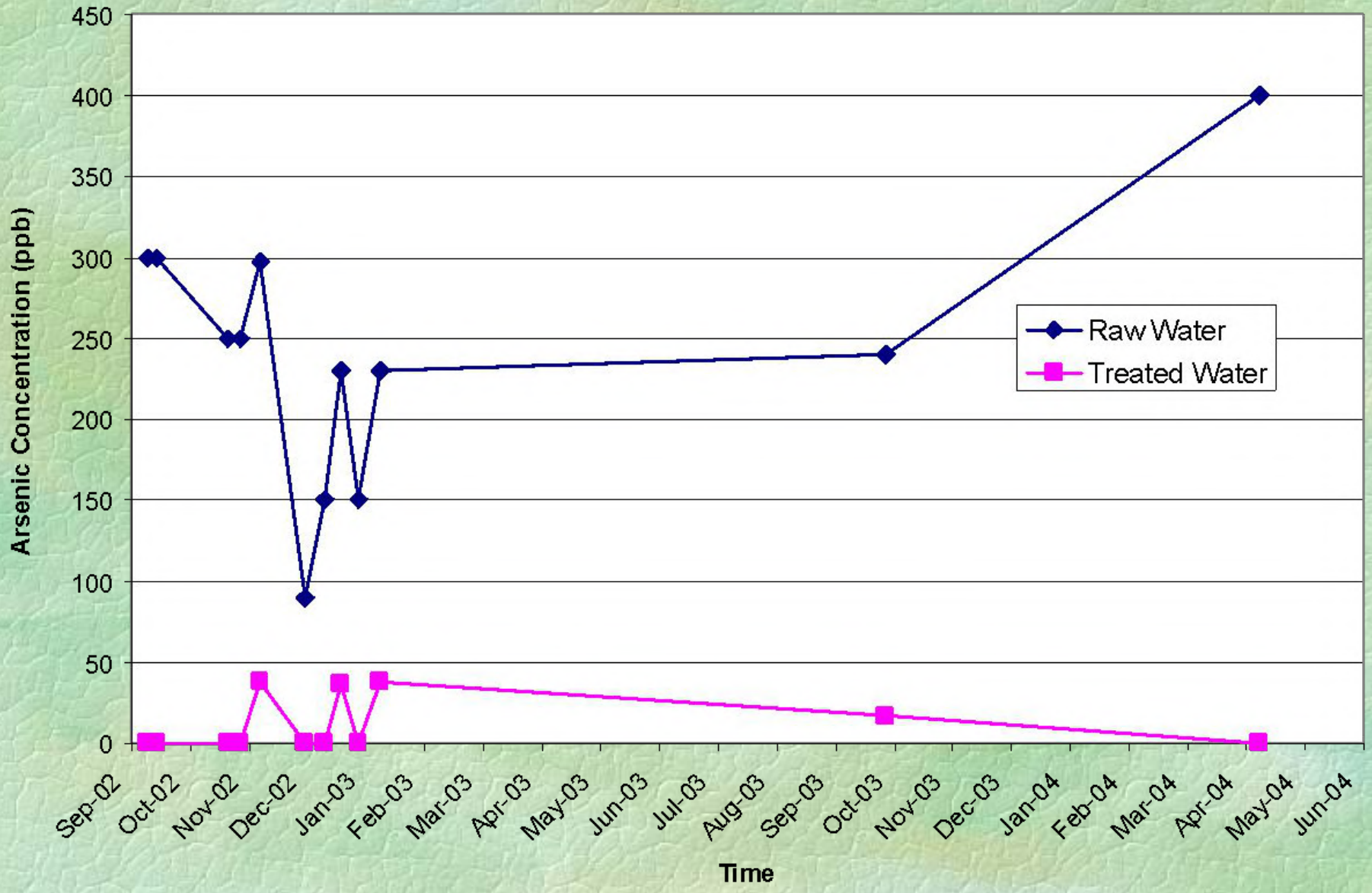
1.5 Years Arsenic Monitoring on Filter B

(Lila Bdr. Pun)

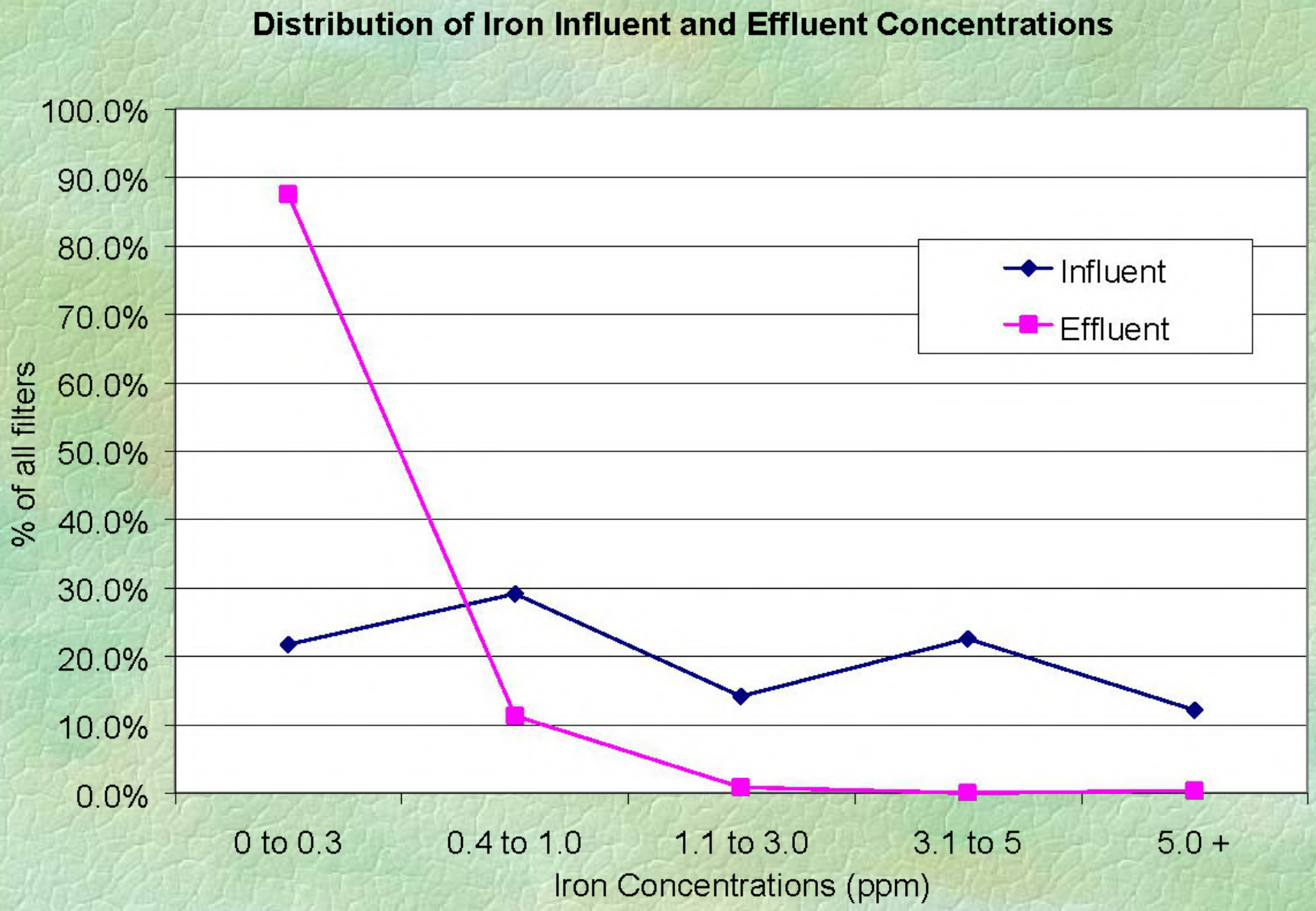


1.5 Year Arsenic Monitoring on Filter C

(Bhanu Primary School)



Filter Performance: Iron (n=611)



Filter Performance: Bacteria

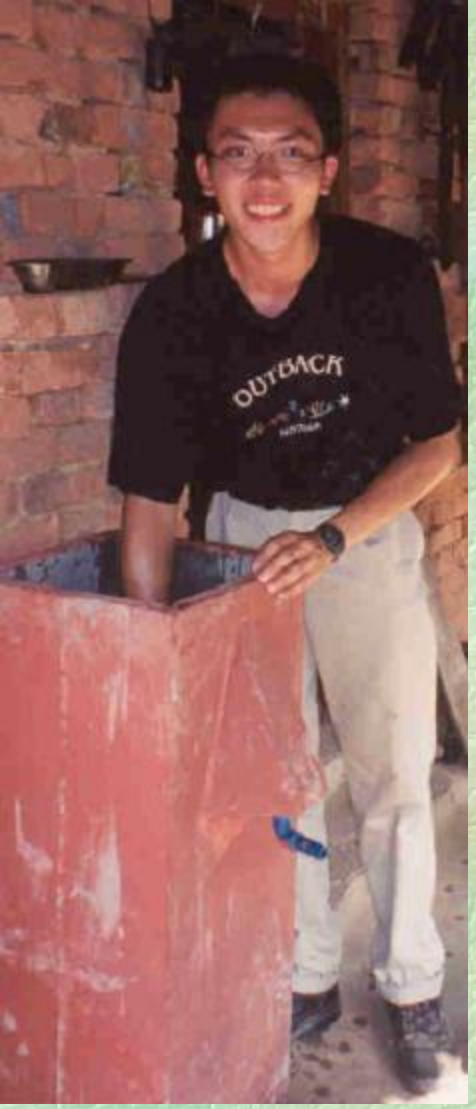
- Insufficient bacteria removal test on the ABF for statistically significant results, (because bacteria membrane filtration test is complicated and required special equipments)
- Our study (7 filters) showed bacteria removal of up to 100% after the filter was in operation for about 2 – 3 months
- We plan to conduct Total Coliform MF experiments starting in June
- Previous studies on the Biosand Filter in Canada, Nicaragua, Dominican Republic, and U.S.A. showed 90 to 99+% bacteria removal

Summary Technical Performance

	Concrete Square	*Concrete Round*	*Plastic Hilltake*	*Plastic Gem505*
Arsenic Removal	88% meet WHO guideline 96% meet Nepali guideline			
Iron Removal	88% below 0.3ppm 99% below 1.0ppm			
Bacteria Removal	Under investigation			
pH Change	Increase by an average of 0.3 to 0.4 pH units			
Flow Rate (Liters per hour)	17	15	25	15

Implementation Issues of 4 Configurations

	Concrete Square	*Concrete Round*	*Plastic Hilltake*	*Plastic Gem505*
Operation	Easy	Easy	Easy	Easy
Maintenance	Simple	Simple	Simple	Simple
Construction	Require trained technician	Require trained technician	Require trained technician	Require trained technician
Production rate	One filter per mold per day	One filter per mold per day	Many filters per day	Many filters per day
Transportation	Very heavy	Very heavy	Somewhat heavy	Light
Aesthetic	Good	Good	Looks like a trash bin	Good



All filters are easy to operate and maintain

Iron mold is required to construct concrete filters

Construction of concrete filters can be time consuming
(1 filter per mold per day)

The concrete filter is very heavy (100+ kg) thus transportation can be difficult

The Plastic Hilltake filters may look like a trash bin therefore not attractive

The Plastic Gem505 Filter is widely available and is easy to transport

The Plastic Gem505 Filter is simple to construct

Cost Comparison of 4 Filter Configurations

	Concrete Square	*Concrete Round*	*Plastic Hilltake*	*Plastic Gem505*
Container and Lid	445	395	1300	405
Basin	250	250	75	75
Piping System	98	98	174	133
Sand & Gravel	3	3	5	3
Iron Nails 5 kg	350	350	350	350
Transportation of sand & gravel	23	23	41	20
Transportation of container & piping	75	75	50	30
Labour	210	210	68	54
Documentation	25	25	25	25
Tools	223	223	54	54
Total Cost	**1702**	**1652**	**2142**	**1137**

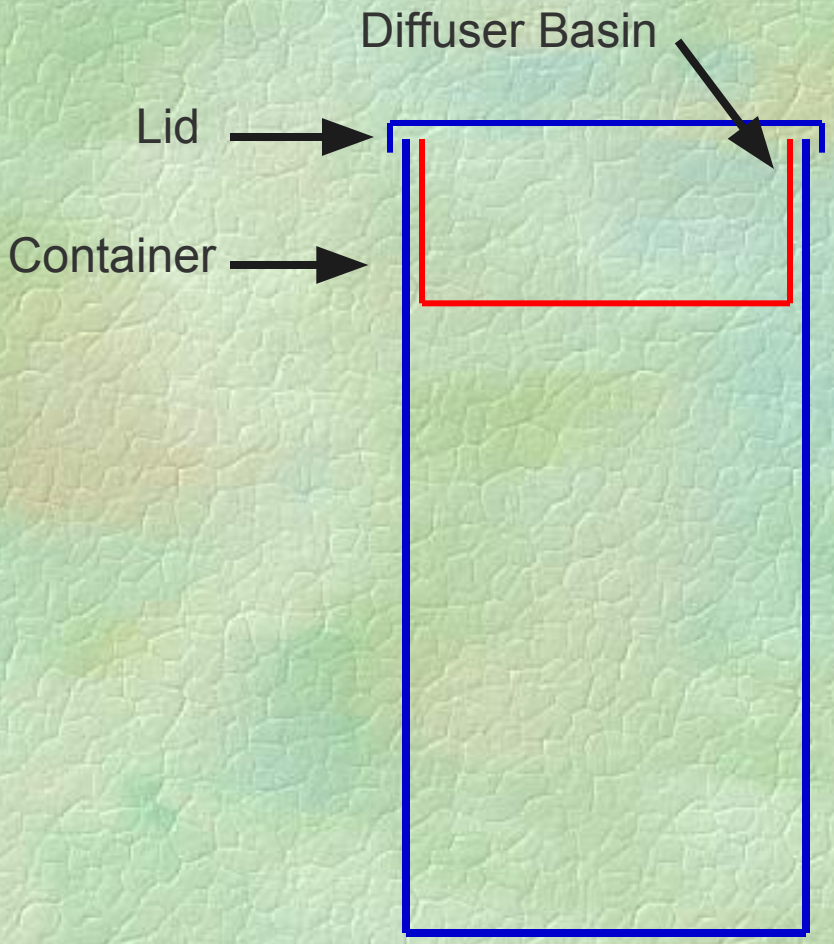
4. Selection of the “Best” Design for the DM2003 Project

Comparison Summary

	Concrete Square	*Concrete Round*	*Plastic Hilltake*	*Plastic Gem505*
Technical Performance	Excellent	Excellent	Excellent	Excellent
Easy for Mass Implement	Difficult	Difficult	Easy	Easy
Cost	Relatively Cheap	Relatively Cheap	Expensive	Cheapest
Recommended for DM2003 Project?	**No**	**No**	**No**	**YES**

5. Details on Gem505 Filter

Major Filter Components

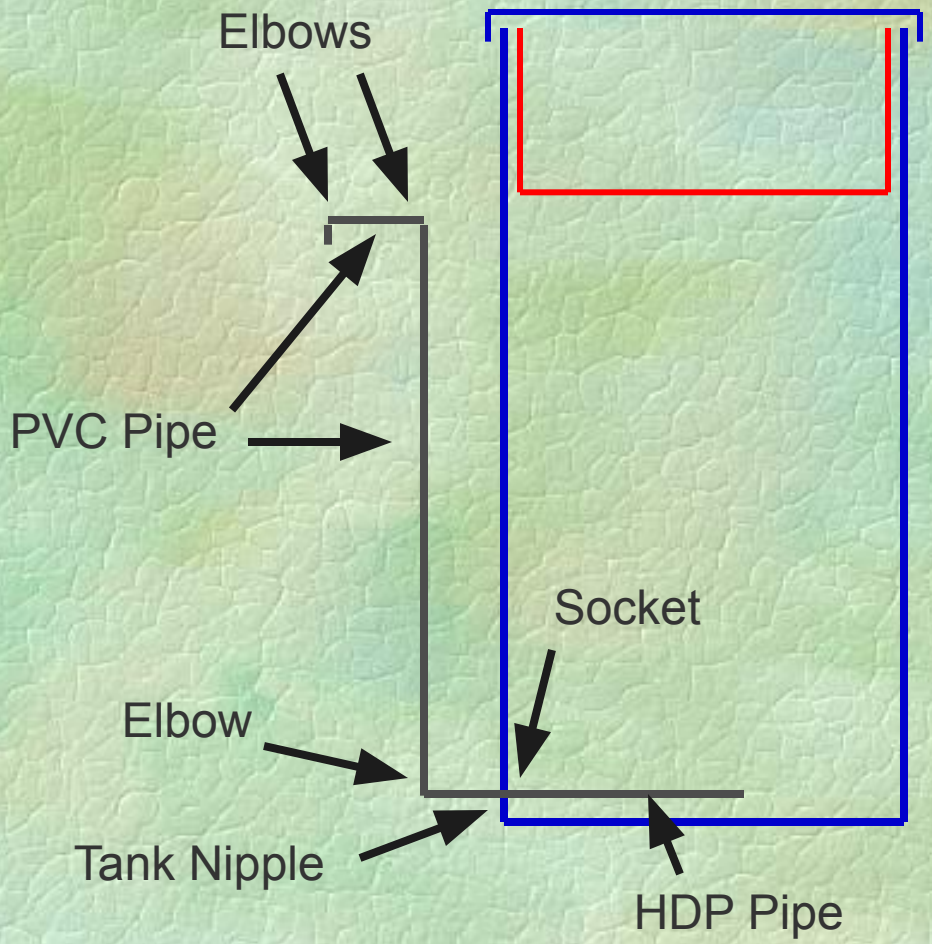


Specifications:

Container & Lid
- Gem model 505

Diffuser Basin
- Gem model 1700

Major Filter Components



Specifications:

Pipe
- ½ inch PVC
- ½ inch HDP

Pipe fittings
- 3 G.I. elbows
- 1 G.I. tank nipple
- 1 G.I. socket

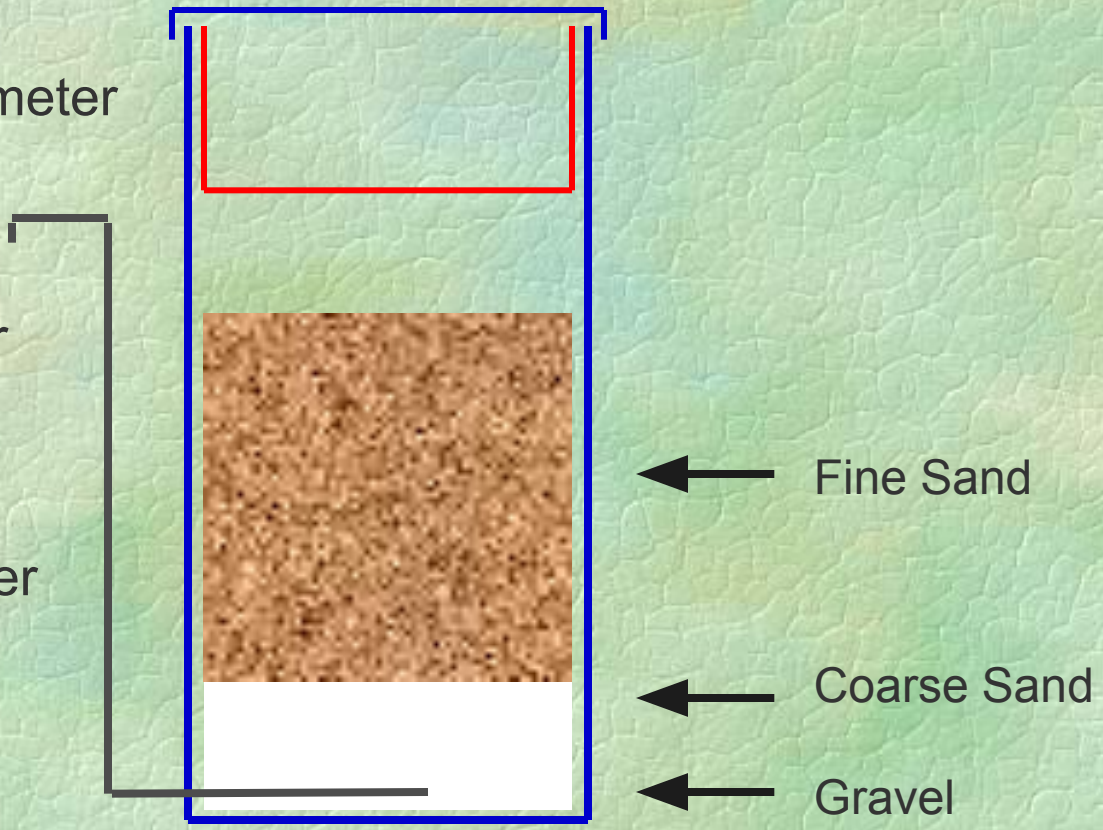
Major Filter Components

Specifications:

Fine Sand
- 20 Liters
- less than 1mm diameter

Coarse Sand
- 4 Liters
- 3 to 6 mm diameter

Gravel
- 6 Liters
- 6 to 15 mm diameter

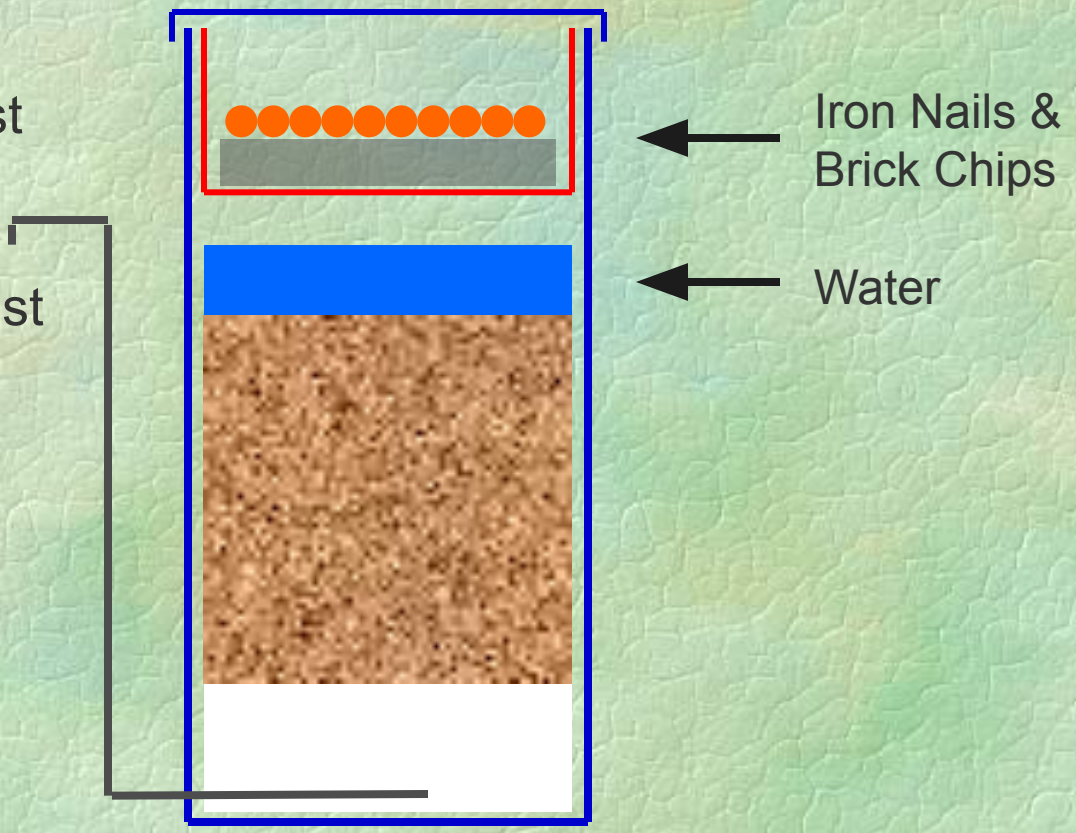


Major Filter Components

Specifications:

Iron nails
- 5 kg
- smallest size is best
- length < 20mm
- must be non-galvanized (must rust)

Brick chips
- any brick is fine
- about 5 to 10 cm diameter



6. Potential Problems

Improper Installation

Although the ABF is a simple technology, proper installation and adequate user awareness/training is necessary to ensure its performance.

We found several common problems why some ABF are not performing:

1. Too high flow rate
2. Too low flow rate
3. Iron nails “hole”
4. Attachment to pipe exit

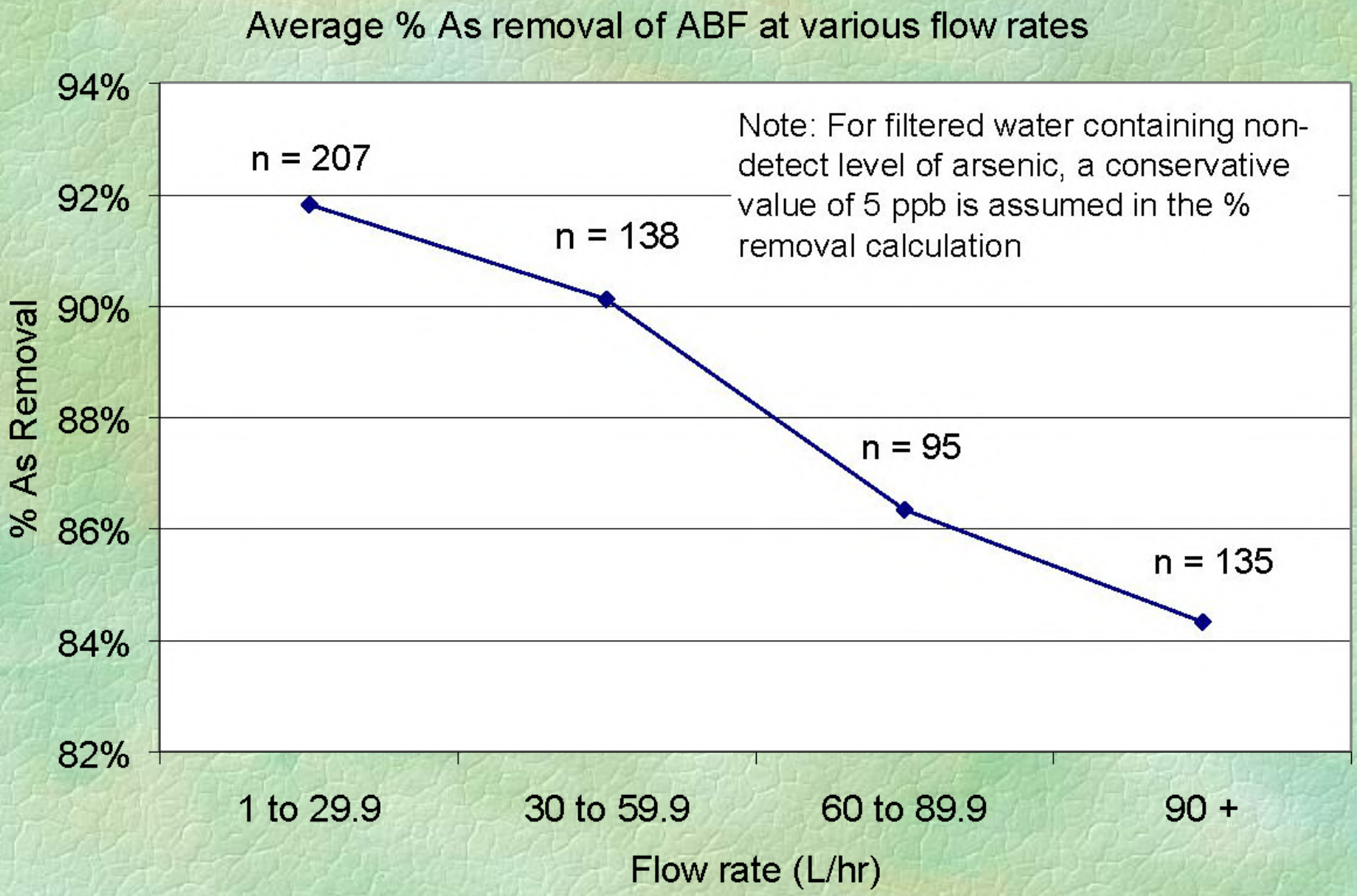
Improper Installation – Too high flow

Consequences:

- Arsenic, iron, and bacteria removal efficiencies compromised due to insufficient contact time

Reasons:

- Incorrect size sand & gravel
- Mixing of sand & gravel
- Improper piping system setup
- Leakage


Average % As removal of ABF at various flow rates
94%
92%
90%
88%
86%
84%
82%
% As Removal
n = 207
n = 138
n = 95
n = 135
Note: For filtered water containing non-detect level of arsenic, a conservative value of 5 ppb is assumed in the % removal calculation
1 to 29.9
30 to 59.9
60 to 89.9
90 +
Flow rate (L/hr)

Improper Installation – Too low flow

Consequences:

- Inadequate filtered water for drinking and cooking

Reasons:

- Incorrect size sand & gravel
- Mixing of sand & gravel
- Insufficient washing/cleaning of sand, gravel, & nails
- Improper piping system setup

Improper Installation – Iron Nails “hole”

Consequences:

- Water bypasses iron nails and therefore arsenic is not removed

Reasons:

- Insufficient protection to iron nails. Force of water create “hole”
- Users unaware of the need to evenly distribute the iron nails

Improper Installation – Iron Nails “hole”

At one filter in Nawalparasi (Som Nath Chaudhary), we discovered iron nails “hole”

Raw water arsenic = 250 ppb
Filtered water arsenic = 70 ppb

We re-distributed the iron nails, add more bricks

Filtered water arsenic = <10 ppb

Improper Installation – Pipe Attachment

Consequences:

- Water level in filter too high affects biofilm growth
- Water level in filter too low air bubble trapped, clogging

Reasons:

- Attachment of tubes, pipes, taps, extensions, etc to the pipe outlet
- User uninformed

Poster of an incorrect design

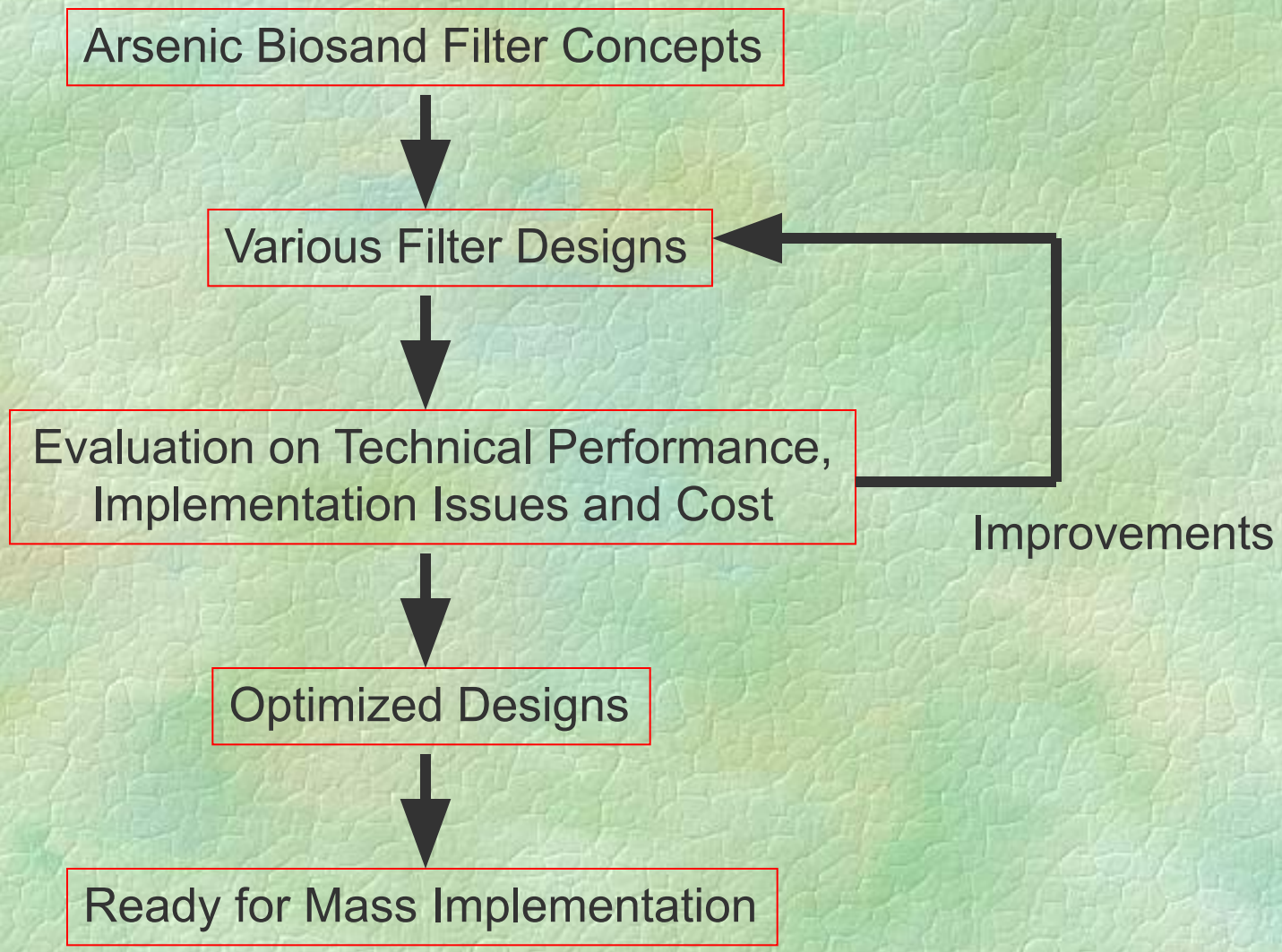
7. Conclusions

Conclusions

- The Arsenic Biosand Filter is an improvement upon the proven Biosand Filter technology
- The Arsenic Biosand Filter can effectively remove arsenic and iron
- Of the 4 different configurations, the Gem505 is the most appropriate for the DM2003 Project
- The construction, operation, and maintenance of the filter is simple
- The filter cost is estimated to be about 1100-1200 NRs
- **Proper construction, installation, monitoring, and user training are HIGHLY IMPORTANT to ensure filter performance!**

Thank You.
Any Questions?

ABF Development Process



Sample No.	ENPHO lab (AAS)	regular ENPHO test kit	HCl ENPHO test kit	ITS test kit
101	20	10	15	20
102	39	40	40	100
103	13	10	10	10
4	56	30	40	70
6	13	30	50	50
23	25	40	40	30
15	52	90	70	100
10	6	10	5	10
30	25	10	25	10
77	40	10	10	50
27	34	20	85	90
18	0	0	50	100
8	10	20	30	30
207	24	0	20	10
208	19	10	20	20
209	15	30	10	20
7	19	20	10	20
401	0	0	0	0
402	8	0	0	0
404	5	0	0	0
405	10	5	5	5
406	37	80	40	80

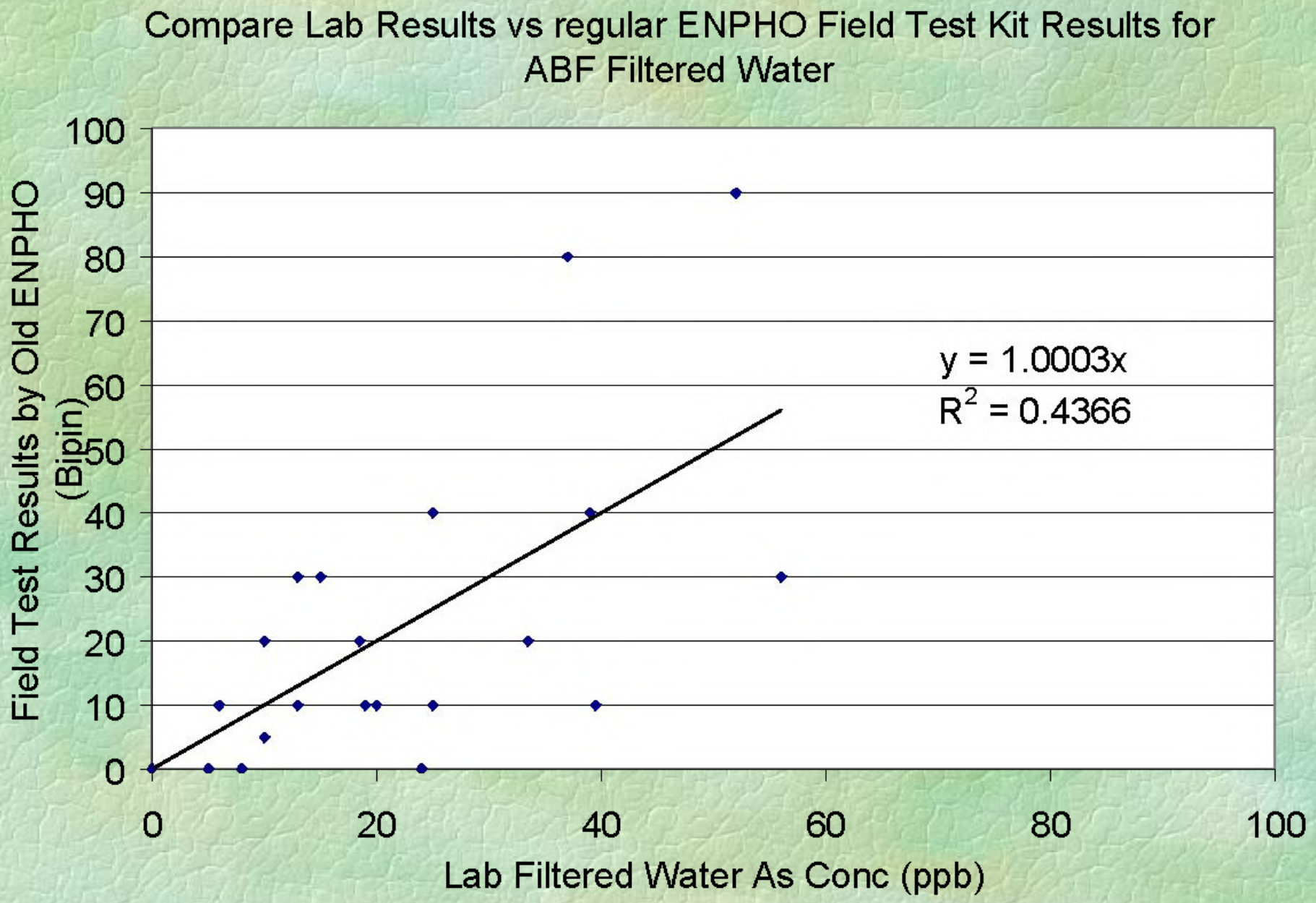
All results are from ABF filtered water.

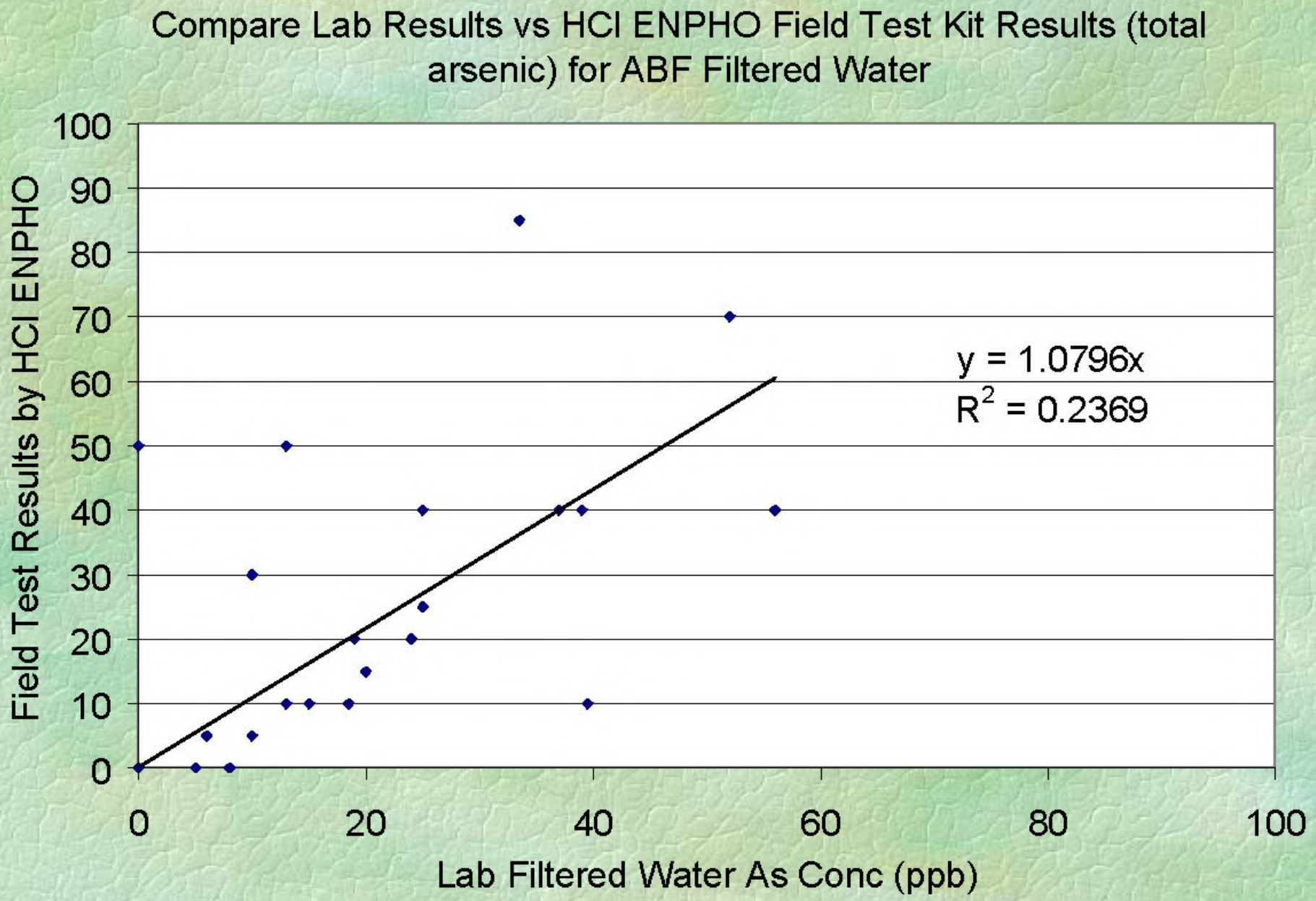
The regular ENPHO kit refers to the existing test kit that consists of ascorbic acid tablet. It is known that this test kit can only detect As(III), but not As(V)

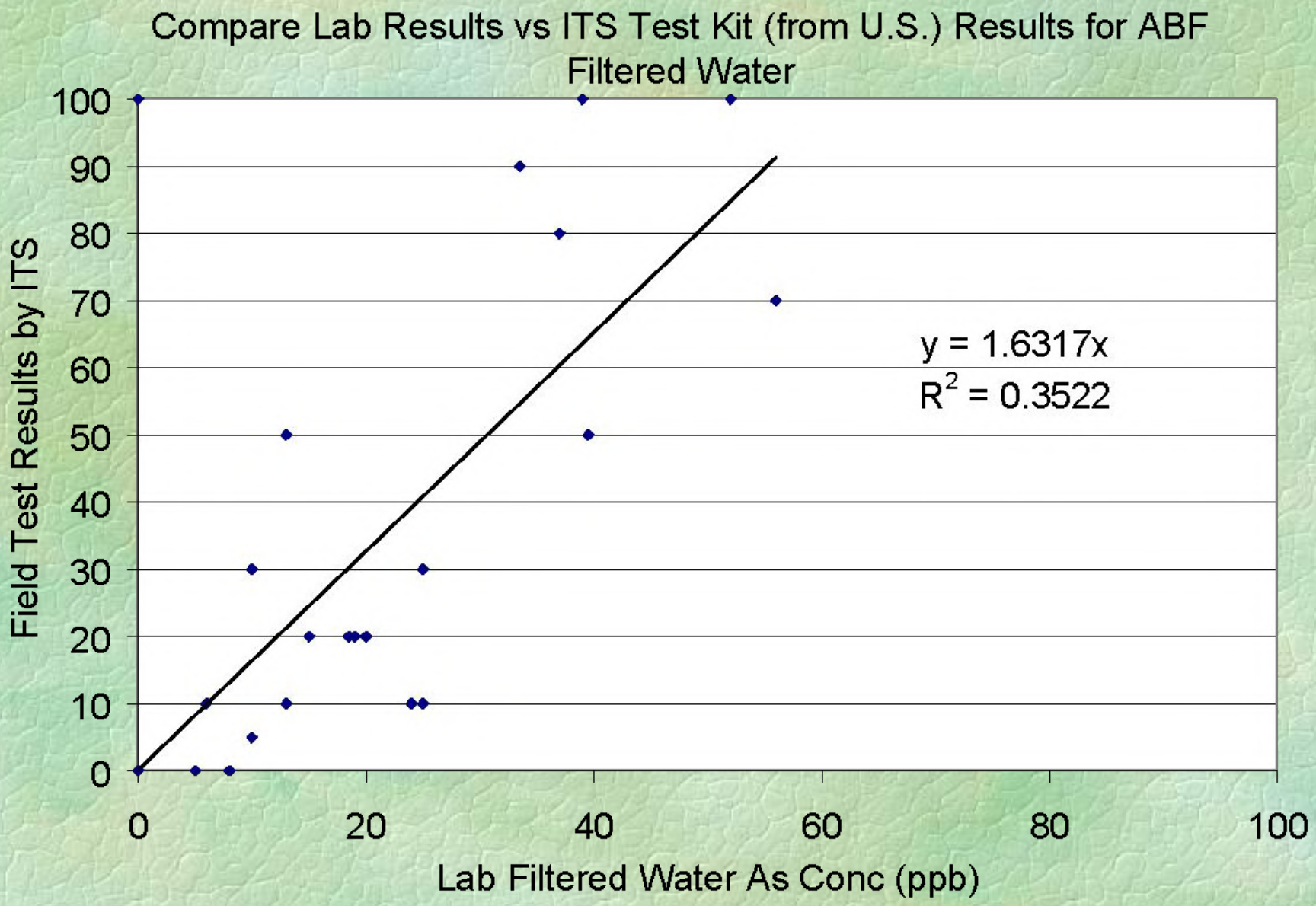
The HCl ENPHO kit uses HCl acid. Because of the lower pH, both As(III) and As(V) can be converted to arsine gas. Therefore, this HCl ENPHO kit can detect total arsenic.

The ITS test kit is purchased from the U.S. This test kit has been approved by the U.S. Environmental Protection Agency for arsenic testing in the U.S.

Thees filtered water arsenic concentration is NOT representative of the filters in general. The above filters have been selected because they were not installed properly and therefore exhibits a higher than normal arsenic concentration in the filtered water.


Compare Lab Results vs regular ENPHO Field Test Kit Results for ABF Filtered Water
Field Test Results by Old ENPHO (Bipin)
Lab Filtered Water As Conc (ppb)
y = 1.0003x
R2 = 0.4366
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100


Compare Lab Results vs HCl ENPHO Field Test Kit Results (total arsenic) for ABF Filtered Water
Field Test Results by HCl ENPHO
Lab Filtered Water As Conc (ppb)
y = 1.0796x
R2 = 0.2369
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100


Compare Lab Results vs ITS Test Kit (from U.S.) Results for ABF Filtered Water
Field Test Results by ITS
Lab Filtered Water As Conc (ppb)
y = 1.6317x
R2 = 0.3522
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100